Struggles at the Frontiers of Systems Engineering and Measurement

20th Practical Software and Systems Measurement Users' Group Meeting and Workshops: ***Aligning Measurement with System Life Cycle Realities***

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Document Markings

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Topics

- Quiz
- Adapting to the Speed of Relevance
- Need to Change the Way We Do Business
- Sustainment and Operations Measurement

Quiz: Agree or Disagree

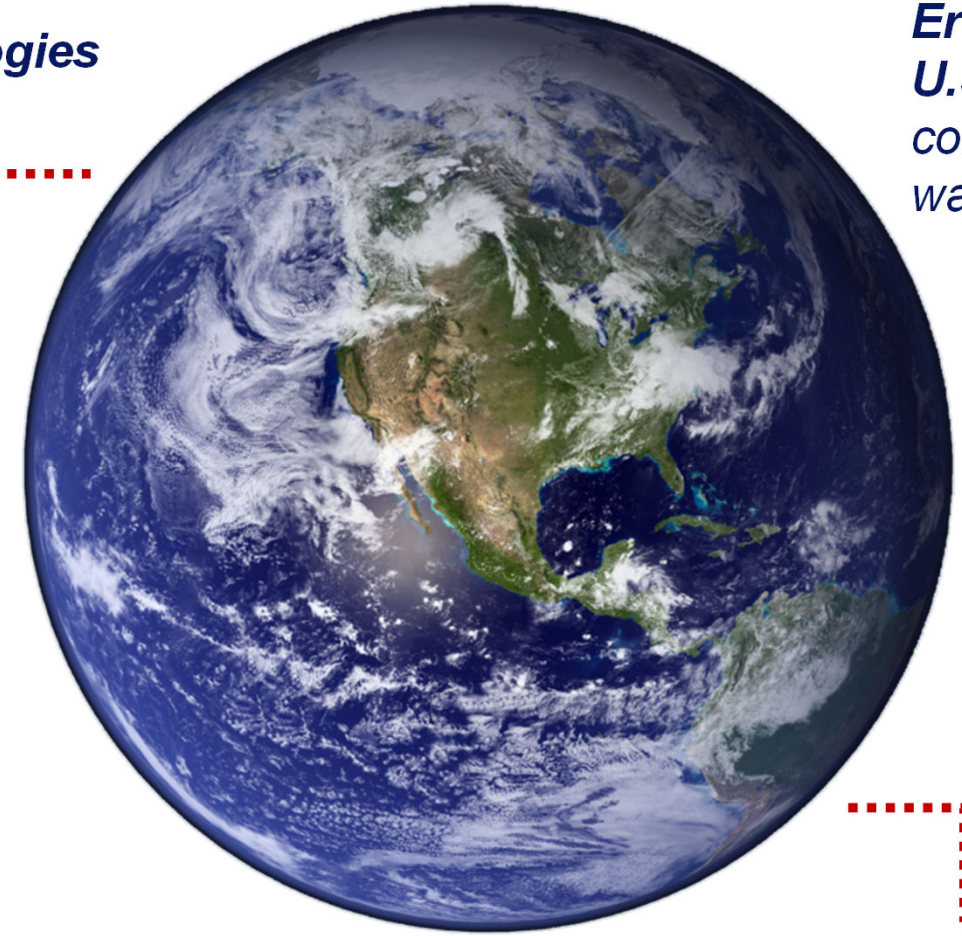
- Are we in a time of dramatic change in DoD?
- Are we responsible for adapting to that change and/or helping others adapt?
- Are we ready, willing and able to make this work?

  *"**Poor acquisition outcomes** are **forfeiting U.S. technology advantages** and depriving the nation of strategic capabilities**…**The acquisition system and **culture must adapt** to the reality that hardware and software systems must change on a frequent basis to meet warfighter needs, adapting to the speed of relevance."*
  – General James Mattis

- So, due to rate of technological advancements impact systems/software engineering continuously making the definition and application of measurement an ongoing struggle.

Near-Peer Adversaries – Need to Think Differently

Invest in technologies *that mitigate our strengths*



Erode traditional U.S. advantage *in conventional warfare*

Exploit U.S. vulnerabilities

Field systems and capabilities ***more rapidly***

We now face a renewed power competition

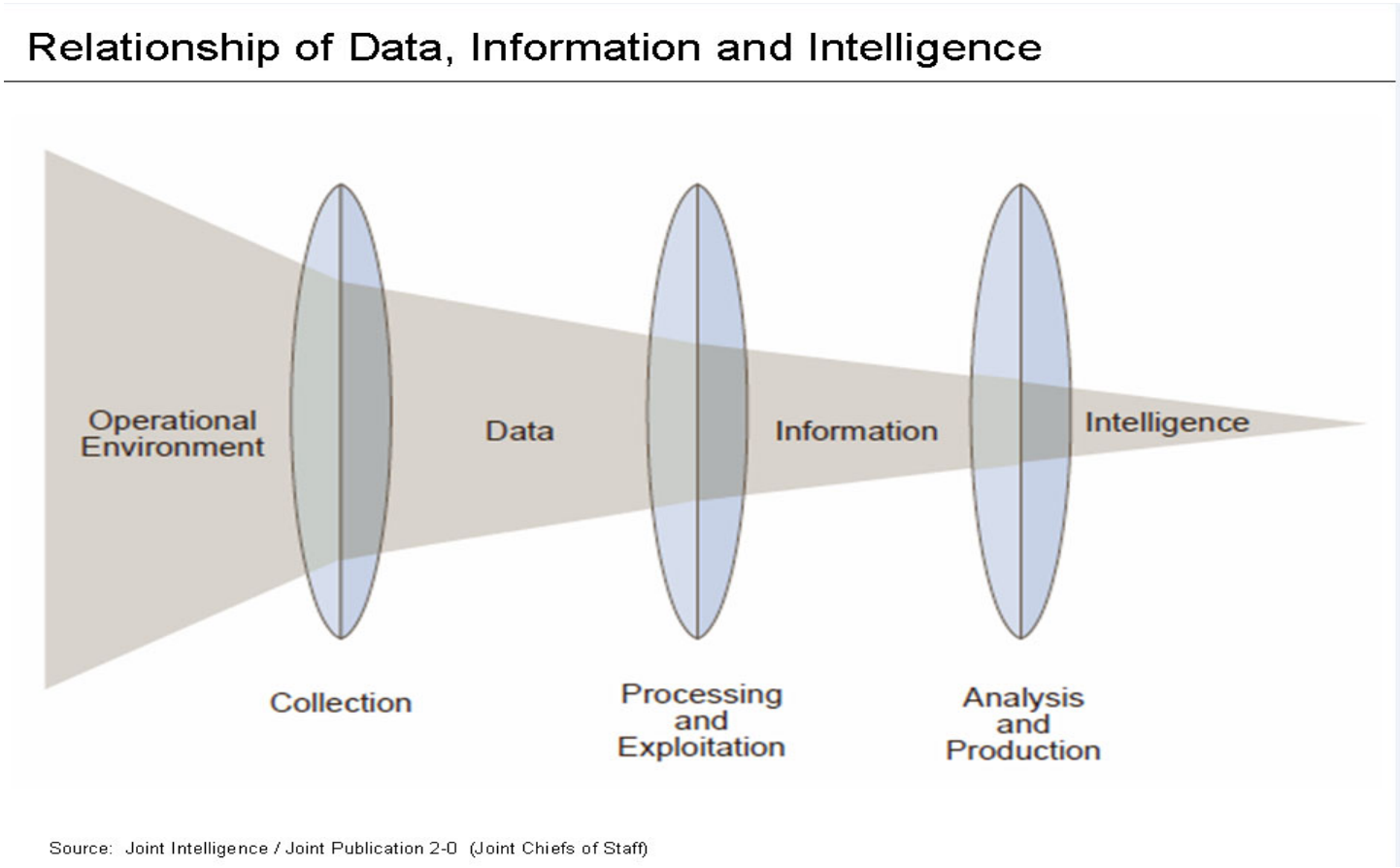
National Defense Strategy Lines of Effort

