Software Engineering Institute | Carnegie Mellon University

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

Copyright 2014 Carnegie Mellon University

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8721-05-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

NO WARRANTY. THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN “AS-IS” BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

This material has been approved for public release and unlimited distribution except as restricted below.

This material may be reproduced in its entirety, without modification, and freely distributed in written or electronic form without requesting formal permission. Permission is required for any other use. Requests for permission should be directed to the Software Engineering Institute at permission@sei.cmu.edu.

Carnegie Mellon® is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.

DM-0001821

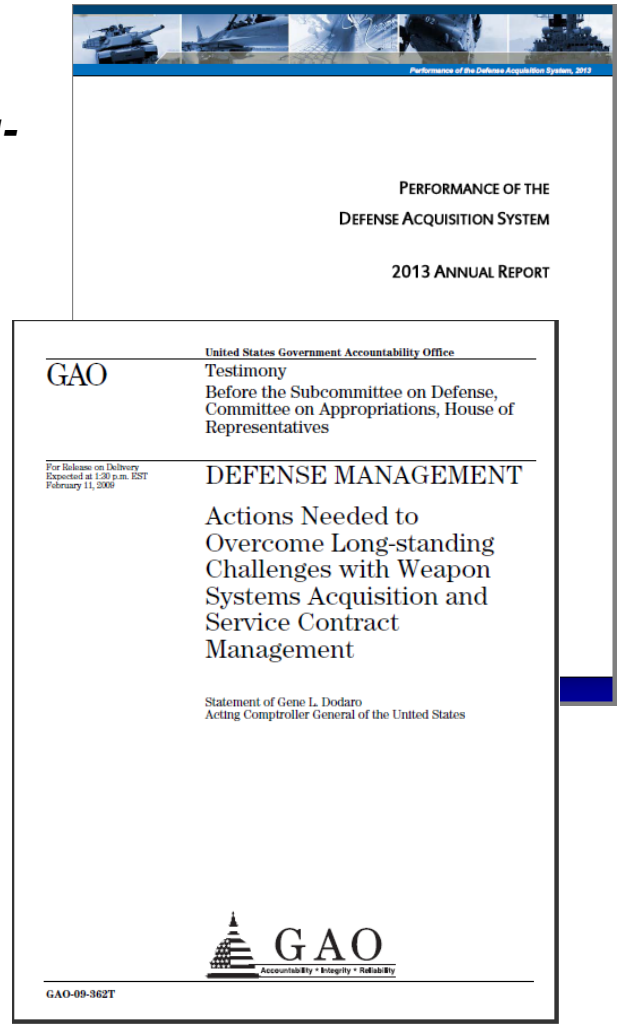
Challenges in DoD Acquisition

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)

© 2014 Carnegie Mellon University

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 Analysis[1]

	Dominant
10 of 18 (56%)	**Poor management performance** • **Systems engineering** • Contractual incentives • **Risk management** • Situational Awareness
5 of 18 (28%)	**Baseline cost and schedule estimates** • **Framing assumptions**
4 of 18 (22%)	**Change in procurement quantity**
	Infrequent
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)

© 2014 Carnegie Mellon University

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?

© 2014 Carnegie Mellon University

The 2012 SE Effectiveness Study

Purpose

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

Method

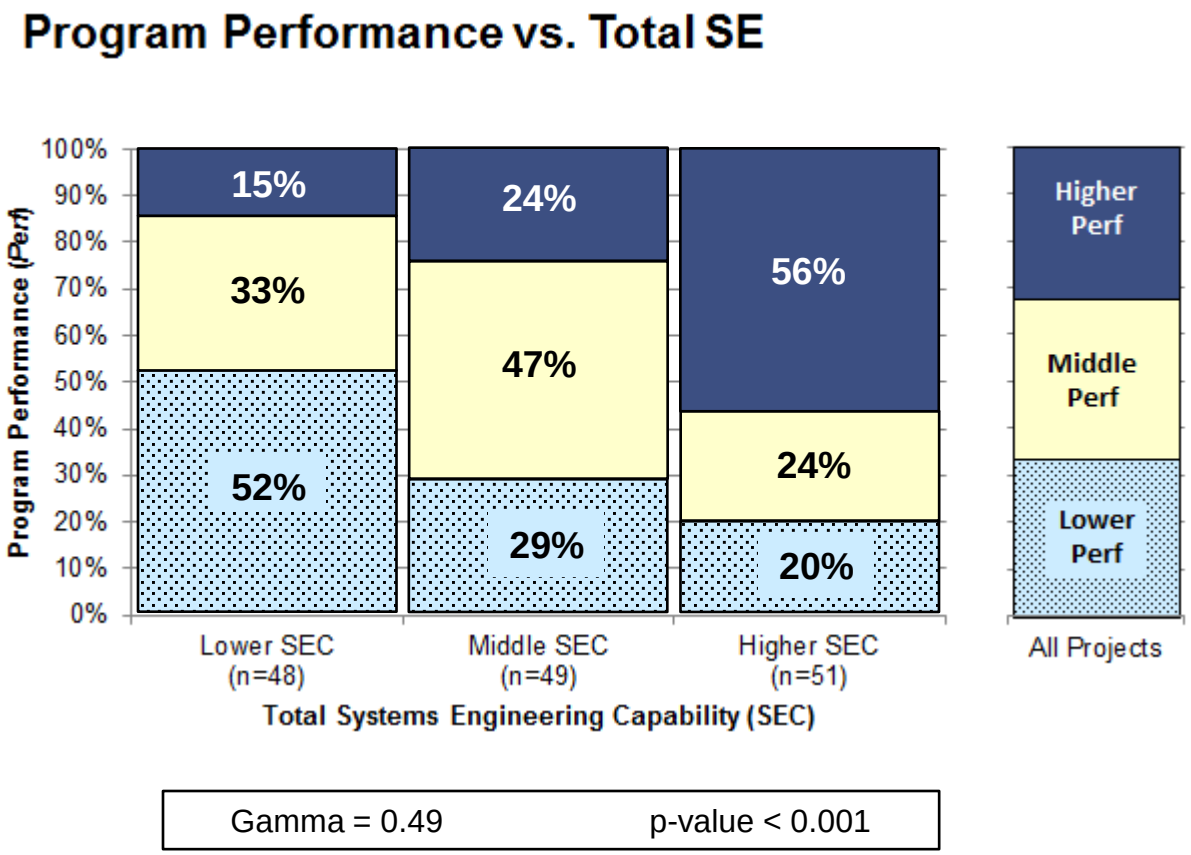
- Contact development projects using the resources of NDIA, AESS, and INCOSE.
- Survey projects to assess their
  - SE activities
  - Project performance
  - Degree of challenge
- Process responses to identify statistical relationships between parameters.

Survey Tenets

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

© 2014 Carnegie Mellon University

The Bottom Line: SE = Performance



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

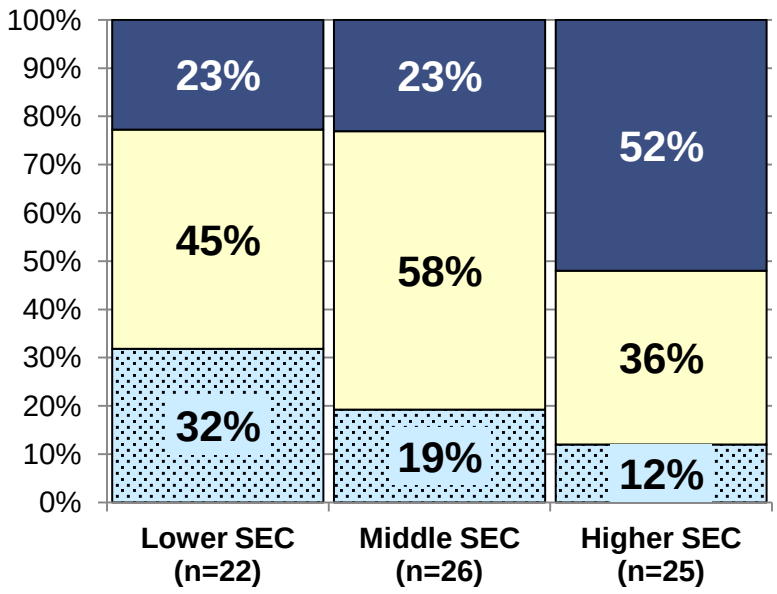
For Higher SEC projects, 57% deliver higher performance

