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The Business Case for Systems Engineering: Comparison of Defense-Domain and Non- Defense Projects

Presenter: Joseph P. Elm

**The Software Engineering Institute (SEI)
a DoD Research FFRDC**



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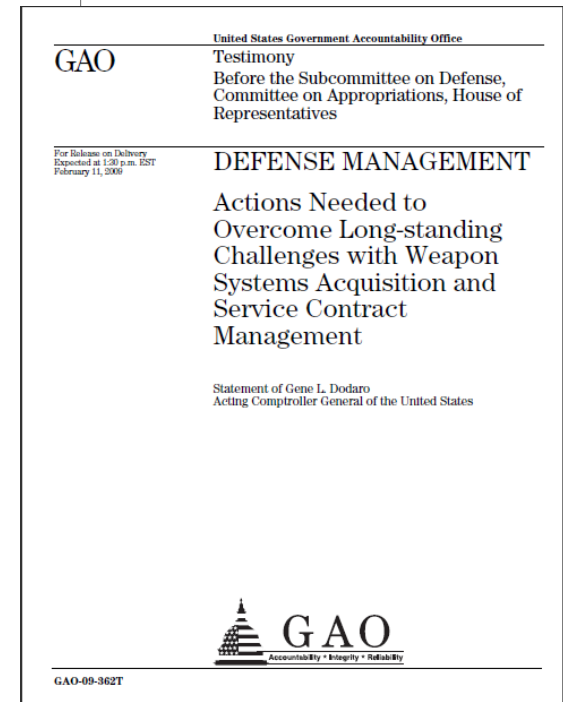
Challenges in DoD Acquisition

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

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

Although DoD is the largest acquirer in the world, acquisition troubles remain ¹

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



1. “Performance of the Defense Acquisition System 2013 Annual Report” Table 2-3, page 34)

Root Cause of Poor Program Performance

Inadequate Systems Engineering!

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

MDAP Cost Growth: PARCA Root Cause Analysis¹

<i>Dominant</i>	
10 of 18 (56%)	Poor management performance <ul style="list-style-type: none">• Systems engineering• Contractual incentives• Risk management• Situational Awareness
5 of 18 (28%)	Baseline cost and schedule estimates <ul style="list-style-type: none">• Framing assumptions
4 of 18 (22%)	Change in procurement quantity
<i>Infrequent</i>	
1 of 18	Immature technology, excessive manufacturing, or integration risk
2 of 18	Unrealistic performance expectations
1 of 18	Unanticipated design, engineering, manufacturing or technology issues
None	Funding inadequacy

1. “Performance of the Defense Acquisition System 2013 Annual Report” Table 2-3, page 34)

Why Do We Fail to Utilize Good SE Practices?

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

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

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

The 2012 SE Effectiveness Study

Purpose

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

Method

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

Survey Tenets

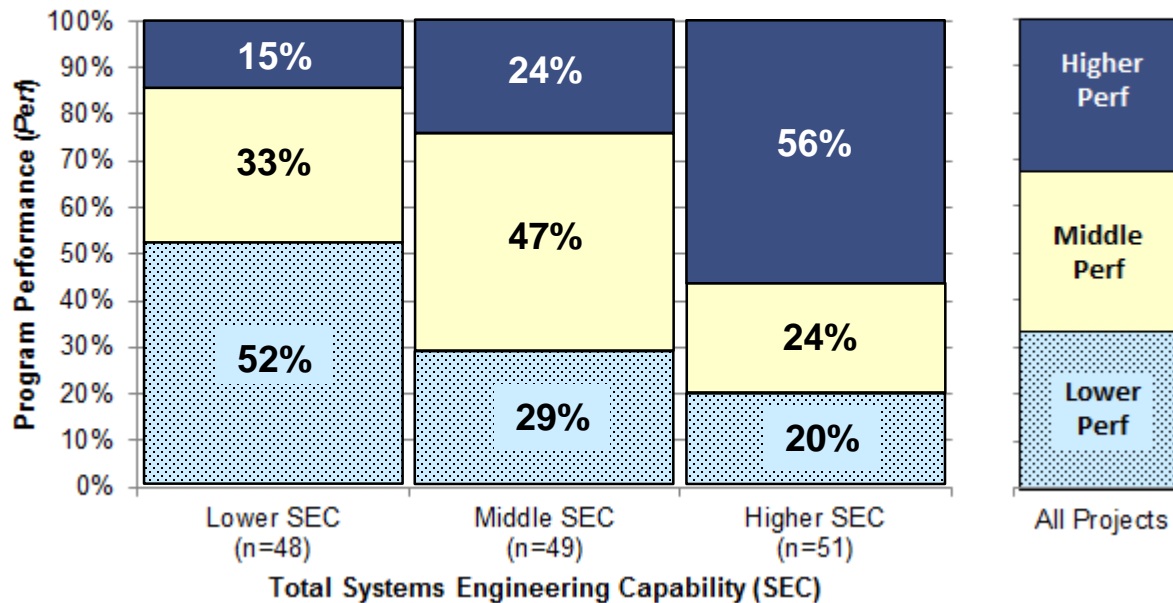
- All data is submitted anonymously and handled confidentially by the SEI.
- Only aggregated non-attributable data is released.



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The Bottom Line: SE = Performance

Program Performance vs. Total SE



Gamma = 0.49 p-value < 0.001

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

For **Lower SEC** projects, only **15%** deliver higher performance

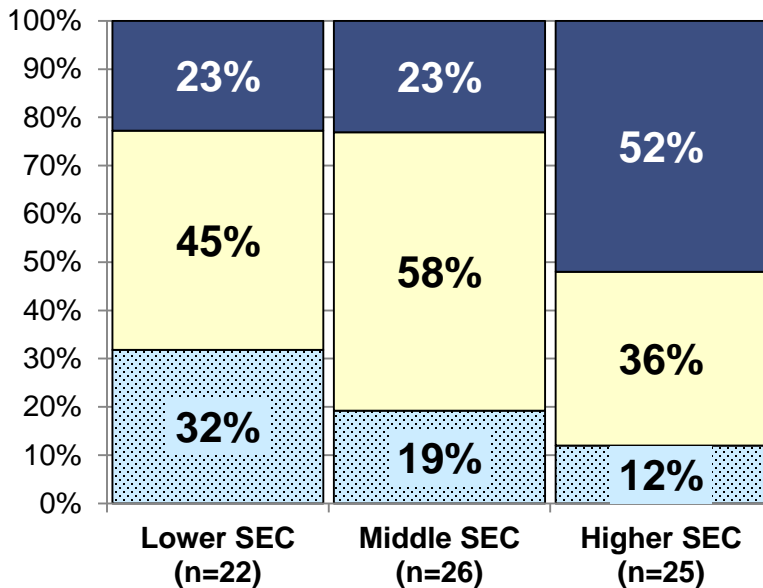
For **Middle SEC** projects, **24%** deliver higher performance

For **Higher SEC** projects, **57%** deliver higher performance

Gamma = 0.49 represents a **VERY STRONG** relationship

For Challenging Projects SE is even MORE important

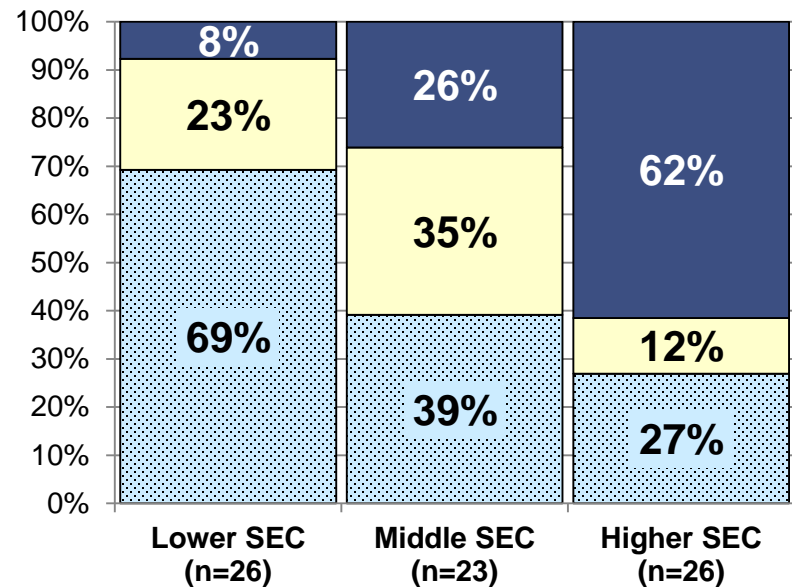
Perf vs. SEC_Total (Low PC)



Gamma = 0.34 p-value = 0.029

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

Perf vs. SEC_Total (High PC)