- Build a More Lethal Force
- Strengthen Alliances and Attract New Partners
- Change the Way We Do Business

"A more lethal force, strong alliances and partnerships, American technological innovation, and a culture of performance will generate decisive and sustained U.S. military advantages."
National Defense Strategy

Intelligence Model – Support for Decision Making

Need to Develop and Field Capabilities Faster to Satisfy the Mission



Software-Enabled Systems Are Today's Strategic Resource

Dr. Bill Scherlis*

"Software is the building material for modern society"

Manual Labor

Water

Steam

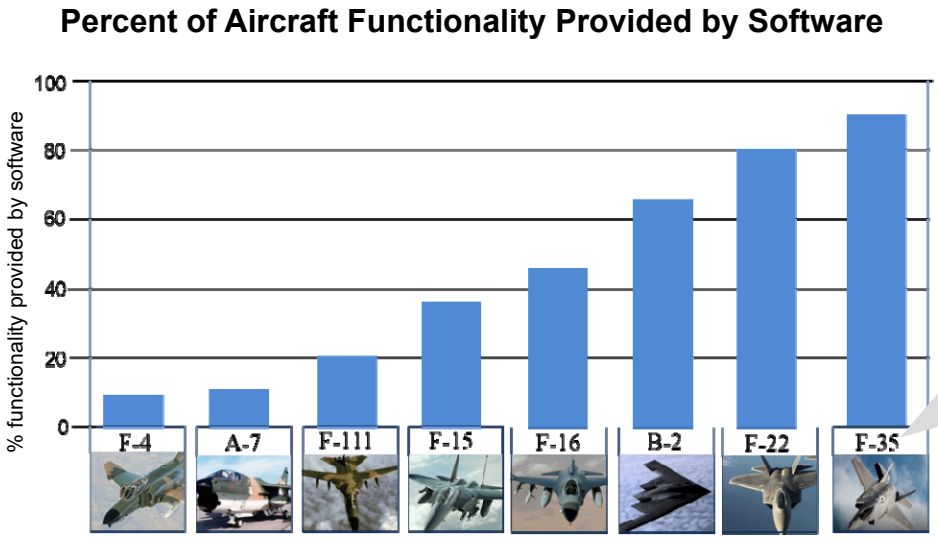
Oil

Software

Increasing Globalization, Productivity, and Complexity

Software is Foundational to the Delivery of Warfighter Capability

Software is inherent in today's complex systems and is often the primary cost, schedule, and technical performance driver in DoD programs.

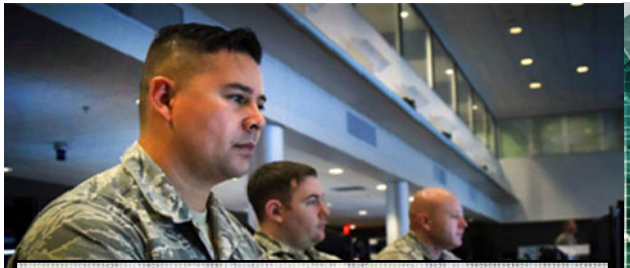


The F-35 is essentially a **"flying computer."**

Software enables almost **90%** of its air system functionality, operations, and support.

Source: *NASA Study on Flight Software Complexity https://www.nasa.gov/pdf/418878main_FSWC_Final_Report.pdf*

Software is a National Defense Priority



NDS Priority – Streamline rapid, iterative approaches from development to fielding

SEI Response – Experiment in situ; establish continuous verification and validation; continuous ATO

NDS Priority – Continuously delivering performance with affordability and speed

SEI Response – Advanced analysis to manage performance and cost (causal modeling, ML, automated software metrics)

NDS Priority – Advanced autonomous systems, artificial intelligence, machine learning

SEI Response – Develop architectures, analyses, and algorithms for intelligent systems

NDS Priority – Address the scope and pace of our adversaries' ambitions and capabilities

SEI Response – Develop and assure AI, cyber physical, and edge systems

NDS Priority – Modernize key capabilities

SEI Response – Modernize acquisition lifecycle practices to continuously deploy capability; Adapt Agile and DevOps for DoD