Gamma = 0.49 represents a VERY STRONG relationship

© 2014 Carnegie Mellon University

For Challenging Projects SE is even MORE important

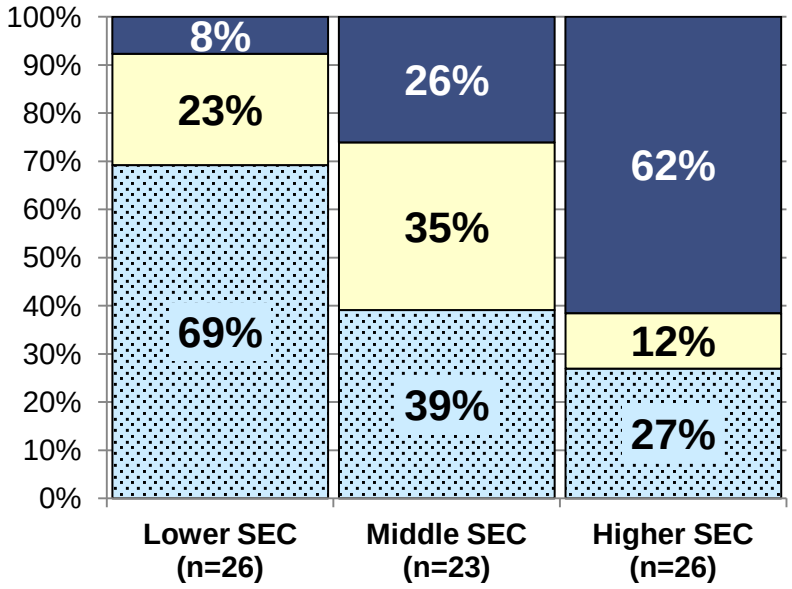
Perf vs. SEC_Total (Low PC)



