INCOSE: Fostering the Growth of Systems Engineering

Michael D. Watson, Ph.D.
INCOSE President

incose.org

Agenda

- Systems Engineering Growth
- Systems Engineering Principles
- Summary

Systems Engineering Discipline Progression

Engineering Disciplines start in practice

- Some disciplines were in practice 1000's of years before formalizing as a discipline
  - Civil Engineering (Buildings, Bridges, Aqueducts)
  - Materials
  - Mechanical Engineering
  - Optical Engineering

Newer disciplines defined practice early

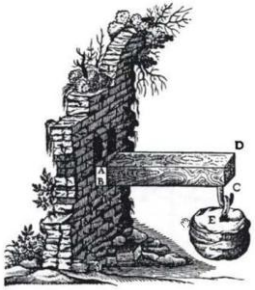
- Systems Engineering
  - Systems Engineering Practitioners come from many disciplines
- Software Engineering



Pyramid of Kfafre*



^

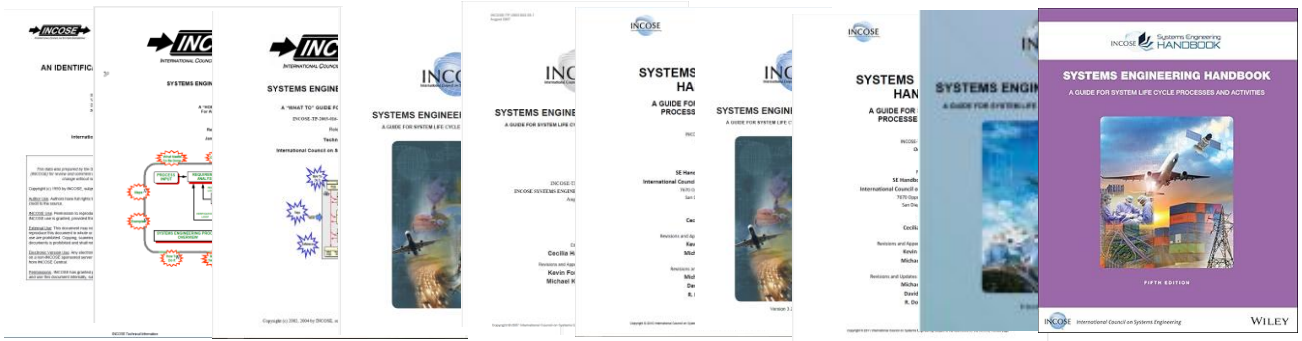


Galileo's Cantilever Beam Proof Construction#

*Eliot Elisofon Photographic Archives, The pyramid of Kfafre, Pyramids of Giza, Egypt, slide, Accessed at https://www.si.edu/spotlight/ancient-egypt/pyramid
#Galileo's Cantilever Beam Proof Construction, Accessed at: https://newtonexcelbach.com/2008/02/27/the-history-of-the-theory-of-beam-bending-part-1/
^Vitruvius, 10 Books on Architecture, accessed on https://m.media-amazon.com/images/I/51IyS95ZGOL._SY522_.jpg

Status of Systems Engineering Discipline

- Systems Engineering is advancing faster than any other discipline in History
  - Systems Engineering Processes defined in the first 50 years of formal practice
  - System Modeling established in the first 65 years
  - Initial Systems Engineering Principles defined in the first 75 years





INCOSE



Systems Engineering Handbook

Draft 1993







SysML v2.0 by OMG

Systems Engineering Principles Release

ISO/IEC 15288

ISO/IEC/IEEE 15288

MIL-STD-499B

ANSI/EIA-632

1st NCOSE Meeting

NCOSE Meeting

1990 — NCOSE Formed

UNISYS

McDonnell Douglas

BOEING

Defense Systems Management College (DSMC)

Synergistic Applications, Inc.