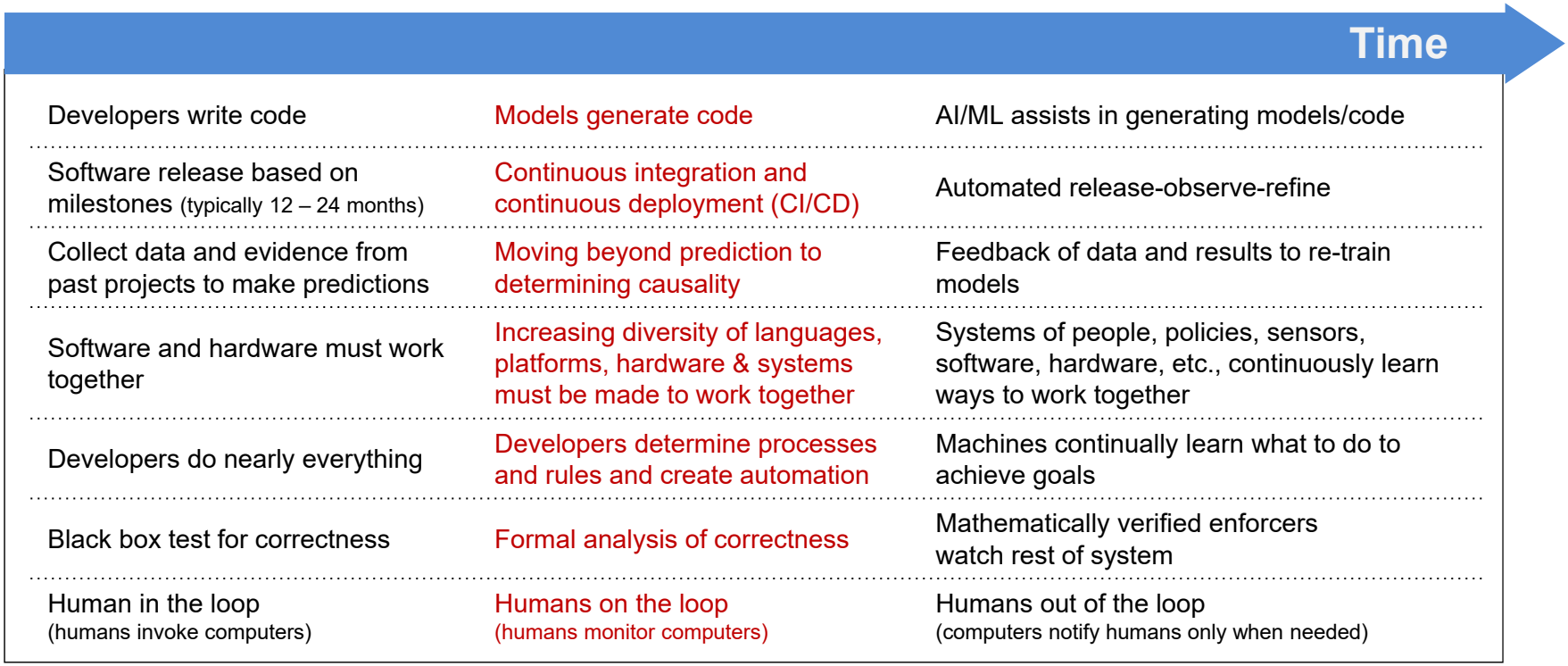
NDS Priority – Evolve innovative operational concepts

SEI Response – Build innovative mission capabilities at the edge

Source: Summary of the 2018 National Defense Strategy (NDS) for the United States of America Department of Defense https://dod.defense.gov/Portals/1/Documents/pubs/

Fundamental Shifts in Software Engineering

As software and systems are increasingly becoming **bigger**, **more complex**, and **intertwined**, software engineering and the roles people play are evolving in response.



Impact of Increasing Software-Intensive Systems

- Emergent behavior
- Requirements for faster delivery of capabilities
- Continuous and asynchronous delivery
- Continuous system evolution and becoming more intertwined
- Human–machine interface issues
- Data-rich environment

Key Points So Far

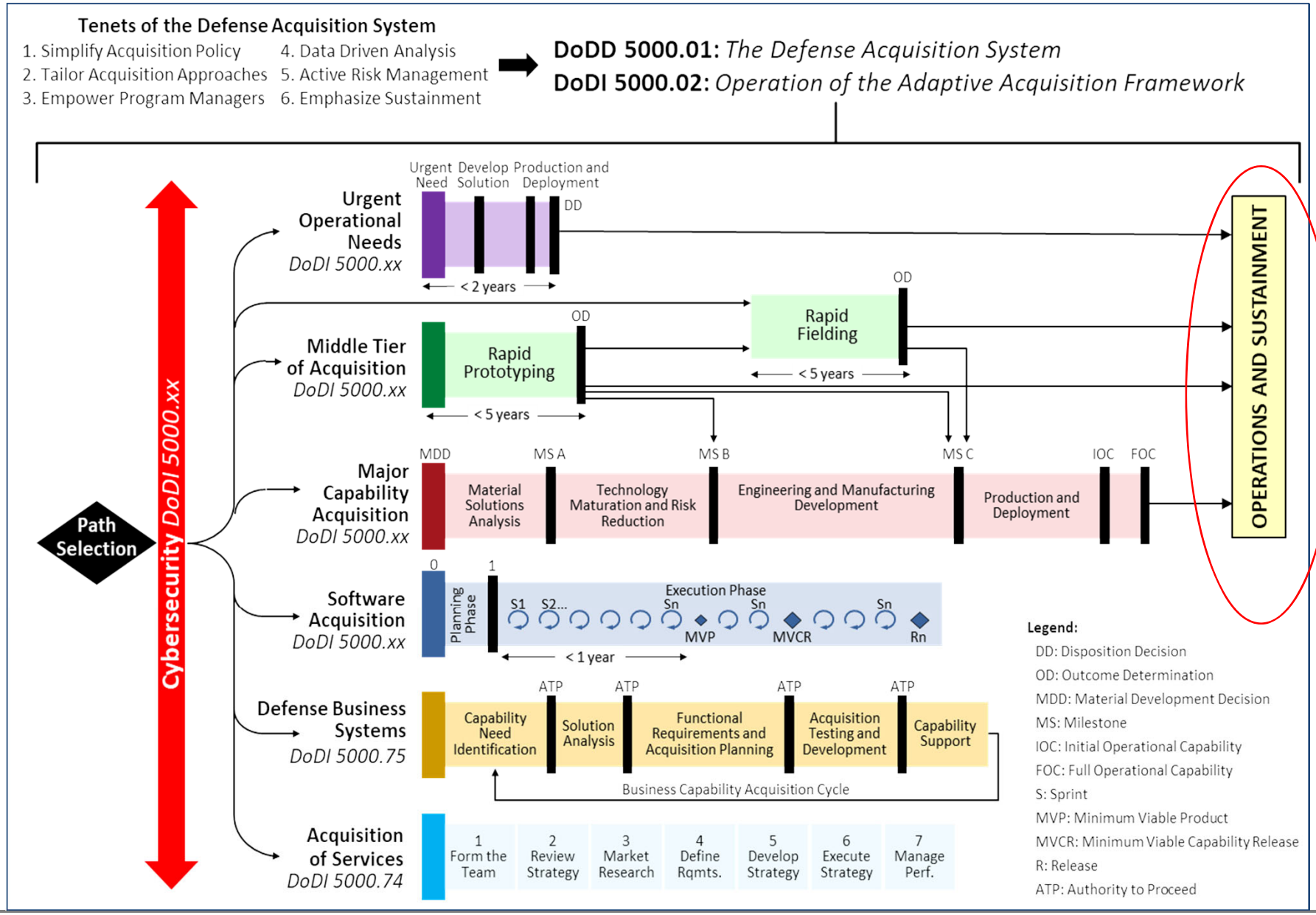
- Software is a **national defense priority**.
- The ubiquity of software and its critical role require fundamental shifts in software engineering to maintain DoD's competitive advantage.
- DoD needs to **rapidly deploy innovation with confidence** within this shifting landscape by:
  - Discovering new principles for **engineering intelligent software systems**
  - Developing new practices for **enabling DoD mission capability with software innovation**
  - Eliminating acquisition barriers by **informing DoD software policy and practice to accelerate acquisition**
- Growing gap between information obtained using traditional project measures and project managers' information needs
- **One more item: The following emerging technologies hold potential for influencing our future research: integration of quantum components into software systems, assuring 5G reliability, low-code platforms, and self-modifying systems.**

Confronting The Challenge & Urgency – Software Acquisition Pathway (SAP)*

- Establishes provides preferred pathway for software acquisition, and development and delivery of Warfighter/end-user capabilities.
- Establishes business decisions to assess risk and enable successful software acquisition and development.
- Promotes continuous integration and continuous delivery of user capabilities.
- Aims to deliver increased military effectiveness on timelines relevant to warfighting needs by simplifying the software acquisition model and placing focus on achieving timely measured outcomes.

