Struggles at the Frontiers of Workforce Development:

… Acquisition and Development of Software Intensive Systems

Software Engineering Institute
Carnegie Mellon University

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17th Annual Systems Engineering Conference
"Improving Acquisition and Performance of Defense Programs and Systems"
27-30 October 2014
Springfield, Virginia

SEI Background

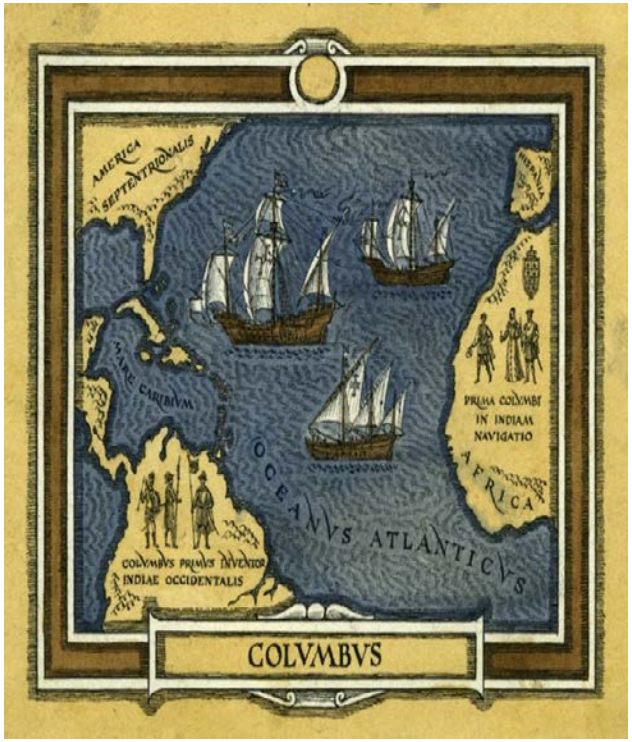
Funded by the U.S. government as a research & development lab (FFRDC)

Created in 1984 and administered by Carnegie Mellon University

Headquartered in Pittsburgh, Pennsylvania; offices and support worldwide

Content

- Struggles Impacting Workforce Development at the Software Frontiers
- Challenges of Workforce Development for IT and Systems Engineering
- Seventeen Workforce Issues for Developing Software-Intensive Systems



Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers

Essential Difficulties

According to Fred Brooks,* software projects are difficult because of accidental and essential difficulties

- Accidental difficulties are caused by the current state of our understanding
  - of methods, tools, and techniques
  - of the underlying technology base
- Essential difficulties are caused by the inherent nature of software
  - invisibility – lack of physical properties
  - Complexity – for its size
  - conformity
  - changeability

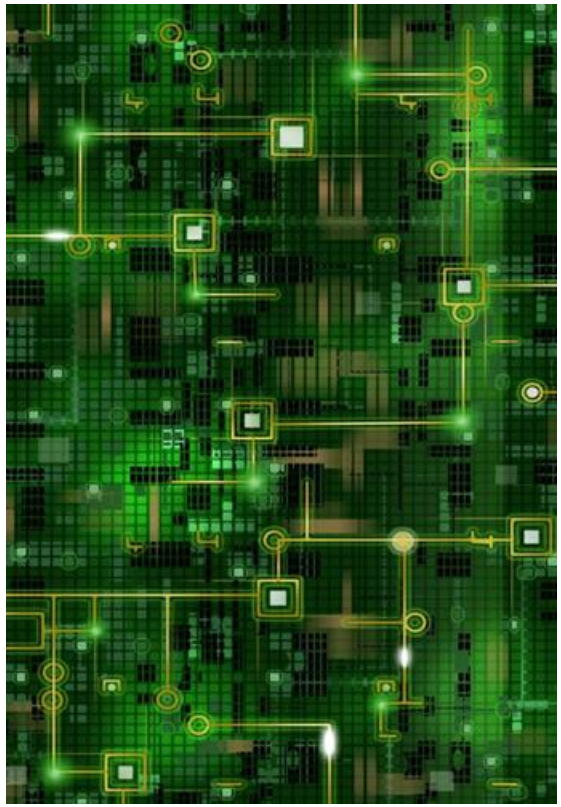
* ***The Mythical Man-Month*** **by Fred Brooks, Addison Wesley, 1995**

Struggles Impacting Workforce Development at the Software Frontiers

Essential Difficulties

Complexity:

- Due to interaction of components, number of possible states grows much faster than lines of code
- For its size, software is very complex compared to other engineering artifacts
- Hardware is complex, but the laws of physical science usually tell us what to expect for a known input

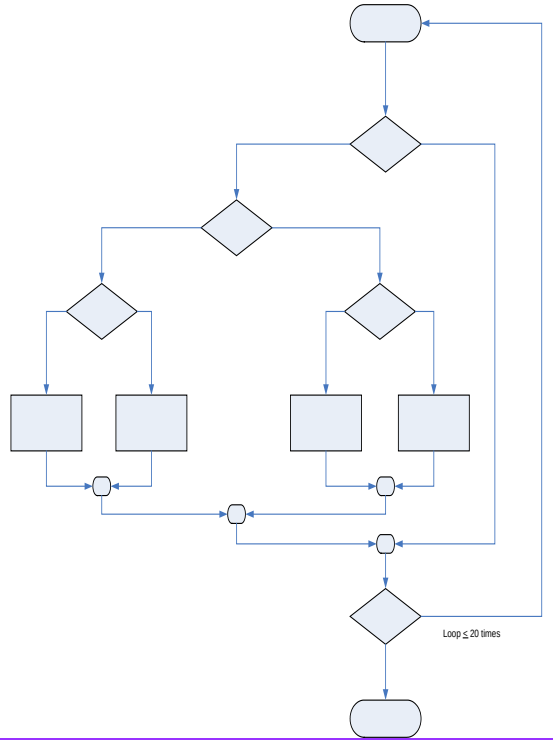


Source SEI

Struggles Impacting Workforce Development at the Software Frontiers

Essential Difficulties - Complexity

- The flowchart might correspond to a 100 LOC module with a single loop that may be executed no more than 20 times.
- There are approximately 10^{14} possible paths that may be executed!
- For any but the smallest programs, complete path coverage for defect detection is impractical.
- Limited natural governance



