Abstract

Target length: ~200 words **Status:** Draft v0.1

Abstract

Systems engineering organizations face a growing gap between the complexity of systems they must develop and their capacity to develop them. While digital engineering transformations help, they amplify human capability rather than substitute for it. This paper articulates a vision for systems engineering practice transformed through collaboration with agentic AI swarms—coordinated multi-agent systems that work alongside human engineers as team members rather than mere tools.

We describe an envisioned future where human-AI teams achieve augmented capacity, enhanced quality, accelerated learning, and democratized expertise, while humans retain the judgment, creativity, and accountability that define engineering responsibility. We chart a decade-long transformation path from near-term task augmentation through coordinated multi-agent support to collaborative human-AI teams. We identify enabling technologies and organizational capabilities required, and connect this vision to industry trajectories including INCOSE Vision 2035, digital engineering transformation, and Industry 4.0.

The paper issues calls to action for practitioners, researchers, organizations, and standards bodies. The future of AI-augmented systems engineering will be shaped by the choices our community makes. We advocate proactive engagement to ensure AI advancement serves engineering needs and preserves engineering values.

Keywords: agentic AI, multi-agent systems, systems engineering, human-AI collaboration, digital engineering, INCOSE Vision 2035

Word count: ~210 words **Keywords:** 6

Revision Notes

- ☐ Verify word count meets venue requirements
- ☐ Ensure alignment with paper content
- ☐ May adjust emphasis based on target venue

Section 1: Introduction

Target length: ~400 words **Status:** Draft v0.1

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1. Introduction: The Capacity Challenge

1.1 The Growing Gap

Systems engineering organizations face a widening gap between the complexity of systems they must develop and their capacity to develop them. Modern engineered systems—satellites, aircraft, medical devices, power grids—integrate more functionality, span more disciplines, and involve more stakeholders than their predecessors. Requirements number in the thousands or tens of thousands. Interfaces proliferate as systems connect to larger ecosystems. Regulatory and safety constraints grow more demanding.

Yet the capacity of engineering organizations has not grown proportionally. Engineering talent remains scarce. Budgets and schedules remain constrained. The result is a capacity deficit: organizations struggling to apply sufficient engineering rigor to

increasingly complex challenges.

1.2 Digital Engineering as Partial Solution

The systems engineering community has responded with digital transformation. Model-based systems engineering replaces documents with formal models. Digital threads maintain continuity from requirements through operations. Automated analysis enables broader design exploration. These advances help—but they do not close the capacity gap. Digital tools amplify human capability; they do not substitute for it. The fundamental constraint remains human engineering capacity.

1.3 The Promise of AI Augmentation

Artificial intelligence offers a different kind of amplification. Recent advances—particularly in large language models and agentic AI systems—demonstrate capabilities directly relevant to systems engineering: natural language understanding, code generation, analytical reasoning, tool use. Individual AI assistants already help engineers draft documents, analyze requirements, and explore designs.

But the full potential lies not in individual AI assistants but in coordinated multi-agent systems—agentic AI swarms—that can collaborate on complex engineering challenges. Just as human engineering organizations achieve what individual engineers cannot, AI swarms can achieve what individual AI agents cannot. The combination of human engineering teams and AI swarms promises a transformation in engineering capacity.

1.4 Purpose of This Paper

This paper articulates a vision for systems engineering practice augmented by agentic AI swarms. We describe what this future could look like, chart the transformation path from present to future, identify enabling technologies and organizational capabilities required, and connect this vision to broader industry trajectories.

Our purpose is not prediction but aspiration—articulating a compelling future state that can guide investment, research, and organizational preparation. The future is not predetermined; it will be shaped by the choices the systems engineering community makes. This vision offers one direction worth pursuing.

The paper proceeds as follows. Section 2 describes the envisioned future state. Section 3 charts the transformation path. Section 4 identifies enabling technologies and capabilities. Section 5 connects to industry trajectories. Section 6 issues calls to action. Section 7 concludes.