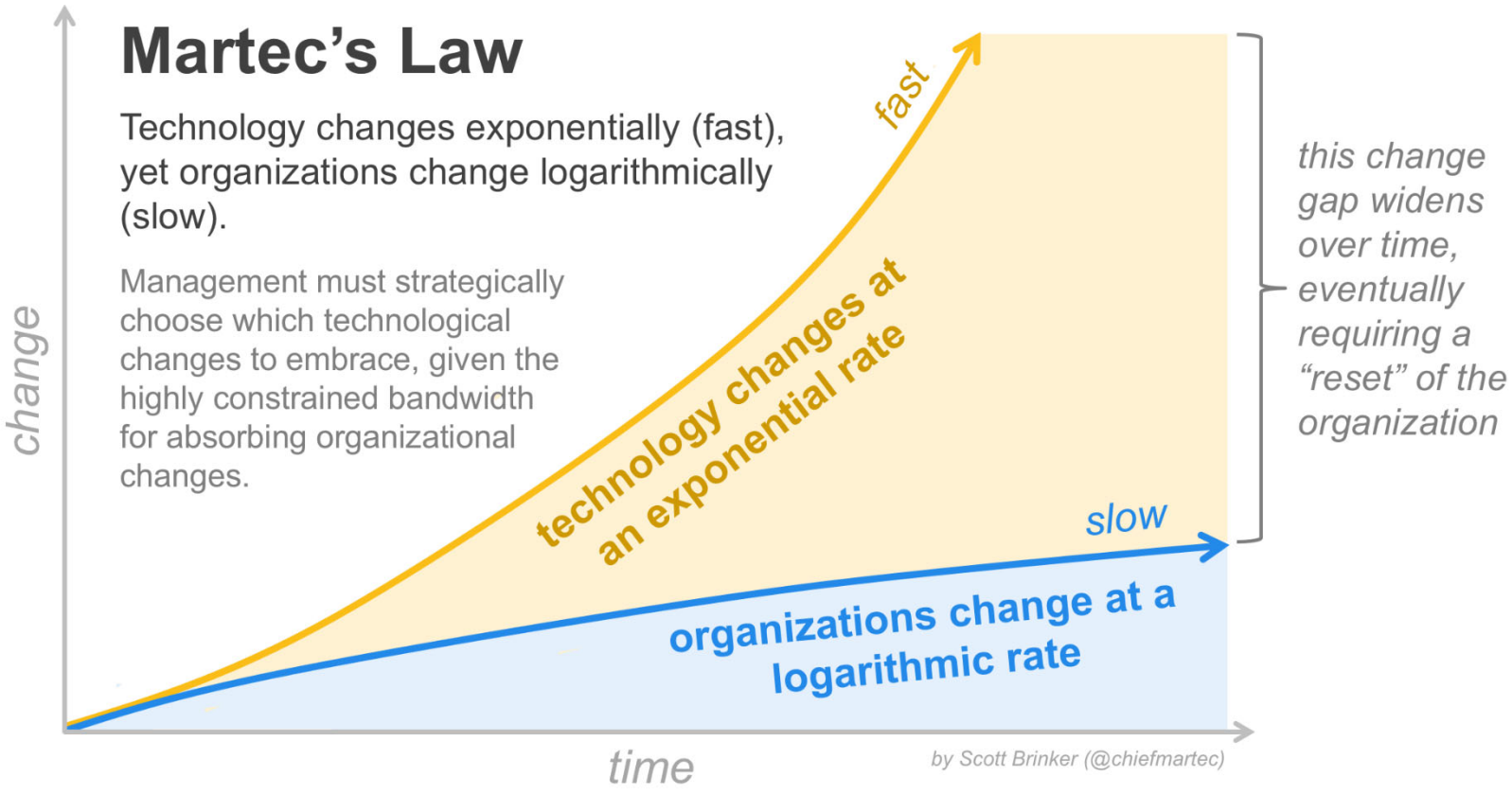
* Source: OUSD (A&S) 7/13/2019 (Draft SAP)

Fundamental Shifts in Acquisition – SAP (Draft)



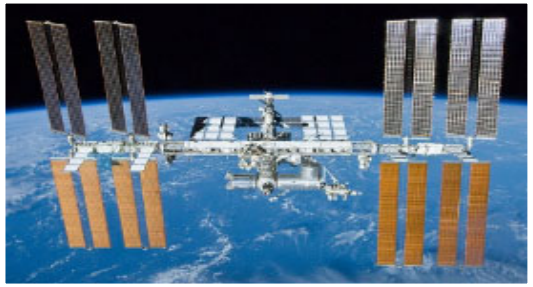
Dynamics of Organizational Culture Change

Determining an Effective Point to Reset Organizations



System Sustainment and Operations

Increase Need for Continuous Engineering Measures



Break point is becoming less relevant where software is handed off for sustainment is increasingly blurred