Lehman Laws:

1. The Law of Continuing Change – programs must change to be useful

2. The Law of Increasing Complexity – programs that change become more complex

Adapted from Pressman, R.S., *Software Engineering: A Practitioner's Approach, Third Edition*, McGraw Hill, 1992

Struggles Impacting Workforce Development at the Software Frontiers - Infancy of Software Engineering

Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers - Infancy of Software Engineering

	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/ treatment	• Several areas of study: computer science, software/ systems engineering, IT, HCI, social dynamics, AI • All nodes attached to/relying on netted system
R&D and Launch Cycle	10-20 years	10-20 years	Significantly **compressed**; solution time to market needs to happen very quickly

Source: SEI

HCI: Human Computer Interaction; AI: Artificial intelligence

Struggles Impacting Workforce Development at the Software Frontiers - Demographics of Workforce Provide Different Views of the Frontiers

Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers - Demographics of Workforce Provide Different Views of the Frontiers

- Demographics of workforce are changing, and different views may emerge with multiple generations to consider
- Generation Y professionals are technically savvy and can better leverage IT capabilities for improved efficiencies and productivity; however, may lack the systems engineering knowledge, skills, and abilities

Silent Generation
1928-1945

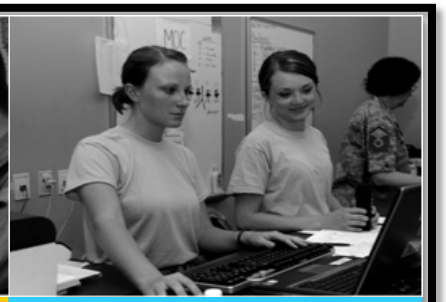
Hard worker
Respects authority
Work is obligation
Formal communicator
Work/family separation

Baby Boomers
1946-1964

Workaholic
Questions authority
Works efficiently
Competitive
Little work/life balance

Generation X
1965-1980

Technically advanced
Prefers informality
Needs structure and direction
Direct/immediate communicator
Seeks work/life balance



Generation Y/Millenials
1981-2000

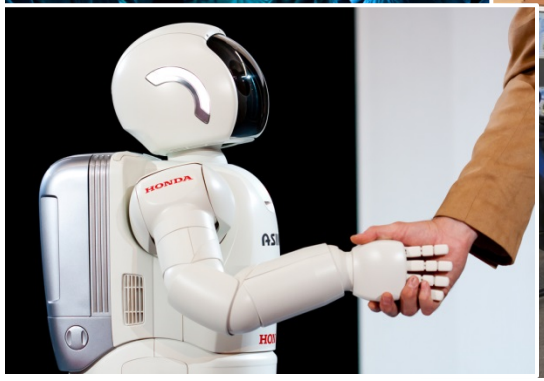
Technically savvy
Embraces diversity
Requires supervision
Indirect/virtual communicator
Demands work/life balance

Sources: SEI, Recommendations for Improving Acquisition Training, May 2010

Achieving Effective Acquisition of Information Technology in the Department of Defense, National Academy of Sciences , 2010

Struggles Impacting Workforce Development at the Software Frontiers - Software Is Everywhere with Limited Natural Governance



Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers - Software Is Everywhere with Limited Natural Governance

Laws of physics

Laws of software

Challenge of algorithms

Difficulty of distribution & concurrency

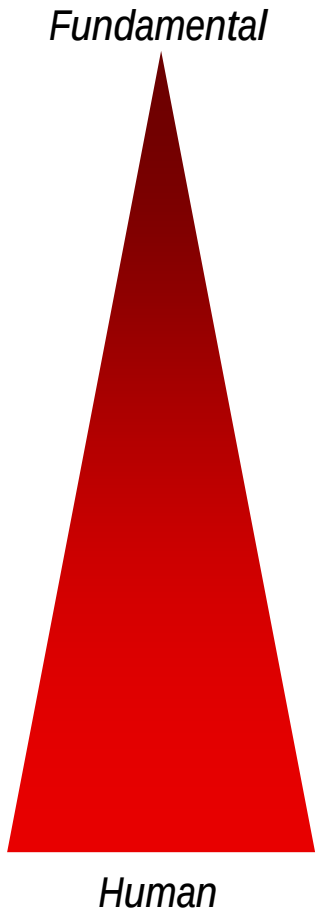
Problems of design

Importance of organization

Impact of economics

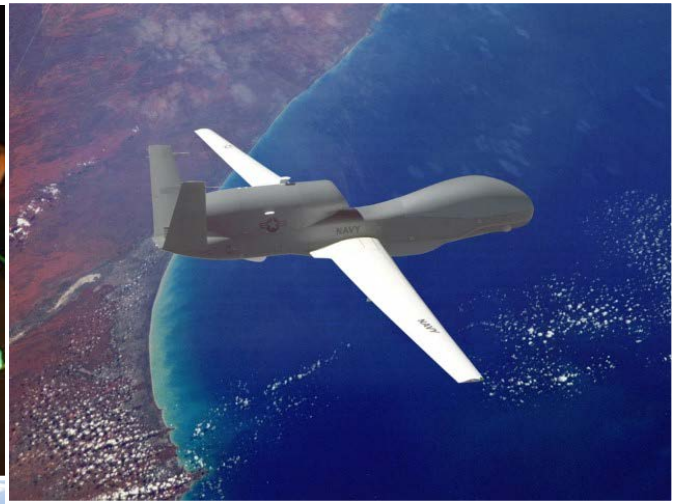
Influence of politics

Limits of human imagination



Source: IBM

Struggles Impacting Workforce Development at the Software Frontiers - Software Is Increasingly Complex

