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The Software Engineering Institute (SEI)
a DoD Research FFRDC
Challenges in DoD Acquisition

**GAO-09-362T - Actions Needed to Overcome Long-standing Challenges with Weapon Systems Acquisition and Service Contract Management**

- “costs … increased 26% and development costs increased by 40% from first estimates”
- “programs … failed to deliver capabilities when promised —often forcing warfighters to [maintain] legacy systems”
- “current programs experienced, on average, a 21-month delay in delivering initial capabilities to the warfighter”

**Although DoD is the largest acquirer in the world, acquisition troubles remain**

- 2011 MDAP RDT&E cost growth (mean) 84%
- 2011 MDAP Procurement cost growth (mean) 28%
- Effectiveness (1984-2011) 89%
- Suitability (1984-2011) 72%
- Nunn-McCurdy breach rate from 1997-2011 31%

Root Cause of Poor Program Performance

Inadequate Systems Engineering!

- Finding from *Performance of the Defense Acquisition System 2013 Annual Report*
  - **Dominant root cause** of MDAP Cost Growth
- Finding from *GAO-09-362T*
  - “… managers rely heavily on assumptions about system requirements, technology, and design maturity, which are consistently too optimistic. These gaps are largely the result of a lack of a disciplined systems engineering analysis prior to beginning system development …”

### MDAP Cost Growth: PARCA Root Cause Analysis

<table>
<thead>
<tr>
<th>Dominant</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor management performance</td>
<td>10</td>
<td>56%</td>
</tr>
<tr>
<td>� Systems engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>� Contractual incentives</td>
<td></td>
<td></td>
</tr>
<tr>
<td>� Risk management</td>
<td></td>
<td></td>
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<tr>
<td>� Situational Awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline cost and schedule estimates</td>
<td>5</td>
<td>28%</td>
</tr>
<tr>
<td>� Framing assumptions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in procurement quantity</td>
<td>4</td>
<td>22%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Infrequent</th>
<th>Count</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immature technology, excessive</td>
<td>1</td>
<td>manufacturing, or integration risk</td>
</tr>
<tr>
<td>Unrealistic performance expectations</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Unanticipated design, engineering,</td>
<td>1</td>
<td>manufacturing or technology issues</td>
</tr>
<tr>
<td>Funding inadequacy</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

1. “Performance of the Defense Acquisition System 2013 Annual Report” Table 2-3, page 34
Why Do We Fail to Utilize Good SE Practices?

It’s difficult to justify the costs of SE in terms that project managers and corporate managers can relate to.

- The costs of SE are evident
  - Cost of resources
  - Schedule time
- The benefits are less obvious and less tangible
  - Cost avoidance (e.g., reduction of rework from interface mismatches)
  - Risk avoidance (e.g., early risk identification and mitigation)
  - Improved efficiency (e.g., clearer organizational boundaries and interfaces)
  - Better products (e.g., better understanding and satisfaction of stakeholder needs)

We need to quantify the effectiveness and value of SE by examining its effect on project performance?
The 2012 SE Effectiveness Study

Purpose

• Strengthen the business case for SE by relating project performance to the use of SE practices.

Method

• Contact development projects using the resources of NDIA, AESS, and INCOSE.
• Survey projects to assess their
  – SE activities
  – Project performance
  – Degree of challenge
• Process responses to identify statistical relationships between parameters.

Survey Tenets

• All data is submitted anonymously and handled confidentially by the SEI.
• Only aggregated non-attributable data is released.
The Bottom Line: SE = Performance

Across ALL projects, 1/3 are at each performance level

For Lower SEC projects, only 15% deliver higher performance

For Middle SEC projects, 24% deliver higher performance

For Higher SEC projects, 57% deliver higher performance

Gamma = 0.49 represents a VERY STRONG relationship

Gamma = 0.49 p-value < 0.001
For Challenging Projects
SE is even MORE important

**Perf vs. SEC_Total (Low PC)**

- Lower SEC (n=22):
  - 23% 45% 32%
  - 52% 19% 12%

- Middle SEC (n=26):
  - 23% 58% 19%
  - 36% 39% 20%

- Higher SEC (n=25):
  - 52% 12% 20%
  - 36% 39% 20%

**Perf vs. SEC_Total (High PC)**

- Lower SEC (n=26):
  - 8% 69% 0%
  - 23% 35% 10%

- Middle SEC (n=23):
  - 26% 39% 10%
  - 35% 62% 20%

- Higher SEC (n=26):
  - 62% 12% 27%
  - 23% 35% 10%

\[ \text{Gamma} = 0.34 \quad \text{p-value} = 0.029 \]

