Systems Engineering Challenges for Integrating Software Assurance into Defense Systems Viewed Through the Prism of Future Systems

26th Annual NDIA 2022 Systems and Mission Engineering Conference
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10/16/2023 - 10/19/2023

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Increasingly Software-enable Systems Are a Significant Strategic Resource

Manual Labor

Water

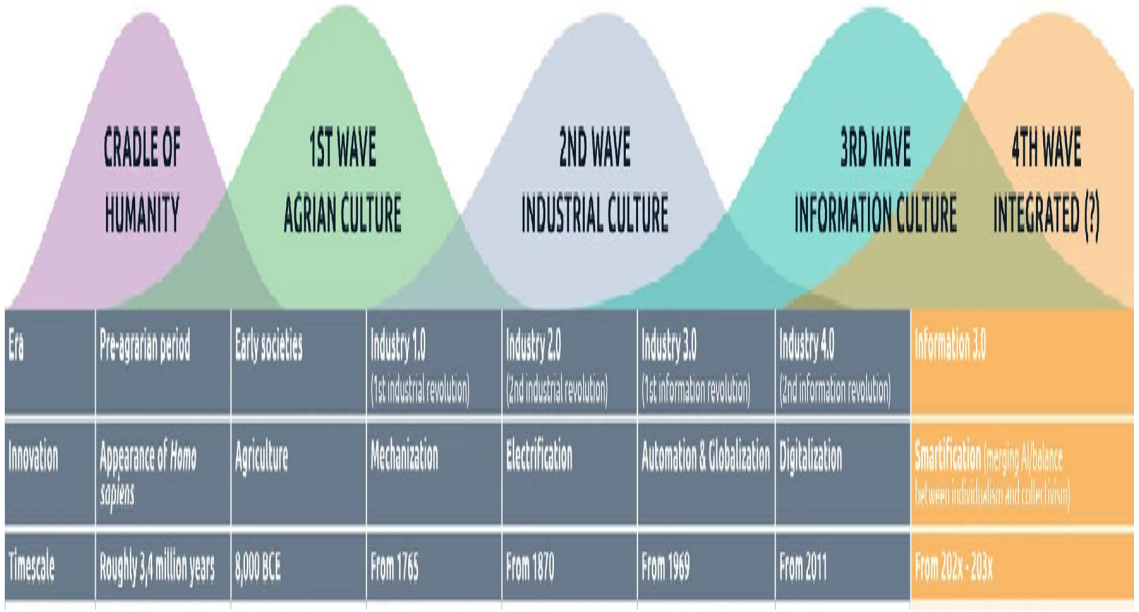
Steam

Oil

Software

Increasing Globalization, Productivity, Complexity and Uncertainty

DoD Vision: Deliver Resilient Software At The Speed Relevance*



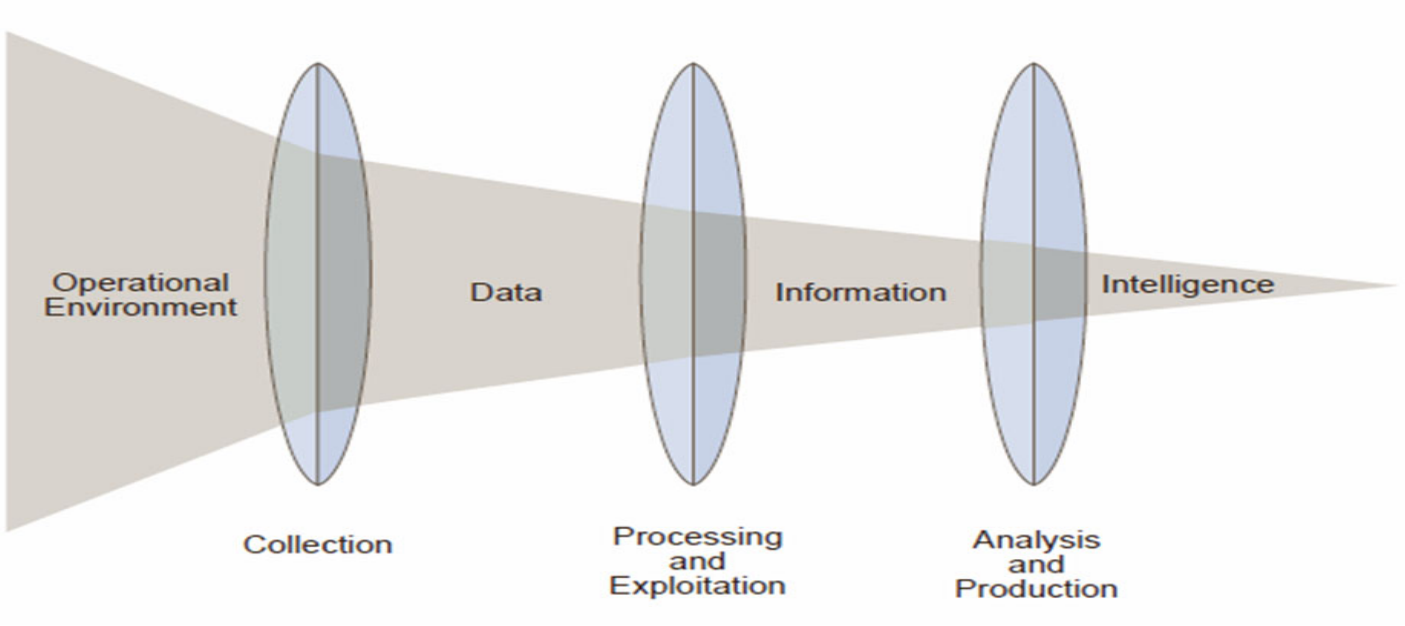
Four Waves of Industrial Revolution

Uncertainties Are The Only Certainties We Have.

Source: Department of Defense Software Strategy Coordinator, November 2021

Enabling Effective Decision Making

Relationship of Data, Information and Intelligence



Source: Joint Intelligence / Joint Publication 2-0 (Joint Chiefs of Staff)

Decision Makers

BANI - How To Make Sense of a Chaotic World?
(Idea: We live in a world of constant change)

- **Brittleness** - The world has become brittle or fragile. The new environment has shorter product lifecycle, disruptive change - the transformation to a digital world.
- **Anxiety** - The situation around us has become more anxious. The current events happening in the world, such as how COVID 19 make the world 'anxious' – mask or no mask.
- **Non-Linearity** - Cause and effect relationships are no longer easily predictable in advance – resources for quantum research.
- **Incomprehensibility** - It is very difficult to understand and comprehend how events are happening and why they are happening - AI/Machine Learning is changing the world and us.