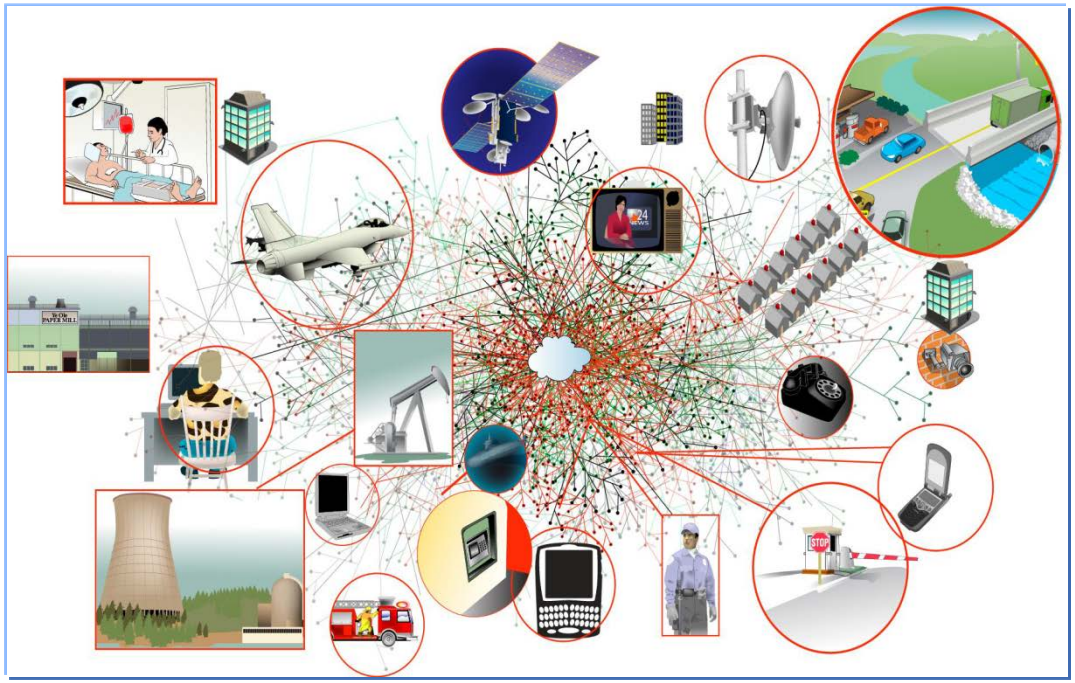


Source: SEI

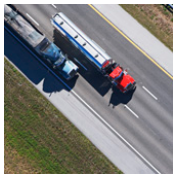
Struggles Impacting Workforce Development at the Software Frontiers - Software Is Increasingly Complex

Increasing Functionality and Complexity:

- System of systems
- Architecture
- Services
- Networked platforms
- People who digitally connect to cyberspace



Transportation Infrastructure



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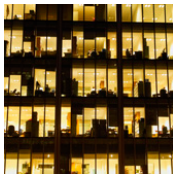
Healthcare Infrastructure



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Banking & Financial Infrastructure

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Energy & Utilities Infrastructure

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Communications Infrastructure

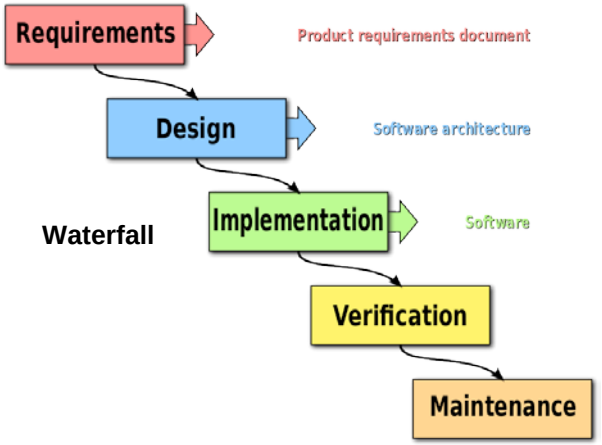
...

