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STRENGTH THROUGH INDUSTRY & TECHNOLOGY

# *Effective Systems Engineering: What's the Payoff for Program Performance?*

***NDIA Systems Engineering Effectiveness Committee***

**CMMI Technology Conference**

**November 15, 2007**

# Does this sound familiar?

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**The SE efforts on my project are critical because they …**

**… pay off in the end.**

**… ensure that stakeholder requirements are identified and addressed.**

**… provide a way to manage program risks.**

**… establish the foundation for all other aspects of the design.**

**… optimize the design through evaluation of alternate solutions.**

**We should reduce SE efforts on this project because …**

**… including SE costs in the bid will make it non-competitive.**

**… we don't have time for '*paralysis by analysis*'. We need to get the design started.**

**… we don't have the budget or the people to support these efforts.**

**… it doesn't produce deliverable outputs.**

**… the customer won't pay for them.**

**These are the ASSERTIONS, but what are the FACTS?**

# The Problem

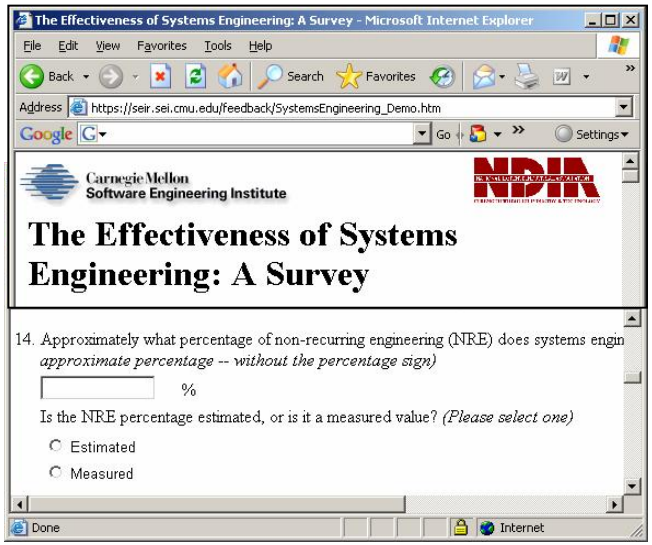
**It is difficult to justify the costs of SE in terms that program managers and corporate managers can relate to.**

- The costs of SE are evident
  - Time
  - Effort
- 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)

**How can we quantify the effectiveness and value of SE?**
**How does SE benefit program performance?**

# Systems Engineering Effectiveness Survey (2004-2007)

**Hypothesis:** The effective performance of SE best practices on a development program yields quantifiable improvements in the program execution (e.g., improved cost performance, schedule performance, technical performance).




**Objectives:**

- Characterize effective SE practices
- Correlate SE practices with measures of program performance

**Approach:**

- Distribute survey to NDIA companies
- SEI analysis and correlation of responses

**Survey Areas:**

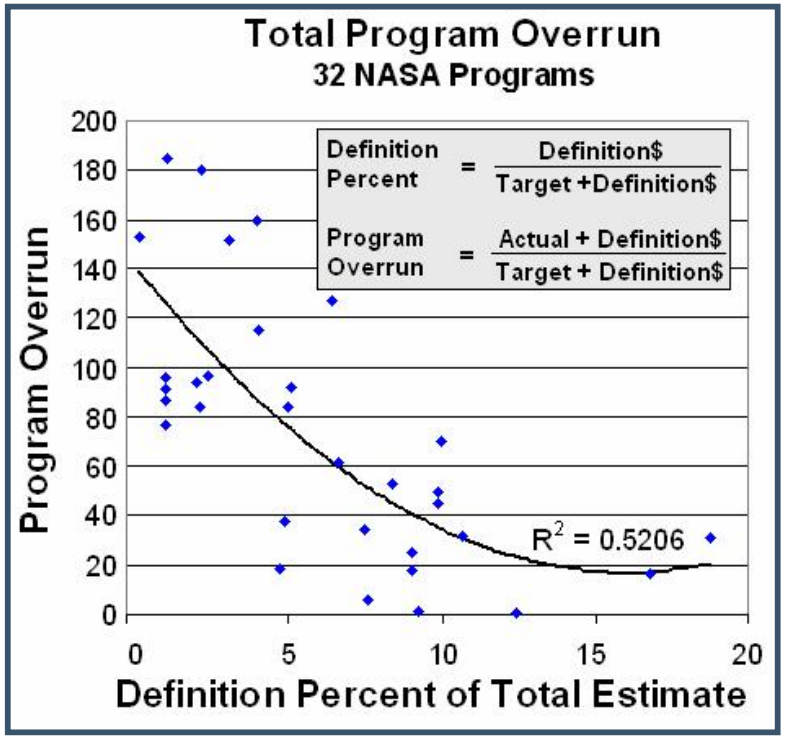
| | | |
|---|---|---|
| Process definition | Trade studies | Project reviews |
| Project planning | Interfaces | Validation |
| Risk management | Product structure | Configuration mgmt |
| Requirements development | Product integration | Metrics |
| Requirements management | Test and verification | |

# The Challenge

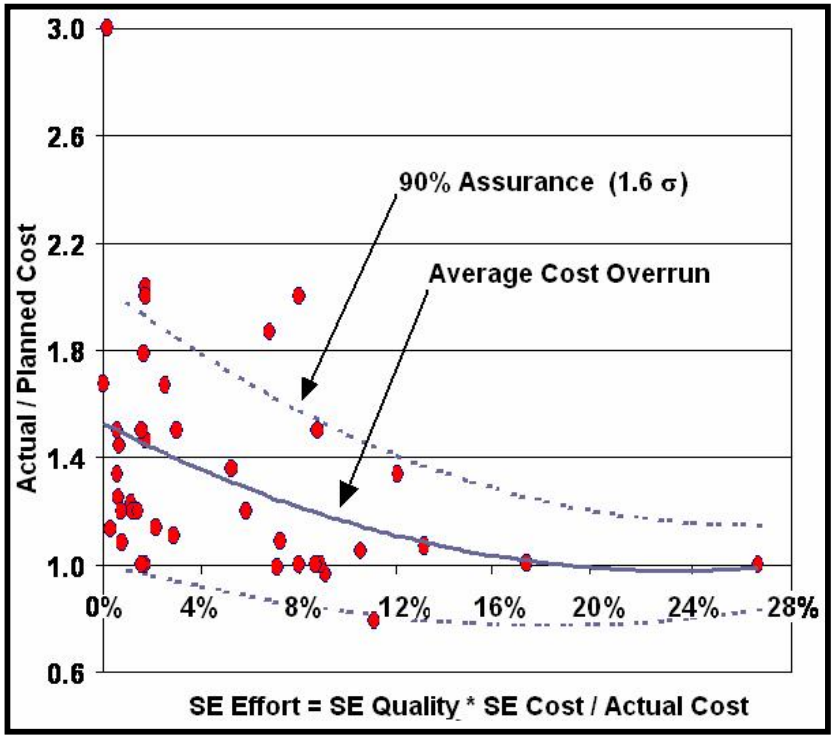
## Previous Studies - Summary

| STUDY | | APPLICABILITY | | |
|---|---|---|---|---|
| **Author & Background** | **Findings** | **SE Activities** | **Definition of Success** | **Characteristics of Project** |
| Gruhl (1992) 32 NASA Pgms | 8-15% Upfront Best | First two of five development phases | Cost (Less cost overrun) | Large; Complex; all NASA |
| Herbsleb (1994) 13 CMM Companies | Process Improvement ROI 4.0 ï 8.8 | CMM Process Areas | Cost (Cost reduction through SE investment) | Various; federal contracting |
| Honour (2004) Survey INCOSE SEs | 15-20% of project should be SE | Overall SE level of effort (Cost) & related SE quality | Cost & Schedule | Various sizes (measured by total project cost) |
| Boehm & Valerdi (2006) COCOMO II | SE importance grows with project size | COCOMO II RESL (Architecture and Risk) | Cost | Various sizes, but software systems only |
| Boehm & Valerdi (2004) COSYSMO | Estimate within 30% effort 50% - 70% of time | 33 activities defined by EIA 632 | Cost | Mostly successful projects from federal contractors |
| Ancona & Caldwell (1990) Boundary Management | Managing team boundary 15%; more is better | Team boundary activities ï interface between team and external | Product Performance (Successfully marketed products) | Technology products |
| Frantz (1995) Boeing side-by-side projects | More SE yielded better quality & shorter duration | Defined by Frantz | Product Performance & Schedule (Quality of product and duration of project) | Three similar systems for manipulating airframes during assembly |

# The Challenge - Supporting Evidence

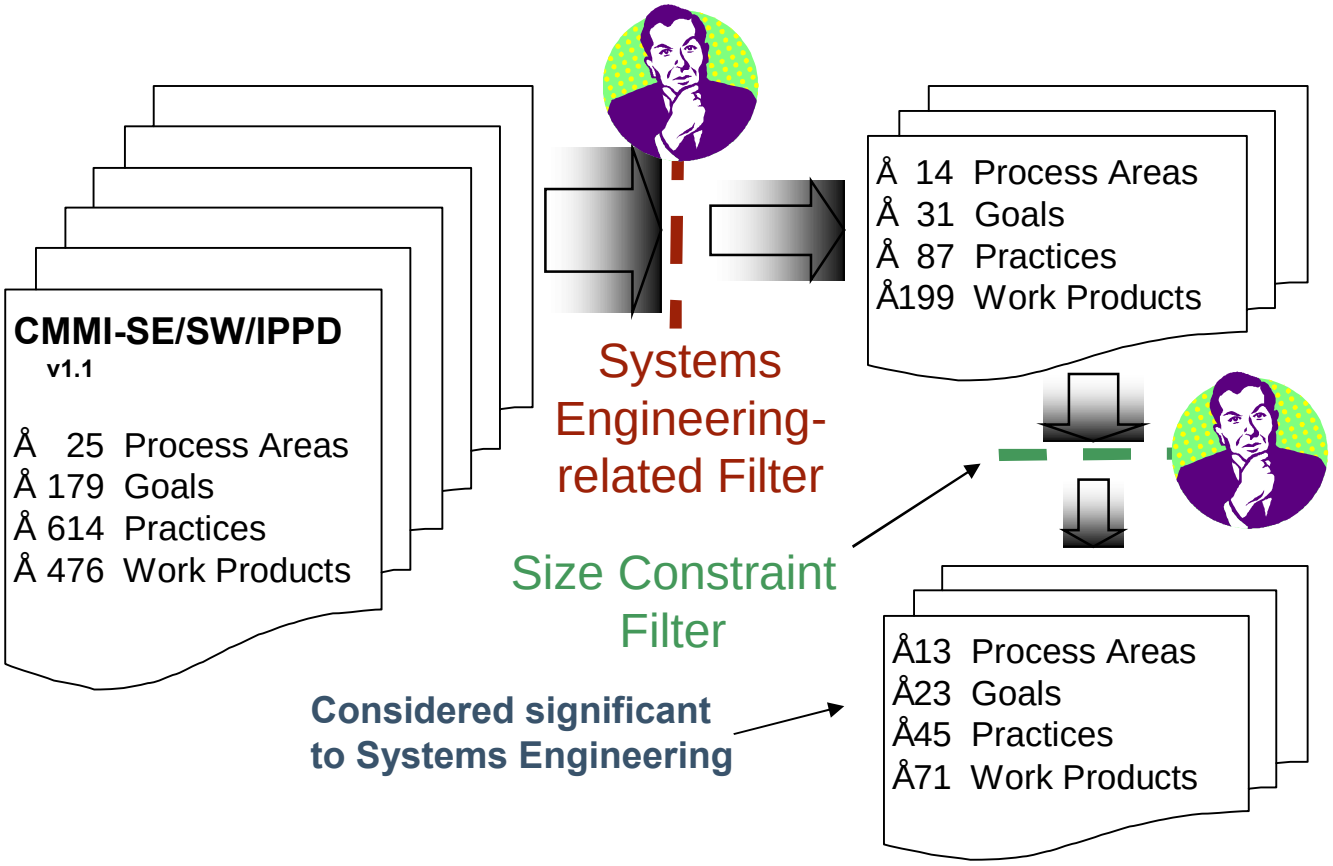



**Gruhl, Werner** (1992), Lessons Learned: Cost/Schedule Assessment, Internal Presentation, NASA Comptroller's Office




**Honour, Eric** (2004), *Understanding the Value of Systems Engineering*, Proceedings of the 14th Annual INCOSE International Symposium

# Survey Development




**Survey content is based on a recognized standard (CMMI)**

# Survey Methodology (Conducted: 2004-2007)

| | |
|---|---|
| Survey Population | **Organizations developing products in support of government contracts (prime or subcontractors).** |
| Sampling Method | **Invitation to qualifying active members of NDIA Systems Engineering Division. Random sampling within organization.** |
| Survey Deployment | **Web deployment (open August 10, 2006 - November 30, 2006). Anonymous response. Questions based on CMMI-SE/SW/IPPD v1.1** |
| Target Respondent | **Program Manager or designee(s) from individual projects** |
| Questionnaire Structure | **1. Characterization of the project /program under consideration<br>2. Evidence of Systems Engineering Best Practices<br>3. Project / Program Performance Metrics** |
| Target Response Time | **30 – 60 minutes** |
| Responses | **64 survey responses (46 complete; 18 partial, but usable)** |
| Analysis | **Raw data analyzed by Software Engineering Institute. Analysis results reviewed by NDIA SE Effectiveness Committee.** |
| Reports | **1. Public NDIA/SEI report awaiting approval.<br>2. Restricted attachment, details provided to respondents only.** |

# Analysis

***Perf* = *f* (*PC*, *PE*, *SEC*, *AC*)**

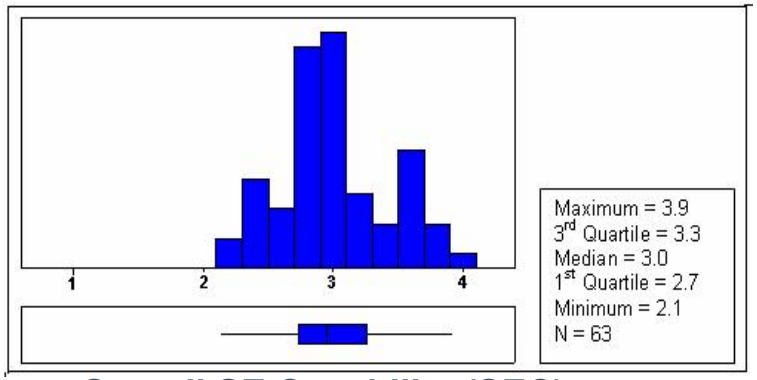
where: ***Perf*** = Project Performance
***PE*** = Project Environment
***SEC*** = Systems Engineering Capability
***PC*** = Project Challenge
**AC** = Acquirer Capability

**SEC can be further decomposed as:**

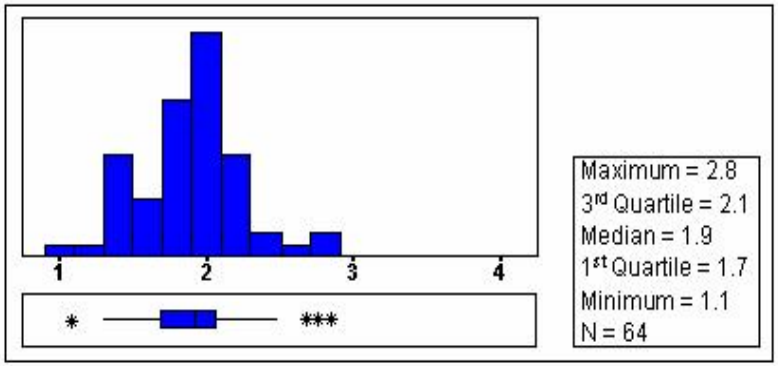
- Project Planning
- Project Monitoring and Control
- Risk Management
- Requirements Development and Management
- Technical Solution
  - Trade Studies
  - Product Architecture
- Product Integration
- Verification
- Validation
- Configuration Management
- IPT-Based Capability

