The Effectiveness of Systems Engineering: on DoD System Development Programs

NDIA Systems Engineering Conference

21 October 2008

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SE Effectiveness -
Overview

The SE Effectiveness Survey

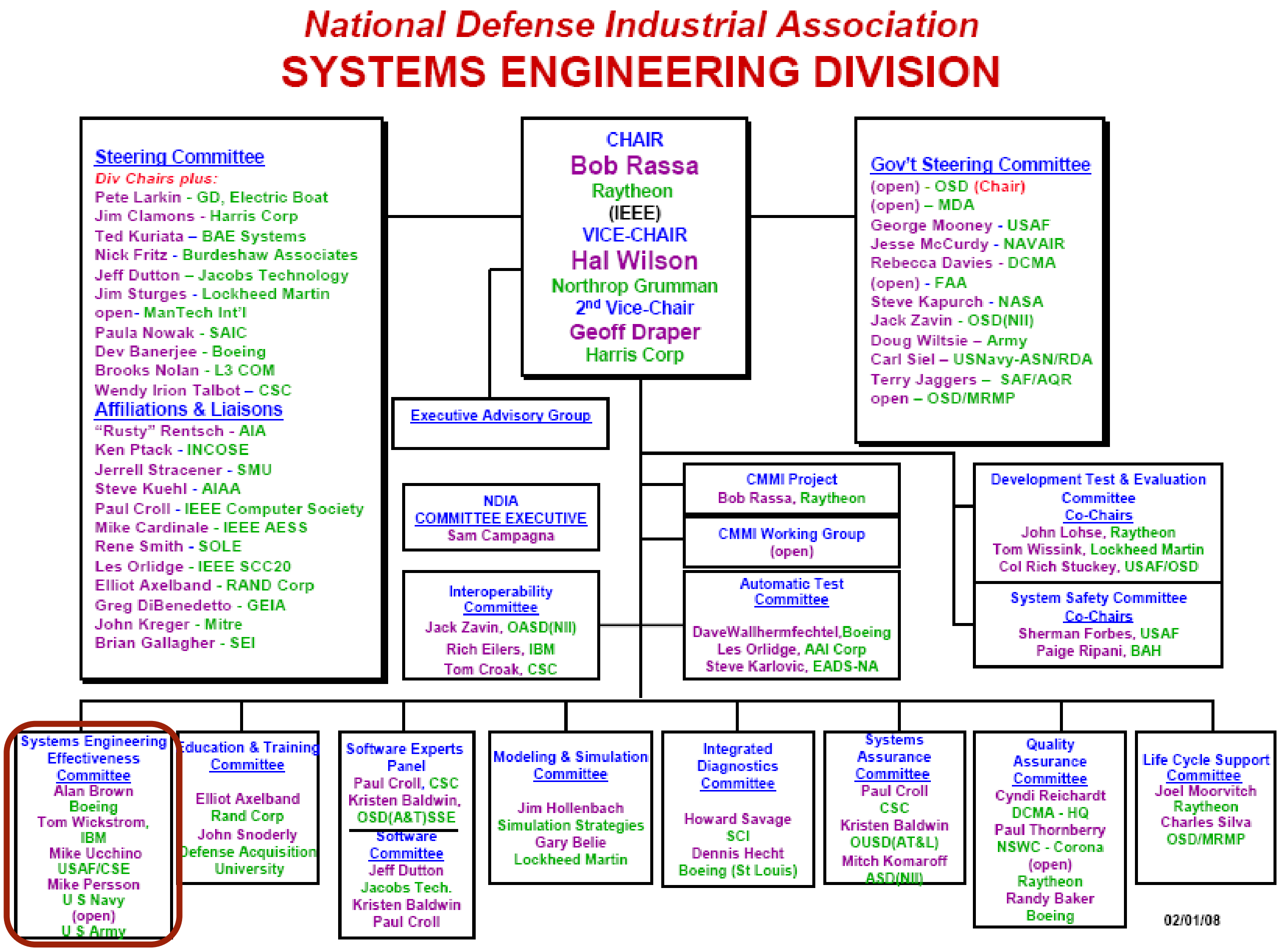
Quantifies the relationship between the application of Systems Engineering best practices and the performance of system development projects

Projects with better Systems Engineering capabilities deliver better Project Performance!

TODAY'S OUTLINE

1. Rationale and Background
2. The Challenge
3. The Rigor
4. The Results!
5. Conclusions & Caveats

NDIA SE Division – Org Chart



Survey Rationale and Background

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

Mink, 2007

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 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)

The Questions

- **How can we quantify the effectiveness and value of SE?**

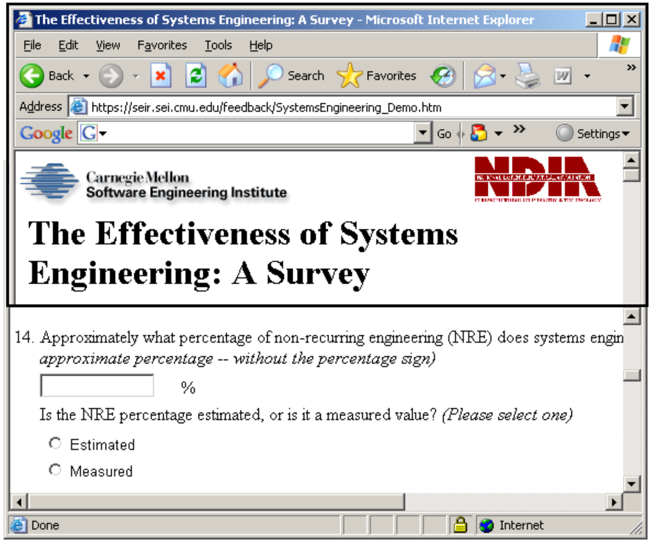
- **How does SE benefit program performance?**

The Solution

Obtain quantitative evidence of the costs and benefits of Systems Engineering

The Challenge –
SE Effectiveness 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).



Objectives:

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

Approach:

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

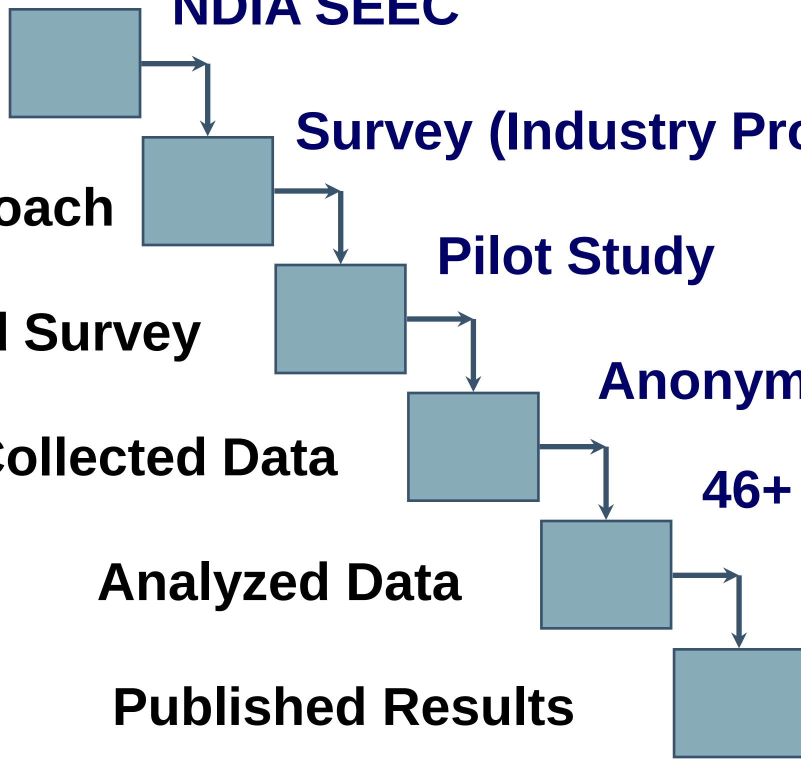
Survey Areas:

Process definition
Project planning
Risk management
Requirements development
Requirements management

Trade studies
Interfaces
Product structure
Product integration
Test and verification

Project reviews
Validation
Configuration management
Metrics

The Rigor -
Followed Planned Lifecycle



Formed Team — **NDIA SEEC**

Developed Approach — **Survey (Industry Projects)**

Validated Survey — **Pilot Study**

Collected Data — **Anonymous via Web**

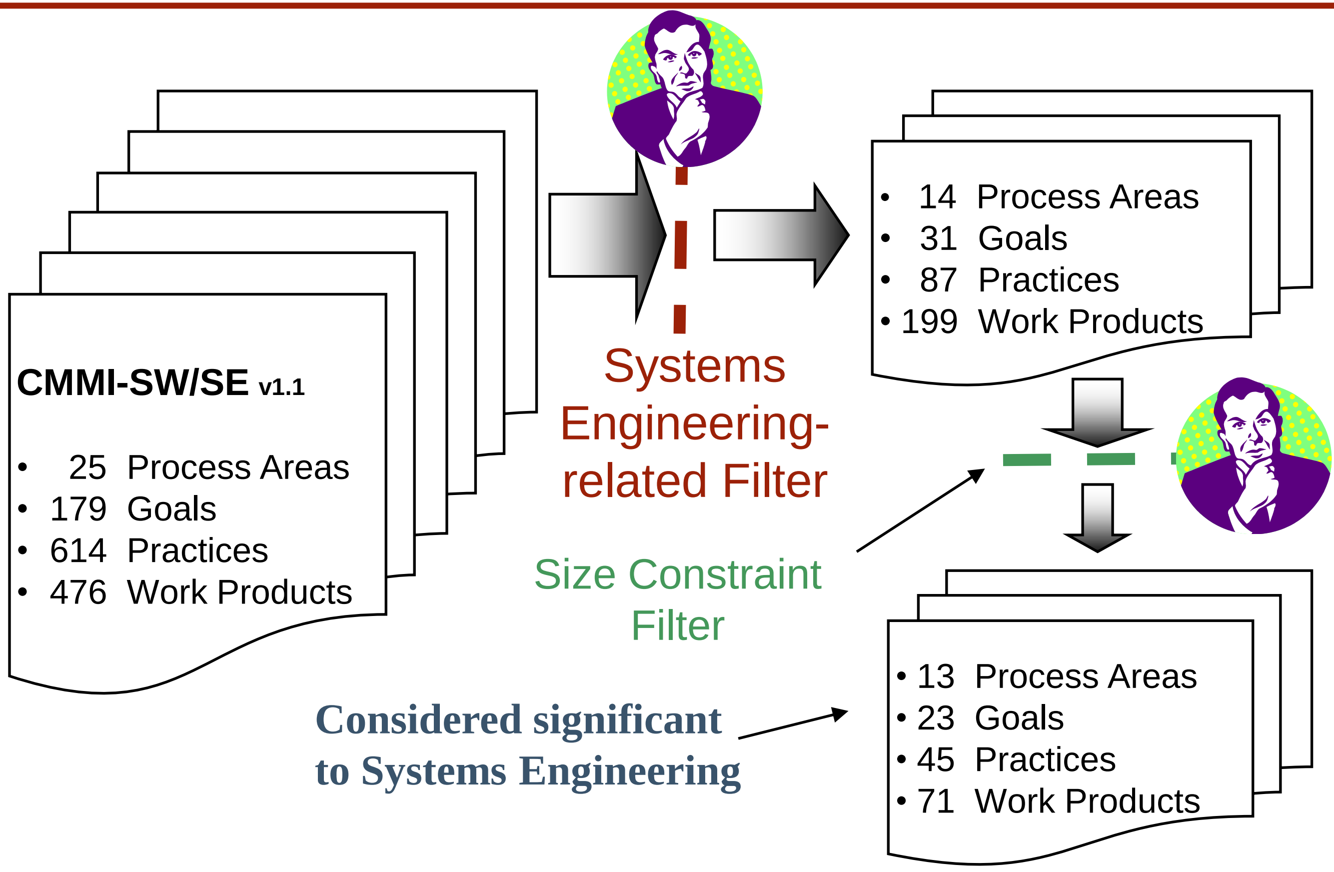
Analyzed Data — **46+ Projects, by SEI**

Published Results — **Two Reports:**

1. ***Public Report***
2. ***Restricted Attachment***

This study spanned three + years

The Rigor -
Formally Selected Set of SE Activities



Survey was developed based on standards and recognized SE experts

Candidate Methods:
Case Studies

Method

- Establish collaboration with one (or a few) defense contractor(s)
- Choose a few completed projects
- Collect and analyze data to quantify the costs and benefits of the SE applied to the projects

Pros

- In-depth, multi-faceted study

Cons

- Reluctance of contractors to expose sensitive data
- Lack of data
  - Consistency: No generally accepted definition of SE
  - Availability: 1) SE efforts not often budgeted and tracked
2) Benefits of SE are difficult to quantify
- Lack of generalization
  - "That doesn't apply to us; we do it differently."
  - "That's just one (or a few) project(s)."

Candidate Methods:
Organizational Survey

Method
- Survey defense contractor organizations
- Collect and analyze data to quantify the costs and benefits of SE applied within the organization

Pros
- Based on a representative sample of the industry

Cons
- Reluctance of contractors to expose sensitive data
- Lack of data
  - Consistency:
    1) No generally accepted definition of SE across organizations
    2) Uneven application of SE within organizations
  - Availability:
    1) SE efforts not often budgeted and tracked
    2) Benefits of SE are difficult to quantify

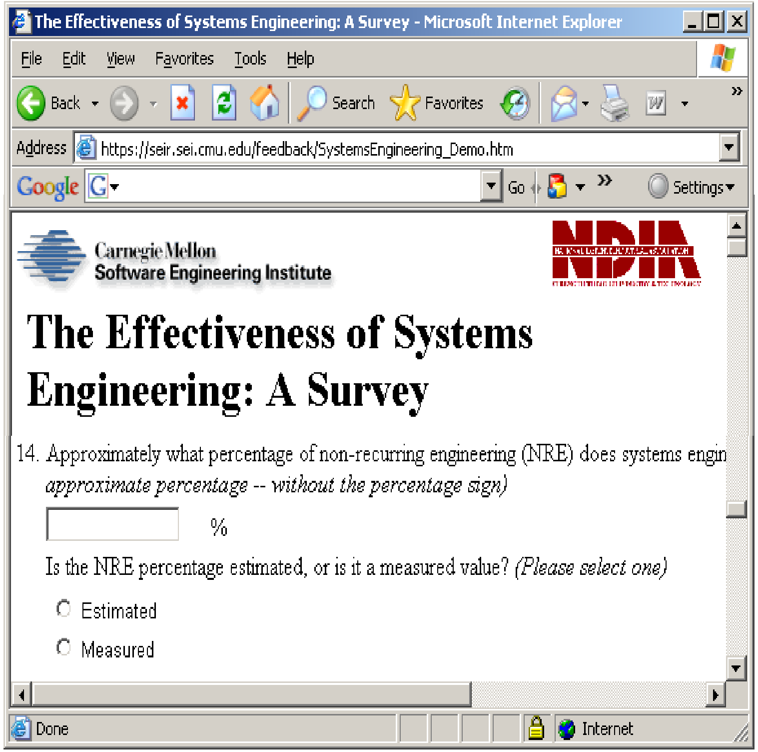
Candidate Methods:
Project Survey

● ✓

Method	• Survey individual defense contractor projects • Collect data on the application of selected SE practices • Collect data on the overall performance of the project • Analyze results to identify relationships between SE application and project performance
Pros	• Based on a representative sample of the industry • The survey provides a common definition of SE • Project performance data is widely available
Cons	• Reluctance of contractors to expose sensitive data

Implementation of the Systems Engineering Effectiveness Survey (SEES)

1. Define the goal
2. Choose the population
3. Define the means to assess usage of SE practices
4. Define the measured benefits to be studied
5. Define the 'other' factors to be studied
6. Develop the survey instrument
7. Execute the survey
8. Analyze the results
9. Report
10. Plan future studies



Population and Sampling Method

Population

- DoD prime contractors and subcontractors who produce products (as opposed to services).

