Complexity and Software: How to Meet the Challenge

NDIA CMMI Technology Conference

Software Engineering Institute
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Pittsburgh, PA 15213

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Overview

Complexity

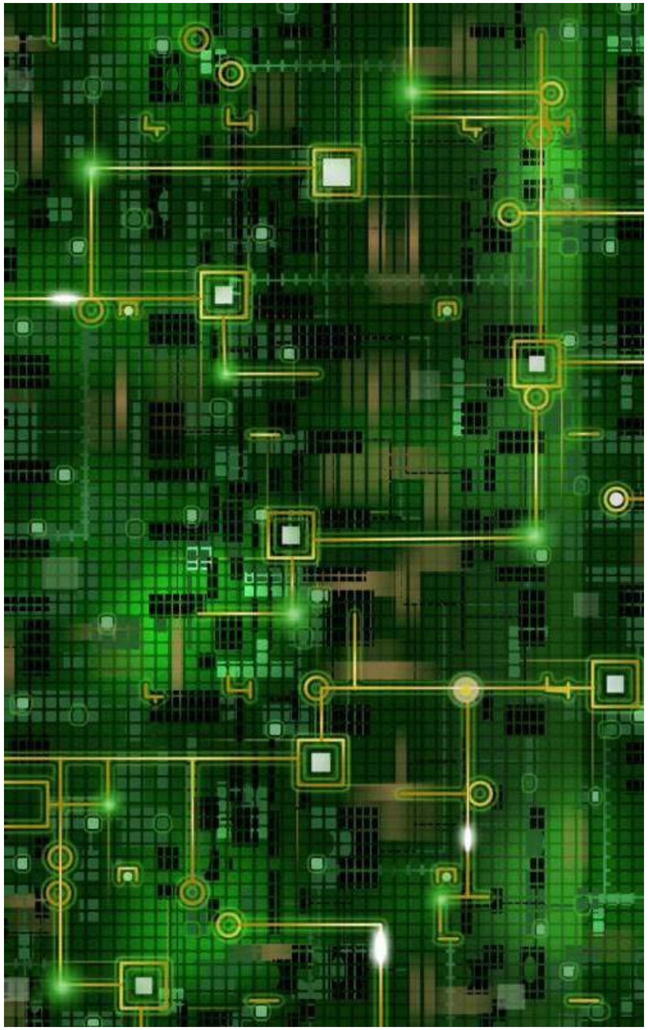
Software

How to Meet the Challenge

Summary

Complex Systems

- Complex systems are already woven tightly into our everyday lives
- 21st century systems will be increasingly complex
- How failing to understand them, their risks, and their management challenges poses a 21st-century hazard



The Rise of Complexity

- Scale
- Interconnectedness
- Autonomy
- Time criticality
- Security
- Safety
- Regulation