**SE capabilities and analyses are fully defined by mappings of associated survey question responses**

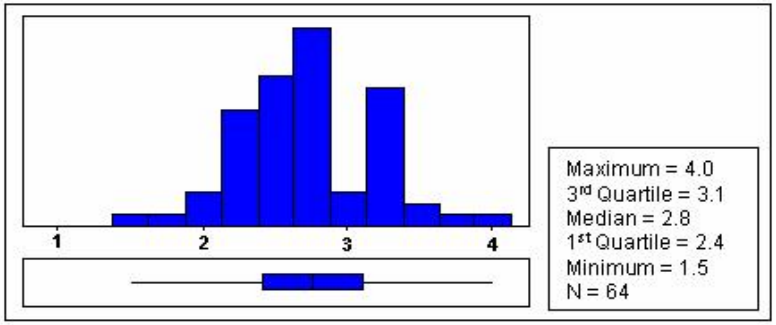
# Validation of Survey Responses



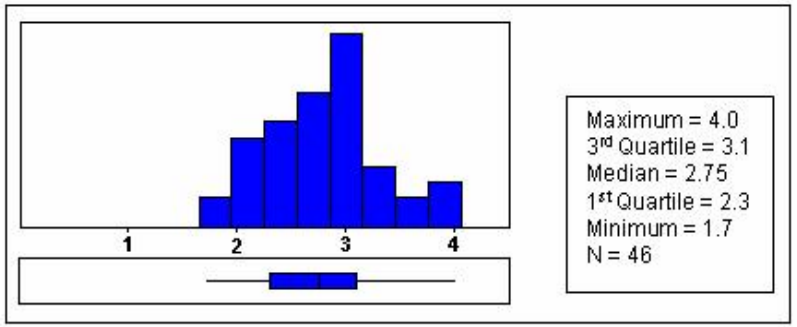

Overall SE Capability (SEC)




Project Challenge (PC)




Acquirer Capability (AC)

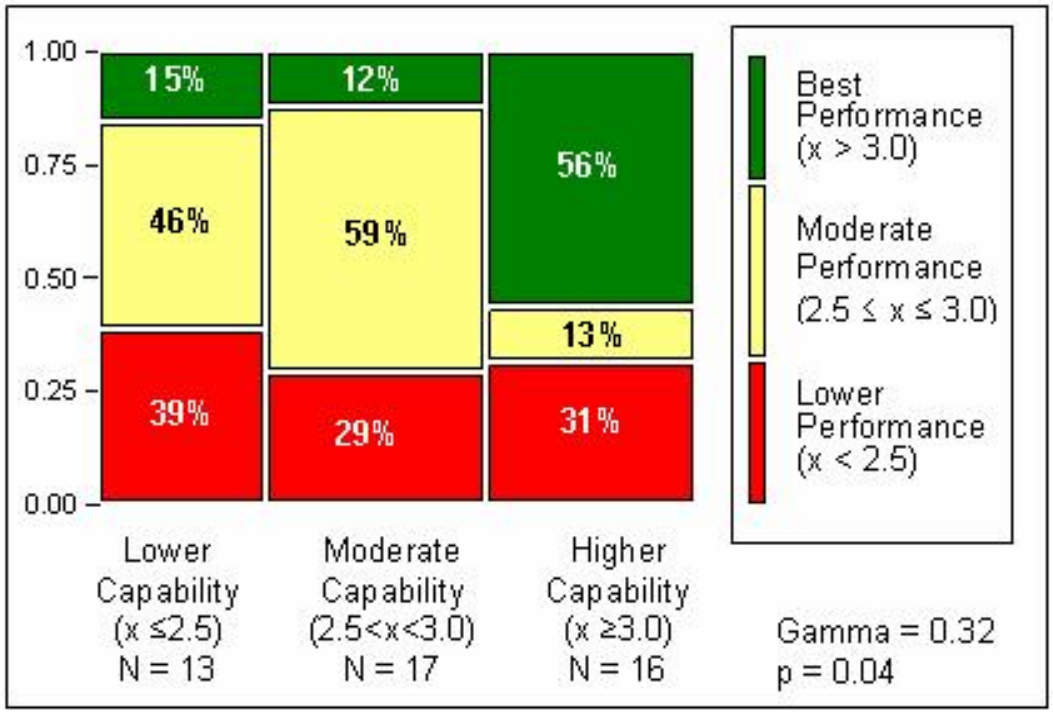



Project Performance (Perf)

**Analyzed distributions, variability, relationships…**
**To ensure statistical rigor and relevance**

# lity (SEC) vs. Project Performance (Perf)

Notation

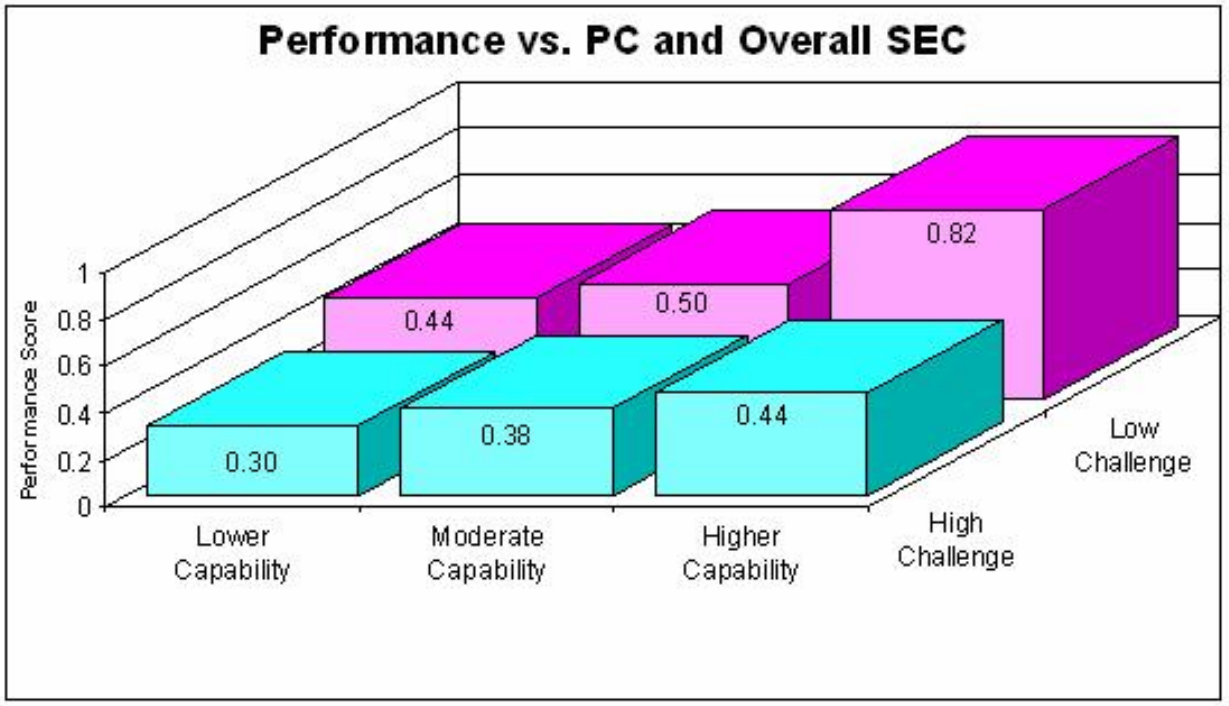



**Projects with better Systems Engineering Capabilities deliver better Project Performance (cost, schedule, functionality)**

# Relating Project Performance to Project Challenge and SE Capability

**Project challenge factors:**

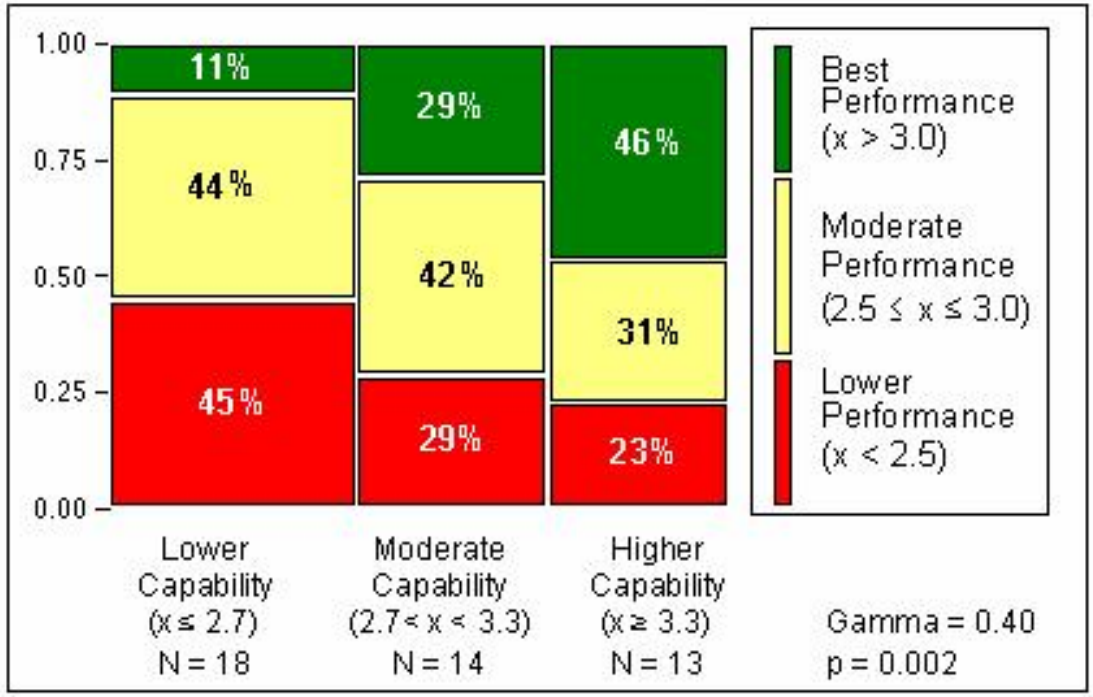
- Life cycle phases
- Project characteristics (e.g., size, effort, duration, volatility)
- Technical complexity
- Teaming relationships




**Projects with better Systems Engineering Capabilities are better able to overcome challenging environments**

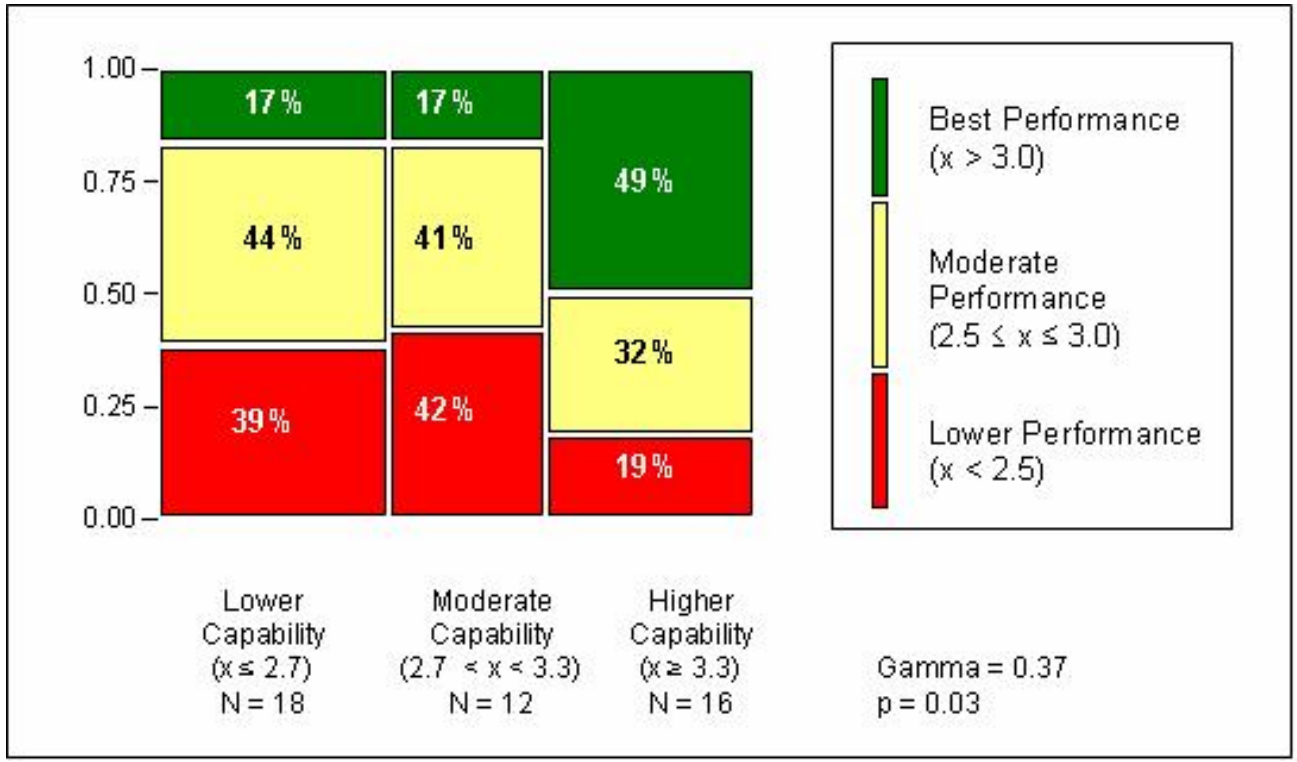
# Results

## 1. Product Architecture and Performance




**Projects with better Product Architecture show a "Moderately Strong / Strong" Positive Relationship with Performance**

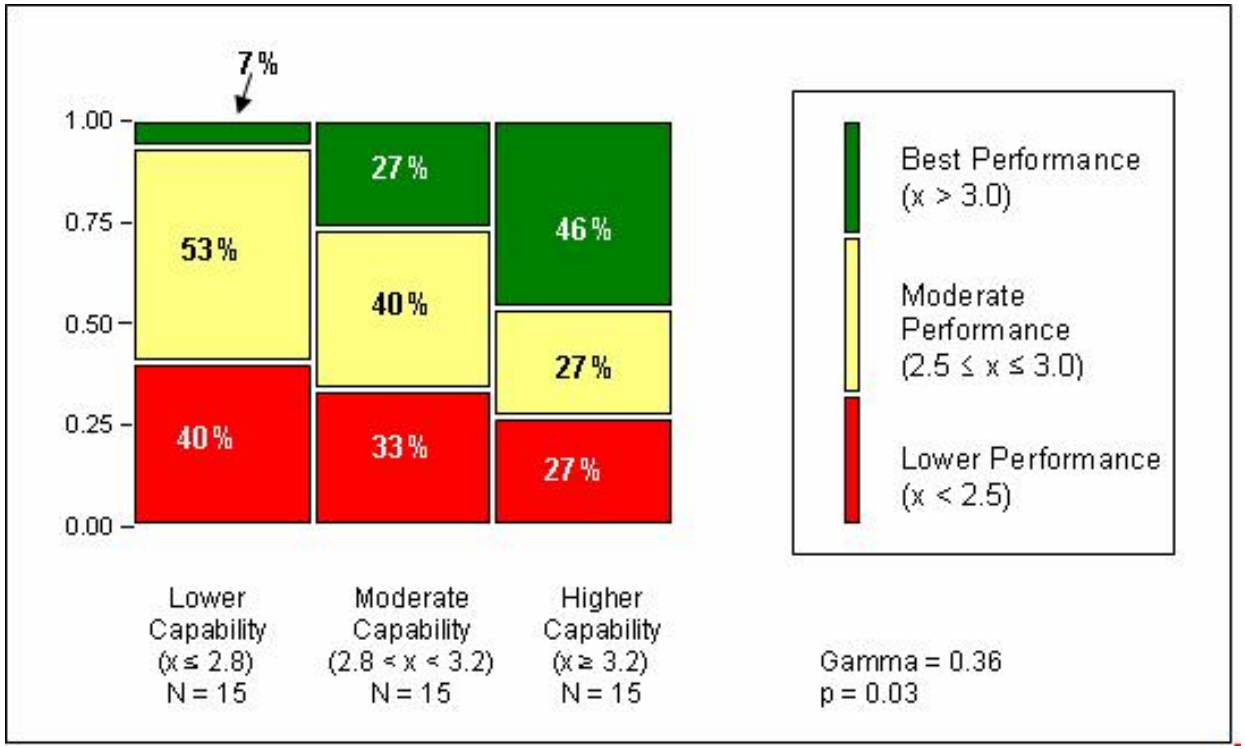
## 2. Trade Studies and Project Performance




