Leveraging Systems Engineering to Improve Program Performance

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Agenda

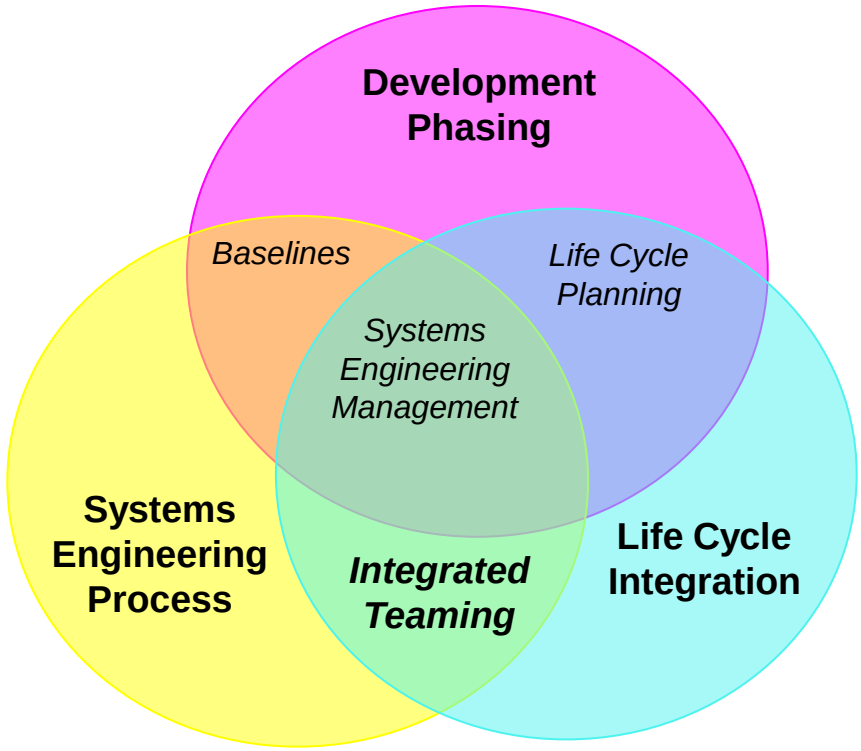
The Need for Systems Engineering

The NDIA Systems Engineering Effectiveness Study (SEES)

Survey Results

Using the Results

Next Steps



What does it take to build a complex weapon system?

Many Systems

- Propulsion
- Hydraulics
- EW
- Power
- Controls
- Radar
- Structures
- Navigation
- Computers
- Communications
- …

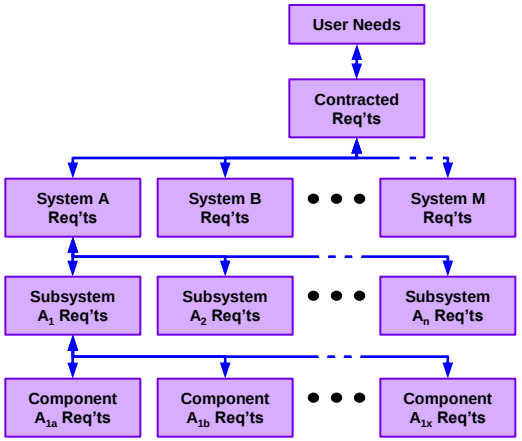
Many disciplines

- Mechanical Engineering – fluidynamics
- Metallurgical Engineering
- Electrical Engineering – power
- Manufacturing Engineering
- Software Engineering
- Electrical Engineering – radar
- Mechanical Engineering – structural
- Electrical Engineering - Communications
- Test Engineering
- …

But, Not Everything Fits Cleanly into One Discipline

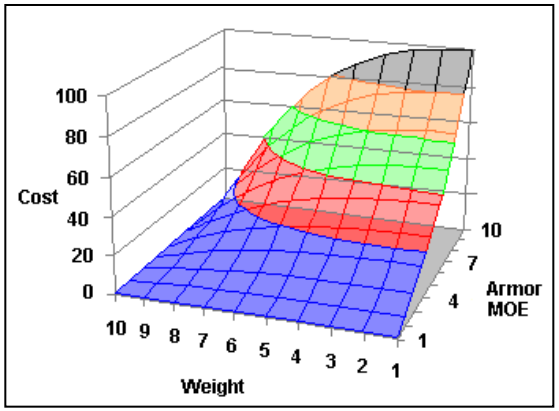
Requirements Development and Management

- Decomposition of requirements
- Allocation of requirements among multiple systems



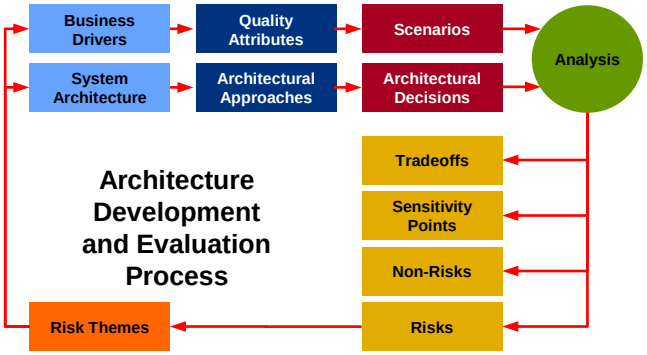
Interdisciplinary Trade Studies

- Capability implementation in hardware vs. software
- Exotic alloys for low weight vs. more common materials for low cost
- Lower radar cross section vs. higher aerodynamic performance



Architecture Development

- Model Driven Design
- Quality Attribute Driven Architecture



Who Pulls it All Together ?

The Systems Engineer

Required skills

- Global system-wide perspective
- Full life-cycle perspective
- Forward-looking
- Multidisciplinary technical knowledge
- Fact-based decision-making
- Multi-tasking

Tasks Performed *

- Requirements Development
- Requirements Management
- Trade Studies
- System Architecture Development
- Interface Management
- Configuration Management
- Project Planning
- Project Monitoring and Control
- Risk Management
- Product Integration Planning and Oversight
- Verification Planning and Oversight
- Validation Planning and Oversight

How likely is project success if these activities are not done well?

* Some tasks are done in partnership with the Project Manager

Does this sound familiar?

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 need to minimize the SE efforts on this project because …

- … including SE costs in our 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.
- … SE doesn't produce deliverable outputs.
- … our customer won't pay for them.

These are the ASSERTIONS, but what are the FACTS?

The Importance of System Engineering

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

- "costs … of major defense acquisition programs increased 26 percent and development costs increased by 40 percent from first estimates"
- "programs … failed to deliver capabilities when promised—often forcing warfighters to spend additional funds on maintaining legacy systems"
- "current programs experienced, on average, a 21-month delay in delivering initial capabilities to the warfighter"

Why?

"… managers rely heavily on assumptions about system requirements, technology, and design maturity, which are consistently too optimistic. These gaps are largely the result of a lack of a disciplined systems engineering analysis prior to beginning system development …

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

We need to quantify the effectiveness and value of SE by examining its effect on program performance?

The Solution

Obtain quantitative evidence of the costs and associated benefits of Systems Engineering activities via a survey of development projects

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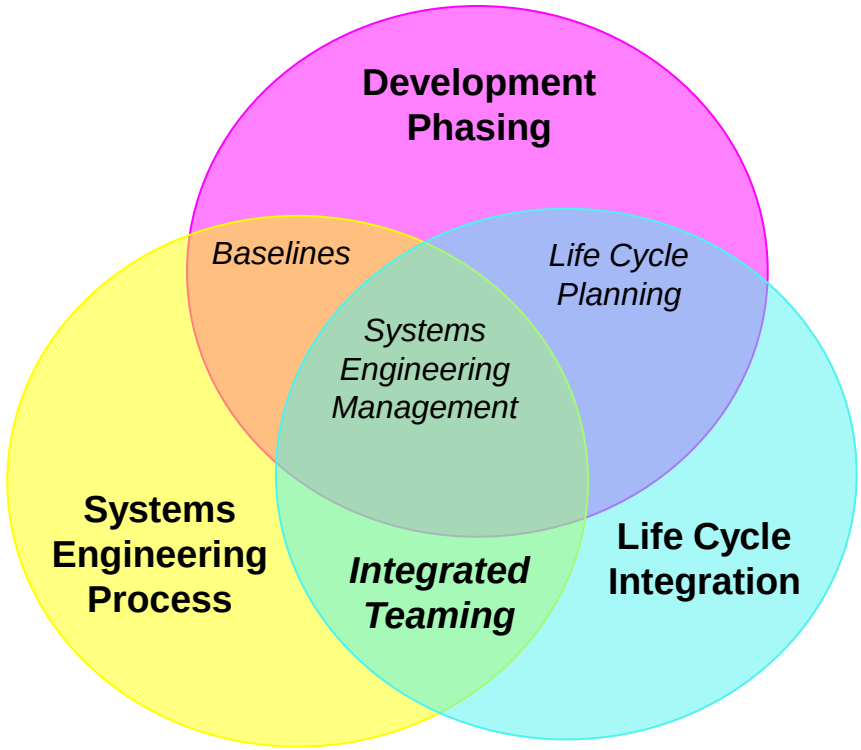


The NDIA Systems Engineering Effectiveness Study

Performed by NDIA in conjunction with the SEI in 2006-2007

Survey 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).

Surveyed 64 projects at defense contractors to assess:

- Characteristics of individual projects (e.g., complexity, size, environment)
- The specific SE practices applied to each project
- The performance of each project, as measured by conformance to budget, schedule, and requirements satisfaction

Data was collected anonymously to encourage honest and accurate reporting.

Results published at:

http://www.sei.cmu.edu/publications/documents/08.reports/08sr034.html

Assessment of SE Practices 1

Question #1
What SE activities do you apply to your project?

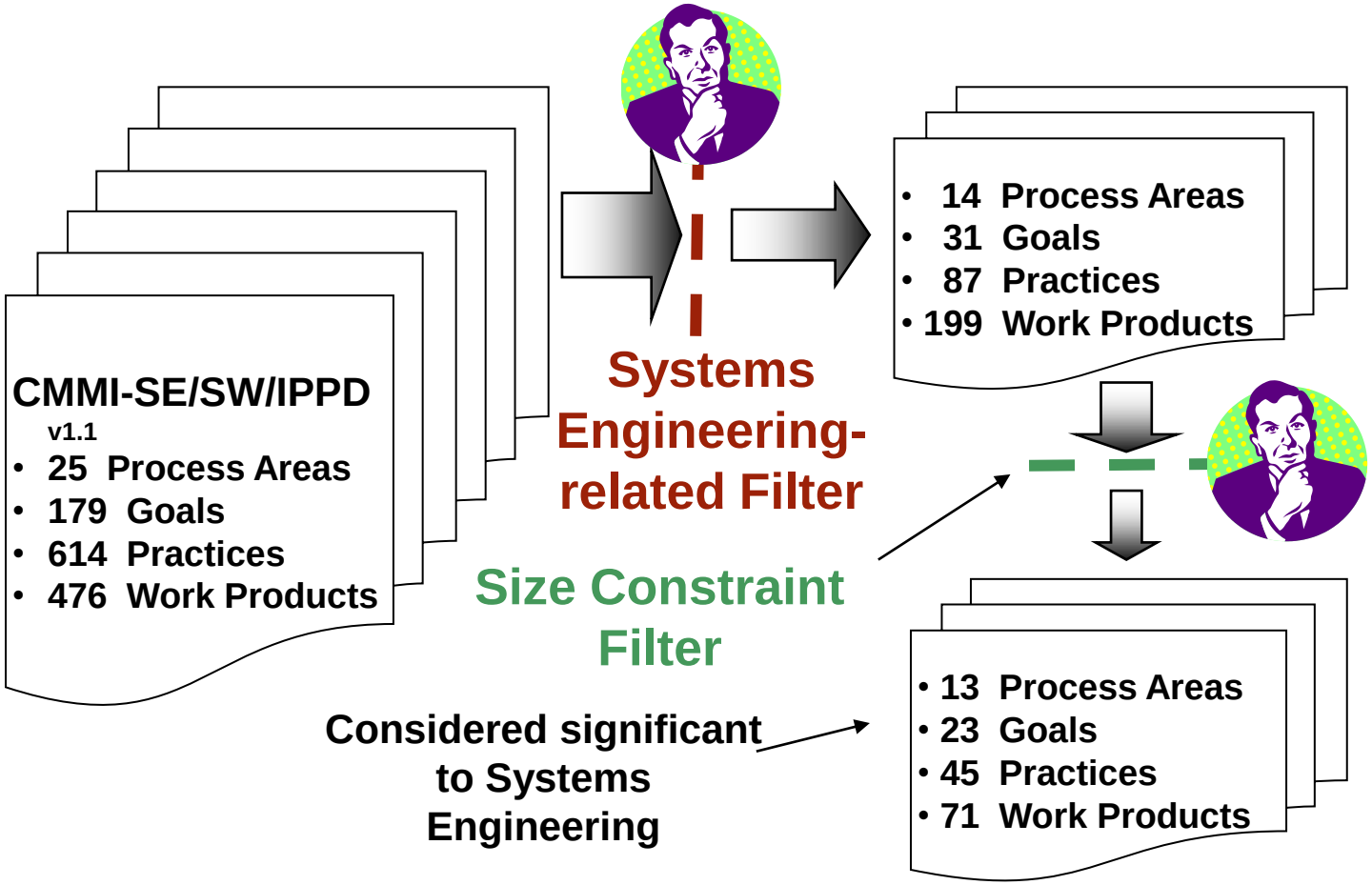
Challenge

- No generally accepted definition of what IS and what IS NOT a part of SE.
  - "How much SE do you do on your project?" ⇐ No answer
- SE is often embedded in other tasks and not budgeted separately
  - "How much does your project spend on SE?" ⇐ No answer

