Value of Systems Engineering

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Heuristic Claim of SE

Better systems engineering leads to
- Better system quality/value
- Lower cost
- Shorter schedule

Key Question: How Much Is Enough?
Project History

- Started working for interviews in 1998
  - 25 organizations interested, but no one willing to be first – motivation was not strong
  - Developed long-term plan to create motivation
- Value of Systems Engineering 2000-2004
  - Survey approach – informal, anonymous
  - Gathered basic data, easy to fill out
  - 2004 results spread widely around world
- SE Return on Investment 2006-2010
  - Detailed interviews, common language/concepts
  - Rigorous statistical analysis
  - Strongly reviewed for accuracy
# Basic Demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>ValueSE Data Set</th>
<th>SE-ROI Data Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of organizations</td>
<td>Unknown</td>
<td>16</td>
</tr>
<tr>
<td>Number of data points</td>
<td>44</td>
<td>48</td>
</tr>
<tr>
<td>Funding method</td>
<td>Unknown</td>
<td>39 contracted, 9 amortized</td>
</tr>
<tr>
<td>Program total cost</td>
<td>$1.1M - $5.6B Median $42.5M</td>
<td>$600K - $1.8B Median $14.4M</td>
</tr>
<tr>
<td>Cost compliance</td>
<td>(0.8):1 – (3.0):1 Median (1.2):1</td>
<td>(0.6):1 – (10):1 Median (1.0):1</td>
</tr>
<tr>
<td>Development schedule</td>
<td>2.8 mo. – 144 mo. Median 43 mo.</td>
<td>2 mo. – 120 mo. Median 35 mo.</td>
</tr>
<tr>
<td>Schedule compliance</td>
<td>(0.8):1 – (4.0):1 Median (1.2):1</td>
<td>(0.3):1 – (2.5):1 Median (1.1):1</td>
</tr>
<tr>
<td>Percent of program used in systems engineering effort, by cost</td>
<td>0.1% - 27% Median 5.8%</td>
<td>0.1% - 80% Median 17.4%</td>
</tr>
<tr>
<td>Subjective assessment of systems engineering quality (1 poor to 10 world class)</td>
<td>Values of 1 to 10 Median 5</td>
<td>Values of 1 to 10 Median 7</td>
</tr>
</tbody>
</table>
Effect of Characterization Parameters

\[ R^2 = 15\% \]

**SE-ROI only**

\[ R^2 = 79\% \]

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Schedule vs. SE Effort
Cost vs. SE Effort

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Return on Investment

Overrun 53% ROI 7:1
Overrun 24% ROI 4.6:1
Overrun 7% ROI 1.1:1
Overrun 3% ROI 0 Optimum SEE=14.4%
Overrun 15% ROI 3.5:1 Median of programs

Equation: $\text{SEE} = 14.4\%$
Technical Quality vs. SE Effort

“Technical Quality” is based on compliance with KPP thresholds and goals:
- 2.0 = Met goals
- 1.0 = Met thresholds
- 0.0 = Failed to meet

Barely significant correlation
12% against required 11% for $\alpha=0.05$
Breakout by SE Activities

- **MD** Mission/Purpose Definition
- **RE** Requirements Engineering
- **SA** System Architecting
- **SI** System Integration
- **VV** Verification & Validation

- **TA** Technical Analysis
- **SM** Scope Management
- **TM** Technical Leadership/Management

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**SE Cost over Program**

- Percent of End-to-End Program Cost Expended During Each Phase

- **Begin**
- **MCR**
- **SRR**
- **SDR**
- **PDR**
- **CDR**
- **TRR**
- **End**

Legend:
- MD
- RE
- SA
- SI
- VV
- TA
- SM
- TM
Successful (~on cost)
- More mission/purpose defn
- More tech leadership/mgmt
- More Systems Engineering

Poor (overran cost)
- More system integration
- More verif & valid
- Less Systems Engineering