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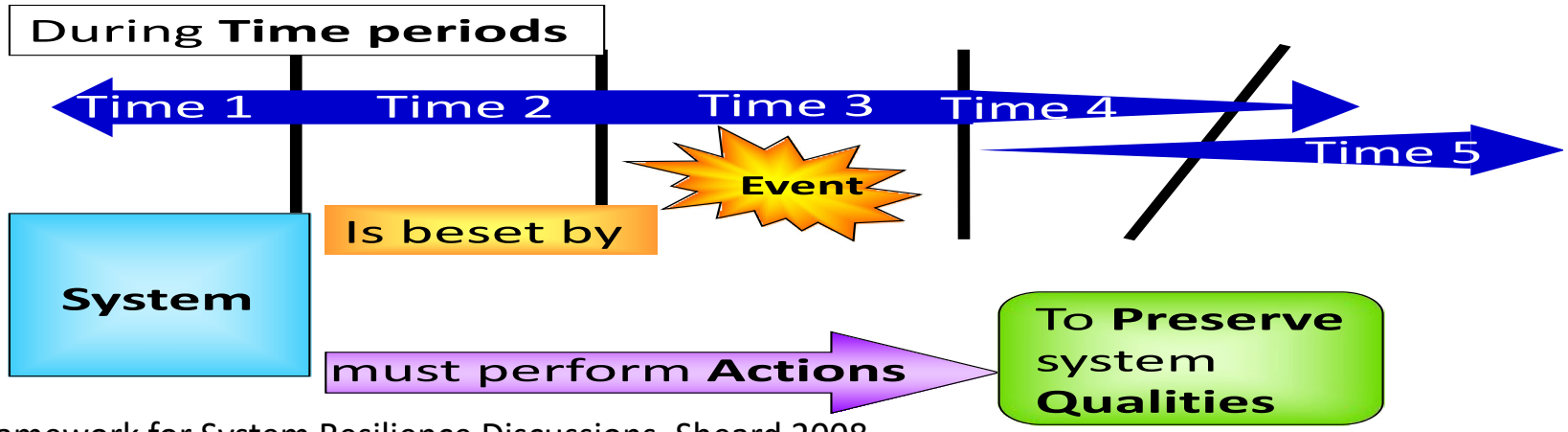
Twenty- First Century Imperatives in Transdisciplinary Engineering

- Norm Augustine: “One should expect that the expected can be prevented, but the unexpected should have been expected”
- Engineering resilience is a system property that allows a system to continue providing useful service despite largely unpredictable and disruptive events internal or external to the system



A Framework for System Resilience Discussions. Sheard 2008

Looking Into the Future - Transdisciplinary Systems Engineering

Finding Your Systems Engineering Role In 21st Century Software -Dominant Organizations**

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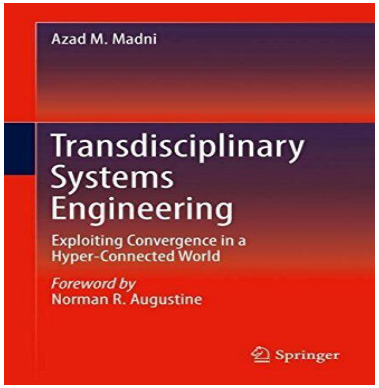

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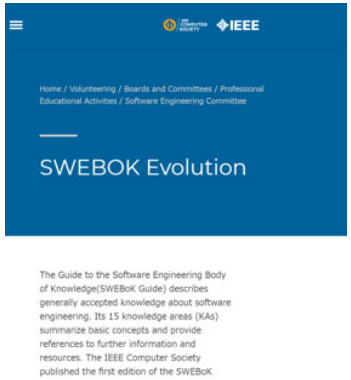

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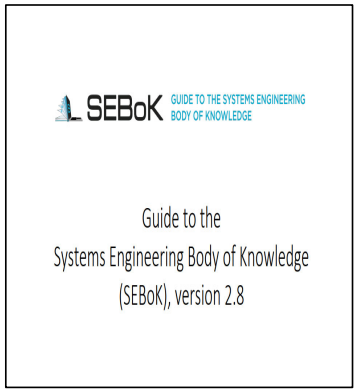

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* Sheard, Bouyaud, Osaisai, Siviy, and Nidiffer, Finding Your Systems Engineering Role In 21st Century Software -Dominant Organizations, 2021

** Azad M. Madni ,Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyper-Connected World, 2018

*** Washizaki, H., Sanchez-Segura, M-I., Garbajosa, J., Tockey, S., Nidiffer, K.E.. “Envisioning Software Engineer Training Needs in The Digital Era Through the SWEBOK V4 Prism”, *Proceedings of the IEEE International Conference on Software Engineering Education and Training* (CSEE&T 2023), August 8-9, 2023, Waseda University, Tokyo Japan.

**** Washizaki, H., Sanchez-Segura, M.I., Garbajosa, J., Tockey, S., Reilly, A.D., Nidiffer, K.E, SWEBOK v4 Article to the Systems Engineering Body of Knowledge (SEBOK v2.8), 2023 – release TBD

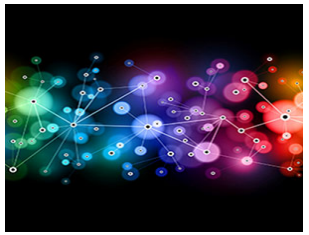
Twenty- First Century Imperatives in Transdisciplinary Engineering

- Today the network of relationships linking the human race to itself and to the rest of the biosphere is so complex that all aspects affect all others to an extraordinary degrees.*
- Someone should be studying the whole system, however crudely it has to be done, because no gluing together of partial studies of a complex nonlinear system can give a good idea of the behavior of the whole.*

*Murray Gell-Mann - physicist

The illiterate of the 21st century will not be those who cannot read or write but those who cannot learn, unlearn and relearn - Alvin Toffler – Futurist

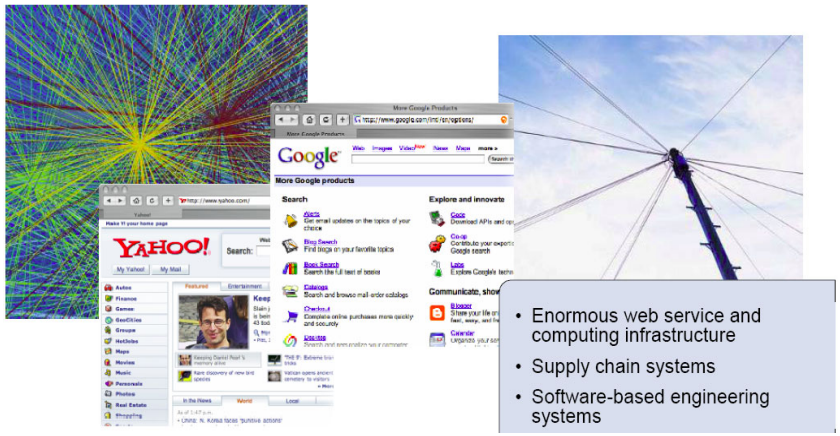
Grand Challenges/Wicked Problems*
Move to Transdisciplinary Engineering



Number	Grand Challenge	Group	Number	Grand Challenge	Group
	Advance personalized learning	Joy of Living	8	Secure cyberspace	Vulnerability
	Enhance virtual reality	Joy of Living	9	Restore and improve urban infrastructure	Sustainablity
	Engineer the tools of scientific discovery	Joy of Living	10	Provide access to clean water	Sustainablity
	Reverse engineer the brain	Health	11	Provide energy from fusion	Sustainablity
	Engineer better medicines	Health	12	Manage the nitrogen cycle	Sustainablity
	Advance health informatics	Health	13	Develop carbon sequestration methods	Sustainablity
	Prevent nuclear terror	Vulnerability		Make solar energy economical	Sustainablity

