Systems Engineering Capability Development

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Overview

- The application of disciplined Systems Engineering has been proven to significantly improve program performance especially on complex systems.

- This fact is particularly important for Department of Defense programs which are often large scale and complex.

- The quickest way to realize systems engineering benefits is to prioritize work efforts based on the highest return on investment.

- One key step to success is for an organization to benchmark their own Systems Engineering capability, identify gaps, and plan to improve.

- This session will discuss an analytical approach for rapidly maturing Systems Engineering capability within institutions as applied across multiple programs and lifecycle phases.

*TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.***

Performance vs. PC and Overall SEC

Source: Software Engineering Institute and NDIA - Elm, Joseph P., et al. A Survey of Systems Engineering Effectiveness—Initial Results, November 2007
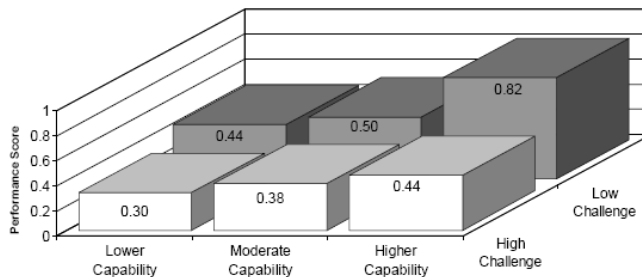
Complexity of Current and Future Systems

- Traditional SE Approaches are not sufficient to tackle increasingly large-scale complex systems

- The SE community is paying increasing attention to issues of Systems of Systems, complex systems, and enterprise systems

- Increased system complexity warrants increased systems engineering capabilities. Considerations include:

  - Agile Constructs and Lean Processes for rapid execution
  - Integrating technologies across multiple Families of Systems
  - Increased demands requiring optimal trades/balancing
  - System of Systems Analysis, Interoperability, constrained integration

Ground Domain Complexity
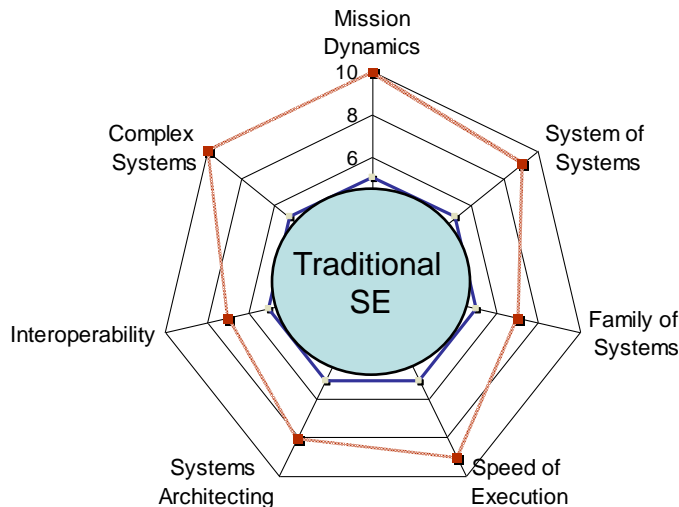
- TARDEC SE Applications
  - Science and Technology Programs
  - Mine Resistant Ambush Protected (MRAP)
    - – Required speed of execution & trades for survivability
  - Condition Based Maintenance
    - Technology Integration across multiple families of systems
  - Joint Lightweight Tactical Vehicle
    - Large new program seeking to balance Payload – Protection – Performance

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Heavy Tactical Vehicle

Medium Tactical Vehicle

Light Tactical Vehicle

Countermine Equipment

Combat Vehicles

Military Bridging

Fuel and Water Storage & Distribution Quality Surveillance Equipment

Trailers

Water Generation and Purification
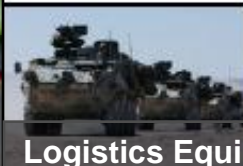
Logistics Equipment

Watercraft

MISSION: TARDEC develops, integrates, and sustains the right technology solutions for all manned and unmanned DOD Ground Systems and Combat Support Systems to improve Current Force effectiveness and provide superior capabilities for the Future Force

VISION: The recognized DOD lead for Ground Systems & Combat Support Systems Technology Integration and Systems of Systems Engineering across the Life Cycle

TARDEC is responsible for research, development and engineering support to more than **2,800** Army systems and many of the Army's and DoD's top joint warfighter development programs.

TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.**
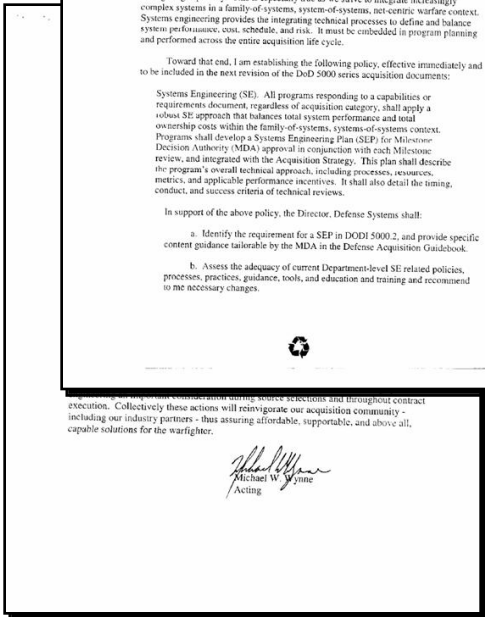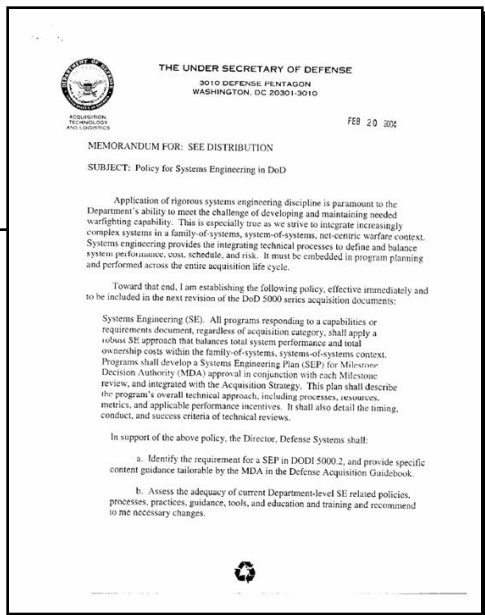
- **The Department of Defense (DOD) and the Department of the Army (DA) have promoted the revitalization of SE and have issued SE Policies aimed at the acquisition community.**
  - Under Secretary of Defense Acquisition, Technology and Logistics Policy for Systems Engineering (SE) in Department of Defense (DOD), 20 February 2004, Addendum 22 October 2004.
  - Department of the Army, Office of the Assistant Secretary of the Army Acquisition, Logistics and Technology (ASA(ALT)) Army Systems Engineering (SE) Policy, 13 June 2005.

- **RDECOM & TARDEC has also issued a SE Policy applying SE discipline to Science & Technology programs.**
  - U.S. Army Research, Development and Engineering Command (RDECOM) Systems Engineering (SE) Policy, 24 April 2007
  - TARDEC Systems Engineering (SE) Policy, 27 September 2007

> *All programs shall apply a robust SE approach that balances system performance with total ownership costs*

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- **Organizational**
  - Isolated pockets of SE practice
  - Competing stove piped processes
  - Lack of integration with business and management practices
  - Organizational Alignment to enable SE

- **Application of SE**
  - Across the lifecycle (concept through disposal)
  - Science and Technology Programs
  - Limited Budget
  - Synchronization Across Programs

- **Misconceptions**
  - Assign an SE to a Project & Systems Engineering Will Get done!
  - Train and Certify the Workforce in SE and SE Will Get done!
  - Take a Ride on the SE "V" (diagram) and SE Will Get done!
  - SE Definition
  - Everything is SE!

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SE Policies
Industry Standards
Communities of Practice

