Systems Engineering
- How Future Trends in Systems and Software Technology Bode Well for the Rapid Adoption of CMMI

CMMI Technology Conference and User Group
November 12-15, 2007
Investigation, Measures and Lessons Learned about the Relationship between CMMI Process Capability and Project or Program Performance
Hyatt Regency Tech Center- Denver, CO
Systems and Software Technology – Enabling the Global Mission

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How Future Trends in Systems and Software Technology Bode Well for Enabling the Rapid Adoption of CMMI

Dr. Kenneth E. Nidiffer

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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

- Environmental Challenges
  - Development
  - Acquisition
- Storms of Change
  - Human Element
  - Project/Risk Management
  - Communications
- Warning Signs
- Concluding Comments

“Perfect Storm” Event, October 1991
National Oceanic & Atmospheric Administration
### Development Challenges: 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>Focus on software</td>
<td>Focus on systems and software</td>
</tr>
<tr>
<td>Premium on cost</td>
<td>Premium on value, speed, quality</td>
</tr>
<tr>
<td>Stable requirements</td>
<td>Rapid Change</td>
</tr>
<tr>
<td>Control over evolution</td>
<td>No control over COTS evolution</td>
</tr>
<tr>
<td>Staffing workable</td>
<td>Scarcity of critical talent</td>
</tr>
</tbody>
</table>

*Trends provided by Don Reifer, REIFER CONSULTANTS, INC.*
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

In The Beginning
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
- 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

Standish Group CHAOS Report

<table>
<thead>
<tr>
<th>Year</th>
<th>On-Time</th>
<th>Late and Over Budget</th>
<th>Cancelled</th>
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<td>2006</td>
<td>35%</td>
<td>19%</td>
<td>46%</td>
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<td>2004</td>
<td>29%</td>
<td>18%</td>
<td>53%</td>
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<td>2002</td>
<td>34%</td>
<td>15%</td>
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<td>2000</td>
<td>28%</td>
<td>23%</td>
<td>49%</td>
</tr>
<tr>
<td>1998</td>
<td>26%</td>
<td>28%</td>
<td>46%</td>
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<tr>
<td>1996</td>
<td>27%</td>
<td>40%</td>
<td>33%</td>
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<tr>
<td>1994</td>
<td>16%</td>
<td>31%</td>
<td>53%</td>
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</table>
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Acquisition Challenges: Some Drivers That Increase the Complexity of Acquiring Software-Intensive Systems

The emerging dynamic is to address both sides, and do so with compressed delivery schedules via improvements in systems/software engineering.

Platform → Enterprise
  Customer Emphasis

Requirements → Objectives
  Acquisition Model

Dominant Prime → Strategic Teaming
  Program Execution

“Boxes” → “Layers & Stacks”
  Integration Challenge

Proprietary → Plug & Play
  Architectures and Standards
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Development and Acquisition Challenges: CMMI Constellations

CMMI-Dev provides guidance for measuring, monitoring and managing development processes.

CMMI-ACQ provides guidance to enable informed and decisive acquisition leadership.

16 Core Process Areas, common to all
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CMMI - ACQ v1.2

Acquisition Category Process Areas (Released Nov)

- Solicitation & Supplier Agreement Development
- Agreement Management
- Acquisition Requirements Development
- Acquisition Technical Management
- Acquisition Validation
- Acquisition Verification

CMMI Model Framework (CMF)

16 Project, Organizational, and Support Process Areas
The ability of organizations to compete will increasingly depend on the innovation of the human element.
The Demographic Context…

- A shrinking pool of experienced workers.
  - 42% decline from 1990 peak (AIA Employment Database)
- Consolidation left our industry with a mature workforce.
  - 54% over age 45 (BAH Study)
- Engineering enrollment trends are down.
  - 15% decline since 1991 (National Science Foundation Indicators)
- Brutal competition for technologists.
  - Demand for experienced engineers is projected to increase by 97% between 1998 and 2008. (US Bureau of Labor Statistics)

A key challenge is how to transform the workforce to meet demand.
More Generation Y Workers Will Enter the Workplace

