

A Survey of Systems Engineering Effectiveness

***by: NDIA Systems Engineering
Effectiveness Committee***

INCOSE - Space Coast Chapter



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Agenda



Introduction – NDIA Systems Engineering Division (SED)

- Organization and Committees

NDIA Systems Engineering Conference Summary

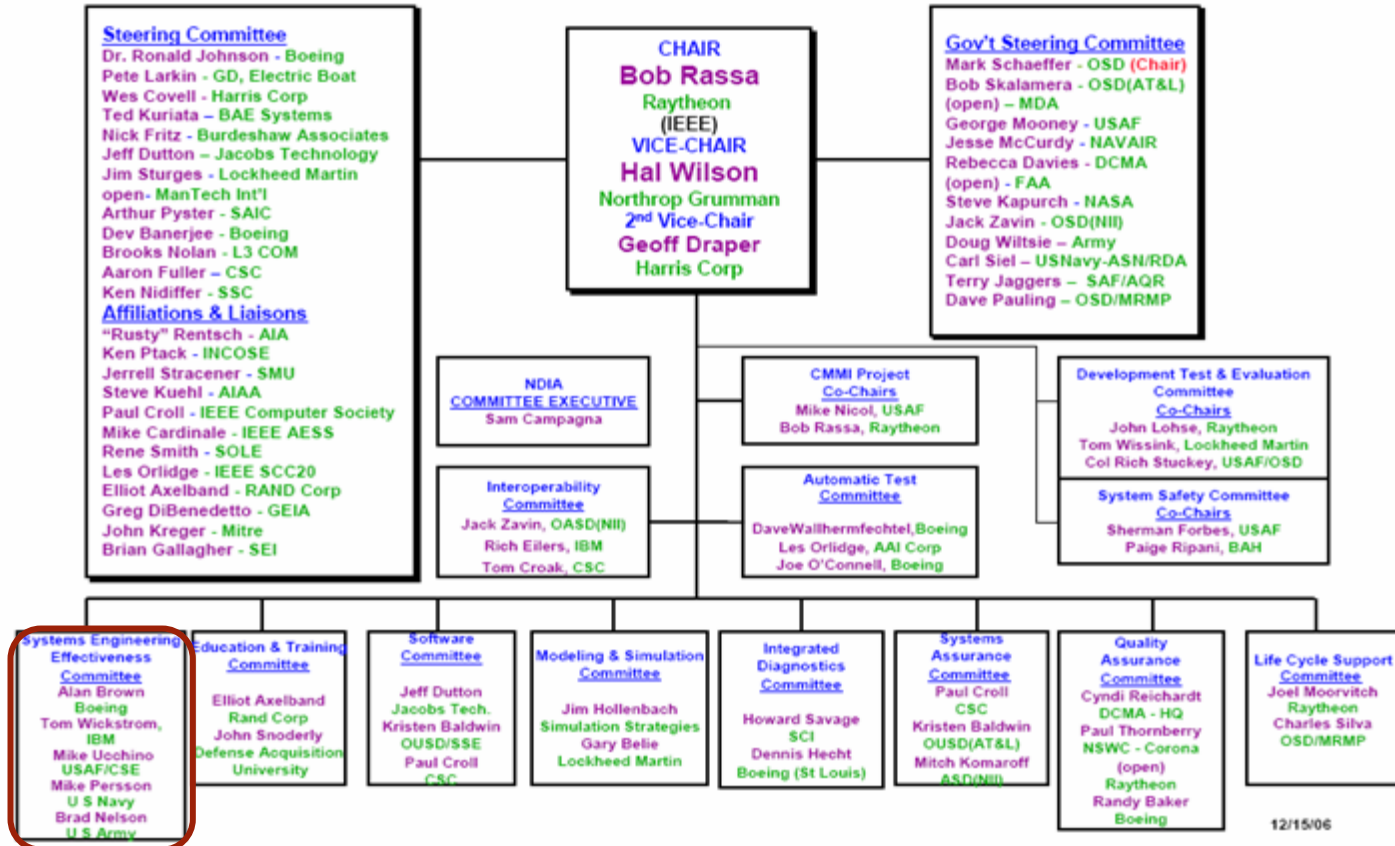
NDIA Systems Effectiveness Committee: A Survey of Systems Engineering Effectiveness

NDIA SE Division web page:

http://www.ndia.org/Template.cfm?Section=NDIA_Divisions_Page&Template=/TaggedPage/TaggedPageDisplay.cfm&TPLID=3&ContentID=677

NDIA SE Division – Org Chart

National Defense Industrial Association SYSTEMS ENGINEERING DIVISION



12/15/06

Key NDIA SE Division Initiatives



OSD (A&T) Initiatives

CMMI Co-Sponsor

Conferences

- NDIA Systems Engineering Conference
- CMMI Technology Conference
- Net-Centric Operations Conference

Committees

Task Groups / Workshops

Awards

- Ferguson Award for SE Excellence
- Top 5 Government Programs

The screenshot displays the NDIA Systems Engineering Committee website. The page features a navigation menu with 'Meetings & Events', 'Advocacy', 'Divisions', and 'Membership & Chapters'. The main content area is titled 'Systems Engineering Committee' and 'Past Meetings and Projects'. It lists several key events and reports, including the 'Defense Software Strategy Summit - October 18 - 19, 2006' and 'Top 5 Systems Engineering Issues (July 2006)'. A sidebar on the right contains 'President's Corner', 'NDIA Resources', and 'Visit Our Sponsors'.

Systems Engineering Committee

Past Meetings and Projects

- **Defense Software Strategy Summit - October 18 - 19, 2006**
 - [NDIA Software Strategy Summit Report](#) (PDF) - UPDATED 3/5/07
 - [Meeting Agenda](#) (PDF)
 - **Keynote Presentations**
 - [Reshaping Software in DoD](#) (PDF) - Hon Dr. James Finley
 - [Top Software Engineering Issues in the Defense Industry](#) (PDF) - Mr. Geoff Draper
 - [An Assessment of the National Security Software Industrial Base](#) (PDF) - Mr. Pierre Chao
 - [Software-Intensive Systems Productivity Research Initiative](#) - Mr. Robert Gold
 - **PEO Panel Presentations**
 - [Perspectives on Software Related Acquisition Issues](#) - Mr. Dave Castellano
 - [Growth Trend in System Software](#) - Lt Gen Michael Hamel, USAF
 - [Defense Software Strategy Summit](#) - Lt Gen Charles Johnson, II, USAF
 - [Tactical Software Acquisition Insights](#) - BG Nick Justice, USA
 - **Service Agency Panel**
 - [ASIA \(BON\) Software Process Improvement Initiative](#) - Mr. Carl Siel
 - [USAF Systems & Software Engineering](#) - Mr. Terry Jagers
 - [Army Strategic Software Improvement Program](#) - Mr. Doug Wiltsie
- **Top 5 Systems Engineering Issues (July 2006)**
 - [NDIA Top 5 Systems Engineering Issues Report](#) (PDF)
 - [NDIA Top 5 Systems Engineering Issues Presentation](#) (PDF)
- **Top Software Issues (September 2006)**
 - [NDIA Top Software Issues Report](#) - 9/26/06 (PDF)
 - [NDIA Top Software Issues Presentation](#) - 9/26/06 (PDF)
- **DoD System of Systems (SoS) Systems Engineering Guide Workshop**
 - [SoS Systems Engineering Guide Overview](#)
 - [SoS Systems Engineering Guide OSD/AT&L](#) - Mr. Robert Skalamera
 - [Defense View on Consideration for SoS Systems Engineering](#) - Ms. Kristen

President's Corner

NDIA Resources

- National Defense Magazine
- Media Room
- Link Central
- Studies, Reports & Proceedings
- Mega Directory

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NDIA SE Conference - October 22-25, 2007

Program Summary - 1



•13 tutorials

- Scheduling; CAIV; EVMS; defect detection/prevention; operational concepts/scenarios; modeling; requirements; SE metrics; SoS technical reviews

•Keynotes:

- Hon. James Finley (DUSD(A&T))
- Hon. Charles McCreary (Director, S&T)
- “Start programs right”; supportability, life cycle costs
- Technology maturity (TRL 6); system reliability

•Plenary: Executive Panel (OSD, Air Force, Army, Navy)

- Service initiatives to institutionalize effective SE practices
- Emphasis on early life cycle involvement and planning

NDIA SE Conference - October 22-25, 2007

Program Summary - 2



•8 concurrent presentation tracks daily

Systems Engineering
Effectiveness

Test & Evaluation

Program Management

Integrated Diagnostics

Modeling & Simulation

Net Centric Operations

Best Practices &
Standardization

Software

Logistics

Supportability and Readiness System Safety

Education & Training

•Key discussion topics:

- CMMI: CMMI-ACQ; CMMI-SVC re-considered; ROI from levels “unproven”
- Institutionalization of SE practices in government and industry (“we don’t start programs right, and we don’t manage them right”)
- OSD systemic root cause analysis of program performance issues
 - Management; Reqs; SE; Staffing; Reliability; Acquisition Strategy; Schedule; Test Planning; Software; Maintainability/Logistics
- Reliability and supportability issues
- Technology maturity: TRL 6 at award (demonstrated in relevant environment)
- NDIA SE effectiveness survey – relates SE capability w/ program performance

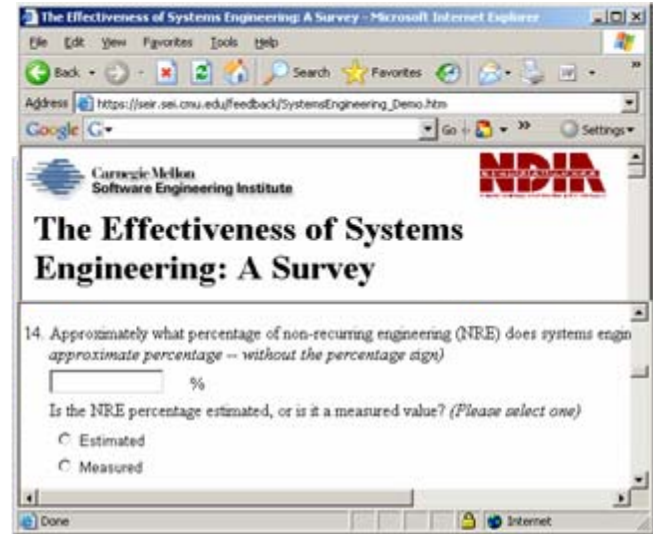
Systems Engineering Effectiveness Survey

Objectives:

- Characterize effective SE practices and benchmarks
- Correlate SE practices with measures of program performance
- Quantify the “Value of Systems Engineering”

Approach:

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



https://seir.sei.cmu.edu/feedback/SystemsEngineering_Demo.htm

Survey Areas:

Process definition

Project /program planning

Risk management

Requirements development

Requirements management

Trade studies

Interfaces

Product structure

Product integration

Test and verification

Project reviews

Validation

Configuration mgmt

Metrics

The Effectiveness of Systems Engineering: *On Federal System Development Programs*


First Public Release
Of Major New NDIA Study by
The Systems Engineering Effectiveness Committee
(SEEC)

Contents of this briefing for INCOSE-SCC derived from
the NDIA SEEC presentation at the NDIA Systems
Engineering Conference, October 23, 2007

Al Mink
SEEC Member
& SRA International

The SE Effectiveness Survey

Quantifies the relationship between the application of Systems Engineering best practices and the performance of system development projects



**Projects with better
Systems Engineering
capabilities deliver
better Project
Performance!**

TODAY'S OUTLINE

1. The Challenge
2. The Rigor
3. The Results!
4. Conclusions & Caveats

The Challenge

Stakeholder Analysis



Those interested in such a study – and their interests

Customers

- DoD #1 SE Issue – “Inconsistent SE Practices across life cycle”
- Validate initiatives to revitalize SE
- Increase emphasis of SE content in RFPs and Proposals

Industry (System Developers & Integrators)

- Proposal may skimp on SE; Budget pressures on SE

Associations & Academia

- Unable to fully satisfy their members and students

SE professionals

- Lack rigorous justification for their recommendations

The Challenge

Previous Studies – Partial Insights



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

Boehm & Valerdi, SE ROI (COCOMO), 2006

Analyzed SE activities from COCOMO II

Valerdi & Boehm, Constructive System Engineering Cost Model (COSYSMO), 2004

Developed parametric estimation model similar to COCOMO

Others...