Word count: ~420 words **Subsections:** 4

Revision Notes

- ☐ Add specific statistics on complexity growth if available
- ☐ Consider adding motivating example
- ☐ May cite specific capacity challenge studies

Section 2: The Envisioned Future

Target length: ~1,000 words **Status:** Draft v0.1

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2. The Envisioned Future

2.1 A Day in the Life: Systems Engineering in 2035

Dr. Sarah Chen arrives at the aerospace company's engineering center to lead the preliminary design review for a next-generation Earth observation satellite constellation. Her morning begins not with a stack of documents to review, but with a briefing from her AI swarm team.

"Good morning, Sarah," her lead systems agent summarizes. "Overnight, the requirements analysis swarm completed consistency checking across 2,847 requirements. We identified 12 potential conflicts between the thermal management and power subsystem requirements—three are likely specification errors, nine represent legitimate trade-offs requiring your judgment. The architecture exploration swarm evaluated 340 configuration variants against the mission effectiveness criteria. I've prepared a short-list of 5 candidates that dominate on at least three key performance parameters."

Sarah reviews the conflict summary on her display. The AI has already traced each conflict to its source requirements, identified affected interfaces, and proposed resolution options with predicted impacts. What would have taken her team weeks of manual analysis is available before her first meeting.

During the design review, Sarah's discipline specialist agents participate alongside human engineers. When a question arises about antenna placement impacts on thermal dissipation, the thermal agent and RF agent engage in a rapid dialogue, exploring the trade space while the humans observe. Within minutes, they present a visualization of the Pareto frontier with three recommended configurations. The human RF engineer adds a constraint the agents hadn't considered—heritage antenna mounting provisions—and the swarm instantly re-evaluates, converging on a revised recommendation.

Throughout the day, verification agents continuously check design decisions against requirements, interface agents monitor for emerging conflicts, and documentation agents maintain the system model in real-time. Sarah's role has evolved from artifact producer to engineering conductor—setting direction, applying judgment, engaging stakeholders, and making decisions that shape the system's character.

2.2 Key Characteristics of the Envisioned State

The scenario above illustrates several transformative characteristics of AI-swarm-augmented systems engineering:

Augmented Capacity. Engineering organizations achieve throughput previously impossible with human effort alone. Comprehensive analysis that once required months occurs in hours. Complete verification coverage—checking every requirement against every design element—becomes feasible rather than aspirational. Organizations can undertake more complex systems, tighter schedules, or both, without proportional increases in engineering headcount.

Enhanced Quality. AI swarms provide comprehensive coverage that human teams cannot match. Every requirement is traced, every interface checked, every consistency constraint evaluated. The swarms never tire, never overlook, never assume. Quality improves not through heroic human effort but through systematic AI-enabled assurance. Human engineers, freed from exhaustive checking, focus their expertise on the subtle judgments and creative insights that determine system success.

Accelerated Learning. Institutional knowledge no longer walks out the door when experienced engineers retire. AI swarms capture patterns from successful projects, encoding expertise that can be applied to future endeavors. Junior engineers work alongside AI agents that embody decades of accumulated wisdom, accelerating their development while preserving organizational capability. The learning is bidirectional—human insights continuously improve swarm behavior, while swarm-surfaced patterns reveal best practices humans hadn't explicitly recognized.

Democratized Expertise. Specialized knowledge becomes accessible through AI mediation. A small engineering team tackling a novel domain can draw on swarm agents encoding expertise from across the industry. The gap between well-resourced and resource-constrained organizations narrows as AI makes specialized capabilities more widely available. Innovation accelerates as diverse teams can engage complex challenges previously reserved for elite organizations.

2.3 What Changes, What Remains

The vision is not one of human replacement but of human amplification. Distinguishing what changes from what remains clarifies the transformation's nature.