Source: SEI

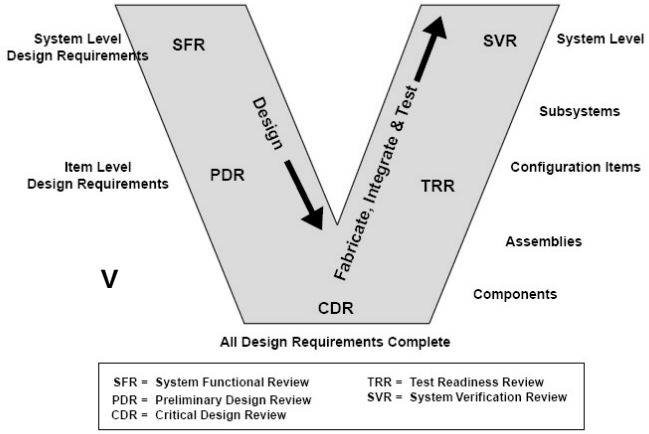
Struggles Impacting Workforce Development at the Software Frontiers - Software Is Increasingly Complex

Increasing Use of Innovative Processes, Methods and Tools

Predictive Models



Waterfall



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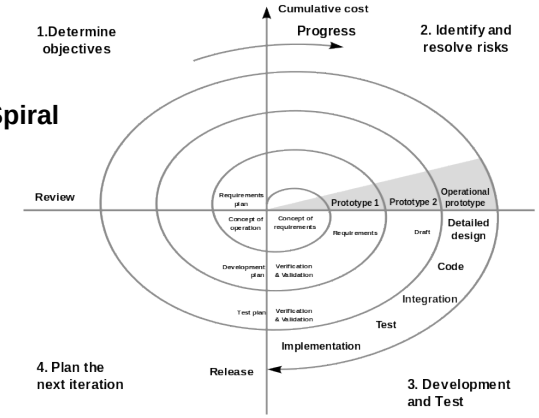
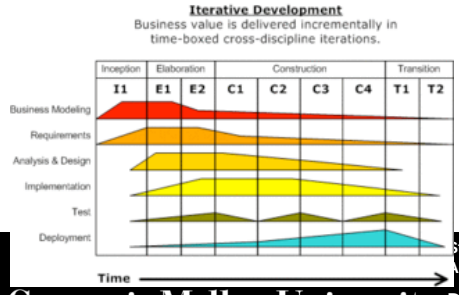
Iterative Models

Spiral



RAD

RUP



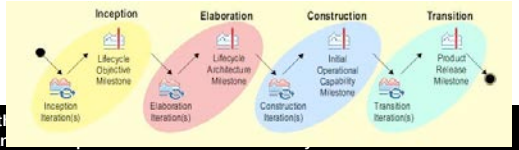
Adaptive Models

Scrum

XP

OpenUP

Source: Noblis



Struggles Impacting Workforce Development at the Software Frontiers - Software Connects Us in Near Real Time

Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers - Software Is Becoming a More Personal and Valued Utility

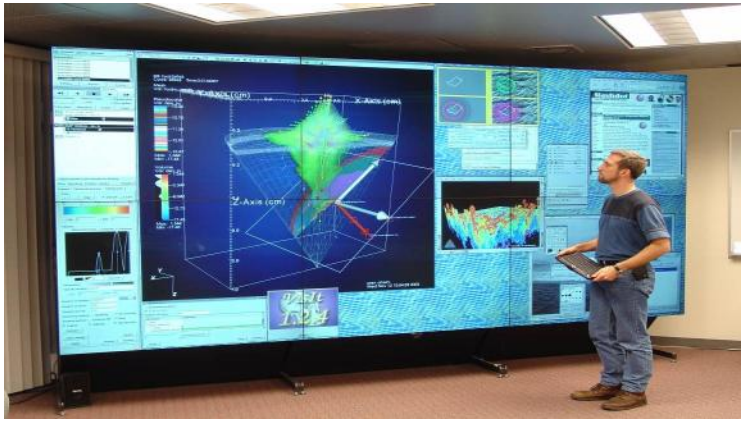
Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers - Software Is Globally Important

Manufacturing

Finance

Space and Aviation



Engineering

Source: SEI

Struggles Impacting Workforce Development at the Software Frontiers - Software Is Today's Strategic Resource

Increasing Globalization

Source: SEI

Challenges of Workforce Development for IT and Systems Engineering

Challenges of Workforce Development for IT and Systems Engineering

Building out capabilities to manage large information technology projects has been a sore spot for the Air Force.*

Specifically, the service has been challenged with developing IT acquisition talent among its ranks, adopting and maintaining processes that foster best practices and aligning acquisition and cybersecurity strategies.*

***Lt. Gen. Charles Davis, the military deputy in the Office of the Assistant Secretary of the Air Force for Acquisition**