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Typical Data:

Cost vs. Tech Lead’ship/Mgmt

![Graph showing the relationship between Effective TM Effort as % Program Cost and Actual/Planned Cost with a curve fit and R² = 0.360. The graph includes data points for Value SE data, SE-ROI data, and All data, with polynomial fits for each set.](image-url)
## Effect of SE Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Code</th>
<th>Cost Compliance</th>
<th>Schedule Compliance</th>
<th>Overall Success</th>
<th>Technical Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Systems Engineering Effort</td>
<td>SE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Perhaps</td>
</tr>
<tr>
<td>Mission/Purpose Definition Effort</td>
<td>MD</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Requirements Engineering Effort</td>
<td>RE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>System Architecting Effort</td>
<td>SA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>System Integration Effort</td>
<td>SI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Verification &amp; Validation Effort</td>
<td>VV</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Technical Analysis Effort</td>
<td>TA</td>
<td>Yes</td>
<td>Yes</td>
<td>Perhaps</td>
<td>No</td>
</tr>
<tr>
<td>Scope Management Effort</td>
<td>SM</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Technical Management/Leadership</td>
<td>TM</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
### Optimum Levels, Median Program

<table>
<thead>
<tr>
<th>Activity</th>
<th>Code</th>
<th>Optimum</th>
<th>Median of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Systems Engineering</td>
<td>SE</td>
<td>14.4%</td>
<td>8.5%</td>
</tr>
<tr>
<td>Mission/Purpose Definition</td>
<td>MD</td>
<td>1.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td>Requirements Engineering</td>
<td>RE</td>
<td>2.0%</td>
<td>0.8%</td>
</tr>
<tr>
<td>System Architecting</td>
<td>SA</td>
<td>3.9%</td>
<td>1.4%</td>
</tr>
<tr>
<td>System Integration</td>
<td>SI</td>
<td>2.8%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Verification &amp; Validation</td>
<td>VV</td>
<td>2.4%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Technical Analysis</td>
<td>TA</td>
<td>1.8%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Scope Management</td>
<td>SM</td>
<td>1.4%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Technical Leadership/Management</td>
<td>TM</td>
<td>3.9%</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

Total of activities = 19.5%

Example: “Space System”

<table>
<thead>
<tr>
<th>Feature</th>
<th>Median</th>
<th>Adjustment</th>
<th>Program Optimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD</td>
<td>1.3%</td>
<td>0.38</td>
<td>0.5%</td>
</tr>
<tr>
<td>RE</td>
<td>2.0%</td>
<td>0.50</td>
<td>1.0%</td>
</tr>
<tr>
<td>SA</td>
<td>3.9%</td>
<td>0.69</td>
<td>2.7%</td>
</tr>
<tr>
<td>SI</td>
<td>2.8%</td>
<td>0.50</td>
<td>1.4%</td>
</tr>
<tr>
<td>VV</td>
<td>2.4%</td>
<td>0.68</td>
<td>1.9%</td>
</tr>
<tr>
<td>TA</td>
<td>1.8%</td>
<td>0.79</td>
<td>1.3%</td>
</tr>
<tr>
<td>SM</td>
<td>1.4%</td>
<td>0.72</td>
<td>1.2%</td>
</tr>
<tr>
<td>TM</td>
<td>3.9%</td>
<td>1.41</td>
<td>5.5%</td>
</tr>
<tr>
<td>SE</td>
<td>14.4%</td>
<td>1.08</td>
<td>15.6%</td>
</tr>
</tbody>
</table>

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Bottom Line

- Better programs expend
  - more SE effort overall
  - more mission definition, more tech leadership

- Nearly all SE activities correlate well with
  - Cost/schedule control
  - Stakeholder overall success

- No SE activities correlate with
  - System technical quality

*SE today leads to better programs – but does not lead to better systems.*

- Results can be used to right-size SE
  - New cost modeling based on optimum success
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Questions?

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