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

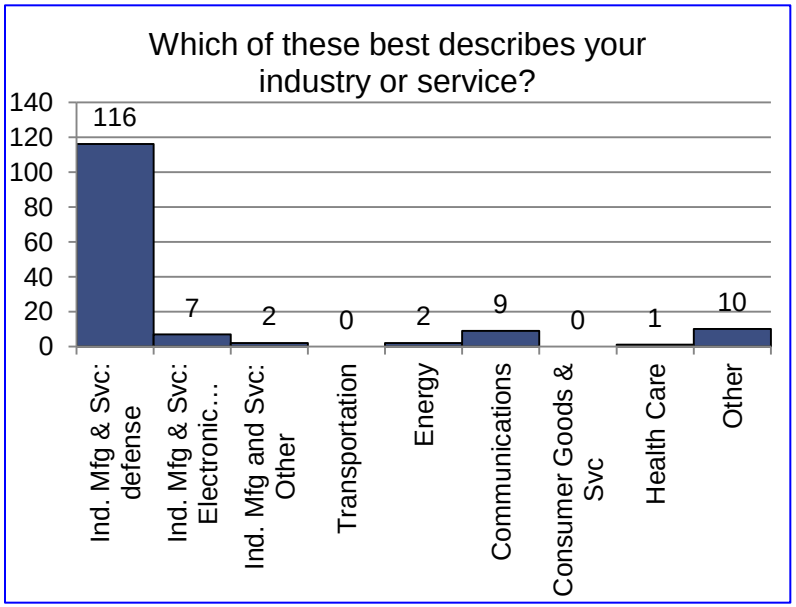
© 2014 Carnegie Mellon University

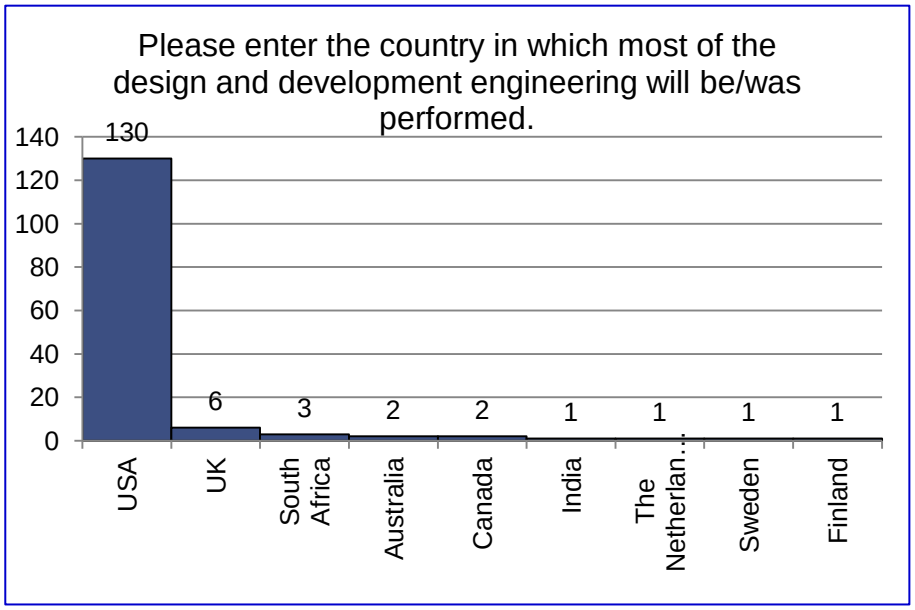
Study Participants

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

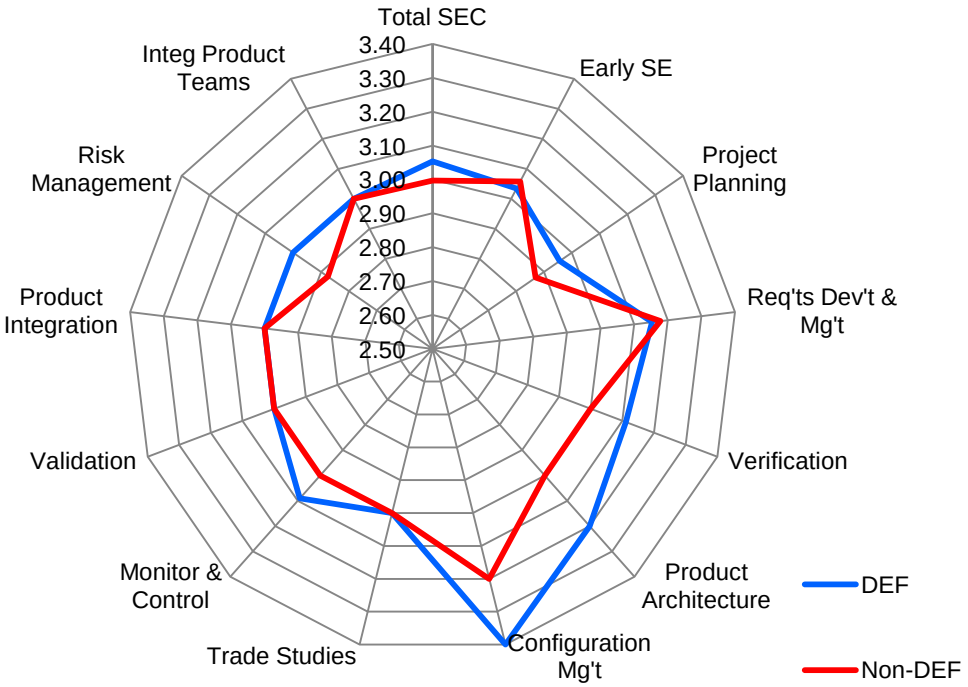




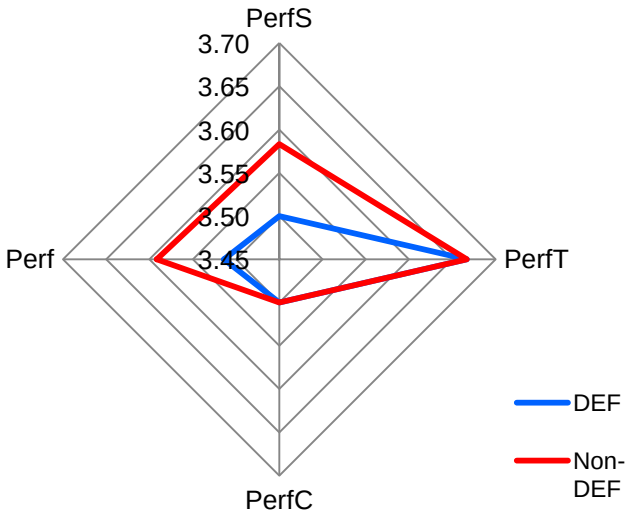
© 2014 Carnegie Mellon University

SE Deployment and Performance

SYSTEMS ENGINEERING DEPLOYMENT

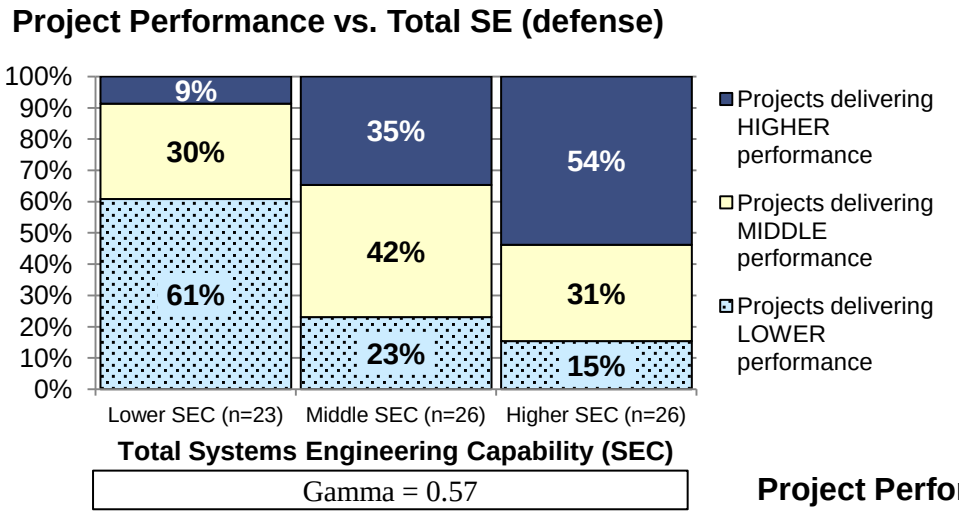


PROJECT PERFORMANCE

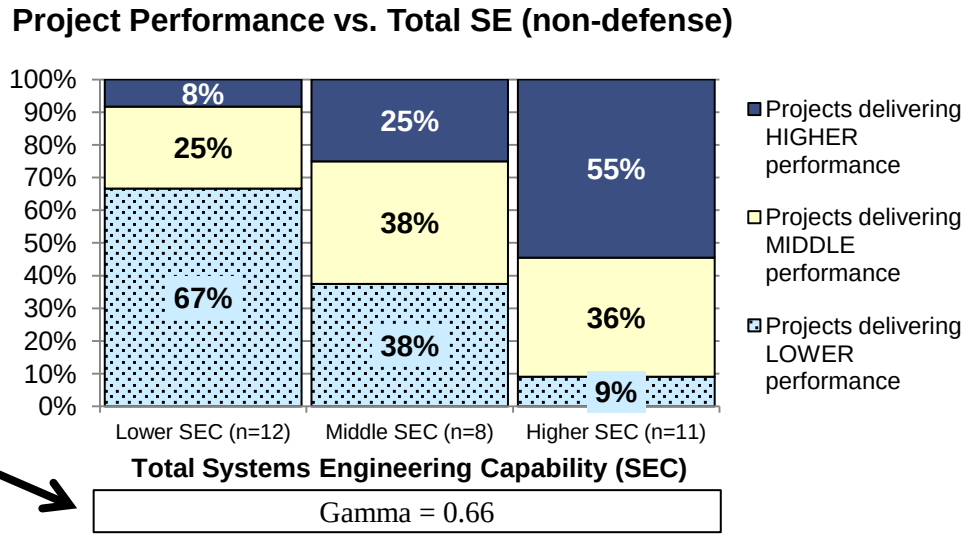


© 2014 Carnegie Mellon University

Total SE vs. Project Performance

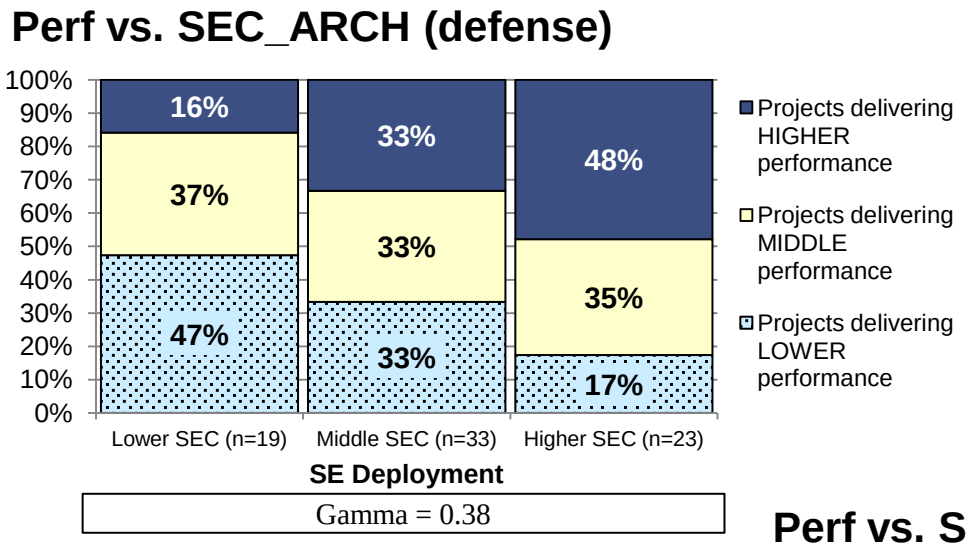


A **Very Strong** relationship between applied SE and Project Performance for both Defense and non-Defense Projects



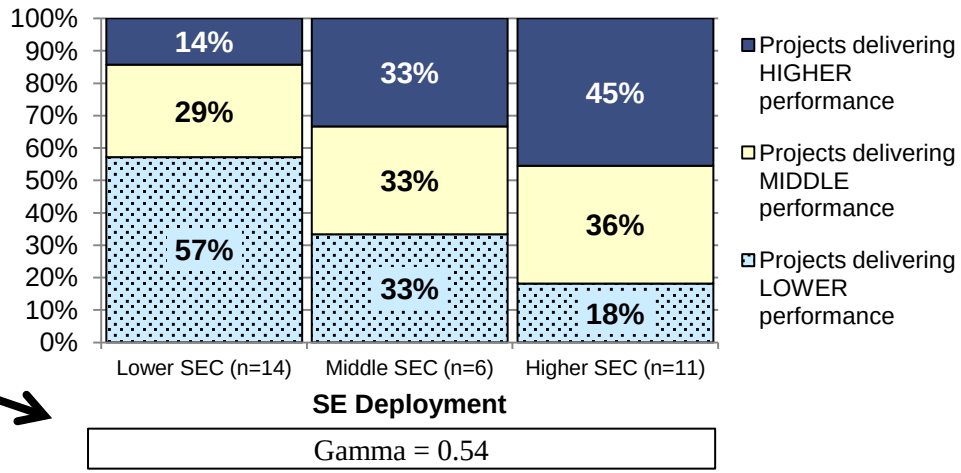
© 2014 Carnegie Mellon University

Architecture vs. Project Performance



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

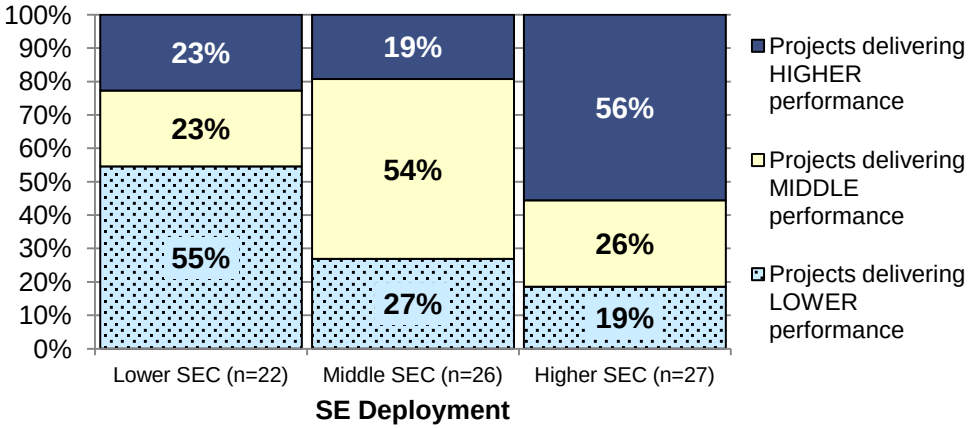
A **Very Strong** relationship for non-defense projects



© 2014 Carnegie Mellon University

Requirements Dev't & Mg't vs. Performance

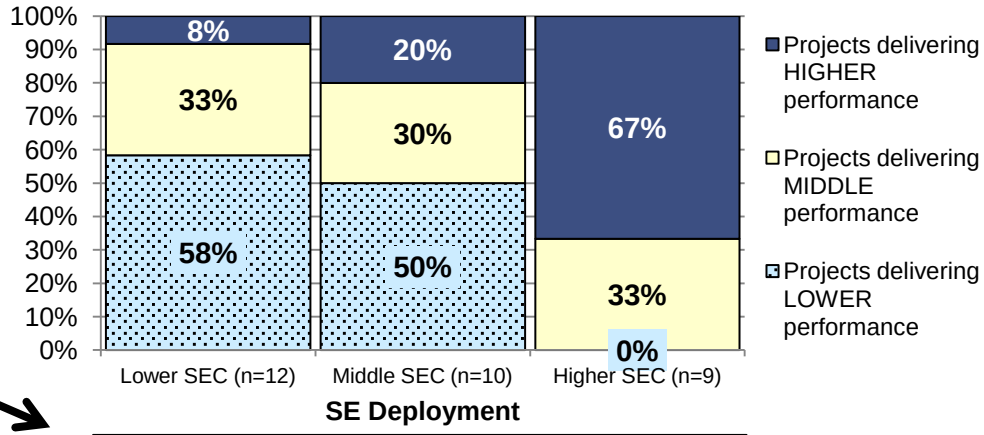
Perf vs. SEC_REQ (defense)



Gamma = 0.46

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

Perf vs. SEC_REQ (non-defense)