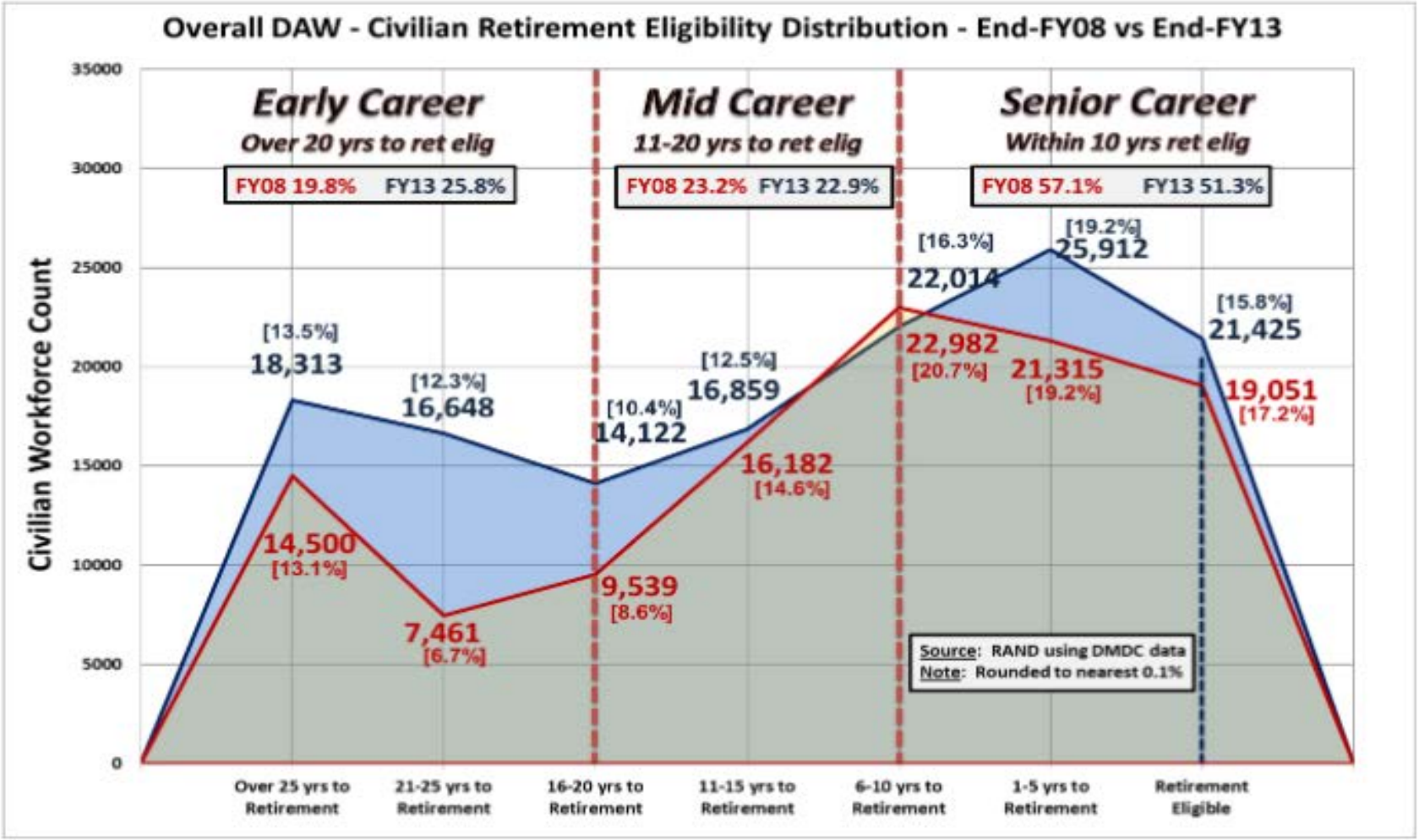
Source: C4ISR & Networks, Feb 2014

Challenges of Workforce Development for IT and Systems Engineering

Software Proves Great Capabilities, but Struggling, Bifurcated Communities

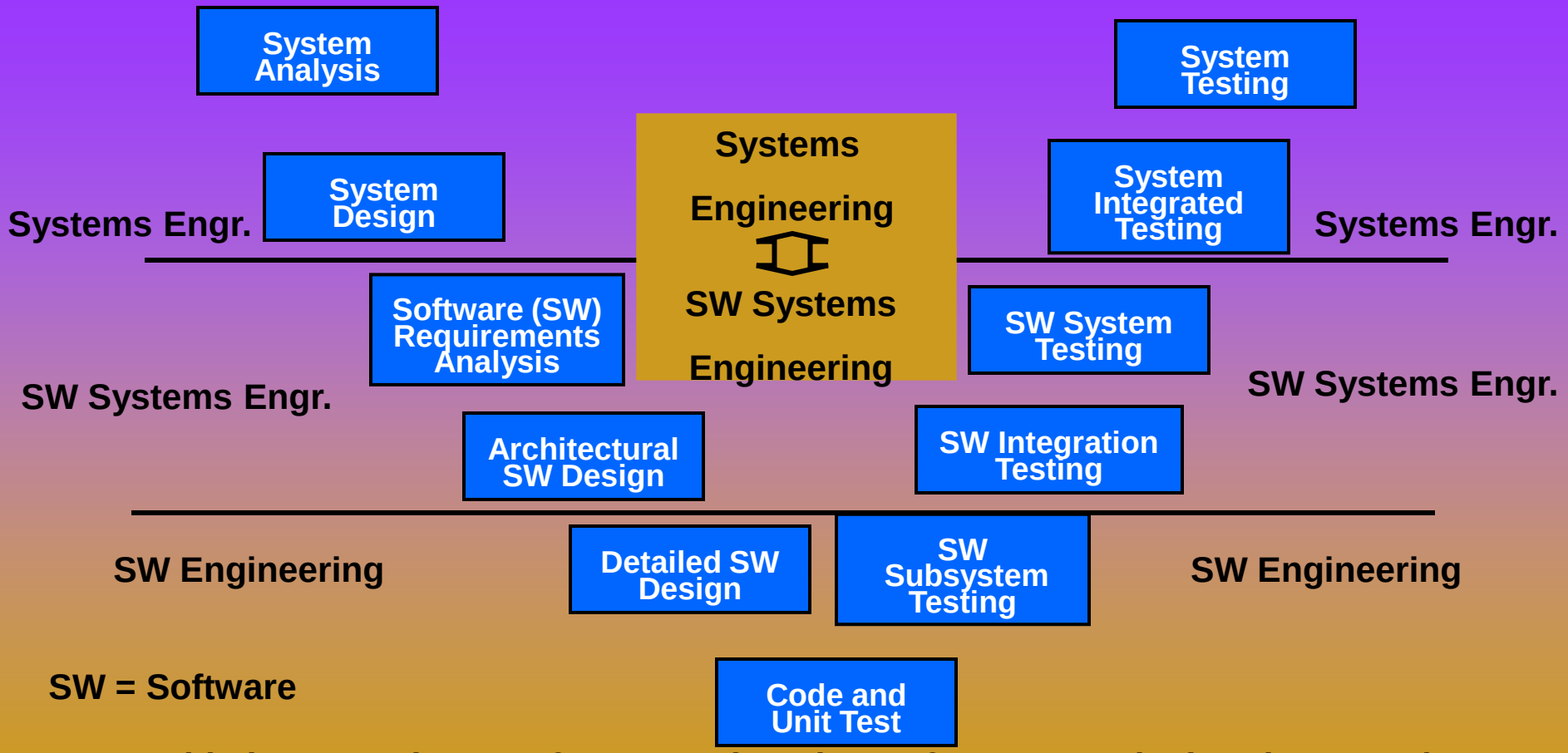
Source: SEI

Challenges of Workforce Development for IT and Systems Engineering



Defense Acquisition Reform: Where Do We Go from Here? Permanent Subcommittee on Investigations, United States Senate; October 2, 2014

Challenges of Workforce Development for IT and Systems Engineering

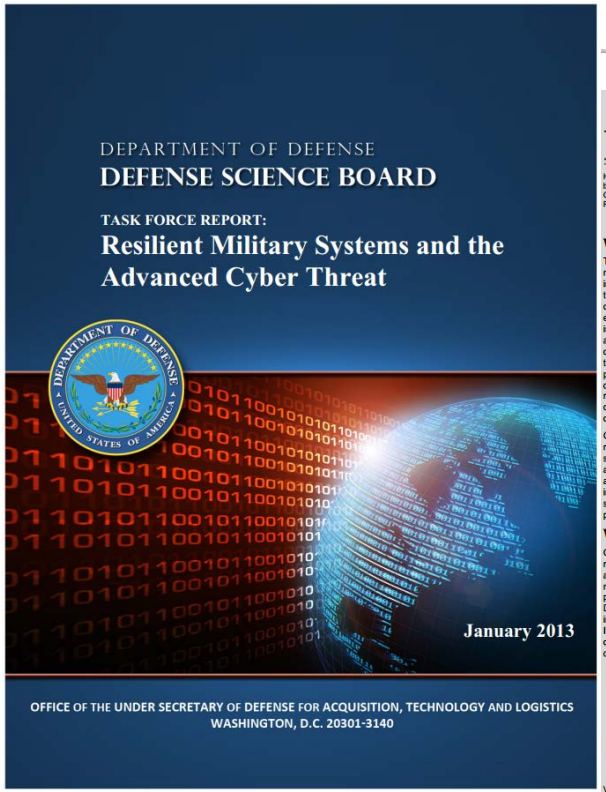


OSD Initiatives: Graduate Software Engineering Reference Curriculum (GSwERC); & Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE (SEBoK; GRCSE™))

Seventeen Workforce Issues for Developing Software-Intensive Systems

Need to Meet the Workforce Challenges

Large U.S. Government Programs Often Stumble



GAO
Accountability • Integrity • Reliability

Highlights

Highlights of GAO-13-297T, a testimony before the Committee on Oversight and Government Reform, House of Representatives

January 22, 2013

INFORMATION TECHNOLOGY

OMB and Agencies Need to Fully Implement Major Initiatives to Save Billions of Dollars

Why GAO Did This Study

The federal government plans to spend more than $74 billion on IT investments in fiscal year 2013. Given the size of these investments and the criticality of many of them to the health, economy, and security of the nation, it is important that OMB and federal agencies provide appropriate oversight of and adequate transparency into these programs. Nevertheless, IT projects too frequently incur cost overruns and schedule slippages, and result in duplicate systems while contributing little to mission-related outcomes.