Gamma = 0.62 p-value = 0.000

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

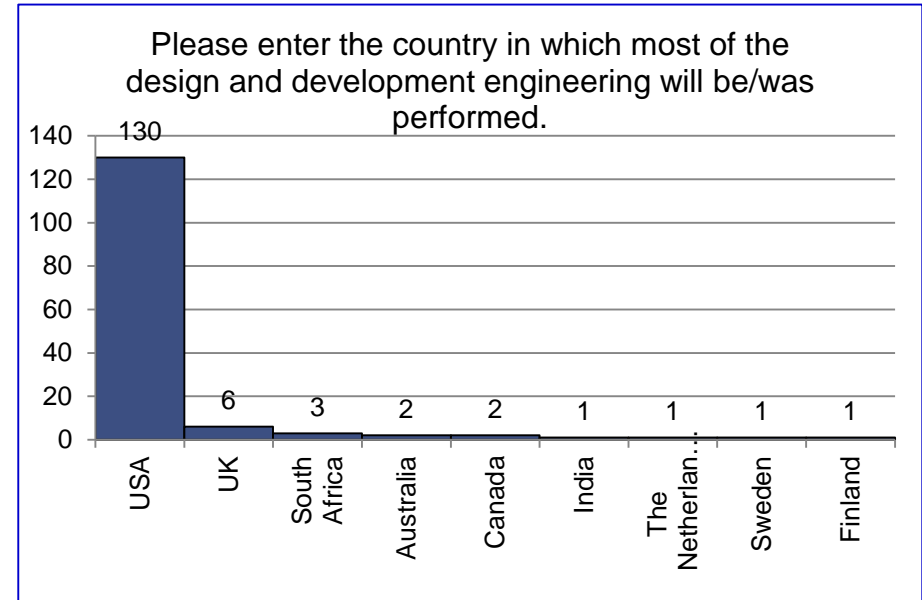
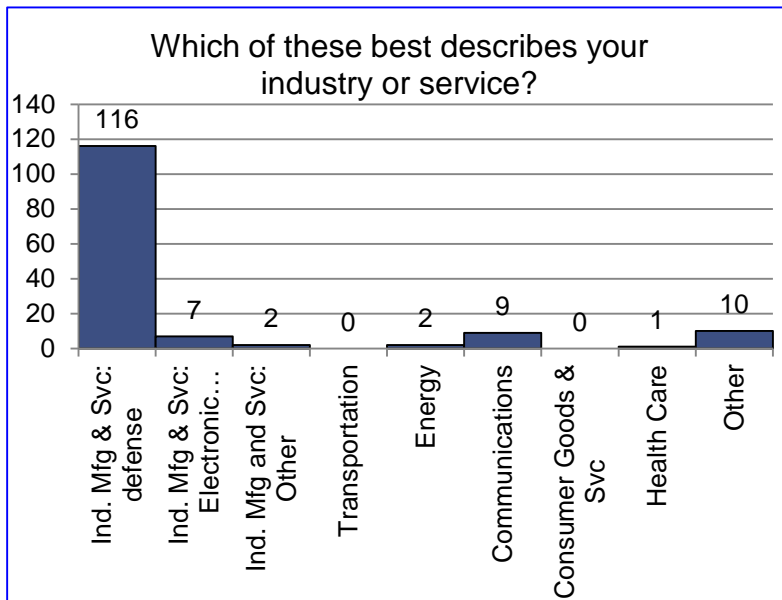
Study Participants

Participant Solicitation

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

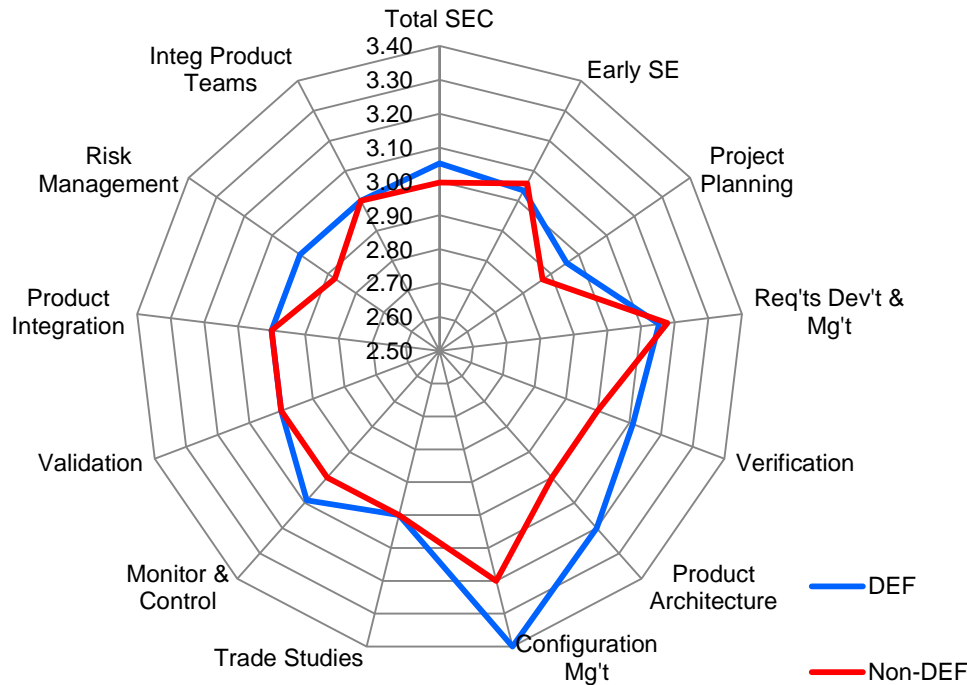


Collected 148 valid responses

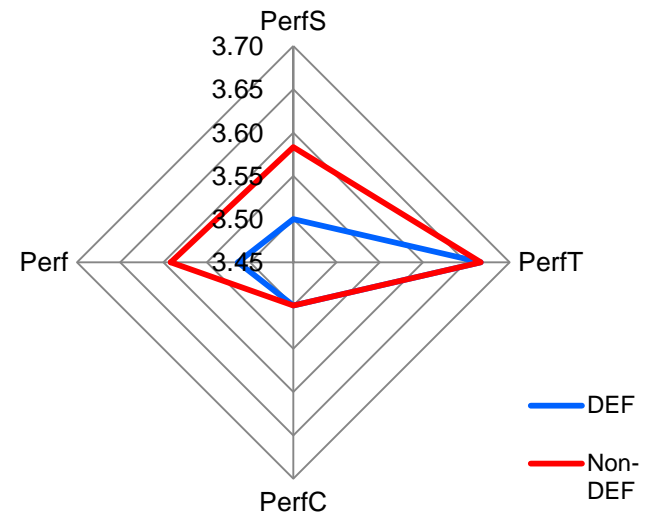


SE Deployment and Performance

SYSTEMS ENGINEERING DEPLOYMENT

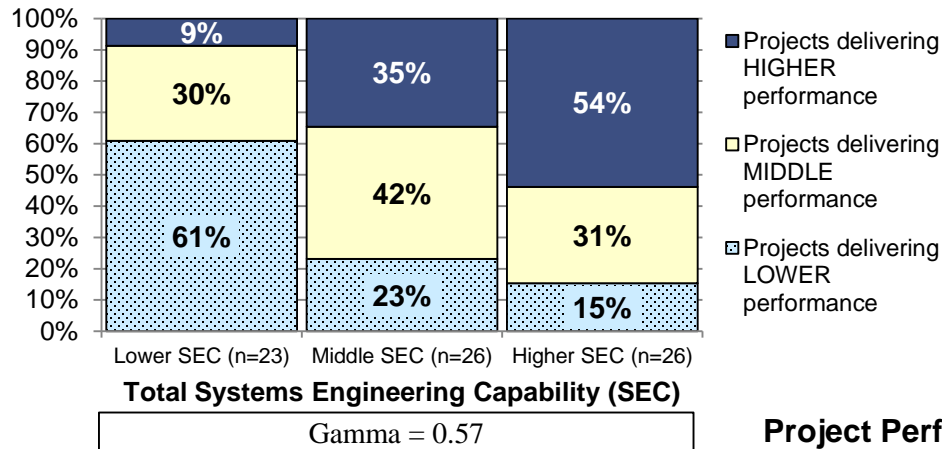


PROJECT PERFORMANCE

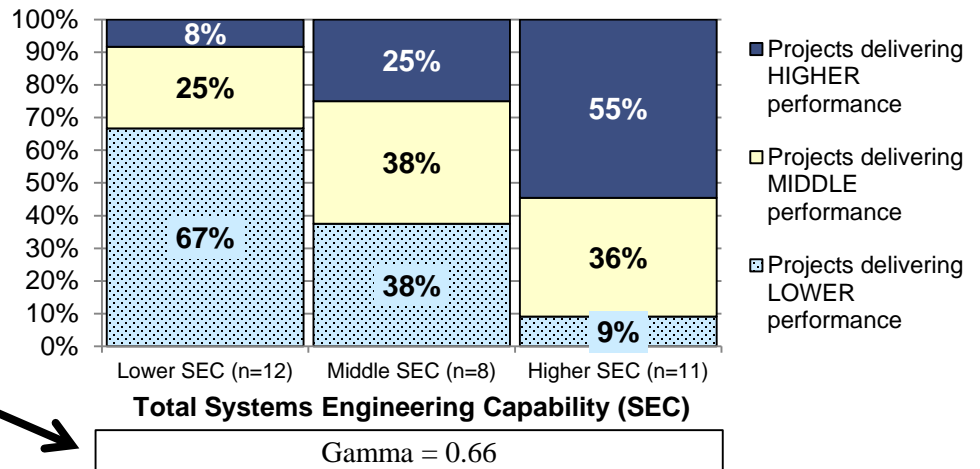


Total SE vs. Project Performance

Project Performance vs. Total SE (defense)



Project Performance vs. Total SE (non-defense)

