Future Trends in Systems & Software Engineering

Second Annual Systems Engineering Conference
4 June 2008
National Reconnaissance Office
Chantilly, Virginia
Theme: Systems Engineering: A Partner in Transformation

Dr. Kenneth E. Nidiffer
Director of Strategic Plans for Government Programs
nidiffer@nro.mil
nidiffer@sei.cmu.edu
The Software Engineering Institute - Improving the State of 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 in Systems and Software Engineering
  - Development
  - Innovation
  - Integration
  - Human Element
  - Communications
  - Process
- Ten Trends
- Wrap-up

“Perfect Storm” Event, October 1991
National Oceanic & Atmospheric Administration
Development Challenges: 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

Systems Engineering – A Partner in Developing More Responsive Space Systems
### Software Engineering Development 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>• Limited 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>

**Emerging Dynamics of Bringing Systems and Software Engineering in Continued Partnership**
The Amount of New Technological Information is Doubling Every Two Years
- Requires More Upfront SE
Growth Trend in Space System Software
(Onboard and Ground Software)

![Bar Chart: Growth Trend in Space System Software](chart.png)

- Millions ESLOC
- DSP, SBIRS High, AEHF, GPS III, TSAT, SR
System/Software Engineering I/F Challenges: Augustine’s Law – Growth of Software - Order of Magnitude Every 10 Years

In The Beginning

1960’s

F-4A 1000 LOC

1970’s

F-15A 50,000 LOC

1980’s

F-16C 300K LOC

1990’s  

F-22 1.7M LOC

2000+  

F-35 >6M LOC
System/Software I/F Challenges: Relationship Between Complexity and Acquisition Success Improving But Not Enough!

Software is Growing in Complexity
- 80% of some weapon system functionality is dependent upon software\(^1\)
- 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%)\(^2\)
- “Successful projects” have 68% of specified features\(^2\)

Software is Pervasive
- Space, IT Systems, C4ISR, Weapons, etc
System/Hardware Engineering I/F Challenges - Moore's Law: The Number of Transistors That Can be Placed on an Integrated Circuit is Doubling Approximately Every Two Years
Systems Engineering Integration Challenges: Some Drivers That Increase the Complexity of Acquiring Systems

Transformation will require addressing both sides, and do so with compressed delivery schedules via improvements in systems/software engineering.
Increased Reliance on Acquirer/Developer to Reduce Integration 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.

©2005 Systems and Software Consortium, Inc.

The ability of organizations to compete will increasingly depend on the innovation of the human element.
The Challenge - Supporting Evidence

Gruhl, Werner (1992), Lessons Learned: Cost/Schedule Assessment, Internal Presentation, NASA Comptroller’s Office

Hypothesis: The effective performance of SE best practices on a development program yields quantifiable improvements in the program execution (e.g., improved cost performance, schedule performance, technical performance).

Objectives:
- Characterize effective SE practices
- Correlate SE practices with measures of program performance

Approach:
- Distribute survey to NDIA companies
- SEI analysis and correlation of responses

Survey Areas:
- Process definition
- Project planning
- Risk management
- Requirements development
- Requirements management
- Trade studies
- Interfaces
- Product structure
- Product integration
- Test and verification
- Configuration mgmt
- Metrics
Society Drivers: Bimodal Demographics (Space Industry)

Reconstituting This Group

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)
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

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

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

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

Ref: Jim Smith, (703) 908-8221, jds@sei.cmu.edu
Human Element Challenge: Bumpy Road at the Systems Engineering/Software Engineering Intersection

The Integration of Systems and Software Engineering will take SE Leadership Commitment

Source: Kurstedt, Harold, Newport Group, 2008

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
Human Element: Current Objective is for Software and Systems Engineering to Become More Integrated Versus Separated

System Analysis

System Design

Software (SW) Requirements Analysis

Architectural SW Design

Detailed SW Design

Code and Unit Test

System Testing

System Integrated Testing

SW System Testing

SW Integration Testing

SW Subsystem Testing

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

- Pre Boom
- Baby Boom
- Generation X
- Generation Y

<table>
<thead>
<tr>
<th>Year</th>
<th>Pre Boom</th>
<th>Baby Boom</th>
<th>Generation X</th>
<th>Generation Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1940</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
Increased Capabilities in the Digital Spectrum Enables SE 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
SE is a Partner in Addressing Both Approaches to Process Improvement

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

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

**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

**Design for Six Sigma**
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 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

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

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

• Process improvement will continue to be important
Recommended Readings


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

Gates, William H. III “*Business @ The Speed of Thought – Using a Digital Nervous System*”, Time Warner Books, 1999