GAO was asked to testify on the results and recommendations from its selected reports that focused on key aspects of the federal government's acquisition and management of IT investments. To prepare this statement, GAO drew on previously published work.

What GAO Recommends

GAO has issued numerous recommendations to OMB and agencies on key aspects of IT management, including (1) OMB's public website, known as the IT Dashboard, which provides detailed information on federal agencies' major IT investments, and (2) efforts to oversee IT operations and consolidate data centers.

View GAO-13-297T. For more information, contact David A. Powner at (202) 512-9286 or pownerd@gao.gov.

What GAO Found

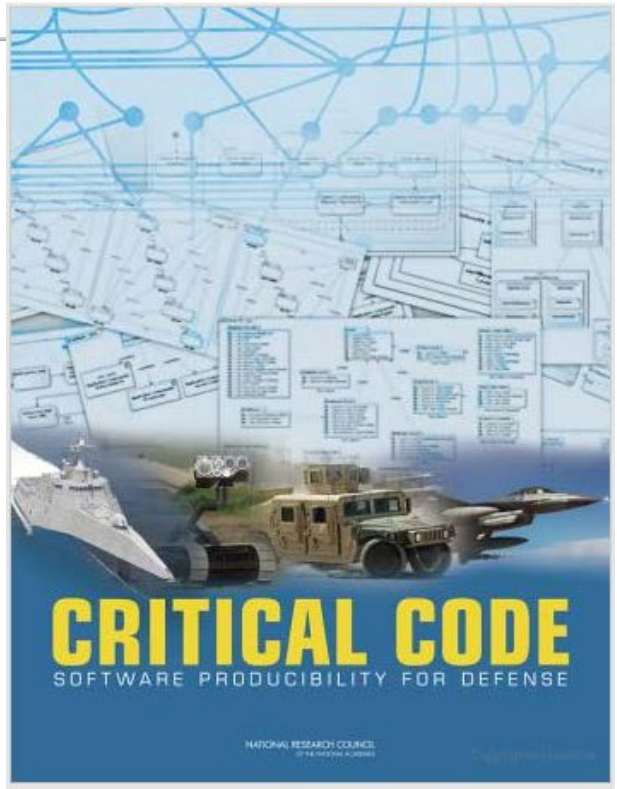
GAO has issued a number of key reports on the federal government's efforts to efficiently acquire and operate information technology (IT) investments and found that if major initiatives are fully implemented, billions of dollars in savings could be realized. In particular, GAO has made recommendations regarding the Office of Management and Budget's (OMB) public website, known as the IT Dashboard, which provides detailed information on federal agencies' major IT investments; agencies' efforts to perform analyses on existing IT investments; and agencies' progress toward consolidating data centers.