January 1991 — 1st NCOSE Workshop

IBM

1992 — NCOSE Meeting

June 1991 — 1st NCOSE Workshop

1993 — NCOSE Meeting

OSD Systems & Software Engineering Office 1st Participation



1993 — MIL-STD-499B

June 1995 — NCOSE → INCOSE

SESA

INCOSE UK

1999 — ANSI/EIA-632

2003 — INCOSE Organizes Response to Form SysML

2003 — ISO/IEC 15288

2007 — SysML v1.0 by OMG

2008 — ISO/IEC/IEEE 15288

2015 — ISO/IEC/IEEE 15288

2022 — Systems Engineering Principles Release

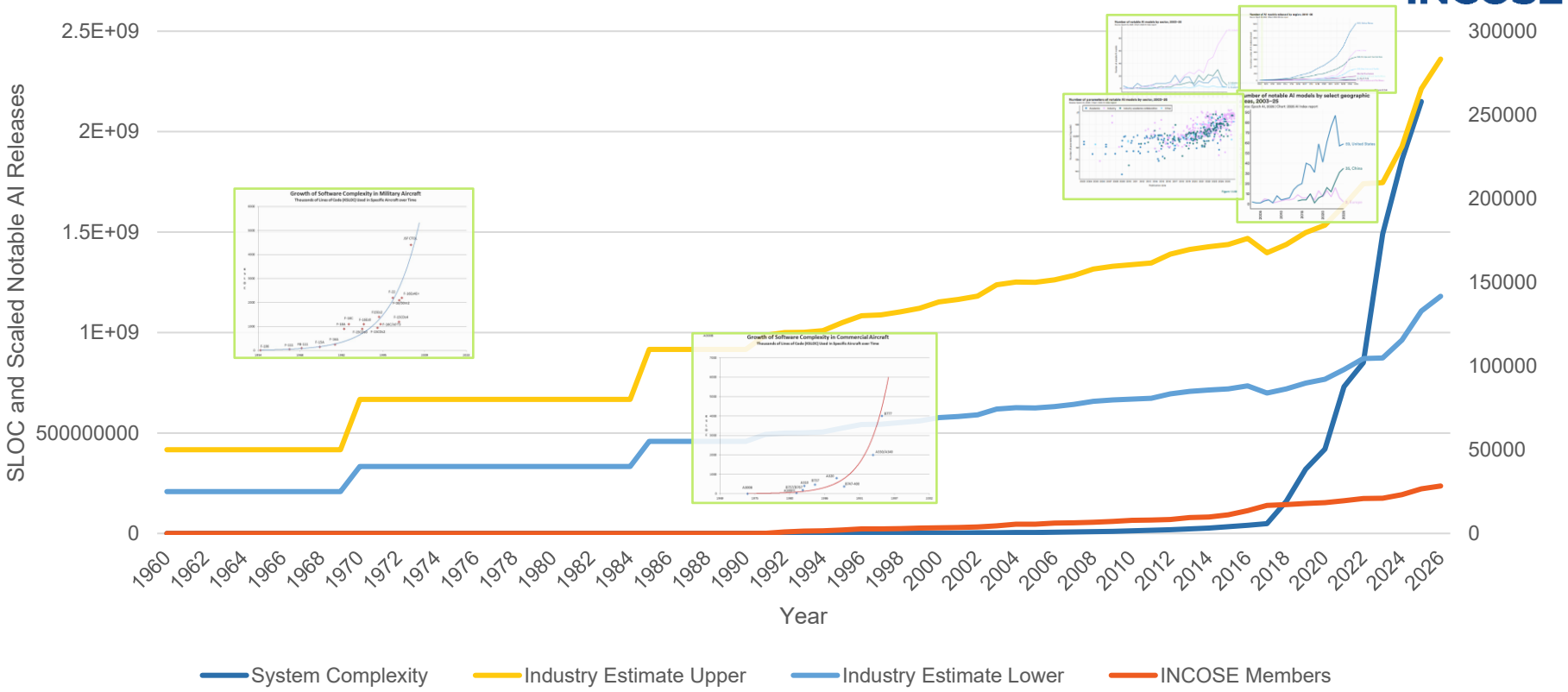
2023 — ISO/IEC/IEEE 15288

2025

Systems Engineering Body of Knowledge (SEBoK)

INCOSE/OMG SysML Collaboration

System Complexity Drives Systems Engineering Growth



AskSage Gemini 3.5 provided inputs for the System Complexity curve

Aircraft SLOC from https://savi.avsi.aero/about-savi/savi-motivation/exponential-system-complexity/

AI data from Sha Sajadieh, Loredana Fattorini, Raymond Perrault, Yolanda Gil, Vanessa Parli, Lapo Santarlasci, Juan Pava, Nestor Maslej, Russ Altman, Erik Brynjolfsson, Carla Brodley, Jack Clark, Virginia Dignum, Vipin Kumar, James Landay, Terah Lyons, James Manyika, Juan Carlos Niebles, Yoav Shoham, Elham Tabassi, Russell Wald, Toby Walsh, Dan Weld. "The AI Index 2026 Annual Report," AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, Stanford, CA, April 2026. https://doi.org/10.48550/arXiv.2606.15708