**Projects with better Trade Studies show a "Moderately Strong / Strong" Positive Relationship with Performance**

# Results

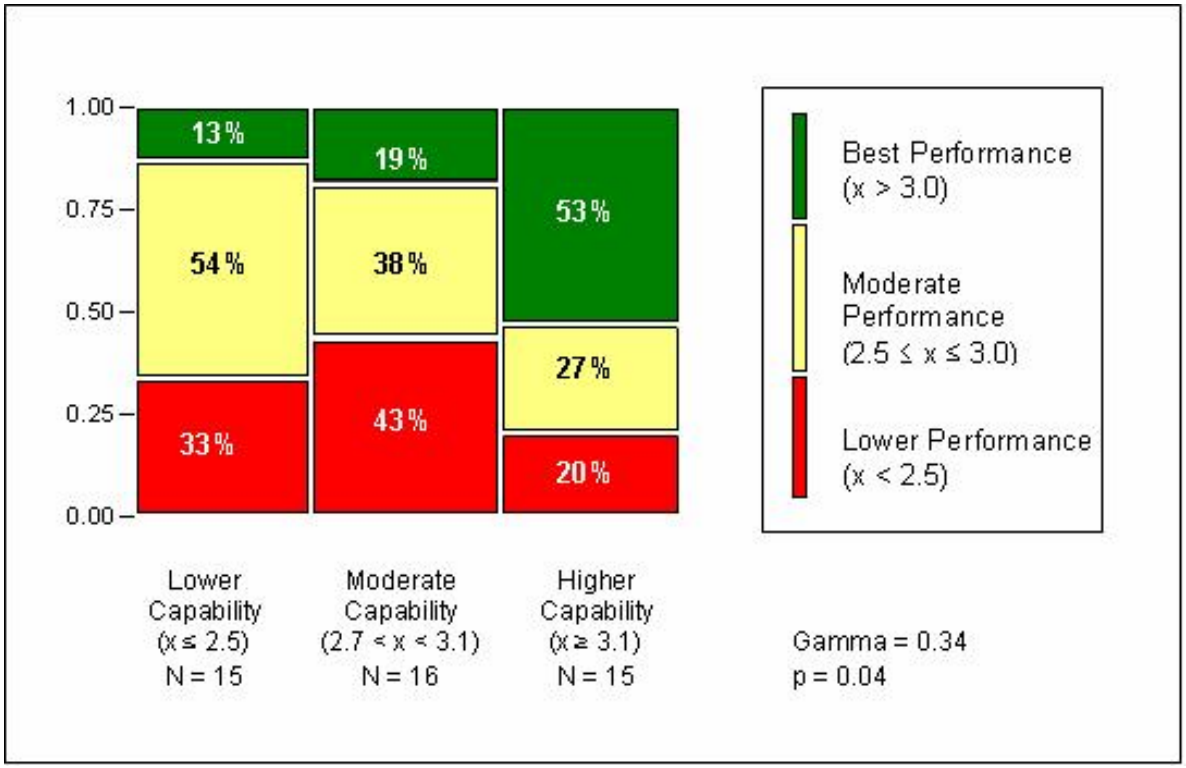
## 3. Technical Solution and Project Performance




**Projects with better Technical Solution show a "Moderately Strong" Positive Relationship with Performance**

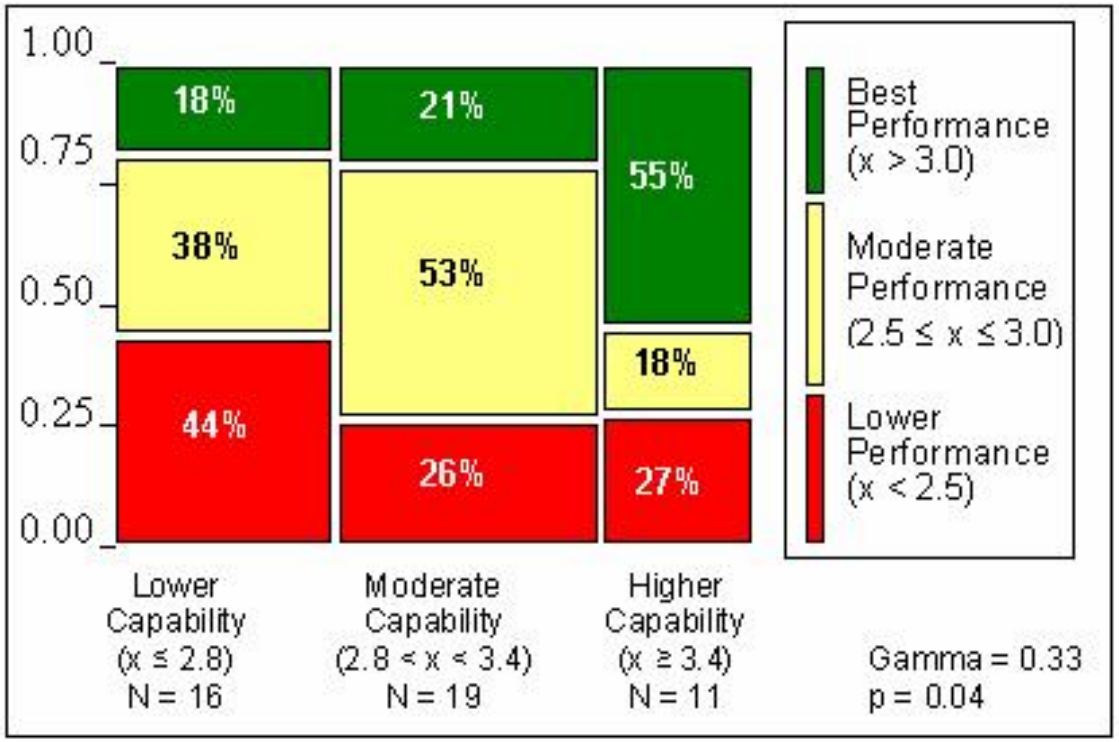
# Results

## 4. IPT-Related Capability and Performance




**Projects with better IPTs show a "Moderately Strong" Positive Relationship with Performance**

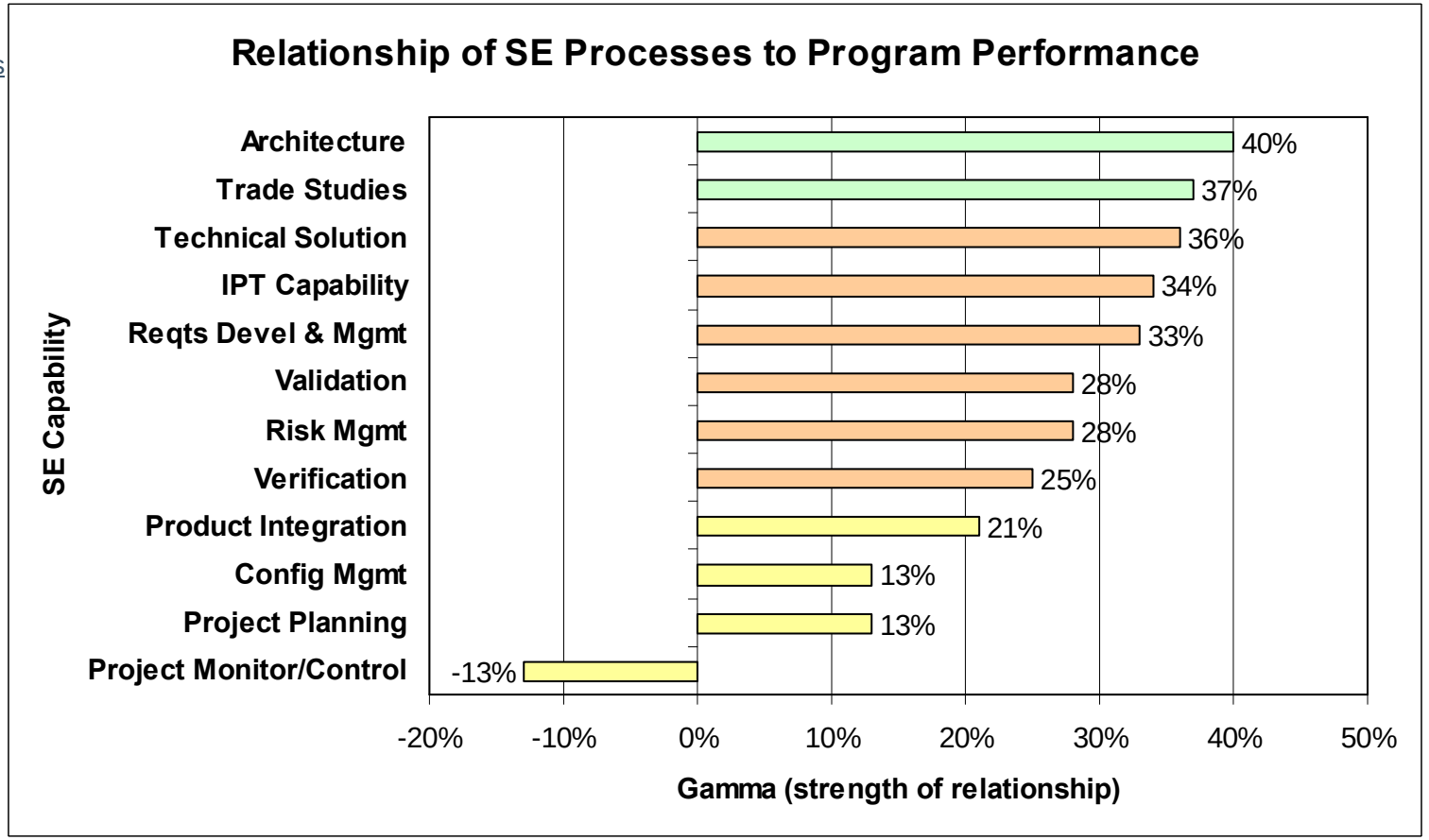
## 5. Requirements and Performance




**Projects with better Requirements Development and Management show a "Moderately Strong" Positive Relationship with Performance**

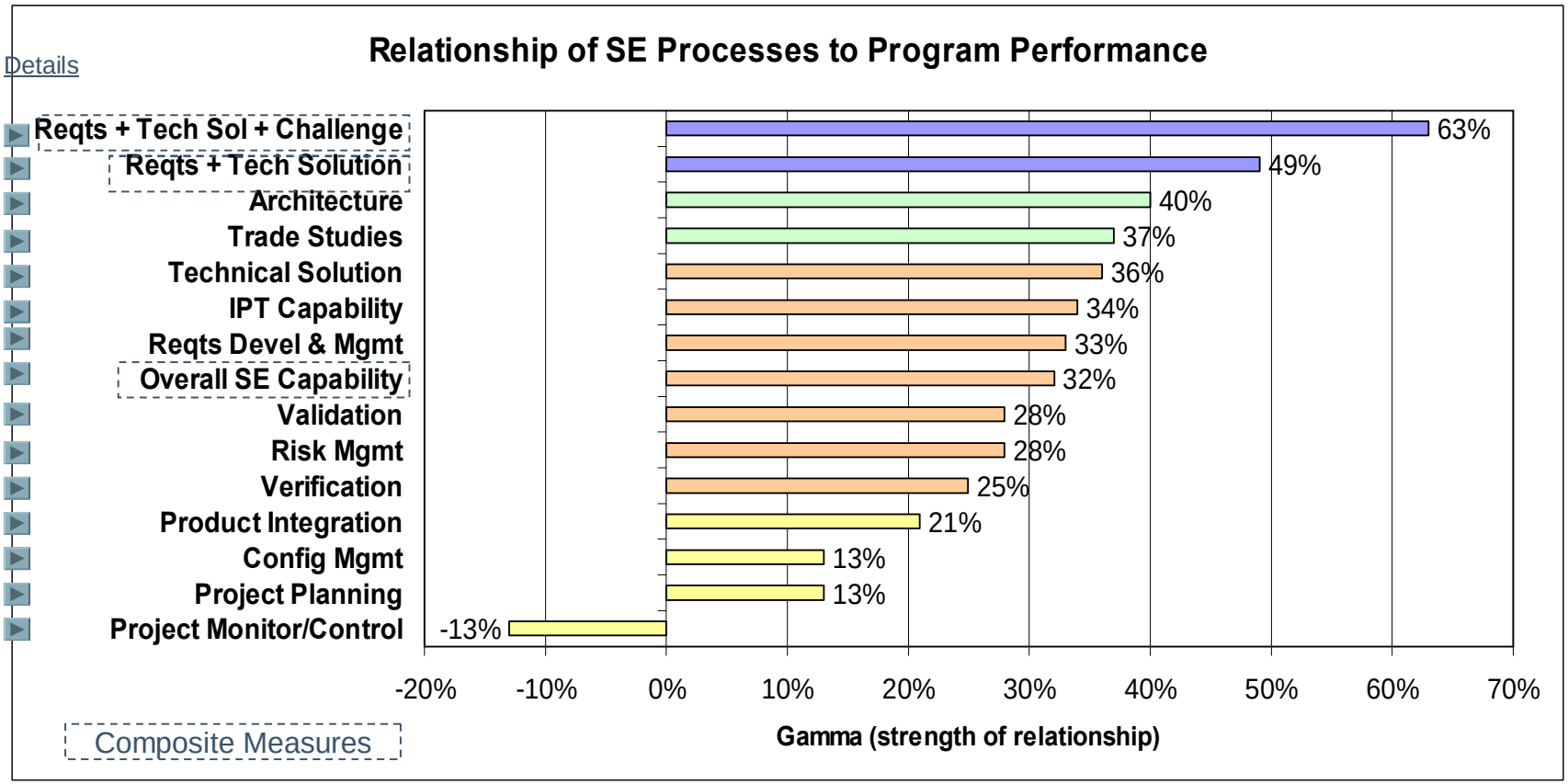
# Summary of Process Relationships

Details




Strong Relationship | Moderately Strong to Strong Relationship | Moderately Strong Relationship | Weak Relationship

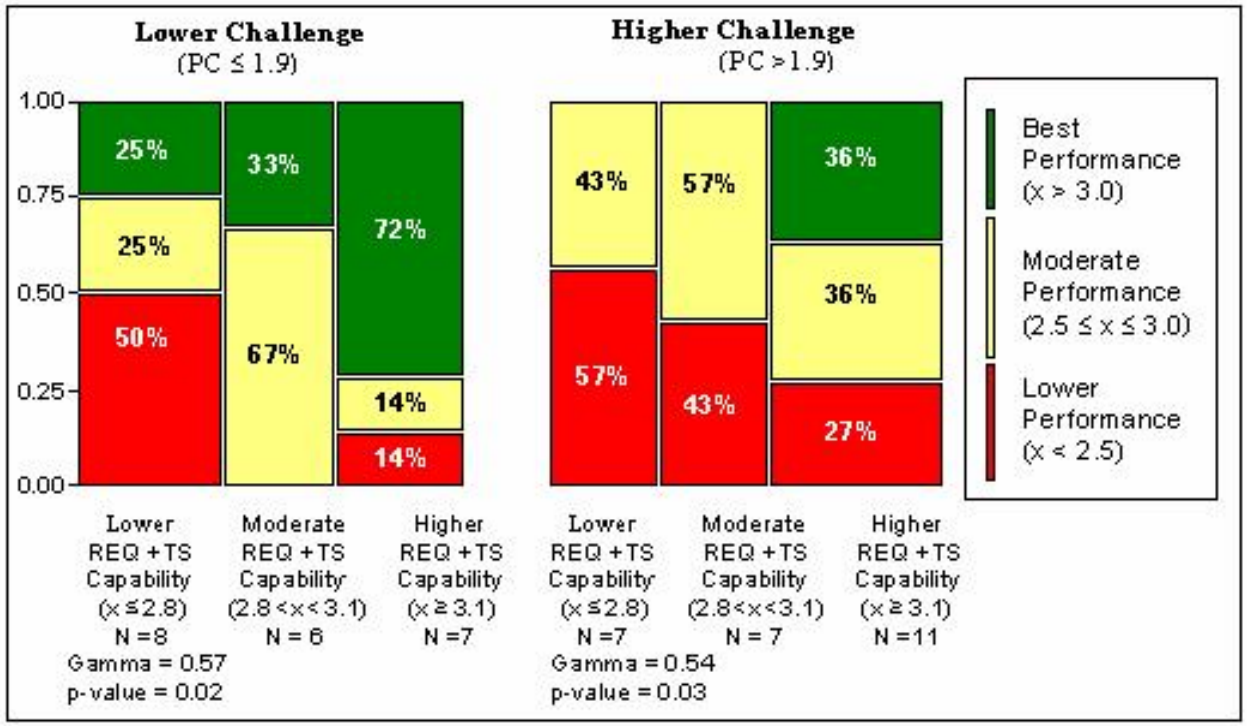
# Summary of Relationships - Composite



# s + Tech Solution controlled by Project Challenge

**Project challenge factors:**

- Life cycle phases
- Project characteristics (e.g., size, effort, duration, volatility)
- Technical complexity
- Teaming relationships