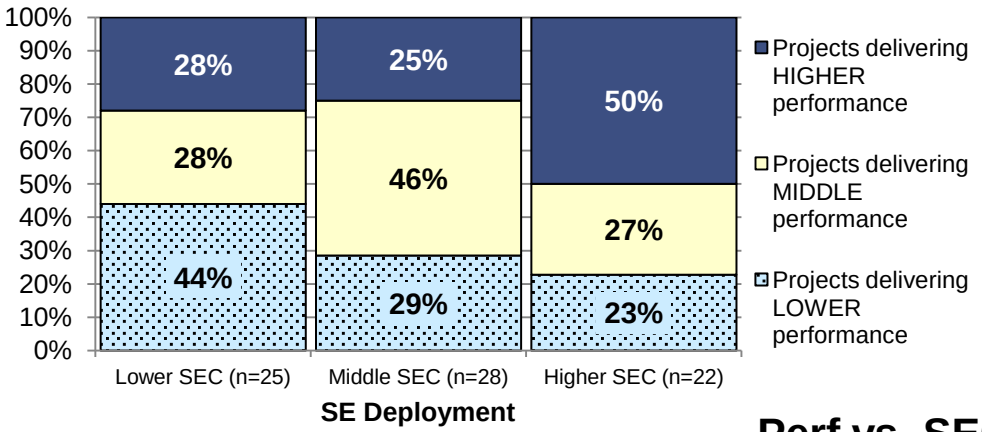


Gamma = 0.6

© 2014 Carnegie Mellon University

Risk Management vs. Project Performance

Perf vs. SEC_RSKM (defense)

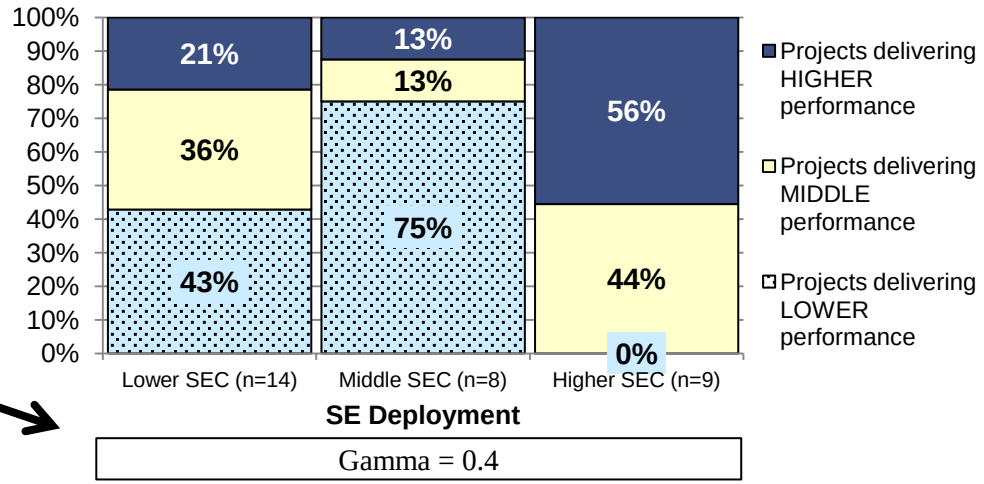


Gamma = 0.28

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)

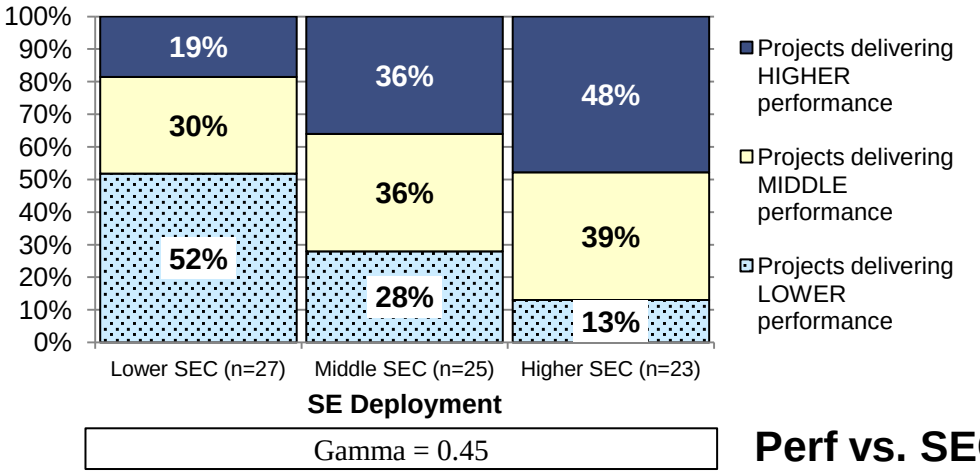


Gamma = 0.4

© 2014 Carnegie Mellon University

Trade Studies vs. Project Performance

Perf vs. SEC_TRD (defense)

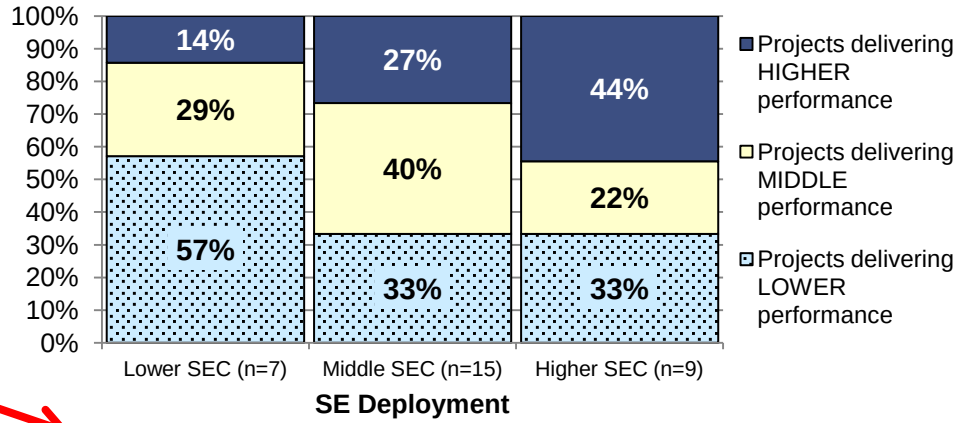


Gamma = 0.45

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

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

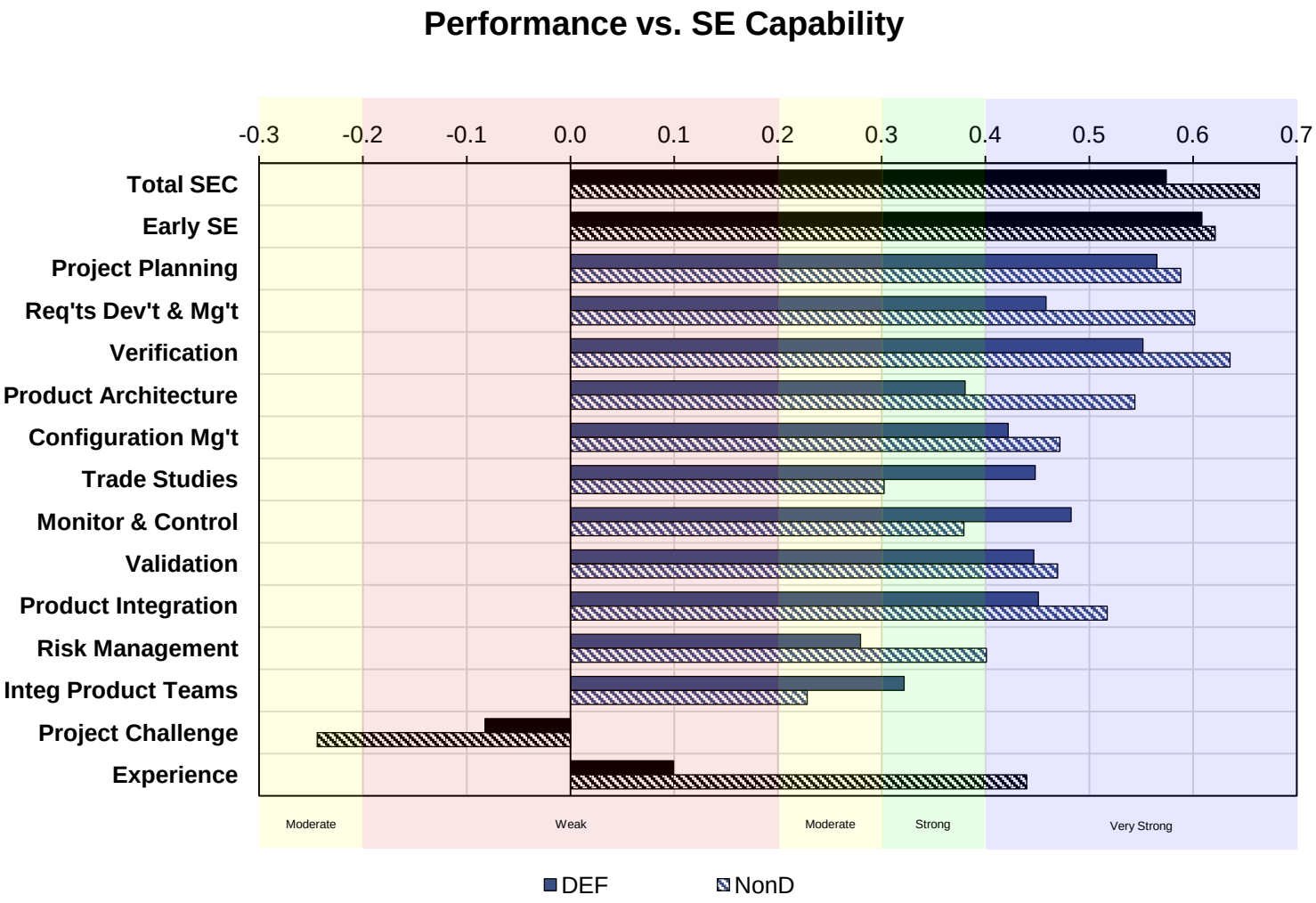
Perf vs. SEC_TRD (non-defense)