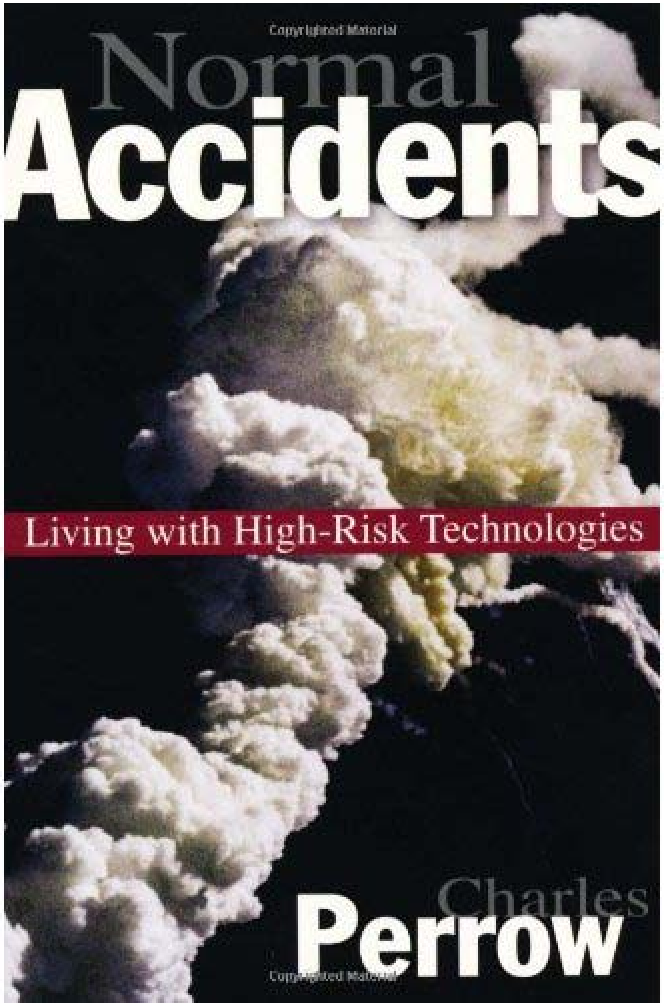
Complexity Brings Rewards – and Perils

Bad things happen when we …

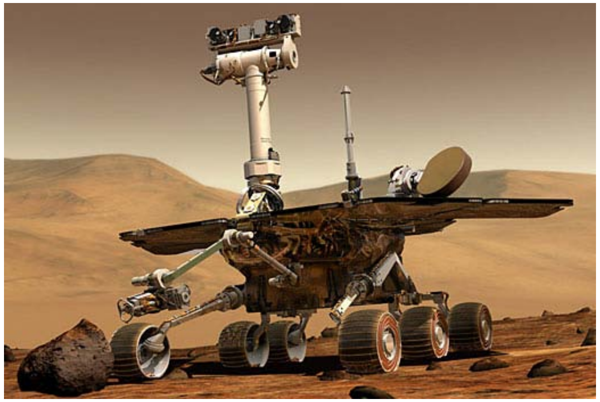
- Misdesign
- Mismanage

… complex systems

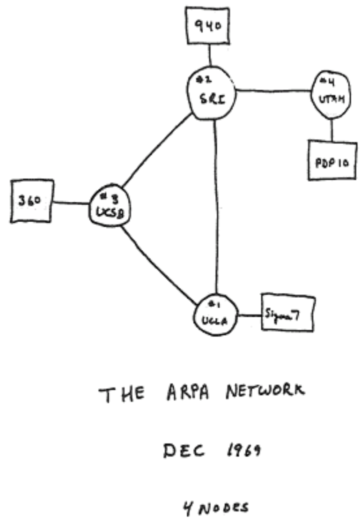
Average person does not know or care about root cause of problem in system complexity