What Changes:

Artifact generation shifts from human-produced to AI-generated with human review. Requirements documents, interface specifications, test procedures, and technical reports emerge from AI agents operating under human direction. Engineers transition from authors to editors, from producers to curators.

Analysis scope expands from sampled to comprehensive. Trade studies that once evaluated a handful of alternatives now explore thousands. Verification that once checked critical paths now achieves complete coverage. The frontier of what is computationally feasible advances dramatically.

Collaboration patterns evolve to include AI participants. Design discussions involve human and AI perspectives. Reviews incorporate AI-generated analyses alongside human judgment. The boundary between human team and AI tool blurs into integrated human-AI collaboration.

Pace of iteration accelerates from sequential human activities to parallel human-AI workflows. Design-analyze-revise cycles that once took weeks compress to days or hours. Rapid iteration enables exploration and learning previously precluded by schedule constraints.

What Remains:

Human judgment remains essential for decisions involving values, priorities, and stakeholder interests. AI swarms can analyze trade-offs, but humans must decide which trade-offs to accept. The engineering choices that define a system's character—its balance of capability, cost, risk, and schedule—remain fundamentally human decisions.

Stakeholder relationships remain human-to-human. Understanding what customers truly need, building trust with program sponsors, navigating organizational dynamics—these interpersonal dimensions of systems engineering resist AI mediation. The systems engineer's role as translator between technical and non-technical worlds persists.

Accountability remains with humans. When systems fail, when requirements are missed, when designs prove inadequate, human engineers and their organizations bear responsibility. AI swarms are tools—powerful tools—but the obligation to deliver systems that work rests with the humans who direct them.

Creativity and insight remain human strengths. AI swarms excel at systematic exploration within defined spaces; humans excel at redefining the spaces themselves. The breakthrough insight, the unconventional approach, the recognition that the problem has been wrongly framed—these remain distinctively human contributions.

The envisioned future is not one where AI replaces systems engineers but where AI amplifies their capabilities, extends their reach, and frees them to focus on the aspects of engineering that most benefit from human judgment, creativity, and accountability.

Word count: ~980 words **Subsections:** 3

Revision Notes

- ☐ Verify scenario details are technically plausible
- ☐ Consider adding second scenario (different domain or lifecycle phase)
- ☐ May adjust tone based on target audience feedback

Section 3: The Transformation Path

Target length: ~1,000 words **Status:** Draft v0.1

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3. The Transformation Path

The vision articulated in Section 2 will not emerge overnight. It requires a deliberate transformation spanning a decade, progressing through distinct phases as technology matures, organizations adapt, and trust develops. This section charts the path from today's nascent AI adoption to tomorrow's collaborative human-AI engineering teams.

3.1 Near-Term (2025-2027): Augmented Individual Tasks

The transformation begins with AI augmentation of discrete engineering tasks. In this phase, individual engineers employ AI assistants to accelerate specific activities while maintaining direct oversight of all outputs.

Characteristic applications include:

- *Documentation assistance:* AI generates initial drafts of technical documents—requirements specifications, interface control documents, test procedures—which engineers review, refine, and approve.
- *Requirements analysis:* AI tools identify potential ambiguities, inconsistencies, and gaps in requirements sets, flagging issues for human resolution.
- *Design exploration:* AI-assisted parametric studies expand the range of alternatives engineers can evaluate within schedule constraints.
- *Code generation:* For software-intensive systems, AI generates code from specifications, subject to human review and testing.

Human role in this phase remains firmly in the loop. Engineers direct AI activities, review all outputs, and make all technical decisions. AI tools function as sophisticated assistants, not autonomous agents. Trust is limited and warranted—AI capabilities are genuine but bounded, and human oversight catches errors that current AI systems inevitably produce.

Organizational adaptation is modest. Existing processes accommodate AI tools as they would any new software capability. Training focuses on effective AI tool use—prompt engineering, output evaluation, integration with existing workflows. Governance addresses AI outputs as engineer-produced artifacts subject to standard review and approval.