**A STRONG relationship between Total SE and Project Performance for LOWER CHALLENGE projects**

\[ \text{Gamma} = 0.62 \quad \text{p-value} = 0.000 \]

**A VERY STRONG relationship between Total SE and Project Performance for HIGHER CHALLENGE projects**
Study Participants

Participant Solicitation

- Contacted key members of major defense contractors to promote study participation
- Contacted the memberships of NDIA SE Division, IEEE AESS, and INCOSE

Collected 148 valid responses

Which of these best describes your industry or service?

- Ind. Mfg & Svc: defense - 116
- Ind. Mfg & Svc: Electronic... - 7
- Ind. Mfg and Svc: Other - 2
- Transportation - 2
- Energy - 9
- Communications - 0
- Consumer Goods & Svc - 1
- Health Care - 10

Please enter the country in which most of the design and development engineering will be/was performed.

- USA - 130
- UK - 6
- South Africa - 3
- Australia - 2
- Canada - 2
- India - 1
- The Netherlands - 1
- Sweden - 1
- Finland - 1
SE Deployment and Performance

SYSTEMS ENGINEERING DEPLOYMENT

PROJECT PERFORMANCE

BCSE: Defense vs. Non-Defense Projects
27-Oct-2014
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Total SE vs. Project Performance

**Project Performance vs. Total SE (defense)**

- **Lower SEC (n=23)**: 9% Higher, 30% Middle, 61% Lower
- **Middle SEC (n=26)**: 35% Higher, 42% Middle, 23% Lower
- **Higher SEC (n=26)**: 54% Higher, 31% Middle, 15% Lower

**Project Performance vs. Total SE (non-defense)**

- **Lower SEC (n=12)**: 8% Higher, 67% Middle, 9% Lower
- **Middle SEC (n=8)**: 25% Higher, 38% Middle, 36% Lower
- **Higher SEC (n=11)**: 55% Higher, 38% Middle, 9% Lower

A Very Strong relationship between applied SE and Project Performance for both Defense and non-Defense Projects.
Architecture vs. Project Performance

Perf vs. SEC_ARCH (defense)

A **Strong** relationship between Architecture activities and Project Performance for Defense Projects

A **Very Strong** relationship for non-defense projects

Perf vs. SEC_ARCH (non-defense)

Gamma = 0.38

Gamma = 0.54

BCSE: Defense vs. Non-Defense Projects
27-Oct-2014
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Requirements Dev’t & Mg’t vs. Performance

Perf vs. SEC_REQ (defense)

A **Very Strong** relationship between Requirements activities and Project Performance for both Defense and non-Defense Projects
Risk Management vs. Project Performance

A Moderate relationship between Risk Management activities and Project Performance for Defense Projects

A Very Strong relationship for non-defense projects
Trade Studies vs. Project Performance

Perf vs. SEC_TRD (defense)

A **Very Strong** relationship between Trade Study activities and Project Performance for Defense Projects

A **Strong** relationship for non-defense projects
Summary of Relationships -1

Performance vs. SE Capability

-0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

Total SEC
Early SE
Project Planning
Req'ts Dev't & Mg't
Verification
Product Architecture
Configuration Mg't
Trade Studies
Monitor & Control
Validation
Product Integration
Risk Management
Integ Product Teams
Project Challenge
Experience

Moderate
Weak
Moderate
Strong
Very Strong

DEF
NonD
Next Steps: Investigate the differences between SE deployment / effectiveness in defense and non-defense domains to find “transplantable” best practices
Questions for Further Study

On non-defense projects, why are SE activities in Requirements, Architecture, Risk Management, and Verification more effective than those on defense-related projects?

On defense projects, why are SE activities in Trade Studies, IPTs, and Project Monitoring and Control more effective than those on non-defense projects?

Why is the relationship between Project Challenge and Project Performance stronger for non-defense projects?

Why is the relationship between Prior Experience and Project Performance stronger for non-defense projects?
Next Steps

Download the 2012 SE Effectiveness reports from the SEI website

http://www.sei.cmu.edu/measurement/research/acquisition/Business-Case-SE.cfm

- The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey
- The Business Case for Systems Engineering Study: Detailed Response Data
- The Business Case for Systems Engineering Study: Assessing Project Performance from Sparse Data

Search for ways to apply the findings within your own work and your own organization.