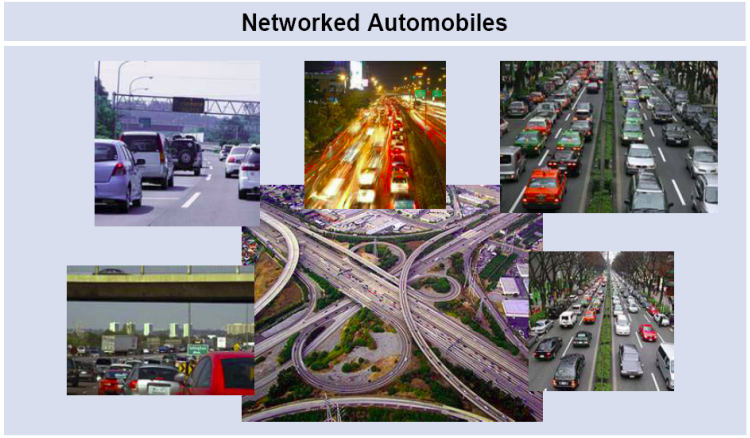
*National Council of Engineering - 2018

Emerging Ultra-Large Systems of Systems Requiring Transdisciplinary Engineering



- Enormous web service and computing infrastructure
- Supply chain systems
- Software-based engineering systems