Sampling Method

- NDIA SE Division represents a reasonable cross section of the chosen population
- Invite all product-supplying organizations within the NDIA SE Division to participate.
- Random sampling within each organization

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

Based on CMMI-SE/SW v1.1

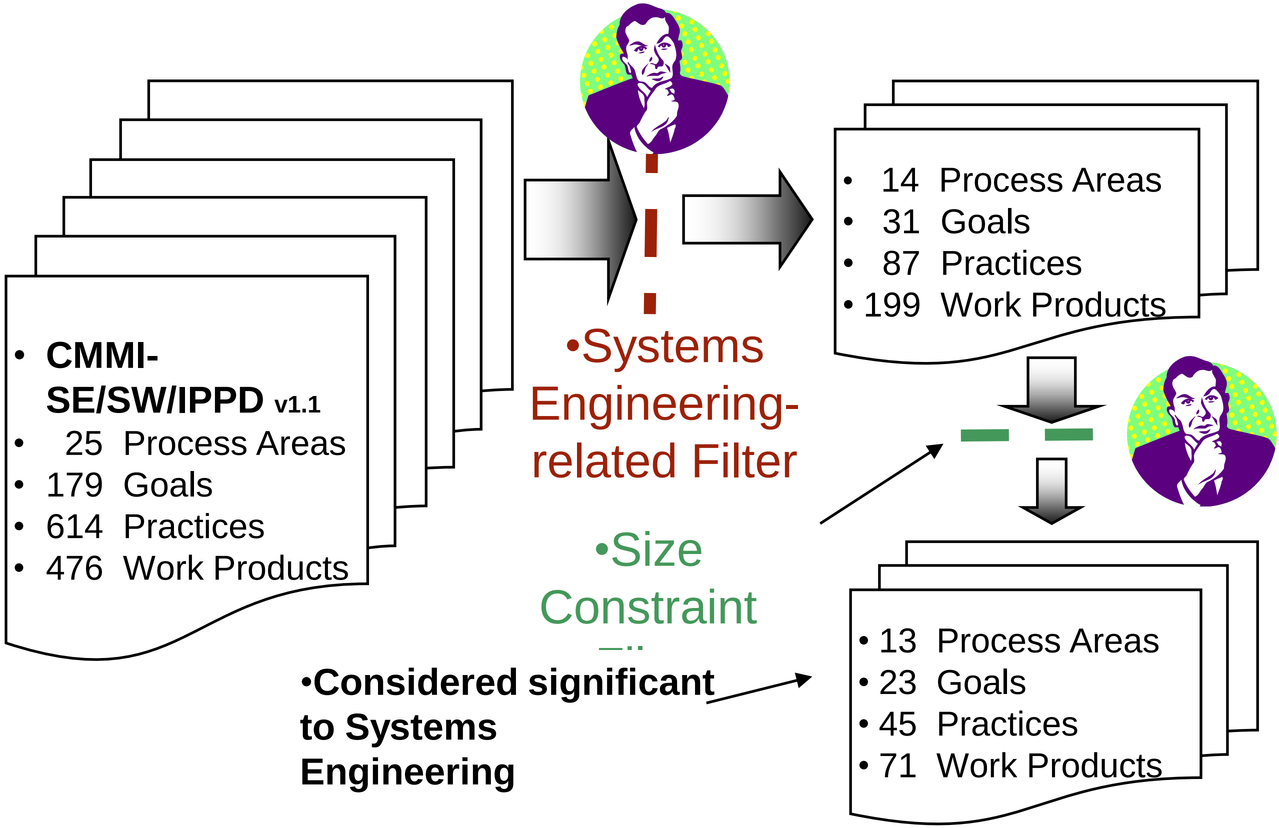
Focused on identifying tangible artifacts of SE activities

- Work products

Work Products chosen by a panel of SE experts from government, industry, and academia

- First pass - selected CMMI Work Products that were (in the judgment of the SE expert panel) related to SE
- Second pass – selected SE-related Work Products that were (in the judgment of the SE expert panel) most significant

Assessment of SE Practices 3



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

Assessment of SE Practices 4

Goal	PRACTICE	WORK PRODUCT	SE Work Product	KEY SE WP	Q#
Integrated Project Management for IPPD					
SG 1: Use the Project's Defined Process - The project is conducted using a defined process that is tailored from the	SP 1.1-1: Establish the Project's Defined Process - Establish and maintain the project's defined process.	The project's defined process			
	SP 1.2-1: Use Organizational Process Assets for Planning Project Activities - Use the organizational process assets and measurement repository for estimating and planning	Project estimates			
		Project plans			
	SP 1.5-1: Contribute to the Organizational Process Assets … measures, and documented … ssets.	Proposed improvements to the organizational process assets			
		Actual process and product measures collected from the project			
		…umentation (e.g., exemplary process descriptions, plans, …checklists, and lessons learned)			
		Presentatio… …tive activities			
		Published principles, shared-visi… and objectives (e.g., posters, wallet cards published on posters suitable for wall hanging)			
SG 4: Organize Integrated Teams for IPPD - The integrated teams needed to execute the project are identified, defined, structured, and tasked.	SP 4.1-1: Determine Integrated Team Structure for the Project - Determine the integrated team structure that will best meet the project objectives and constraints.	Assessments of the product and product architectures, including risk and complexity	Y		
		Integrated team structures based on the WBS and adaptations	Y	Y	Proj05 Proj06
		Alternative concepts for integrated team structures that include responsibilities, scope, and interfaces	Y		
		Selected integrated team structure	Y		
	SP 4.2-1: Develop a Preliminary Distribution of Requirements to Integrated Teams - Develop a preliminary distribution of requirements, responsibilities, authorities, tasks, and interfaces to teams in the selected integrated team structure.	Preliminary distribution of integrated team authorities and responsibilities	Y		
		Preliminary distribution of the work product requirements, technical interfaces, and business (e.g., cost accounting, project management) interfaces each integrated team will be responsible for satisfying	Y		
	SP 4.3-1: Establish Integrated Teams - Establish and maintain teams in the integrated team structure.	A list of project integrated teams	Y		
		List of team leaders	Y		
		Responsibilities and authorities for each integrated team	Y	Y	Proj03
		Requirements allocated to each integrated team	Y		
		Measures for evaluating the performance of integrated teams	Y	Y	Proj04
	relative priority.				