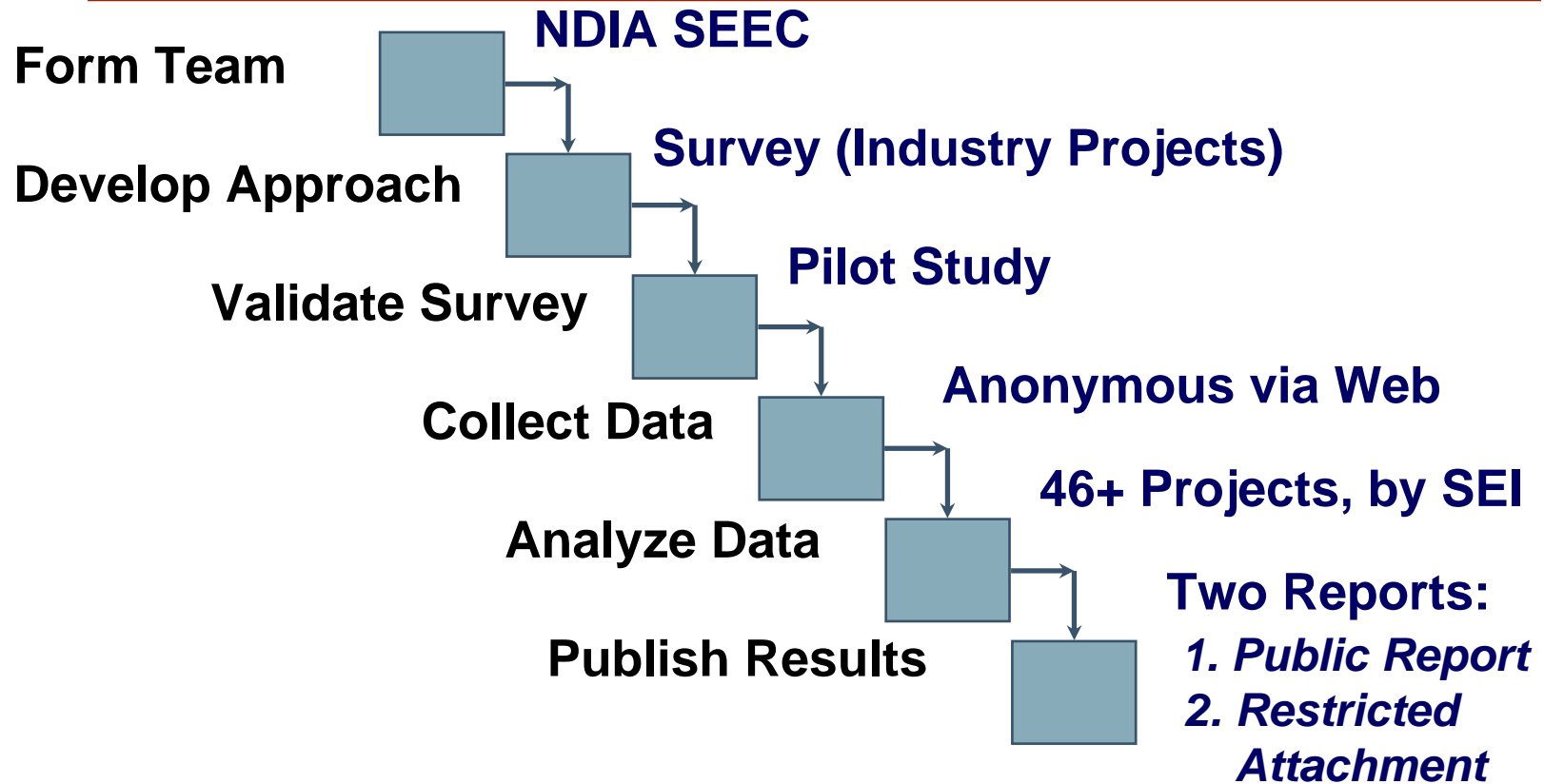
The Challenge

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 – 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 – 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 Rigor

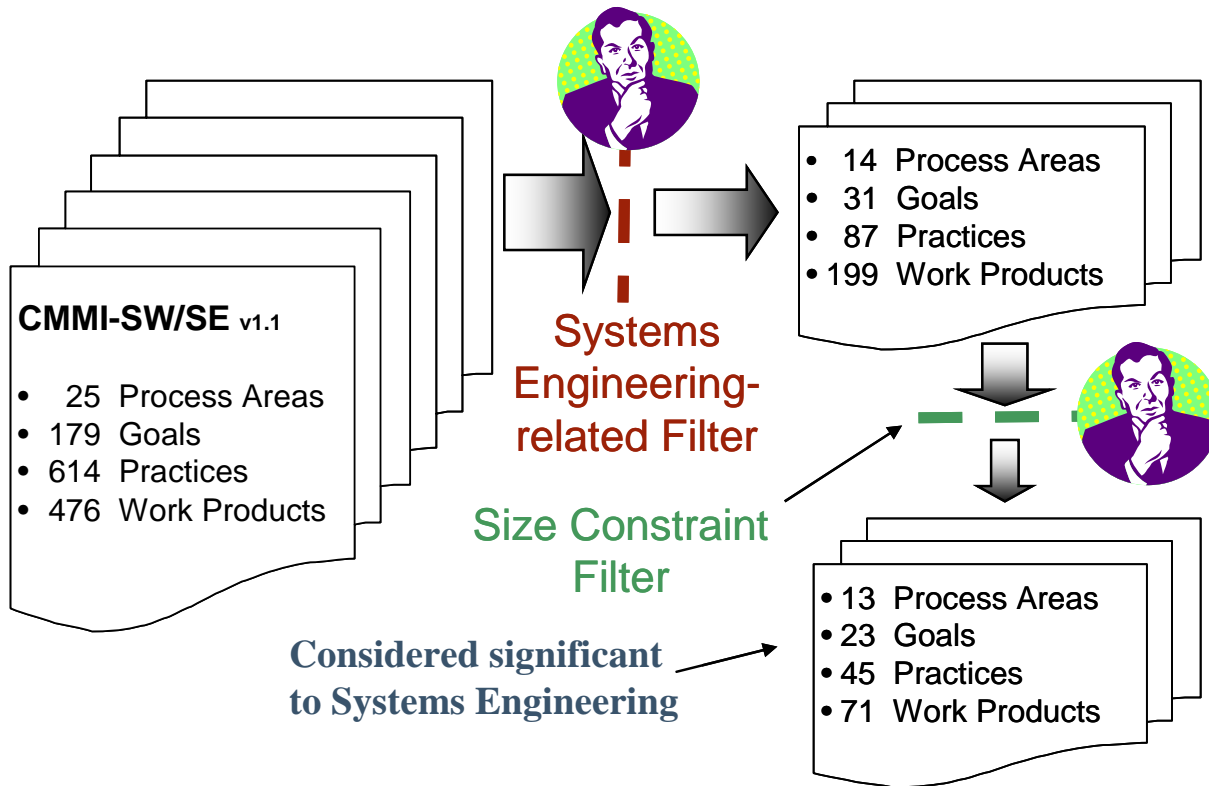
Followed Planned Lifecycle



This study spanned three years

The Rigor

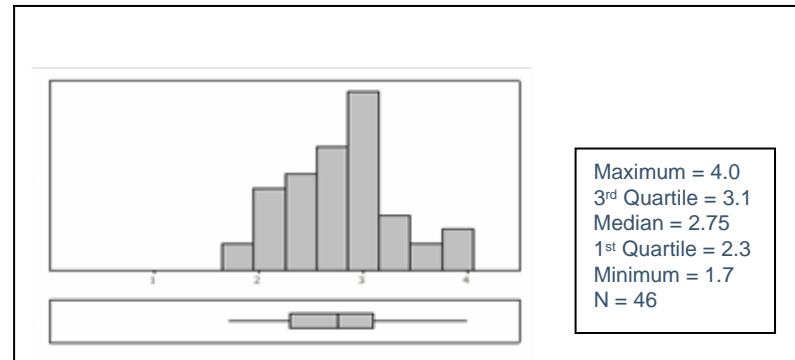
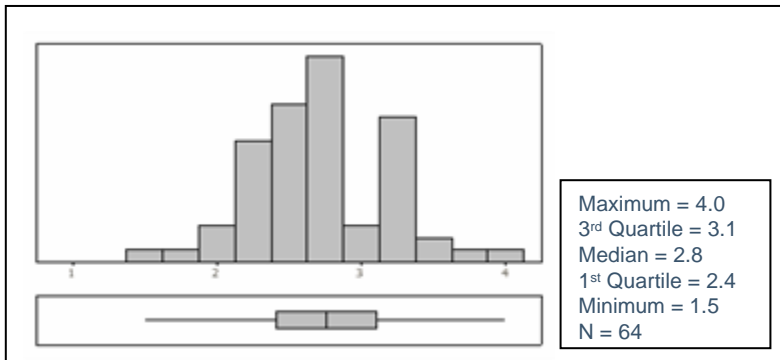
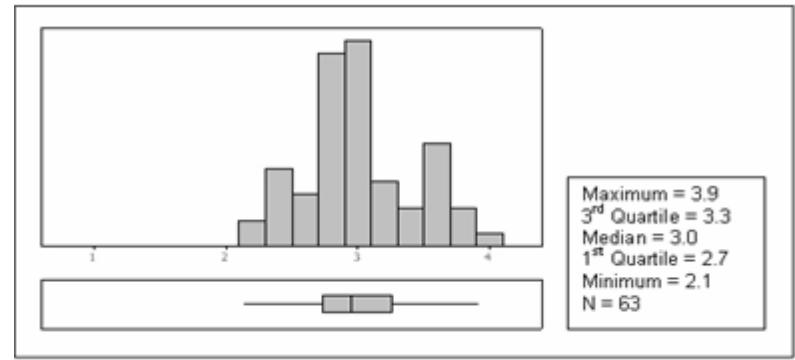
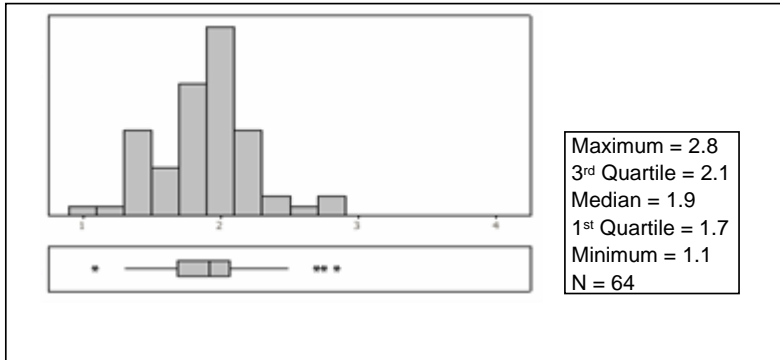
Formally Selected Set of SE Activities



**Survey was developed based on standards
and recognized SE experts**

The Rigor

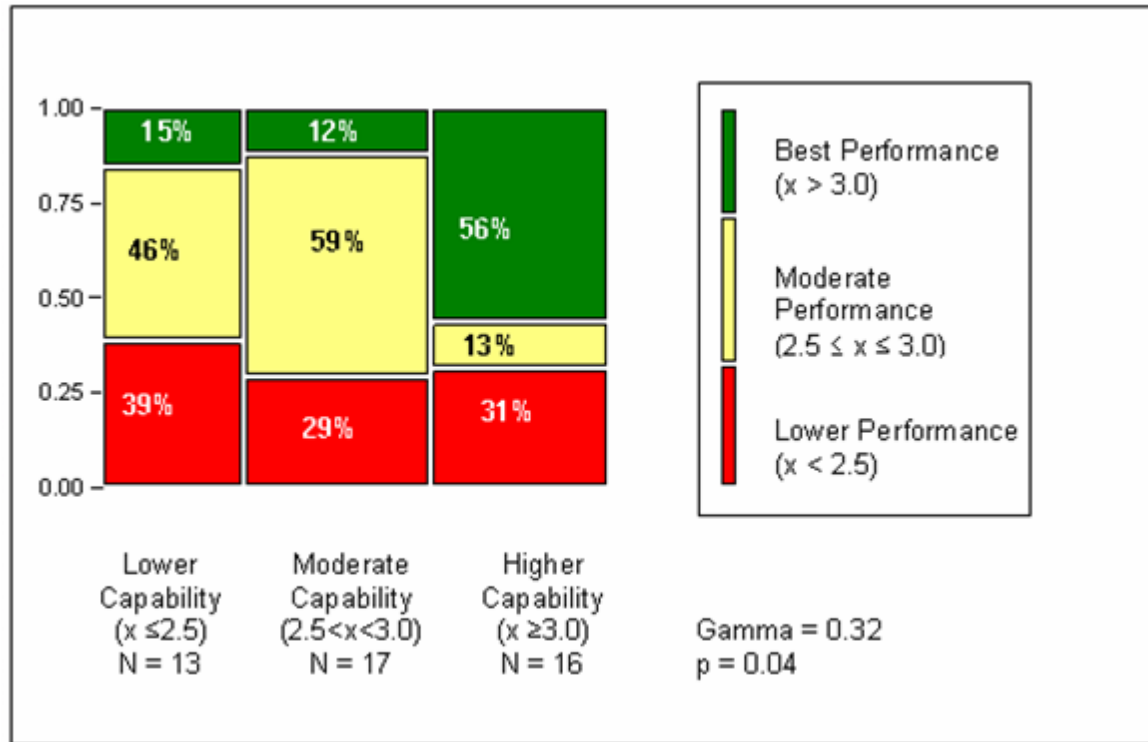
Validated Survey Responses



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

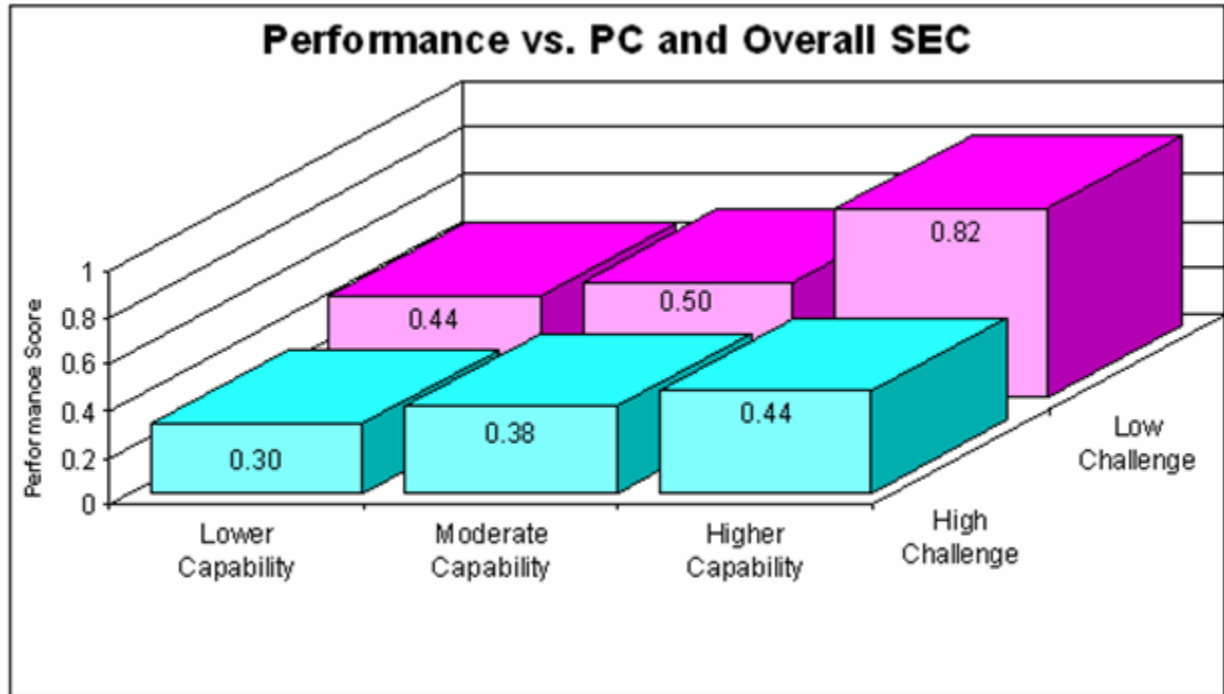
Results

SE Capability & Project Performance



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

Relating Project Performance to Project Challenge and SE Capability



Project challenge factors:

Project challenge factors:

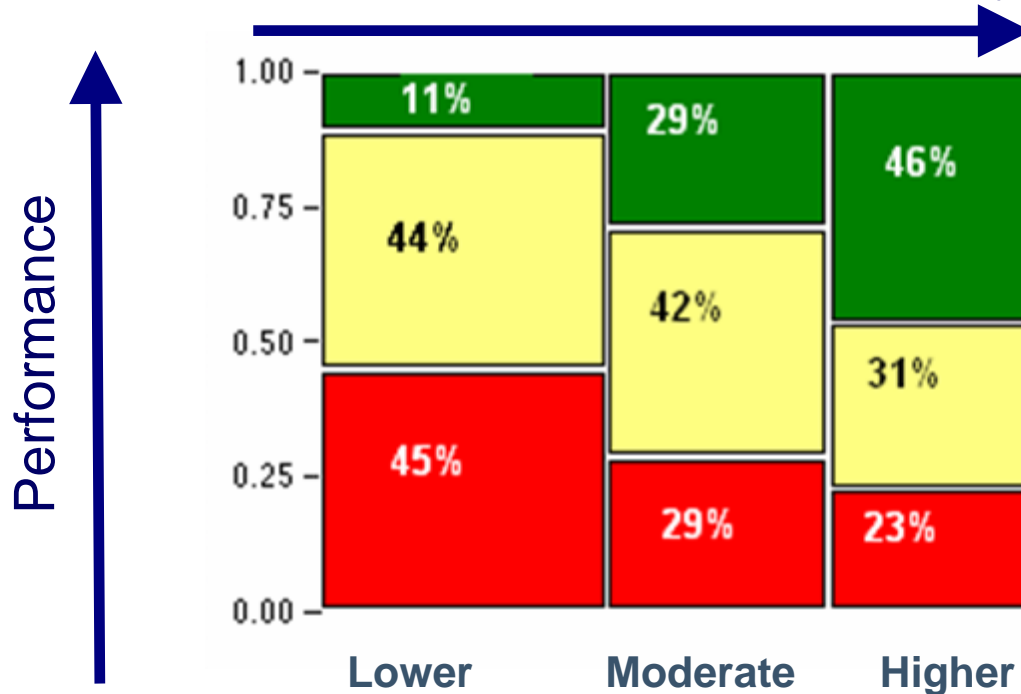
- Life cycle phases
- Project characteristics (e.g., size, effort, duration, volatility)
- Technical complexity
- Teaming relationships

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

Results

1. Product Architecture and Project Performance

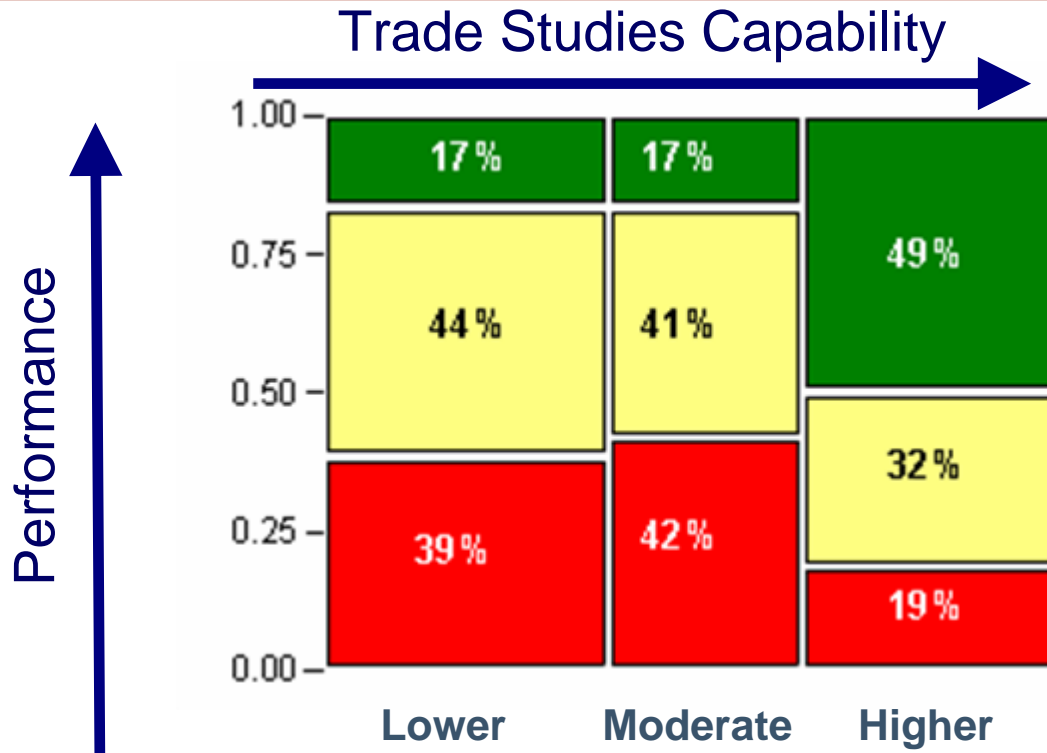
Product Architecture Capability



Projects with better Product Architecture show a “Moderately Strong / Strong” Positive Relationship with Performance

Results

2. Trade Studies and Project Performance

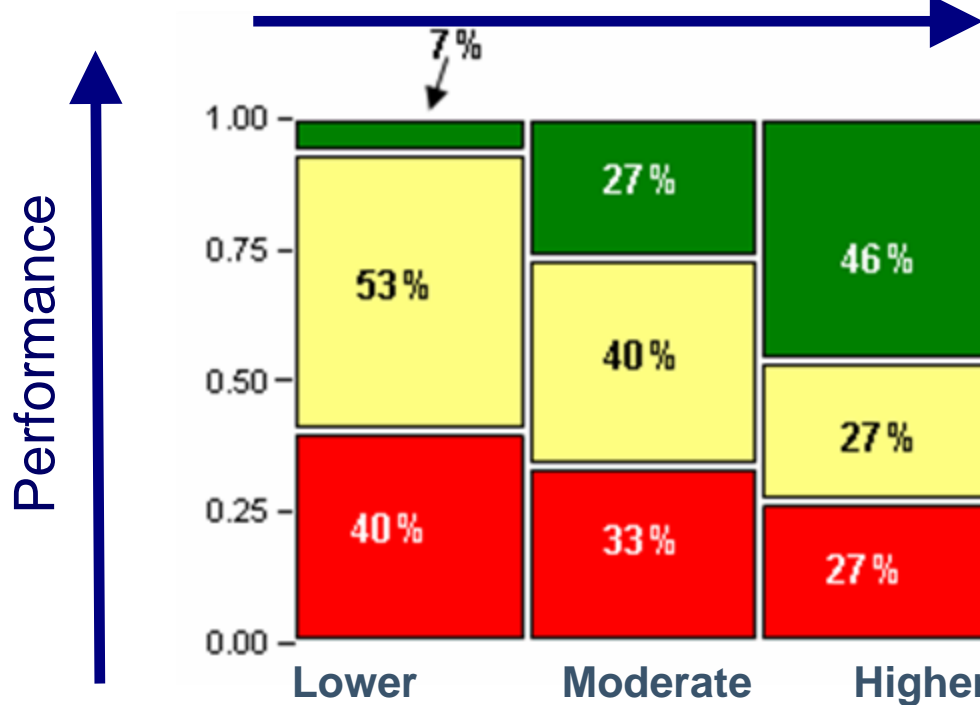


Projects with better Trade Studies show a “Moderately Strong / Strong” Positive Relationship with Performance

Results

3. Technical Solution and Project Performance

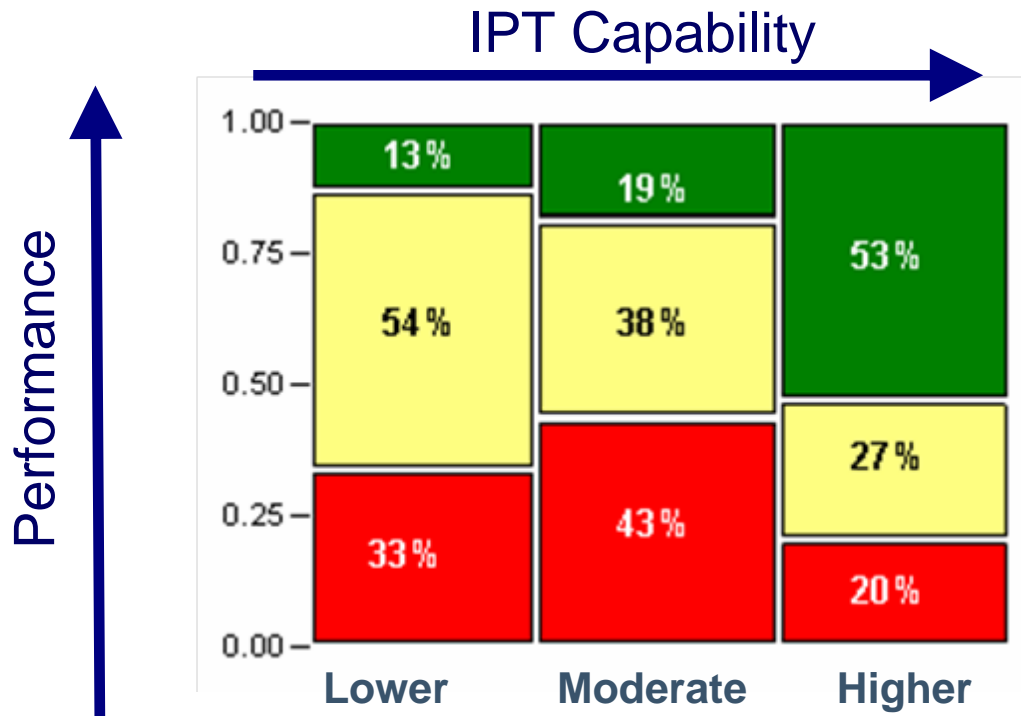
Technical Solution Capability



Projects with better Technical Solution show a “Moderately Strong” Positive Relationship with Performance

Results

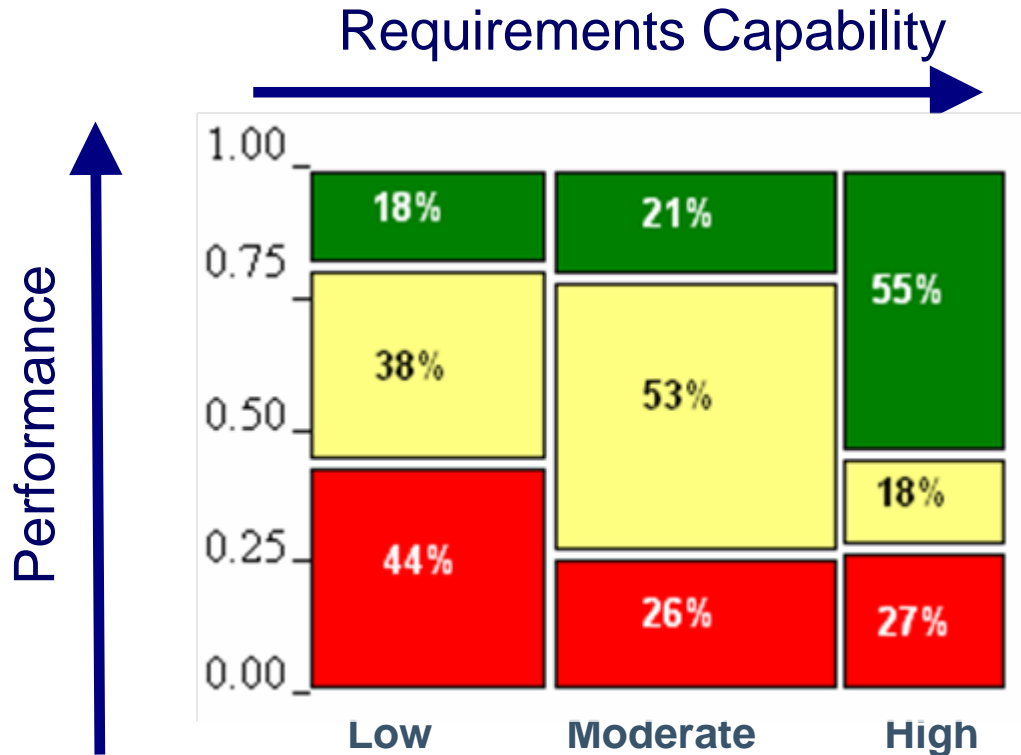
4. IPTs and Project Performance



Projects with better IPTs show a “Moderately Strong” Positive Relationship with Performance