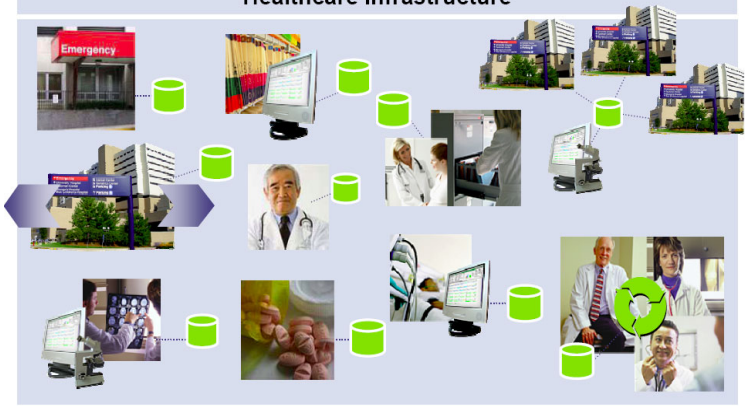
Networked Automobiles



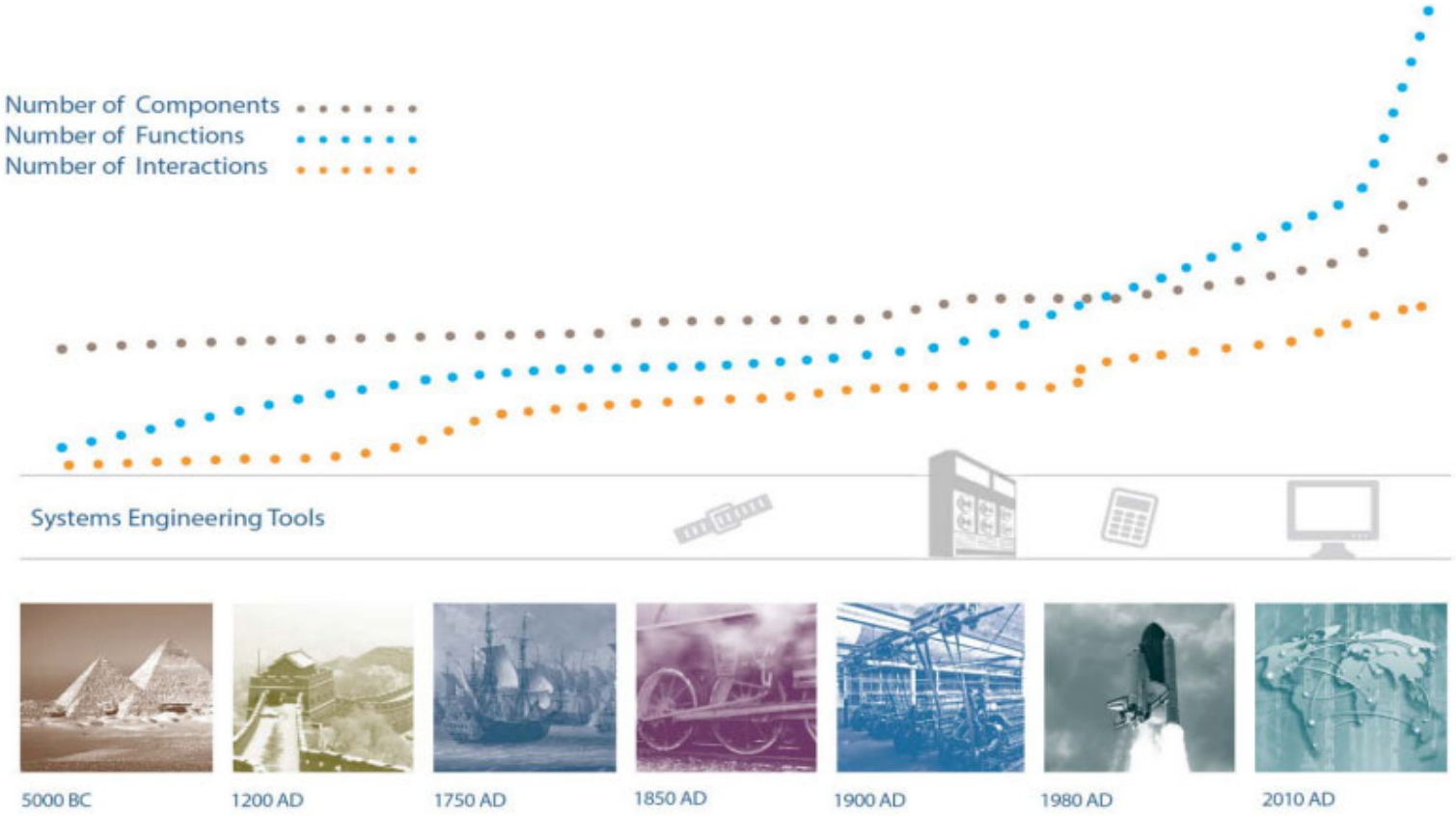
Homeland Security

Source: www.sei.cmu.edu/uls

Healthcare Infrastructure



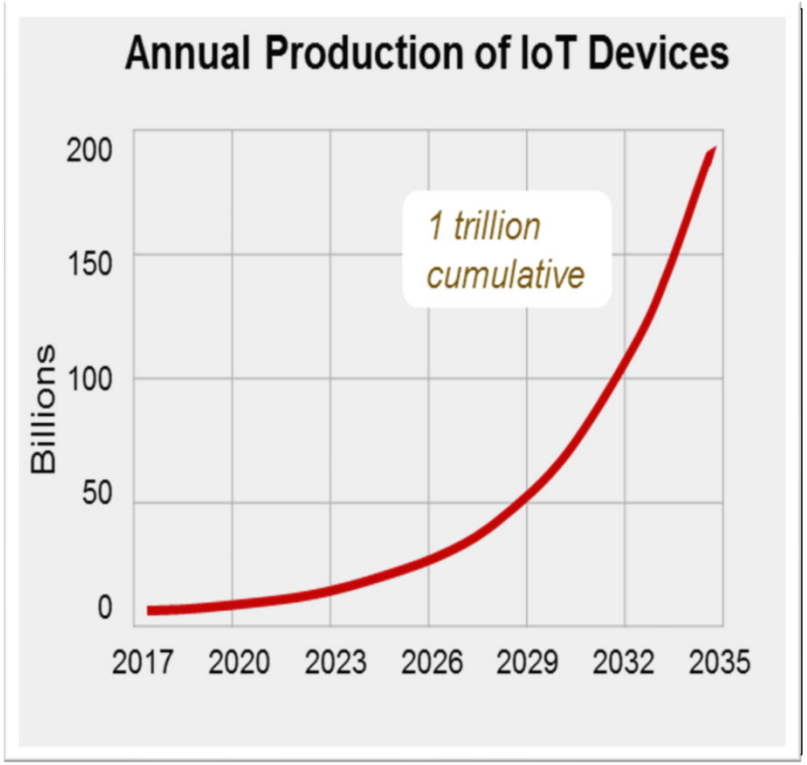
Trend: Increasing Number of Components, Functions and Intersections*



* Roedler G., Systems Engineering of the Future: Shaping the Future of Systems Engineering, Feb 28, 2018

Trend: Increasing Number of Connected Platforms*

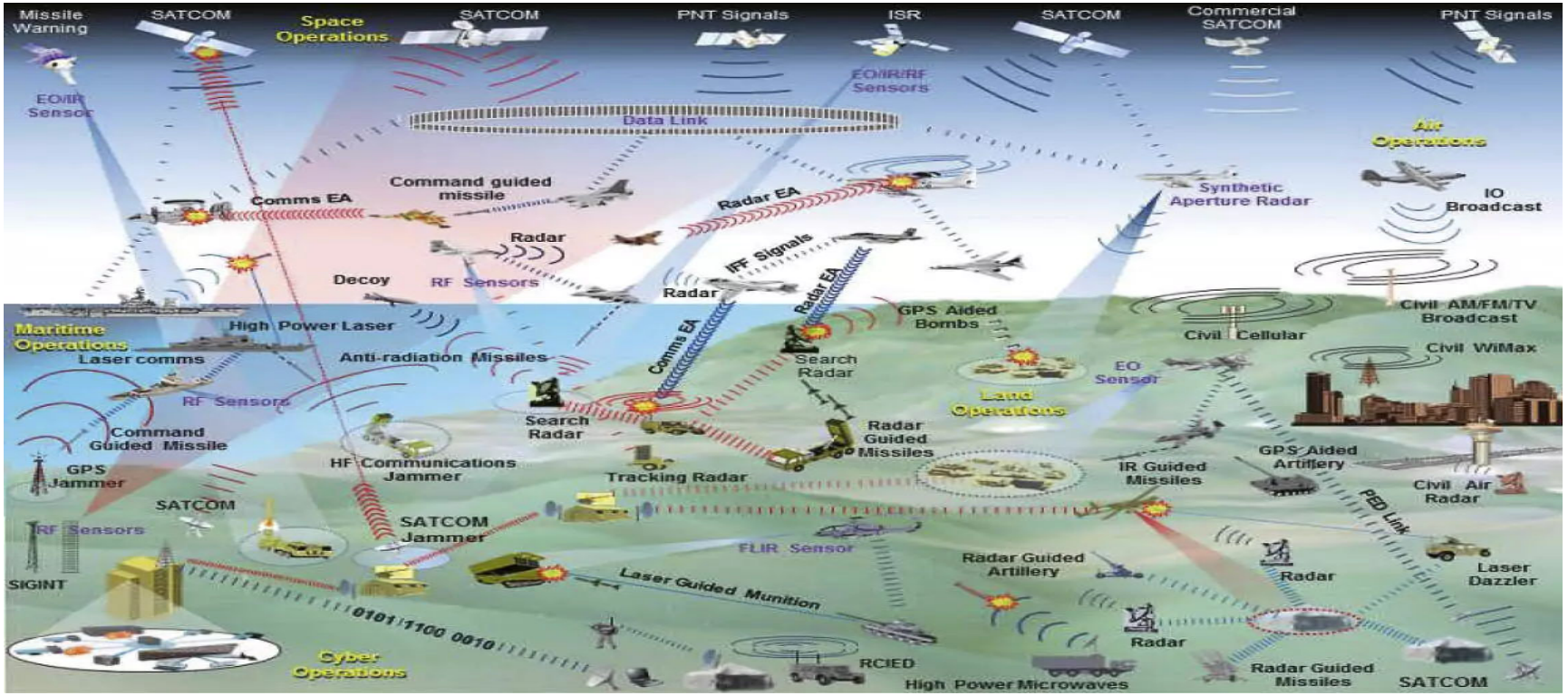
- An internet of things (IoT) platform is software that enables development, deployment, and management of solutions that connect to and capture data from IoT endpoints.
- IoT platforms can be delivered as a hybrid combination of edge platforms and/or cloud IoT platforms as a service



Source data: ARM Holdings

*AFCEA Technical Vectors, 2021

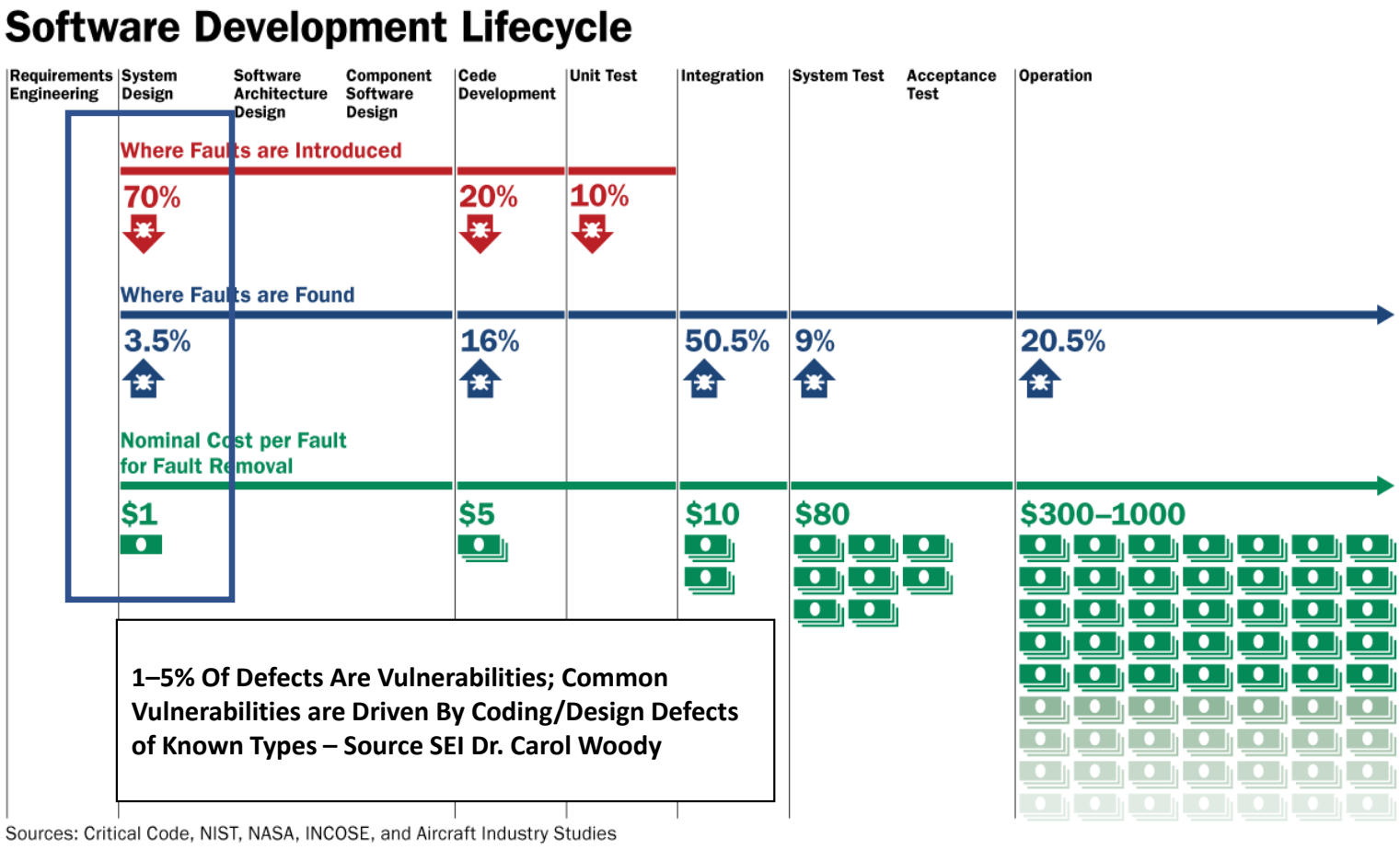
Engineered Systems Are Distinct But Becoming Intimately Intertwined Transdisciplinary Engineering Disciplines