**Projects with higher Requirements and Technical Solution capability are better able to achieve higher performance even in challenging programs**

# Summary

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## SE Effectiveness

- Provides credible measured evidence about the value of disciplined Systems Engineering
- Affects success of systems-development projects

## Specific Systems Engineering Best Practices

- Highest relationships to activities on the ñleft side of SE Veeò
- The environment (Project Challenge) affects performance too:
  - Some projects are more challenging than others ... and higher challenge affects performance negatively in spite of better SE
  - Yet good SE practices remain crucial for both high and low challenge projects

# Potential Next Steps

**Provide recommendations for action upon survey findings**

**Conduct additional follow-on surveys and analysis of collected data**

- IV&V
- Broadened sample space
- Trending
- Improvements to survey instrument

**Survey system acquirers**

# Acknowledgements

## Primary Contributors

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# SE Effectiveness

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# Backup

## NDIA SE Effectiveness Survey Analysis Slides

# Conclusions & Caveats

## *Consistent with "Top 10 Reasons Projects Fail*"*

1. **Lack of user involvement**
2. **Changing requirements**
3. **Inadequate Specifications**
4. Unrealistic project estimates
5. Poor project management
6. **Management change control**
7. Inexperienced personnel
8. Expectations not properly set
9. **Subcontractor failure**
10. **Poor architectural design**

**Above Items Can Cause Overall Program Cost and Schedule to Overrun**

* Project Management Institute

Matching items noted in **RED**

# ns & Caveats

## *Consistent with "Top 5 SE Issues*" (2006)*

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- Key **systems engineering practices** known to be effective are **not consistently applied** across all phases of the program life cycle.
- **Insufficient systems engineering is applied early** in the program life cycle, compromising the foundation for initial requirements and architecture development.
- **Requirements are not always well-managed**, including the effective translation **from capabilities statements** into executable requirements to achieve successful acquisition programs.
- The quantity and quality of **systems engineering expertise is insufficient** to meet the demands of the government and the defense industry.
- Collaborative environments, including **SE tools, are inadequate** to effectively execute SE at the joint capability, system of systems, and system levels.

* OUSD AT&L Summit

Matching items noted in **RED**

# Summary SE Relationships to Project Performance

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Details

| | Gamma | p | Relative Project Performance: Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project Challenge** | | | | | | | | | | | | | | | | | |
| PC | -31% | 5.0% | 1.0 | 22% | 28% | 50% | 1.85 | 1.85 | 42% | 58% | 0% | 2.05 | 2.05 | 38% | 38% | 25% | 4.0 |
| **Project Environment** | | | | | | | | | | | | | | | | | |
| CMMI | 22% | 13.0% | 1.0 | 36% | 57% | 7% | 1.95 | 1.95 | 29% | 36% | 35% | 2.7 | 2.7 | 33% | 28% | 39% | 4.0 |
| IMP | 5% | 39.0% | 1.0 | 25% | 55% | 20% | 2.17 | 2.17 | 42% | 29% | 29% | 2.84 | 2.84 | 33% | 25% | 42% | 4.0 |
| EXP | 9% | 33.0% | 1.0 | 29% | 42% | 29% | 2.5 | 2.5 | 39% | 44% | 17% | 3.5 | 3.5 | 29% | 29% | 42% | 4.0 |
| **Systems Engineering Capability** | | | | | | | | | | | | | | | | | |
| IPT | 34% | 4.0% | 1.0 | 33% | 54% | 13% | 2.5 | 2.5 | 43% | 38% | 19% | 3.1 | 3.1 | 20% | 27% | 53% | 4.0 |
| PP | 13% | 25.0% | 1.0 | 33% | 54% | 13% | 2.8 | 2.8 | 29% | 35% | 36% | 3.3 | 3.3 | 35% | 29% | 36% | 4.0 |
| PMC | -13% | 25.0% | 1.0 | 23% | 54% | 23% | 2.5 | 2.5 | 23% | 46% | 31% | 3.0 | 3.0 | 45% | 25% | 30% | 4.0 |
| RSKM | 28% | 6.1% | 1.0 | 35% | 47% | 18% | 2.8 | 2.8 | 27% | 66% | 7% | 3.6 | 3.6 | 36% | 0% | 64% | 4.0 |
| REQ | 33% | 4.0% | 1.0 | 44% | 38% | 18% | 2.8 | 2.8 | 26% | 53% | 21% | 3.4 | 3.4 | 27% | 18% | 55% | 4.0 |
| TRADE | 37% | 3.0% | 1.0 | 39% | 44% | 17% | 2.7 | 2.7 | 42% | 41% | 17% | 3.3 | 3.3 | 19% | 32% | 49% | 4.0 |
| ARCH | 40% | 0.2% | 1.0 | 45% | 44% | 11% | 2.7 | 2.7 | 29% | 42% | 29% | 3.3 | 3.3 | 23% | 31% | 46% | 4.0 |
| TS | 36% | 3.0% | 1.0 | 40% | 53% | 7% | 2.8 | 2.8 | 33% | 40% | 27% | 3.2 | 3.2 | 27% | 27% | 46% | 4.0 |
| PI | 21% | 16.0% | 1.0 | 36% | 54% | 14% | 1.5 | 1.5 | 33% | 38% | 29% | 3.5 | 3.5 | 29% | 29% | 42% | 4.0 |
| VER | 25% | 9.0% | 1.0 | 31% | 62% | 7% | 2.7 | 2.7 | 33% | 34% | 33% | 3.2 | 3.2 | 33% | 20% | 47% | 4.0 |
| VAL | 28% | 7.0% | 1.0 | 54% | 23% | 23% | 2.7 | 2.7 | 17% | 66% | 17% | 3.3 | 3.3 | 29% | 33% | 38% | 4.0 |
| CM | 13% | 26.0% | 1.0 | 29% | 47% | 24% | 3.0 | 3.0 | 46% | 36% | 18% | 3.67 | 3.67 | 28% | 33% | 39% | 4.0 |
| Overall SEC | 32% | 4.0% | 1.0 | 39% | 46% | 15% | 2.5 | 2.5 | 29% | 59% | 12% | 3.0 | 3.0 | 31% | 13% | 56% | 4.0 |
| REQ+TS | 49% | 0.5% | 1.0 | 43% | 50% | 13% | 2.8 | 2.8 | 23% | 62% | 15% | 3.1 | 3.1 | 22% | 28% | 50% | 4.0 |
| **Acquirer Capability** | | | | | | | | | | | | | | | | | |
| AC | -35% | 3.0% | 1.0 | 7% | 60% | 33% | 2.5 | 2.5 | 41% | 32% | 26% | 3.0 | 3.0 | 50% | 25% | 25% | 4.0 |
| **Combined Capability and Challenge** | | | | | | | | | | | | | | | | | |
| REQ+TS+PC | 63% | 0.0% | 1.0 | 67% | 33% | 0% | 1.7 | 1.7 | 25% | 45% | 30% | 2.3 | 2.3 | 14% | 36% | 50% | 4.0 |

| Gamma relationship | Chance probability |
|---|---|
| Strong | Very low |
| Moderately strong to strong | Low |
| Moderately strong | Moderately low |
| Weak | Fair |

# elationships to Project Performance

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Details

**Relative Project Performance**

| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project Challenge** | | | | | | | | | | | | | | | | | |
| PC | -31% | 5.0% | 1.0 | 22% | 28% | 50% | 1.85 | 1.85 | 42% | 58% | 0% | 2.05 | 2.05 | 38% | 38% | 25% | 4.0 |
| **Project Environment** | | | | | | | | | | | | | | | | | |
| CMMI | 22% | 13.0% | 1.0 | 36% | | | | | | | | | | | | | |
| IMP | 5% | 39.0% | 1.0 | 25% | | | | | | | | | | | | | |
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| PMC | -13% | 25.0% | 1.0 | 23% | 54% | 23% | 2.5 | 2.5 | 23% | 46% | 31% | 3.0 | 3.0 | 45% | 25% | 30% | 4.0 |
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| TS | 36% | 3.0% | 1.0 | 40% | 53% | 7% | 2.8 | 2.8 | 33% | 40% | 27% | 3.2 | 3.2 | 27% | 27% | 46% | 4.0 |
| PI | 21% | 16.0% | 1.0 | 36% | 54% | 14% | 1.5 | 1.5 | 33% | 38% | 29% | 3.5 | 3.5 | 29% | 29% | 42% | 4.0 |
| VER | 25% | 9.0% | 1.0 | 31% | 62% | 7% | 2.7 | 2.7 | 33% | 34% | 33% | 3.2 | 3.2 | 33% | 20% | 47% | 4.0 |
| VAL | 28% | 7.0% | 1.0 | 54% | 23% | 23% | 2.7 | 2.7 | 17% | 66% | 17% | 3.3 | 3.3 | 29% | 33% | 38% | 4.0 |
| CM | 13% | 26.0% | 1.0 | 29% | 47% | 24% | 3.0 | 3.0 | 46% | 36% | 18% | 3.67 | 3.67 | 28% | 33% | 39% | 4.0 |
| Overall SEC | 32% | 4.0% | 1.0 | 39% | 46% | 15% | 2.5 | 2.5 | 29% | 59% | 12% | 3.0 | 3.0 | 31% | 13% | 56% | 4.0 |
| REQ+TS | 49% | 0.5% | 1.0 | 43% | 50% | 13% | 2.8 | 2.8 | 23% | 62% | 15% | 3.1 | 3.1 | 22% | 28% | 50% | 4.0 |
| **Acquirer Capability** | | | | | | | | | | | | | | | | | |
| AC | -35 | | | | | | | | | | | | | | 25% | 25% | 4.0 |
| **Combined Capability and** | | | | | | | | | | | | | | | | | |
| REQ+TS+PC | 63 | | | | | | | | | | | | | | 36% | 50% | 4.0 |

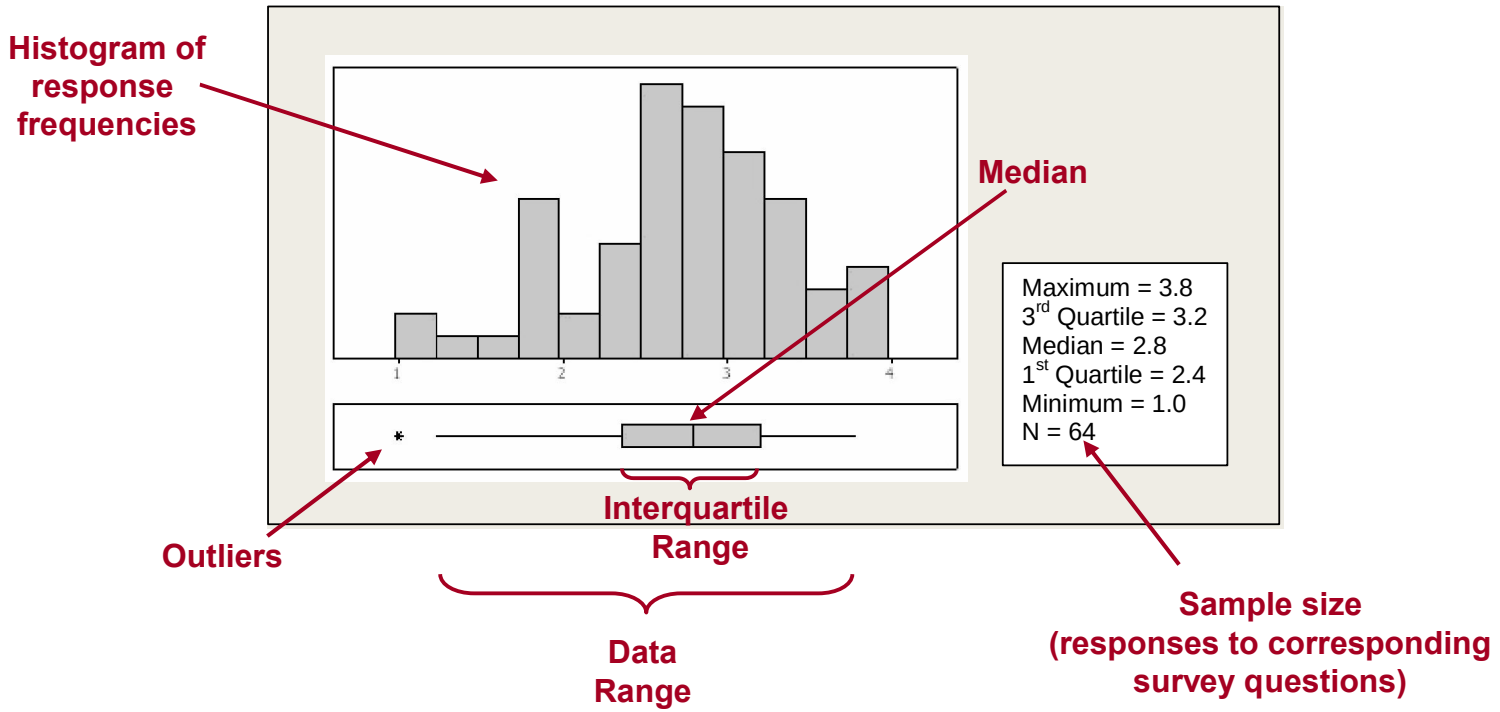
Highest scoring SE capability areas in Higher Performing Projects*:
Risk Management; Requirements Development and Management; IPTs

*Based on small partitioned sample size

Lowest scoring SE capability areas in Lower Performing Projects*:
Validation; Architecture; Requirements Development and Management

| Gamma relationship | Chance probability |
|---|---|
| Strong | Very low |
| Moderately strong to strong | Low |
| Moderately strong | Moderately low |
| Weak | Fair |

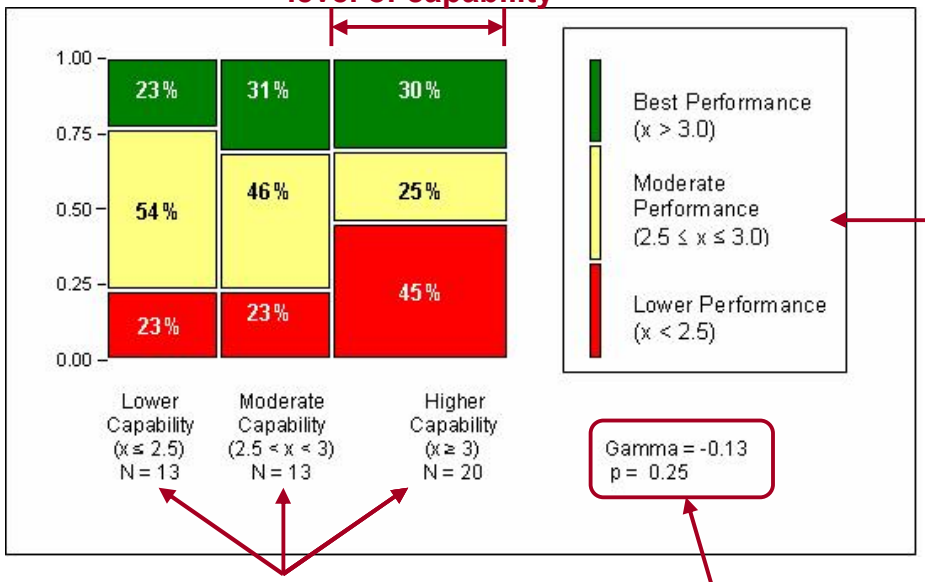
# Terminology and Notation
## *Distribution Graph*