Examples: Good … and Bad

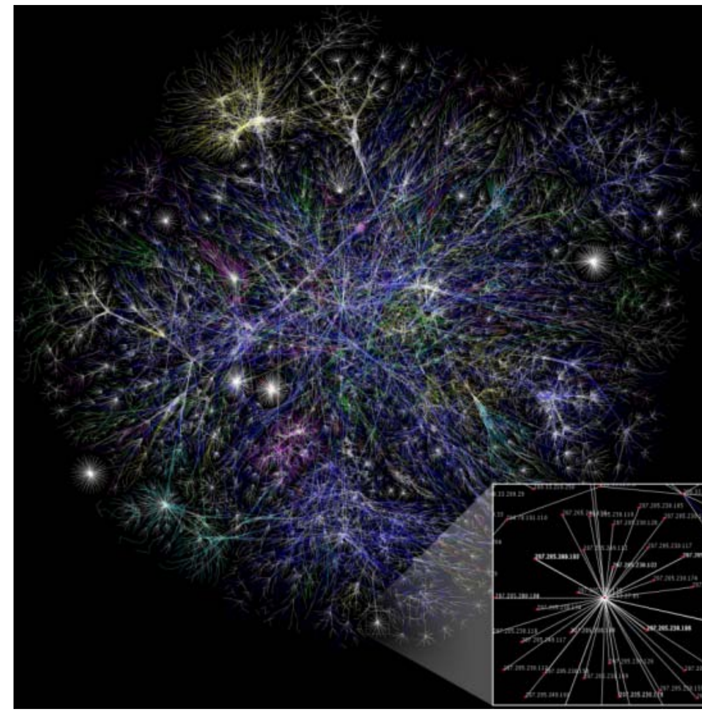


An Interconnected Society

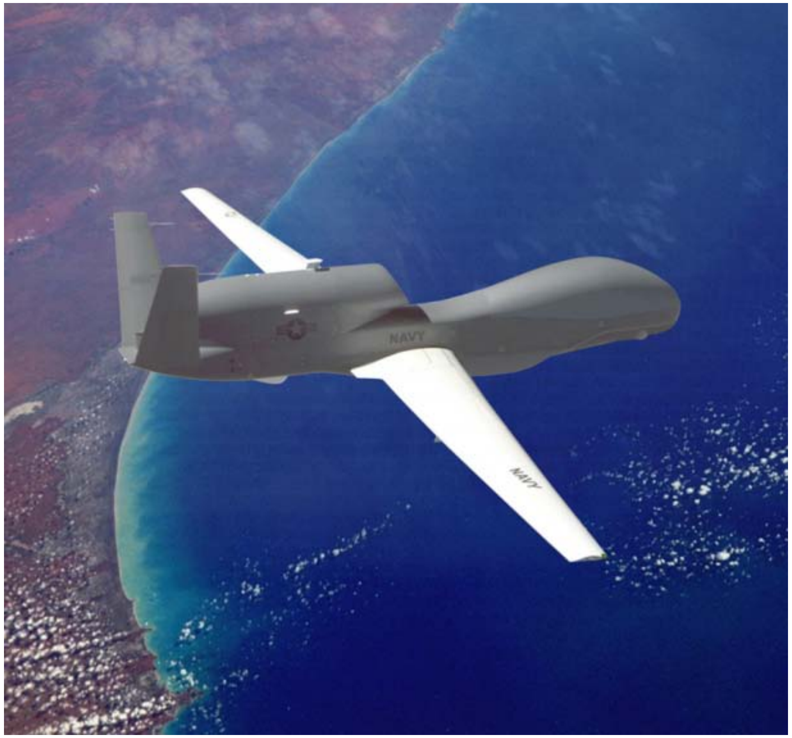


The Internet, 1969

The Internet, Today



Autonomous Systems



Human System Interaction

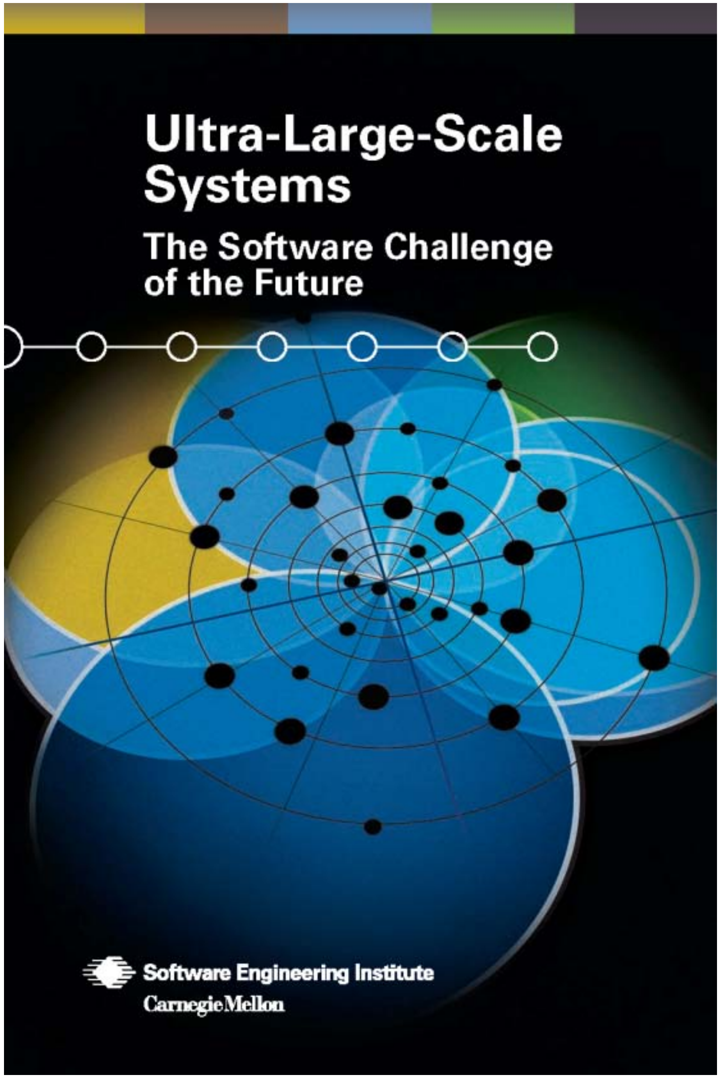
Complex Systems at the SEI

The SEI is at the nexus of systems and complexity:

- We study them side-by-side
- For 25 years, we've been helping engineers design and manage software systems
- It's our job to "ring the bell" on the importance of managing complexity

We also appreciate risk and the importance of managing it

- Process improvement
- Risk management and resilience
- Architectural approaches
- Multi-view models



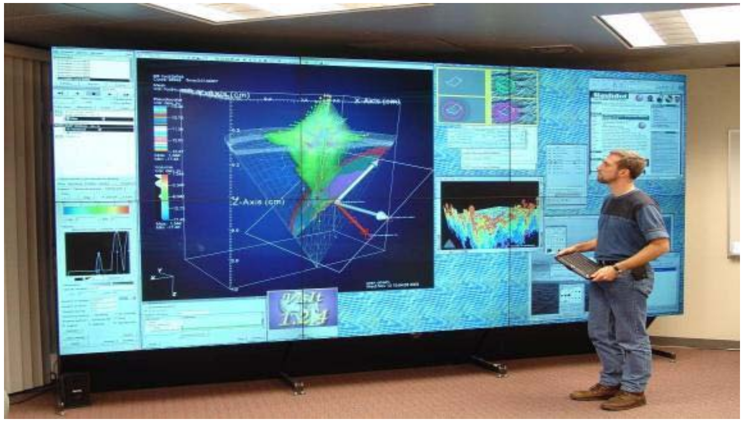
Software is Everywhere

Software is Important

Manufacturing

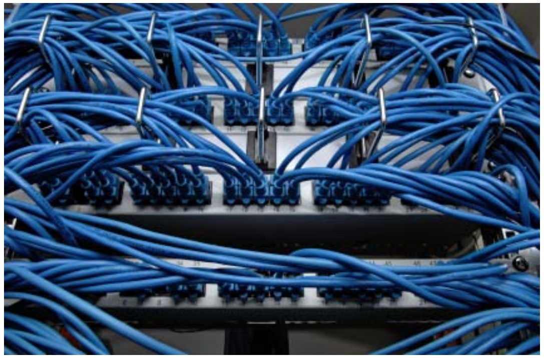
Finance

Space



Engineering

Software is Increasingly Complex



Software Connects Us

Software is Becoming More Personal

“Software is Eating the World”

Marc Andreessen essay, August 20, 2011

- Software is eating the world … it is everywhere
- “A trend I've observed, one that makes me optimistic about the future growth of the American and world economies … “
- “More and more major businesses and industries are being run on software and delivered as online services—from movies to agriculture to national defense.”

How to Handle Complexity

Models, Process and Process Improvement

Architecture

Risk Management and Resiliency

Evolution and Disruption

People

Process Improvement, People, and Models

Process Improvement helps us standardize, examine and improve how we work

- Process improvement also lets us learn from others and ourselves

Models help us simplify complex systems and give us insightful views

Process improvement and models are tools for people, not their masters

- People design, develop and operate systems

Why Use CMMI?

Makes you more competitive

Improves your quality

Links you with a global market

Scales to your needs

Helps you prioritize

The Key Ideas of CMMI

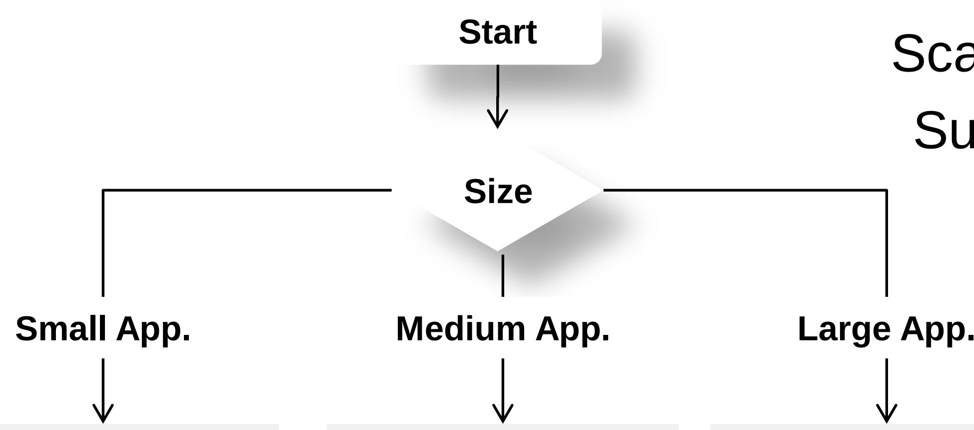
Elements:

- know your customer
- know your company
- focus on quality
- commit to continuous improvement
- make decisions based on data

Benefits:

- deliver quality products
- fewer delivered defects
- less rework
- meet schedules
- reduce costs profits
- quicker, more agile cycles
- more business

TSP – Software Engineering Best Practice



Scalable…small to large projects

Supports broad portfolio of work

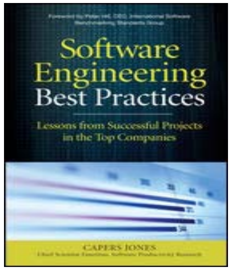
Best standard practice

Rank	Method
1	Agile
2	**TSP/PSP**
3	Waterfall
4	CMMI ML2

Rank	Method
1	**TSP/PSP**
2	Agile
3	CMMI ML3
4	RUP

Rank	Method
1	**TSP/PSP**
2	CMMI 3,4, 5
3	RUP
4	Hybrid

Best development practices by size of application[1]



1. Software Engineering Best Practices, C. Jones, 2010

Software Engineering Issues in R&D

U.S. SOFTWARE PERFORMANCE LEVELS

PROJECT MANAGEMENT		TECHNICAL STAFFS		SOFTWARE USERS	
Sizing	Fair	Requirements	Fair	Requirements	Poor
Estimating	Poor	Design	Good	Schedule Demands	Poor
Planning	Fair	Coding	Good	Reviews	Fair
Tracking	Poor	Reviews	Fair	Acceptance Test	Fair
Measuring	Poor	Testing	Good	Usage	Good
Overall	Poor		Good		Fair

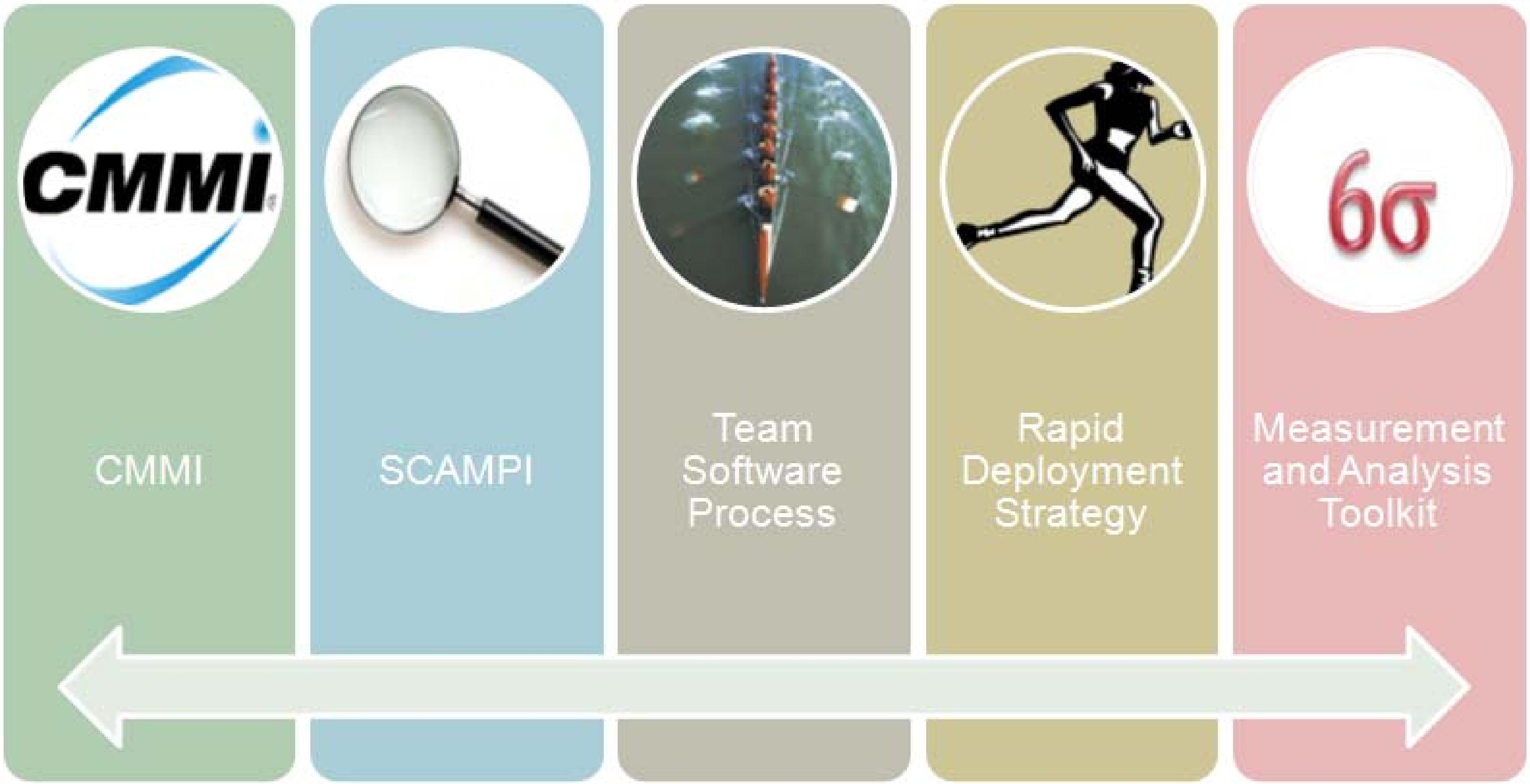
Conclusion: U. S. technical skills are better than U. S. management skills.
Project management and quality are frequent problem areas.

