New Concepts and Trends

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The Software Engineering Institute - Improving the Practice of Engineering: Create, Apply and Amplify

Federally Funded Research and Development Center

Created in 1984

Sponsored by the U.S. Department of Defense

Locations in Pittsburgh, PA; Washington, DC; Frankfurt, Germany

Operated by Carnegie Mellon University
Overview

• Transformational Trends
  – Development
  – Acquisition
  – Human Element
  – Risk Management
  – Communications

• Ten Future Trends

• Wrap-up

“Perfect Storm” Event, October 1991
National Oceanic & Atmospheric Administration
Development: Need for Space, Air, Ground, Water, Underwater Software-Intensive Systems that are Interconnected

- Several million SLOC programs; “Hybrid” systems combining legacy re-use, COTS, new development
- Multi-contractor teams using different processes; dispersed engineering, development & operational locations
- New technologies create opportunities/challenges; products change/evolve, corporations mutate
- Business/operational needs change - often faster than full system capability can be implemented
- Skillset Shortfalls; Cost and schedule constraints
- Demands for increased integration, interoperability, system of system capabilities
- Enterprise perspectives/requirements; sustainment concerns

Development Complexity of Software-Intensive Systems is Increasing
# Software Engineering Trends That Impact Systems Engineering

<table>
<thead>
<tr>
<th>Traditional</th>
<th>Future</th>
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<tbody>
<tr>
<td>Standalone systems</td>
<td>Everything connected-maybe</td>
</tr>
<tr>
<td>Mostly source code</td>
<td>Mostly COTS components</td>
</tr>
<tr>
<td>Requirements-driven</td>
<td>Requirements are emergent</td>
</tr>
<tr>
<td>Control over evolution</td>
<td>No control over COTS evolution</td>
</tr>
<tr>
<td>Focus on software</td>
<td>Focus on systems and software</td>
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<tr>
<td>Stable requirements</td>
<td>Rapid change</td>
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<tr>
<td>Premium on cost</td>
<td>Premium on value, speed, quality</td>
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<tr>
<td>Staffing workable</td>
<td>Scarcity of critical talent</td>
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*Emerging Dynamics of Bringing Systems and Software Engineering in Continued Partnership*
The Acceleration of Innovation in the 21st Century: 
- Impacting Both Defense and Society

The Amount of New Technological Innovation is Doubling Every Two Years
- Requires More Upfront SE/SW Engineering to Leverage Trends
Augustine’s Law: Growth of Software - Order of Magnitude Every 10 Years

In The Beginning

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<tbody>
<tr>
<td>F-4A</td>
<td>F-15A</td>
<td>F-16C</td>
<td>F-22</td>
<td>F-35</td>
</tr>
<tr>
<td>1000</td>
<td>50,000</td>
<td>300K</td>
<td>1.7M</td>
<td>&gt;6M</td>
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<tr>
<td>LOC</td>
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F-15A 1970's LOC 50,000

F-16C 1980's LOC 300K

F-22 1990's LOC 1.7M

F-35 2000+ LOC >6M

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Trend & Implications: Augustine’s Law Will Hold

2080?

F-50 - 4.7B Lines of Code

Need for increased functionality will be a forcing function to bring the fields of software and systems engineering closer together
Moore's Law: The Number of Transistors That Can be Placed on an Integrated Circuit is Doubling Approximately Every Two Years
Increased Technological Rate of Adoption

- **Electricity (1873)**
- **Telephone (1876)**
- **Radio (1905)**
- **Television (1926)**
- **VCR (1952)**
- **Microwave (1953)**
- **PC (1975)**
- **Cell Phone (1983)**
- **Internet (1975)**

Source: Rich Kaplan, Microsoft

Automobile = 56 years
Telephone = 36 years
Television = 26 years
Cell phone = 14 years

No. of Years Since Invention

Percentage of Ownership

Electricity = 100%
Radio = 100%
Television = 100%
VCR = 100%
Microwave = 100%
PC = 100%
Cell Phone = 100%
Internet = 100%

Source: Rich Kaplan, Microsoft
Relationship Between Complexity and Acquisition Success Improving and More Improvements are on the Way

Software is Growing in Complexity
- 80% of some weapon system functionality is dependent upon software
- Consequences of software failure can be catastrophic

Software Acquisition is Difficult
- 46% are over-budget (by an average of 47%) or late (by an average of 72%)
- “Successful projects” have 68% of specified features

Software is Pervasive
- IT Systems, C4ISR, Weapons, etc

On-going Changes to the Acquisition Process Targeted at Correcting this Issue
Acquisition: Life of a Program Manager in a System of Systems and/or Net-Centric Operation…
Acquisition: Effectively Managing Risk

A Key Challenge is How to Obtain a Better Alignment of Risk Among the Relevant Stakeholders
Acquisition Challenges: Some Drivers That Increase the Risk of Acquiring Software-Intensive Systems

Platform → Enterprise

Requirements → Objectives/Capabilities

Dominant Prime → Strategic Teaming

“Boxes” → “Layers & Stacks”

Proprietary → Plug & Play

Customer Emphasis

Acquisition Model

Program Execution

Integration Challenge

Architectures and Standards

Need Exists to Address Both Sides, and Do So with Compressed Delivery Schedules via Improvements in Systems/Software Engineering
Increased Reliance on Acquirer/Developer to Reduce Risk by Effectively Navigating the Green/Acquisition Space

Navigating the “Green Space”

Risk-Reward Preferences

Increasing gap between industry’s acceptable risk/reward ratios (dashed line) and the reality of the marketplace (solid line)

The “Green Space” defines the area where industry initiatives must provide a payoff by reducing risk and/or increasing reward.