Contact the SEI with questions or to obtain assistance.
For more information, contact

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BACK UP
References


IPT Utilization vs. Project Performance

Perf vs. SEC_IPT (defense)

A **Strong** relationship between IPT Utilization and Project Performance for Defense Projects

A **Moderate** relationship for non-defense projects
**Project Planning vs. Project Performance**

Perf vs. SEC_PP (defense)

![Bar chart showing project performance by SEC_PP for defense projects.]

- Lower SEC (n=22): 9% Higher, 59% Middle, 25% Lower
- Middle SEC (n=28): 32% Higher, 43% Middle, 28% Lower
- Higher SEC (n=25): 56% Higher, 28% Middle, 16% Lower

Perf vs. SEC_PP (non-defense)

![Bar chart showing project performance by SEC_PP for non-defense projects.]

- Lower SEC (n=13): 8% Higher, 69% Middle, 29% Lower
- Middle SEC (n=7): 23% Higher, 43% Middle, 9% Lower
- Higher SEC (n=11): 45% Higher, 29% Middle, 45% Lower

Gamma = 0.57 for defense projects and Gamma = 0.59 for non-defense projects.

**A Very Strong relationship between Project Planning activities and Project Performance for both Defense and non-Defense Projects.**
Verification vs. Project Performance

Perf vs. SEC_VER (defense)

A Very Strong relationship between Verification activities and Project Performance for both Defense and non-Defense Projects

Perf vs. SEC_VER (non-defense)

Gamma = 0.55

Gamma = 0.64
Validation vs. Project Performance

Perf vs. SEC_VAL (defense)

A Very Strong relationship between Validation activities and Project Performance for both Defense and non-Defense Projects
Product Integration vs. Project Performance

Perf vs. SEC_PI (defense)

A **Very Strong** relationship between Product Integration activities and Project Performance for both Defense and non-Defense Projects.

Gamma = 0.45

Perf vs. SEC_PI (non-defense)

Gamma = 0.52
Configuration Mg’t vs. Project Performance

Perf vs. SEC_CM (defense)

- Lower SEC (n=27): 15% Higher, 33% Middle, 52% Lower
- Middle SEC (n=29): 45% Higher, 31% Middle, 24% Lower
- Higher SEC (n=19): 42% Higher, 42% Middle, 16% Lower

Gamma = 0.42

Perf vs. SEC_CM (non-defense)

- Lower SEC (n=12): 8% Higher, 58% Middle, 33% Lower
- Middle SEC (n=11): 36% Higher, 36% Middle, 13% Lower
- Higher SEC (n=8): 50% Higher, 38% Middle, 13% Lower

Gamma = 0.47

A **Very Strong** relationship between Configuration Management activities and Project Performance for both Defense and non-Defense Projects.
Monitoring & Control vs. Project Performance

Perf vs. SEC_PMC (defense)

A **Very Strong** relationship between Project Monitoring and Control activities and Project Performance for Defense Projects

A **Strong** relationship for non-defense projects

Perf vs. SEC_PMC (non-defense)

Gamma = 0.48

Gamma = 0.38
Prior Experience vs. Project Performance

**Perf vs. EXP (defense)**

- Lower EXP (n=24): 29% higher, 42% middle, 29% lower
- Middle EXP (n=40): 30% higher, 35% middle, 35% lower
- Higher EXP (n=11): 55% higher, 18% middle, 27% lower

Gamma = 0.1

**Perf vs. EXP (non-defense)**

- Lower EXP (n=12): 17% higher, 67% middle, 25% lower
- Middle EXP (n=12): 33% higher, 42% middle, 14% lower
- Higher EXP (n=7): 43% higher, 43% middle, 17% lower

Gamma = 0.44

A **Weak** relationship between Prior Experience and Project Performance for Defense Projects

A **Strong** relationship for non-defense projects
Project Challenge vs. Project Performance

Perf vs. PC (defense)

A **Weak Negative** relationship between Project Challenge and Project Performance for Defense Projects

A **Moderate Negative** relationship for non-defense projects
Early SE vs. Project Performance

Perf vs. Early_SE (defense)

A **Very Strong** relationship between Early SE activities and Project Performance for both Defense and non-Defense Projects