EXC/23

From *Team Software Process (TSP) in Context*, by Capers Jones

Accelerated Improvement Method (AIM)

Integrates and Leverages SEI Technologies



AIM – Predictably Improves Software Engineering Practice

Summary of field trial results

- rapid deployment – 15 months
- tactical project-focused approach
- supports implementation in-progress on critical software engineering projects
- predictable improvement timeline and cost
- faster, higher ROI addresses “no-time” and “can’t afford” barriers to change
- same TSP performance benefits

AIM Results	CGI Results	Typical Range
CMMI-DEV ML1 to ML3 (months)	**15**	**36 to 48**
Schedule Variance	**<10%**	**25% to 100%**
Effort Variance	**7%**	**25% to 100%**
Productivity	**up 35%**	
Quality (defects)	**down 50%**	

Architecture is Important

The quality and longevity of a software-reliant system is largely determined by its architecture.

In recent studies by OSD, the National Research Council, NASA, and the NDIA, architectural issues are identified as a systemic cause of software problems in DoD systems.

Why is Software Architecture Important?

Represents *earliest* design decisions	• hardest to change • most critical to get right • communication vehicle among stakeholders
First design artifact addressing	• performance • modifiability • reliability • security
Key to systematic *reuse*	• transferable, reusable abstraction
Key to system *evolution*	• manage future uncertainty • assure cost-effective agility

The right architecture paves the way for system success.
The wrong architecture usually spells some form of disaster.

Trends Leading to Architecture Challenges

Scale and complexity

Increased operational tempo

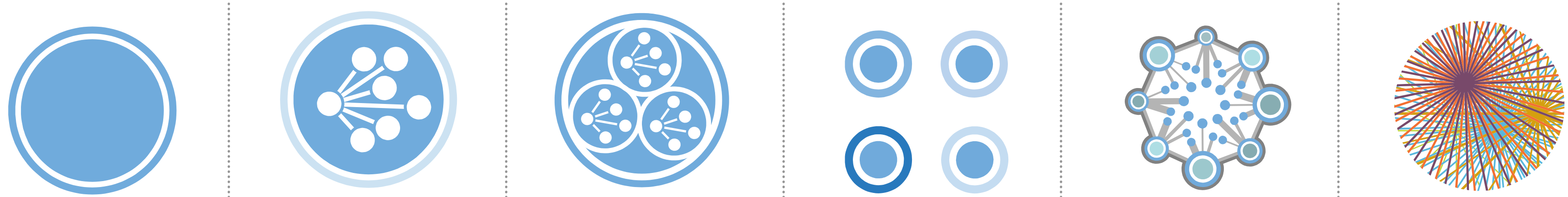
Decentralization and distribution

Disruptive technologies

Architecture Challenges Extend Across a Spectrum of System Types and Scale

Challenges include:

- determining how to structure and adapt systems at all scales
- managing interactions among these types of systems
- assuring software-reliant capabilities that are sufficiently reliable, secure, responsive, and adaptable to change



Stand-alone Systems
software applications

Embedded Systems
software embedded in hardware devices

Cyber-Physical Systems
mutually dependent computational systems and physical processes

Software Product Lines
families of similar systems

Systems of Systems
federations of independent systems

Ultra-Large-Scale Systems
webs of software-reliant systems, people, economies, and cultures

Predict and control behavior

Assure and bound behavior

Coupling to organizational structure and practices increases

Quality Attribute Requirements

Quality attributes include

- performance
- availability
- interoperability
- modifiability
- evolvability
- usability
- security
- etc.