Pre Boom  Baby Boom  Generation X  Generation Y


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
Current Trends is for Software and Systems Engineering to Become More Integrated Versus Separated

OSD Initiative: Integrated Software and Systems Engineering Curriculum
Creating a Reference Curriculum for Graduate Software Engineering Education

iSSEc is sponsored by DOD and led by Stevens, involving 4 sets of stakeholders:

- The industrial and government workforce who are the customers of SWE graduate education
- Academics who provide SWE and SE graduate education
- Professional societies with a vested interest in SWE and SE graduate education
- Government organizations who fund improvements in SWE graduate education

iSSEc recognizes that the divide between systems and software engineers in industry, government, and academia works against successfully delivering modern systems in which software is almost always central.

iSSEc will integrate SE principles and practices into the SWE curriculum.
Performance - Flexible Boundary-Crossing Acquisition Structure

Forms of Collaboration from "Architecting Principles for Systems of Systems", by Mark W. Maier
http://www.infoed.com/open/papers/systems.htm
2005 study confirmed*:

ÂIn advanced knowledge-based organizations, managementâ€™s desire for the flow of knowledge is greater than the desire to control boundaries

ÂUnlike the matrix organization, there is less impact on the dynamics of formal power and control

ÂImportant 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
Human Element: Increased Focus on Doing More with Less

Random motion – lots of energy, not much progress
No teamwork – individual effort
Frequent conflict
You never know where you'll end up

Directed motion – every step brings you closer to the goal
Coordinated efforts
Cooperation
Predictable results

Processes Can Make the Difference
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CMM and CMMI Technology Transfer Trends

Intro to the CMM and CMMI Attendees (Cumulative)
A key challenge is how to obtain a better alignment of risk among the key stakeholders who often leverage technology.
Greater Demand for Improvements in Project Performance

*What Got us Where We Are*  
*Won’t Necessarily Get us Where We Need to Be!*
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Ref: Ray Kurzweil
Moore's Law - The Number of Transistors That Can be Placed on an Integrated Circuit is Doubling Approximately Every Two Years
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Example of Acceleration: Increased Technology Rate of Adoption

Source: Rich Kaplan, Microsoft

<table>
<thead>
<tr>
<th>Technology</th>
<th>Year Invented</th>
<th>Years Since Invention</th>
</tr>
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<tbody>
<tr>
<td>Automobile</td>
<td>1886</td>
<td>56</td>
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<tr>
<td>Telephone</td>
<td>1876</td>
<td>36</td>
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<tr>
<td>Television</td>
<td>1926</td>
<td>26</td>
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<tr>
<td>Cell Phone</td>
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<tr>
<td>PC</td>
<td>1975</td>
<td></td>
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<tr>
<td>Internet</td>
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<td></td>
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<tr>
<td>VCR</td>
<td>1952</td>
<td></td>
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<tr>
<td>Microwave</td>
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<td></td>
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<tr>
<td>Television</td>
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<td>Electricity</td>
<td>1873</td>
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<tr>
<td>Telephone</td>
<td>1876</td>
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</tr>
</tbody>
</table>

Percentage of Ownership vs. No. of Years Since Invention

Source: Rich Kaplan, Microsoft
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.

### Number of Appraisals and Maturity Levels Reported to the SEI by Country

<table>
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<tr>
<th>Country</th>
<th>Number of Appraisals</th>
<th>Maturity Level 1 Reported</th>
<th>Maturity Level 2 Reported</th>
<th>Maturity Level 3 Reported</th>
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</tbody>
</table>
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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
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New Aviation Ship Integration Center, a state-of-the-art research facility established in partnership with the U.S. Navy to conduct modeling, simulation, research, development and in-depth analysis for CVN 21-class aircraft carriers and other aviation-capable ships.
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)
  - Design for Six Sigma

**Model-Driven (e.g., 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
  - Ref. Dr. Rick Hefner, Northrop Grumman
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Communication of Ideas and Decision Velocity

Implications: Improvements in Collaboration Mechanisms Are Enablers for System Engineering Success
Software Engineering Trends That Bode Well for the Rapid Adoption of CMMI

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”
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 the networks

Process improvement will continue to be important
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Questions?


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