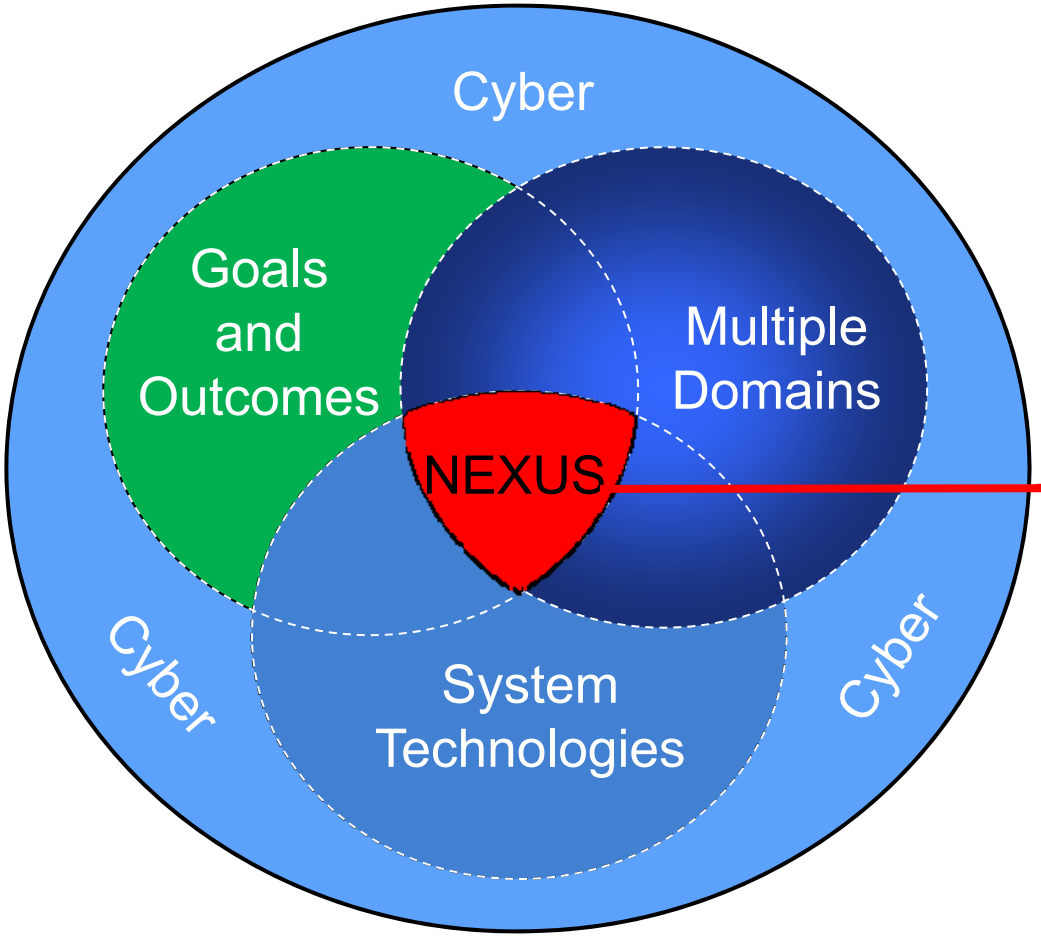
Involves coordinating processes, procedures, people, and information

Challenges include

- rising costs
- recertification/retesting
- dynamic operating environments
- legacy environments
- workforce
- Need for LC* measures

*LC = Lifecycle

System Sustainment and Operations Data Measurement Needs



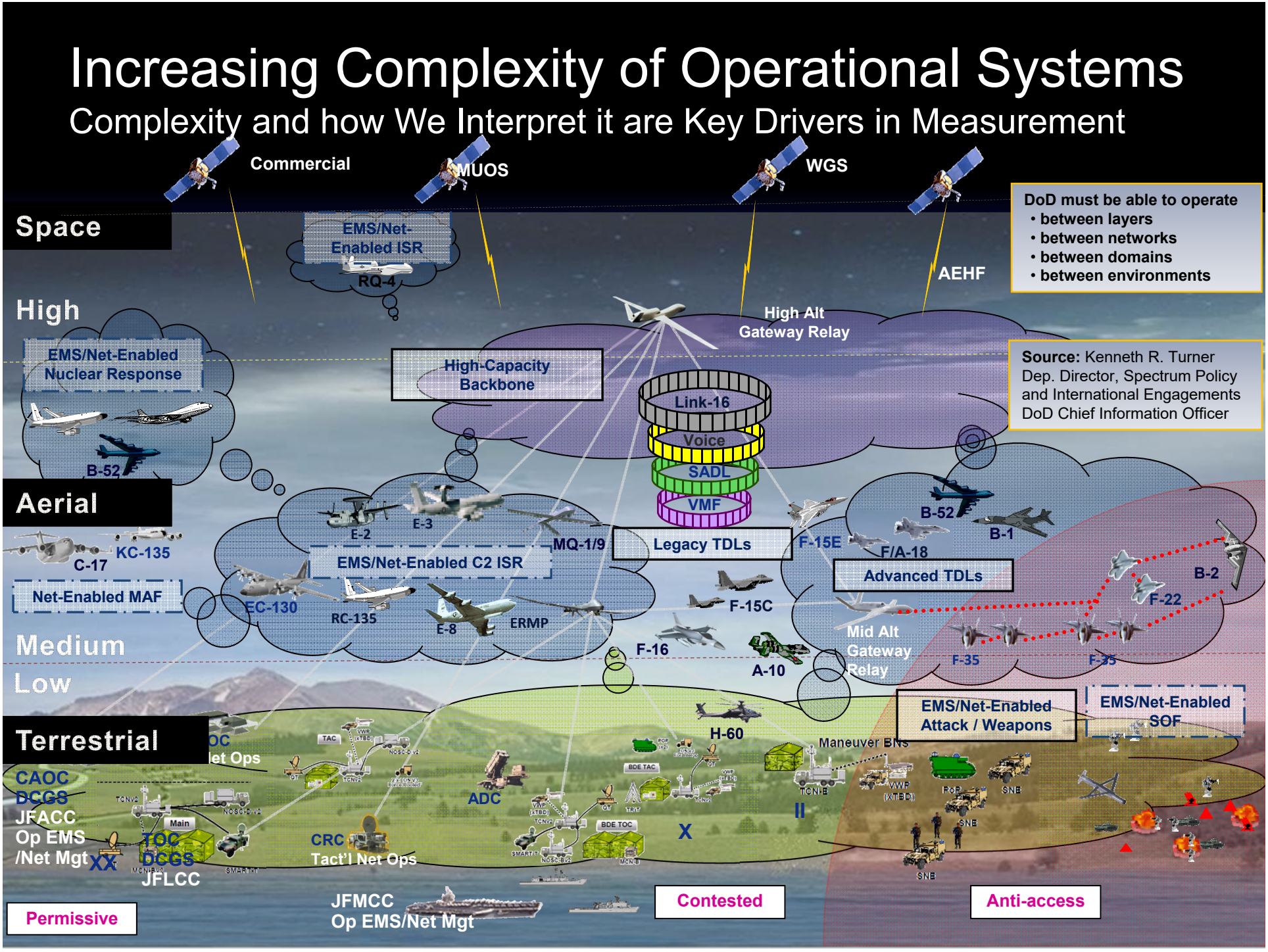
Source: SEI

Nexus Drivers

- Dynamic policies and domain characteristics
- Rapidly changing needs
- Blurring of traditional organizational lines
- Complex governance
- Funding, resources, workforce constraints
- Technology optempo!
  - collecting big data
  - processing information
  - using different development approaches
- Measurement model may be domain dependent