Solution

- Avoid a defining SE
  - Too much controversy
- Ask about the results of activities that are generally agreed to be SE

Assessment of SE Practices 2



Survey content is based on a recognized standard (CMMI)

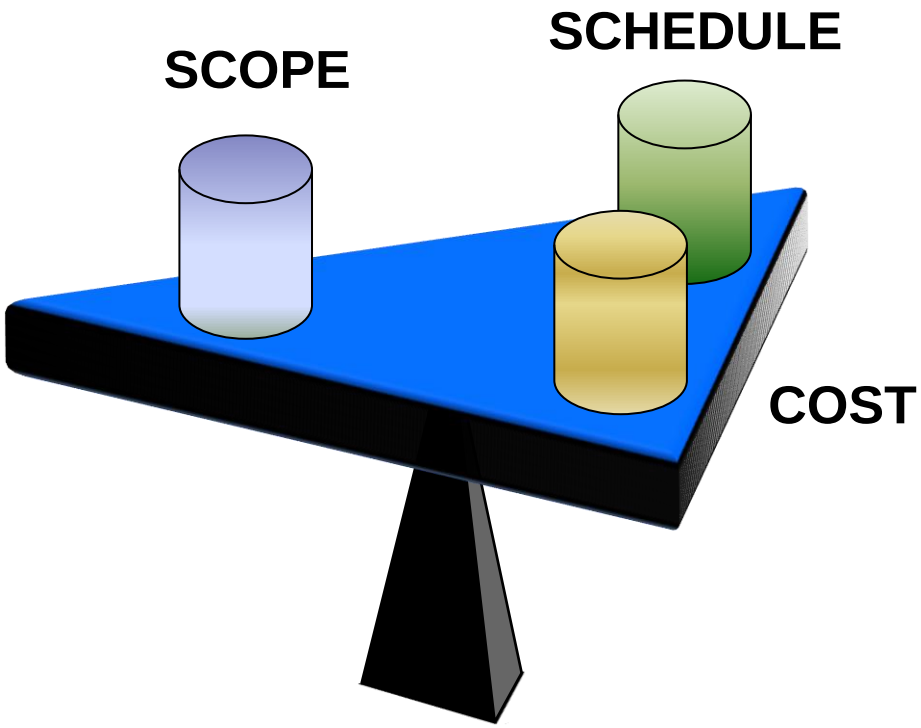
Assessment of Project Performance

Address TOTAL Project Performance

- Project Cost
- Project Schedule
- Project Scope

Focus on commonly used measurements

- Earned Value Management (CPI, SPI, baseline management)
- Requirements satisfaction
- Budget re-baselining and growth
- Milestone and delivery satisfaction



Assessment of Other Factors

Question #3
What other factors affect project performance?

SE Capability is not the ONLY thing that can impact Project Performance. What about:

- **Project Challenge** – some projects are more complex than others
  - Lifecycle scope, technology maturity, interoperability needs, precedence, size, duration, organizational complexity, quality of definition
- **Acquirer Capability** – some acquirers are more capable than others
  - Requirements quality, acquirer engagement, consistency of direction
- **Project Environment** – projects executed in and deployed to different environments have different needs
  - Acquiring organization, user organization, deployment environment, contract type, developer's experience, developer's process quality

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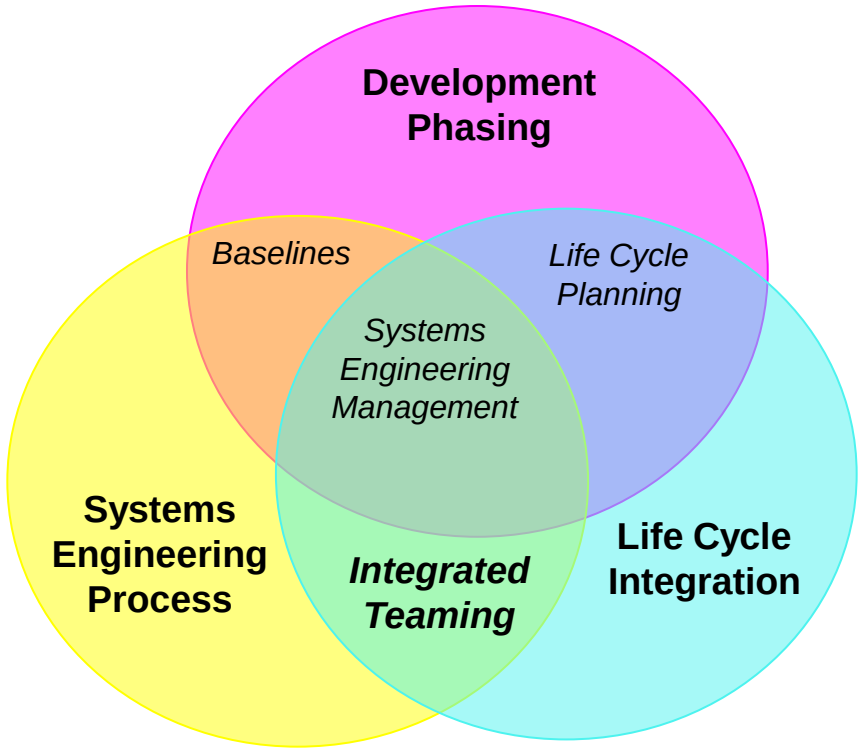
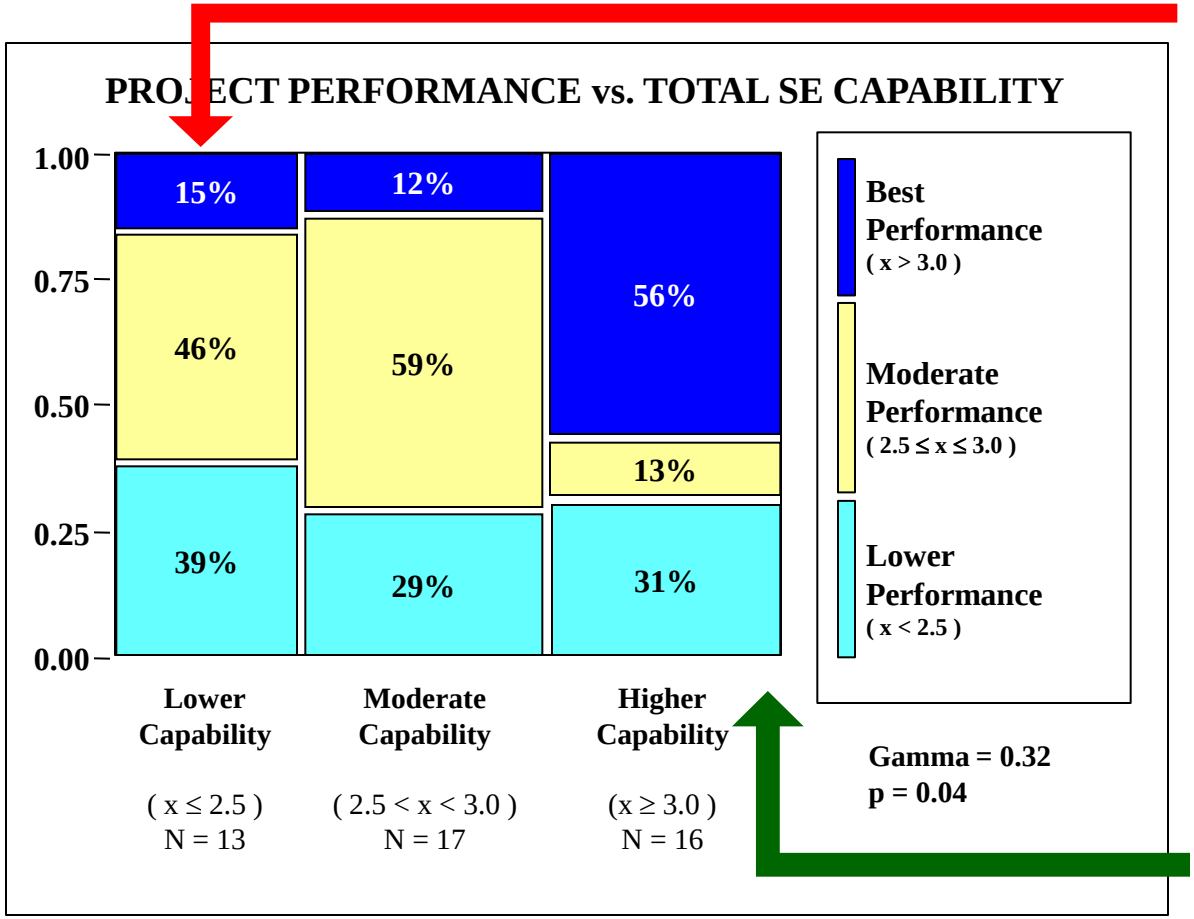


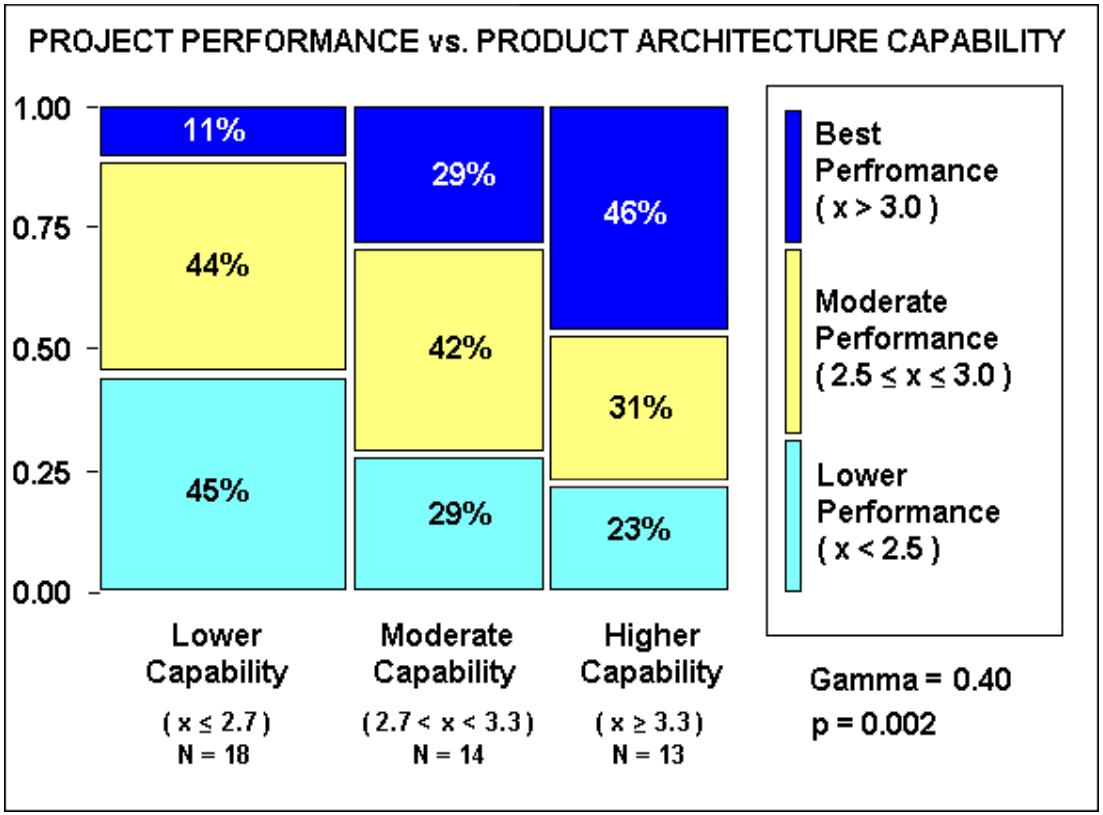
The Bottom Line [1]



For the projects that deployed the least SE, only 15% delivered the best project performance.

