Future Trends in Systems and Software Engineering
- Special Emphasis on Implications to the CMMI

Software Process Improvement Network Meeting
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Presented By: Dr. Kenneth E. Nidiffer
nidiffer@systemsandsoftware.org
(703) 742-7110
Agenda

• Storms of the 80s
  – The software crisis
  – Birth of SPC (SSCI) and the SEI

• Storms of Change Today
  – Market Dynamics
  – Human Element
  – Project Management
  – Digital Spectrum
  – Software
  – Systems of Systems
  – Rapidly Changing Tech Base

• Concluding Comments

“Perfect Storm” Event, October 1991
National Oceanic & Atmospheric Administration
Market Dynamics: Drivers That Increase the Demand on System Engineering

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

The ability of organizations to compete will increasingly depend on the innovation of the human element.
Evidence of the Accelerating Pace of Change

Implication: Nature abhors a vacuum - to stay competitive innovation needs to occur at an ever accelerating pace
Society Drivers: Bimodal Demographics (Space Industry)

Average Space Industry S&E Workforce Age Distribution

Implication: Industry/Government 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)
Challenges Facing the Program Manager
Risk Focus Different for Program Managers: Government - “Get On Contract” ; Industry - “Effectively Execute”

A key challenge is how to obtain a better alignment of good acquisition and system engineering principles.
Shift to Service Delivery versus Produce and Delivery Perspective

Service-Oriented Architectures (SOA)

- Service-Oriented Architecture is an approach to building IT systems out of common parts
  - Represents a breakthrough in the way we build IT systems
    - Composed of reusable components, called services
    - Service is a building block that performs a distinct function
  - Evolution of client/server architecture
    - Functions of user I/F, application logic and data management are separated and decomposed still further

- Why Now
  - Internet and World Wide Web
  - Standardization (common parts)
  - Vender Market
  - Business Focused
Implication: Increased Reliance on System Engineering to Effectively Navigate 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.

Accelerating Development: Innovation, Iterative Development, Knowledge Management, Strategic Teaming
Flow of Knowledge Versus Control: Innovation & Knowledge Transfer - Flexible Boundary-Crossing 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.

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

Significant difference between CMMI Level 1 and Level 4/5 organizations is how information is controlled
Communities - Key Asset to Provide the Speed and Innovation Needed for Marketplace Leadership and Positioning

The ability to think “collectively” leads to out-of-box
Innovation platform - A studio for staging ideas. A collection point for collaboration best practices.

John Kao
Introducing Innovation
… Implications of Transforming the Culture of DoD, Oct 22, 2003
Strategic Alignment and Teaming

• Maintaining process maturity of heterogeneous teams
  – Processes that interoperate
  – Process architecture integration

• Subcontracting and outsourcing policies, processes, and practices
  – Selection criteria
  – Contractual agreements
  – Management

Need exists for mechanisms to enhance and speed process integration within multi-organization projects, multi-corporation teaming, complex prime-sub relationships, and after mergers or acquisitions.
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
Effective Transfer of Ideas Enables Successful Systems Engineering

Idea Transfer*

The length of a school bus” is the approximately the distance engineers bother to travel to ask questions.

They don’t climb stairs!

*Alistair Cockburn, Presentation at SSCI, 3/29/06
Implication: Improvements in Collaboration Mechanisms Are Enablers for System Engineering Success

Communication of Ideas and Decision Velocity

High Bandwidth

Virtual Presence
Voice over IP
Whiteboarding
File Transfer
Internet Surfing
Call
Chat
IM/Chat & Presence Awareness

Low Bandwidth

Unstructured
Highly Structured

3D Data Visualization
Spatial Applications
Application Scheduling,
tracking, retrieval & Coordination
applications
Transaction Processing Systems
Web Services
Collaboration Portals
Scheduling, tracking, retrieval & Coordination
applications

Implication: Improvements in Collaboration Mechanisms Are Enablers for System Engineering Success
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
## 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>
</tr>
<tr>
<td>• Stable requirements</td>
<td>• Rapid change</td>
</tr>
<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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*New approaches to building computational systems will emerge, e.g. SEI’s Functional Extraction, SSCl’s Agile Development approaches*

*Trends provided by Don Reifer, REIFER CONSULTANTS, INC.*
Trend & Implications: Augustine’s Law Will Hold

Need for increased functionality will be a forcing function to bring the fields of software and systems engineering closer together.