Results

5. Requirements and Project Performance

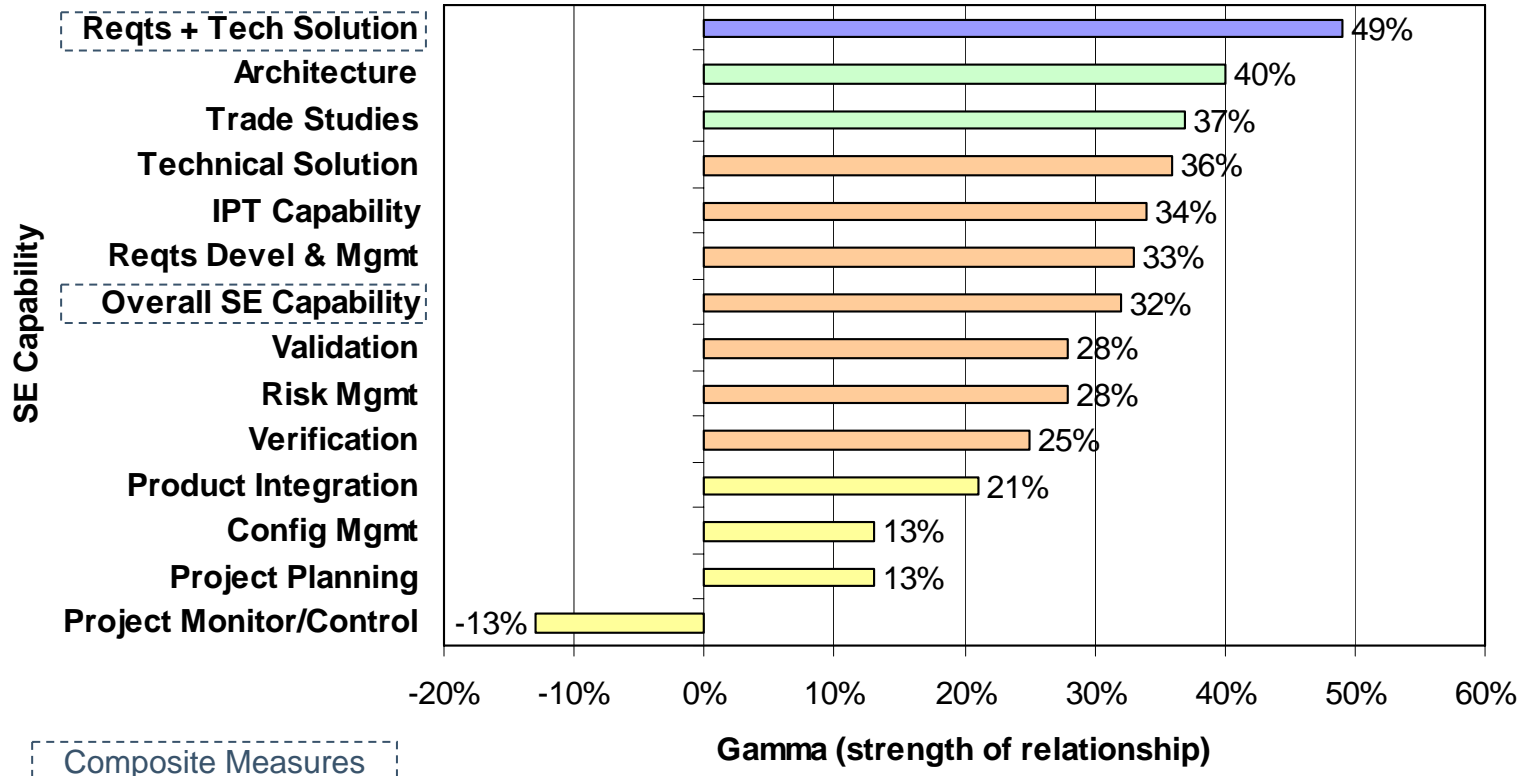


Projects with better Requirements Development and Management show a “Moderately Strong” Positive Relationship with Performance

Results

Summary of Relationships

Relationship of SE Processes to Program Performance



■ Strong Relationship
 ■ Moderately Strong to Strong Relationship
 ■ Moderately Strong Relationship
 ■ Weak Relationship

Conclusions & Caveats

Summary

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 “left side of SE Vee”
- 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

Conclusions & Caveats

Next Steps

- **Correlate Report Findings with Other Sources**
- **Develop Improvement Recommendations**
 - Policy, guidance, training, measures, reviews
- **Conduct Additional Analysis of Collected Data**
 - IV & V
 - Discover other relationships and correlations
- **Repeat the Survey to Gauge Improvements**
- **Survey Acquirers**

Acknowledgements



Primary Contributors

Alan R. Brown	Robert Bruff	Brian Donahue	Nicole Donatelli	Geoffrey Draper	Terry Doran
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Supporters

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Gerald Miller	Mike Phillips	Dave Zubrow	Larry Farrell		

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Questions?

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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**

Conclusions & Caveats



Consistent with “Top 5 SE Issues” (2006)*

- 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



Relative Project Performance

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

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
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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
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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
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Gamma relationship		Chance probability	
	Strong		Very low
	Moderately strong to strong		Low

Gamma relationship		Chance probability	
	Moderately strong		Moderately low
	Weak		Fair

Summary SE Relationships to Project Performance



Relative Project Performance

Gamma		Lower					Moderate					Higher					
Min. Range	#	Lo	# Med	Hi	Max. Range	Min. Range	#	Lo	# Med	Hi	Max. Range	Min. Range	#	Lo	# Med	Hi	Max. Range

Project Challenge

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Project Environment

CMMI	22%	13.0%
IMP	5%	39.0%
EXP	9%	33.0%

1.0	36%
1.0	25%
1.0	29%

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

*Based on small partitioned sample size

Systems Engineering Capability

Capability Area	Gamma	p	Min. Range	#	Lo	# Med	Hi	Max. Range	Min. Range	#	Lo	# Med	Hi	Max. Range	Min. Range	#	Lo	# Med	Hi	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			
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	37%	4.0%	1.0	39%	44%	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			
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Acquirer Capability

AC	-35	25%	25%	4.0
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Combined Capability and

REQ+TS+PC	63	36%	50%	4.0
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Lowest scoring SE capability areas in Lower Performing Projects*: Validation; Architecture; Requirements Development and Management

Gamma relationship

Strong
Moderately strong to strong

Chance probability

Very low
Low

Gamma relationship

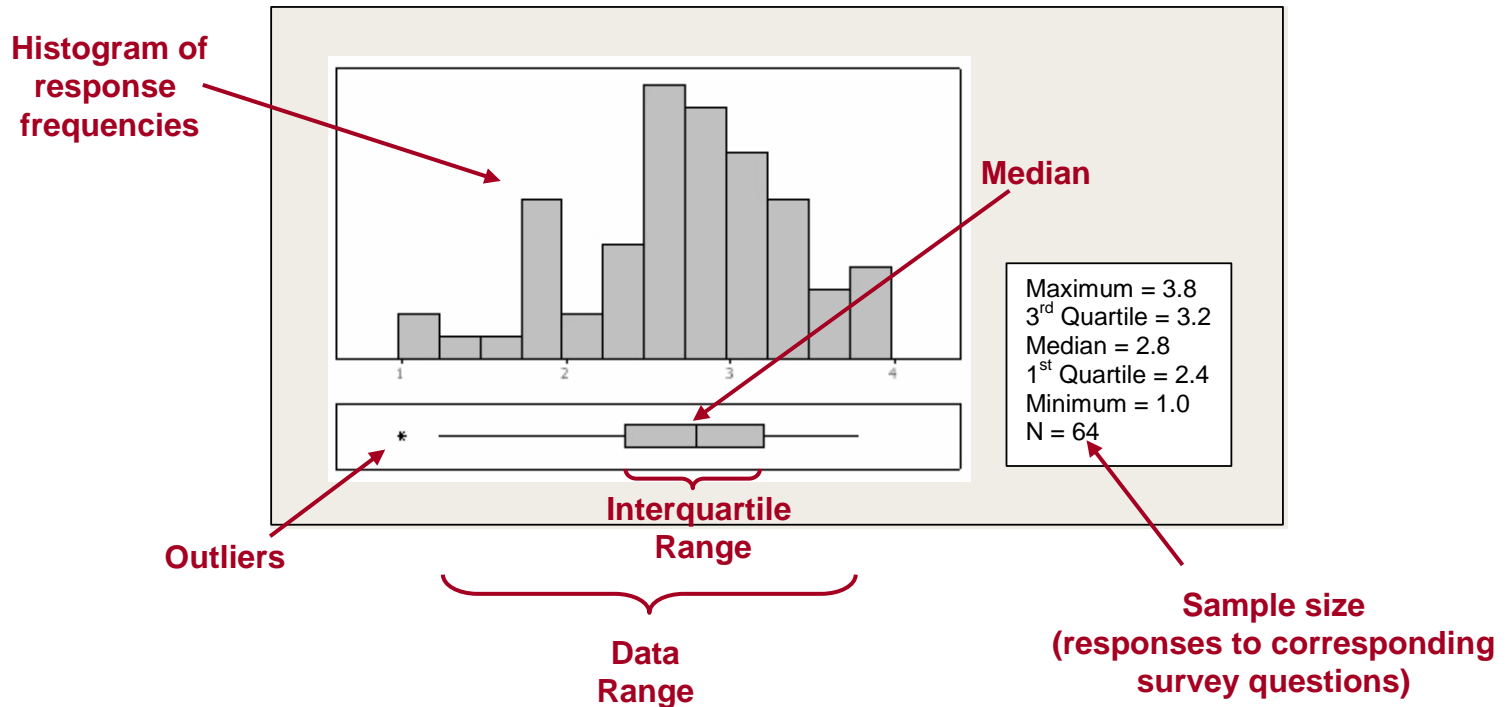
Moderately strong
Weak

Chance probability

Moderately low
Fair

Terminology and Notation

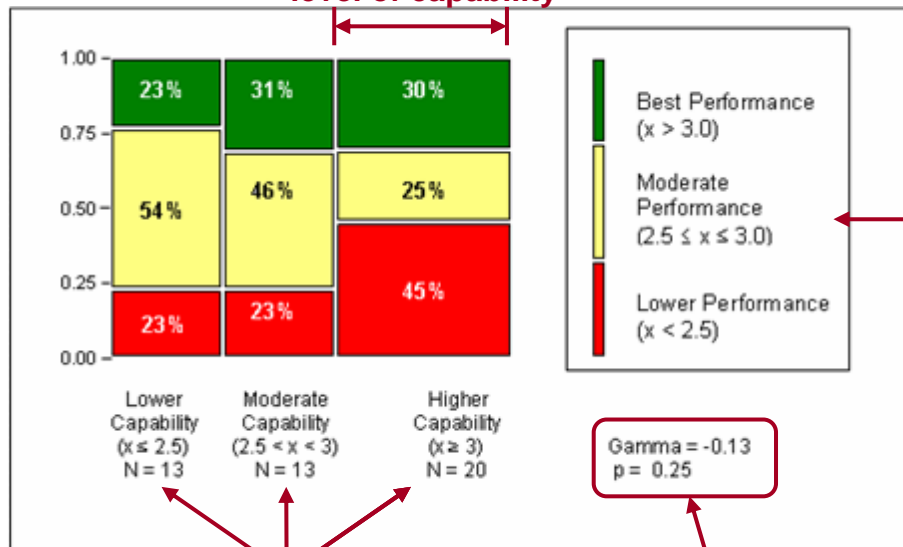
Distribution Graph



Terminology and Notation

Mosaic Chart

Column width represents proportion of projects with this level of capability



Relative performance distribution of the sample

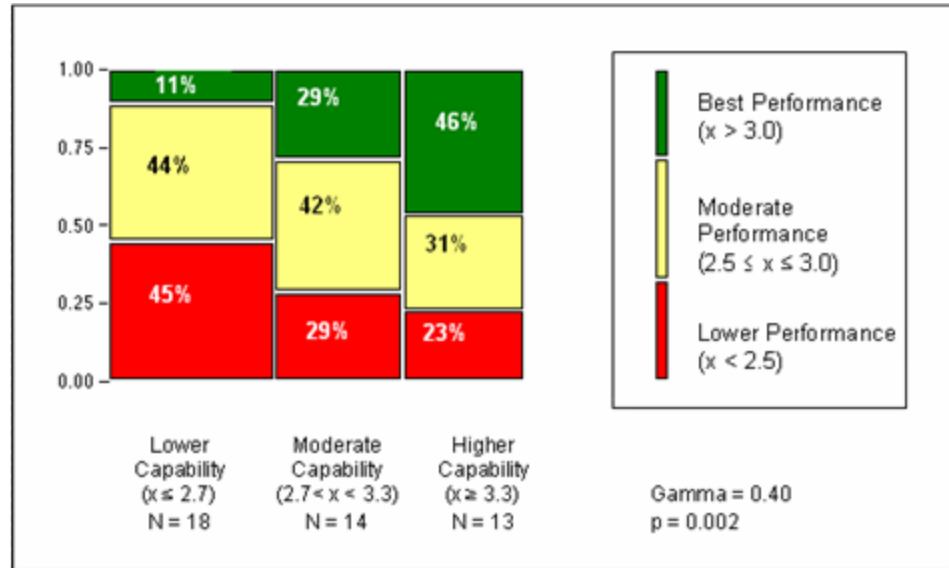
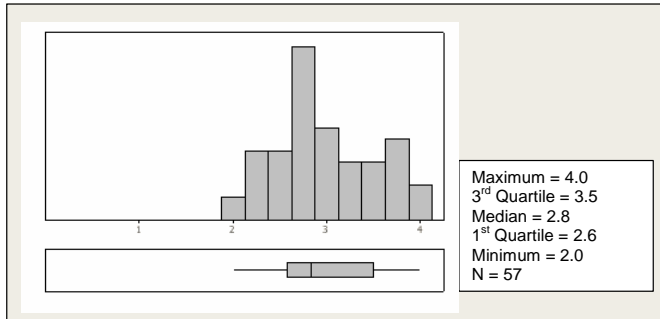
Gamma: measures strength of relationship between two ordinal variables