Goal	PRACTICE	WORK PRODUCT	SE Work Product	KEY SE WP	Q#
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		Integrated team structures based on the WBS and adaptations	Y	Y	Proj05 Proj06
		Alternative concepts for integrated team structures that include responsibilities, scope, and interfaces	Y		
		Selected integrated team structure	Y		

- Identified as key SE artifacts
- Identified as SE artifacts

Assessment of SE Practices 5

- SE Work Products chosen in the following CMMI Process Areas:

CMMI Process Area		# WP	
• Organizational Process Definition	OPD	1	
• Project planning	PP	10	
• Risk management	RSKM	6	
• Requirements development	RD	8	
• Integrated Project Management	IPM	3	
• Requirements management	RM	10	
• Configuration management	CM	7	Trade studies
• Technical Solution	TS	13	Interfaces
• Product Integration	PI	1	Product architecture
• Verification	VER	10	
• Validation	VAL	2	

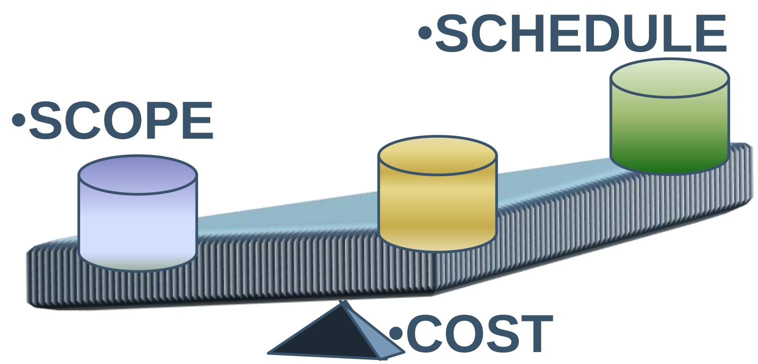
Assessment of Project Performance

•<u>Question #2</u>

•**How is your project going?**

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

Developing the Survey Instrument:
Requirements

Target Respondent

- Program / Project Manager or designee for individual projects

Deployment

- Web based
- Anonymous
  - No questions eliciting identification of respondent, project, or organization

Target Response Time

- Average: 30 minutes
- Maximum: 60 minutes

Developing the Survey Instrument:

Questionnaire Structure

Section 1 - Project Characterization

- Project Challenge
- Acquirer Capability
- Project Environment

Section 2 - SE Capability Assessment

- Process Definition, Project Planning & Risk Management
- Requirements Development, Requirements Management & Trade Studies
- Interfaces, Product Structure & Integration
- Verification, Validation, & Configuration Management

Section 3 - Project Performance Assessment

- Earned Value Management
- Other Performance Indicators

Developing the Survey Instrument: Question Formats 1

Quantitative Questions

- Some questions require numeric answers
  - What is the current total contract value of this project?
- Other questions require an approximate numeric response
  - The schedule of this project's critical path when compared to the current IMS approved by the acquirer is:

    ☐ Greater than 6 months late

    ☐ Greater than 3 months late

    …

    ☐ Greater than 6 months early

Free Form Questions

- Provides an opportunity for the respondent to enter his thoughts
  - What performance indicators (beyond cost and schedule) have been particularly useful in managing your project?

Developing the Survey Instrument:

Question Formats 2

Likert Items

- Many of the questions assessing SE Capabilities use a “Likert” format
  - a psychometric scale commonly often used in survey research
  - respondents specify their level of agreement to a statement

    “My project has a <*work product*> with <*defined characteristics*>”

    ☐Strongly Disagree ☐Disagree ☐Agree ☐Strongly Agree

•**Example**

•This project has a top-level plan, such as an Integrated Master Plan (IMP) that is an event-driven plan (i.e., each accomplishment is tied to a key project event.

•☐ Strongly Disagree ☐ Disagree ☐ Agree ☐ Strongly Agree

Developing the Survey Instrument: Testing 1

Deployed to volunteers among the organizations participating in the development of the survey

Interviews with respondents addressing:

- Understanding of the questions
  - Nearly all questions interpreted without ambiguity
  - Some rewording to ensure consistent understanding
- Time required for completion
  - Typical 45 minutes. Maximum >2 hours
  - Issues with questions requiring quantitative inputs
- Suggestions for improvements

Developing the Survey Instrument:
Testing 2

Questionnaire revised to address results of initial testing

- Elimination of questions
- Replacement of pure quantitative questions with approximate quantitative questions
  - Selection of ranges of values rather than the entry of numeric values
  - Provided cues for the level of detail desired

Redeployed for testing

- All questions interpreted without ambiguity
- Time required for completion
  - Typical 30 minutes. Maximum 60 minutes

Survey Deployment

Challenges	Solutions
Ease of Participation •Method of response must be easy to encourage maximum participation	• Deployment and response via the internet
Confidentiality •Many NDIA members represent commercial defense contractors. •Proprietary data cannot be exposed	• Data collection and analysis done by the SEI. Only aggregated results provided
Anonymity •Further protection of proprietary data	• No questions soliciting respondent, project, or organization identification • "blind" authentication for survey login
Incentivization • Respondents and their organizations need a reason (beyond altruism) to participate	• Respondent solicitation through company management hierarchy • Early access to survey results to support benchmarking and process improvement

Survey Deployment:
Respondent Solicitation 1

Review the roster of "Active Members" of the NDIA Systems Engineering Division

Select organizations that develop and produce products (rather than services)

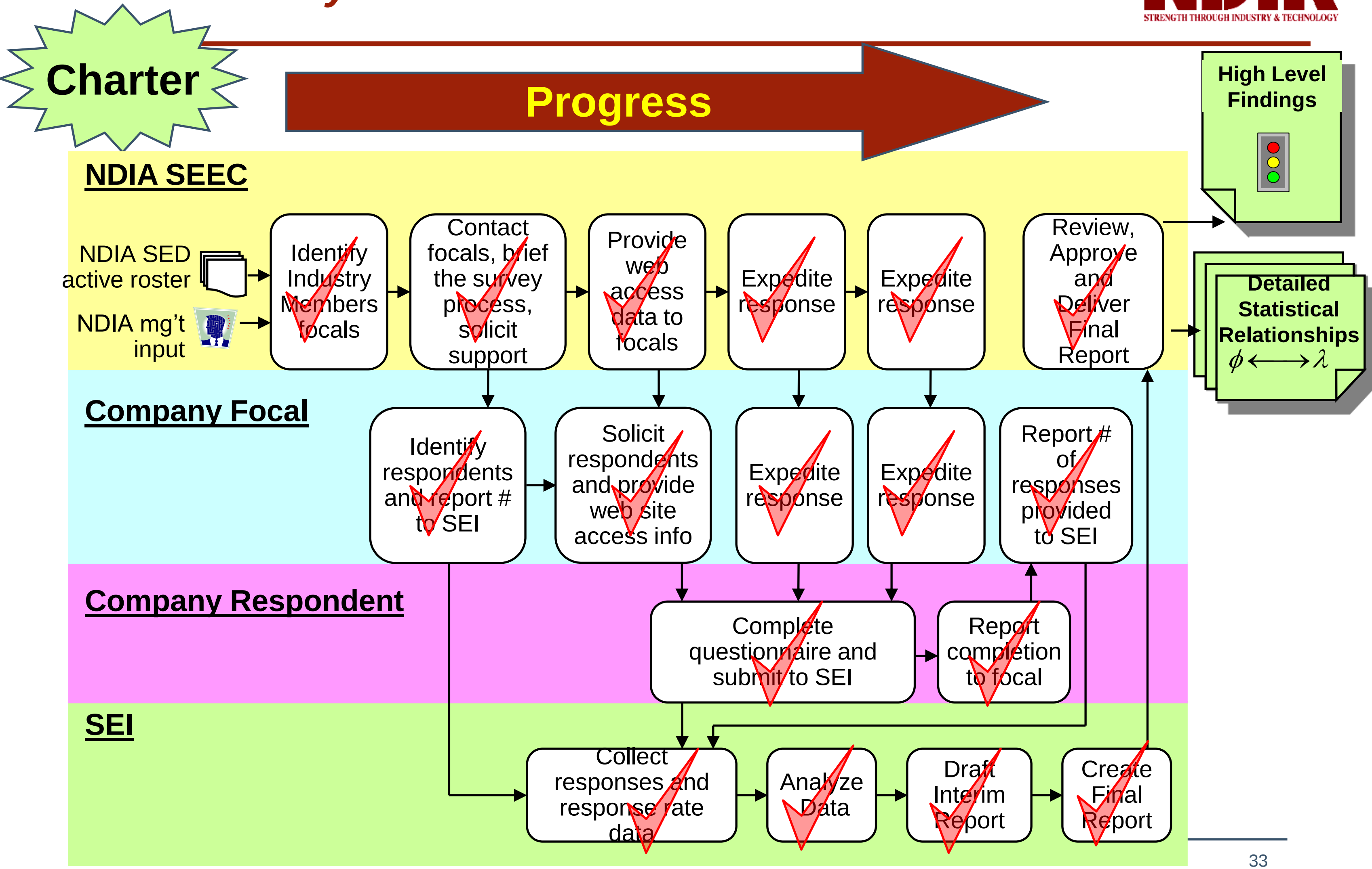
Identify "focal" person within each organization