OMB has taken significant steps to enhance the oversight, transparency, and accountability of federal IT investments by creating its IT Dashboard, and by improving the accuracy of investment ratings. However, there were issues with the accuracy and reliability of cost and schedule data in the Dashboard, and GAO has recommended steps that OMB and agencies should take to improve these data—this is important since the Dashboard reports 190 investments totaling almost $12.5 billion being at risk. GAO recently reported that six federal agencies consistently rated the majority of their IT investments as low risk. Further, the Department of Defense's (DOD) ratings reflected considerations in addition to those OMB recommends, and consequently it did not rate any of its investments as high risk. However, GAO has recently reported that several DOD investments experienced significant performance problems and were indeed high risk, and that DOD business systems modernization is a high-risk area. In the past, OMB reported trends for risky IT investments needing management attention as part of its annual budget submission, but discontinued this reporting in fiscal year 2010. GAO recommended OMB analyze agencies' investment risk over time as reflected in the Dashboard's ratings and present its analysis with the President's annual budget submission.

While agencies plan to spend billions on operational investments—more than $54 billion in fiscal year 2013— they have not always provided adequate oversight of these investments. Specifically, GAO reported in October 2012 that five agencies had operational investments with a fiscal year 2011 budget of over $3 billion that had not undergone operational analyses as required by OMB. The report also noted that until operational investments are fully assessed, there was increased potential for these multibillion dollar investments to result in unnecessary waste and duplication. GAO recommended that the five agencies conduct required analyses.

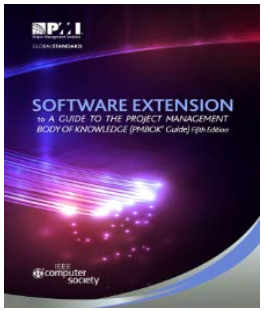
GAO reported on the federal government's progress toward data center consolidation (which OMB expects will save $3 billion by 2015). In July 2012, GAO found that agencies updated their required inventories and plans, but only 3 of 24 agencies in the review submitted complete inventories and only 1 agency submitted a complete plan, as required by OMB. Until these inventories and plans were complete, agencies would continue to be at risk of not realizing anticipated savings, improved infrastructure utilization, or energy efficiency. Accordingly, GAO reiterated a prior recommendation to update inventories and plans, and also recommended that agencies use best practices when developing estimates.

United States Government Accountability Office



Source: SEI

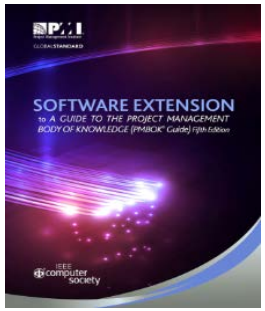
Seventeen Current Struggles in Developing Software Intensive Systems



1. Software requirements often change during a software project as knowledge is gained and the scope of the project and the product emerge.
2. Requirements for new and modified software often influence, and are influenced by, an organization's business processes and employees' workflow processes of employees.
3. Intellectual capital of software personnel is the primary capital asset for software projects and software development organizations because software is a direct product of human cognitive processes.
4. Communication and coordination within software teams and with project stakeholders often lack clarity.

* **Software Extension to the PMBOK**

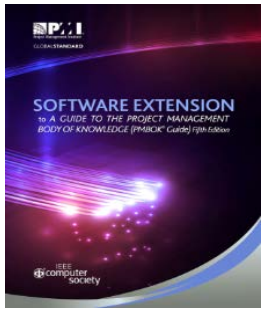
Seventeen Current Struggles in Developing Software Intensive Systems



5. Creation of software requires innovative problem solving to create unique solutions. Software projects are more akin to research and development projects than to construction or manufacturing projects.
6. Exhaustive testing of software is impractical because of the time that would be required to test all logical paths and interfaces under all combinations of input data and \stimuli.
7. Software development often involves inclusion of different vendor products and development of interfaces to other software; this may result in integration and performance issues.

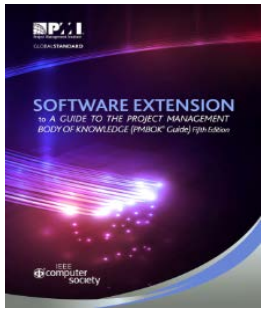
* **Software Extension to the PMBOK**

Seventeen Current Struggles in Developing Software Intensive Systems



8. Software projects involve risk and uncertainty because they require innovation, the product is intangible, and stakeholders may not effectively articulate, or agree on, the needs to be satisfied by the software product.
9. Planning and estimation for software projects is challenging because they depend on requirements, which are often imprecise, and on historical data, which is often missing or inapplicable. Preparing accurate estimates is also challenging because the efficiency and effectiveness of software developers are widely variable.
10. Product complexity makes development and modification of software challenging because of the enormous number of logical paths within program modules, the number of data values that exercise the paths, and the combinations of interface details among program modules.