Voice of the Customer
Mission Requirements
Voice of the Business

SE Centers of Excellence
Products, Services, & Innovations

- Human Capital
- Training & Development
- Tools & Infrastructure
- Integrated Processes
- Metrics
- Transformation
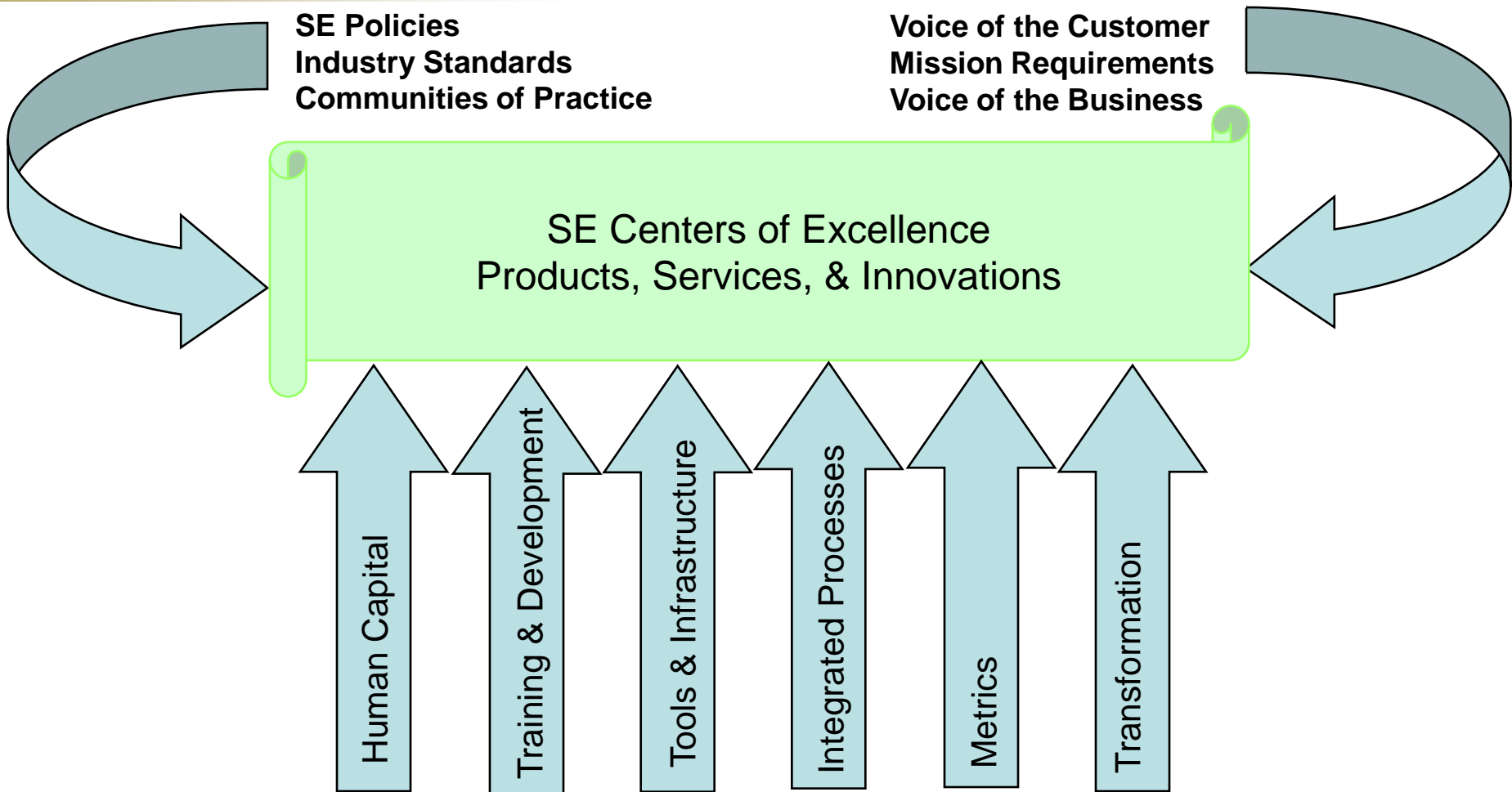
Established an SE Framework and an integrated organizational structure to enable SE!

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

- **Define and Document the Requirements**
  - Conduct QFD Sessions to Solicit the VOC
  - Benchmark Other SE Organizations/Efforts
  - Leverage DOD / Industry / Academia Studies

- **Baseline Capabilities**
  - Establish a Baseline of TARDEC's Systems Engineering Capabilities and Performance
  - Identify Areas for Improvement and Make the Business Case for Change Based on Risks and Opportunities

- **Capability Development Plan**
  - Build a focused and prioritized work plan to address gaps
  - Leverage Strengths and Best Practices from Industry
  - Institutionalize Systems Engineering

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Project Performance vs. Systems Engineering Capability

Legend:
- Higher Project Performance (green)
- Moderate Project Peformance (yellow)
- Lower Project Performance (red)

	Projects with Lower SE Capability	Projects with Moderate SE Capability	Projects with Higher SE Capability
Higher	15%	12%	56%
Moderate	46%	59%	13%
Lower	39%	29%	31%