For the projects that deployed the most SE, 56% delivered the best project performance

Product Architecture Capability vs. Project Performance

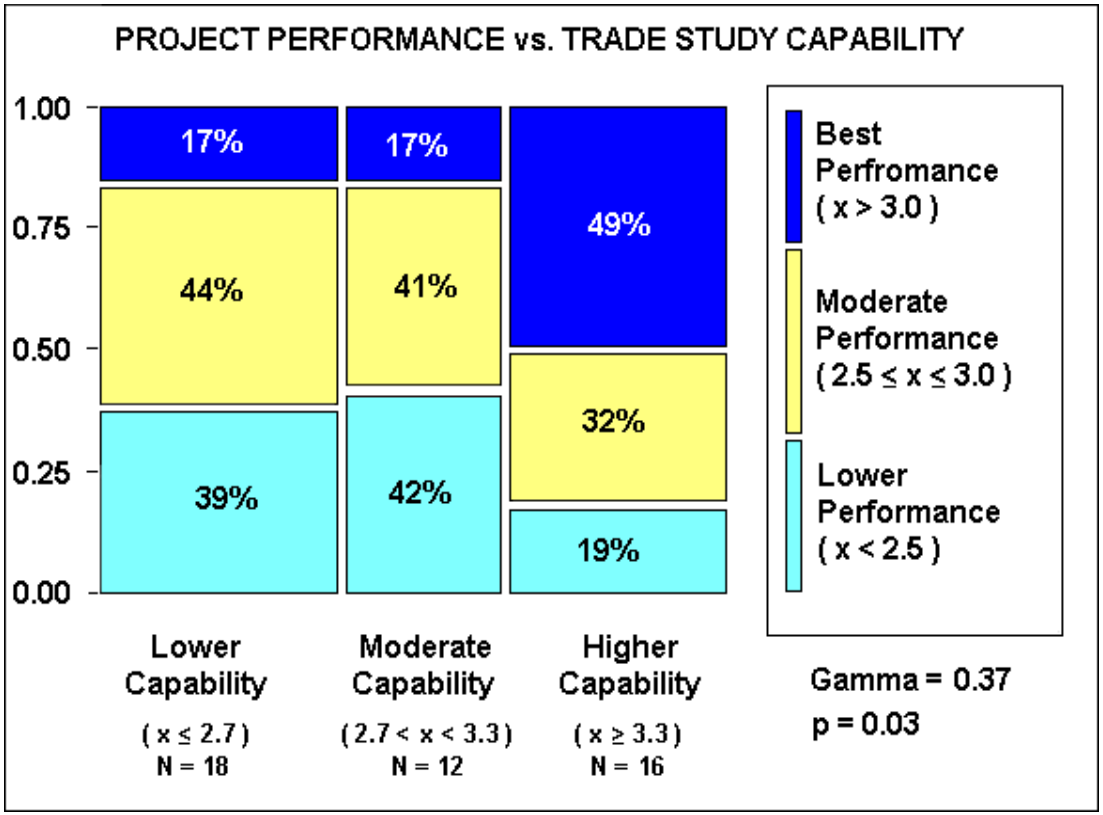


Product architecture assessment examined

- High-level product structure documentation
  - Including multiple views
- Interface Descriptions

Better Product Architecture has a "Moderately Strong / Strong" positive relationship with Better Performance

Trade Study Capability vs. Project Performance

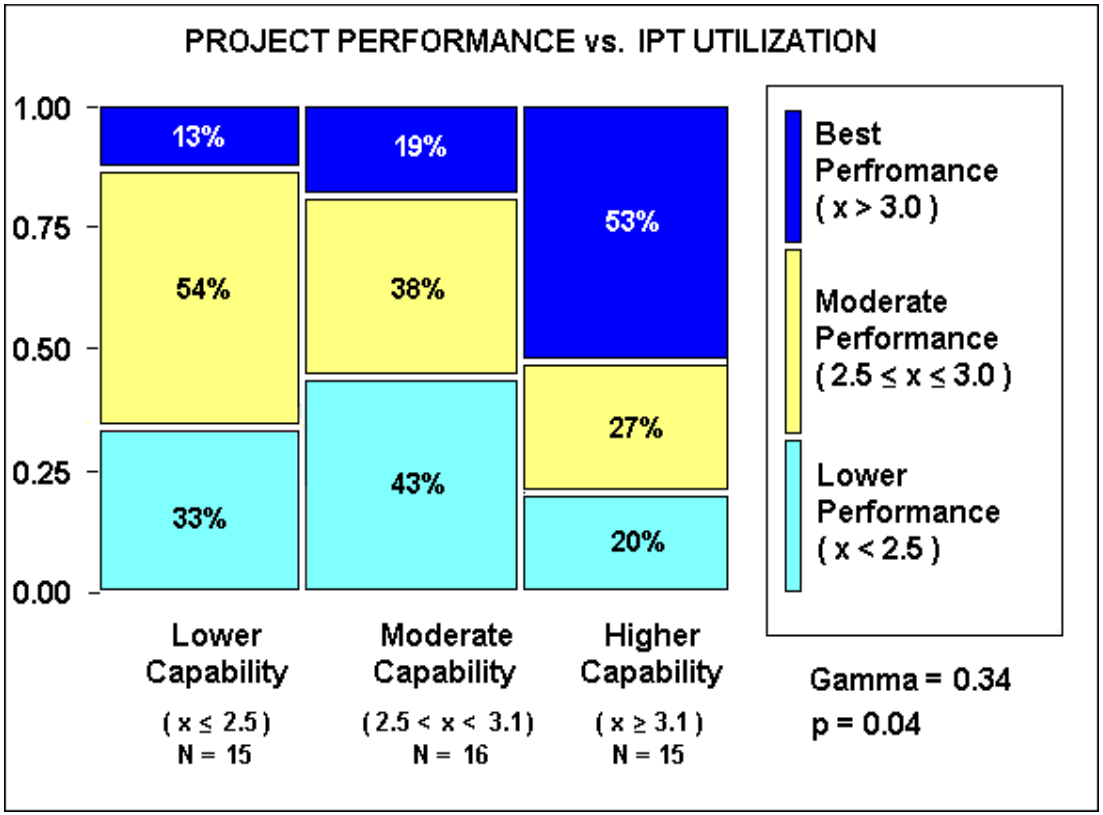


Trade Study assessment examined

- Documentation of Trade Study selection criteria
- Documentation or Trade Study results
- Stakeholder involvement

Better Trade Studies have a "Moderately Strong / Strong" positive relationship with Better Performance

IPT Utilization vs. Project Performance

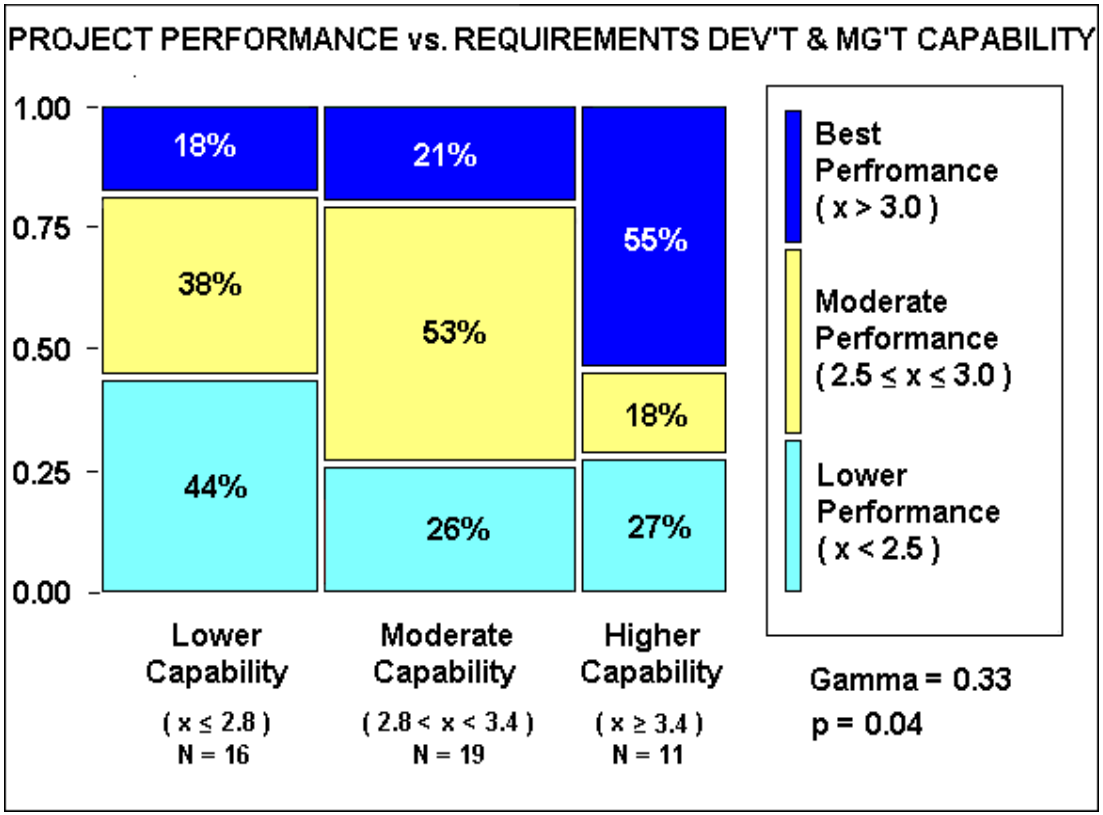


IPT (Integrated Project Team) assessment examined

- Effective IPT Usage on Project
- Supplier participation
- IPT for Systems Engineering
- SE Representation on each IPT

Better IPT Deployment has a "Moderately Strong" positive relationship with Better Performance

Requirements Development & Management vs. Project Performance

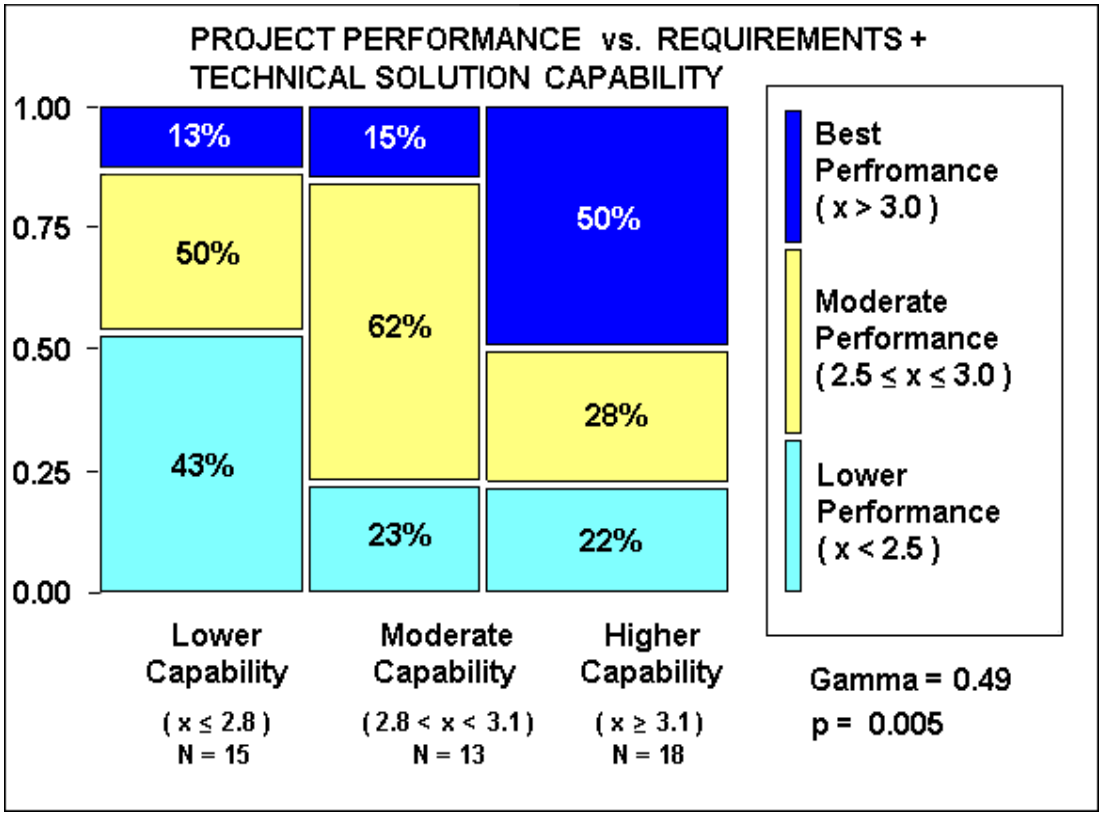


Requirements assessment examined

- Customer & derived requirements lists
- Hierarchical allocation to system elements
- CONOPs, scenarios, and Use cases
- Criteria for authorization of req'ts providers and acceptance of req'ts
- Change control process
- Traceability to Stakeholder needs