# Terminology and Notation

## *Mosaic Chart*

**Column width represents proportion of projects with this level of capability**




**Relative performance distribution of the sample**

**Gamma: measures strength of relationship between two ordinal variables**

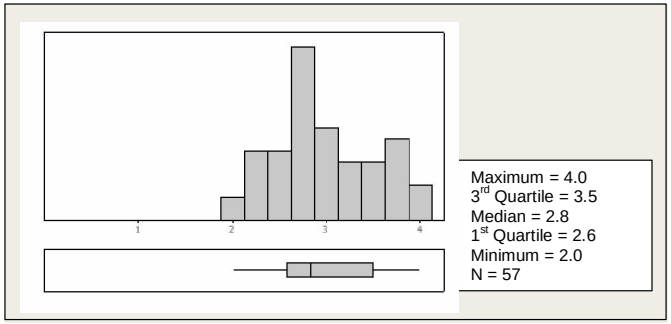
**p: probability that an associative relationship would be observed by chance alone**

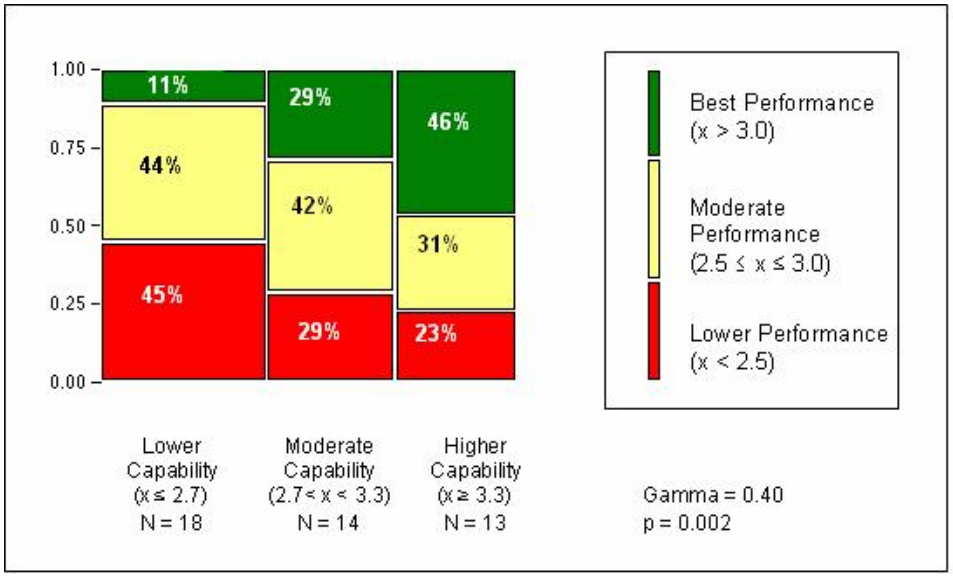
**Projects exhibiting a given level of relative capability (Lowest, Intermediate, Highest)**

**Sample size and distribution for associated survey responses (capability + performance)**

**Measures of association and statistical test**

# SE Capability: Product Architecture (ARCH)




| Relationship to project performance: | Moderately strong to strong positive relationship |
|---|---|

**SE Capability**

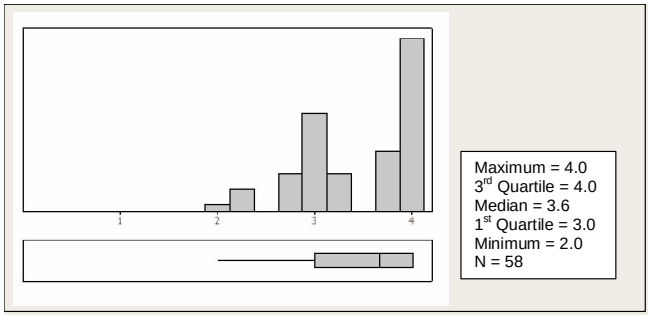
| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ARCH | 40% | 0.2% | 1.0 | 45% | 44% | 11% | 2.7 | 2.7 | 29% | 42% | 29% | 3.3 | 3.3 | 23% | 31% | 46% | 4.0 |

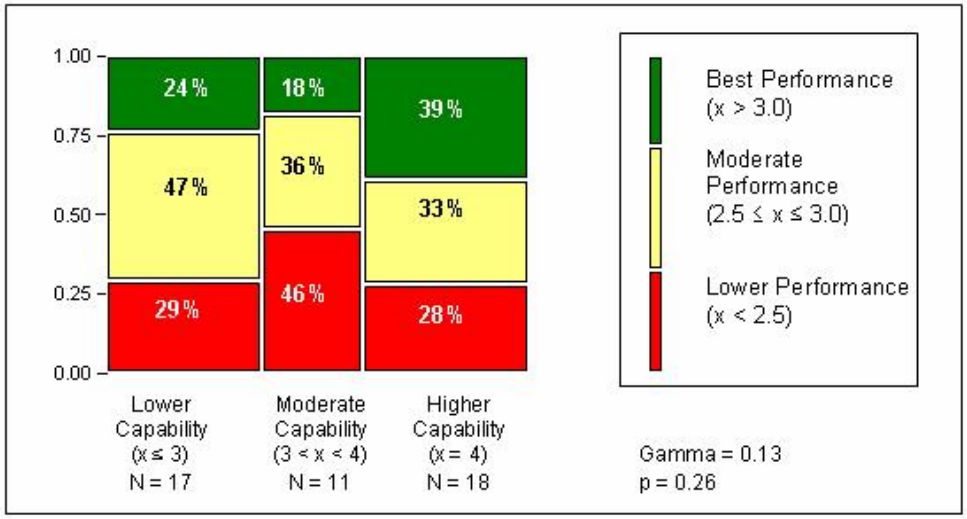
# SE Capability: Product Architecture (ARCH)

## Survey Questions

| ID | Question | Response range |
|---|---|---|
| *IF01* | This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF02* | Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF03a* | For this project, the product high-level structure is documented, kept up to date, and managed under configuration control | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF03b* | For this project, the product high-level structure is documented using multiple views (e.g. functional views, module views, etc. | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF03c* | For this project, the product high-level structure is accessible to all relevant project personnel | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF04* | This project has defined and documented guidelines for choosing COTS product components | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Configuration Management (CM)




| Relationship to project performance: | Weak positive relationship |
|---|---|

**SE Capability**

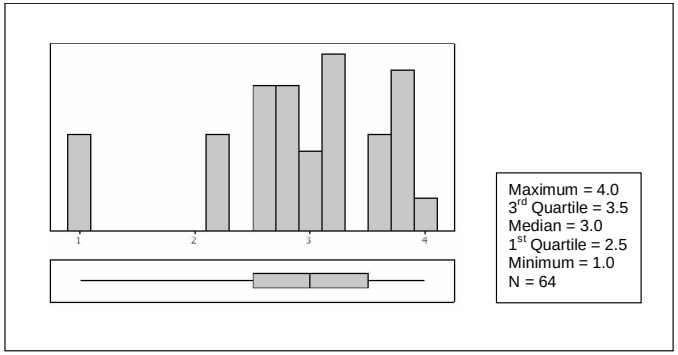
| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| CM | 13% | 26.0% | 1.0 | 29% | 47% | 24% | 3.0 | 3.0 | 46% | 36% | 18% | 3.67 | 3.67 | 28% | 33% | 39% | 4.0 |

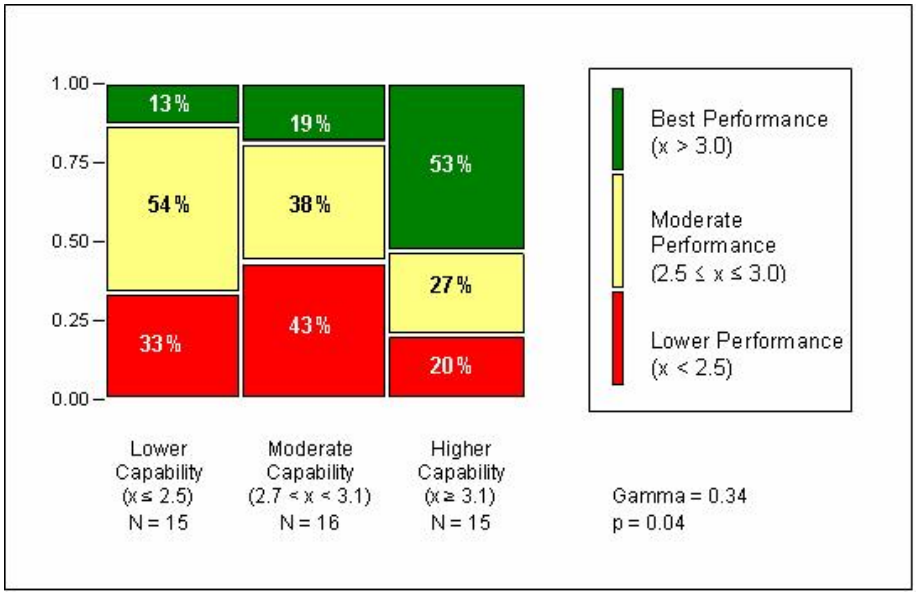
# SE Capability: Configuration Management (CM)

## Survey Questions

| ID | Question | Response Range |
|---|---|---|
| *V&V06* | This project has a configuration management system that charters a Change Control Board to disposition change requests | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V07* | This project maintains records of requested and implemented changes to configuration-managed items | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V08* | This project creates and manages configuration baselines (e.g., functional, allocated, product) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: IPT-Related Capability (IPT)




| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

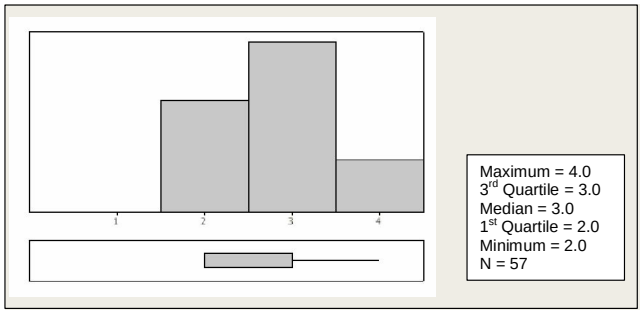
| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IPT | 34% | 4.0% | 1.0 | 33% | 54% | 13% | 2.5 | 2.5 | 43% | 38% | 19% | 3.1 | 3.1 | 20% | 27% | 53% | 4.0 |

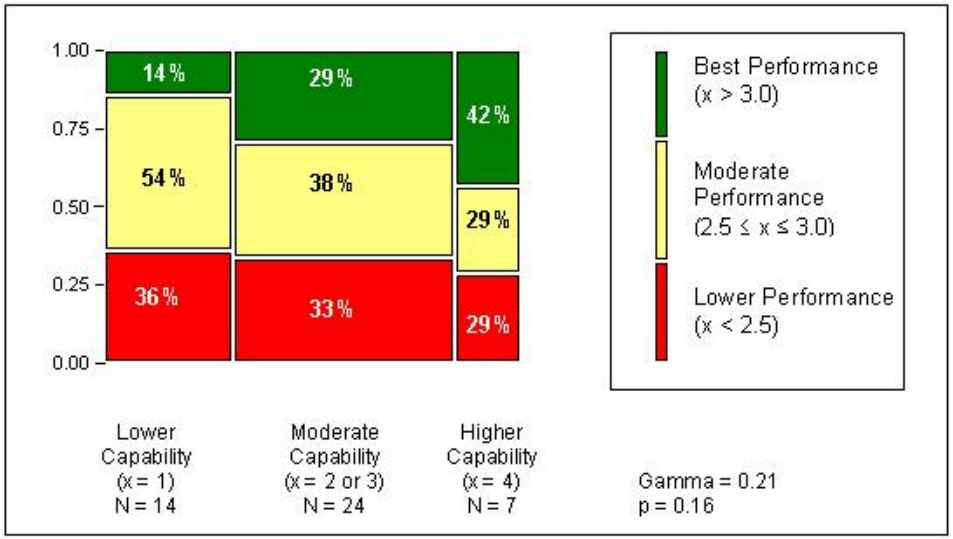
# SE Capability: IPT-Related Capability (IPT)

## Survey Questions

| ID | Question | Response range |
|---|---|---|
| *Proj03* | This project uses integrated product teams (IPTs) | •Yes<br>•No |
| *Proj04* | This project makes effective use of integrated product teams (IPTs) | •highly compliant<br>•largely compliant;<br>•moderately compliant<br>•not compliant |
| *Proj06* | My suppliers actively participate in IPTs | •highly compliant<br>•largely compliant;<br>•moderately compliant<br>•not compliant |
| *Proj07a* | This project has an IPT with assigned responsibility for systems engineering | •highly compliant<br>•largely compliant;<br>•moderately compliant<br>•not compliant |
| *Proj07b* | This project has Systems Engineering representation on each IPT | •highly compliant<br>•largely compliant;<br>•moderately compliant<br>•not compliant |

# SE Capability: Product Integration (PI)




| Relationship to project performance: | Weak positive relationship |
|---|---|

**SE Capability**

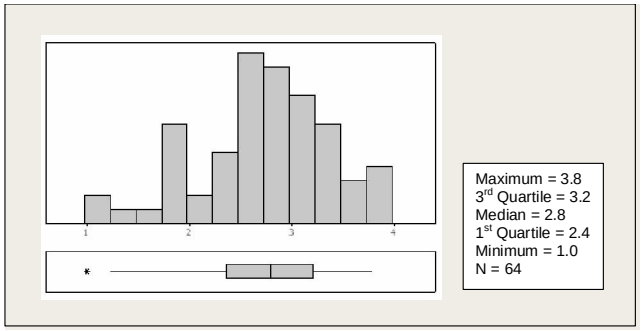
| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| PI | 21% | 16.0% | 1.0 | 36% | 54% | 14% | 1.5 | 1.5 | 33% | 38% | 29% | 3.5 | 3.5 | 29% | 29% | 42% | 4.0 |

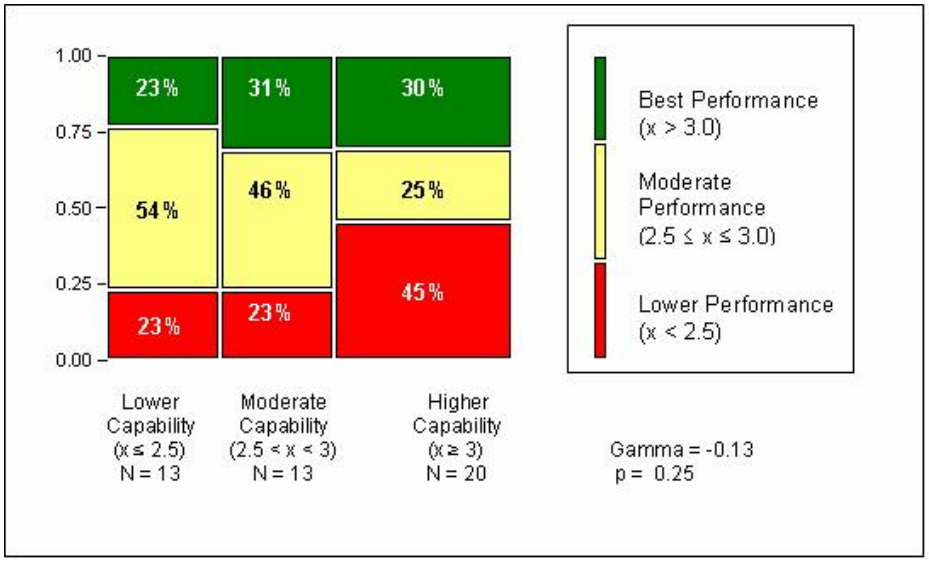
# SE Capability: Product Integration (PI)

## Survey Question

| ID | Question | Response range |
|---|---|---|
| *IF05* | This project has accurate and up-to-date documents defining its product integration process, plans, criteria, etc. throughout the life cycle | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Project Monitoring and Control (PMC)




| Relationship to project performance: | Weak negative relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PMC | -13% | 25.0% | 1.0 | 23% | 54% | 23% | 2.5 | 2.5 | 23% | 46% | 31% | 3.0 | 3.0 | 45% | 25% | 30% | 4.0 |