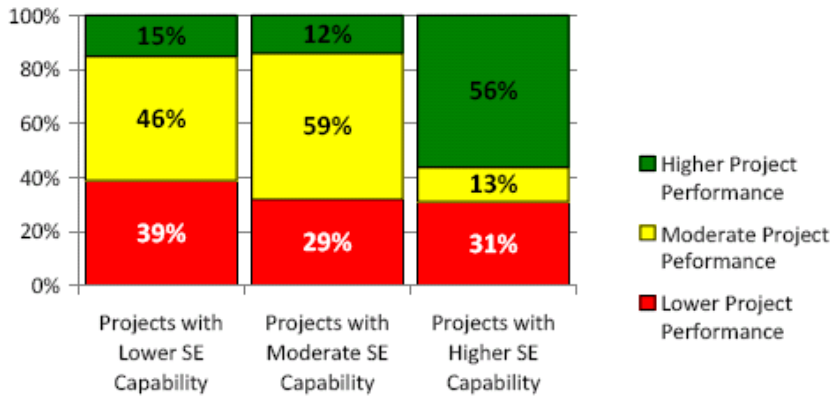Study demonstrated that projects with better Systems Engineering Capabilities delivered better Project Performance.

Performance vs. PC and Overall SEC

Values shown: 0.30, 0.38, 0.44 (low challenge / lower, moderate, higher capability); 0.44, 0.50, 0.82 (high challenge)
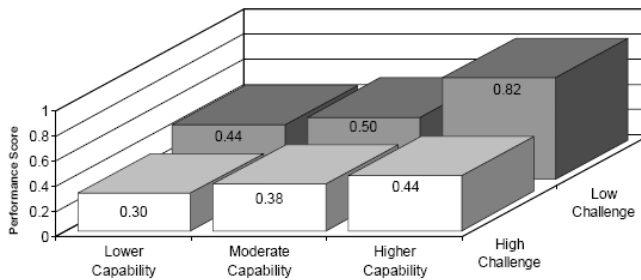
Statistical relationship with Project Performance is quite strong when both *SE Capability and Project Challenge* are *considered together*

Supplier's Systems Engineering Capability[3]	Relationship to Project Performance	Relationship (Gamma[4])
Project Planning	Weak positive relationship	+0.13
Project Monitoring and Control	Weak negative relationship	-0.13
Risk Management	Moderately strong positive relationship	+0.28
Requirements Development and Management	Moderately strong positive relationship	+0.33
Trade Studies	Moderately strong positive relationship	+0.37
Product Architecture	Moderately strong to strong positive relationship	+0.40
Technical Solution	Moderately strong positive relationship	+0.36
Product Integration	Weak positive relationship	+0.21
Verification	Moderately strong positive relationship	+0.25
Validation	Moderately strong positive relationship	+0.28
Configuration Management	Weak positive relationship	+0.13
IPT-Related Capability	Moderately strong positive relationship	+0.34

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Booz Allen's Integrated Acquisition Capability™ (IAC)

Integrated Acquisition Capability™

Leadership Capability | **Acquisition Capability** | **Program Capability** | **Technical Capability**

Core Capabilities

Leadership Capability:
1. Program Strategy
2. Program Authorities
3. Program Operating Model
4. Institutional Knowledge Capture and Dissemination

Acquisition Capability:
1. Concept Development
2. Acquisition Strategy
3. Acquisition Process
4. Major Restructuring
5. Acceptance & Transfer
6. Follow-on Business Development

Program Capability:
1. Program Planning
2. Performance Mgmt
3. Supplier Management
4. Logistics Management
5. Schedule Management
6. Financial Management
7. Risk Management

Technical Capability:
1. Stakeholder Requirements Definition
2. Requirements Analysis
3. Architectural Design
4. Implementation
5. Integration
6. Verification (including T&E)
7. Transition
8. Validation

Supporting Capabilities

Leadership Capability:
5. People Development and Deployment
6. Process Management
7. Tools & Infrastructure Support

Acquisition Capability:
7. Life Cycle Approach
8. External Stakeholder Management
9. Cost Estimating
10. Legal & Regulatory Compliance

Program Capability:
8. Program Organization
9. Contract Management
10. Mission & Info Assurance
11. Program Review Process
12. Configuration & Data Mgmt
13. Infrastructure Management

Technical Capability:
9. Technical Performance Management
10. Modeling & Simulation
11. Technology Mgmt
12. Development Infrastructure

Integrated Acquisition Capability™ is a proprietary methodology and trademark of Booz Allen Hamilton, Inc.