3.2 Mid-Term (2027-2030): Coordinated Multi-Agent Support

As AI capabilities mature and organizational experience accumulates, the transformation progresses to coordinated multi-agent support. Multiple specialized AI agents work together on complex analyses, with human oversight shifting from reviewing every output to managing by exception.

Characteristic applications include:

- *Cross-discipline analysis:* Swarms of discipline-specialist agents (thermal, structural, electrical, software) collaborate on integrated analyses, identifying cross-domain issues that single-discipline reviews miss.
- *Continuous verification:* Agent swarms maintain ongoing verification of design decisions against requirements, alerting engineers to emerging issues rather than discovering them at formal reviews.
- *Trade study automation:* Multi-objective optimization swarms explore trade spaces comprehensively, presenting human engineers with Pareto-optimal alternatives and sensitivity analyses.
- *Interface management:* Interface agents monitor evolving designs across subsystem boundaries, identifying conflicts and proposing resolutions.

Human role evolves to oversight and exception handling. Engineers define objectives, constraints, and evaluation criteria; agent swarms execute analyses; humans review results and intervene when swarm outputs require judgment or when novel situations exceed agent capabilities. Trust expands as track records accumulate—agents that have proven reliable in specific task domains earn greater autonomy within those domains.

Organizational adaptation becomes more substantial. Processes evolve to accommodate continuous AI-generated analyses alongside milestone-based human reviews. New roles emerge: swarm configuration specialists, AI output auditors, human-AI collaboration facilitators. Governance frameworks address questions of agent authority, output attribution, and decision accountability that discrete tools did not raise.

3.3 Long-Term (2030-2035): Collaborative Human-AI Teams

The transformation culminates in true collaborative human-AI teams where AI swarms function as team members with defined roles, responsibilities, and authorities. The boundary between human team and AI capability dissolves into integrated collaboration.

Characteristic applications include:

- *AI team members:* Agent swarms occupy defined roles in engineering teams—not as tools used by humans, but as participants contributing alongside humans. Design reviews include AI perspectives; technical discussions engage AI reasoning; project planning accounts for AI capacity.
- *Continuous lifecycle support:* From concept through disposal, AI swarms maintain awareness of system state, automatically updating analyses as designs evolve, operations data accumulates, and maintenance history grows.
- *Emergent capability:* Swarm collaboration produces insights neither humans nor individual agents would generate—emergent collective intelligence that enhances human capability.
- *Institutional memory:* AI swarms embody organizational knowledge, preserving expertise across personnel transitions and making accumulated wisdom accessible to every project.

Human role focuses on judgment, creativity, and accountability. Engineers set direction, make value-laden decisions, engage stakeholders, and bear responsibility for outcomes. They conduct the orchestra rather than play every instrument. Their expertise evolves from domain-specific technical depth to engineering leadership, stakeholder engagement, and human-AI collaboration management.

Organizational adaptation is profound. Engineering organizations restructure around human-AI teams rather than human teams with AI tools. Career paths, performance metrics, and organizational structures reflect the new reality. Governance frameworks address AI participation in engineering decisions, with clear accountability chains ensuring human responsibility for outcomes.

3.4 Transformation Milestones

Table 1 summarizes key milestones marking progress along the transformation path.

Phase	Period	AI Role	Human Role	Trust Level	Key Milestone
Near-term	2025-2027	Task assistant	In the loop	Limited, verified	AI-generated artifacts in production use
Mid-term	2027-2030	Coordinated analyzers	Exception handler	Earned by track record	AI swarms in certified system development
Long-term	2030-2035	Team member	Conductor	Calibrated collaboration	Human-AI teams as standard practice

Critical path items determining transformation pace include:

- *AI capability advancement:* Reasoning, domain knowledge, coordination at scale
- *Trust development:* Demonstrated reliability building confidence
- *Organizational learning:* Adapting processes, roles, and culture
- *Governance maturation:* Frameworks for AI participation in engineering decisions
- *Workforce evolution:* Skills for human-AI collaboration

The pace of transformation will vary across organizations, domains, and application contexts. Safety-critical domains will proceed more cautiously than commercial applications. Well-resourced organizations will move faster than constrained ones. The milestones above represent a plausible trajectory, not a predetermined schedule.