# CL Capability: Project Monitoring and Control (PMC)

## Survey Questions (Part 1)

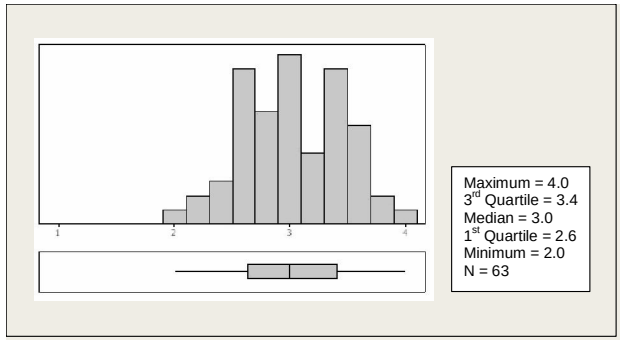
| ID | Question | Response range |
|---|---|---|
| *Cont13* | Do you separately cost and track systems engineering activities? | Yes<br>No |
| *Cont14a* | Approximately what percentage of non-recurring engineering (NRE) does systems engineering represent? | Percentages quantized as:<br>•<= 5%<br>•<= 10%<br>•<= 15%<br>•<= 25%<br>•> 25% |
| *Cont14b* | Is the NRE percentage estimated, or is it a measured value? | •estimated<br>•measured |
| *Perf01* | This project creates and manages cost and schedule baselines | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *Perf02b* | EVMS data are available to decision makers in a timely manner (i.e. current within 2 weeks) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *Perf02c* | The requirement to track and report EVMS data is levied upon the project's suppliers | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *Perf02d* | Variance thresholds for CPI and SPI variance are defined, documented, and used to determine when corrective action is needed | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

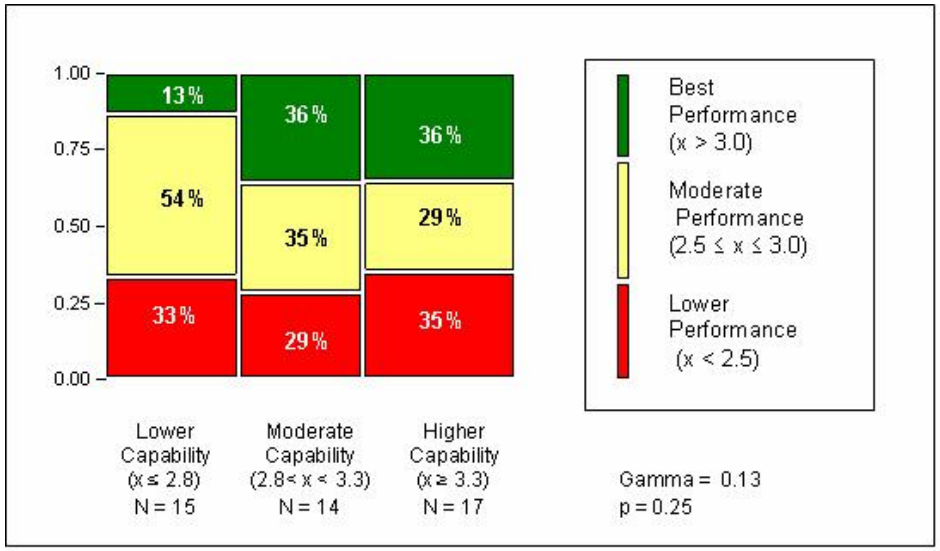
# SE Capability: Project Monitoring and Control (PMC)

## Survey Questions (Part 2)

| ID | Question | Response range | |
|---|---|---|---|
| *Perf02e* | EVMS is linked to the technical effort through the WBS and the IMP/IMS | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree | |
| *OPerf05* | Does this project track reports of problems from fielded items? | •Yes<br>•No | Scored by the number of positive responses |
| *OPerf06* | Does the project conduct an engineering assessment of all field trouble reports? | •Yes<br>•No | |
| *OPerf07* | The results of this engineering assessment feed into é | •operational hazard risk assessments<br>•materiel readiness assessments<br>•system upgrades planning<br>•other | |

# SE Capability: Project Planning (PP)




| Relationship to project performance: | Weak positive relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| PP | 13% | 25.0% | 1.0 | 33% | 54% | 13% | 2.8 | 2.8 | 29% | 35% | 36% | 3.3 | 3.3 | 35% | 29% | 36% | 4.0 |

# CL Capability: Project Planning (PP)

## Survey Questions (Part 1)

| ID | Question | Response range |
|---|---|---|
| *PD01* | This project utilizes a documented set of systems engineering processes for the planning and execution of the project | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD02a* | This project has an accurate and up-to-date Work Breakdown Structure (WBS) that includes task descriptions and work package descriptions | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD02b* | This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is based upon the product structure | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD02c* | This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is developed with the active participation of those who perform the systems engineering activities | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD02d* | This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is developed with the active participation of all relevant stakeholders, e.g., developers, maintainers, testers, inspectors, etc. | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD03a* | This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is complete, accurate and up-to-date | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD03b* | This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is developed with the active participation of those who perform the systems engineering activities | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# CL Capability: Project Planning (PP)

## Survey Questions (Part 2)

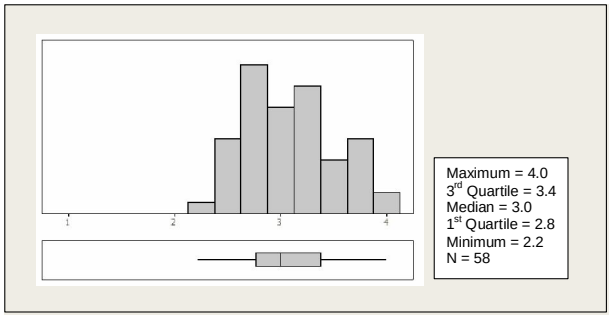
| ID | Question | Response range |
|---|---|---|
| *PD03c* | This projectôs Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is developed with the active participation of all appropriate functional stakeholder | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD04a* | This project has a top-level plan, such as an Integrated Master Plan (IMP), that is an event-driven plan (i.e., each accomplishment is tied to a key project event) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD04b* | This project has a top-level plan, such as an Integrated Master Plan (IMP), that documents significant accomplishments with pass/fail criteria for both business and technical elements of the project | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD04c* | This project has a top-level plan, such as an Integrated Master Plan (IMP), that is consistent with the WBS | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD05a* | This project has an integrated event-based schedule that is structured as a networked, multi-layered schedule of project tasks required to complete the work effort | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD05b* | This project has an integrated event-based schedule that contains a compilation of key technical accomplishments (e.g., a Systems Engineering Master Schedule) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD05c* | This project has an integrated event-based schedule that references measurable criteria (usually contained in the Integrated Master Plan) required for successful completion of key technical accomplishments | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

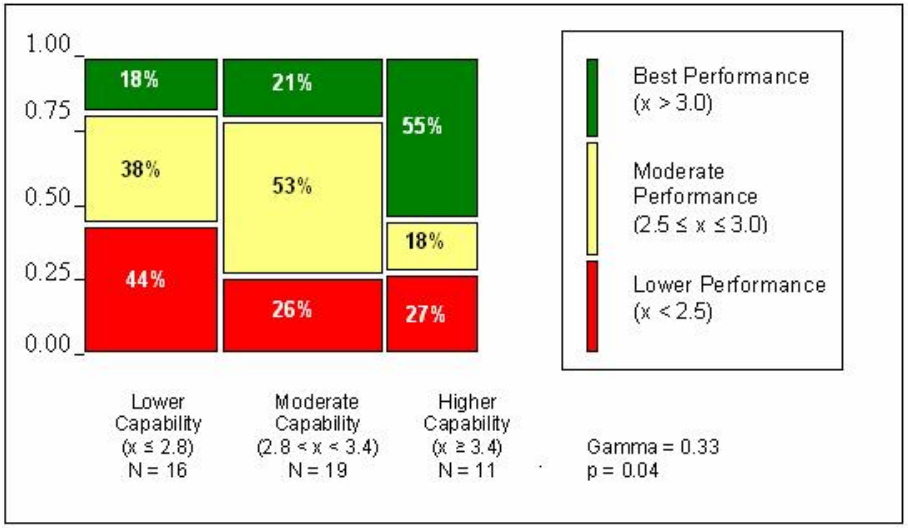
# CL Capability: Project Planning (PP)

## Survey Questions (Part 3)

| ID | Question | Response range |
|---|---|---|
| *PD05d* | This project has an integrated event-based schedule that is consistent with the WBS | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD05e* | This project has an integrated event-based schedule that identifies the critical path of the program schedule | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD06* | This project has a plan or plans for the performance of technical reviews with defined entry and exit criteria throughout the life cycle of the project | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD07* | This project has a plan or plans that include details of the management of the integrated technical effort across the project (e.g., a Systems Engineering Management Plan or a Systems Engineering Plan) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD08* | Those who perform systems engineering activities actively participate in the development and updates of the project planning | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD09* | Those who perform systems engineering activities actively participate in tracking/reporting of task progress | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Requirements Development & Mgmt (REQ)




| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| REQ | 33% | 4.0% | 1.0 | 44% | 38% | 18% | 2.8 | 2.8 | 26% | 53% | 21% | 3.4 | 3.4 | 27% | 18% | 55% | 4.0 |

# CL Capability: Requirements Development & Mgmt (REQ)

## Survey Questions (Part 1)

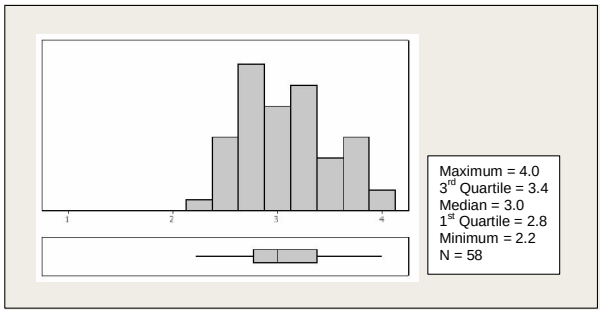
| ID | Question | Response range |
|---|---|---|
| *RD01a* | This project maintains an up-to-date and accurate listing of all requirements specified by the customer, to include regulatory, statutory, and certification requirements | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD01b* | This project maintains an up-to-date and accurate listing of all requirements derived from those specified by the customer | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD02* | This project maintains up-to-date and accurate documentation clearly reflecting the hierarchical allocation of both customer and derived requirements to each element (subsystem, component, etc.) of the system in the configuration baselines | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD03a* | This project documents and maintains accurate and up-to-date descriptions of operational concepts and their associated scenarios | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD03b* | This project documents and maintains accurate and up-to-date descriptions of use cases (or their equivalent) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD03c* | This project documents and maintains accurate and up-to-date descriptions of product installation, maintenance and support concepts | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD04* | This project has documented criteria for identifying authorized requirements providers to avoid requirements creep and volatility | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

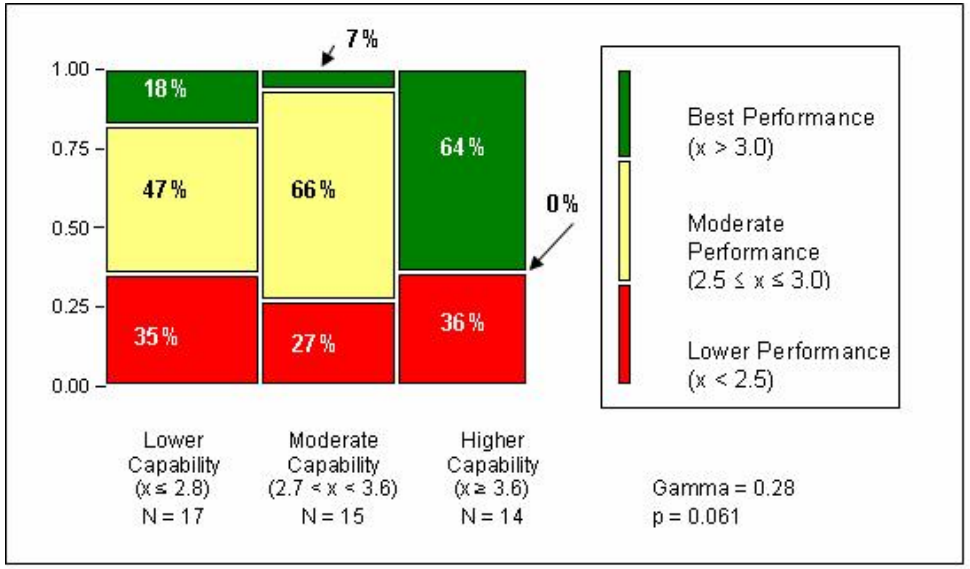
# CL Capability: Requirements Development & Mgmt (REQ)

## Survey Questions (Part 2)

| ID | Question | Response range |
|---|---|---|
| *RD05* | This project has documented criteria (e.g., cost impact, schedule impact, authorization of source, contract scope, requirement quality) for evaluation and acceptance of requirements | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD06* | The requirements for this project are approved in a formal and documented manner by relevant stakeholders | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD07* | This project performs and documents requirements impact assessments for proposed requirements changes | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD08* | This project develops and documents project requirements based upon stakeholder needs, expectations, and constraints | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD09* | This project has an accurate and up-to-date requirements tracking system | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD10a* | For this project, the requirements documents are managed under a configuration control process | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD10b* | For this project, the requirements documents are accessible to all relevant project staff | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Risk Management (RSKM)




| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

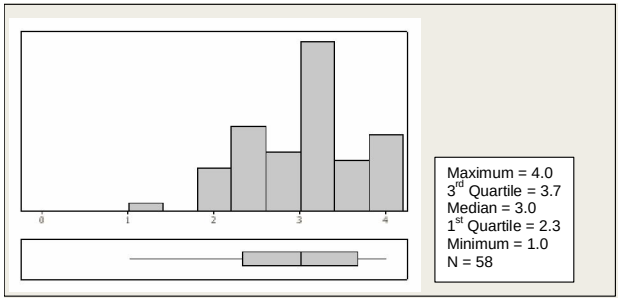
| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RSKM | 28% | 6.1% | 1.0 | 35% | 47% | 18% | 2.8 | 2.8 | 27% | 66% | 7% | 3.6 | 3.6 | 36% | 0% | 64% | 4.0 |

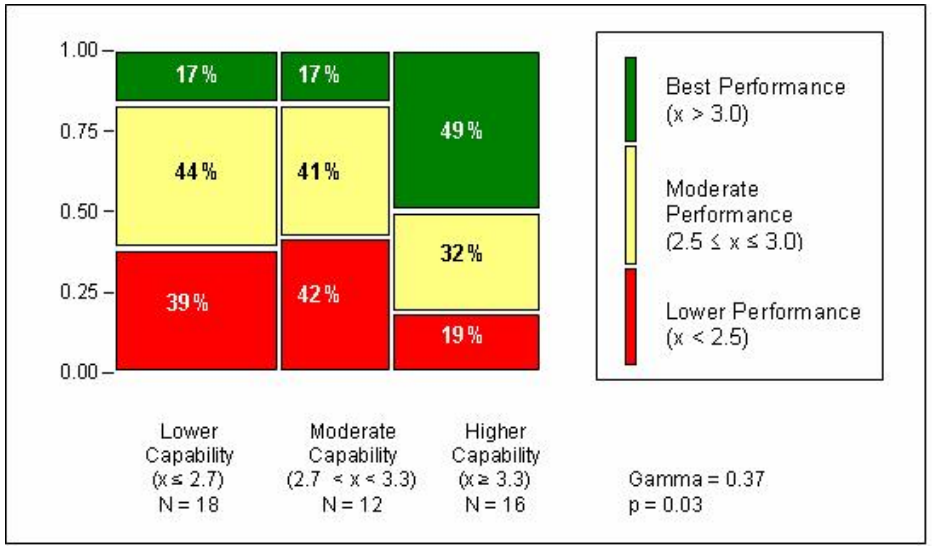
# SE Capability: Risk Management (RSKM)