- Involved with / interested in SE
- As high as possible within the organization's management hierarchy

Contact Focals

- Brief the survey and solicit their support within their organization
- Ask them to solicit respondents, and provide the tools to assist them
    - Respondent solicitation by proxy enhances anonymity

The Rigor –
SEEC Survey Process



The Rigor – *Survey Methodology*

Survey Population	**Organizations developing products in support of government contracts (prime or subcontractors).**
Sampling Method	**Invitation to qualifying active members of NDIA Systems Engineering Division. Random sampling within organization.**
Survey Deployment	**Web deployment (open August 10, 2006 - November 30, 2006). Anonymous response. Questions based on CMMI-SE/SW/IPPD v1.1**
Target Respondent	**Program Manager or designee(s) from individual projects**
Questionnaire Structure	**1. Characterization of the project /program under consideration 2. Evidence of Systems Engineering Best Practices 3. Project / Program Performance Metrics**
Target Response Time	**30 – 60 minutes**
Responses	**64 survey responses (46 complete; 18 partial, but usable)**
Analysis	**Raw data analyzed by Software Engineering Institute. Analysis results reviewed by NDIA SE Effectiveness Committee.**
Reports	**1. Public NDIA/SEI report released November 2007. 2. Restricted attachment, details provided to respondents only.**

The Rigor – *Analysis*

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

where:

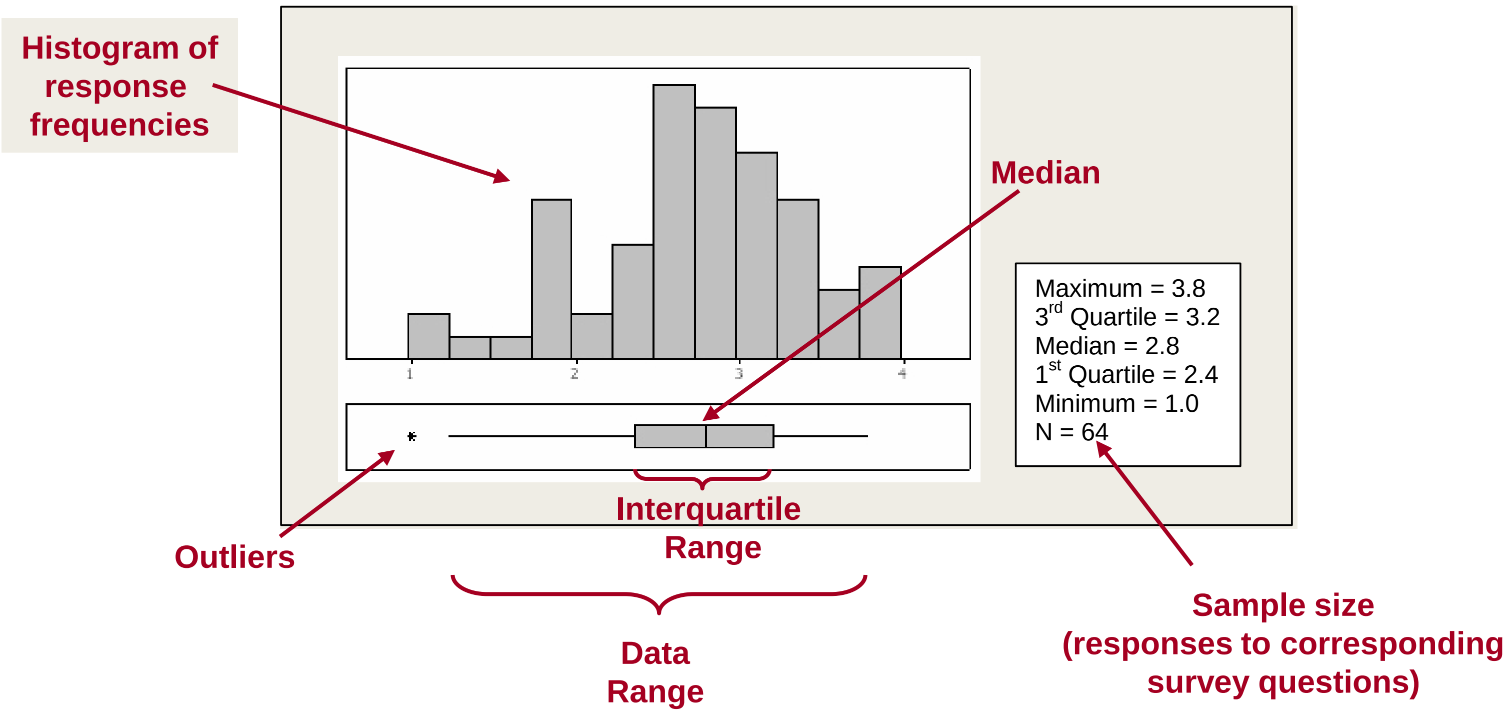
Perf = Project Performance
PE = Project Environment
SEC = Systems Engineering Capability
PC = Project Challenge
AC = Acquirer Capability

SEC can be further decomposed as:

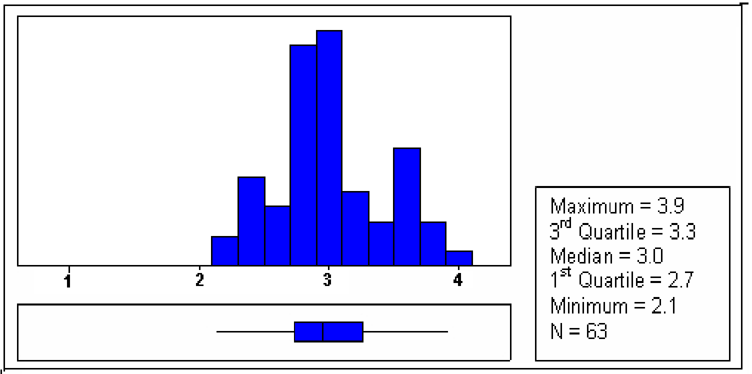
- Project Planning
- Project Monitoring and Control
- Risk Management
- Requirements Development and Management
- Technical Solution
  - Trade Studies
  - Product Architecture
- Product Integration
- Verification
- Validation
- Configuration Management
- IPT-Based Capability