Better Requirements Development and Management has a "Moderately Strong" positive relationship with Better Performance

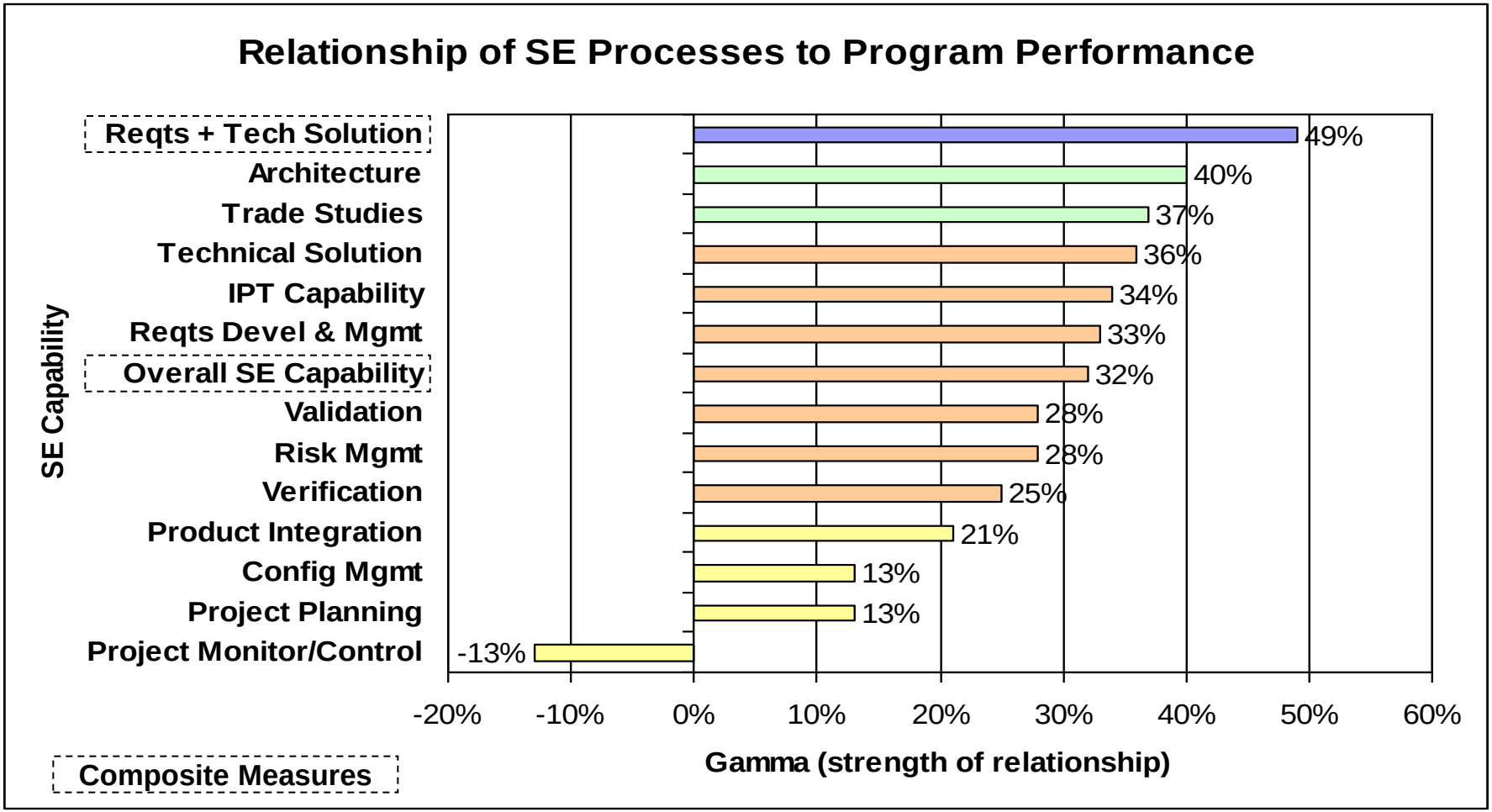
Req’ts + Architecture +Trade Study Capability vs. Project Performance



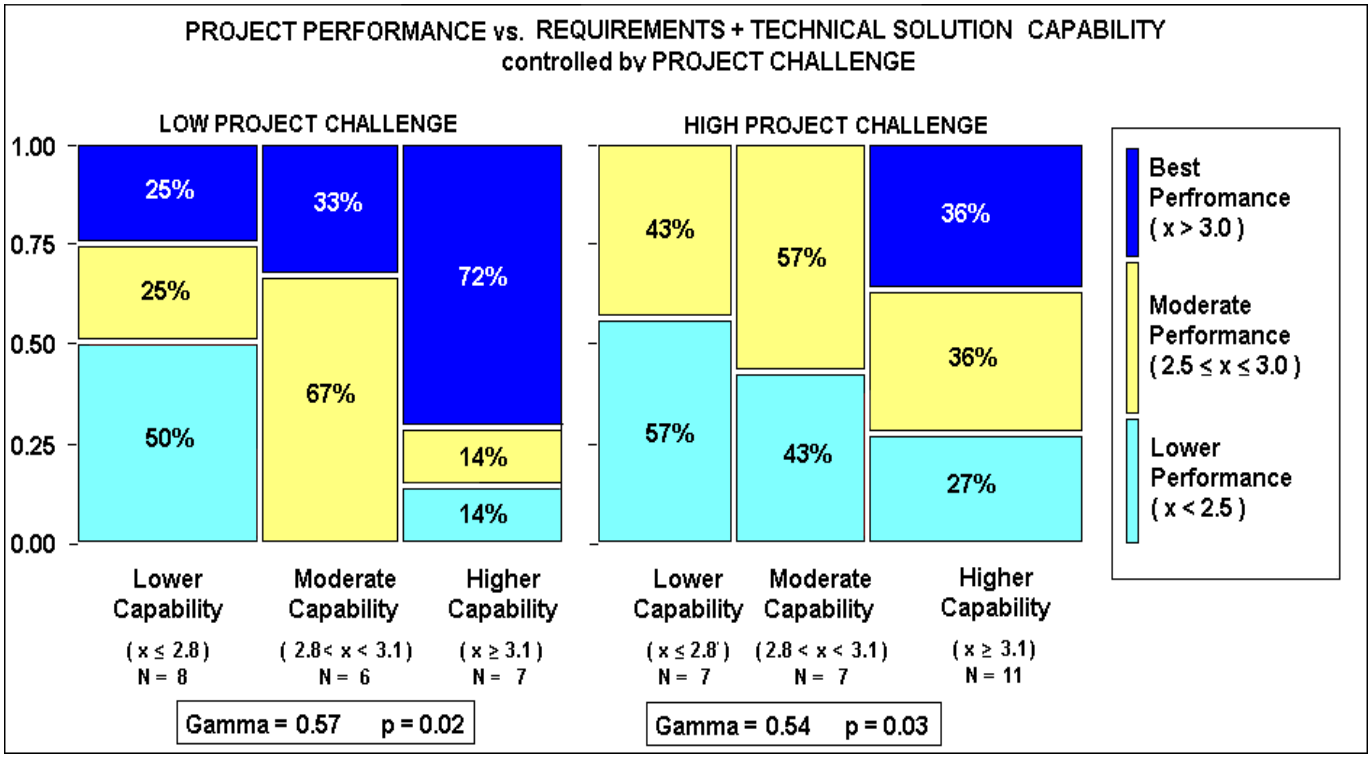
When looking at the impact of COMBINED SE activities, we see even stronger relationships

Better Requirements Dev’t & Mg’t and Better Technical Solution processes have a “Strong” positive relationship with Better Performance

Summary of Relationships



Req’ts + Architecture + Trade Study vs. Project Performance, controlled by Project Challenge



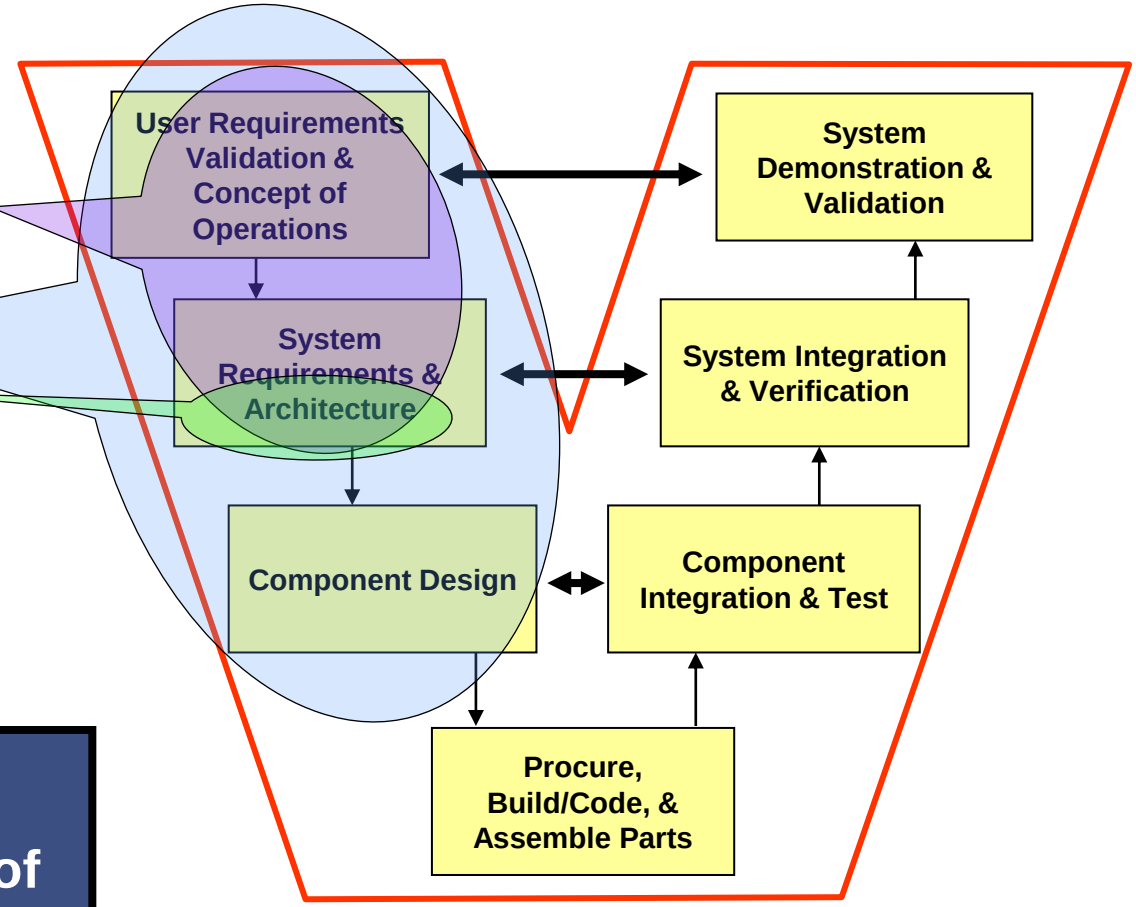
Project challenge factors:

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

Regardless of Project Challenge, better Requirements Dev’t and Mg’t and better Technical Solution processes shows a “Strong” positive relationship with Better Performance

Mapping of Results to System Development

- Project Planning
- Project Monitoring & Control
- Risk Management
- Requirements Dev't & Mg't
- Technical Solution
  - Trade Studies
  - Product Architecture
- Product Integration
- Verification
- Validation
- Configuration Management
- IPT-Based Capability



http://ax.losangeles.af.mil/se_revitalization/main.htm

V-Model of System Development

Conclusion

The early phases of SE have the most impact

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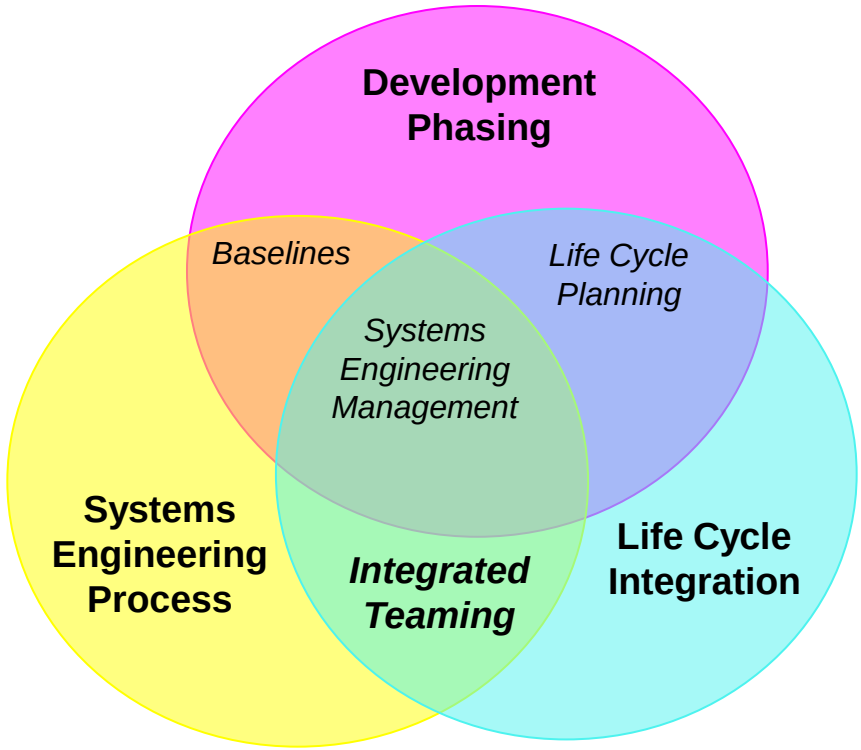

SE Works !!!
So, Why Don't Suppliers and Acquirers Do It ?