Gamma = 0.3

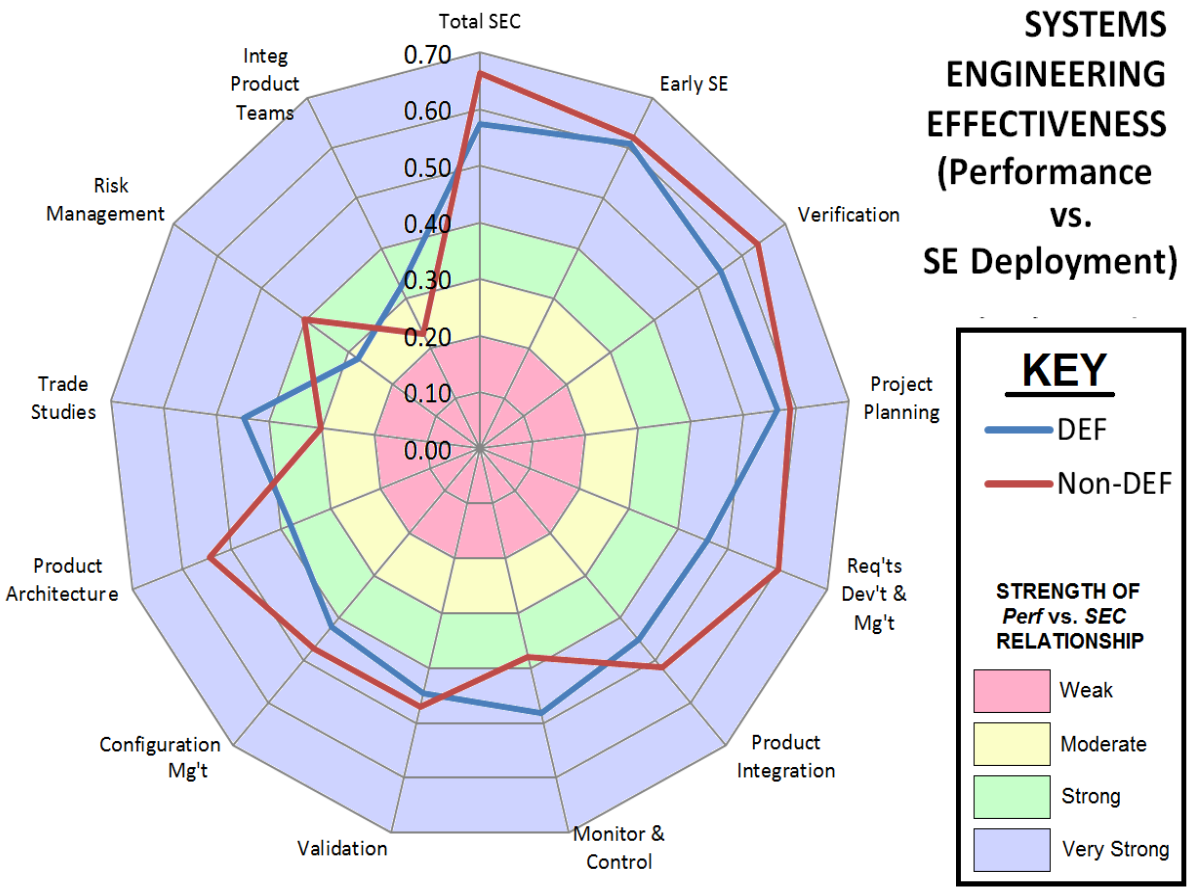
© 2014 Carnegie Mellon University

Summary of Relationships -1



© 2014 Carnegie Mellon University

Summary of Relationships -2



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

© 2014 Carnegie Mellon University

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?

© 2014 Carnegie Mellon University

SEI – Your Resource for Software and Systems Engineering

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

© 2014 Carnegie Mellon University

Software Engineering Institute | Carnegie Mellon University

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
NDIA
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

AESS tm

BACK UP

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)

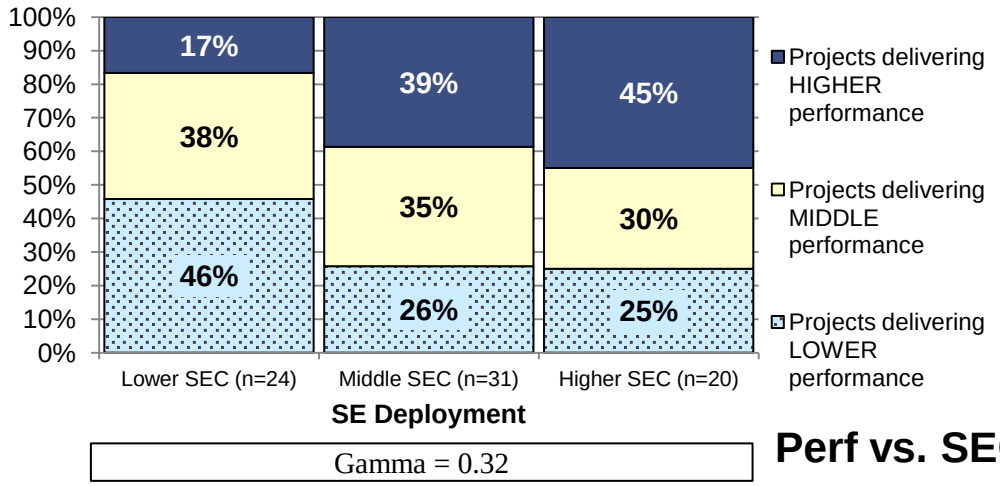
Elm, J. "**The Business Case for Systems Engineering Study: Assessing Project Performance from Sparse Data**". Carnegie Mellon University; Pittsburgh, PA 2012 (available at http://resources.sei.cmu.edu/library/asset-view.cfm?assetid=34055)

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=?????)

© 2014 Carnegie Mellon University

IPT Utilization vs. Project Performance

Perf vs. SEC_IPT (defense)

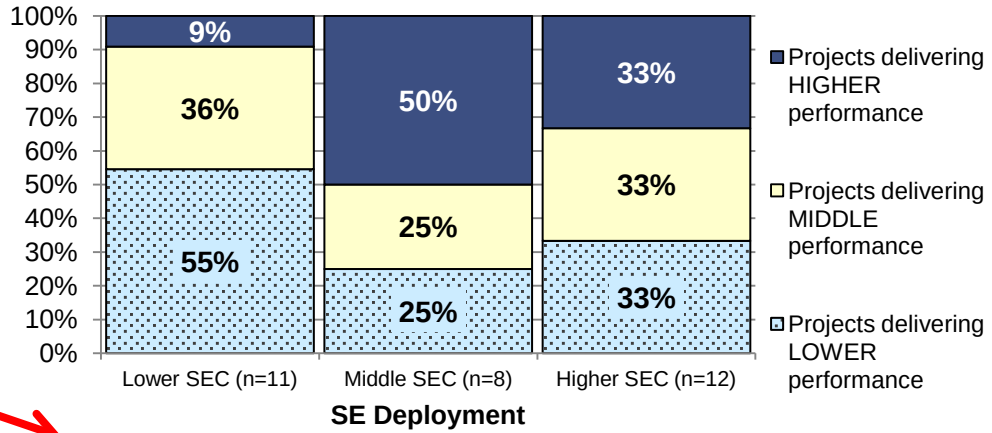


Gamma = 0.32

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

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

Perf vs. SEC_IPT (non-defense)