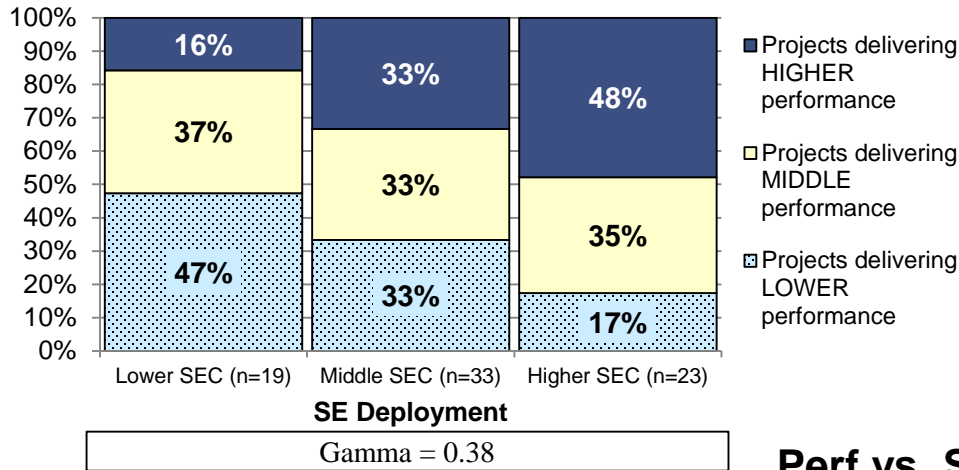


A **Very Strong** relationship between applied SE and Project Performance for both Defense and non-Defense Projects

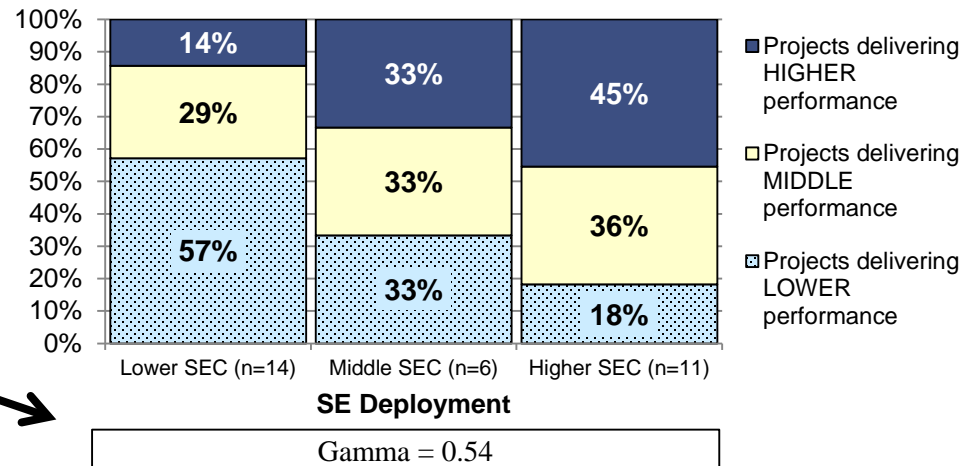


Architecture vs. Project Performance

Perf vs. SEC_ARCH (defense)



Perf vs. SEC_ARCH (non-defense)

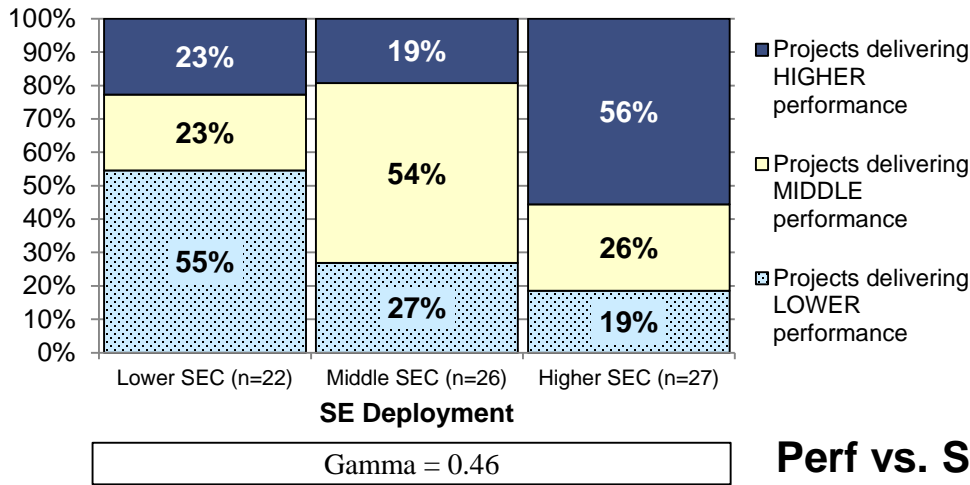


A **Strong** relationship between Architecture activities and Project Performance for Defense Projects

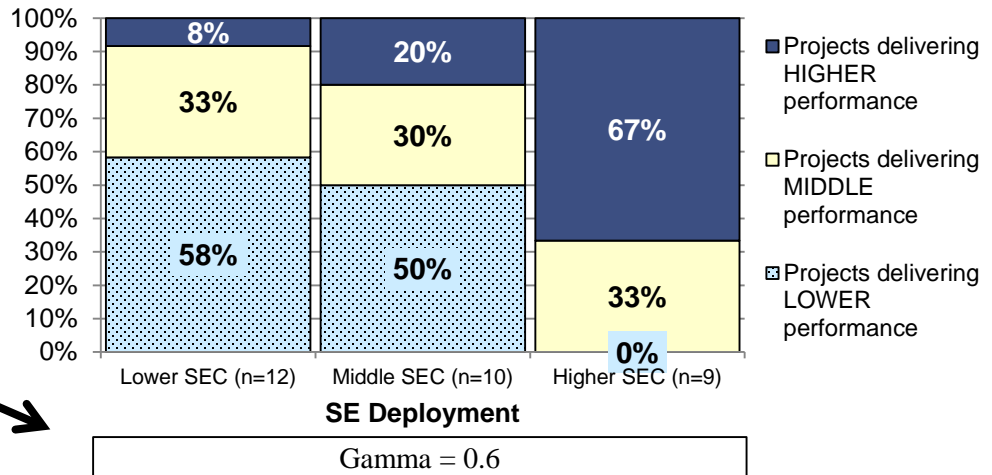
A **Very Strong** relationship for non-defense projects

Requirements Dev't & Mg't vs. Performance

Perf vs. SEC_REQ (defense)



Perf vs. SEC_REQ (non-defense)

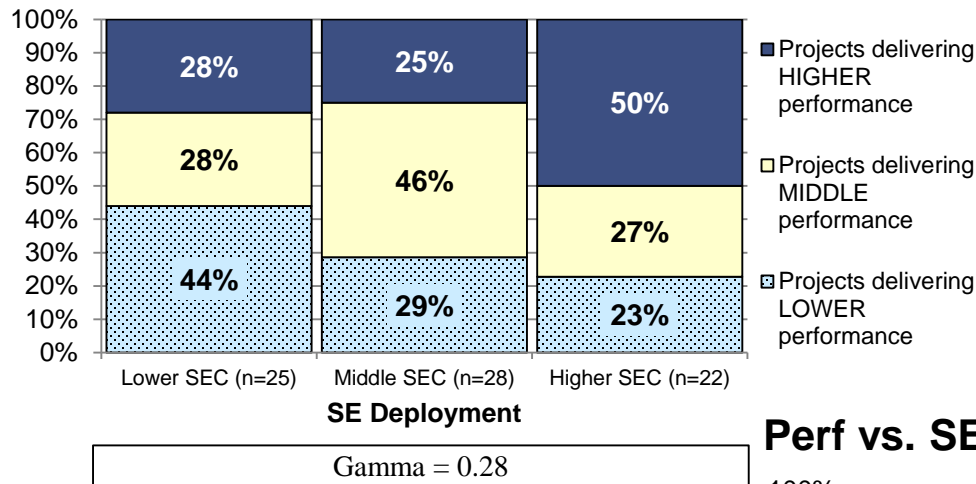


A **Very Strong** relationship between Requirements activities and Project Performance for both Defense and non-Defense Projects



Risk Management vs. Project Performance

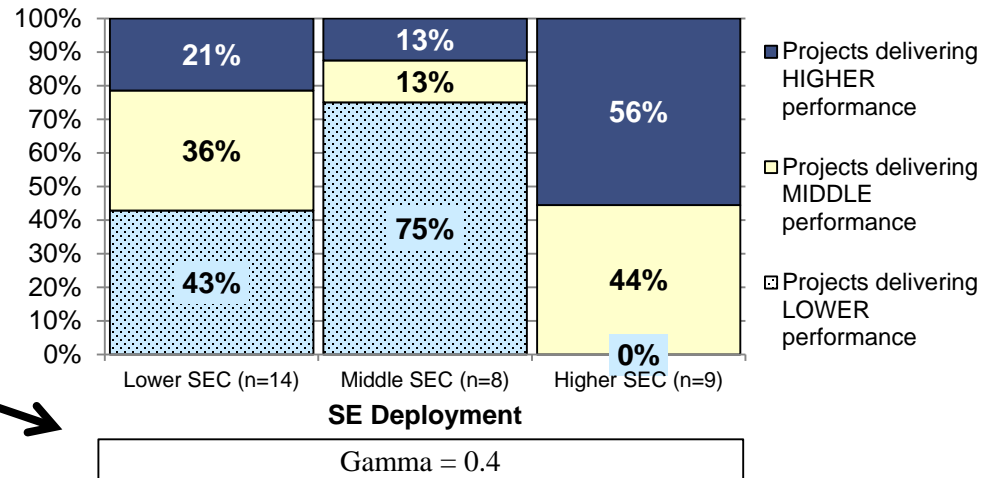
Perf vs. SEC_RSKM (defense)