Supplier Issues

Insufficient budget

Schedule driven programs

- Need for immediate tangible results
- Fear of 'paralysis by analysis'

Failure to understand value of SE

- Absence of deliverable outputs from SE

Lack of available SE staff

Lack of incentives

- Lack of contractual requirements for SE
- No encouragement or reward
- Inattention to SE efforts and results

Acquirer Issues

Lack of Policy requiring SE?

- No! Policy exists promoting the use of SE
  - USD/AT&L "Policy for Systems Engineering in DoD" of 20-Feb-2004
  - ASA(ALT) Memorandum, "Army Systems Engineering Policy" of 13-J*un-2005*
  - SAF Memorandum, "Systems Engineering Plan (SEP) Requirements Memo" of 14-*Mar-2007*

Lack of effective guidance for implementing effective SE?

- Maybe. Guidance exists but much of it is difficult to operationalize
  - Defense Acquisition Guidebook

Lack of understanding

- Probably. Implementing effective SE is a very difficult task. Without both training **and** experience, it is difficult to know what to do.

Suggestions for System Acquirers 1

Ensure that suppliers provide effective SE

- **Include SE requirements in RFPs**
  - Evaluate bidder's SE Plan as part of the source selection criteria
  - Require evidence of SE performance through CDRLs
  - Require periodic self-assessment and reporting of SE performance
  - Require SE visibility in IMS, IMP, EVMS, etc.
  - Require independent assessment and reporting of SE performance at PDR, CDR, etc.
- **Stress SE performance in negotiations and contracting**
  - Mandate compliance with RFP requirements and bidder proposals for SE
  - Avoid compression / elimination of SE efforts to accommodate schedule
  - Include incentives for early and effective SE activities
- **Monitor SE performance during contract execution**
  - Provide timely and comprehensive review of SE deliverables
    - Insure sufficient program office staff and skills to do this
  - Participate in SE IPTs

Suggestions for System Acquirers 2

Ensure that the Program Office provides effective SE

- **Include sufficient SE expertise in the Program Office**
  - Hire trained and capable Systems Engineers
  - Provide SE training for Program Office staff
    - Develop on-line JIT training
  - Include SE staff in the Program Office decision making process
- **Set an example. Employ SE best practices for:**
  - Requirements Development and Management
  - Trade Studies
  - Architecture Development, Evaluation, and Management
  - Configuration Management
- **Discuss and stress the supplier's SE performance in ALL reviews with the contractors. Let them know you're watching!**
- **Collect and analyze data from all programs to improve understanding of the effectiveness of specific SE activities.**

Suggestions for System Suppliers

Define, develop, deploy, monitor, and enforce SE processes for ALL projects throughout the organization

Ensure SE competency within the organization

- Build or maintain a cadre of skilled System Engineers
- Provide SE training for both Systems Engineers and Program Managers

Ensure SE integration within the organization

- Clearly define SE roles, responsibilities, and authorities

Identify and adopt SE assessment methods

- Identify, evaluate, and adopt SE assessment methods
- Train internal staff in assessment processes

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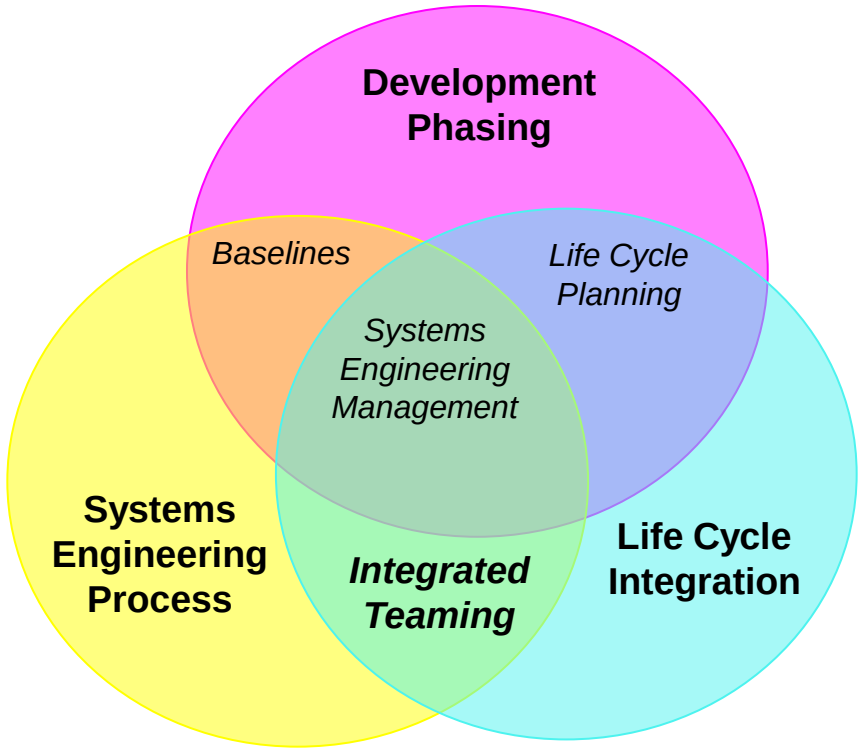


Moving Forward

Study results have been adopted by several major aerospace and defense suppliers.

- Used the survey instrument to assess their internal projects
- Compared results against benchmarks established by the study
- Used results to guide SE process improvement activities.

Presented study results and recommendations to OSD in 2007

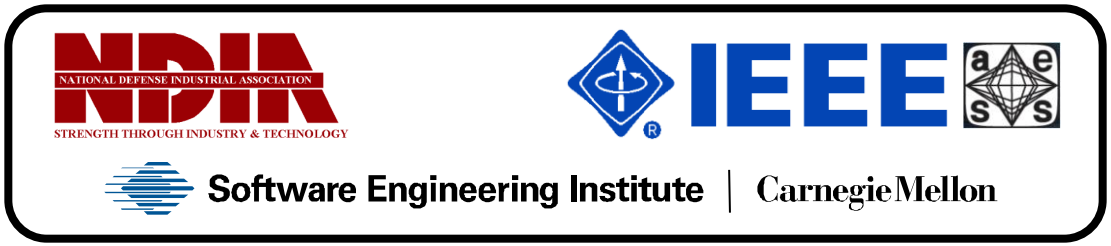
Held discussions with IEEE in 2009 regarding extension of the study to a wider audience

Briefed OSD leadership (Mr. Stephen Welby) in May-2010

- Received an enthusiastic response
- Interest in gathering more data
- Some interest in disseminating data throughout DoD
- Some interest in incorporating findings into DoD acquisition guidance

So, Here we are today …

The 'NEW' SE Effectiveness Committee



Role	Designee	Affiliations
Project Manager	William Lyons	• IEEE AESS Board of Governors • The Boeing Company
Deputy Project Manager	Robert C. Rassa	• President, NDIA Systems Engineering Division • Raytheon Systems Company
Deputy Project Manager	Alan R. Brown	• Chair, NDIA Systems Engineering Effectiveness Committee • The Boeing Company
OSD Liaison	Michael McLendon	• OSD (DDR&E) *
Lead Researcher	Joseph P. Elm	• Software Engineering Institute

Companies Represented on the SE Effectiveness Committee		
Boeing	Oliva Engineering	Textron System
Georgia Tech	OSD	USAF - AFMC/EN
Harris	Raytheon	USAF - SAF/AQRE
INCOSE	Sikorsky	Northrop Grumman
Lockheed Martin	Software Engineering Institute	

* On IPA assignment from Software Engineering Institute

The Mission

Promote the achievement of quantifiable and persistent improvement in project performance through appropriate application of systems engineering principles and practices

- Identify principles and practices shown to provide benefit
  - This is an extension and a confirmation of the prior NDIA study
- Assist DoD, industry, and academia in developing the guidance and direction to implement those principles and practices
- Assist DoD, industry and academia in establishing a means of monitoring / tracking the results of these efforts
  - An on-going data collection and analysis process

The Plan

Phase I

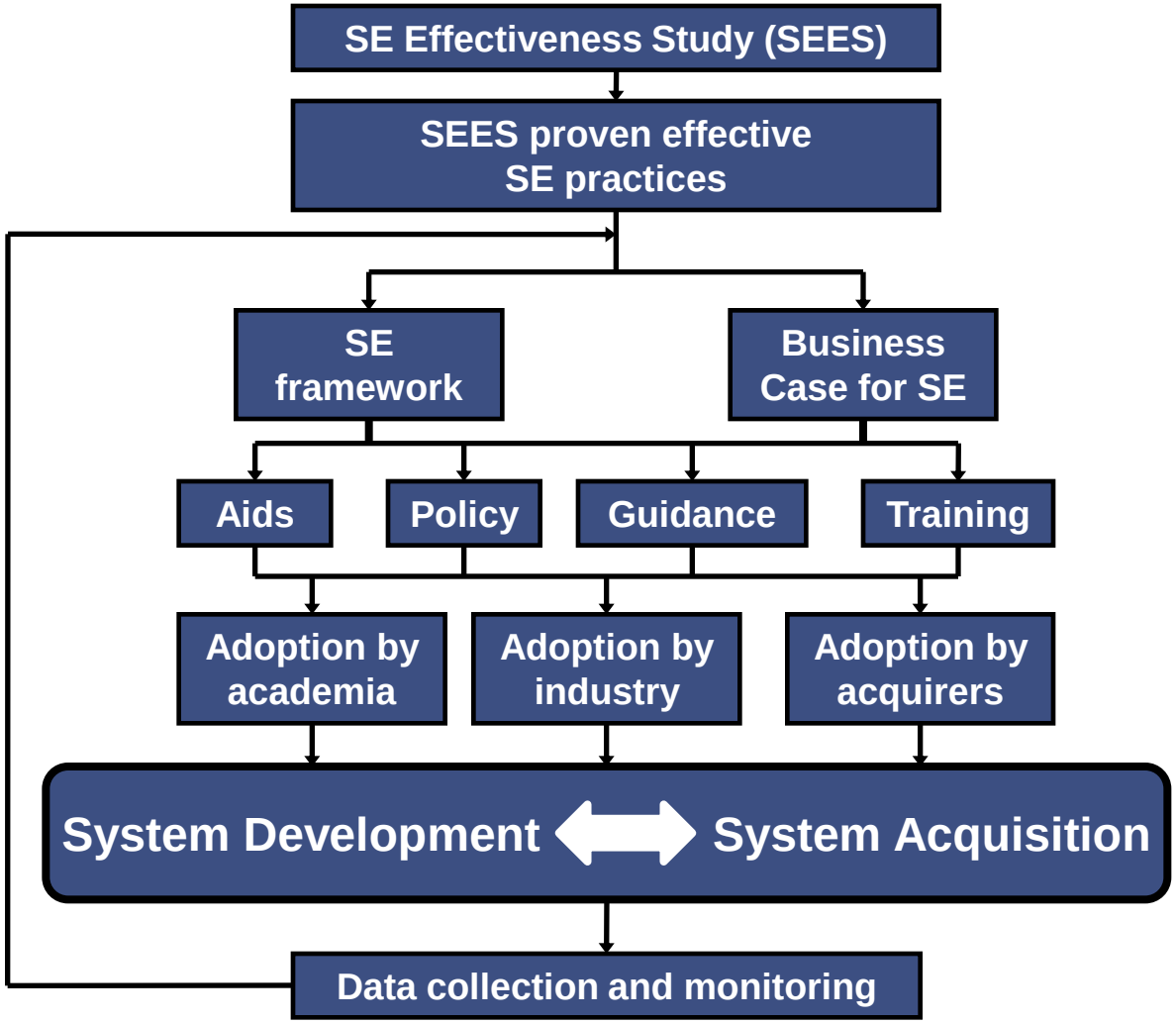
Jun-2010 thru Mar 2012

Phase II

Mar-2012 thru Jun 2013

Phase III

Jun-2013 thru Oct 2013



Status

Committee formed and organized

- Weekly teleconferences
- Collaborative web site established

Project planning completed

- Task Plan developed

Survey preparation in progress

- Questionnaire developed with collaboration from NDIA, IEEE, and INCOSE
- Survey sampling process developed
- Survey analysis plan developed
- Survey infrastructure (web sites, data repositories) in development

Survey Tenets

All data will be submitted anonymously

- No data collected will identify the respondent, project, or organization

All data will be handled confidentially

- Data will be submitted directly to a secure web site managed by the SEI
  - The SEI is a federally funded research and development center. It does not compete with any responding organizations, and frequently operates as a trusted broker in matters of confidential and proprietary information.
- Only authorized SEI staff will have access to the submitted data

Only aggregated data will be released to the participants and the public

- No released data will be traceable to a project, person, or organization.

