Modernizing Systems and Software
- How Evolving Trends in Future Trends in Systems and Software Technology Bode Well for Advancing the Precision of Technology

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Overview

• Transformational Trends
  – Development
  – Acquisition
  – Human Element
  – Risk Management
  – Communications
• Ten Future Trends
• Wrap-up
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>
</tr>
</thead>
<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>
</tr>
<tr>
<td>Stable requirements</td>
<td>Rapid change</td>
</tr>
<tr>
<td>Premium on cost</td>
<td>Premium on value, speed, quality</td>
</tr>
<tr>
<td>Staffing workable</td>
<td>Scarcity of critical talent</td>
</tr>
</tbody>
</table>

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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

Ray Kurzweil, et. al
Augustine’s Law: Growth of Software - Order of Magnitude Every 10 Years

**In The Beginning**

<table>
<thead>
<tr>
<th>Era</th>
<th>Aircraft</th>
<th>LOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960’s</td>
<td>F-4A</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>F-15A</td>
<td>50,000</td>
</tr>
<tr>
<td>1970’s</td>
<td>F-16C</td>
<td>300K</td>
</tr>
<tr>
<td>1980’s</td>
<td>F-22</td>
<td>1.7M</td>
</tr>
<tr>
<td>1990’s</td>
<td>F-35</td>
<td>&gt;6M</td>
</tr>
</tbody>
</table>
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 Placed on an Integrated Circuit is Doubling Approximately Every Two Years
Increased Technological Rate of Adoption

- **Electricity** (1873)
- **Telephone** (1876)
- **Automobile** (1886)
- **Television** (1926)
- **Radio** (1905)
- **VCR** (1952)
- **Microwave** (1953)
- **PC** (1975)
- **Cell Phone** (1983)
- **Internet** (1975)

- **Automobile**: 56 years
- **Telephone**: 36 years
- **Television**: 26 years
- **Cell phone**: 14 years

Percentage of Ownership

**Source**: Rich Kaplan, Microsoft

No. of Years Since Invention

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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

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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**
  - **Customer Emphasis**

- **Requirements**
  - **Acquisition Model**

- **Dominant Prime**
  - **Program Execution**

- **“Boxes”**
  - **Integration Challenge**

- **Proprietary**
  - **Architectures and Standards**

- **Enterprise**
  - **Objectives/Capabilities**

  - **Strategic Teaming**

  - **“Layers & Stacks”**

  - **Plug & Play**

*Need Exists to Address Both Sides, and Do So with Compressed Delivery Schedules via Improvements in Systems/Software Engineering*
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

Advanced Knowledge-Based Organizations (Big A)

From “Science and Technology to Support FORCEnet,” Raytheon TD-06-008. Used by permission.

Ref: Jim Smith, (703) 908-8221, jds@sei.cmu.edu
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)
Objective is for Software and Systems Engineering to Become More Integrated Versus Separated

OSD Initiative: Integrated Software and Systems Engineering Curriculum

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Human Element in the Work-Space Environment

Source: Doug Phair; Technology Evangelist; dphair@mitre.org; February 2008
Managing Multiple Generations: Cultural Differences

Traditionalist
1928-1945
- Hard worker
- Respects authority
- Work is an obligation
- Communicates formally & in person
- Organizational loyalty
- Work & family don’t mix

Baby-Boomer
1946 - 1964
- Workaholic
- Questions authority
- Works efficiently
- Competitive
- No news is good news
- Work to live, little balance between work/family

Generation X
1965 - 1980
- Technically savvy
- Prefer informality
- Learns quickly
- Communicates directly & immediately
- Wants structure & direction
- Seek work/life balance

Generation Y
1980 - 2000
- Prefer informality
- Learn quickly
- Embrace diversity
- Requires supervision
- Indirect communication: email & texting
- Seek “demand” work/life balance

Source: Hammill 2005

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Trends Affecting the Workforce

From | To
---|---
Doers differ from thinkers | Doers must be thinkers
Assets are things | Assets are people
Labor is an expense | People are an investment
Lifetime employment | Lifetime employability
Top down control | Decentralized decisions
Localized work | Networked problems solved
Measure for results | Measure for improvements

Pfeffer (1994)
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
Communications Among Systems – Fostering a Growing Interdependence and Integration
Implication: Improvements in Collaboration Mechanisms Are Enablers for System and Software Engineering Success

High Bandwidth

Virtual Presence

Voice over IP

Whiteboarding

File Transfer

Internet Surfing

Email

Low Bandwidth

Communication of Ideas and Decision Velocity

3D Data Visualization

Spatial Applications

Application Portals

Web Services

Transaction Processing Systems

Scheduling, tracking, retrieval & Coordination applications

Unstructured

Highly Structured

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Problem Identification: Ultra-Large-Scale (ULS) Systems – The Software Challenge of the Future

Gather leading experts to study:

- Characteristics of ULS systems
- Challenges and breakthroughs required
- Promising research and approaches

Intended outcomes:

- ULS Systems Research Agenda
- Program proposal
- Collaborative research network

**About the Effort**
Funded by the Army (ASA ALT)
Staffing: 9 member SEI team; 13 member expert panel

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Systems and Software Engineering: Ten Trends

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

• *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*

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

• *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*

• *Improvements in program 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

• Increased need for a large number of complex systems and systems of systems will lead to investments in research and technology

• Systems and software engineers will continually find way to innovative to reduce complexity
  – Increased importance of modeling and simulation
  – Increased reliance on architectures (top-down and bottoms-up)
  – Increased design for continuous evolution and deployment at all levels will occur
    ➢ Understanding users and their context will evolve, e.g. leaner system and software engineering process assets on projects

• Increased customer requests for system and software engineering support earlier in life cycle

• Shift of systems and software engineering focus from the platform to systems of systems

• Process improvement will continue to be important
Recommended Readings


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