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

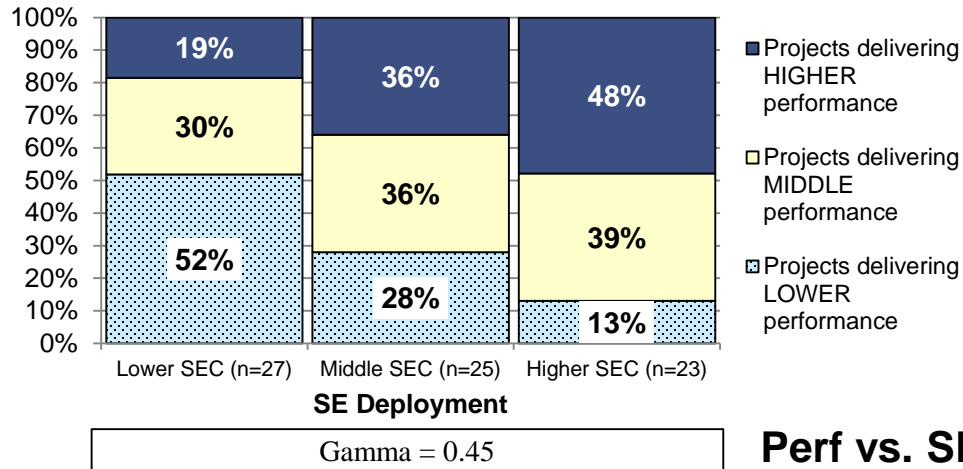
A **Very Strong** relationship for non-defense projects

Perf vs. SEC_RSKM (non-defense)

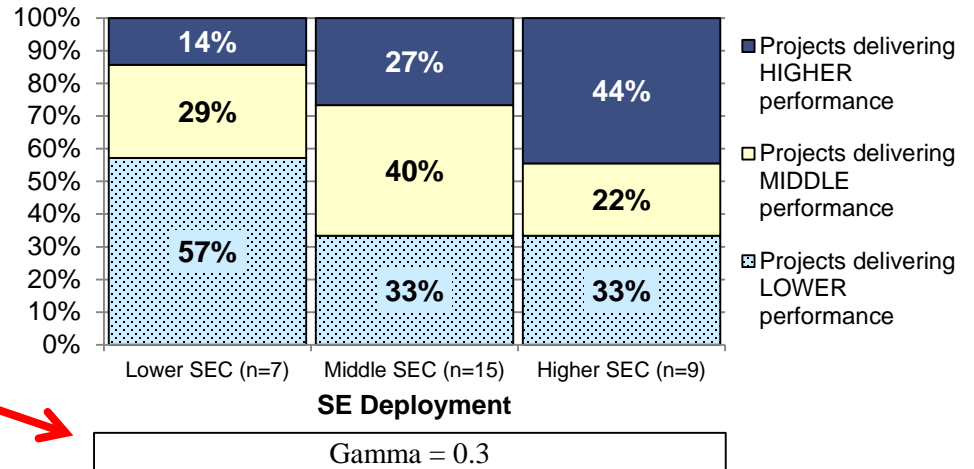


Trade Studies vs. Project Performance

Perf vs. SEC_TRD (defense)



Perf vs. SEC_TRD (non-defense)

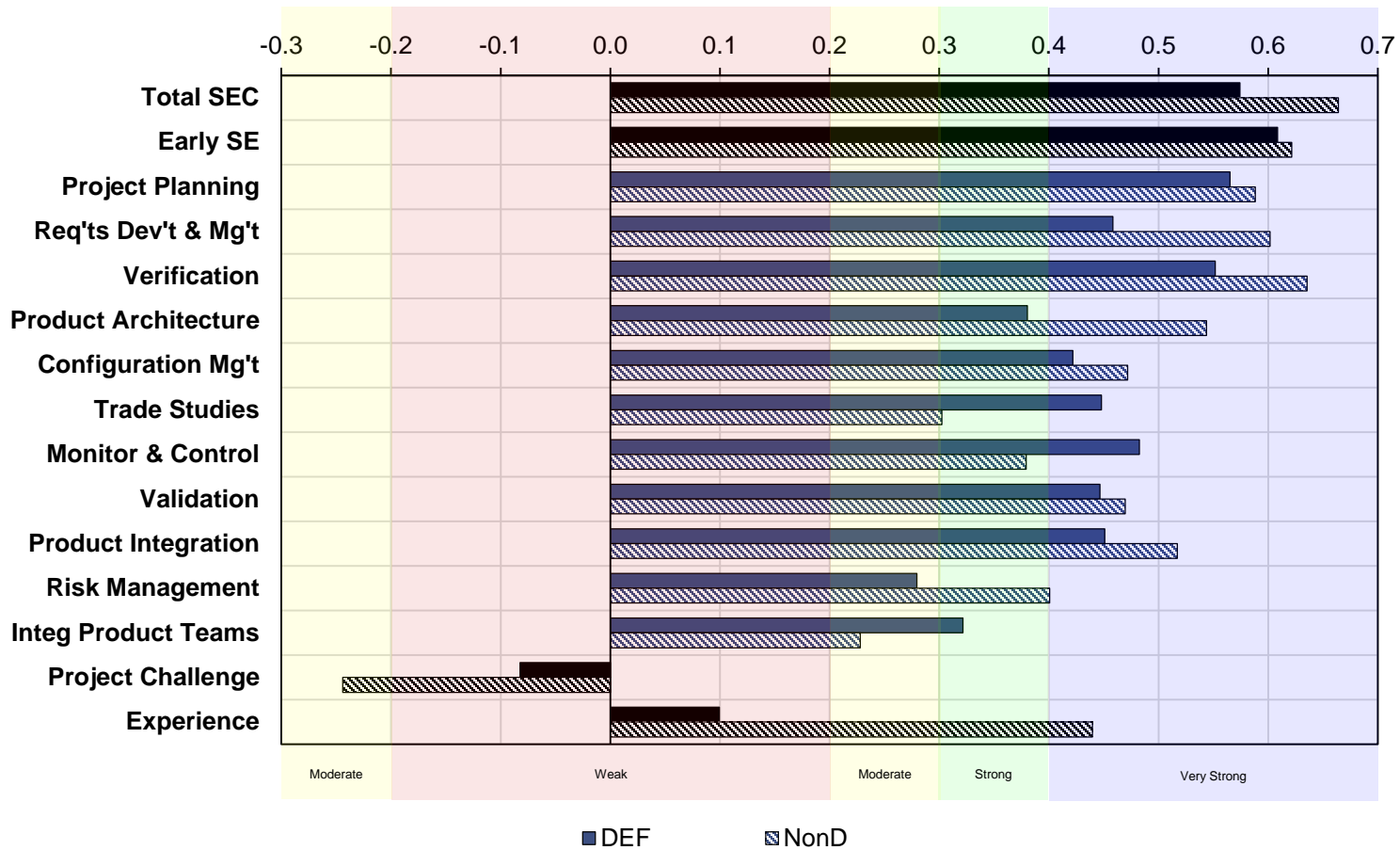


A **Very Strong** relationship between Trade Study activities and Project Performance for Defense Projects

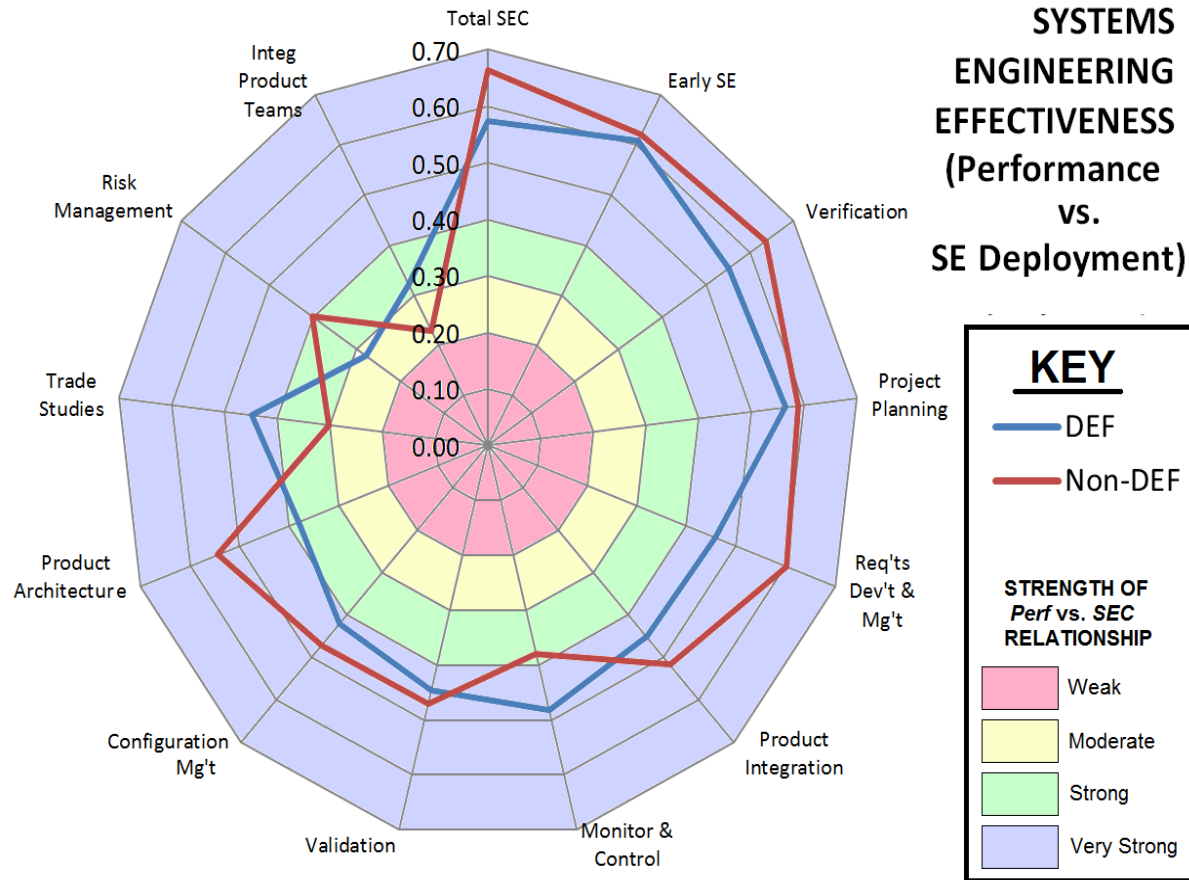
A **Strong** relationship for non-defense projects