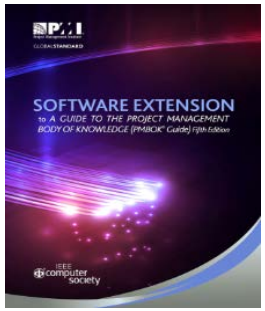
Seventeen Current Struggles in Developing Software Intensive Systems



11. Because most software is interconnected, information security techniques are necessary. Software security is a large and growing challenge.
12. Objective quantification and measurement of software quality are difficult because of the intangible nature of software.
13. Software developers use processes, methods, and tools that are constantly evolving and frequently updated.
14. Software is often the element of a system that is changed when functionality, behavior, or quality attributes must be changed.
15. A software product may be required to operate on a variety of hardware platforms and infrastructure software.

* **Software Extension to the PMBOK**

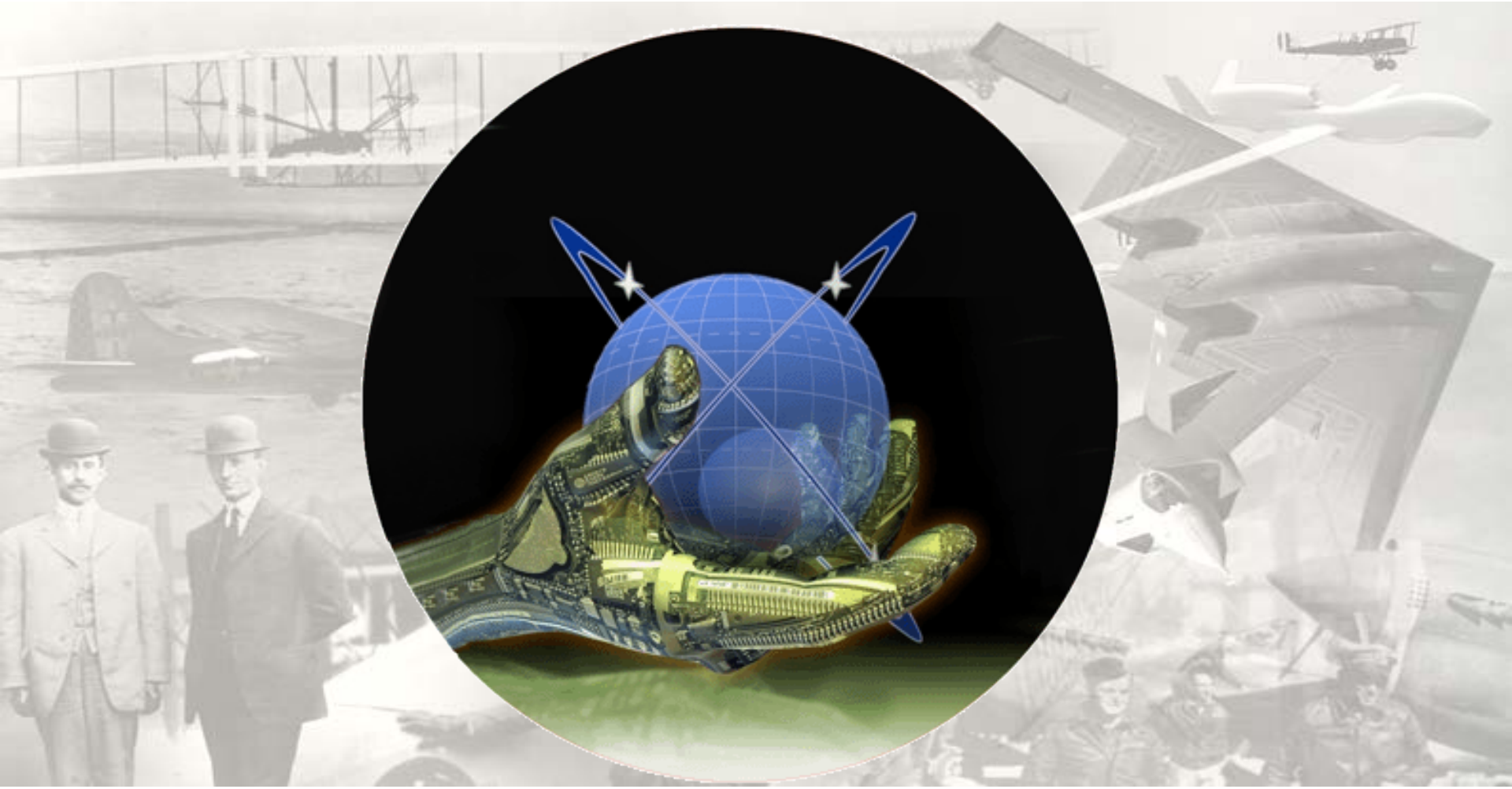
Seventeen Current Struggles in Developing Software Intensive Systems



16. Executable software is not a standalone product. It is executed on computing hardware and is often an element of a system consisting of diverse hardware, other software, and manual procedures.
17. Platform technologies, infrastructure software, and vendor-supplied software are frequently changed or updated, which can necessitate changes to the software being developed.

* Software Extension to the PMBOK

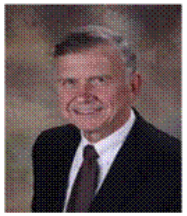
Questions?



Contact Information

Dr. Kenneth E. Nidiffer, Director of Strategic Plans

for Government Programs



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