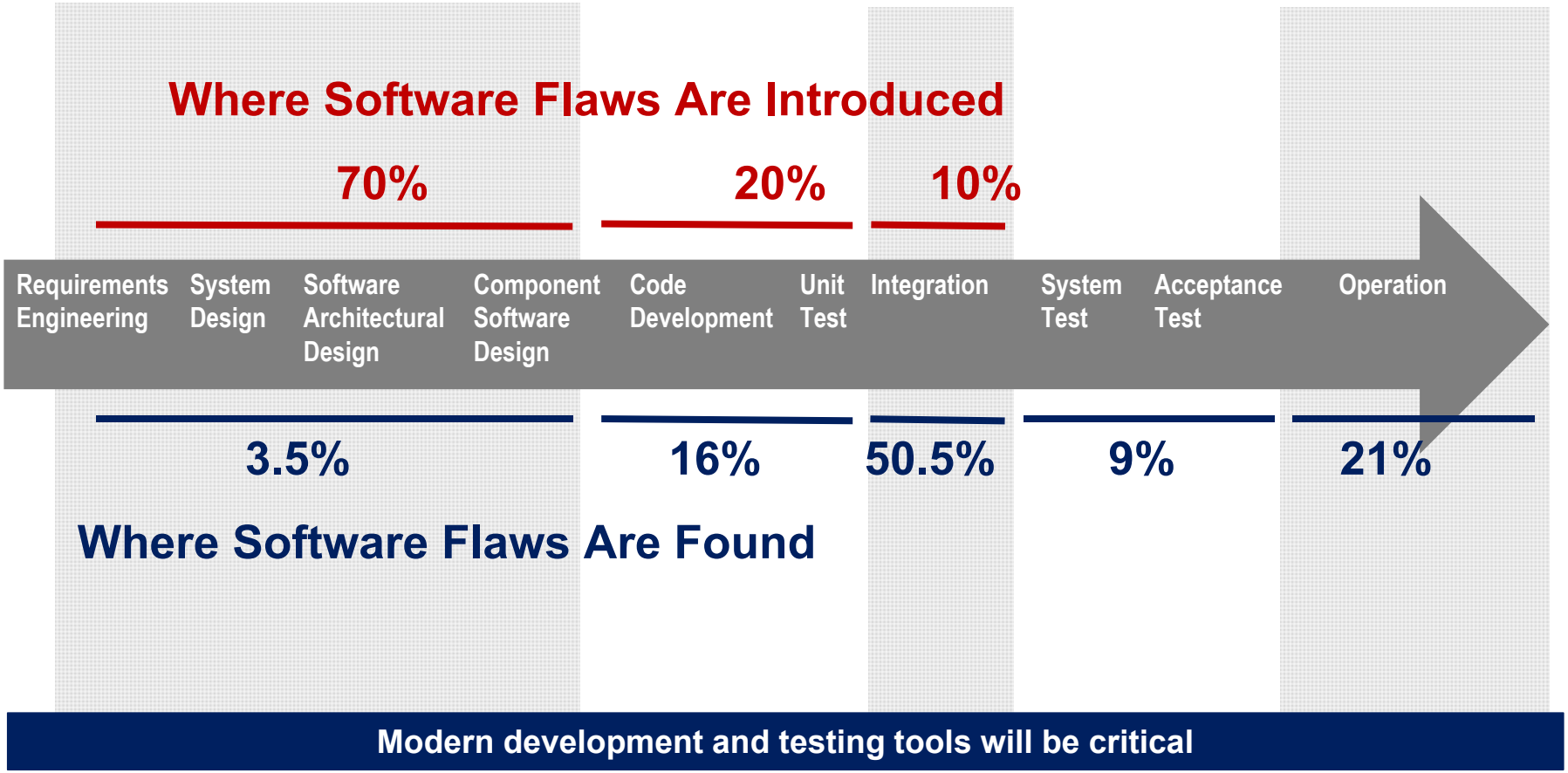
Increasing Complexity of Operational Systems

Complexity and how We Interpret it are Key Drivers in Measurement



Example: Software Assurance Measurement

Improving Architectural Design And Measurement Over the SDLC



Sources: *Critical Code,* NIST, NASA, INCOSE, and aircraft industry studies

Working in the Infancy of the Software Engineering Discipline – Human Capital

Improving the Workforce by Developing Software Core Competencies and a Career Field

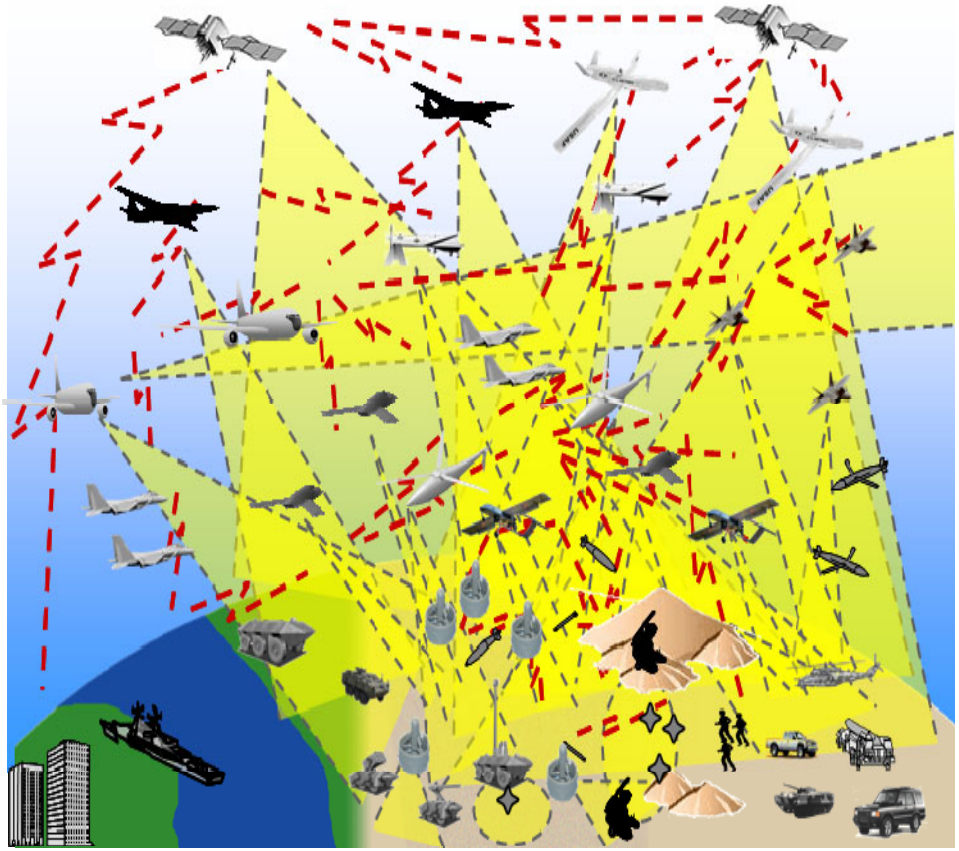
	Physical Science	Bioscience	Computer/Software/Cyber Science
Origins/History	Begun in antiquity	Begun in antiquity	Mid-20th century
Enduring Laws	Laws are foundational to furthering exploration in the science	Laws are foundational to furthering exploration in the science	Only mathematical laws have proven foundational to computation
Framework of Scientific Study	Four main areas: astronomy, physics, chemistry, and earth sciences	Science of dealing with health maintenance and disease prevention and treatment	• Several areas of study: computer science, software/systems engineering, IT, HCI, social dynamics, AI • All nodes are attached to and rely on a netted system
R&D and Launch Cycle	10–20 years	10–20 years	Significantly compressed; solution time to market must happen very quickly

HCI: human–computer interaction; AI: artificial intelligence

Source: SEI

Enduring Questions That Drive Hard Choices About This Imperative

- How much is enough?
- How much does “enough” cost?
- Is “enough” affordable?
- How does one decide?
- How does one evaluate the “goodness” of the decision?