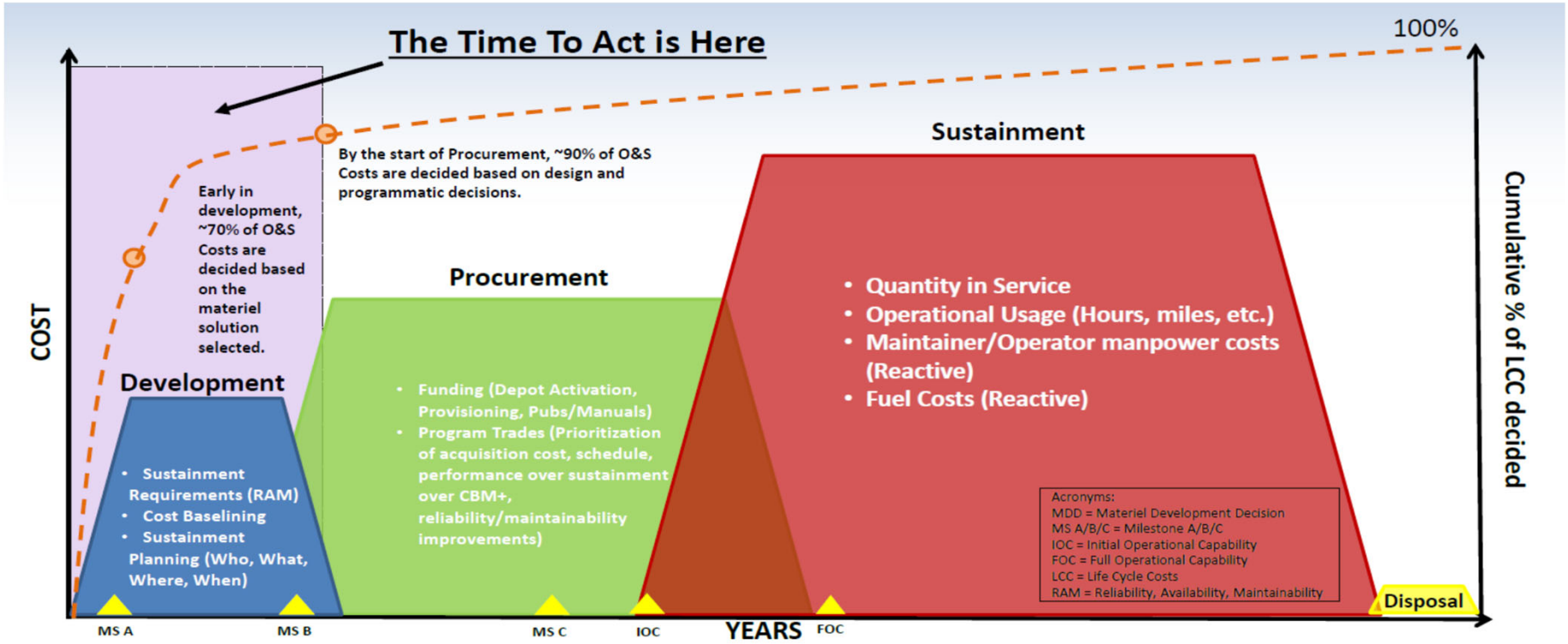
Engineered Systems Are Distinct But Becoming Intimately Intertwined Transdisciplinary Engineering Disciplines

Category	Characteristics	Examples	Roles Played
Older physical systems	Relatively "dumb"	Bridges, buildings, vehicles, roads	Predominantly systems engineers
Computational systems	Computational algorithms, behaviors, and software representations	Information systems, operating systems, middleware	Predominantly software engineers
Cyber-physical systems	Complex configurations of physical and computational elements	Self-driving vehicles, Internet of things, robotic manufacturing systems	Complex interactions of Transdisciplinary Engineering