Participation

Our target audience is Project Managers, Chief Engineers, Lead System Engineers, etc. of projects delivering products (not services)

- Not limited to defense industries – all industries are welcome
- Not limited to US companies – all are welcome

Reaching potential respondents

- Grass roots approach
  - Broadcast an invitation to participate to members of participating organizations (NDIA, IEEE-AESS, INCOSE)
- Top down approach
  - Identify SE leadership at major companies
    - Network through participating organizations (NDIA, IEEE-AESS, INCOSE)
  - Contact them directly and solicit their support
    - Identify potential respondents within their company
    - Promote participation

Why should you participate?

It's good for you

- A better understanding of the effectiveness of specific SE practices will help you do your job better, and help you justify SE efforts to your management

It's good for your company

- A business case for SE will help your company apply resources where they can have the most impact

It's good for the world

- Better SE leading to better projects will produce lower costs, faster deliveries, and better performance for systems

There is a reward

- As in the prior NDIA study of SE Effectiveness, survey participants will receive early access to study results, enabling them to evaluate their SE practices against an industry benchmark.

Watch your email !

Many of you will be receiving an email participation inquiry, asking the following:

Name _____

Organization _____

Email address _____

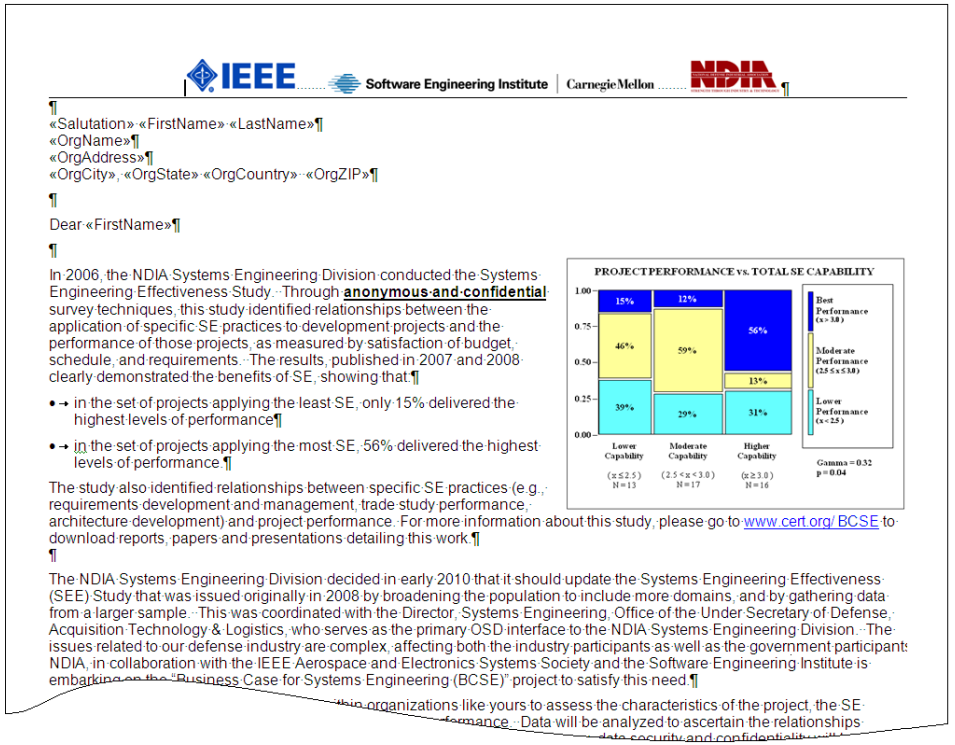
☐ **Yes, my organization and/or project is willing to participate in this study**

☐ **No my organization is not willing to participate in this study**

Reason for declining _____

_____

Anyone else in your organization we should contact _____



IEEE Software Engineering Institute | Carnegie Mellon NDIA

«Salutation» «FirstName» «LastName»
«OrgName»
«OrgAddress»
«OrgCity», «OrgState» «OrgCountry» «OrgZIP»

Dear «FirstName»

In 2006, the NDIA Systems Engineering Division conducted the Systems Engineering Effectiveness Study. Through **anonymous and confidential** survey techniques, this study identified relationships between the application of specific SE practices to development projects and the performance of those projects, as measured by satisfaction of budget, schedule, and requirements. The results, published in 2007 and 2008 clearly demonstrated the benefits of SE, showing that:

- → in the set of projects applying the least SE, only 15% delivered the highest levels of performance
- → in the set of projects applying the most SE, 56% delivered the highest levels of performance

PROJECT PERFORMANCE vs. TOTAL SE CAPABILITY

The study also identified relationships between specific SE practices (e.g., requirements development and management, trade study performance, architecture development) and project performance. For more information about this study, please go to www.cert.org/ BCSE to download reports, papers and presentations detailing this work.

The NDIA Systems Engineering Division decided in early 2010 that it should update the Systems Engineering Effectiveness (SEE) Study that was issued originally in 2008 by broadening the population to include more domains, and by gathering data from a larger sample. This was coordinated with the Director, Systems Engineering, Office of the Under Secretary of Defense, Acquisition Technology & Logistics, who serves as the primary OSD interface to the NDIA Systems Engineering Division. The issues related to our defense industry are complex, affecting both the industry participants as well as the government participants. NDIA, in collaboration with the IEEE Aerospace and Electronics Systems Society and the Software Engineering Institute is embarking on the "Business Case for Systems Engineering (BCSE)" project to satisfy this need.

...thin organizations like yours to assess the characteristics of the project, the SE ...formance. Data will be analyzed to ascertain the relationships ...data security and confidentiality...

We use your email to send an invitation to the survey web site. Your responses to the web site remain anonymous.

Please Help Us Make this Study a Success !

For more information, contact:

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BACKUP

Acknowledgements

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FAQs 1

Q1: What do you mean by '*the least SE*' and '*the most SE*'?

A1: It's all relative. Our survey scored each project's SE performance by assessing artifacts resulting from SE activities such as Requirements Development and Management, Trade Studies, System Architecture Development, Interface (External and Internal) Management, and many more. Based on these scores, the projects were binned into categories of *Higher*, *Intermediate*, or *Lower* SE capability.

Q2: …and what is 'Best Performance'?

A2: Again, it's a relative measure of project performance. Our survey scored each project's performance by assessing it's conformance to budget and schedule, and it's satisfaction of requirements. Based on these scores, the projects were binned into categories of *Best, Moderate*, or *Lower* Project Performance.

Q3: So what does it mean?

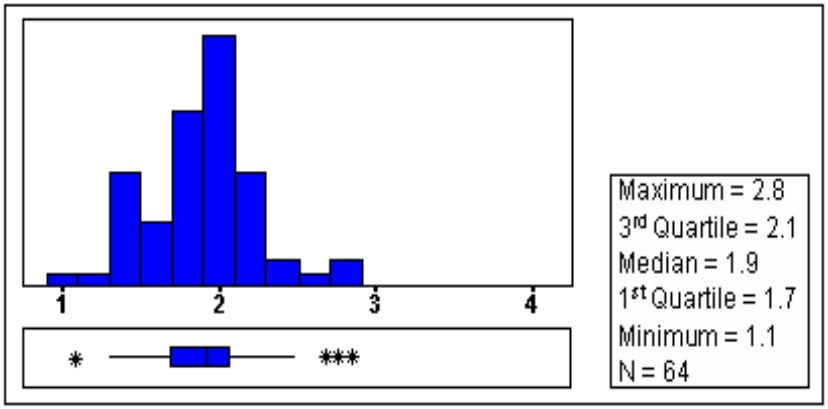
A3: Projects that do a better job of Systems Engineering perform better (closer to budget, closer to schedule, and meet more requirements) than projects that do a poorer job of Systems Engineering

FAQs 2

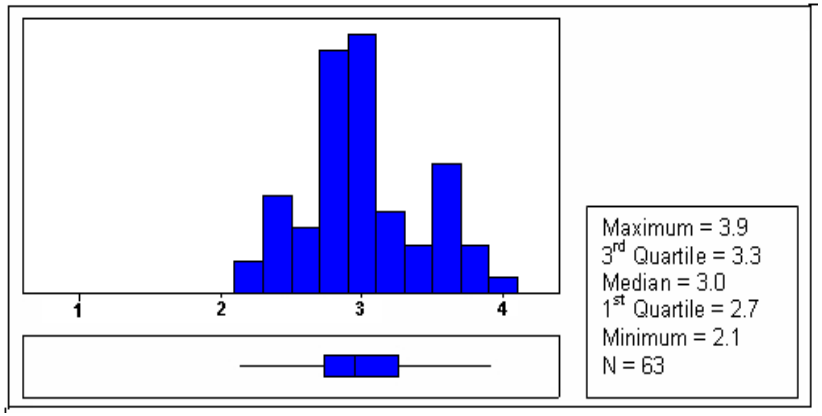
Q3: How do you know that SE was responsible for the better performance?

A3: We also collected and analyzed data for other factors that could impact project performance – things like Project Challenge, Project Environment, and Acquirer capability, looking for their relationships to project performance. Among the things that we found was the that good SE helps programs regardless of how challenging they are

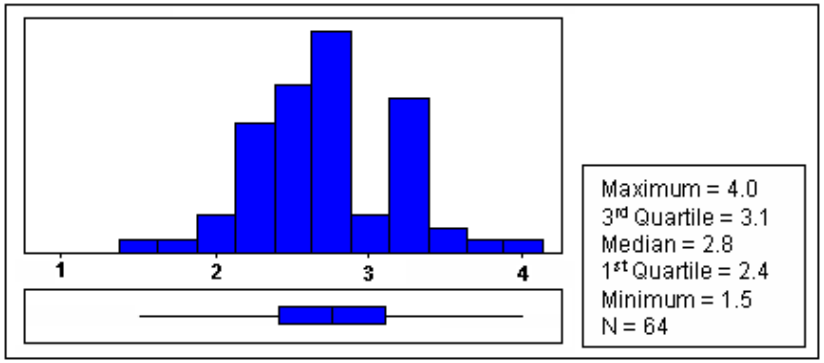
Overview of Projects Surveyed



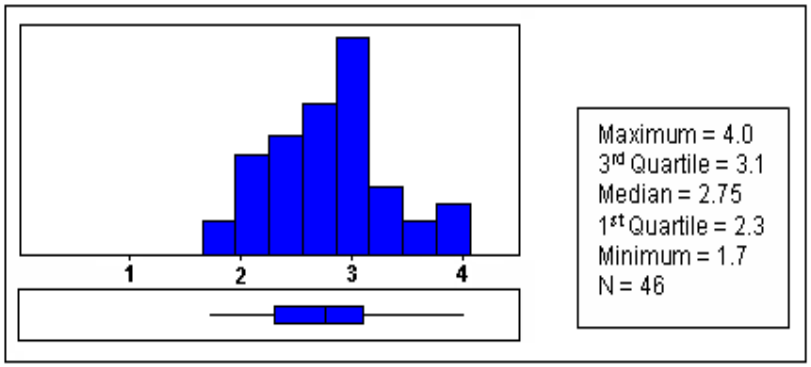
Project Challenge (PC)



Overall SE Capability (SEC)



Acquirer Capability (AC)



Project Performance (Perf)