Quality attribute requirements stem from business and mission goals.

Key quality attributes need to be characterized in a system-specific way.

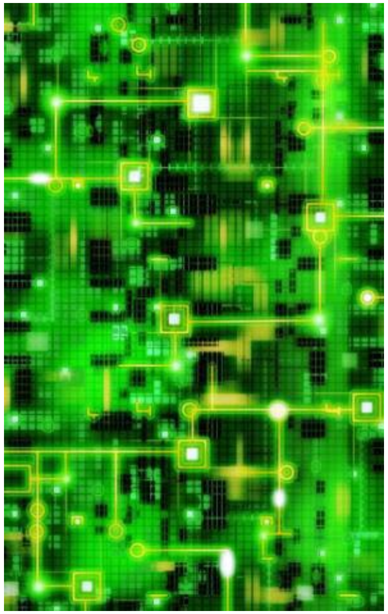
Otherwise, they are not operational.

Key Principles of Resiliency

Resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.

- security “built in”
- failure scenarios understood, planned for
- redundancy is provided for in key areas
- capability remains available under adverse conditions

resilience



At SEI, both organizational and software:

- Resilience Maturity Model (RMM)
- Security Quality Requirements Engineering (SQUARE)
- Current blog series topic (http://blog.sei.cmu.edu/)

Continuity

A key aim of resiliency (and managing operational risk)

Business Functions:

- Developing and executing continuity plans, recovery plans, and restoration plans

IT Function:

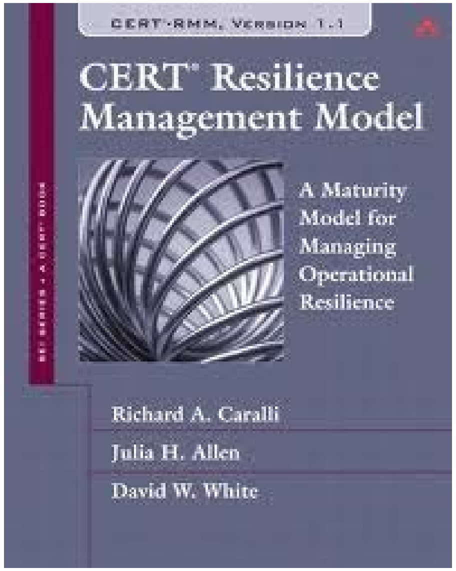
- Developing, implementing, and managing processes to deliver IT services and manage IT infrastructures

Resiliency Maturity Model

What is CERT-RMM?

CERT-RMM is a maturity model for managing and improving operational resilience.

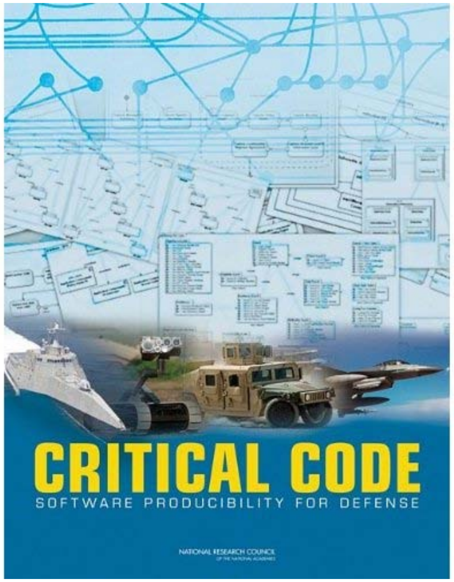
- Guides implementation and management of operational resilience activities
- Converges key operational risk management activities: security, business continuity/disaster recovery, and IT operations
- Defines maturity through capability levels (like CMMI)
- Improves confidence in how an organization responds in times of operational stress