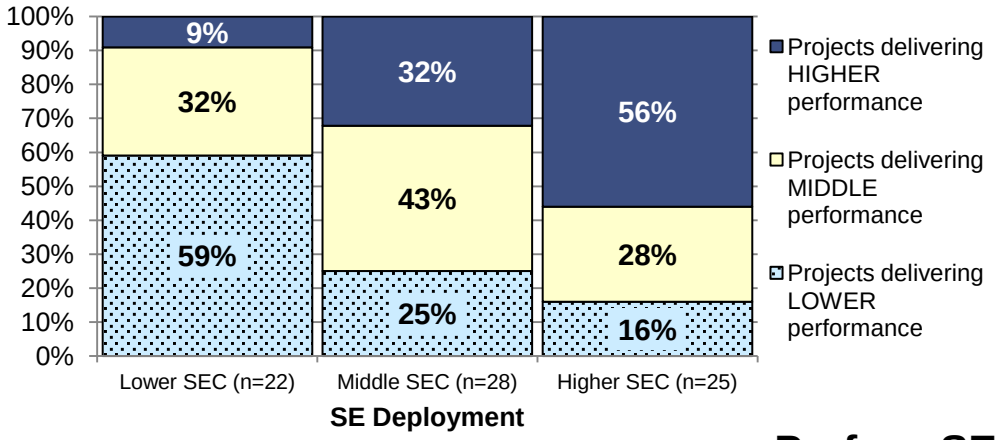


Gamma = 0.23

© 2014 Carnegie Mellon University

Project Planning vs. Project Performance

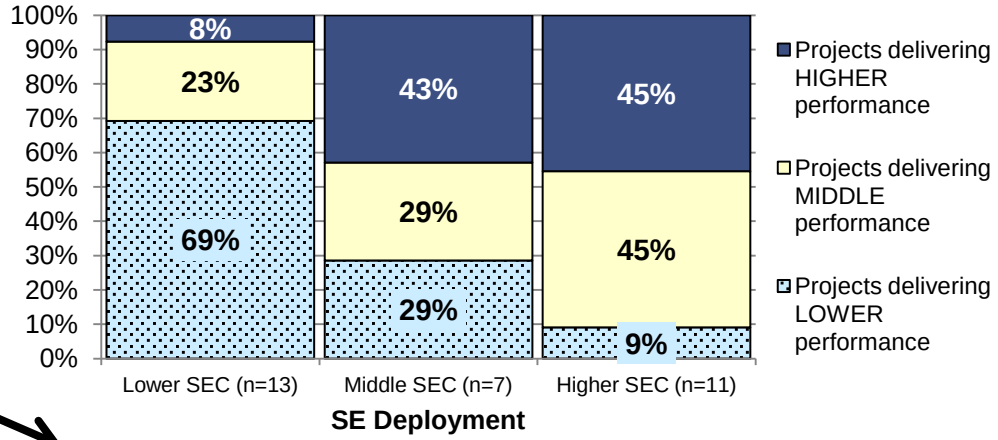
Perf vs. SEC_PP (defense)



Gamma = 0.57

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

Perf vs. SEC_PP (non-defense)

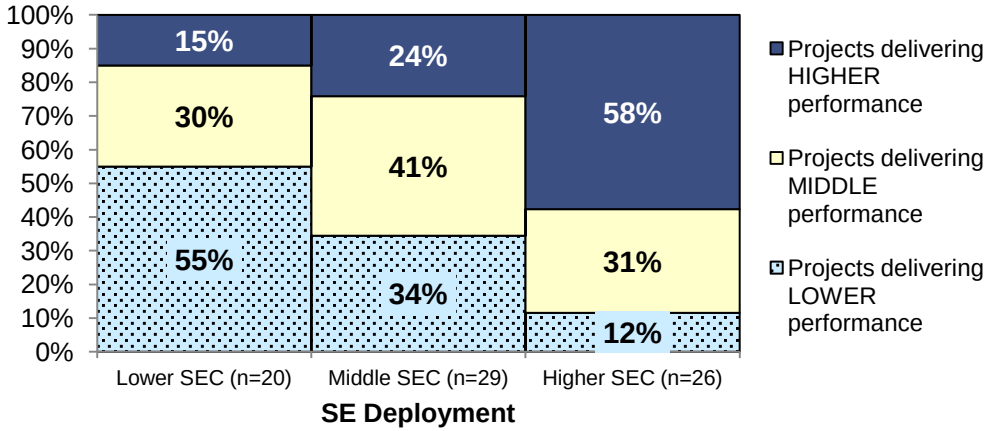


Gamma = 0.59

© 2014 Carnegie Mellon University

Verification vs. Project Performance

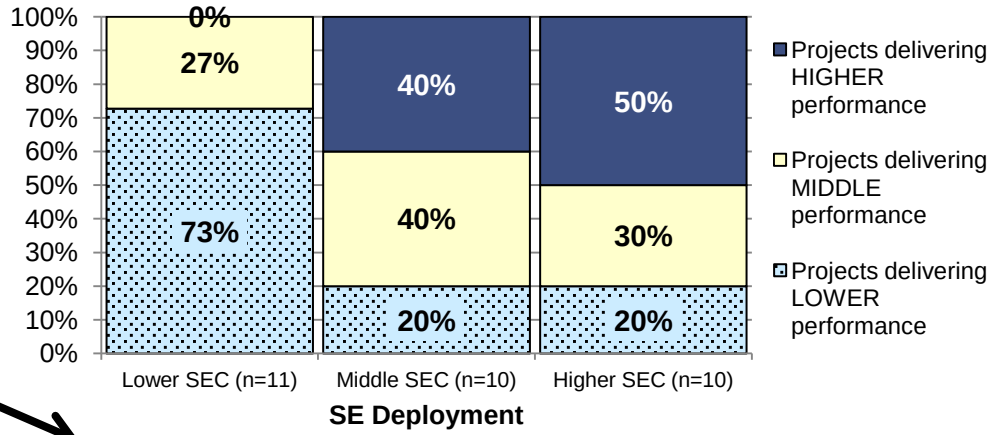
Perf vs. SEC_VER (defense)



Gamma = 0.55

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

Perf vs. SEC_VER (non-defense)

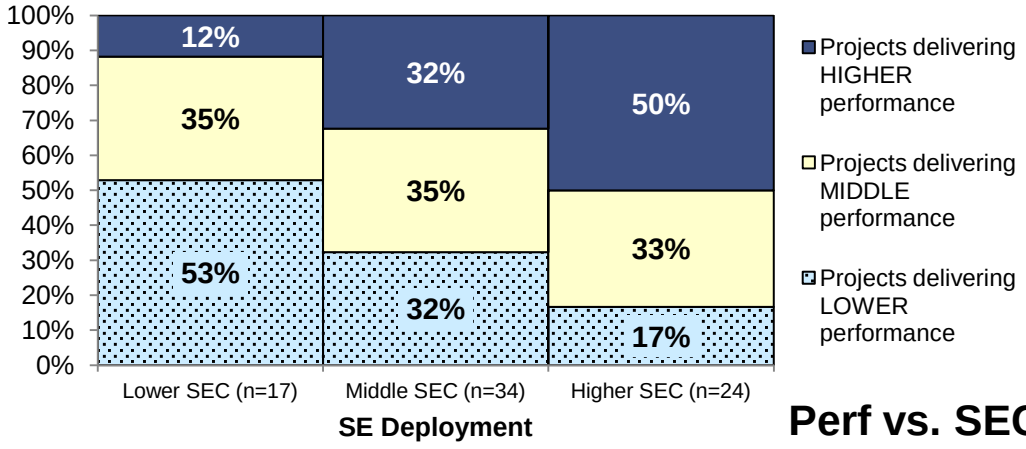


Gamma = 0.64

© 2014 Carnegie Mellon University

Validation vs. Project Performance

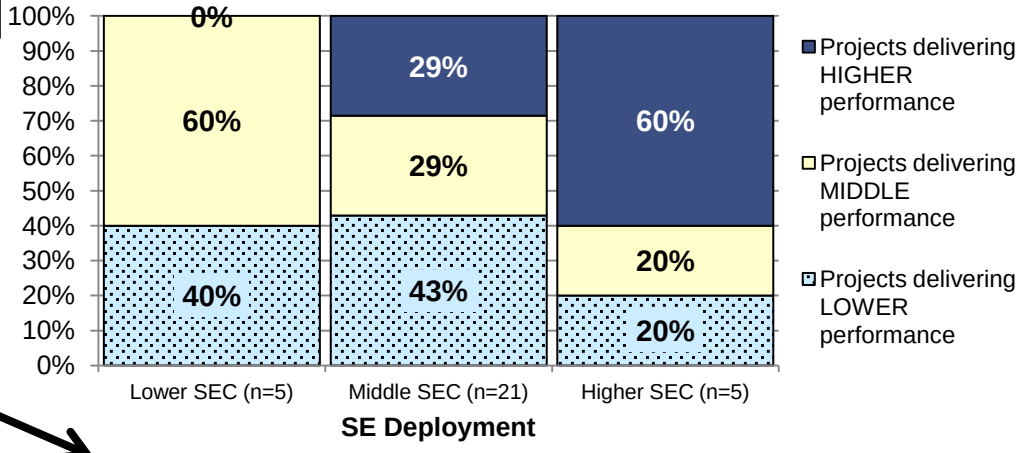
Perf vs. SEC_VAL (defense)



Gamma = 0.45

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

Perf vs. SEC_VAL (non-defense)