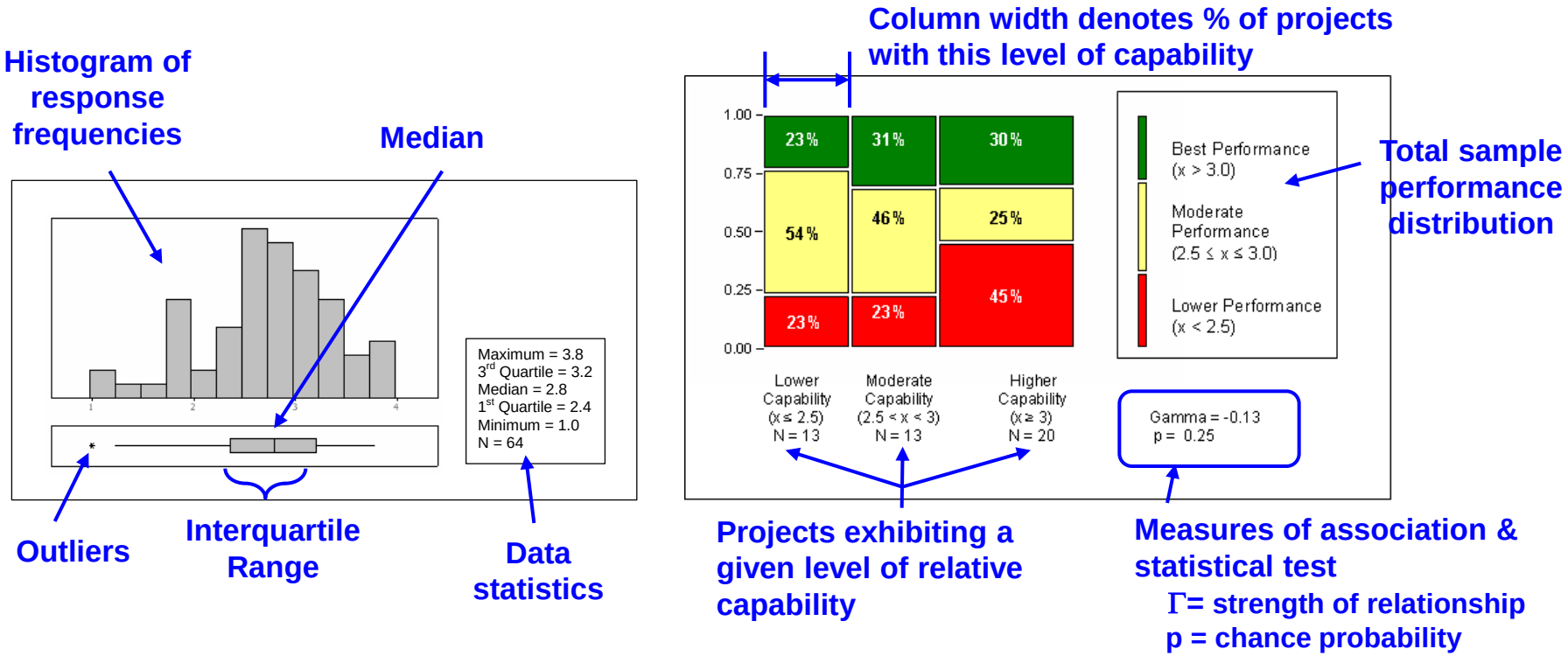
Sufficient variation to support analysis

Analysis

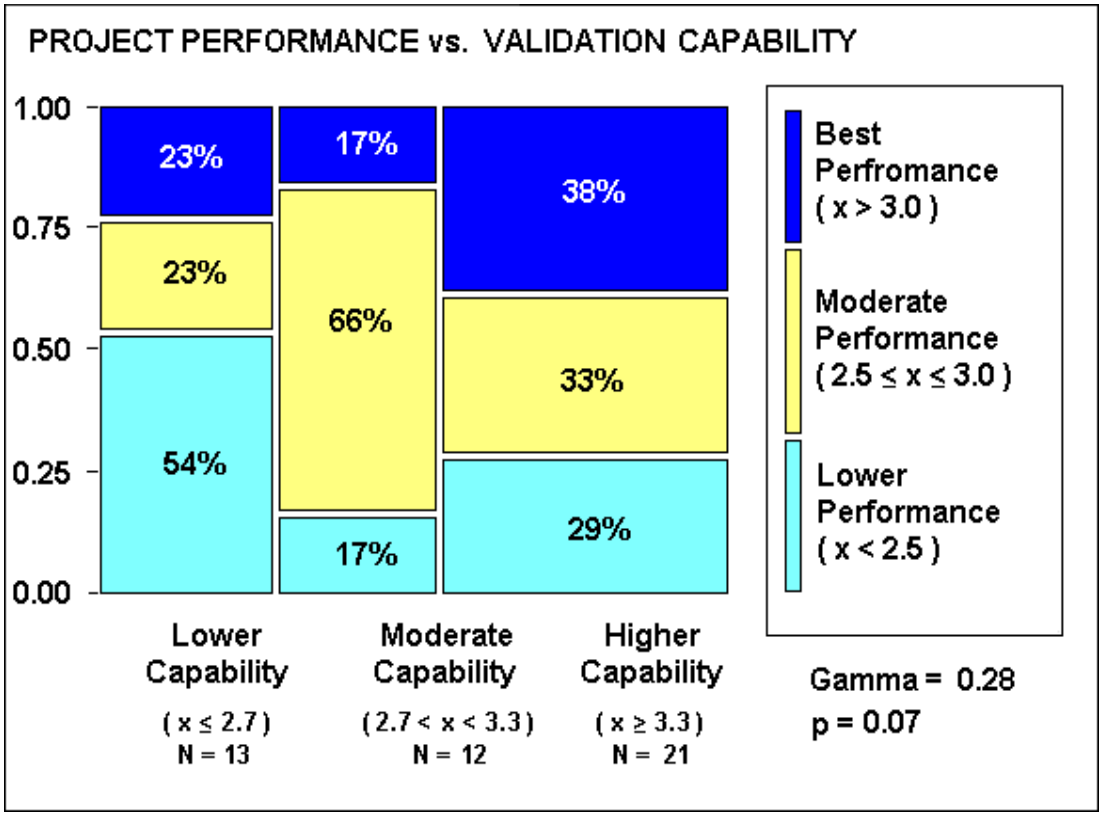
Calculate 'scores' for each variable (e.g., Perf , PC, AC, SEC, SEC_{PP}, SEC_{PMC}, SEC_{RSKM})

Analyze variable distributions to ensure sufficient variation for analysis

Analyze relationships between variables



Validation vs. Project Performance

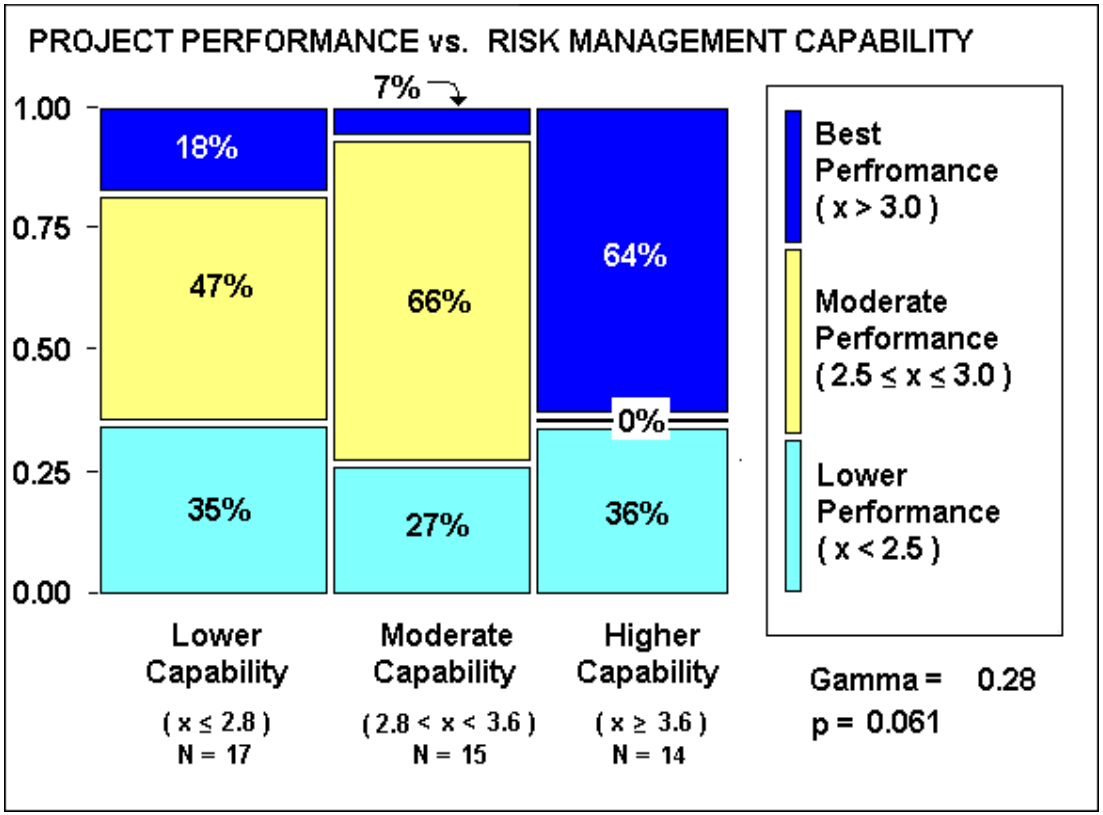


Validation assessment examined

- Validation Procedures
- Documented Acceptance Criteria
- List of items under Configuration Management

Better Validation capabilities have a "Moderately Strong" positive relationship with Better Performance

Risk Management vs. Project Performance

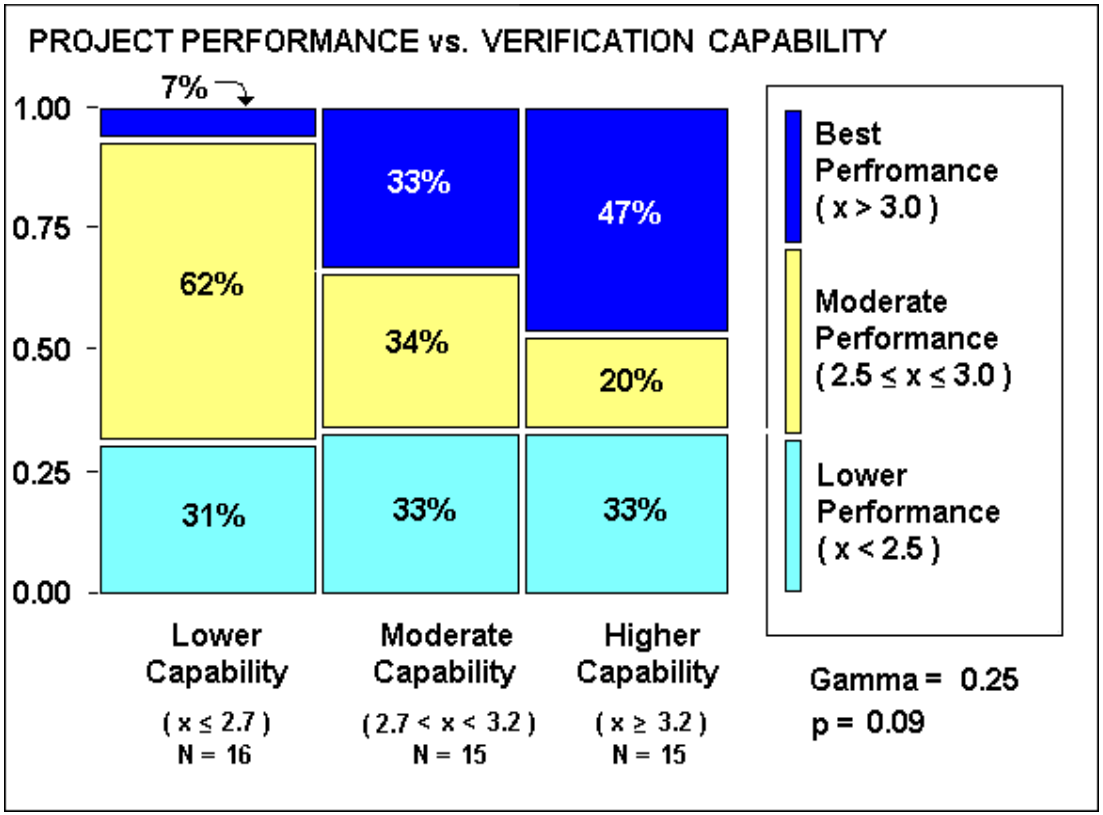


Risk Management assessment examined

- List of Risks
- Risk Mitigation Plans
- Monitoring and Reporting of Risks and Mitigation Plans
- Integration with Project Decision Making
- Integration with IMS

Better Risk Management has a "Moderately Strong" positive relationship with Better Performance