Summary of Relationships -1

Performance vs. SE Capability



Summary of Relationships -2



Next Steps: Investigate the differences between SE deployment / effectiveness in defense and non-defense domains to find “transplatable” best practices

Questions for Further Study

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

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

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

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

Next Steps

Download the 2012 SE Effectiveness reports from the SEI website

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

- The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey
- The Business Case for Systems Engineering Study: Detailed Response Data
- The Business Case for Systems Engineering Study: Assessing Project Performance from Sparse Data
- The Business Case for Systems Engineering: Comparison of Defense Domain and Non-Defense Projects

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

Contact the SEI with questions or to obtain assistance.

SEI – Your Resource for Software and Systems Engineering

THANK YOU

For more information, contact

Software Engineering Institute

4500 Fifth Avenue
Pittsburgh, PA 15213-2612

info@sei.cmu.edu

412-268-5800

1-888-201-4479

OR

Joseph P. Elm

jelm@sei.cmu.edu

412-268-9132





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References

Elm, J.; Goldenson, D.; El Emam, K.; Donatelli, N.; Neisa, A. “**A Survey of Systems Engineering Effectiveness – Initial Results**”. Carnegie Mellon University; Pittsburgh, PA. 2007
(available at <http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=8493>)

Elm, J.; Goldenson, D. “**The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey**”. Carnegie Mellon University; Pittsburgh, PA 2012
(available at <http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=34061>)

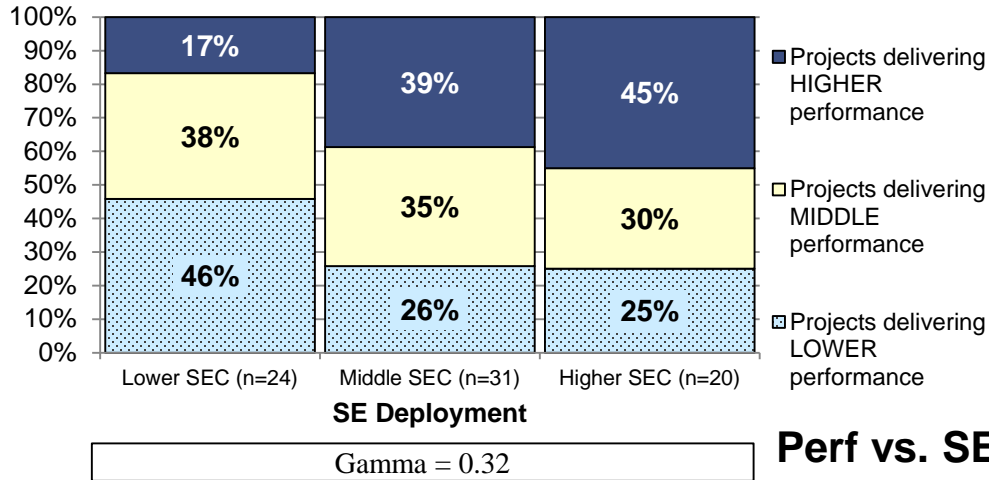
Elm, J.; Goldenson, D. “**The Business Case for Systems Engineering Study: Detailed Response Data**”. Carnegie Mellon University; Pittsburgh, PA 2012
(available at <http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=73582>)

Elm, J. “**The Business Case for Systems Engineering Study: Assessing Project Performance from Sparse Data**”. Carnegie Mellon University; Pittsburgh, PA 2012
(available at <http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=34055>)

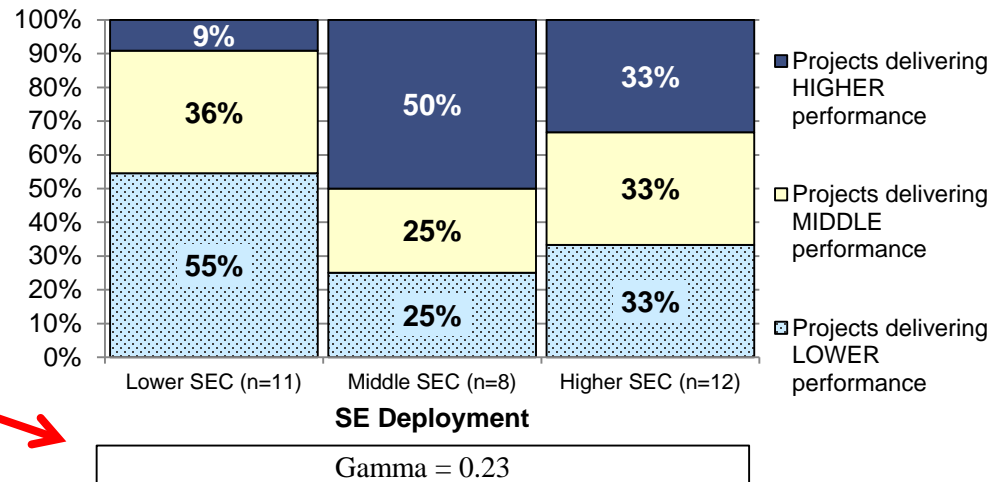
Elm, J.; Goldenson, D. “**The Business Case for Systems Engineering: Comparison of Defense Domain and Non-Defense Projects**”. Carnegie Mellon University; Pittsburgh, PA 2014
(available at <http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=?????>)

IPT Utilization vs. Project Performance

Perf vs. SEC_IPT (defense)



Perf vs. SEC_IPT (non-defense)

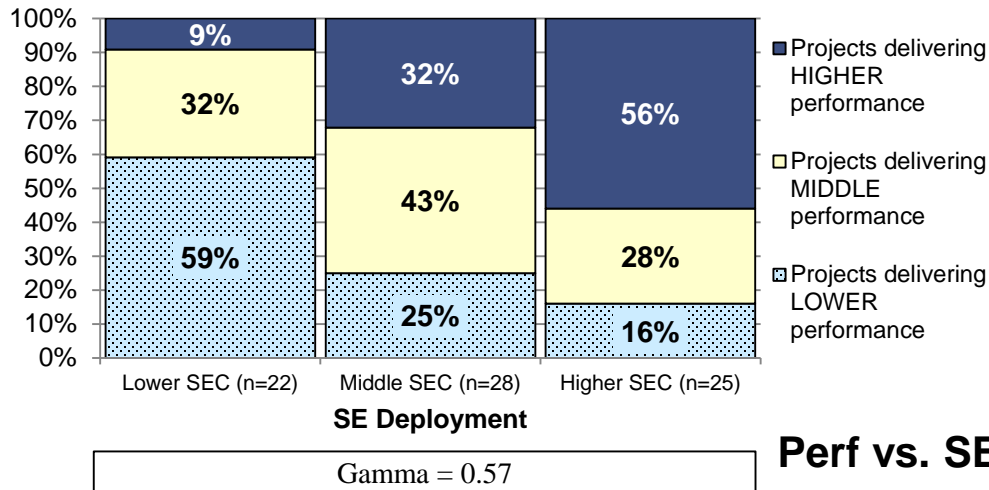


A **Strong** relationship between IPT Utilization and Project Performance for Defense Projects