Word count: ~950 words **Subsections:** 4 **Tables:** 1

Revision Notes

- ☐ Verify timeline aligns with realistic AI capability projections
- ☐ Consider adding specific technology enablers for each phase
- ☐ May add examples from specific domains

Section 4: Enabling Technologies and Capabilities

Target length: ~800 words **Status:** Draft v0.1

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4. Enabling Technologies and Capabilities

Realizing the vision requires advances across multiple dimensions: AI capabilities must mature, infrastructure must evolve, and organizations must adapt. This section identifies the key enablers whose development will pace the transformation.

4.1 AI Capabilities Required

Current AI systems, while impressive, fall short of the capabilities required for full realization of the vision. Key advances needed include:

Improved reasoning and planning. Today's large language models excel at pattern completion but struggle with multi-step reasoning, causal inference, and long-horizon planning. Effective participation in systems engineering requires AI that can reason about complex system behaviors, trace causation through interconnected subsystems, and plan sequences of analyses to answer engineering questions. Research directions including chain-of-thought prompting, neuro-symbolic architectures, and world models may address these limitations.

Domain knowledge grounding. Current AI systems possess broad but shallow knowledge, sometimes generating plausible-sounding but technically incorrect content. Systems engineering applications require AI grounded in authoritative domain knowledge—physics principles, engineering standards, regulatory requirements, organizational practices. Retrieval-augmented generation, domain-specific fine-tuning, and knowledge graph integration offer paths toward reliable domain grounding.

Multi-agent coordination at scale. While current multi-agent systems demonstrate coordination among small numbers of agents, the vision requires effective coordination among tens or hundreds of specialized agents working in parallel. Challenges include communication efficiency, conflict resolution, emergent behavior management, and maintaining coherent progress toward objectives. Advances in swarm intelligence, distributed coordination protocols, and hierarchical agent architectures are needed.

Explainability and transparency. Engineers cannot responsibly rely on AI outputs they cannot understand. The vision requires AI systems that can explain their reasoning, trace conclusions to evidence, quantify uncertainty, and acknowledge limitations. Interpretable AI, explanation generation, and uncertainty quantification research must mature to enable appropriate human oversight.

4.2 Infrastructure Requirements

AI-augmented systems engineering requires supporting infrastructure beyond the AI systems themselves:

Digital thread and authoritative source of truth. AI swarms must operate on consistent, authoritative system representations. The digital thread concept—maintaining continuous, traceable information flow from requirements through design, production, and operations—provides the foundation for AI swarm operations. Without authoritative, machine-accessible system representations, AI agents lack the substrate for effective contribution.

Model-based representations. The shift from document-centric to model-centric systems engineering enables AI engagement with system representations. Model-Based Systems Engineering (MBSE) maturity—with formal system models, standardized modeling languages (SysML, UAF), and integrated model repositories—provides the structured representations AI systems can process, analyze, and extend.

Secure, auditable AI execution environments. In regulated domains, AI contributions must be traceable and auditable. Infrastructure must record AI activities, preserve decision rationale, and enable post-hoc review. Security requirements must address AI system integrity, protection against adversarial manipulation, and containment of potentially harmful emergent behaviors.

Computational resources. AI swarms require substantial computational capacity—far more than individual AI assistants. Organizations must provision inference infrastructure capable of supporting concurrent operation of many specialized agents, or access cloud-based AI services with appropriate security and reliability characteristics.