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

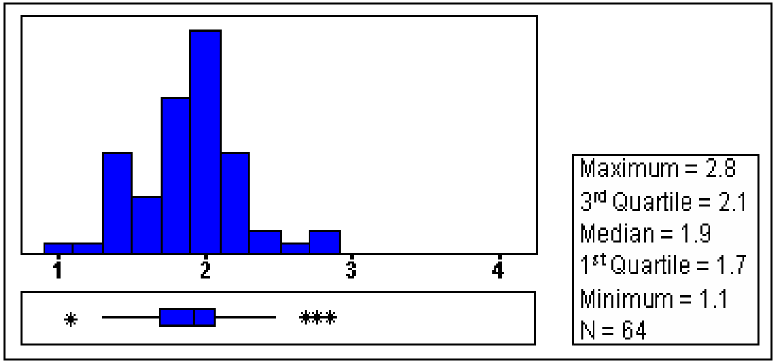
The Rigor - *Terminology and Notation*
Distribution Graph



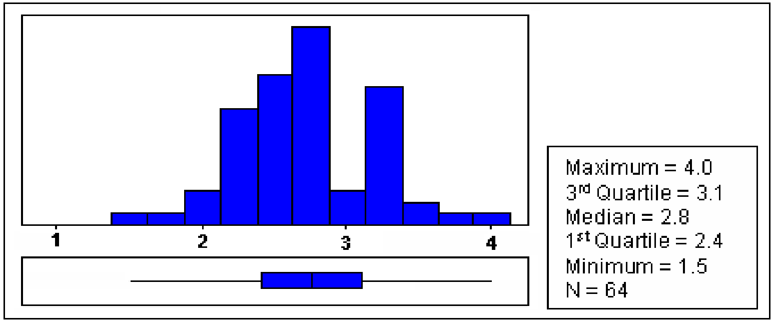
The Rigor -
Validation of Survey Responses



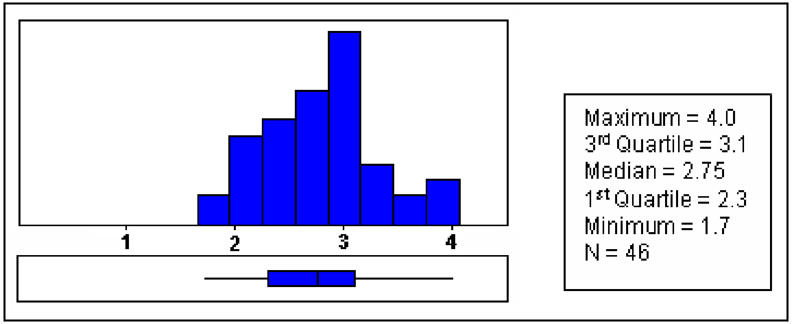
Overall SE Capability (SEC)



Project Challenge (PC)



Acquirer Capability (AC)



Project Performance (Perf)

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

Analysis

MOSAIC Charts 1

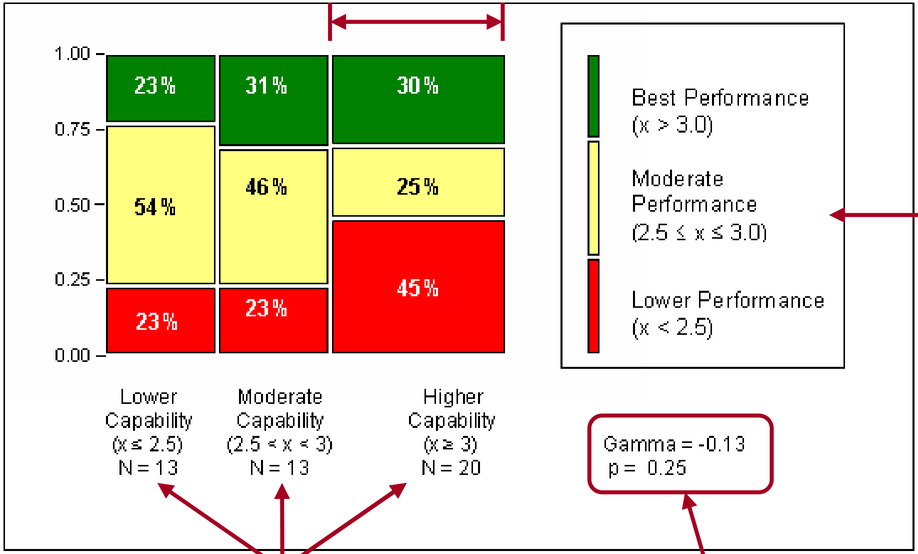
•Variable A		•Low	•Med	•High
	•High	•A=High •B=Low	•A=High •B=Med	•A=High •B=High
	•Med	•A=Med •B=Low	•A=Med •B=Med	•A=Med •B=High
	•Low	•A=Low •B=Low	•A=Low •B=Med	•A=Low •B=High

•Variable B

The Results! - *Terminology and Notation*

Mosaic Chart

Column width represents proportion of projects with this level of capability



Relative performance distribution of the sample

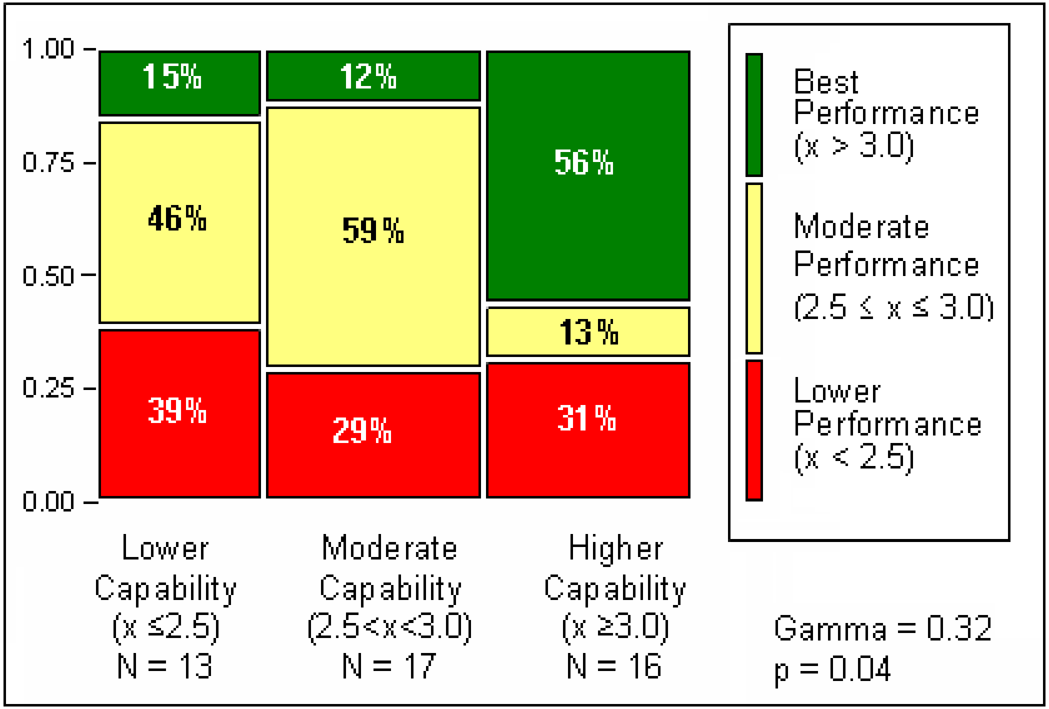
Projects exhibiting a given level of relative capability (Lowest, Intermediate, Highest); Sample size and distribution for associated survey responses (capability + performance)

Measures of association and statistical test

<u>Gamma</u>: measures strength of relationship between two ordinal variables

<u>p</u>: probability that an associative relationship would be observed by chance alone