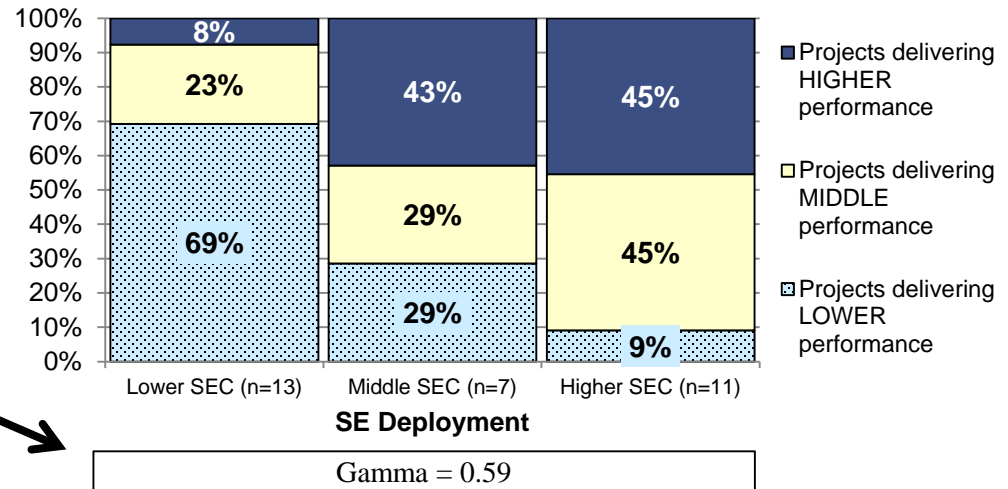
A **Moderate** relationship for non-defense projects

Project Planning vs. Project Performance

Perf vs. SEC_PP (defense)



Perf vs. SEC_PP (non-defense)

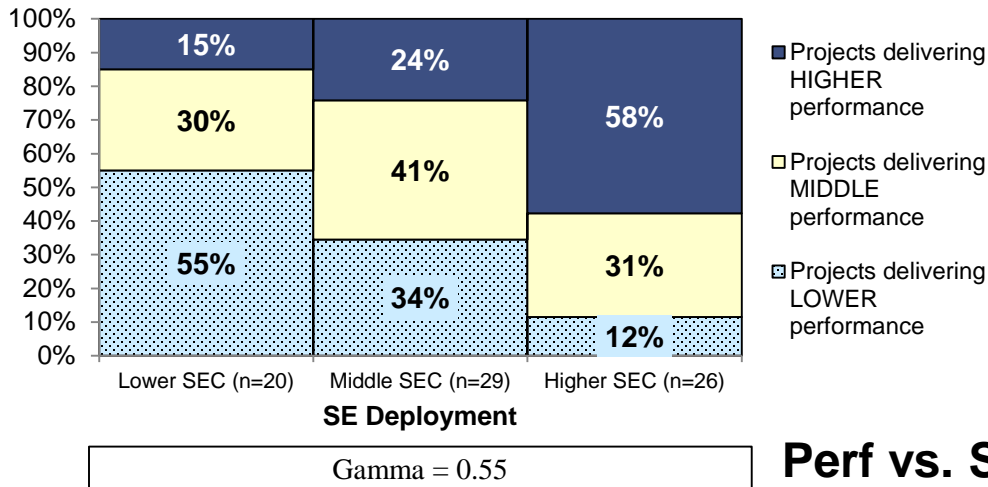


A **Very Strong** relationship between Project Planning activities and Project Performance for both Defense and non-Defense Projects

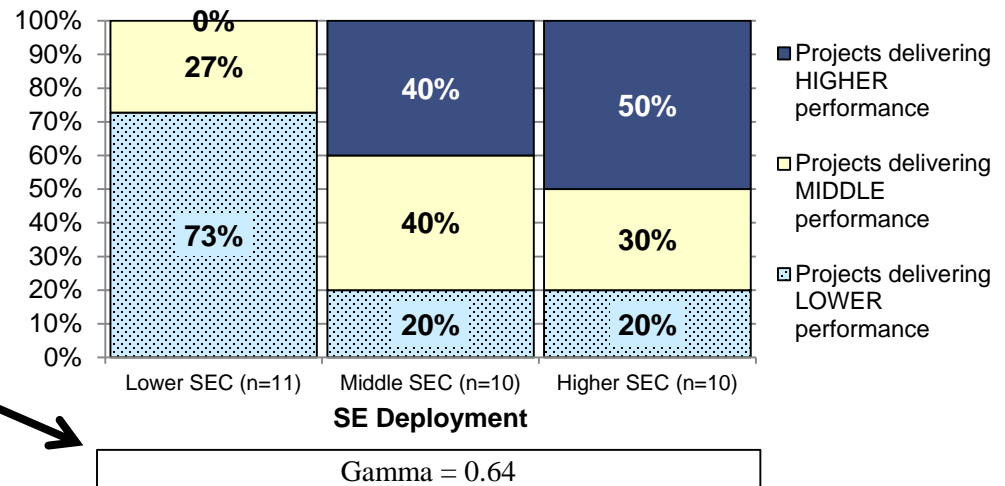


Verification vs. Project Performance

Perf vs. SEC_VER (defense)



Perf vs. SEC_VER (non-defense)

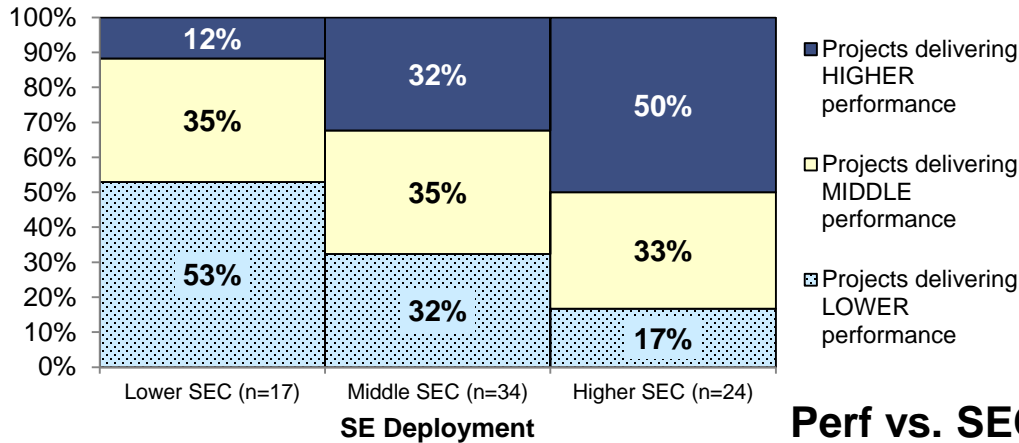


A **Very Strong** relationship between Verification activities and Project Performance for both Defense and non-Defense Projects

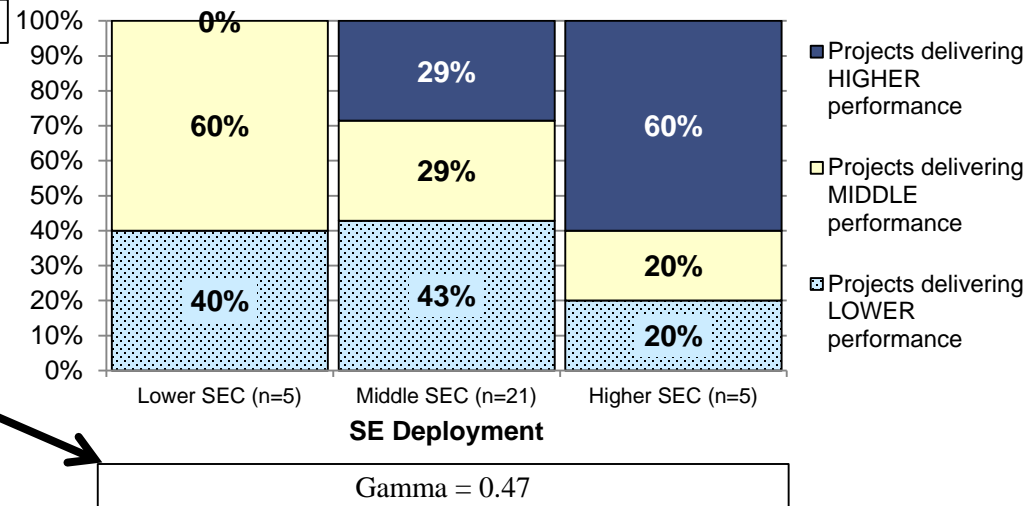


Validation vs. Project Performance

Perf vs. SEC_VAL (defense)



Perf vs. SEC_VAL (non-defense)