F-50 - 4.7B Lines of Code
Emerging Technologies for Complex Systems

- Systems of systems (SoS)
  - Increases in Complexity
  - Strategic Teaming
- Knowledge Management
- Variable Reduction
  - Reliance on architectures
    - Service oriented architectures (SOAs)
  - Modeling and simulation
- Agile development
- Autonomous computing
- Model-based development (MBD)
System of Systems

• Defining SoS
  – Planning, analyzing, organizing, and integrating the capabilities
  – Mix of existing and new systems
  – Greater than the sum of the parts

• Current activities
  – EPA program; GEOSS
  – Purdue University’s SoS Program
  – Concurrent Technologies Corporation’s SoS Engineering Center of Excellence
  – SoS Conferences
Trend: Increased Number of Complex Systems and Systems of Systems*

- Large software size: 10-100 MLOC
- Number of external interfaces: 30-300
- Number of “Competitive” suppliers: 20-200
  - Even more separate work locations
- Depth of supplier hierarchy: 6-12 levels
- Number of coordination groups: 20-200
  - Reviews, changes, risks, requirements, architecture, standards, procedures, technologies, -ilities, integration, test, deployment, personnel, infrastructure, COTS,…
- Multi-platform, hybrid communications, intelligent components
- Unprecedentedness
- Emergence
- Rapid change
- Multi-cultural globalization

* Boehm and Turner: The Future of Software and Systems Engineering Processes, SSCI Member Forum, 2005
Taking Knowledge to the Node

Less a Matter of Hitting a Window

And More a Matter of The Right Window - Right Now
Implication: Systems Engineers Will Need to Continually Find Innovative Ways to Reduce Complexity

Organizations must innovate to stay relevant

Source: Northrop Grumman
Increased Importance of Modeling and Simulation

Northrop Grumman Unveils New Modeling and Simulation Research Center

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.
Increased Reliance on Architectures (Enterprise, Domain and Solution)

**Zachman Framework**

- **Scope**:
  - Data View
  - Function View
  - Network View
  - People View
  - Time View
  - Motivation View

- **Business Model**
- **System Model**
- **Technology Model/Detailed Representations**

**DOD Architectural Framework (DODAF)**

**Federal Enterprise Architectural Framework (FEAF)**
What size problem can a given number of people attack, using different sizes of organizational assets?

Many people (using a light set of assets)

Many people (using a heavier set of assets)

Many people (using a very heavy set of assets)

*Slide adapted from Alistair Cockburn, Presentation at SSCI, 3/29/06
Rapid Changing Technology Base - Distribution of Value and Capability

The First Principle of Security/Survivability: Distribution of Value, but…

must retain the capability to apply overwhelming force or resources, when needed
Implication: Increased Customer Requests for System Engineering Support Earlier in Life Cycle

Support Capability Based Assessments
- Define relationships with related capabilities, architectures (e.g., GIG)
- Identify alternatives; trade cost, sched, perf
- Determine system performance parameters and verification plans
- Identify incremental, system specifications

Operational
Enterprise
SoS
System
Components

Develop, test, and assess increments of capability

Demonstrate capabilities meet user needs
Assess portfolio performance (CAR)
Integrate assess cost, sched, perf
Assess system performance against capability needs
Integrate and test

Joint Capabilities Integration and Development System (JCIDS)
Implication: Shift of Systems Engineering Focus
From the Platform to the Network

Past Focus

- Inexpensive Memory
- Data Rich
- Un Optimized SW

Future Focus

Net Enabled Performance Measures – Specific Attention to Application Domain
- Optimized Memory
- Open Architected SW

Net Centric Implementation

Cost Per Operation

Memory/Performance

Cost of Efficiency

1960 2000 2015+
**Trend: Systems Engineering will be Enabled by Advances in Diverse Technologies**

<table>
<thead>
<tr>
<th>System Architecture</th>
<th>Software</th>
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<tr>
<td>Client-server</td>
<td>Agile methods/XP</td>
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<tr>
<td>Bio-computing</td>
<td>Cognitive environments</td>
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<td>Quantum machines</td>
<td>Agents</td>
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<tr>
<td>Vector arrays</td>
<td>User-based programming</td>
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<td>Model Based Development</td>
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<td>COTS usage</td>
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<td>Publish-subscriber</td>
<td>Game-based development</td>
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<td>Generation</td>
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<td>Function Extraction</td>
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**Networking**

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<thead>
<tr>
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<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
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**Components**

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*Don Reifer, Future Shock, Software Estimating in 2010, CSE, USC, 2005*
Software and Systems Engineering: Trends and Implications

• Greater demands on systems engineers

• Industry/Gov’t will increasingly focus on attracting, training and retaining systems engineering talent

• Increased reliance on system engineering to effectively navigate the acquisition/”green” space

• Augustine’s Law will continue to hold and will be a forcing function to bring the fields of software and systems engineering closer together

• Improvements in collaboration mechanisms will be significant enablers for increases in systems engineering communication and “decision velocity”
Systems Engineering: Trends and Implications

• **Increased number of complex systems and systems of systems**

• **Systems engineers will need to continually find innovative ways to reduce complexity**
  – **Increased importance of modeling and simulation**
  – **Increased reliance on architectures**
  – **Leaner system engineering process assets on projects**

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

• **Shift of systems engineering focus from the platform to the networks**

• **Systems engineering will be enabled by advances in diverse technologies**
Questions?


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