## Survey Questions

| ID | Question | Response range |
|---|---|---|
| *PD11a* | This project has a Risk Management process that creates and maintains an accurate and up-to-date list of risks affecting the project (e.g., risks to cost, risks to schedule, risks to performance) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD11b* | This project has a Risk Management process that creates and maintains up-to-date documentation of risk mitigation plans and contingency plans for selected risks | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD11c* | This project has a Risk Management process that monitors and reports the status of risk mitigation activities and resources | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD11d* | This project has a Risk Management process that assesses risk against achievement of an event-based schedule | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *PD12* | This project's Risk Management process is integrated with program decision-making | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Trade Studies (TRADE)




| Relationship to project performance: | Moderately strong to strong positive relationship |
|---|---|

**SE Capability**

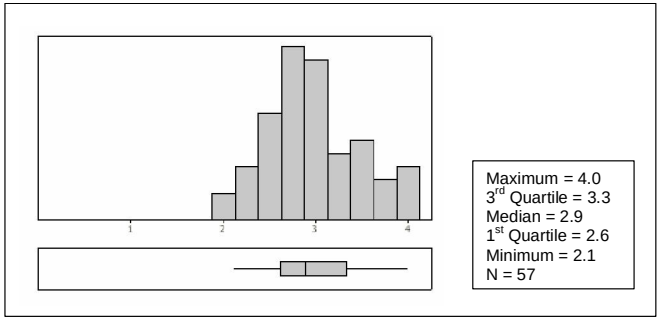
| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| TRADE | 37% | 3.0% | 1.0 | 39% | 44% | 17% | 2.7 | 2.7 | 42% | 41% | 17% | 3.3 | 3.3 | 19% | 32% | 49% | 4.0 |

# SE Capability: Trade Studies (TRADE)

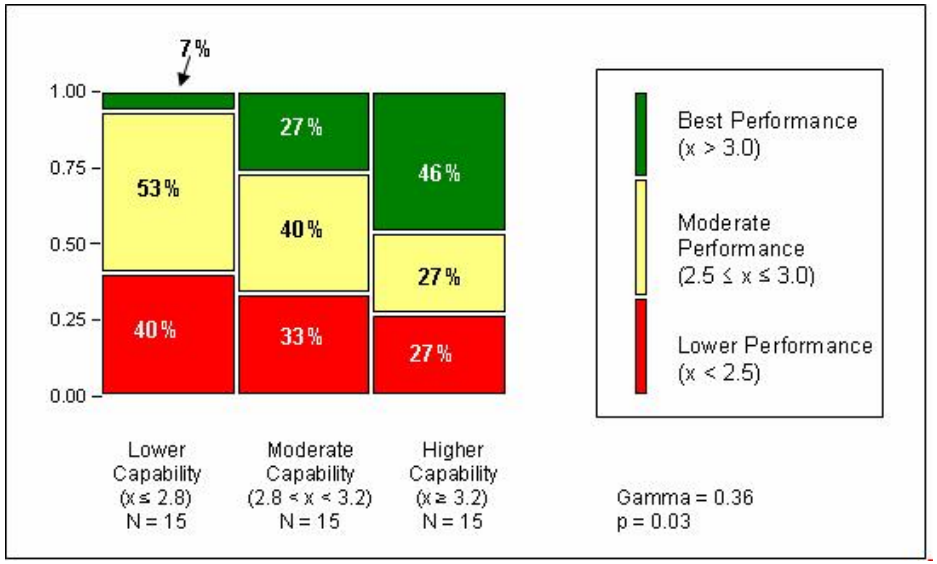
## Survey Questions

| ID | Question | Response range |
|---|---|---|
| *RD11* | Stakeholders impacted by trade studies are involved in the development and performance of those trade studies | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD12* | This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD13* | Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Technical Solution (TS)




*Note: TS is a composite measure equivalent to ARCH + TRADE.*




| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TS | 36% | 3.0% | 1.0 | 40% | 53% | 7% | 2.8 | 2.8 | 33% | 40% | 27% | 3.2 | 3.2 | 27% | 27% | 46% | 4.0 |

# SE Capability: Technical Solution (TS)

## Survey Questions (Part 1)

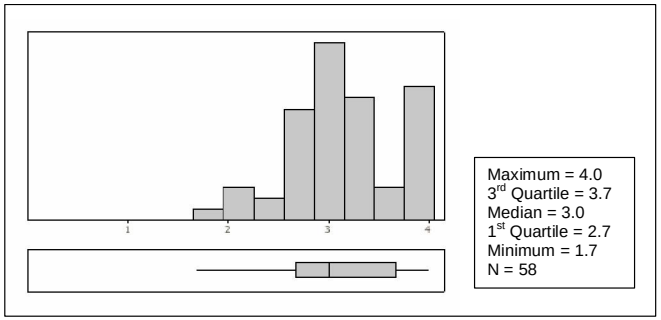
| ID | Question | Response Range |
|---|---|---|
| *RD11* | Stakeholders impacted by trade studies are involved in the development and performance of those trade studies | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD12* | This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *RD13* | Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF01* | This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF02* | Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

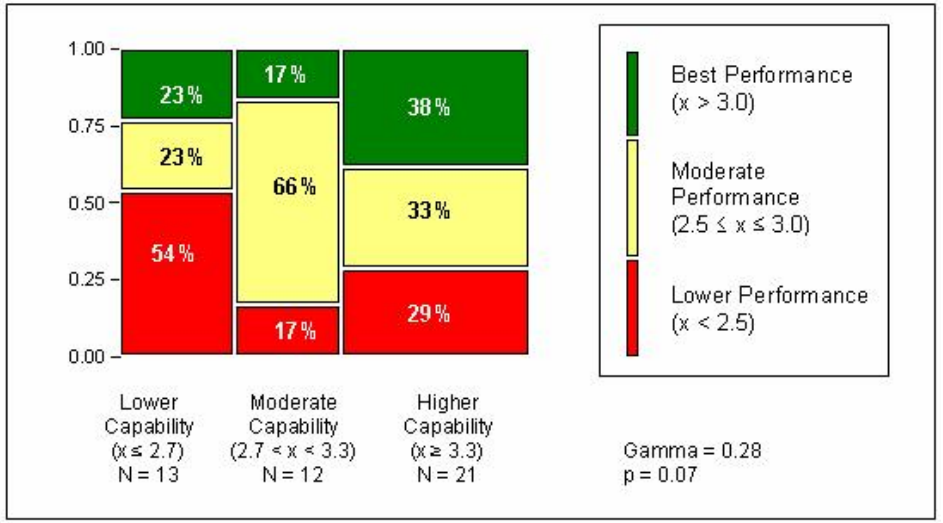
# SE Capability: Technical Solution (TS)

## Survey Questions (Part 2)

| ID | Question | Response Range |
|---|---|---|
| *IF03a* | For this project, the product high-level structure is documented, kept up to date, and managed under configuration control | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF03b* | For this project, the product high-level structure is documented using multiple views (e.g. functional views, module views, etc.) | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF03c* | For this project, the product high-level structure is accessible to all relevant project personnel | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *IF04* | This project has defined and documented guidelines for choosing COTS product components | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Validation (VAL)




| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

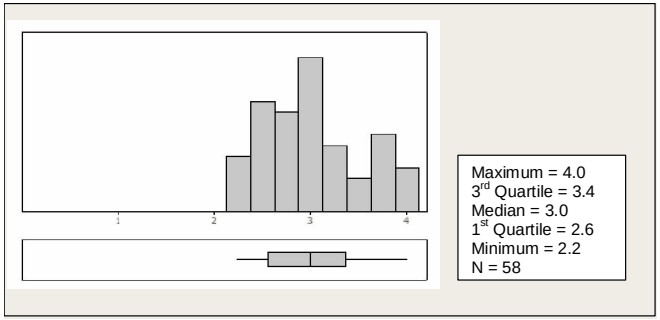
| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VAL | 28% | 7.0% | 1.0 | 54% | 23% | 23% | 2.7 | 2.7 | 17% | 66% | 17% | 3.3 | 3.3 | 29% | 33% | 38% | 4.0 |

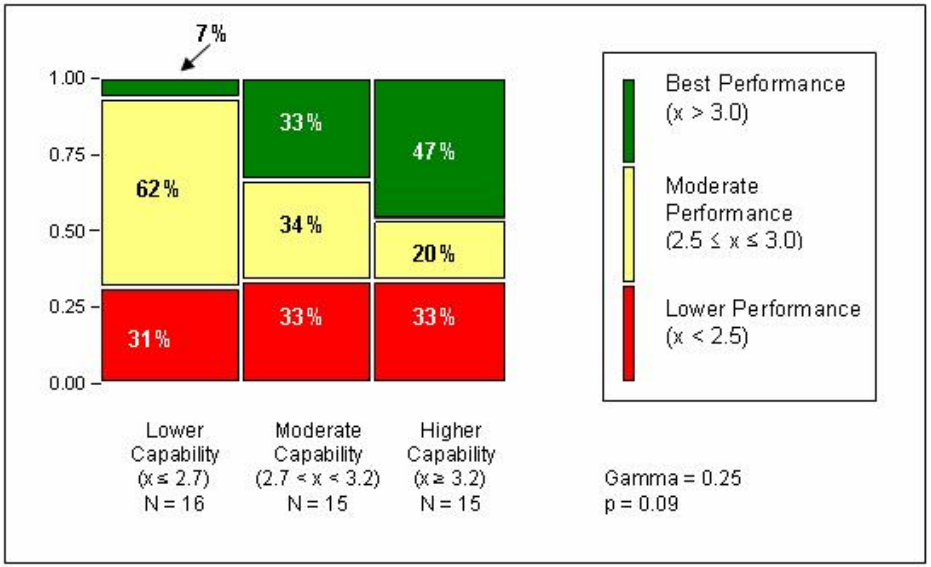
# SE Capability: Validation (VAL)

## Survey Questions

| ID | Question | Response Rate |
|---|---|---|
| *V&V04a* | This project has accurate and up-to-date documents defining the procedures used for the validation of systems and system elements | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V04b* | This project has accurate and up-to-date documents defining acceptance criteria used for the validation of systems and system elements | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V05* | This project maintains a listing of items managed under configuration control | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Verification (VER)




| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VER | 25% | 9.0% | 1.0 | 31% | 62% | 7% | 2.7 | 2.7 | 33% | 34% | 33% | 3.2 | 3.2 | 33% | 20% | 47% | 4.0 |

# SE Capability: Verification (VER)

## Survey Questions (Part 1)

| ID | Question | Response range |
|---|---|---|
| *V&V01a* | This project has accurate and up-to-date documents defining the procedures used for the test and verification of systems and system elements | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V01b* | This project has accurate and up-to-date documents defining acceptance criteria used for the verification of systems and system elements | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V02a* | This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that defines entry and exit criteria for work products | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V02b* | This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that includes training requirements for the reviewers | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V02e* | This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that addresses identified risks and risk mitigation activities during reviews | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V02f* | This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that examines completeness of configuration baselines | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

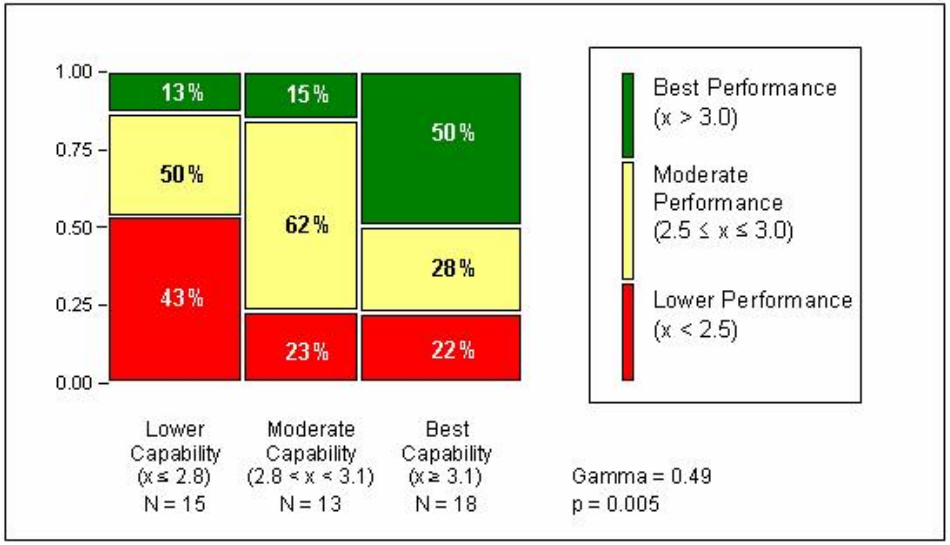
# SE Capability: Verification (VER)

## Survey Questions (Part 2)

| ID | Question | Response range |
|---|---|---|
| *V&V03* | This project conducts non-advocate reviews (e.g. reviews by qualified personnel with no connection to or stake in the project) and documents results, issues, action items, risks, and risk mitigations | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V02c* | This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that defines criteria for the selection of work products (e.g., requirements documents, test plans, system design documents, etc.) for review | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |
| *V&V02d* | This project has a documented and practiced review (e.g. peer reviews, design reviews, etc.) process that tracks action items to closure | •strongly disagree<br>•disagree<br>•agree<br>•strongly agree |

# SE Capability: Combined Reqts+Tech Solution (REQ+TS)

*(This is a higher order measure; see base measures for distribution)*

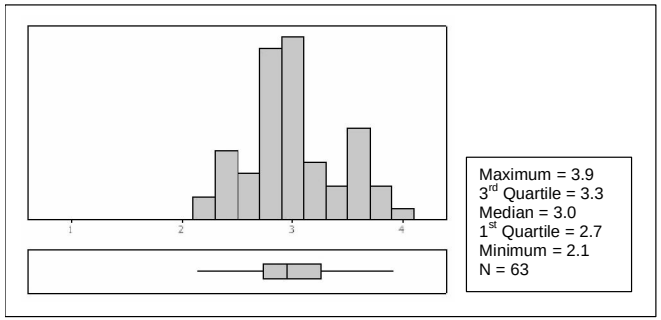


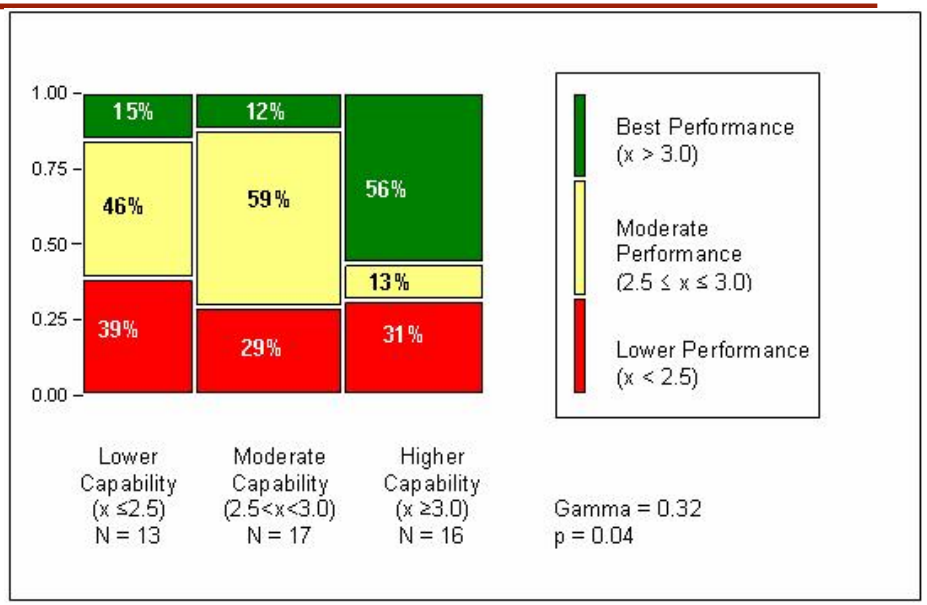

| Relationship to project performance: | Strong positive relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| REQ+TS | 49% | 0.5% | 1.0 | 43% | 50% | 13% | 2.8 | 2.8 | 23% | 62% | 15% | 3.1 | 3.1 | 22% | 28% | 50% | 4.0 |