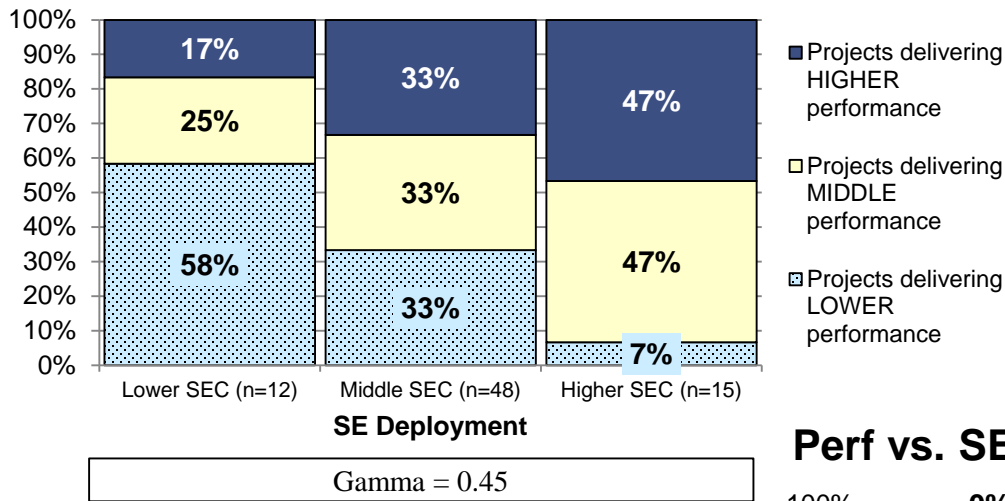
Gamma = 0.45

Gamma = 0.47

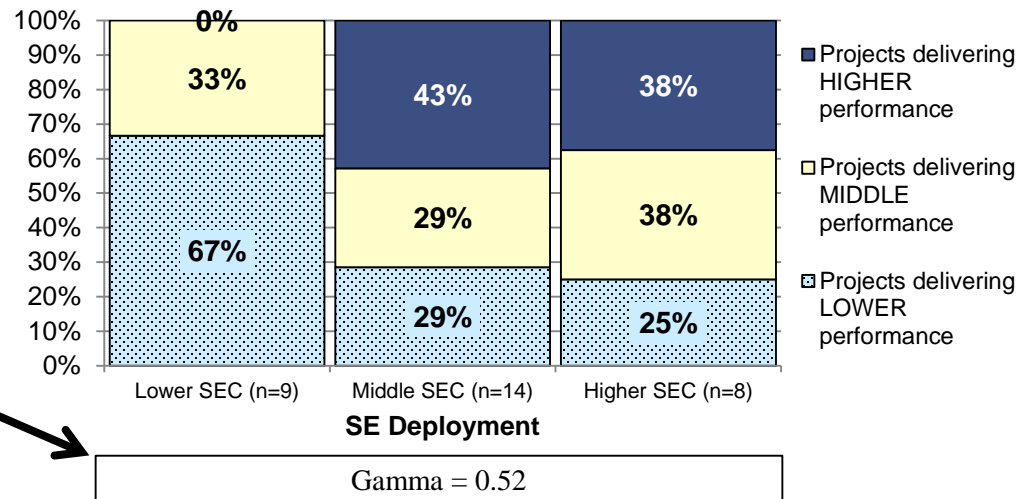
A **Very Strong** relationship between Validation activities and Project Performance for both Defense and non-Defense Projects

Product Integration vs. Project Performance

Perf vs. SEC_PI (defense)



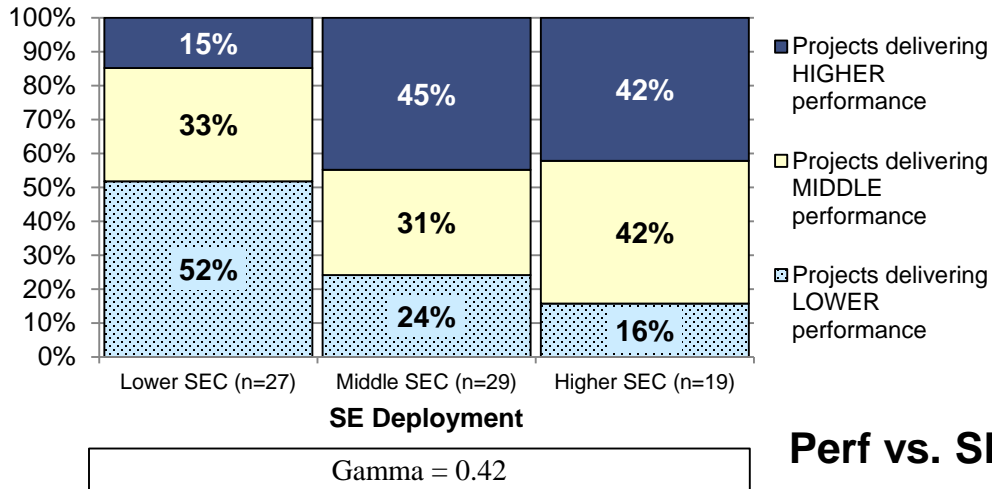
Perf vs. SEC_PI (non-defense)



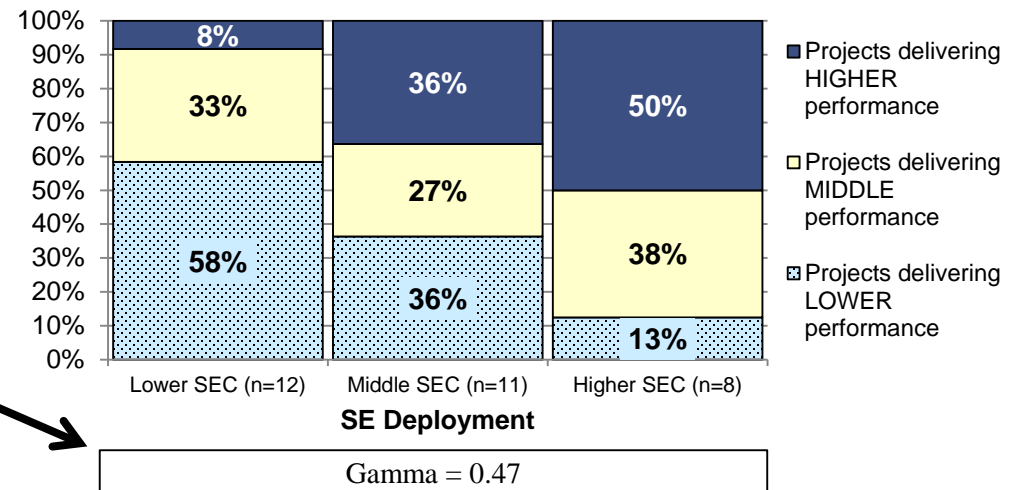
A **Very Strong** relationship between Product Integration activities and Project Performance for both Defense and non-Defense Projects

Configuration Mg't vs. Project Performance

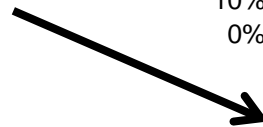
Perf vs. SEC_CM (defense)



Perf vs. SEC_CM (non-defense)

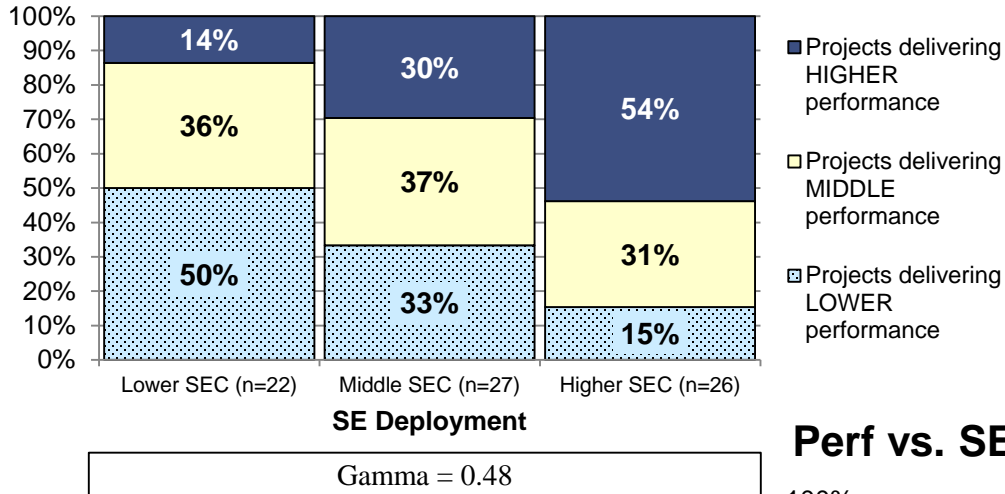


A **Very Strong** relationship between Configuration Management activities and Project Performance for both Defense and non-Defense Projects



Monitoring & Control vs. Project Performance

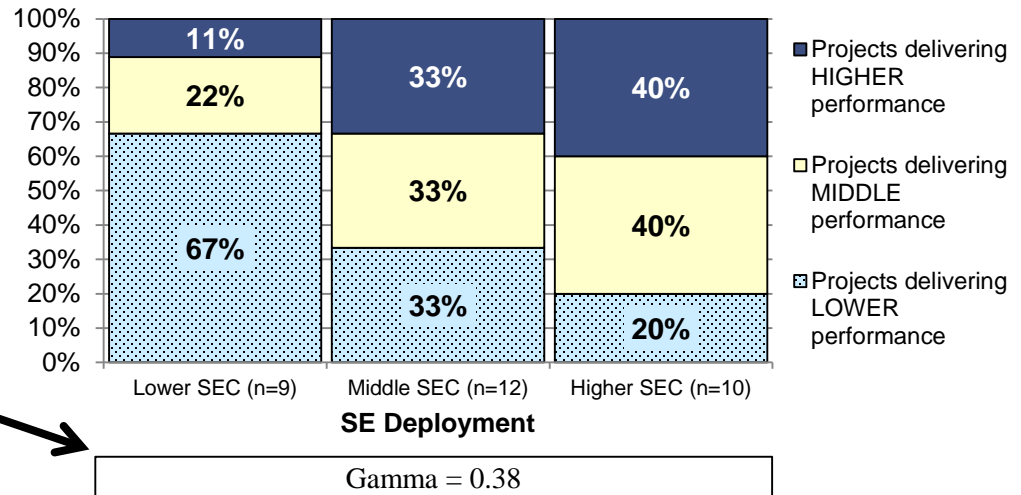
Perf vs. SEC_PMC (defense)



