The Value of Systems Engineering

What do we know about it?
How do we discover more?

- Al Mink
  Systems Value / GMU
Value of SE

Overview

1. The Problem
2. What We Know Today
3. The Race to Discover More
4. Conclusions
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The Problem (Stakeholder Analysis)

What – and how much – SE is appropriate for a particular system development program?

- Customers
  - Unsure of how to evaluate bids
  - May not receive best value for the systems they acquire
  - DoD #1 SE Issue – “Inconsistent SE Practices across life cycle”

- Industry (System Developers & Integrators)
  - Unsure of what to bid, and later loath to add SE costs

- Associations & Academia
  - Unable to fully satisfy their members and students

- SE professionals
  - Lack rigorous justification for their recommendations
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The Problem (IDEF 0 View)

SE produces more than products -- It affects the value of operational system produced

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The Problem (Pareto View)

Buede, Figure 1.2

SE activity upfront affects entire development

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What we know today – Studies & Models

**Gruhl**, National Avionics and Space Administration (NASA), 1992
*Compared upfront expenditures to eventual cost growth*

**Herbsleb**, Software Engineering Institute (SEI), 1994
*Studied ROI on process improvement in software*

**Honour**, International Council on Systems Engineering (INCOSE), 2002
*Surveyed industry to compare SE Effort to cost & schedule*

**Valerdi & Boehm**, Constructive System Engineering Cost Model (COSYSMO), 2004
*Developed parametric estimation model similar to COCOMO*

**Others**…
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What we know today – NASA Study

Total Program Overrun
32 NASA Programs

Definition Percent = \[
\frac{\text{Definition $}}{\text{Target + Definition$}}
\]

Program Overrun = \[
\frac{\text{Actual + Definition$}}{\text{Target + Definition$}}
\]

Source: Werner Gruhl
NASA Comptroller’s Office
& Honour 2004

R² = 0.5206
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What we know today – INCOSE Study

SE Effort = SE Quality * SE Cost/Actual Cost

Source: Honour 2004

90% Assurance (1.6σ)

Average Cost Overrun
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*What we know today – ROI of SE*

### SE ROI by Software Size of System

<table>
<thead>
<tr>
<th>KSLOC</th>
<th>Very Low</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
<th>Very High</th>
<th>Extra High</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-</td>
<td>52%</td>
<td>-20%</td>
<td>-45%</td>
<td>-58%</td>
<td>-77%</td>
</tr>
<tr>
<td>100</td>
<td>-</td>
<td>248%</td>
<td>80%</td>
<td>18%</td>
<td>-10%</td>
<td>-54%</td>
</tr>
<tr>
<td>1,000</td>
<td>-</td>
<td>512%</td>
<td>204%</td>
<td>91%</td>
<td>42%</td>
<td>-30%</td>
</tr>
<tr>
<td>10,000</td>
<td>-</td>
<td>840%</td>
<td>356%</td>
<td>177%</td>
<td>99%</td>
<td>-4%</td>
</tr>
</tbody>
</table>

*Boehm & Valerdi, 2006*
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What we know today – ROI of SE

SE Activities Affect Software Development

Development Cost Increase:
Minimal SE compared to Robust SE

Boehm & Valerdi, 2006
Software Product Size (KLOC)

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What we know today – COSYSMO

Limited ability to estimate “effort”

Size
Drivers

Effort
Multipliers

COSYSMO

Person
Months of systems engineering effort

Pred(30) 50% uncalibrated
Pred(30) 70% calibrated

Valerdi, 2005
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What we know today – Summary

Today we possess a *limited* understanding of the **SE effort** required for **success** of a **project**

8-15% in Aggregate*

Cost, Relative to budget

Of General Nature

* COSYSMO tracks 33 SE activities
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The Race to Discover More

Four Separate Efforts Underway
All four should increase our understanding of the SE effort required for success of a project.
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The Race to Discover More - Methodology

All Four Appear to Follow a General Approach

1. Form Team
2. Develop Approach
3. Identify Projects
4. Collect Data
5. Analyze Data
6. Publish Results
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The Race to Discover More - Methodology

How the pieces fit together

4. Data Collection
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The Race to Discover More

Capturing Data – Three Categories

4.1 Measure SE Effort (Activities)
4.2 Measure Success
4.3 Characterize Project
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The Race to Discover More – Define SE Activities

Defining “SE Activities” – One View

A.11 Perform System Level Design Activities

SE 101

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The Race to Discover More – Define SE Activities

Defining “SE Activities” – Many Views

Fragmented by domain opinions
- Military – DOD/MOD
- Space - NASA/ESA
- Commercial products
- Aircraft
- Automobiles
- Nuclear waste
- Process engineering
- Tool vendors

Fragmented by discipline opinions
- Technical leaders
- System architects
- System analysts
- Requirements engineers
- Operations analysts
- Design engineers

Fragmented by standards
- ANSI/EIA-632
- IEEE-1220
- ISO-15288
- CMMI
- MIL-STD-499C

Honour 2005
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The Race to Discover More – Define SE Activities

How the Different Efforts Define “SE Effort”

Standards

- ANSI/EIA-632
- IEEE-1220
- ISO/IEC-15288
- CMM/CMMI
- MIL-STD-499C
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Emerging Approaches to Move Forward – Define Other Measures

In addition to defining & measuring SE Effort…

Cost, schedule, & quality

Success factors
- EVMS
- Award Fee
- Requirements Trace
- Others…

Tailored to project

Project characteristics
- Size ($)
- Size (hours)
- Technology
- Complexity
- Others…
One Other Difference – Collection Mechanism

4. Data Collection

Mechanism
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The Race to Discover More – Define SE Activities

How the Different Efforts Collect Data

Data Collection Mechanisms

Survey

Interview

Work Shops

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Conclusions

- **Value of SE**
  - Remains fundamental to furthering SE as a respected discipline

- **Four approaches underway to determine SE Value**
  - With a fifth – Bob Bruff – on the horizon…

- **They share commonalities, but also differ:**
  - Differing types of projects
  - Differing SE Activities & Deliverables
  - Differing success factors (cost, schedule, quality, etc.)

- **Challenges Remain**
  - Useful project data – may not be widely available
  - Four separate projects – what if they report different results?
  - Success may be elusive – “The Shangri-La of ROI” (Sheard 2000)

- **Make a difference! Support these approaches**
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Conclusion

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Questions?

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