The Result: Reducing Vulnerabilities and Technical Debt Becomes More Important

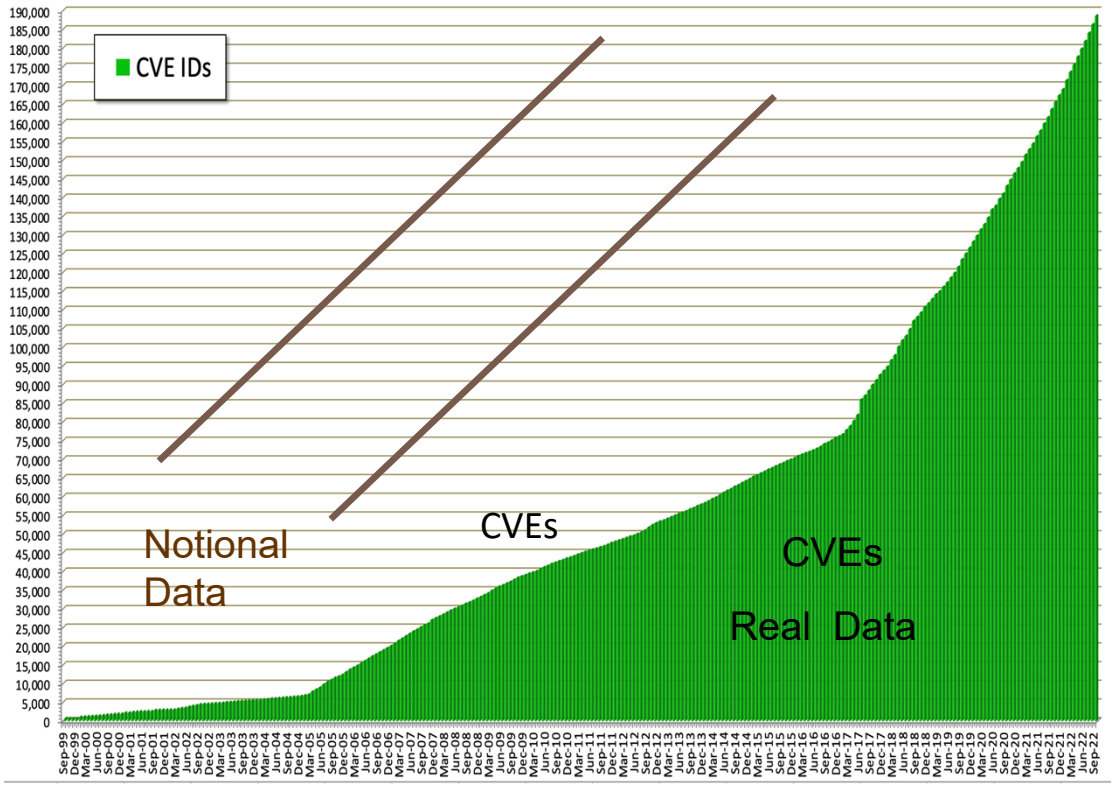


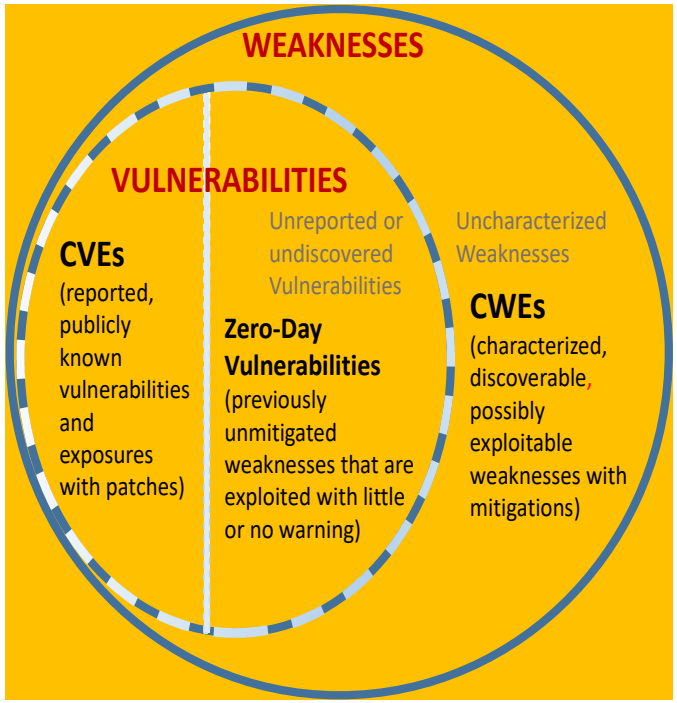
“Bake In” Data During System Design



Source: 2022 PSM Workshop, Principal Deputy Assistant Secretary of Defense

The Result: Software Assurance Is and Has Been a Security Issue CVE 1999 to 2022: Reported Common Vulnerabilities and Exposures (CVEs)





Source: Robert A. Martin, MITRE Corporation, October 2022

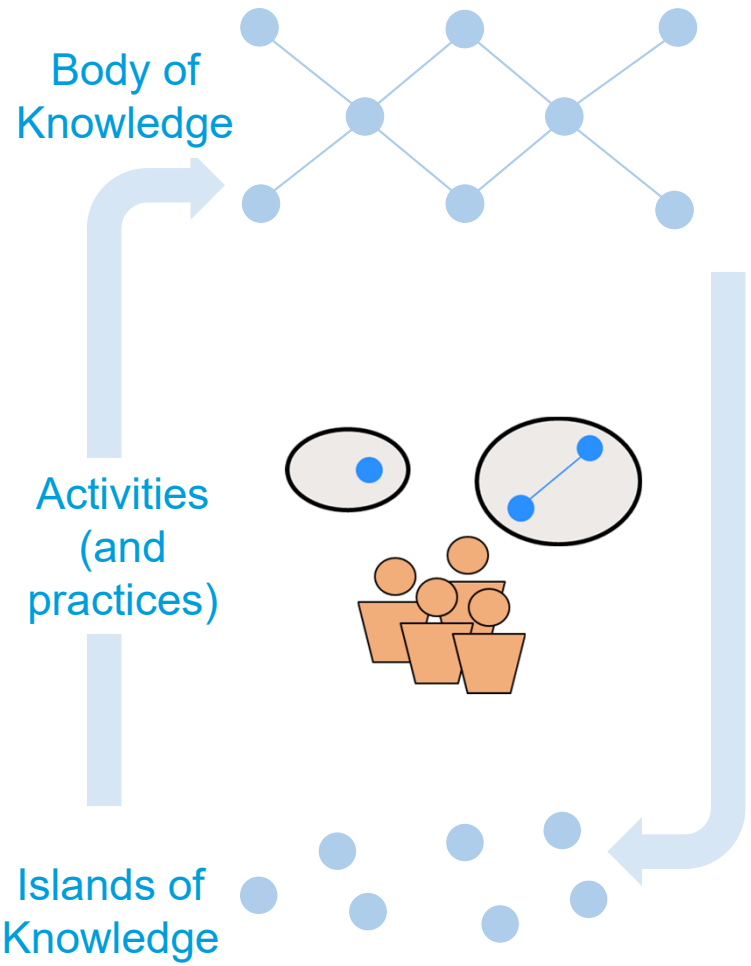
Leveraging Transdisciplinary Engineering Competencies.

- Software will continue to grow in a social technical ecosystem comprising customers, end users', developers, maintainers, testers and other stakeholders.
- The increasing complexity is becoming apparent that the people aspect of software deserves greater attention and more emphasis.
- The people aspect comprises the peoples' decisions, personal skill sets, training motivation, creativity and talent.
- Principal issue greater than increasing software complexity – more about effectively leveraging transdisciplinary engineering competencies.

Guide to the Software Engineering Body of Knowledge (SWEBOK)

http://swebokwiki.org

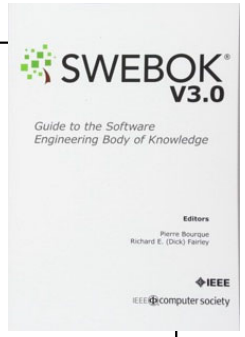
- Objective
  - Guiding learners, researchers and practitioners to identify and have common understanding on **"generally-accepted-knowledge"** in software engineering
  - **Defining boundary** of software engineering and related disciplines
  - Providing **foundations for certifications and educational curriculum**
- Adoption
  - IEEE-CS software professional **certification programs** based on SWEBOK (Associate Software Developer, Professional Software Developer, Professional Software Engineering Master)
  - **ISO/IEC 24773-4: Certification of software and systems engineering professionals** - Part 4: Software engineering
  - **Software Engineering Competency Model (SWECOM)**



SWEBOK Evolution from V3 to V4

- Modern software engineering, practice change and update, BOK grows and recently developed areas
- Public review under progress! https://www.computer.org/volunteering/boards-and-committees/professional-educational-activities/software-engineering-committee/swebok-evolution