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

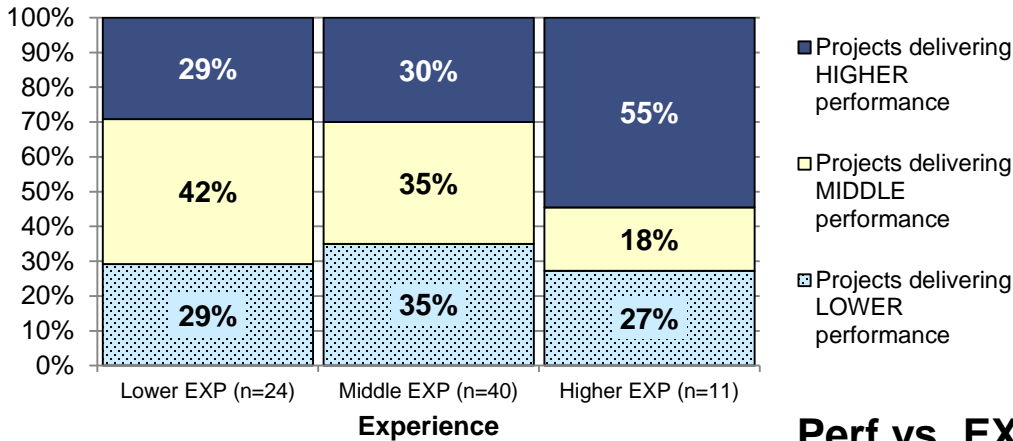
A **Strong** relationship for non-defense projects

Perf vs. SEC_PMC (non-defense)



Prior Experience vs. Project Performance

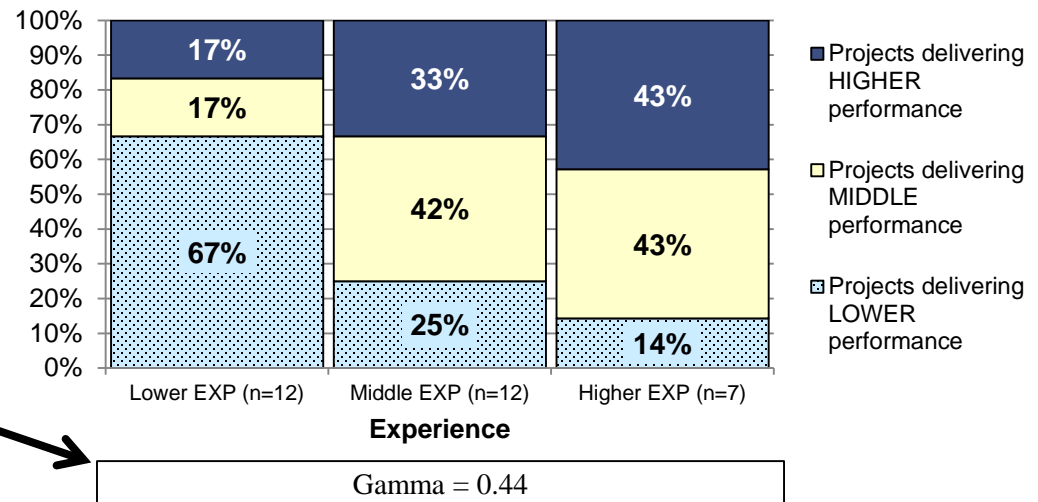
Perf vs. EXP (defense)



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

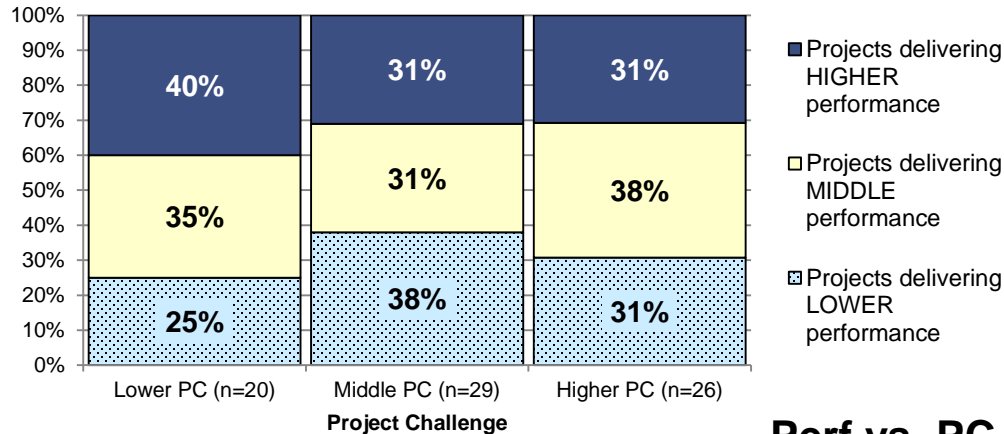
A **Strong** relationship for non-defense projects

Perf vs. EXP (non-defense)



Project Challenge vs. Project Performance

Perf vs. PC (defense)



Gamma = -0.08

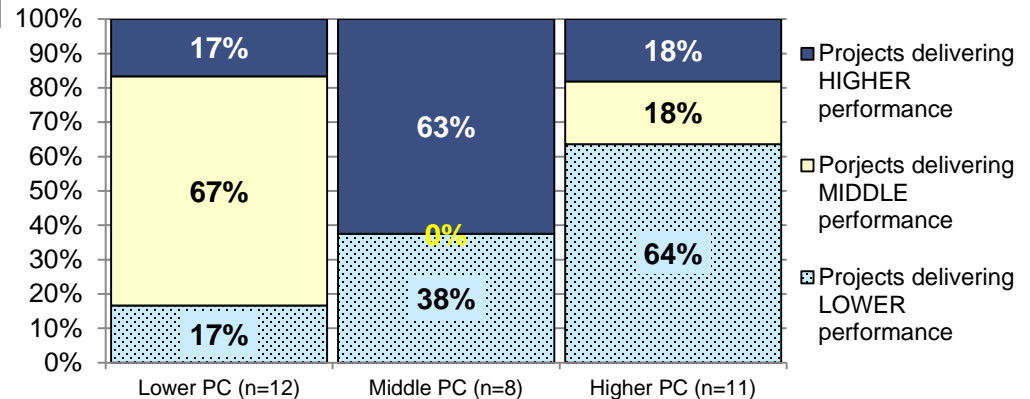


A **Weak Negative** relationship between Project Challenge and Project Performance for Defense Projects

A **Moderate Negative** relationship for non-defense projects



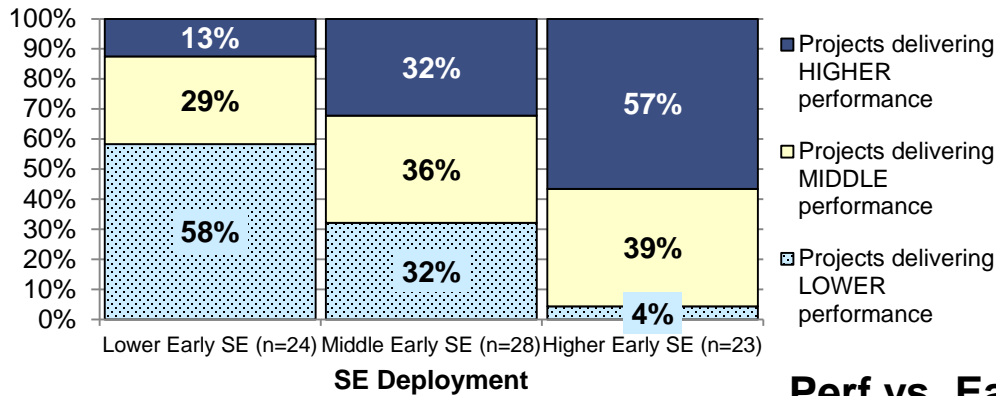
Perf vs. PC (Non-defense)



Gamma = -0.24

Early SE vs. Project Performance

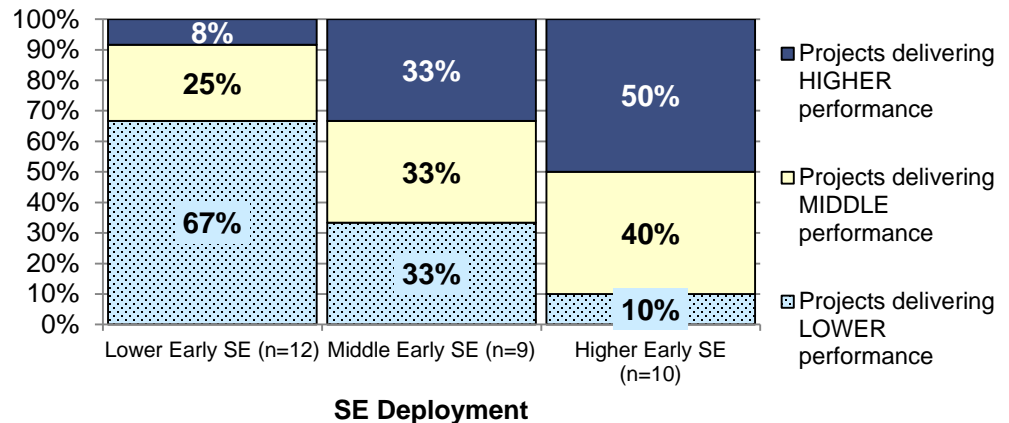
Perf vs. Early_SE (defense)



Early SE

- Project Planning
- Requirements Development
- Trade Studies
- Product Architecture

Perf vs. Early_SE (non-defense)



Gamma = 0.61

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

Gamma = 0.62