4.3 Organizational Enablers

Technology alone is insufficient; organizational adaptation is equally essential:

Workforce skills evolution. Tomorrow's systems engineers need skills today's engineers may lack: formulating effective AI directions, evaluating AI outputs, diagnosing AI failures, and collaborating effectively with AI team members. Engineering education must evolve to include AI collaboration competencies alongside traditional technical skills. Professional development must prepare current practitioners for the transformed practice.

Process adaptation. Engineering processes designed for human execution require rethinking for human-AI collaboration. Sequential milestone reviews may not suit continuous AI-generated analysis. Document-based deliverables may not capture AI contributions effectively. Configuration management must address AI-generated artifacts. Quality assurance must incorporate AI output validation.

Governance frameworks. Organizations must establish clear frameworks for AI involvement in engineering decisions. Key questions include: What decisions can AI agents make autonomously? How are AI contributions attributed and reviewed? Who is accountable when AI-influenced decisions lead to problems? How are AI capabilities certified for use in regulated contexts? Governance frameworks must provide clear answers while remaining adaptable as capabilities evolve.

Trust calibration. Effective human-AI collaboration requires appropriately calibrated trust—neither blind faith nor excessive skepticism. Organizations must develop mechanisms for building warranted trust: track records of AI performance, transparent capability boundaries, processes for identifying and learning from failures. Trust should be task-specific and earned incrementally.

4.4 Enabler Maturity Assessment

The pace of transformation depends on progress across all enablers. Table 2 provides a summary assessment.

Enabler Category	Current State	Required State	Gap Assessment
AI reasoning	Emerging	Robust	Significant
Domain grounding	Limited	Comprehensive	Moderate
Multi-agent coordination	Early research	Production-ready	Significant
Explainability	Nascent	Standard practice	Significant
Digital thread	Partial adoption	Universal	Moderate
MBSE maturity	Growing	Widespread	Moderate
Workforce skills	Minimal	Ubiquitous	Significant
Governance frameworks	Ad hoc	Established	Significant

No single enabler presents an insurmountable barrier, but progress is needed across the full portfolio. The transformation will advance as the slowest-moving enablers allow.

Word count: ~800 words **Subsections:** 4 **Tables:** 1

Revision Notes

- ☐ Add specific research programs or initiatives addressing each gap
- ☐ Consider adding timeline estimates for enabler maturation
- ☐ May cite specific capability demonstrations

Section 5: Connection to Industry Trajectories

Target length: ~600 words **Status:** Draft v0.1

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5. Connection to Industry Trajectories

The vision articulated in this paper does not exist in isolation. It connects to and builds upon broader transformations already underway in systems engineering practice. This section positions AI-swarm-augmented systems engineering within these ongoing industry trajectories.

5.1 INCOSE Vision 2035

The International Council on Systems Engineering (INCOSE) has articulated a vision for the future of systems engineering that emphasizes transformation toward more capable, efficient, and impactful practice [56]. Key themes of INCOSE Vision 2035 include:

- *Addressing global challenges* through engineered systems that are more sustainable, resilient, and responsive to societal needs

- *Accelerating the pace of systems realization* while maintaining quality and managing complexity
- *Leveraging digital and model-based approaches* to enable more effective engineering
- *Developing the systems engineering workforce* with new skills and capabilities

AI swarm augmentation aligns directly with these themes. Swarm-augmented engineering teams can address greater complexity, accelerate development timelines, leverage digital representations fully, and enable engineers to focus on higher-value activities. The vision presented here offers a path toward INCOSE's aspirations—AI swarms as an enabling capability for the transformed practice INCOSE envisions.

5.2 Digital Engineering Transformation

Major systems engineering organizations are pursuing digital engineering transformations that create the foundation for AI swarm augmentation:

Department of Defense Digital Engineering Strategy calls for transitioning from document-based to model-based engineering, establishing authoritative sources of truth, and enabling data-driven decision-making across the acquisition lifecycle. The digital thread concept—continuous, traceable information from requirements through sustainment—provides the substrate AI swarms require.