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
40%	0.2%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	45%	44%	11%	2.7

Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
2.7	29%	42%	29%	3.3

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
3.3	23%	31%	46%	4.0

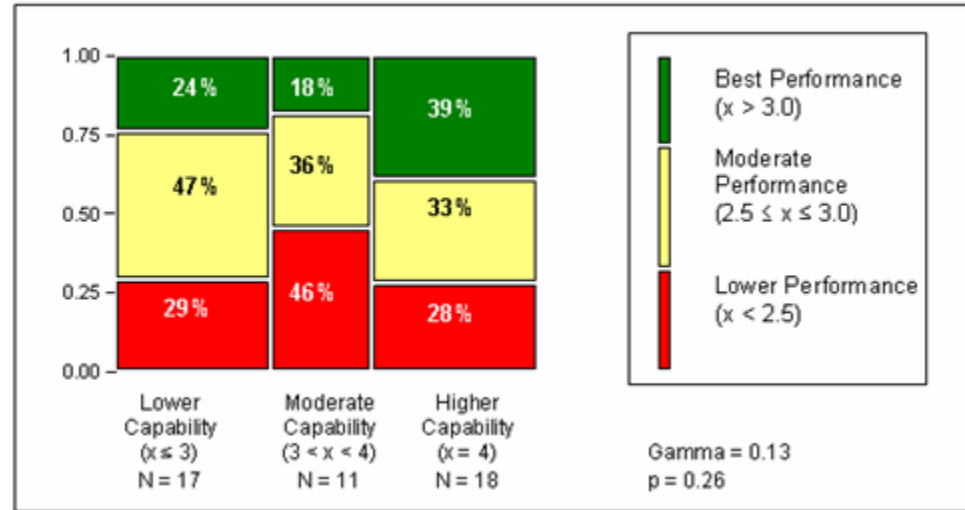
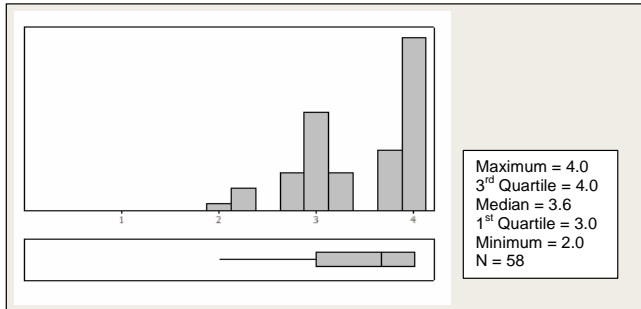
ARCH

SE Capability: Product Architecture (ARCH)

Survey Questions

ID	Question	Response range
<i>IF01</i>	This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail	<ul style="list-style-type: none"> ●strongly disagree ●disagree ●agree ●strongly agree
<i>IF02</i>	Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them	<ul style="list-style-type: none"> ●strongly disagree ●disagree ●agree ●strongly agree
<i>IF03a</i>	For this project, the product high-level structure is documented, kept up to date, and managed under configuration control	<ul style="list-style-type: none"> ●strongly disagree ●disagree ●agree ●strongly agree
<i>IF03b</i>	For this project, the product high-level structure is documented using multiple views (e.g. functional views, module views, etc.	<ul style="list-style-type: none"> ●strongly disagree ●disagree ●agree ●strongly agree
<i>IF03c</i>	For this project, the product high-level structure is accessible to all relevant project personnel	<ul style="list-style-type: none"> ●strongly disagree ●disagree ●agree ●strongly agree
<i>IF04</i>	This project has defined and documented guidelines for choosing COTS product components	<ul style="list-style-type: none"> ●strongly disagree ●disagree ●agree ●strongly agree

SE Capability: Configuration Management (CM)



Relationship to project performance: Weak positive relationship

SE Capability

CM

Gamma	p
13%	26.0%

Lower					
Min. Range	# Lo	# Med	# Hi	Max. Range	
1.0	29%	47%	24%	3.0	

Moderate					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.0	46%	36%	18%	3.67	

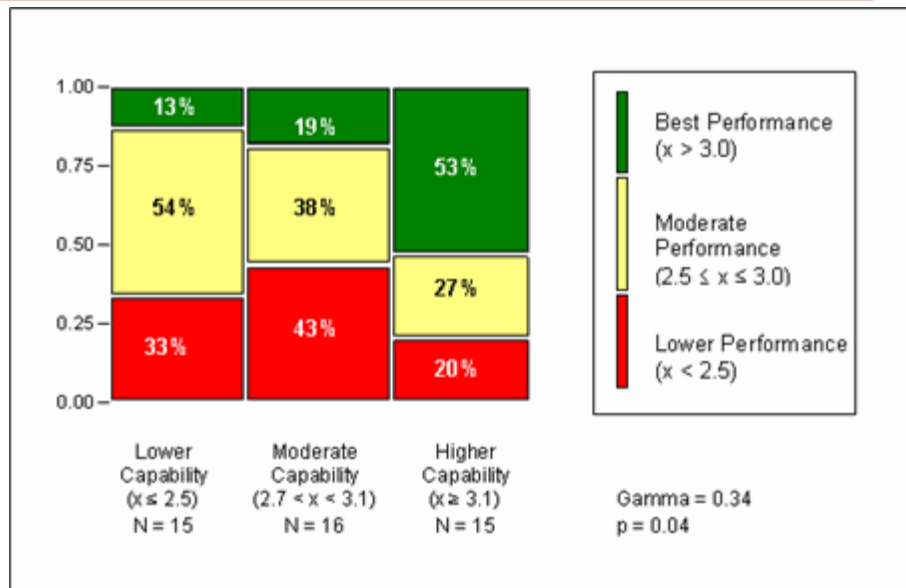
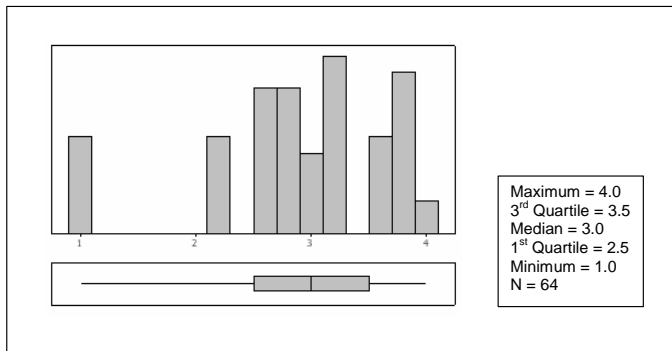
Higher					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.67	28%	33%	39%	4.0	

SE Capability: Configuration Management (CM)

Survey Questions

ID	Question	Response Range
V&V06	This project has a configuration management system that charts a Change Control Board to disposition change requests	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
V&V07	This project maintains records of requested and implemented changes to configuration-managed items	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
V&V08	This project creates and manages configuration baselines (e.g., functional, allocated, product)	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree

SE Capability: IPT-Related Capability (IPT)



Relationship to project performance: Moderately strong positive relationship

SE Capability

IPT

Gamma	p
34%	4.0%

Lower					
Min. Range	# Lo	# Med	# Hi	Max. Range	
1.0	33%	54%	13%	2.5	

Moderate					
Min. Range	# Lo	# Med	# Hi	Max. Range	
2.5	43%	38%	19%	3.1	

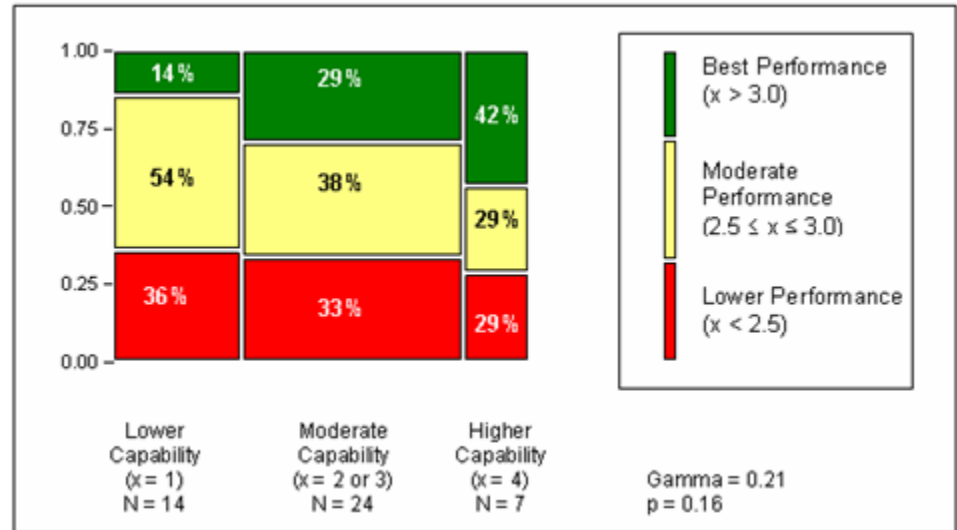
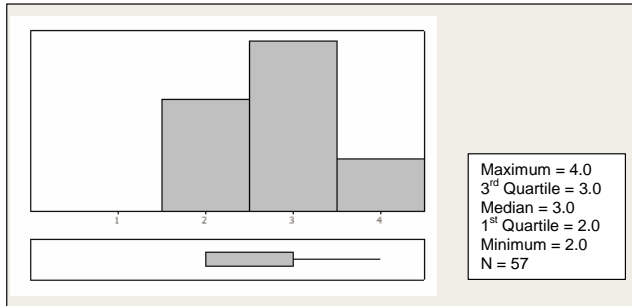
Higher					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.1	20%	27%	53%	4.0	

SE Capability: IPT-Related Capability (IPT)

Survey Questions

ID	Question	Response range
<i>Proj03</i>	This project uses integrated product teams (IPTs)	<ul style="list-style-type: none"> •Yes •No
<i>Proj04</i>	This project makes effective use of integrated product teams (IPTs)	<ul style="list-style-type: none"> •highly compliant •largely compliant; •moderately compliant •not compliant
<i>Proj06</i>	My suppliers actively participate in IPTs	<ul style="list-style-type: none"> •highly compliant •largely compliant; •moderately compliant •not compliant
<i>Proj07a</i>	This project has an IPT with assigned responsibility for systems engineering	<ul style="list-style-type: none"> •highly compliant •largely compliant; •moderately compliant •not compliant
<i>Proj07b</i>	This project has Systems Engineering representation on each IPT	<ul style="list-style-type: none"> •highly compliant •largely compliant; •moderately compliant •not compliant

SE Capability: Product Integration (PI)



Relationship to project performance: Weak positive relationship

SE Capability

Gamma	p
21%	16.0%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	36%	54%	14%	1.5

Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.5	33%	38%	29%	3.5

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
3.5	29%	29%	42%	4.0

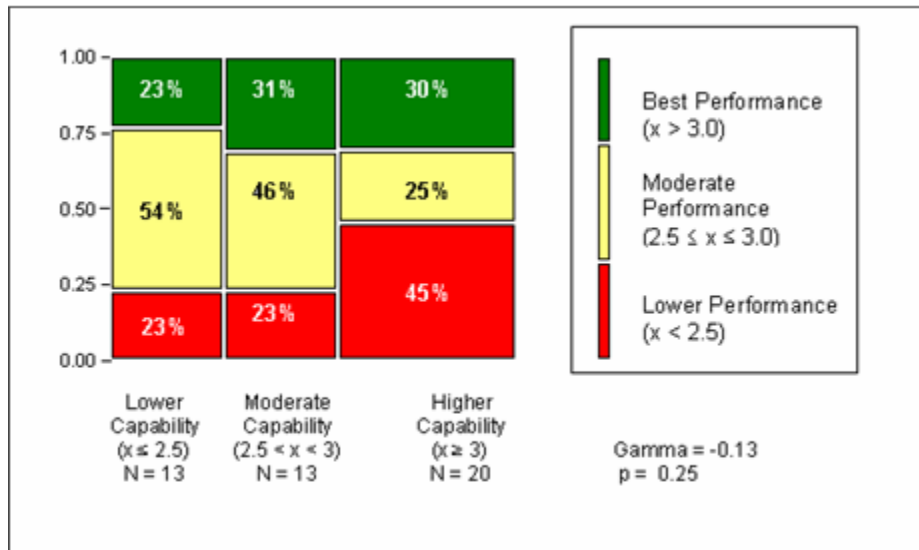
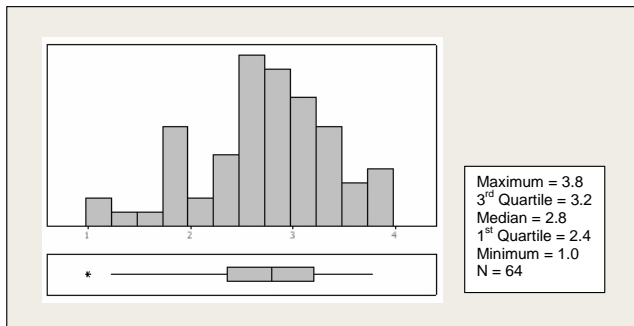
PI

SE Capability: Product Integration (PI)

Survey Question

ID	Question	Response range
<i>IF05</i>	This project has accurate and up-to-date documents defining its product integration process, plans, criteria, etc. throughout the life cycle	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree

SE Capability: Project Monitoring and Control (PMC)



Relationship to project performance: Weak negative relationship

SE Capability

PMC

Gamma	p
-13%	25.0%

Lower					
Min. Range	# Lo	# Med	# Hi	Max. Range	
1.0	23%	54%	23%	2.5	

Moderate					
Min. Range	# Lo	# Med	# Hi	Max. Range	
2.5	23%	46%	31%	3.0	

Higher					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.0	45%	25%	30%	4.0	

SE Capability: Project Monitoring and Control (PMC)

Survey Questions (Part 1)