Verification vs. Project Performance

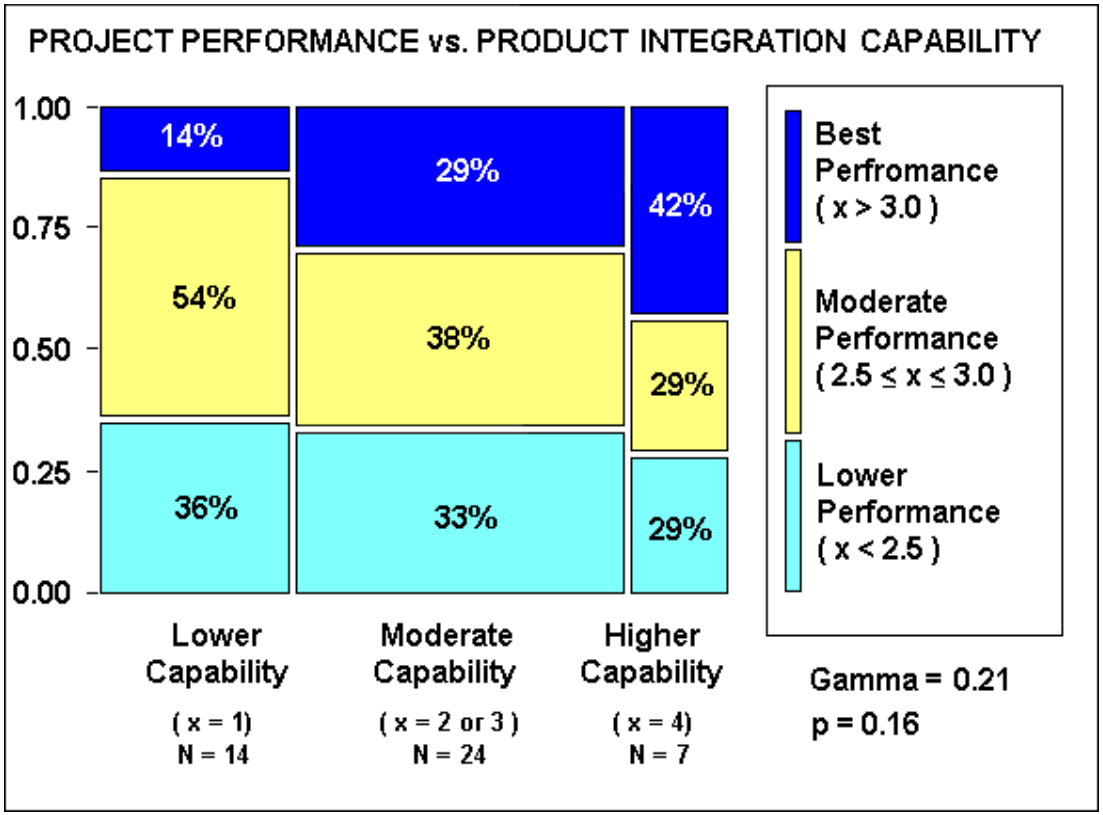


Verification assessment examined

- Verification Procedures
- Documented Acceptance Criteria
- Documented Technical Review Process
- Documented non-advocate reviews

Better Verification capabilities have a "Moderately Strong" positive relationship with Better Performance

Product Integration vs. Project Performance

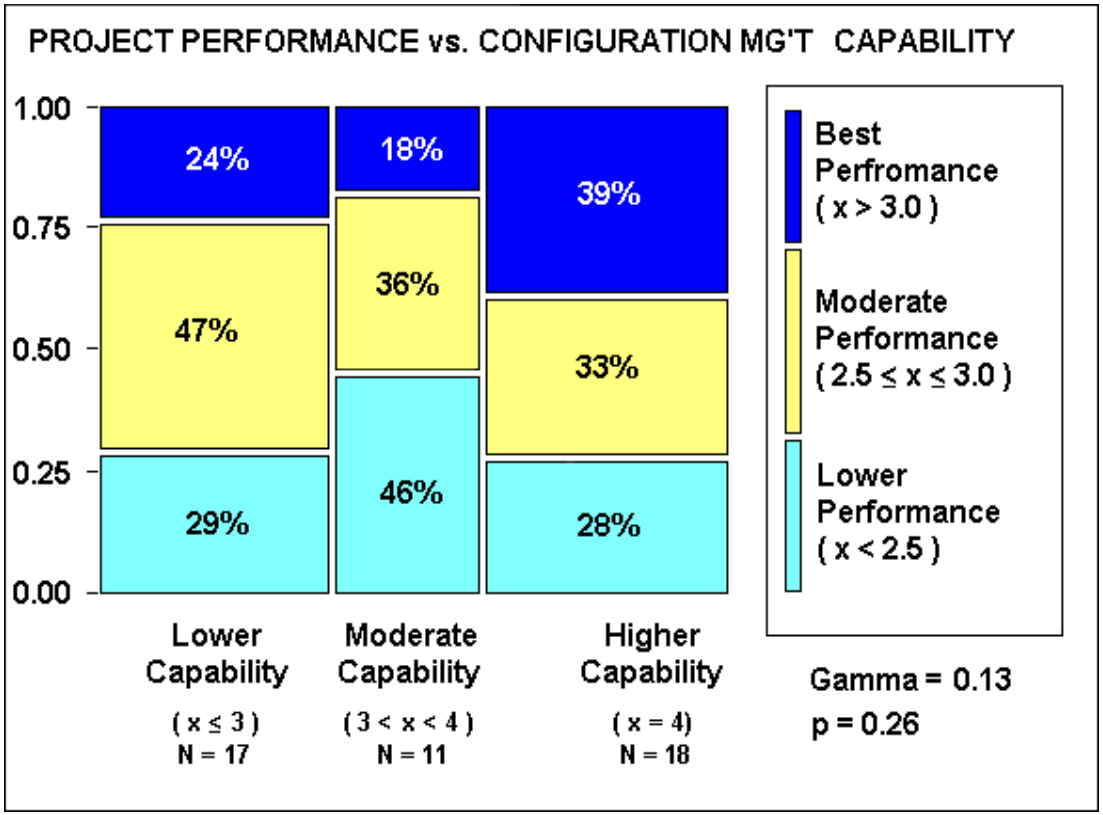


Product Integration assessment examined

- Documented Integration Process
- Documented Integration Criteria

Better Product Integration capabilities have a "Weak" positive relationship with Better Performance

Configuration Mg't vs. Project Performance

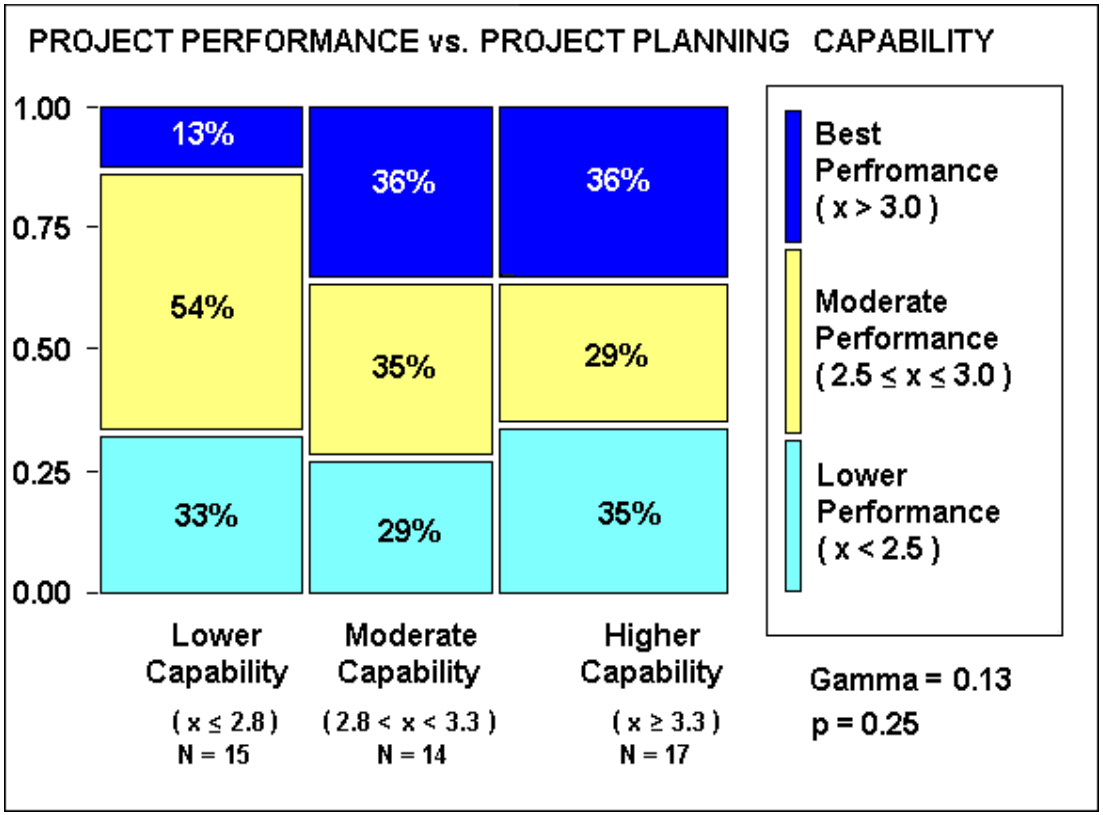


Product Integration assessment examined

- Change Control Board Charter
- Records of requested and implemented changes
- Configuration Baselines

Better Configuration Management capabilities have a "Weak" positive relationship with Better Performance

Project Planning vs. Project Performance

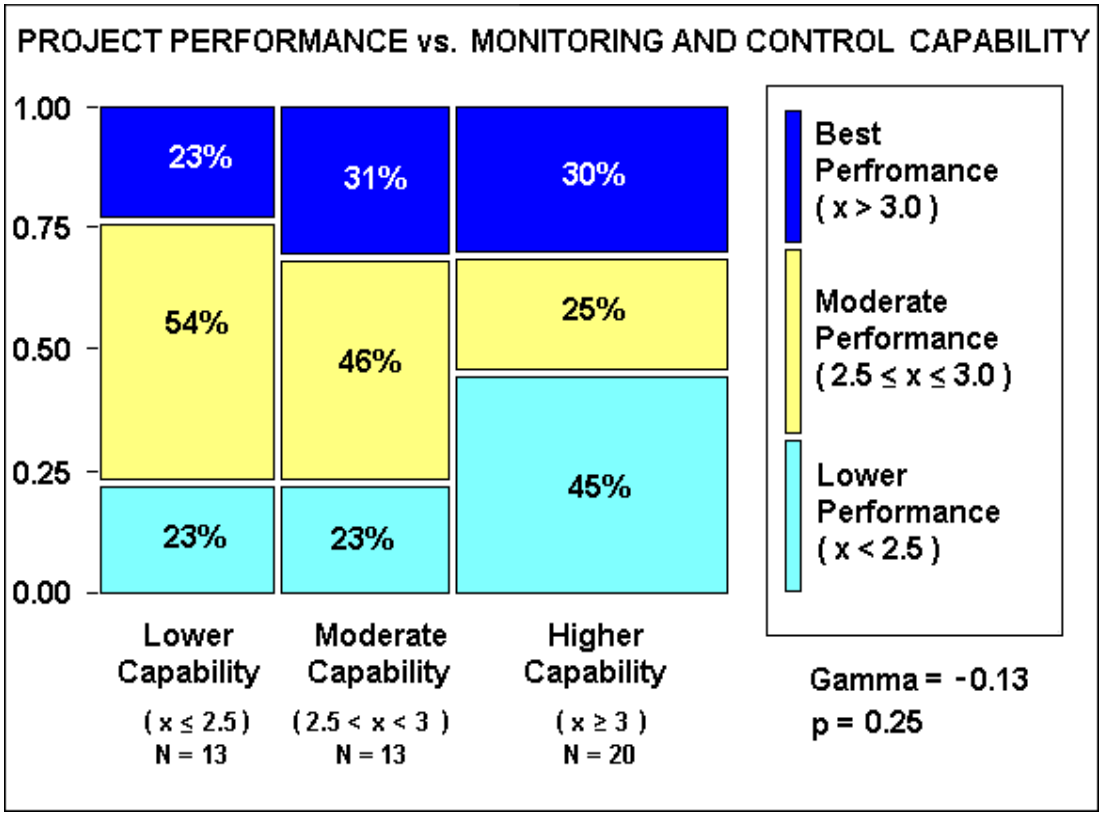


Project Planning assessment examined

- Project Planning Processes
- Work Breakdown Structure
- Technical Approach
- IMP and IMS
- Plan for technical reviews
- Systems Engineering Plan

Better Project Planning capabilities have a "Weak" positive relationship with Better Performance

Project Monitoring vs. Control and Project Performance



Project Planning assessment examined

- SE Costing and Tracking
- Cost and Schedule Baselines
- EVMS Data
- EVMS Data from Suppliers
- Defined Thresholds for SPI and CPI variance

Better Project Monitoring and Control capabilities have a "Weak" negative relationship with Better Performance