The Results! – *Total SE Capability (SEC) vs. Project Performance (Perf)*

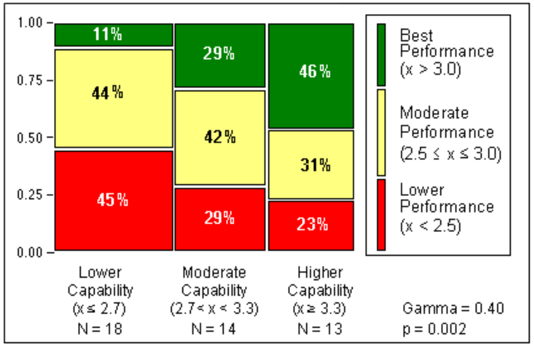


Projects with better Systems Engineering Capabilities deliver better Project Performance (cost, schedule, functionality)

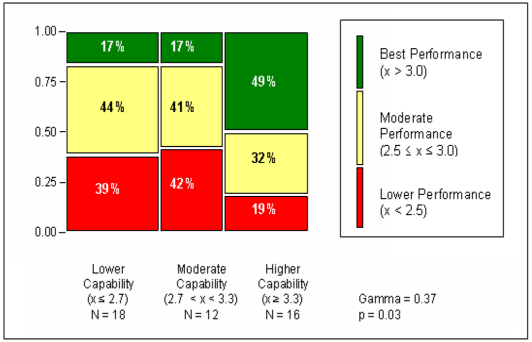
The Results! - *Higher SE Capabilities are Related to Better Program Performance*

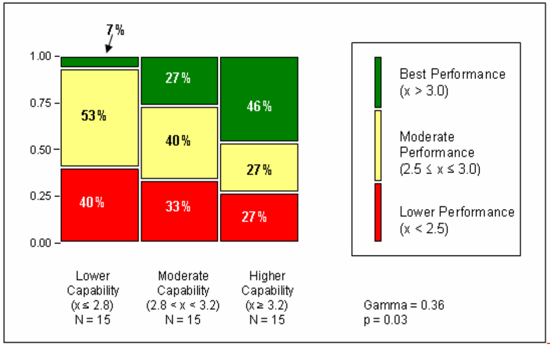
NDIA NATIONAL DEFENSE INDUSTRIAL ASSOCIATION STRENGTH THROUGH INDUSTRY & TECHNOLOGY