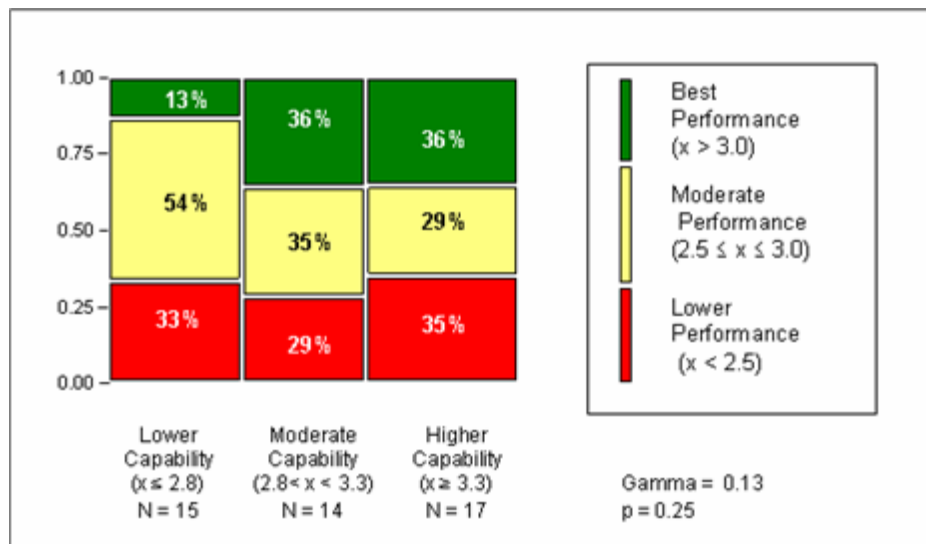
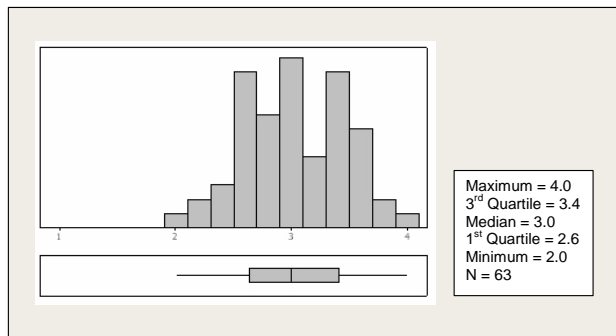
ID	Question	Response range
<i>Cont13</i>	Do you separately cost and track systems engineering activities?	Yes No
<i>Cont14a</i>	Approximately what percentage of non-recurring engineering (NRE) does systems engineering represent?	Percentages quantized as: •<= 5% •<= 10% •<= 15% •<= 25% •> 25%
<i>Cont14b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

SE Capability: Project Monitoring and Control (PMC)

Survey Questions (Part 2)

ID	Question	Response range	
<i>Perf02e</i>	EVMS is linked to the technical effort through the WBS and the IMP/IMS	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree 	
<i>OPerf05</i>	Does this project track reports of problems from fielded items?	<ul style="list-style-type: none"> •Yes •No 	Scored by the number of positive responses
<i>OPerf06</i>	Does the project conduct an engineering assessment of all field trouble reports?	<ul style="list-style-type: none"> •Yes •No 	
<i>OPerf07</i>	The results of this engineering assessment feed into ...	<ul style="list-style-type: none"> •operational hazard risk assessments •materiel readiness assessments •system upgrades planning •other 	

SE Capability: Project Planning (PP)



Relationship to project performance: Weak positive relationship

SE Capability

PP

Gamma	p
13%	25.0%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	33%	54%	13%	2.8

Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
2.8	29%	35%	36%	3.3

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
3.3	35%	29%	36%	4.0

SE 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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
PD02a	This project has an accurate and up-to-date Work Breakdown Structure (WBS) that includes task descriptions and work package descriptions	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
PD02b	This project has an accurate and up-to-date Work Breakdown Structure (WBS) that is based upon the product structure	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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.	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE Capability: Project Planning (PP)

Survey Questions (Part 2)

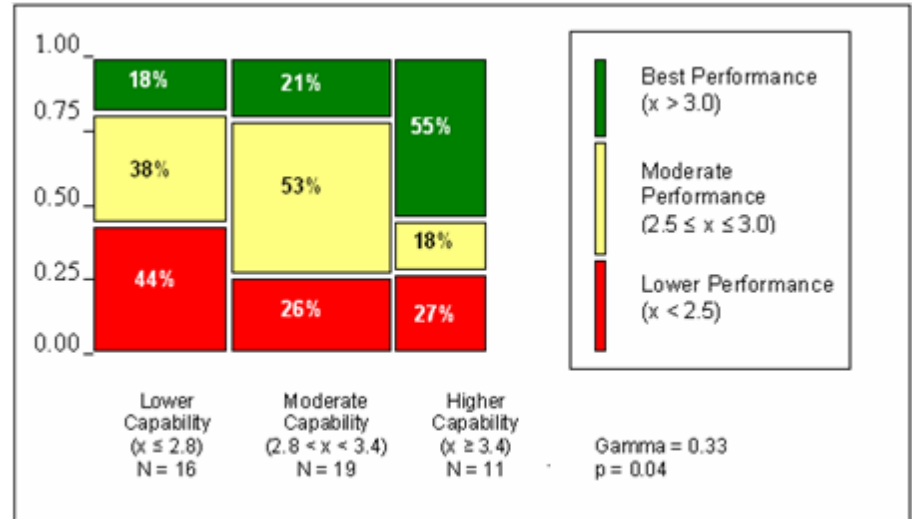
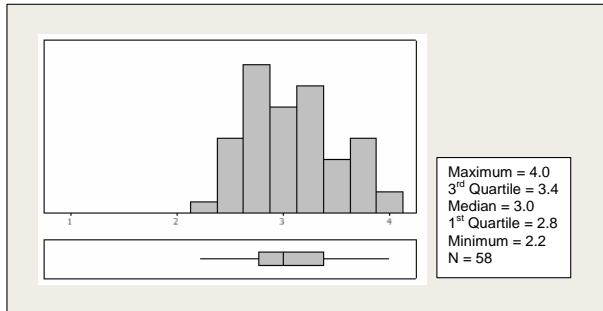
ID	Question	Response range
<i>PD03c</i>	This project's Technical Approach (i.e. a top-level strategy and methodology to create the initial conceptual design for product development) is developed with the active participation of all appropriate functional stakeholder	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD04a</i>	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)	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD04b</i>	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD04c</i>	This project has a top-level plan, such as an Integrated Master Plan (IMP), that is consistent with the WBS	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD05a</i>	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD05b</i>	This project has an integrated event-based schedule that contains a compilation of key technical accomplishments (e.g., a Systems Engineering Master Schedule)	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD05c</i>	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE Capability: Project Planning (PP)

Survey Questions (Part 3)

ID	Question	Response range
<i>PD05d</i>	This project has an integrated event-based schedule that is consistent with the WBS	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD05e</i>	This project has an integrated event-based schedule that identifies the critical path of the program schedule	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD06</i>	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD07</i>	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)	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD08</i>	Those who perform systems engineering activities actively participate in the development and updates of the project planning	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD09</i>	Those who perform systems engineering activities actively participate in tracking/reporting of task progress	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE Capability: Requirements Development & Mgmt (REQ)



Relationship to project performance: **Moderately strong positive relationship**

SE Capability

Gamma	p
33%	4.0%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	44%	38%	18%	2.8

Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
2.8	26%	53%	21%	3.4

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
3.4	27%	18%	55%	4.0

REQ

SE Capability: Requirements Development & Mgmt (REQ)

Survey Questions (Part 1)

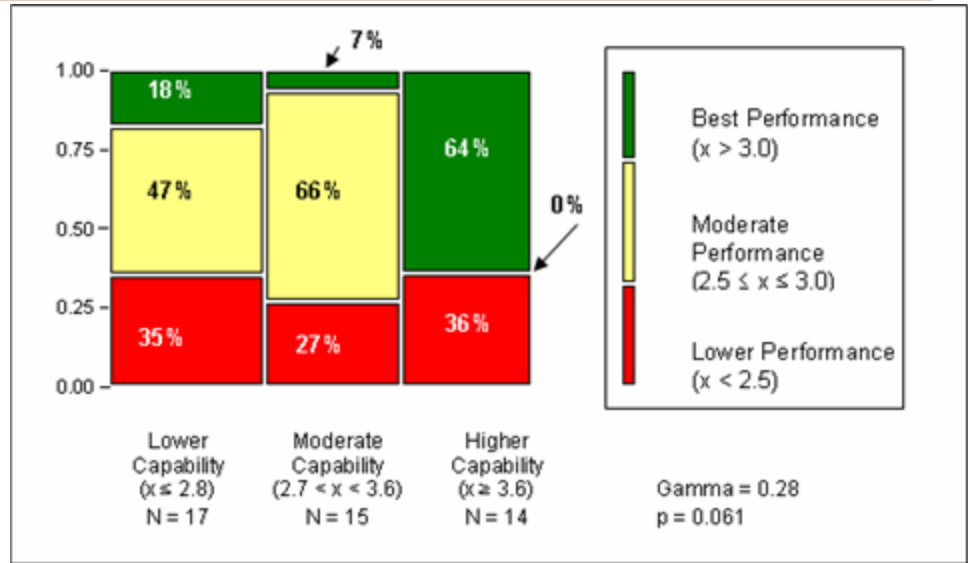
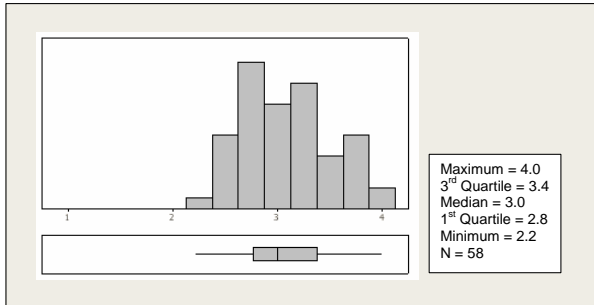
ID	Question	Response range
<i>RD01a</i>	This project maintains an up-to-date and accurate listing of all requirements specified by the customer, to include regulatory, statutory, and certification requirements	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD01b</i>	This project maintains an up-to-date and accurate listing of all requirements derived from those specified by the customer	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD02</i>	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD03a</i>	This project documents and maintains accurate and up-to-date descriptions of operational concepts and their associated scenarios	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD03b</i>	This project documents and maintains accurate and up-to-date descriptions of use cases (or their equivalent)	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD03c</i>	This project documents and maintains accurate and up-to-date descriptions of product installation, maintenance and support concepts	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD04</i>	This project has documented criteria for identifying authorized requirements providers to avoid requirements creep and volatility	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE 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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
RD06	The requirements for this project are approved in a formal and documented manner by relevant stakeholders	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
RD07	This project performs and documents requirements impact assessments for proposed requirements changes	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
RD08	This project develops and documents project requirements based upon stakeholder needs, expectations, and constraints	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
RD09	This project has an accurate and up-to-date requirements tracking system	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
RD10a	For this project, the requirements documents are managed under a configuration control process	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
RD10b	For this project, the requirements documents are accessible to all relevant project staff	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE Capability: Risk Management (RSKM)



Relationship to project performance:

Moderately strong positive relationship

SE Capability

Gamma	p
28%	6.1%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	35%	47%	18%	2.8

Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
2.8	27%	66%	7%	3.6

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
3.6	36%	0%	64%	4.0

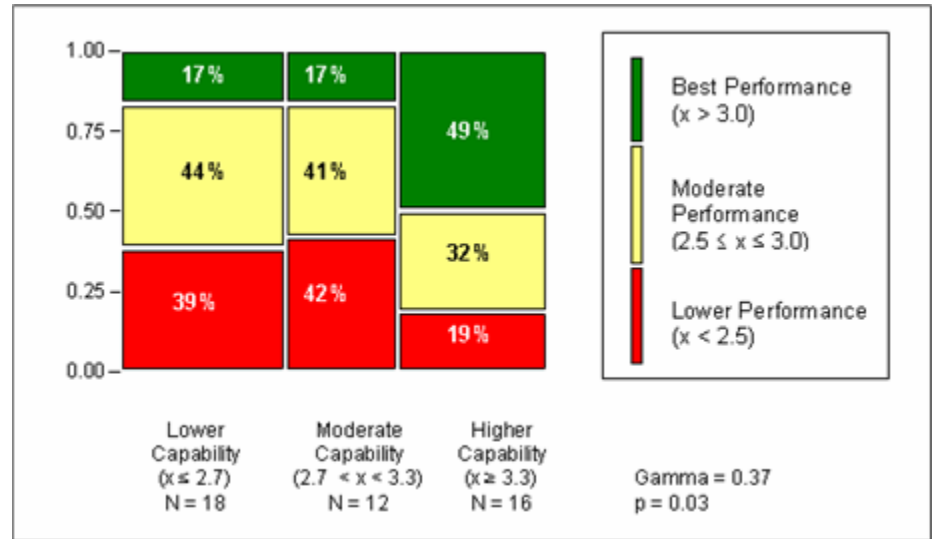
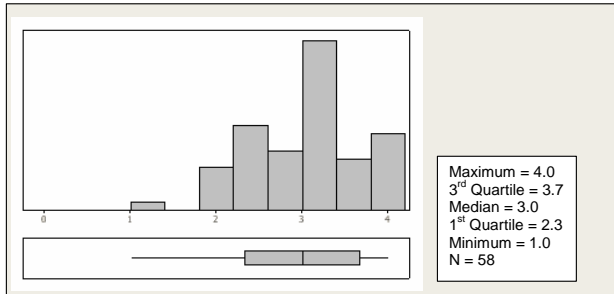
RSKM

SE Capability: Risk Management (RSKM)

Survey Questions

ID	Question	Response range
<i>PD11a</i>	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)	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD11b</i>	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD11c</i>	This project has a Risk Management process that monitors and reports the status of risk mitigation activities and resources	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD11d</i>	This project has a Risk Management process that assesses risk against achievement of an event-based schedule	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>PD12</i>	This project's Risk Management process is integrated with program decision-making	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE Capability: Trade Studies (TRADE)