NASA Model-Based Systems Engineering Pathfinder advances model-based approaches across NASA missions, developing practices, tools, and workforce capabilities for model-centric engineering. NASA's emphasis on formal verification and validation creates natural opportunities for AI swarm contribution.

Industry digital transformation initiatives at aerospace, defense, and commercial organizations pursue similar goals: integrated digital representations, automated analysis and verification, continuous lifecycle support. These initiatives create the infrastructure and organizational readiness that AI swarm adoption requires.

AI swarms can serve as accelerators for digital engineering transformation. Organizations that have established digital foundations are positioned to adopt AI augmentation; AI augmentation, in turn, amplifies the value of digital investments. The synergy suggests prioritizing digital engineering maturity as preparation for AI-augmented practice.

5.3 Industry 4.0 and Digital Twins

The convergence of AI, simulation, and engineering practice extends beyond systems engineering into broader Industry 4.0 concepts:

Digital twins—virtual representations maintained in correspondence with physical systems—offer opportunities for AI swarm contribution throughout the system lifecycle. AI swarms can maintain and analyze digital twins, using operational data to improve predictions, identify anomalies, and optimize performance.

Continuous engineering blurs the boundaries between development and operations. Rather than handing off a completed design, engineering teams maintain ongoing involvement through digital twin analysis and model-based sustainment. AI swarms enable the continuous analysis and adaptation that continuous engineering requires.

Smart manufacturing integrates AI throughout production processes. Systems engineering swarms can maintain continuity from design through production, ensuring that manufacturing execution aligns with design intent and that production feedback informs design evolution.

5.4 Convergent Trajectories

These industry trajectories—INCOSE's vision for transformed SE practice, digital engineering transformations across organizations, and Industry 4.0 concepts—converge toward an engineering future where:

- Digital representations are authoritative and ubiquitous

- Analysis is continuous rather than milestone-bound
- Human expertise focuses on judgment and creativity
- AI capabilities amplify human capacity

The vision of AI-swarm-augmented systems engineering represents not a diversion from current trajectories but their logical extension. Organizations advancing digital engineering maturity, building model-based capabilities, and developing digital twin strategies are preparing—intentionally or not—for AI swarm adoption.

Word count: ~600 words **Subsections:** 4

Revision Notes

- ☐ Add specific citations for DoD, NASA initiatives
- ☐ Consider adding industry examples
- ☐ May expand INCOSE Vision 2035 alignment

Section 6: Realizing the Vision: A Call to Action

Target length: ~500 words **Status:** Draft v0.1

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6. Realizing the Vision: A Call to Action

The vision articulated in this paper will not realize itself. Its achievement requires deliberate action across the systems engineering community—practitioners, researchers, organizations, and standards bodies each contributing to the transformation.

6.1 For Systems Engineering Practitioners

Individual systems engineers shape the transformation through their daily choices and career development:

Develop AI collaboration skills. Learn to formulate effective directions for AI systems, evaluate AI outputs critically, and integrate AI tools into engineering workflows. These skills will differentiate effective engineers in the transformed practice.

Experiment with AI tools. Engage with current AI capabilities, even when imperfect, to build intuition about AI strengths and limitations. Early experience positions practitioners to contribute to and benefit from advancing capabilities.

Provide feedback. As AI tools enter engineering practice, practitioner feedback shapes their evolution. Report limitations, suggest improvements, and communicate requirements. Tool developers need engineering expertise to build effective solutions.

Share experience. Document and communicate lessons learned from AI adoption—both successes and failures. The community learns faster when experience circulates freely.

6.2 For Systems Engineering Researchers

The research community must address fundamental challenges blocking the vision's realization:

Advance coordination science. Develop theoretical foundations and practical methods for multi-agent coordination in engineering contexts. How should agent swarms be organized? How should conflicts be resolved? How can coordination overhead be minimized?

Create evaluation frameworks. Establish benchmarks and metrics for assessing AI swarm effectiveness in systems engineering. Without rigorous evaluation methods, progress cannot be measured and claims cannot be validated.