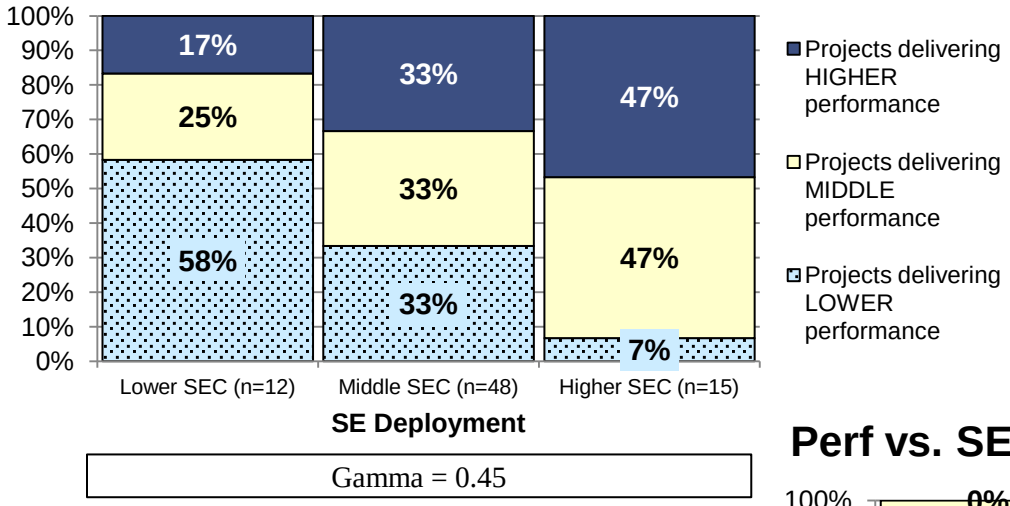


Gamma = 0.47

© 2014 Carnegie Mellon University

Product Integration vs. Project Performance

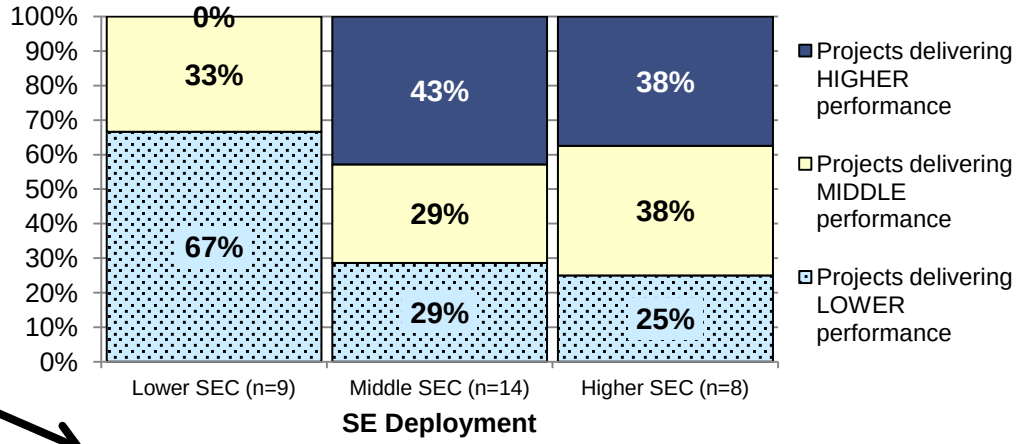
Perf vs. SEC_PI (defense)



Gamma = 0.45

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

Perf vs. SEC_PI (non-defense)

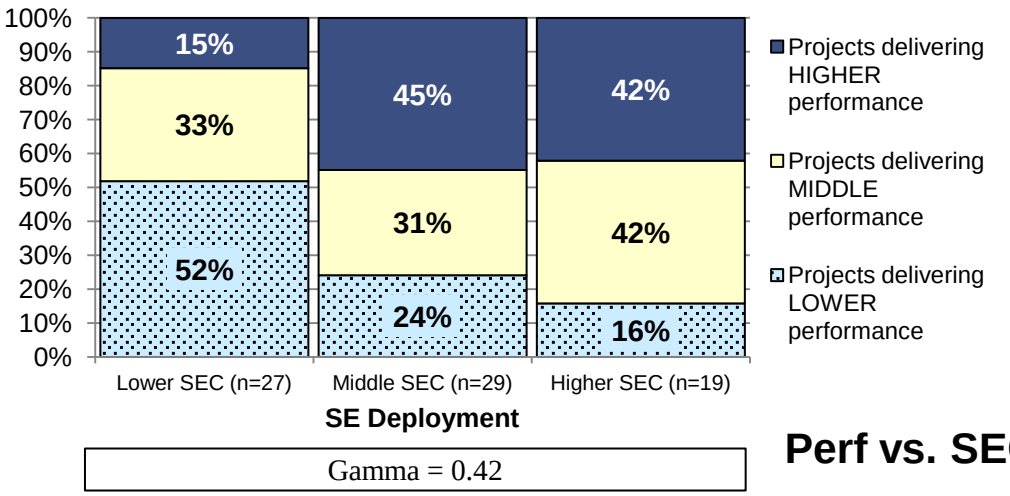


Gamma = 0.52

© 2014 Carnegie Mellon University

Configuration Mg't vs. Project Performance

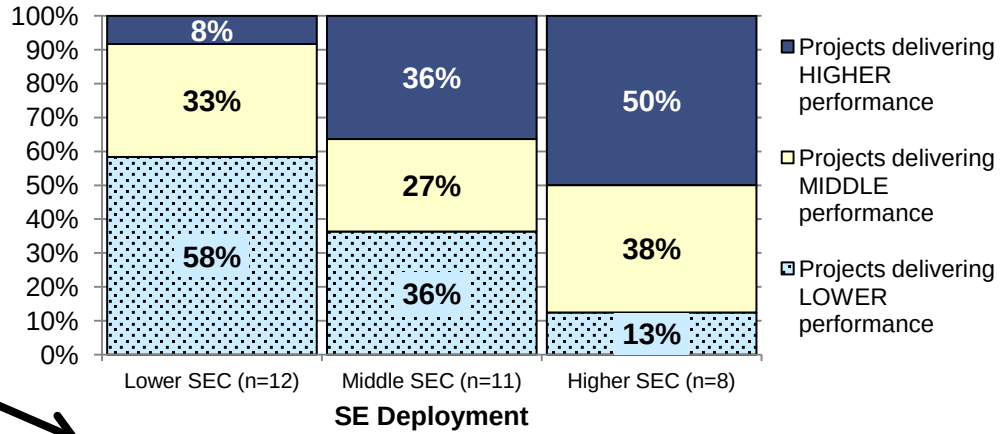
Perf vs. SEC_CM (defense)



Gamma = 0.42

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

Perf vs. SEC_CM (non-defense)

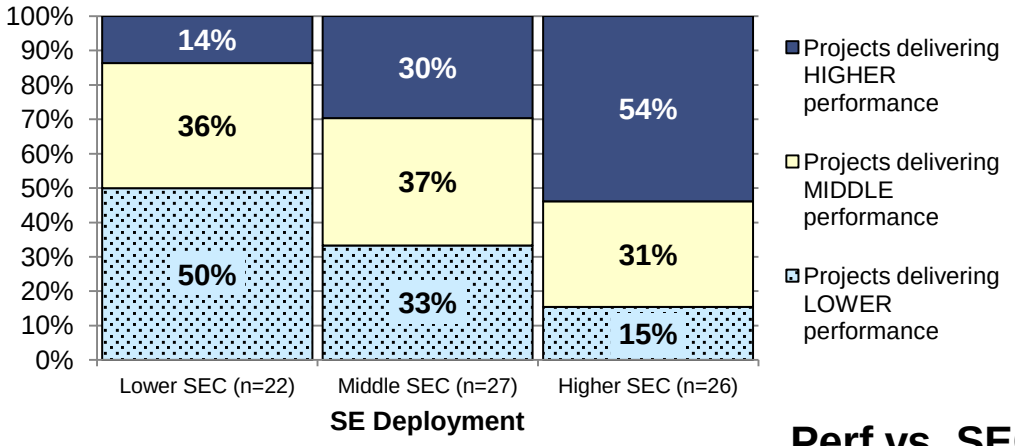


Gamma = 0.47

© 2014 Carnegie Mellon University

Monitoring & Control vs. Project Performance

Perf vs. SEC_PMC (defense)

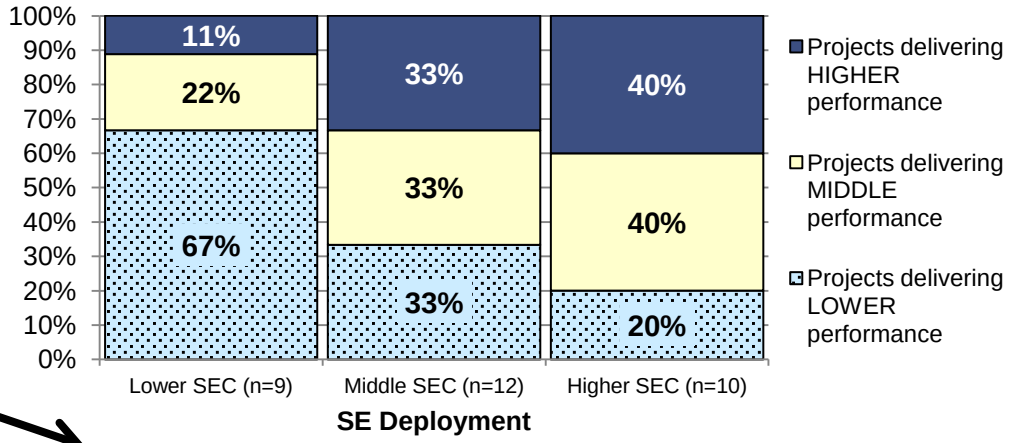


Gamma = 0.48

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)