Relationship to project performance: Moderately strong to strong positive relationship

SE Capability

Gamma	p
37%	3.0%

Lower					
Min. Range	# Lo	# Med	# Hi	Max. Range	
1.0	39%	44%	17%	2.7	

Moderate					
Min. Range	# Lo	# Med	# Hi	Max. Range	
2.7	42%	41%	17%	3.3	

Higher					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.3	19%	32%	49%	4.0	

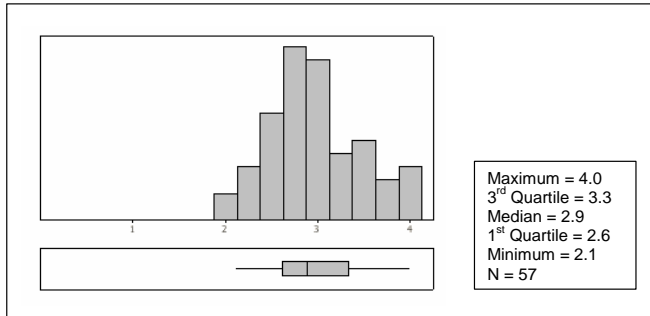
TRADE

SE Capability: Trade Studies (TRADE)

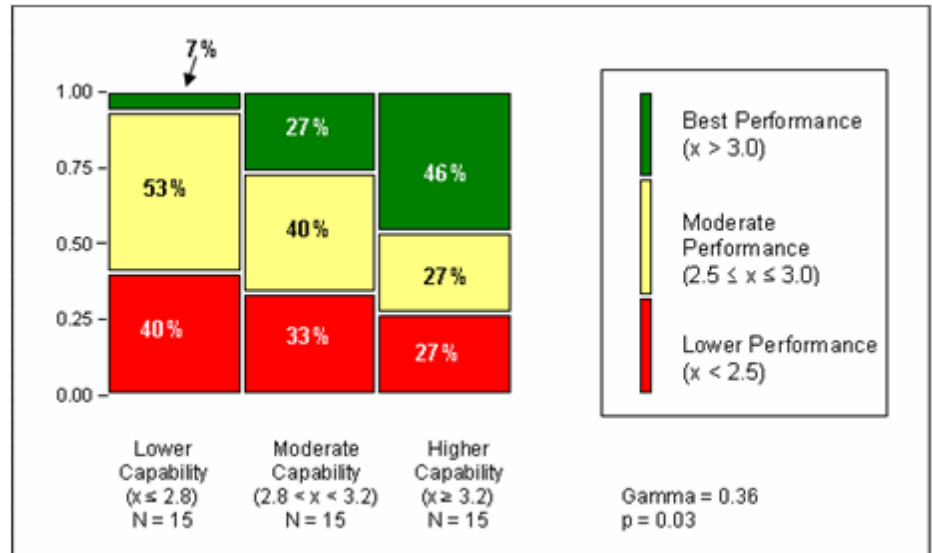
Survey Questions

ID	Question	Response range
<i>RD11</i>	Stakeholders impacted by trade studies are involved in the development and performance of those trade studies	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
<i>RD12</i>	This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
<i>RD13</i>	Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff	<ul style="list-style-type: none">•strongly disagree•disagree•agree•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
36%	3.0%

Lower					
Min. Range	# Lo	# Med	# Hi	Max. Range	
1.0	40%	53%	7%	2.8	

Moderate					
Min. Range	# Lo	# Med	# Hi	Max. Range	
2.8	33%	40%	27%	3.2	

Higher					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.2	27%	27%	46%	4.0	

TS

SE Capability: Technical Solution (TS)

Survey Questions (Part 1)

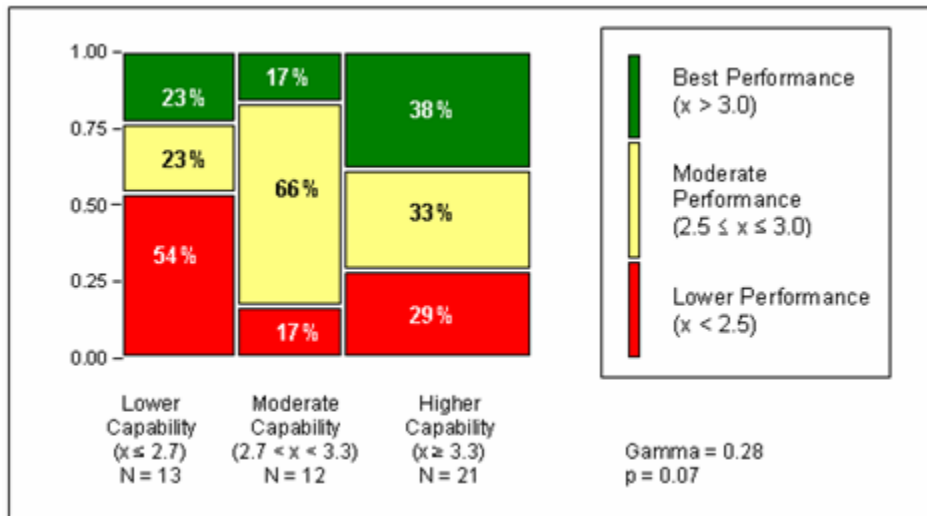
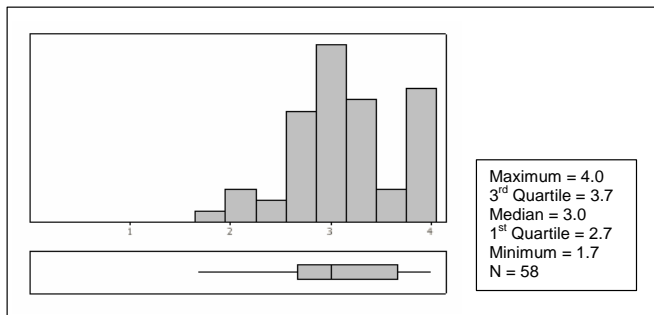
ID	Question	Response Range
<i>RD11</i>	Stakeholders impacted by trade studies are involved in the development and performance of those trade studies	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD12</i>	This project performs and documents trade studies between alternate solutions based upon definitive and documented selection criteria	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>RD13</i>	Documentation of trade studies is maintained in a defined repository and is accessible to all relevant project staff	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>IF01</i>	This project maintains accurate and up-to-date descriptions (e.g. interface control documents, models, etc.) defining interfaces in detail	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree
<i>IF02</i>	Interface definition descriptions are maintained in a designated location, under configuration management, and accessible to all who need them	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

SE Capability: Technical Solution (TS)

Survey Questions (Part 2)

ID	Question	Response Range
<i>IF03a</i>	For this project, the product high-level structure is documented, kept up to date, and managed under configuration control	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
<i>IF03b</i>	For this project, the product high-level structure is documented using multiple views (e.g. functional views, module views, etc.)	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
<i>IF03c</i>	For this project, the product high-level structure is accessible to all relevant project personnel	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
<i>IF04</i>	This project has defined and documented guidelines for choosing COTS product components	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree

SE Capability: Validation (VAL)



Relationship to project performance: Moderately strong positive relationship

SE Capability

VAL

Gamma	p
28%	7.0%

Lower					
Min. Range	# Lo	# Med	# Hi	Max. Range	
1.0	54%	23%	23%	2.7	

Moderate					
Min. Range	# Lo	# Med	# Hi	Max. Range	
2.7	17%	66%	17%	3.3	

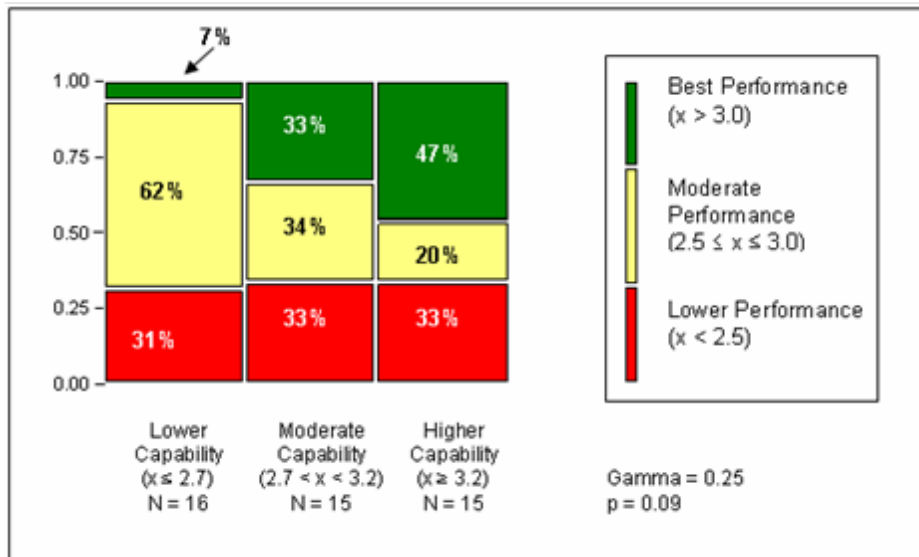
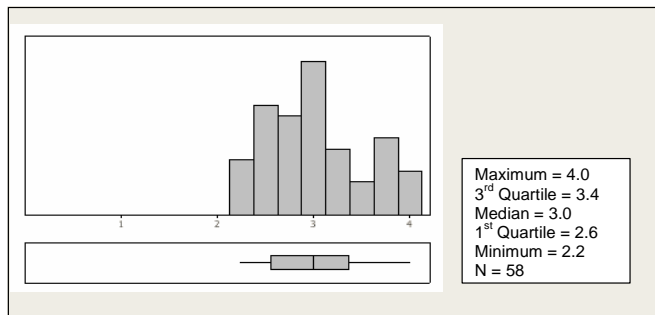
Higher					
Min. Range	# Lo	# Med	# Hi	Max. Range	
3.3	29%	33%	38%	4.0	

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	<ul style="list-style-type: none">•strongly disagree•disagree•agree•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	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree
V&V05	This project maintains a listing of items managed under configuration control	<ul style="list-style-type: none">•strongly disagree•disagree•agree•strongly agree

SE Capability: Verification (VER)



Relationship to project performance: **Moderately strong positive relationship**

SE Capability

	Gamma		Lower					Moderate					Higher				
	Gamma	p	Min. Range	# Lo	# Med	# Hi	Max. Range	Min. Range	# Lo	# Med	# Hi	Max. Range	Min. Range	# Lo	# Med	# Hi	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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •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	<ul style="list-style-type: none"> •strongly disagree •disagree •agree •strongly agree

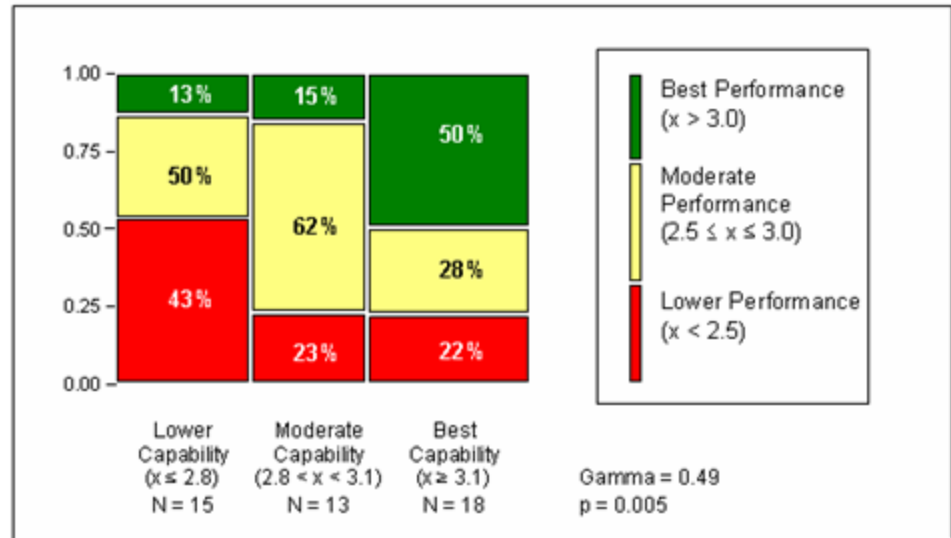
SE Capability: Verification (VER)

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	<ul style="list-style-type: none">•strongly disagree•disagree•agree•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	<ul style="list-style-type: none">•strongly disagree•disagree•agree•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	<ul style="list-style-type: none">•strongly disagree•disagree•agree•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

REQ+TS

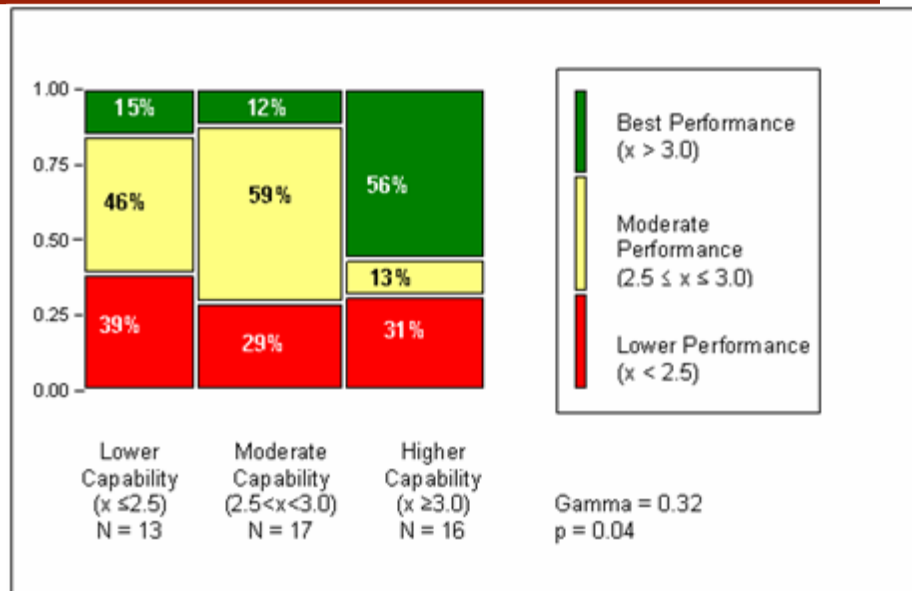
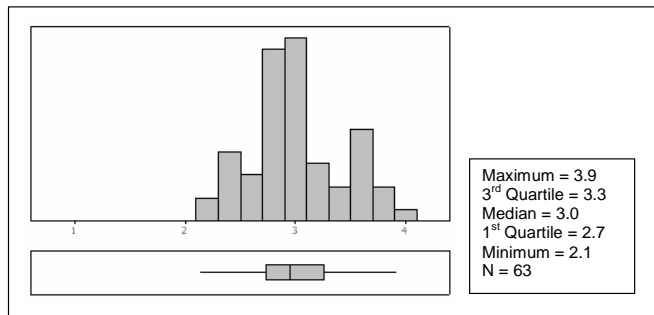
Gamma	p
49%	0.5%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	43%	50%	13%	2.8

Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
2.8	23%	62%	15%	3.1

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
3.1	22%	28%	50%	4.0

SE Capability: Total Systems Engineering Capability



Relationship to project performance: Moderately strong positive relationship

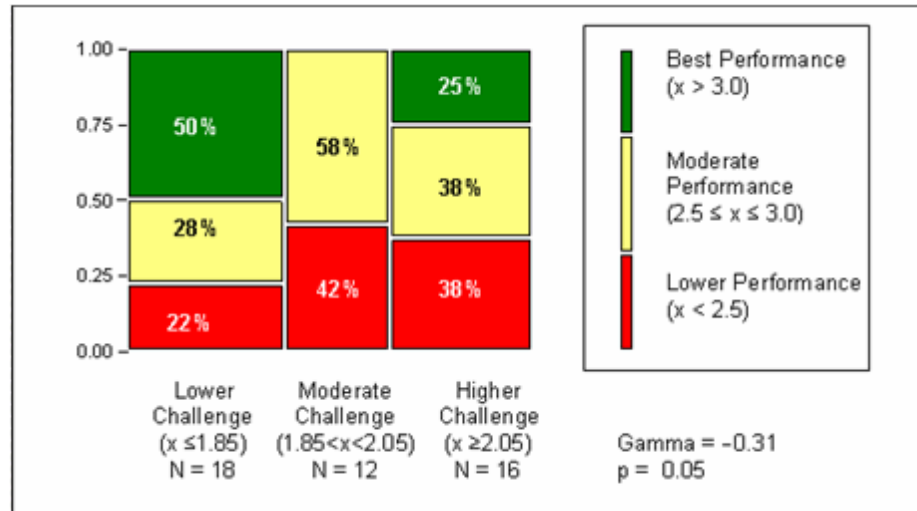
SE Capability

	Gamma	p	Lower					Moderate					Higher				
			Min. Range	# Lo	# Med	# Hi	Max. Range	Min. Range	# Lo	# Med	# Hi	Max. Range	Min. Range	# Lo	# Med	# Hi	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
-31%	5.0%

Lower				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.0	22%	28%	50%	1.85

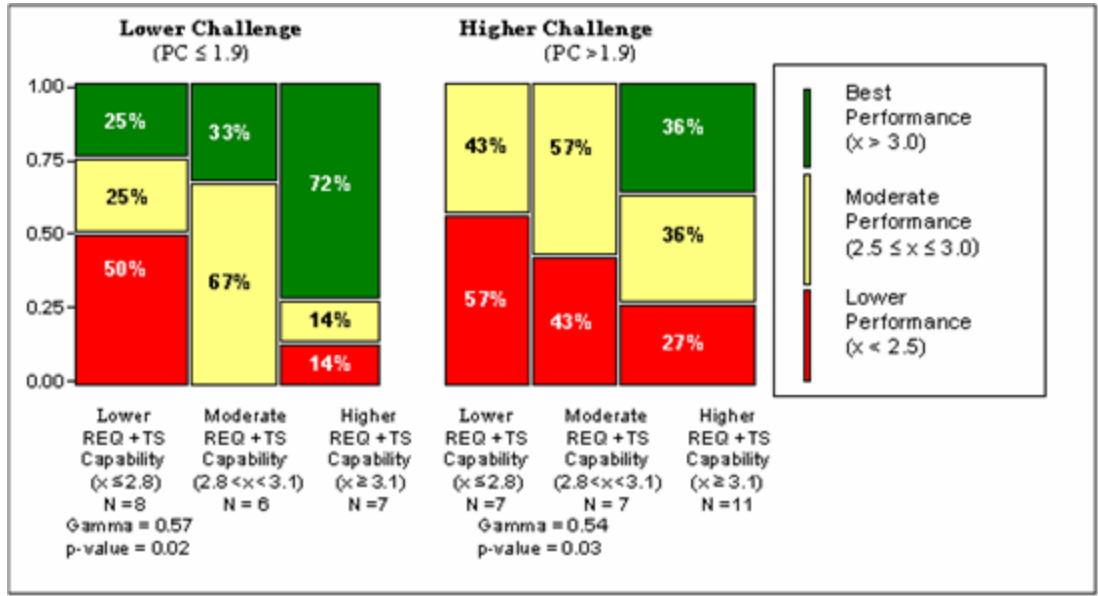
Moderate				
Min. Range	# Lo	# Med	# Hi	Max. Range
1.85	42%	58%	0%	2.05

Higher				
Min. Range	# Lo	# Med	# Hi	Max. Range
2.05	38%	38%	25%	4.0

PC

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

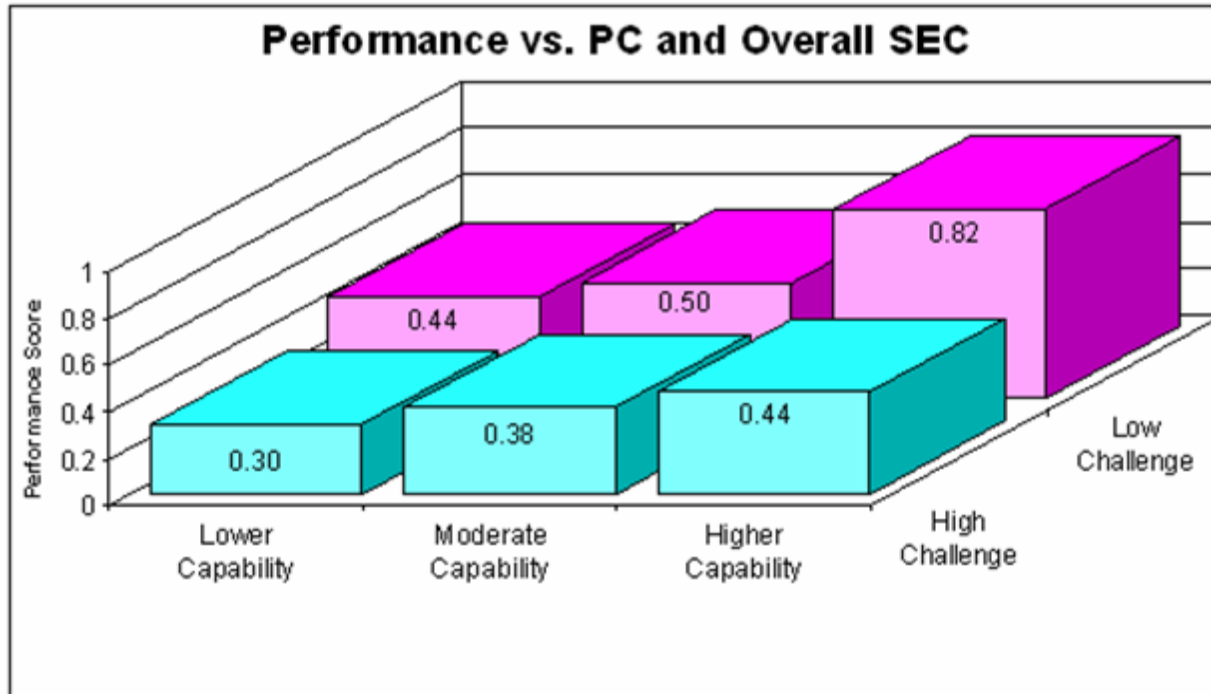


Relationship to project performance: Very strong positive relationship

SE Capability + Project Challenge

	Overall		Lower				Moderate				Higher						
	Gamma	p	Min. Range	# Lo	# Med	# Hi	Max. Range	Min. Range	# Lo	# Med	# Hi	Max. Range	Min. Range	# Lo	# Med	# Hi	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

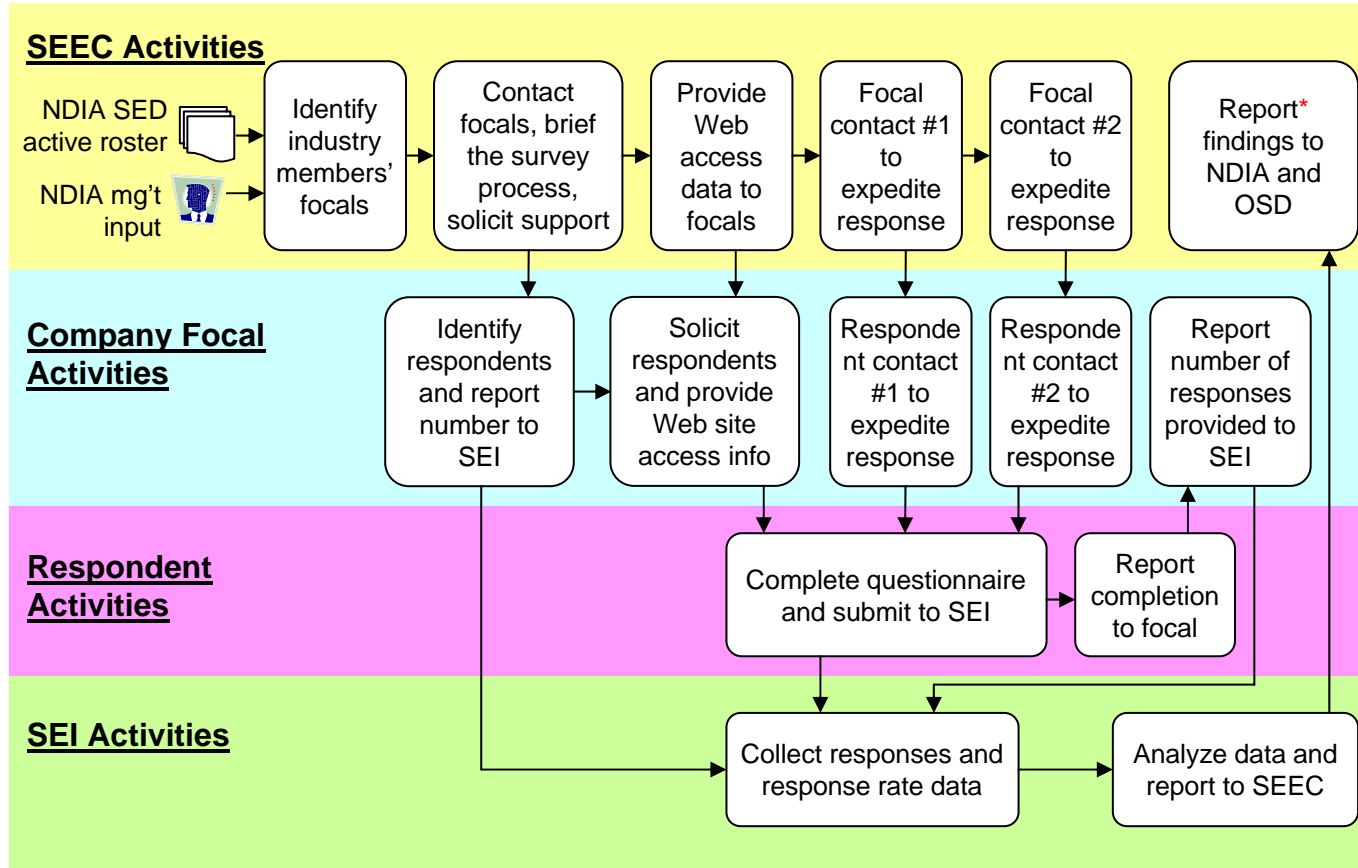


SE Effectiveness

Relationship of SEC to Performance

Supplier Systems Engineering Capability ^[1]	Relationship to Project Performance	Relationship (Gamma ^[2])	Section Reference
Project Planning	Weak positive relationship	+0.13	5.1.3.2
Project Monitoring and Control	Weak negative relationship	-0.13	5.1.3.3
Risk Management	Moderately strong positive relationship	+0.28	5.1.3.4
Requirements Development & Management	Moderately strong positive relationship	+0.33	5.1.3.5
Trade Studies	Strong positive relationship	+0.37	5.1.3.6
Product Architecture	Moderately strong to strong positive relationship	+0.40	5.1.3.7
Technical Solution	Moderately strong positive relationship	+0.36	5.1.3.8
Product Integration	Weak positive relationship	+0.21	5.1.3.9
Verification	Moderately strong positive relationship	+0.25	5.1.3.10
Validation	Moderately strong positive relationship	+0.28	5.1.3.11
Configuration Management	Weak positive correlation	+0.13	5.1.3.12
IPT-Related Capability	Moderately strong positive correlation	+0.34	5.1.3.1

SE Effectiveness Methodology (In Detail)



SE Effectiveness

Methodology (Mathematical Statement)



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

Perf - Project Performance

PC - Project Challenge

PE - Project Environment

SEC - Systems Engineering Capability

AC - Acquirer Capability

Results

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
Process Improvement	Weak positive	+0.05
Project Monitoring and Control	Weak negative	-0.13