SWEBOK V3



Requirements

Design
Construction
Testing

Maintenance
Configuration Management
Engineering Management
Process
Models and Methods
Quality

Professional Practice
Economics
Computing Foundations
Mathematical Foundations
Engineering Foundations

SWEBOK V4

Requirements
Architecture
Design
Construction
Testing
Operations
Maintenance
Configuration Management
Engineering Management
Process
Models and Methods
Quality
Security
Professional Practice
Economics
Computing Foundations
Mathematical Foundations
Engineering Foundations

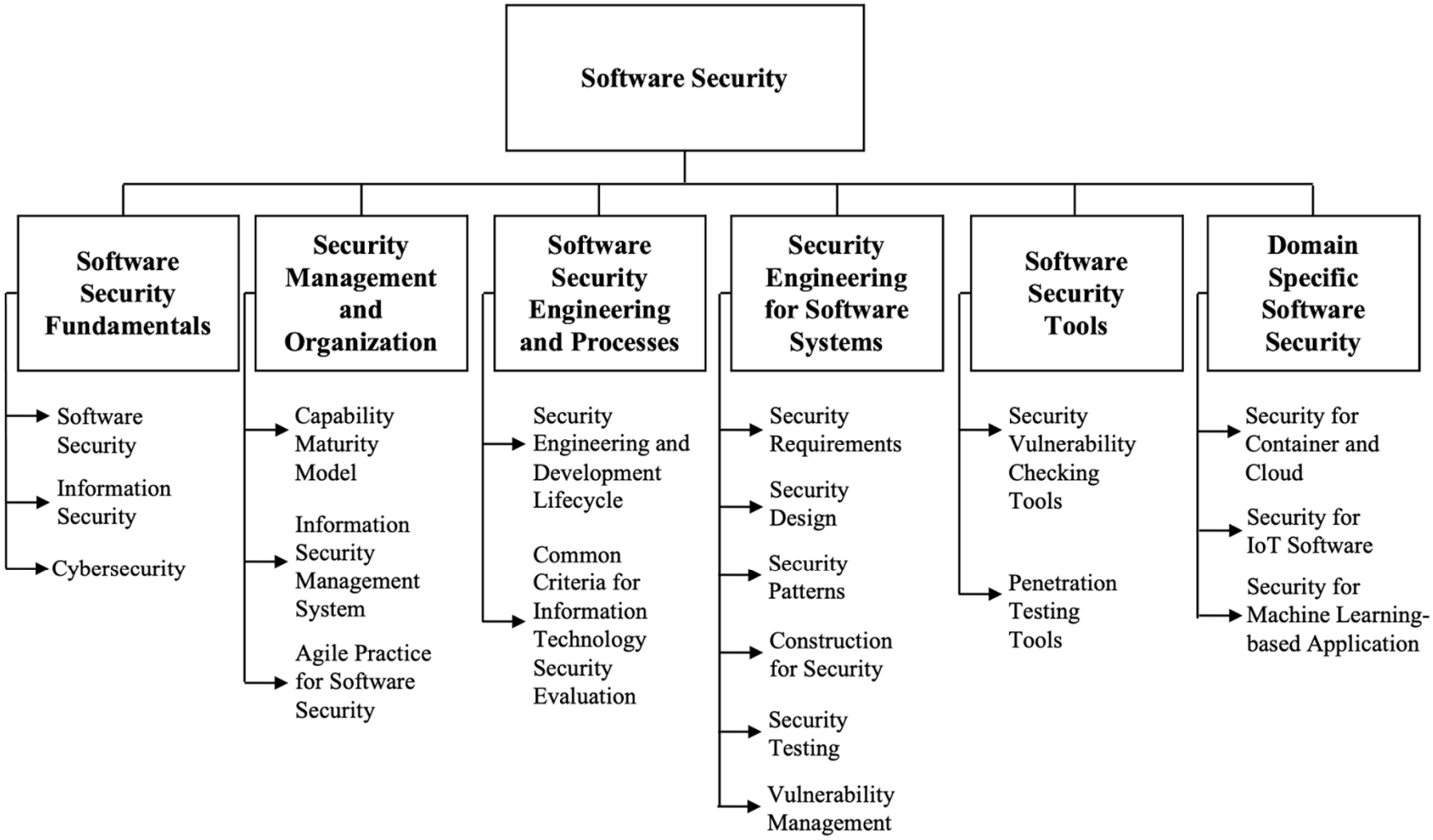
Agile testing
. . .

Agile, DevOps

Agile security
. . .

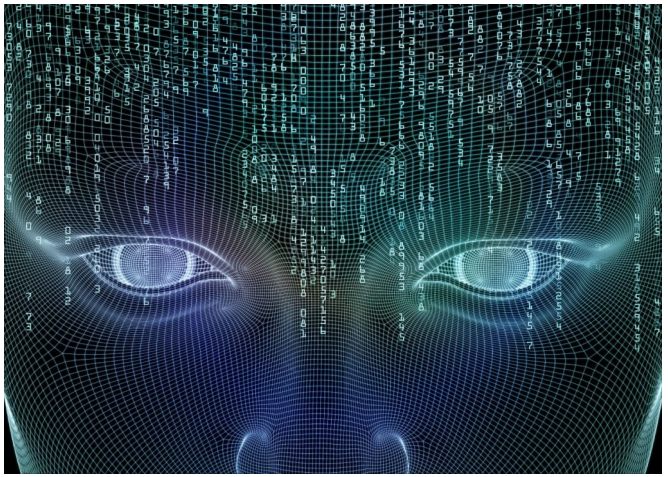
AI for SE, SE for AI

Example of New Knowledge Area Structure (SWEBOK)



Improving Our Cyber Security Posture

1. Improve Policy
2. Update Acquisition Processes
3. Improve Software Development Processes*
4. Improved Transdisciplinary Engineering Convergence



* Williams, C, Why DOD Is So Bad at Buying Software, FCW and Defense Systems Defense Systems, Nov 08, 2021

The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking - Albert Einstein

Example 1: Improved Transdisciplinary Engineering Convergence - Ten Things Systems Engineers Need to Know About Software Engineering*

1. Systems Engineering and Software Engineering are Distinct Disciplines
   a. Systems Engineers apply their problem-solving skills (based on continuous mathematics and the physical sciences) to develop physical systems.
   b. Software engineers apply their problem-solving skills (based on discrete mathematics and computer science) to develop computational systems.
2. Software Is a Logical Medium
   a. Software elements of software-enabled systems are logical constructions expressed in algorithmic form,
   b. in contrast to the physical elements of systems that are realized in mechanical, electrical, chemical, biological, and other physical media.