# SE Capability:
# Total Systems Engineering Capability



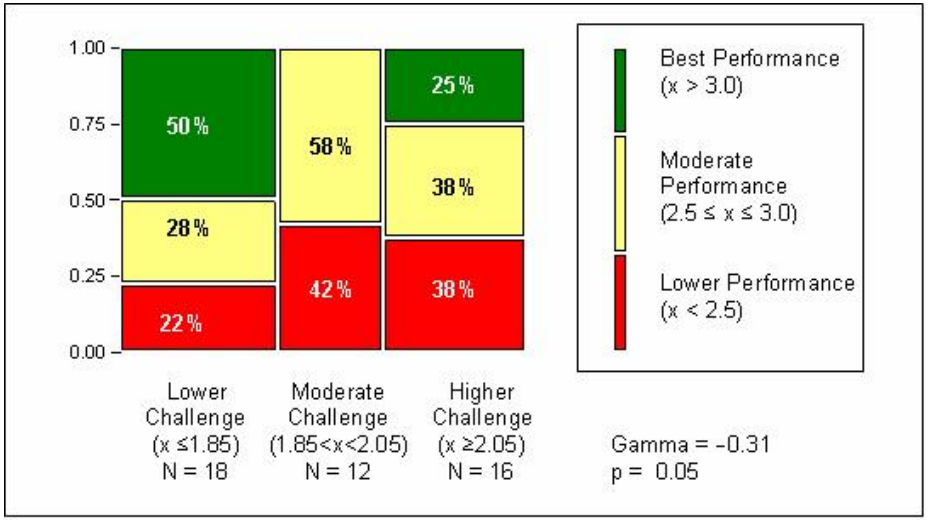

| Relationship to project performance: | Moderately strong positive relationship |
|---|---|

**SE Capability**

| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overall SEC | 32% | 4.0% | 1.0 | 39% | 46% | 15% | 2.5 | 2.5 | 29% | 59% | 12% | 3.0 | 3.0 | 31% | 13% | 56% | 4.0 |

# Project Challenge (PC)

**Project challenge factors:**
- Life cycle phases
- Project characteristics
  (e.g., size, effort, duration, volatility)
- Technical complexity
- Teaming relationships



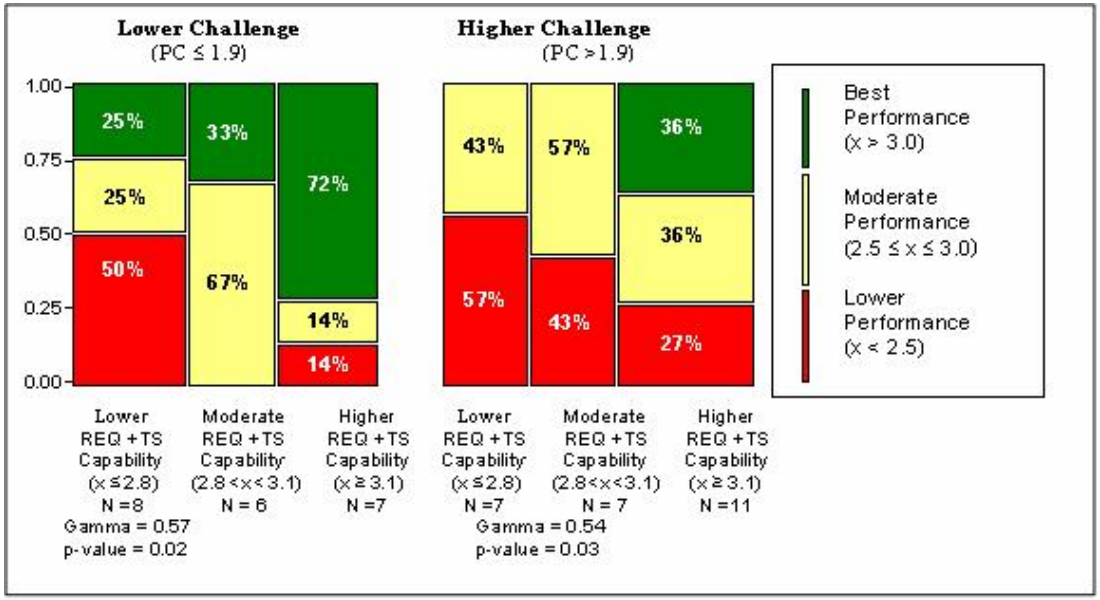

| Relationship to project performance: | Moderately strong negative relationship |
|---|---|

**Project Challenge**

| | Gamma | p | Lower | | | | | Moderate | | | | | Higher | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range | Min. Range | # Lo | # Med | # Hi | Max. Range |
| PC | -31% | 5.0% | 1.0 | 22% | 28% | 50% | 1.85 | 1.85 | 42% | 58% | 0% | 2.05 | 2.05 | 38% | 38% | 25% | 4.0 |

# SE Capability: Reqts+Tech Solution with Project Challenge

**Project challenge factors:**
- Life cycle phases
- Project characteristics
  (e.g., size, effort, duration, volatility)
- Technical complexity
- Teaming relationships

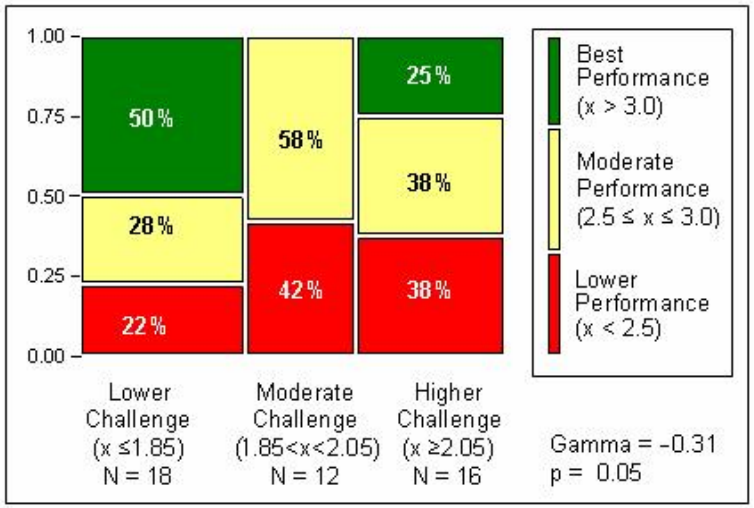


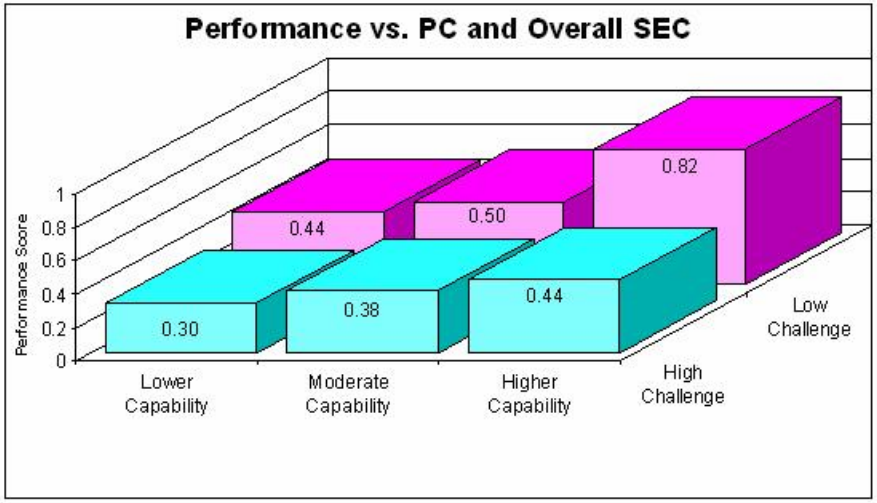

| Relationship to project performance: | Very strong positive relationship |
|---|---|

**SE Capability + Project Challenge**

| | Gamma | p | Lower Min. Range | Lower # Lo | Lower # Med | Lower # Hi | Lower Max. Range | Moderate Min. Range | Moderate # Lo | Moderate # Med | Moderate # Hi | Moderate Max. Range | Higher Min. Range | Higher # Lo | Higher # Med | Higher # Hi | Higher Max. Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REQ+TS+PC | 63% | 0.0% | 1.0 | 67% | 33% | 0% | 1.7 | 1.7 | 25% | 45% | 30% | 2.3 | 2.3 | 14% | 36% | 50% | 4.0 |

# Relating Project Performance to Project Challenge and SE Capability

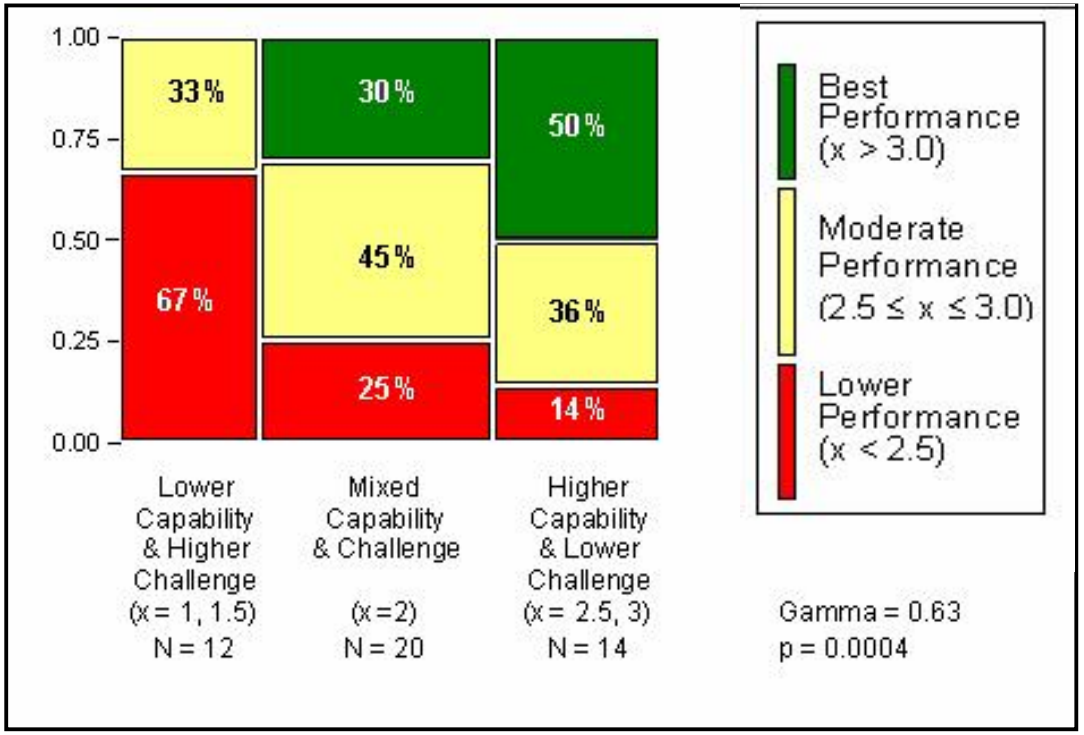


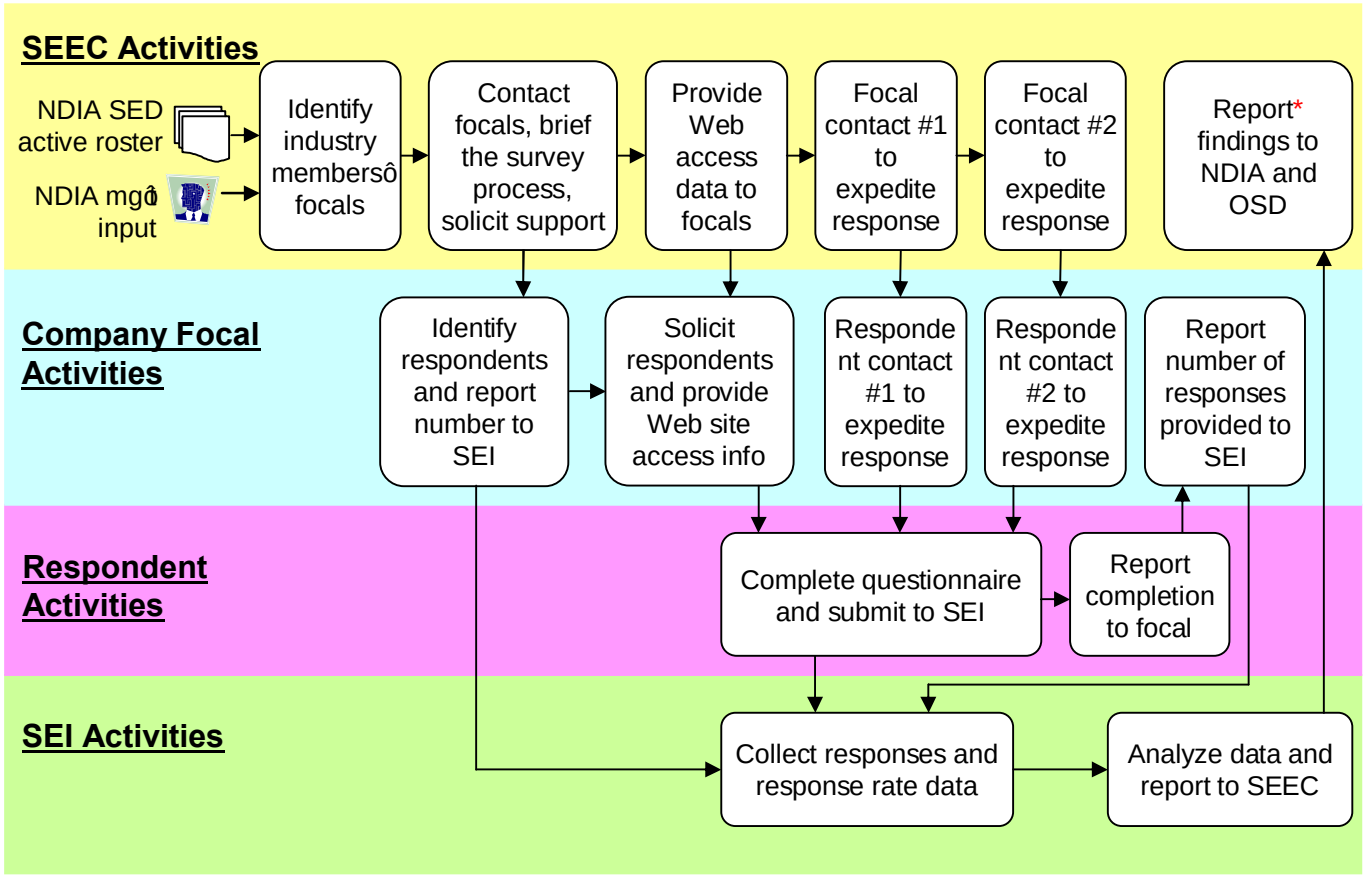
# Reqts + Tech Solution + Project Challenge and Performance

**Project challenge factors:**

- Life cycle phases
- Project characteristics (e.g., size, effort, duration, volatility)
- Technical complexity
- Teaming relationships



# veness Methodology (In Detail)



# Summary of Relationships

| Driving Factor | Relationship to Project Performance | |
|---|---|---|
| | Description | Γ |
| Requirements and Technical Solution Combined with Project Challenge | Very strong positive | +0.63 |
| Combined Requirements and Technical Solution | Strong positive | +0.49 |
| Product Architecture | Moderately strong to strong positive | +0.40 |
| Trade Studies | Moderately strong to strong positive | +0.37 |
| IPT-Related Capability | Moderately strong positive | +0.34 |
| Technical Solution | Moderately strong positive | +0.36 |
| Requirements Development and Management | Moderately strong positive | +0.33 |

| Driving Factor | Relationship to Project Performance | |
|---|---|---|
| | Description | Γ |
| Total Systems Engineering Capability | Moderately strong positive | +0.32 |
| Project Challenge | Moderately strong negative | -0.31 |
| Validation | Moderately strong positive | +0.28 |
| Risk Management | Moderately strong positive | +0.28 |
| Verification | Moderately strong positive | +0.25 |
| Product Integration | Weak positive | +0.21 |
| Project Planning | Weak positive | +0.13 |
| Configuration Management | Weak positive | +0.13 |
| Project Monitoring and Control | Weak negative | -0.13 |
| Process Improvement | Weak positive | +0.05 |