Systems Engineering Principles

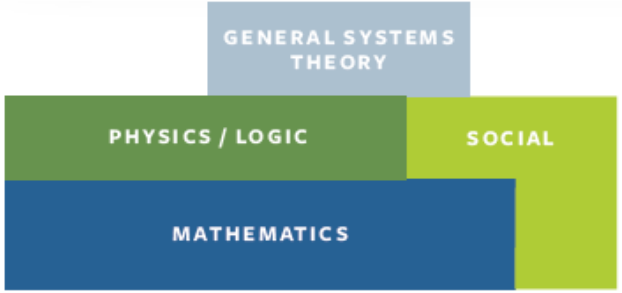
- Principle 5: The real system is the perfect representation of the system.
  - $I(f,g) = \int f(x)\log(f(x))\,dx - \int f(x)\log(g(x|\theta))\,dx$ where,
    - $f(x)$ is the real physical system,
    - $g(x|\theta)$ is the model of the system, and
    - θ are the model parameters.

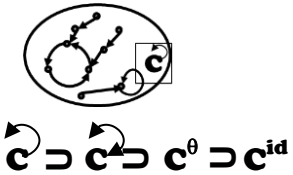
  - Autonomous/Automated algorithms operate with a limited set of parameters (i.e., $(g(x|\theta))$.
    - They do not sense the full state of the system or surroundings.



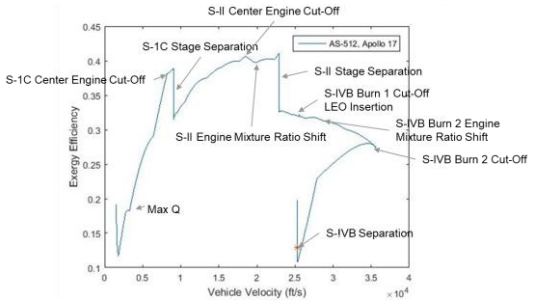
Systems Engineering Principles

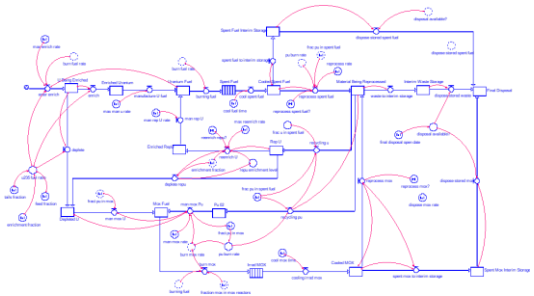
- Principle 15: Systems engineering is based on a middle range set of theories.
  - Sub-Principle 15(a): Systems engineering has a systems theory basis
  - Sub-Principle 15(b): Systems engineering has a physical/logical basis specific to the system.
  - Sub-Principle 15(c): Systems engineering has a mathematical basis
  - Sub-Principle 15(d): Systems engineering has a sociological basis specific to the organization.

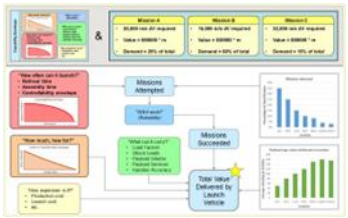






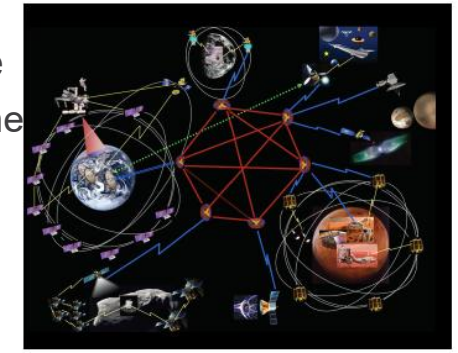






Systems Engineering Principles

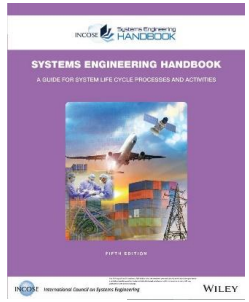
- Principle 11: Systems engineering spans the entire system life-cycle
  - Sub-Principle 11(a): Systems engineering obtains an understanding of the system
    - Consider sources of unexpected emergence
  - Sub-Principle 11(b): Systems engineering defines the mission context (system application)
  - Sub-Principle 11(c): Systems engineering models the system
    - The suite of systems engineering models may provide some insight into positive and negative emergent properties
  - Sub-Principle 11(d): Systems engineering designs and analyzes the system
  - Sub-Principle 11(e): Systems engineering tests the system
  - Sub-Principle 11(f): Systems engineering supports the production of the system
  - Sub-Principle 11(g): Systems engineering supports operations, maintenance, and retirement
    - Operations, maintenance, and retirement can lead to emergent properties (i.e., from social interaction or AI application) that should be considered in the system modeling and system design