Key Ideas in Software Engineering -1

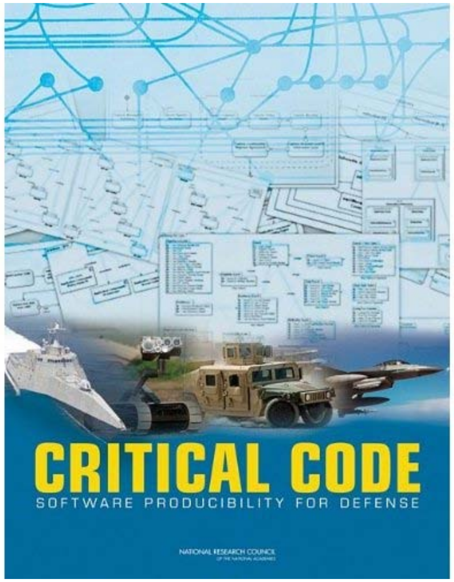
Critical Code—Software Practice and Research

1. There is a rapid growth in the strategic significance of software for DoD
   – DoD needs to actively address its software producibility needs
   – DoD cannot rely on industry alone to address software challenges for defense
2. Iterative engineering of innovative software can be successfully managed
   – Apply advanced technologies and practice for iterative incremental development of software intensive systems
   – Update earned value models and practices to support management process
3. There is insufficient DoD-aligned software experience
   – DoD needs to be a smart software customer



Key Ideas in Software Engineering -2

4. Assert DoD architectural leadership
   – In highly complex systems, architecture decisions may need to dominate functional capability choices
5. Adopt a strategic approach to software assurance
   – Integrate preventive practices into development to support ongoing creation of evidence in support of assurance
6. It is essential to reinvigorate DoD software engineering research
   – NITRD data reveal the extent of the S&T disengagement
   – Apply appropriate criteria in identifying goals for research programs
   – Focus research effort on identified goals in seven technological areas

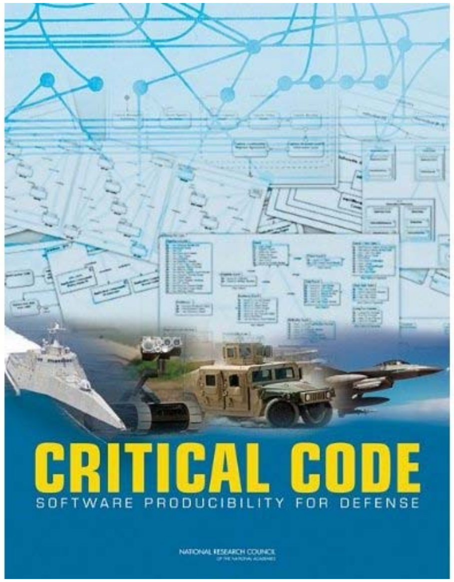


Recommendations -1

Summary of recommendations

Improve critical areas of current practice

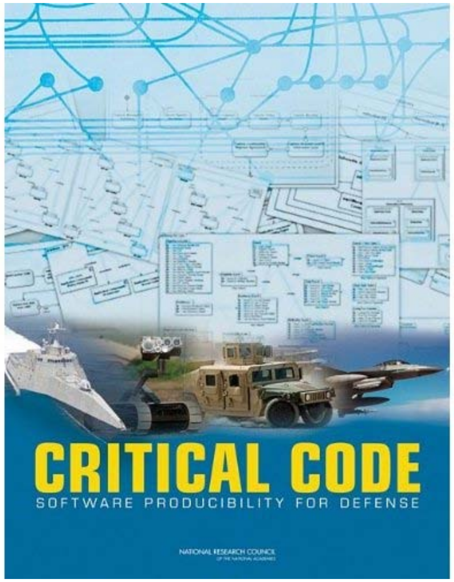
- Process and measurement
  - Enable incremental iterative development at arm's length
- Architecture
  - Enable architecture leadership, interlinking, flexibility
- Assurance and security
  - Enable high assurance at scale with rich supply chains



Recommendations -2

Undertake research to support the critical areas of practice

1. Architecture modeling and architectural analysis
2. Validation, verification, and analysis of design and code
3. Process support and economic models for assurance
4. Requirements
5. Language, modeling, code and tools
6. Cyber-physical systems
7. Human-system interaction



People

Summary

Software has increasing impact

Software challenges are growing

Software engineering provides useful tools

Great people are crucial

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