Study human-AI teaming. Investigate effective patterns for human-AI collaboration in engineering contexts. What oversight models work? How should trust be calibrated? What skills do humans need?

Develop domain integration methods. Research approaches for grounding AI systems in domain-specific knowledge and constraints. How can physics, standards, and organizational practices be reliably encoded?

6.3 For Systems Engineering Organizations

Organizations must prepare for and enable the transformation:

Invest in digital infrastructure. Establish the digital thread, model-based representations, and data management capabilities that AI augmentation requires. These investments pay dividends even before AI adoption and position organizations for AI-enabled acceleration.

Evolve processes and governance. Adapt engineering processes for human-AI collaboration. Develop governance frameworks addressing AI involvement in engineering decisions. Start with low-risk applications and extend as experience and trust develop.

Build organizational AI literacy. Ensure engineering leadership understands AI capabilities and limitations. Develop workforce strategies addressing skill evolution. Create organizational capacity for responsible AI adoption.

Pilot and learn. Conduct controlled pilots of AI augmentation in suitable contexts. Capture lessons learned rigorously. Build organizational experience systematically rather than through ad hoc experimentation.

6.4 For Standards Bodies

Professional societies and standards organizations must enable responsible adoption:

Develop guidance for AI involvement. Establish frameworks for appropriate AI participation in engineering activities, distinguishing contexts where AI contribution is appropriate from those requiring human execution.

Address certification implications. Clarify how AI contributions affect system certification in regulated domains. Define requirements for AI tool qualification and AI-generated artifact verification.

Enable interoperability. Develop standards enabling AI systems to interoperate with engineering tools and representations. Common formats, interfaces, and protocols accelerate capability development.

Facilitate community learning. Create forums for sharing experience with AI adoption. Collect and disseminate best practices. Enable the community to learn collectively.

Word count: ~530 words **Subsections:** 4

Revision Notes

- ☐ Consider adding specific examples of current initiatives in each category
- ☐ May add prioritization guidance
- ☐ Could reference specific standards development efforts

Section 7: Conclusion

Target length: ~300 words **Status:** Draft v0.1

7. Conclusion

This paper has articulated a vision for systems engineering practice transformed by collaboration with agentic AI swarms. In this envisioned future, human engineers work alongside AI team members that provide augmented capacity, enhanced quality, accelerated learning, and democratized expertise—while humans retain the judgment, creativity, and accountability that define engineering responsibility.

The transformation will not occur instantaneously. We have charted a decade-long path progressing from near-term task augmentation through mid-term coordinated multi-agent support to long-term collaborative human-AI teams. Each phase builds capabilities and trust that enable the next.

Realizing this vision requires progress across multiple dimensions: AI capabilities must advance in reasoning, domain knowledge, coordination, and explainability; infrastructure must mature toward digital threads and model-based representations; organizations must evolve skills, processes, and governance. No single enabler presents an insurmountable barrier, but progress is needed across the full portfolio.

The vision connects to and extends industry trajectories already underway. INCOSE's Vision 2035, digital engineering transformations, and Industry 4.0 concepts all point toward a future where digital representations are authoritative, analysis is continuous, and human expertise focuses on judgment and creativity. AI swarm augmentation represents the logical extension of these trajectories.

The systems engineering community faces a choice. We can react to AI advancement as it unfolds, adapting after the fact to capabilities others develop for other purposes. Or we can actively shape how AI is applied to engineering practice, ensuring that the resulting systems serve engineering needs and preserve engineering values.

We advocate the latter path. The opportunity before us—to amplify engineering capacity, extend engineering reach, and free engineers to focus on what matters most—is too significant to leave to chance. The vision articulated here offers a direction worth pursuing. The time to begin is now.

Word count: ~310 words

Revision Notes

- ☐ Ensure conclusion reflects paper content accurately
- ☐ Consider strengthening final call to action
- ☐ May adjust emphasis based on audience