Acquisition changes based on previous legislation have introduced new levels of risk.


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Acquisition Performance – Flexible Boundary-Crossing Acquisition Structure

2005 study confirmed*:

- In advanced knowledge-based organizations, management’s desire for the flow of knowledge is greater than the desire to control boundaries
- Unlike the matrix organization, there is less impact on the dynamics of formal power and control
- Important to measure the system in terms of user performance

* Using Communities of Practice to Drive Organizational Performance and Innovation, 2005, APQ study

Ref: Jim Smith, (703) 908-8221, jds@sei.cmu.edu

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The ability of organizations to compete will increasingly depend on the innovation of the human element.
Society Drivers: Bimodal Demographics (Space Industry)

Reconstituting This Group

Graduate School Shortfall

Area of Concern

Average Space Industry S&E Workforce Age Distribution

Trend: Industry/Gov’t Will Increasingly Focus on Attracting, Training and Retaining Systems Engineering Talent

Source: Lockheed Martin (0004305-001: AIAA SE Workforce Data. Frank Cappuccio VP & GM Skunk Works)
Human Element Challenge: Bumpy Road at the Systems Engineering/Software Engineering Intersection

Whole System → Parts of System
Contradiction in Focus/Optimizing

Long Time → Rapid
Contradiction in Cycle Time

Circular Causality → Linear Causality
Contradiction in Design Dependency

Systematic → Art
Contradiction in Spirit

Generalist → Wants Detail
Contradiction in Detail

Source: Kurstedt, Harold, Newport Group - 2008
Objective is for Software and Systems Engineering to Become More Integrated Versus Separated

OSD Initiative: Integrated Software and Systems Engineering Curriculum
Human Element in the Work-Space Environment

Source: Doug Phair; Technology Evangelist; dphair@mitre.org; February 2008
## Human Element: More Generation Y Workers Will Enter the Workplace

<table>
<thead>
<tr>
<th>Pre Boom</th>
<th>Baby Boom</th>
<th>Generation X</th>
<th>Generation Y</th>
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### Generation Y Characteristics
- Born late 1970s to mid-1990s
- Larger than Generation X
- More ethnically diverse
- Technologically savvy

### What Makes Generation Y Tick
- High Expectation of Employers
- Goals, Goals, Goals
- Desire for Immediate Responsibility
- Balance and Flexibility

Source: Cara Spiro, DAU, 2006
Higher-Maturity Approaches to Process Improvement Are Important and Synergistic Trends

**Data-Driven (e.g., Six Sigma, Lean)**

- Determine what your processes can do (Voice of Process)
  - Statistical Process Control
- Clarify what your customer wants (Voice of Customer)
  - Critical to Quality (CTQs)
- Identify and prioritize improvement opportunities
  - Causal analysis of data
- Determine where your customers/competitors are going (Voice of Business)
  - Design for Six Sigma

**Model-Driven (e.g., CMM, CMMI)**

- Determine the industry best practice
  - Benchmarking, models
- Compare your current practices to the model
  - Appraisal, education
- Identify and prioritize improvement opportunities
  - Implementation
  - Institutionalization
- Look for ways to optimize the processes

*CMMI and Six Sigma, Siviy, et al, 2007, Addison Wesley*
Communication: Increased Capabilities in the Digital Spectrum Enables Improvements in Communication and Collaboration

Rule #4: The best companies are the best collaborators*

* Friedman, Thomas L. “The World Is Flat”, Farrar, Straus and Giroux, 2005
Systems and Software Engineering: Ten Trends

1. Greater demands on systems and software engineers will stimulate growth in the field – nationally and internationally

2. Industry/Gov’t will increasingly focus on attracting, training and retaining systems and software engineering talent – short and long run – with emphasis on providing a Generation Y work environment

3. Increased reliance on systems and software engineering processes and technologies to effectively manage the acquisition/”green” space

4. The laws of Augustine’s and Moore will continue to hold and will continue to be a forcing function to bring the fields of software and systems engineering closer together

5. Improvements risk-reduction collaboration mechanisms will be significant enablers for increases in systems and software engineering communication and “decision velocity”
Systems and Software Engineering: Ten Trends

6. Systems and software engineers will continually find ways to innovative to reduce complexity

7. Increased importance of modeling and simulation

8. Increased customer requests for system and software engineering support will occur earlier in life cycle

9. Shift of systems and software engineering focus from the platform to the networks and ground systems

10. Process improvement will continue to be important!
Recommended Readings


Friedman, Thomas L. “The World Is Flat”, Farrar, Straus and Giroux, 2005