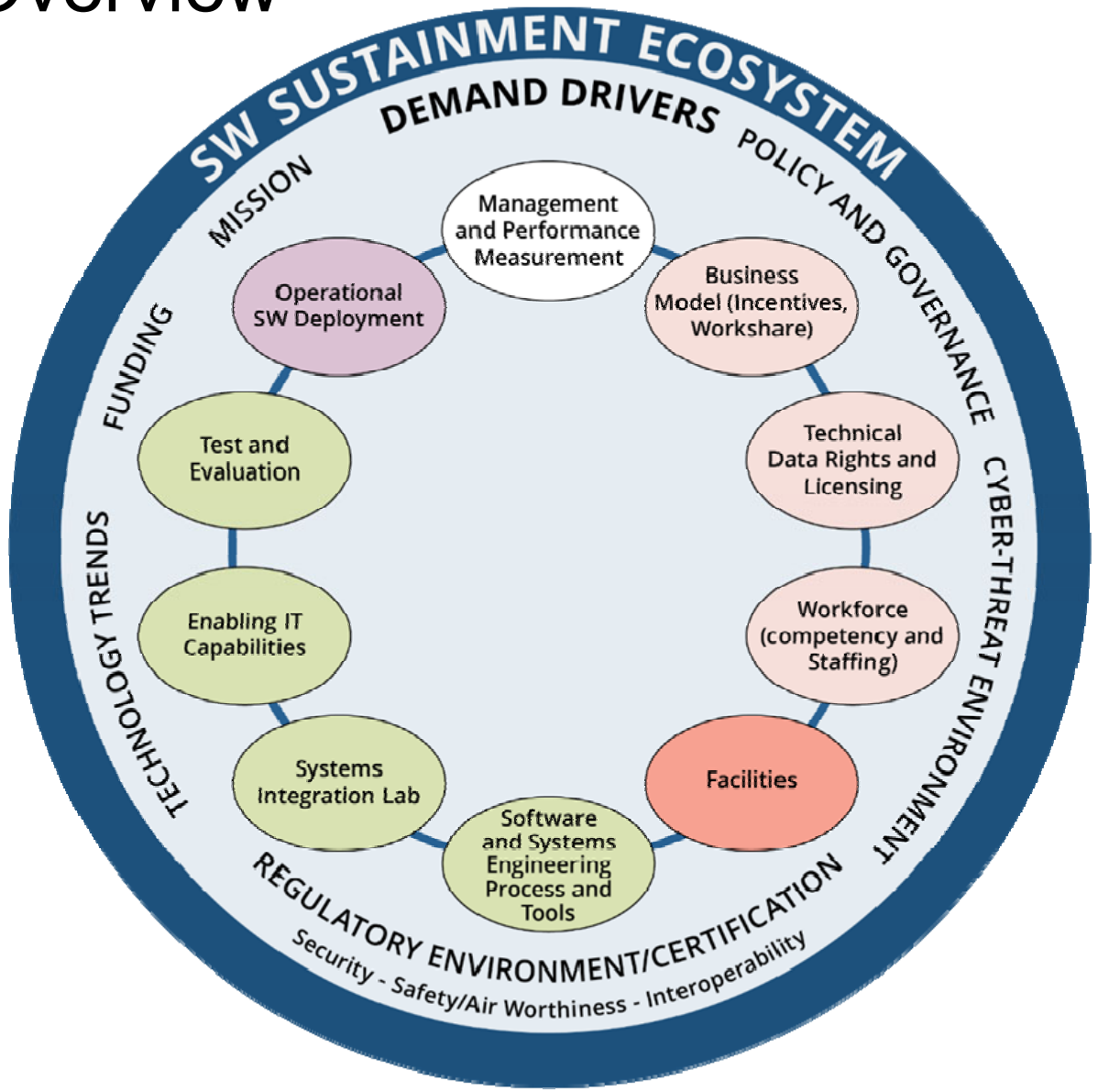


Measures supporting advancements in the rapid delivery of capabilities in an asymmetric threat environment

Source: SEI

SW Ecosystem Overview

- Four **infrastructure** elements: Basic, fundamental resources necessary for the sustainment activities
- Three **knowledge and expertise** elements: Skill sets, the government organic workforce, access to necessary technical information needed to deliver and deploy the capabilities for the warfighter
- Three ungrouped elements:
  - Facilities
  - Operational SW Deployment
  - Mgt/ Performance Measurement



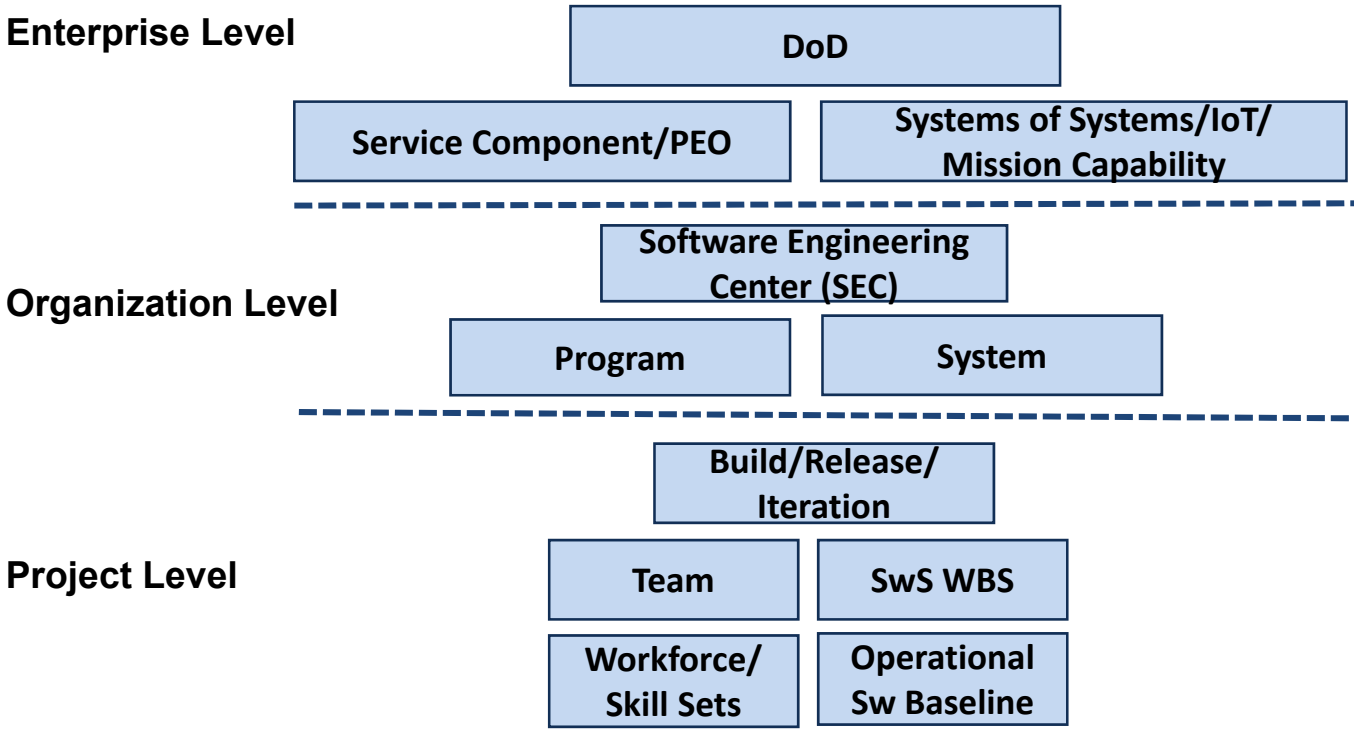
ISO/IEC/IEEE 15939
Systems and Software Engineering – Measurement Process