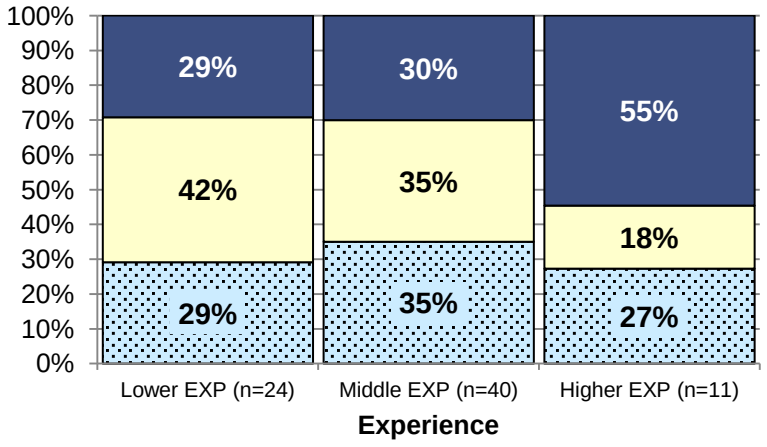


Gamma = 0.38

© 2014 Carnegie Mellon University

Prior Experience vs. Project Performance

Perf vs. EXP (defense)

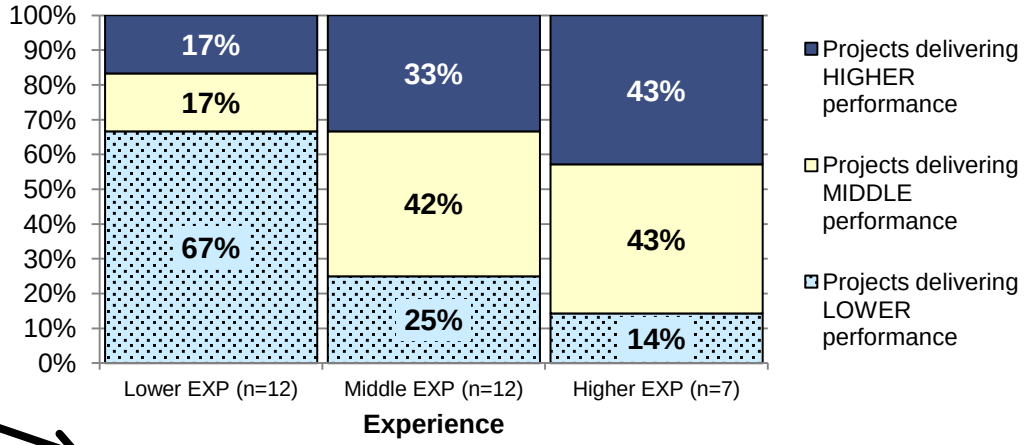


Gamma = 0.1

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

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

Perf vs. EXP (non-defense)

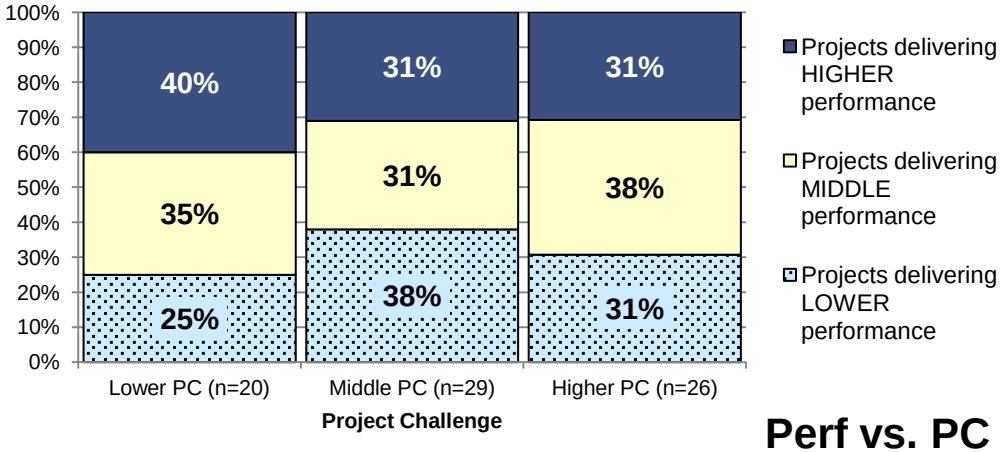


Gamma = 0.44

© 2014 Carnegie Mellon University

Project Challenge vs. Project Performance

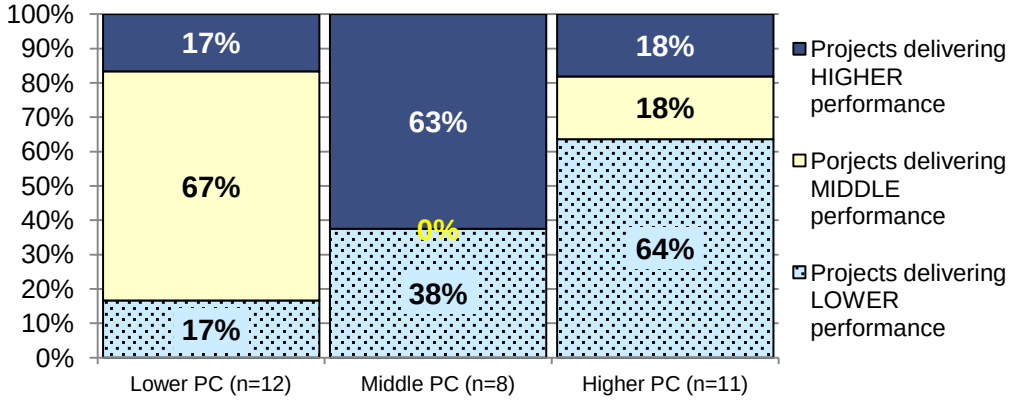
Perf vs. PC (defense)



Gamma = -0.08

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

Perf vs. PC (Non-defense)



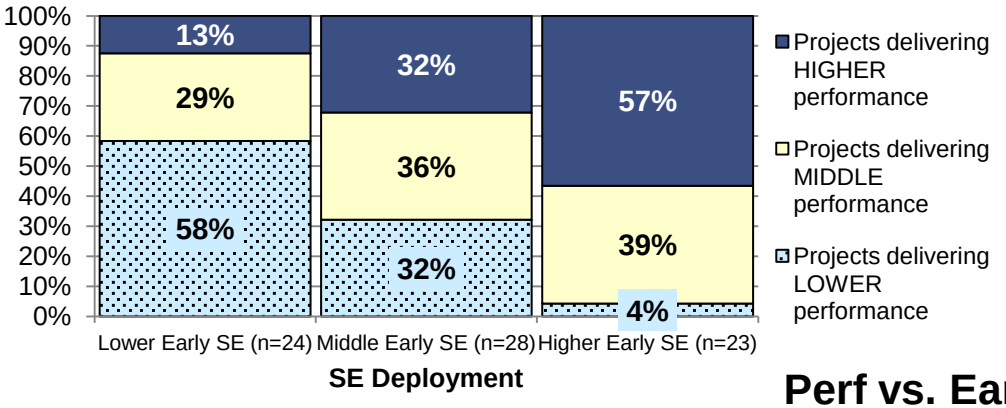
A **Moderate Negative** relationship for non-defense projects

Gamma = -0.24

© 2014 Carnegie Mellon University

Early SE vs. Project Performance

Perf vs. Early_SE (defense)



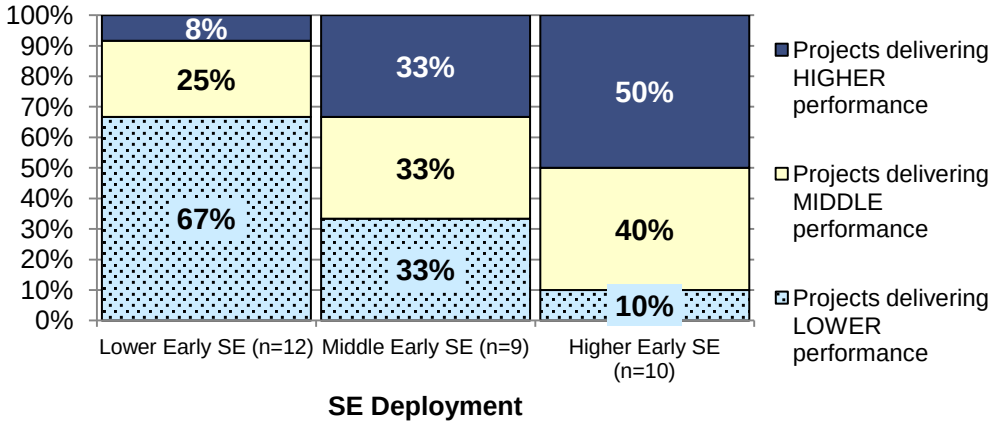
Gamma = 0.61

Early SE

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

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

Perf vs. Early_SE (non-defense)



Gamma = 0.62

© 2014 Carnegie Mellon University