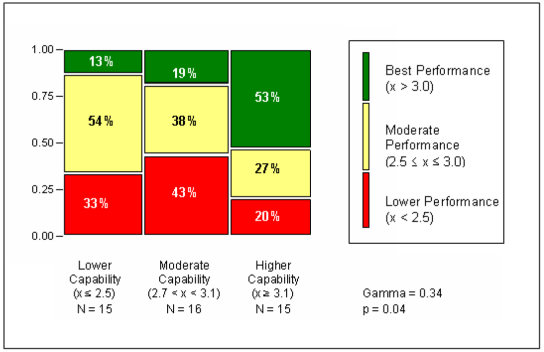
1. Product Architecture

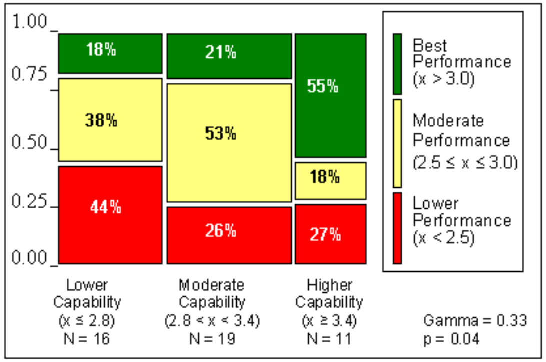


2. Trade Studies









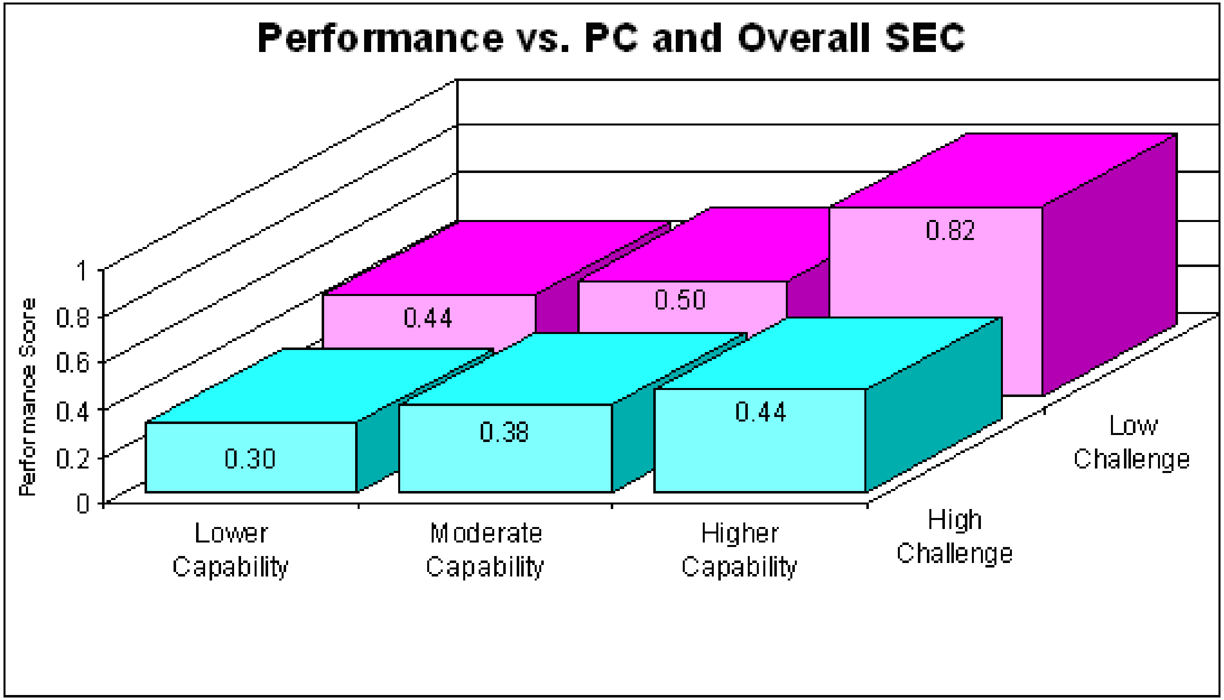
3. Technical Solution

4. IPT Capability

5. Requirements

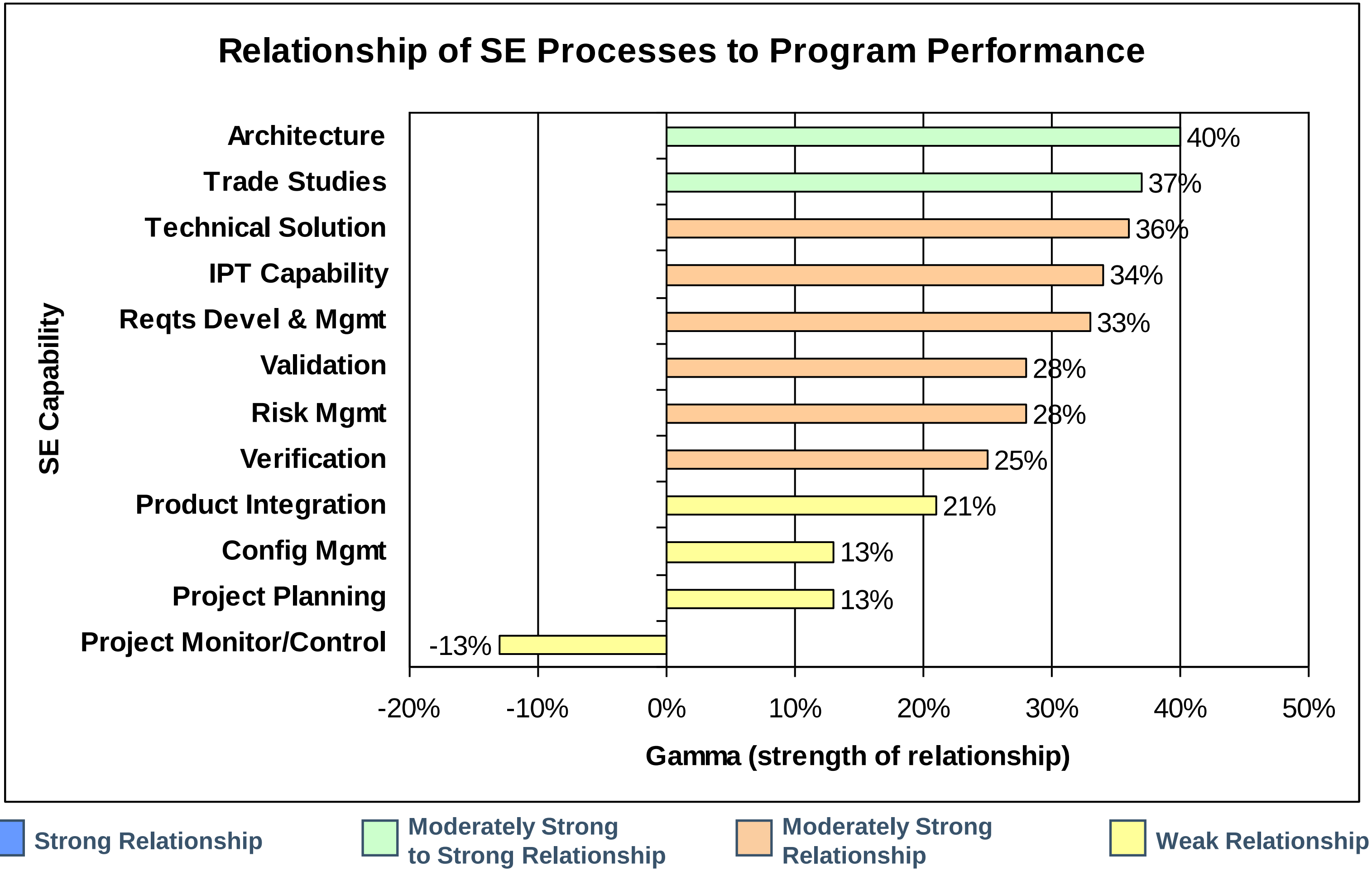
The Results! - *Relating Project Performance to Project Challenge and SE Capability*

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



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

The Results! -
Summary of Process Relationships



Value of the Research

Provide guidance for defense contractors in **planning capability improvement efforts**

Establish an **SE Capability Benchmark** for defense contractors

Provide **justification** and defense of defense contractor **SE investments**

Provide **guidance for acquirer evaluations** and source selections

Provide **guidance for contract monitoring**

Provide recommendations to OSD for areas to **prioritize SE revitalization**

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**
  - Correlate report findings with results of OSD systemic root cause analysis project (SEEC/OSD work group established)
- **Pursue Specific Improvement Recommendations with OSD**
  - Policy, Compliance, Education, Data Collection (specific recommendations submitted to OSD)
- **Conduct Additional Analysis of Collected Data**
  - Independent Verification & Validation
  - Discover other relationships and correlations
- **Expand the Survey to Gauge Improvements**
  - Incorporate Lessons Learned from participants
- **Expand the Survey to Commercial Industries**
  - Discussion with IEEE AEES Board of Governors
- **Survey Acquirers**

Survey Results

“A *Survey of Systems Engineering Effectiveness--Initial Results*” (CMU/SEI-2007-SR-014) available for download as a PDF file on the SEI web site at:

http://www.sei.cmu.edu/publications/documents/07.reports/07sr014.html

Acknowledgements

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Supporters

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SE Effectiveness

Questions?

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Back - up

DoD Systemic Root Cause Analysis
- Why do projects fail?

...We Don't Start Them Right

- Insufficient requirements analysis and definition at program initiation
  - Not tangible, measurable, testable, stable
  - User R&M requirements are not underpinned by sound rationale
- Acquisition strategies based on poor technical assumptions, competing budget priorities, and unrealistic expectations
- Budget not properly phased
- Lack of rigorous systems engineering approach
- Schedule realism – success oriented, concurrent, poor estimation and/or planning
- Inadequate test planning – breadth, depth, resources
- Optimistic/realistic reliability growth – not a priority during development
- Inadequate software architectures, design/development discipline, and organizational competencies
- Sustainment/life-cycle costs not fully considered (short-sighted)

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...We Don't Manage Them Right

- Insufficient trade space
  - Resources, schedule, performance, requirements
- Insufficient risk management
- Inadequate IMP, IMS, EVMS
- Most programs lack quantifiable entrance/exit criteria
- Maturing "suitability" (e.g., RAM) is not always a priority
- Maturing "effectiveness" is not always a priority
- Concurrent test program; inadequate scope due to schedule and resource insufficiencies, etc.
- Inadequate OTRR process – no strong DT&E gate prior to IOT&E
- Inadequate government staff; Inexperienced and/or limited contractor staffing
- Poorly defined IPT roles, responsibilities and authority
  - Overall poor communications across government and industry staff

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Top 10 Emerging Systemic Issues
(from 52 "Deep Dive" Program Reviews since Mar 04)

1. Management	• IPT roles, responsibilities, authority, poor communication • Inexperienced staff, lack of technical expertise
2. Requirements	• Creep/stability • Tangible, measurable, testable
3. Systems Engineering	• Lack of a rigorous approach, technical expertise • Process compliance
4. Staffing	• Inadequate Government program office staff
5. Reliability	• Ambitious growth curves, unrealistic requirements • Inadequate "test time" for statistical calculations
6. Acquisition Strategy	• Competing budget priorities, schedule-driven • Contracting issues, poor technical assumptions
7. Schedule	• Realism, compression
8. Test Planning	• Breadth, depth, resources
9. Software	• Architecture, design/development discipline • Staffing/skill levels, organizational competency (process)
10. Maintainability/Logistics	• Sustainment costs not fully considered (short-sighted) • Supportability considerations traded

Major contributors to poor program performance

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Root causes from DoD analysis of program performance issues appear consistent with NDIA SE survey findings.

<u>**Reference**</u>**:**
Systemic Root Cause Analysis,
Dave Castellano, Deputy Director Assessments & Support, OUSD(A&T)
NDIA Systems Engineering Conference, 2007
and NDIA SE Division Annual Planning Meeting

Recommendations

1. Policy: **Develop policy requiring programs to apply SE practices known to contribute to improved project performance.**
   - Contractual compliance to bidder's SE processes
2. Compliance: **Ensure that SE practices and associated work products are applied to projects as promised and contracted.**
   - Verification via evaluations, audits, milestones, reviews
3. Education: **Train program staff in the value and importance of SE and in the application of SE policy.**
   - Including SE value, policy, technical evaluation
4. Data Collection: **Establish means to continue data collection on the effectiveness of SE to enable continuous process improvement.**
   - Follow-on surveys, analysis, trending

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

* Project Management Institute

Matching items noted in RED

Above Items Can Cause Overall Program Cost and Schedule to Overrun

Conclusions & Caveats -

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

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

- 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**

The 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