Provides an elaboration of the measurement process from ISO/IEC 15288 and ISO/IEC 12207

The measurement process is applicable to system and software engineering and management disciplines

The process is described through a model that defines the activities of the measurement process that are required to adequately specify what measurement information is required, how the measures and analysis results are to be applied, and how to determine if the analysis results are valid. The measurement process is flexible, tailorable, and adaptable to the needs of different users.

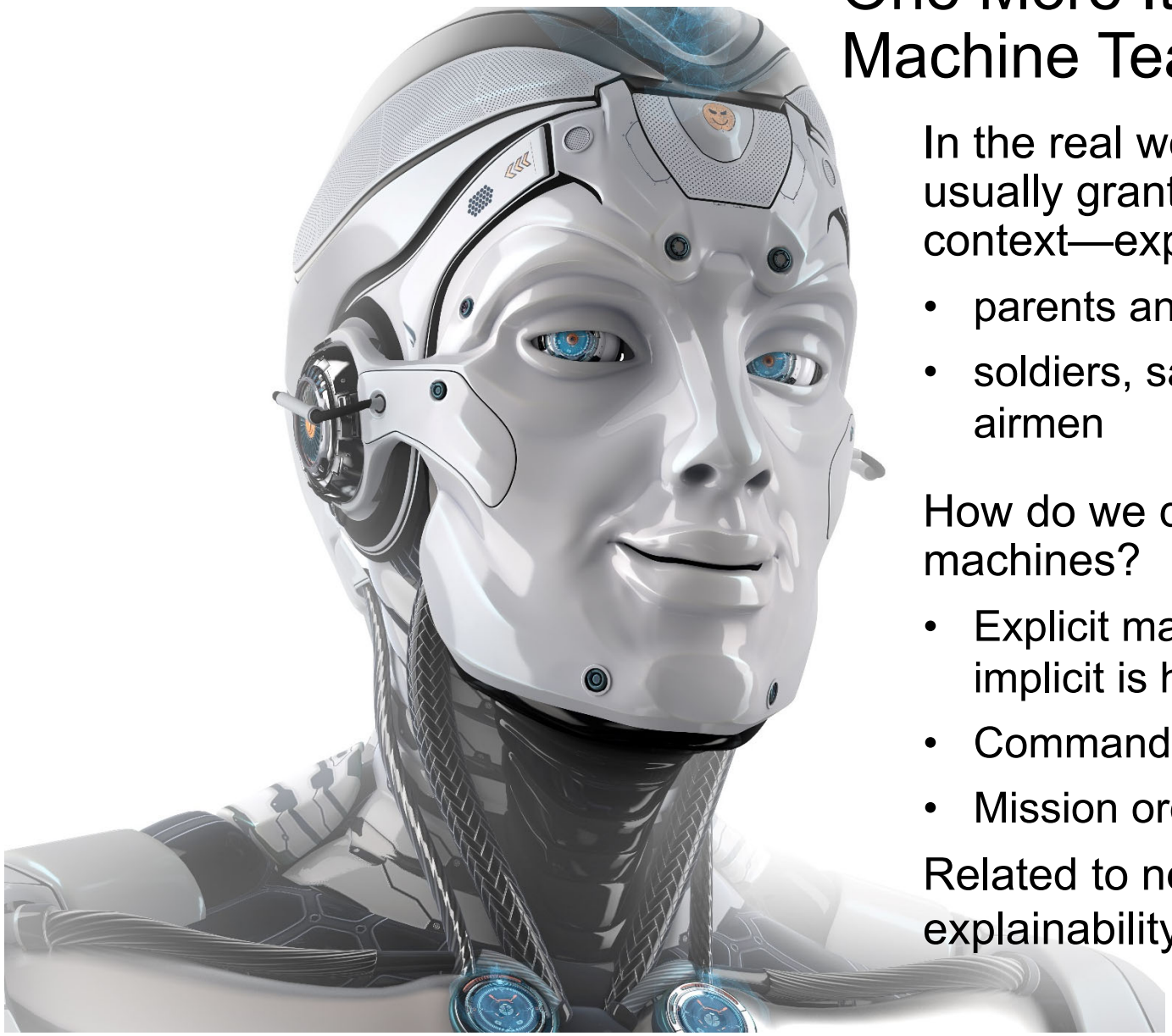
Perspectives*



Perspective is everything in terms of defining measures

*Sw Sustainment Performance Measurement Workshop 29-30 May 2019

One More Item: Human – Machine Teaming



In the real world, autonomy is usually granted within some context—explicit or implicit

- parents and children
- soldiers, sailors, marines, and airmen

How do we do this for machines?

- Explicit may be easy, but implicit is hard for machines
- Commander's intent
- Mission orders

Related to need for explainability and predictability

So Where Does This Lead Us?

- A more robust measurement approach will be needed (i.e., digital engineering coupled with data analytics)
- Senior leadership needs quantitative understanding of importance of software across the DoD enterprise
- As software-dominated system projects become larger in scope/complexity, capitalizing on opportunities for making better decisions will become more important
  - Critical to shift from “what happened?” (which is a question of information based on sparse data) ….
  - …. To seeking leading indicators on what’s going to happen and change outcomes to achieve the desired state insight by asking “what happened, why, how do we solve the problem, and can we evaluate that it has been solved?”
- Enabling an analytics-based framework that seeks to leverage traditional measurement, metrics, data, and information – if done right will provide meaningful understanding and insight

Final Thought

Measurement of advanced program management, with operational participation, will determine if we create
C3PO and Johnny 5 . . .

…or the Borg

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