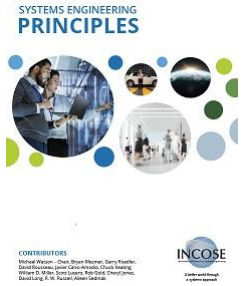


System Engineering Conclusions

- Systems Engineering is young in its development as an engineering discipline.
- Systems Engineering has grown faster than any other engineering discipline.
- Recent development in Artificial Intelligence, responding to the drive for more complex systems are now accelerating the need for these advancements in systems engineering.
- This accelerated growth has brought systems engineering to the doorstep of its fundamental scientific and mathematical basis.
- Systems Engineering Principles have been published that provide guidance towards the scientific and mathematical basis.





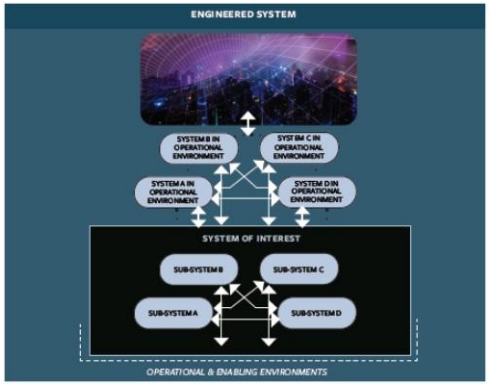


Back up

Systems Engineering Principles

- Principle 1: Systems engineering in application is specific to stakeholder needs, solution space, resulting system solution(s), and context throughout the system life cycle.

- Principle 2: Systems engineering has a holistic system view that includes the system elements and the interactions amongst themselves, the enabling systems, and the system environment.





Systems Engineering Principles

- Principle 3: Systems engineering influences and is influenced by internal and external resource, political, economic, social, technological, environmental, and legal factors.

- Principle 4: Both policy and law must be properly understood to not overly constrain or under constrain the system implementation.

- Principle 6: A focus of systems engineering is a progressively deeper understanding of the interactions, sensitivities, and behaviors of the system, stakeholder needs, and its operational environment.

- Principle 7: Systems Engineering addresses changing stakeholder needs over the system life cycle.

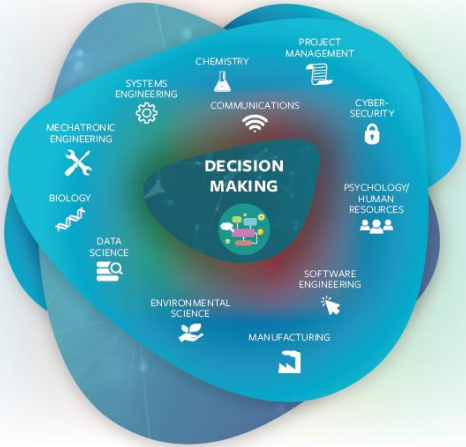


Systems Engineering Principles

- Principle 8: Systems engineering addresses stakeholder needs, taking into consideration budget, schedule, and technical needs, along with other expectations and constraints.
  - Sub-Principle 8(a): Systems engineering seeks a best balance of functions and interactions within the system budget, schedule, technical, and other expectations and constraints.

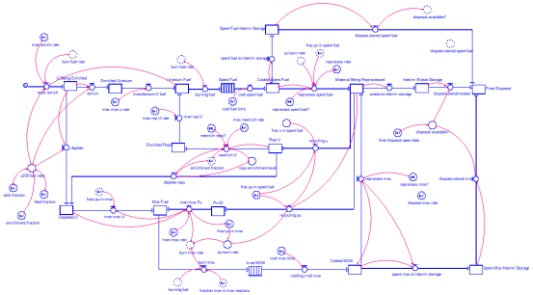
- Principle 9: Systems engineering decisions are made under uncertainty accounting for risk
  - Unexpected emergence is a source of risk or opportunity that is difficult to identify

- Principle 10: Decision quality depends on knowledge of the system, enabling system(s), and interoperating system(s) present in the decision-making process



Systems Engineering Principles

- Principle 12: Complex systems are engineered by complex organizations
  - Emergence can occur in the organizational context



- Principle 13: Systems Engineering integrates engineering and science disciplines in an effective manner

- Principle 14: Systems engineering is responsible for managing the discipline interactions within the organization
  - In the form of Information Flow through the organization
    - Project Management is responsible for project organization
    - Line Management is responsible for corporate structure and personnel
  - Every organization (i.e., company, agency) and region (i.e., Country, geographical region) has a different culture
  - Some organizational structures will “mirror” the system functions