* Fairley, R., Systems Engineering of Software-Embedded Systems, Wiley, 2019

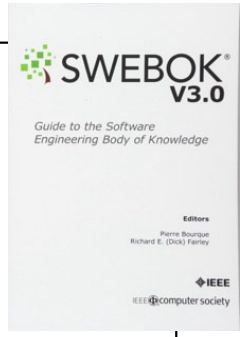
Example 2: Improved Transdisciplinary Engineering Convergence - Evolution of the Guide to The Software Engineering Body of Knowledge (SWEBOK 4.0)

- History: 2001 v1, 2004 v2, 2005 ISO/IEC Technical Report, 2014 v3, **2022 v4**
- Objective:
  - Guiding learners, researchers and practitioners to identify and have common understanding on **"generally-accepted-knowledge**" in software engineering
  - **Defining boundary** of software engineering and related disciplines
  - Providing **foundations for certifications and educational curriculum**
- Example:
  - *Update to SEBOK – Article on SWEBOK v4

*Washizaki, H., Sanchez-Segura, M.I., Garbajosa, J., Tockey, S., Reilly, A.D., Nidiffer, K.E, SWEBOK v 4, Article to the Systems Engineering Body of Knowledge (SEBOK), 2023 – release TBD

Example 3: : Improved Transdisciplinary Engineering Convergence - Evolution of the Guide to The Software Engineering Body Of Knowledge (SWEBOK 4.0)

SWEBOK V3



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SWEBOK V4

Requirements
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Computing Foundations
Mathematical Foundations
Engineering Foundations

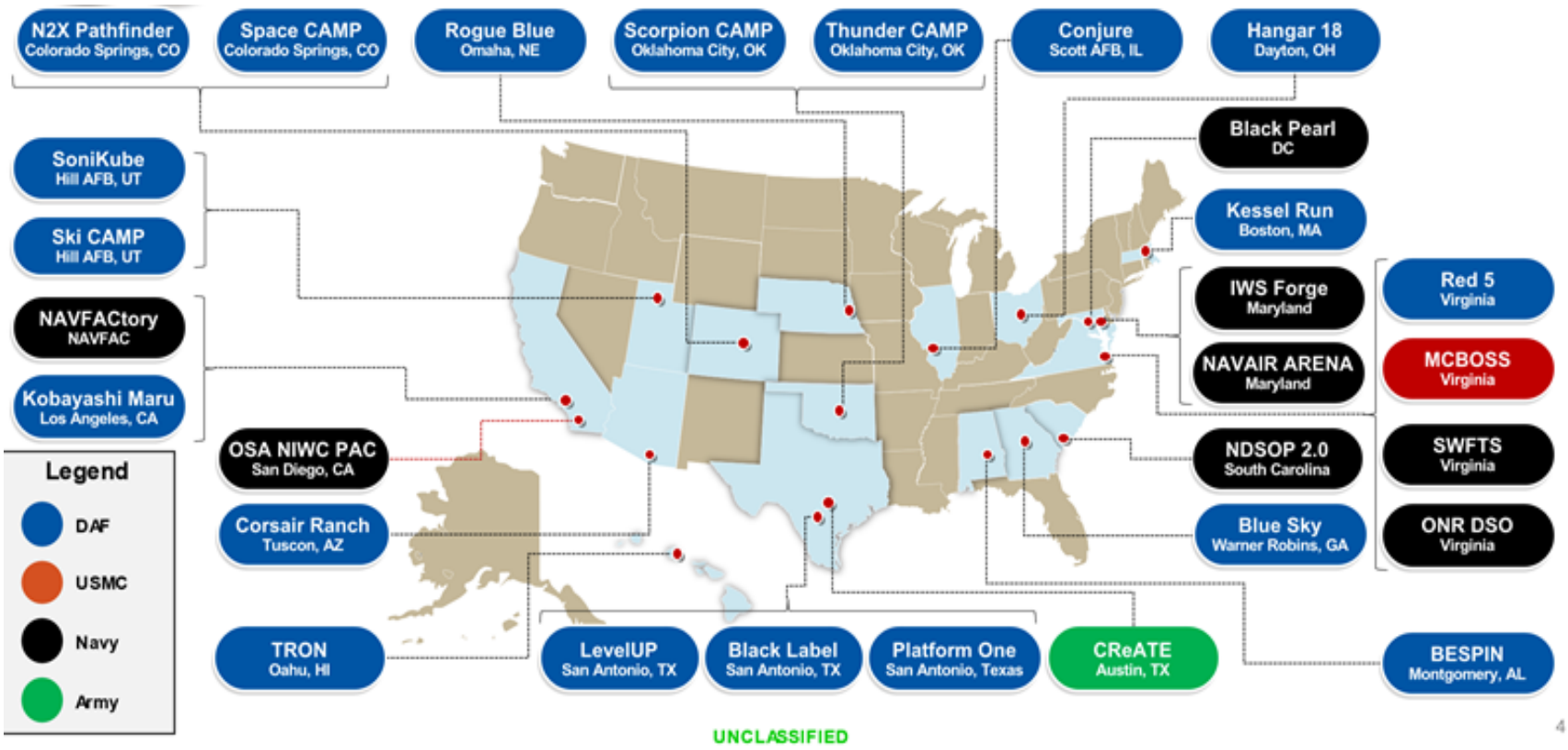
Agile testing
. . .

Agile, DevOps

Agile security
. . .

AI for SE, SE for AI

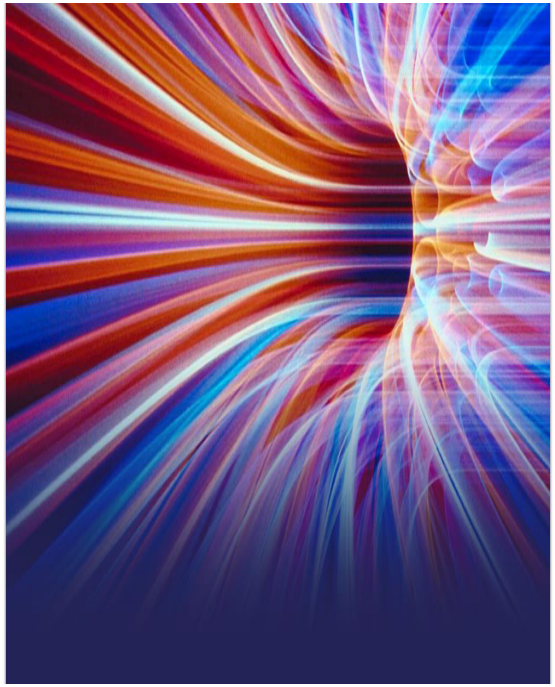
Example 4: Surveying the Software Factory Ecosystem



The most dangerous phrase in the language is, "We've always done it this way".- Rear Admiral Grace Hopper

So Where Does This Lead Us?

- The scale of complicated and complex software-enable systems & services will continue to increase exponentially with intricate and often hidden interfaces & interrelationships, operating in a dynamic and non-deterministic world.
- Increases in product functionality, software assurance goals and deliveries of overall value at the speed of relevance are dependent on transdisciplinary systems engineering teams working as intimately intertwined disciplines throughout the life cycle.
- Transdisciplinary team disciplines need to be brought forward (from right to left) in the life cycle. As system engineering partners (outside-in) versus a specialty engineering functions executed late in the development life cycle.



Thank you – Questions/Comments

Contact Information

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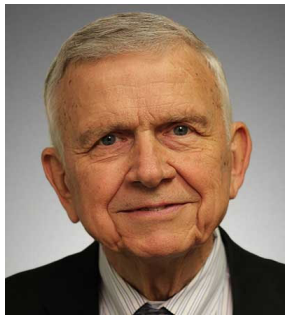

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