- Depicts the complete set of capabilities required to successfully execute a program
- Derived from multiple industry and government standards as well as extensive experience
- Provides a common framework for assessing and building capabilities across industries
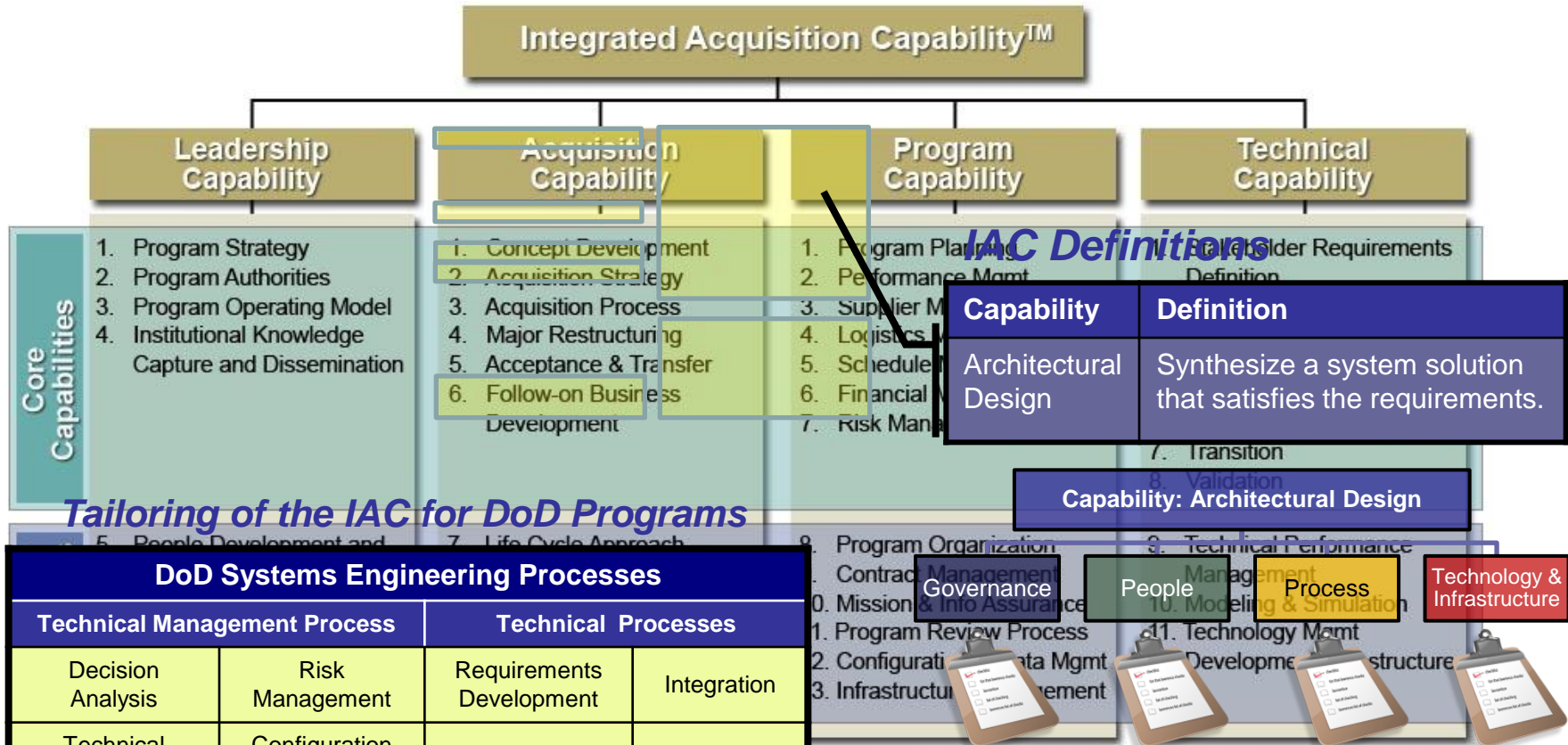- The IAC is a proprietary methodology easily tailored to each unique client environment

Systems Engineering Capability Development

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Building a Systems Engineering Capability Development Plan

INPUTS

- Integrated Acquisition Capability™ (IAC) Framework

- Direction from Organization on Focus Areas / Scope

- Previous Assessments

- Organizational Chart & Contact List

- Program Documentation (e.g. SE artifacts, processes, etc.)

Phase I

▸ Preparation Phase
- Setup Assessment Tool
- Tailor Interview Questions
- Tailor Document Review List
- Schedule Interviews & Collect Documents

Phase II

▸ Data Collection Phase
- Conduct Interviews
- Perform Document Reviews
- Explore Cross References
- Record Findings

Phase III

▸ Analysis Phase
- Synthesize Data
- Identify Strengths & Weaknesses
- Score Capabilities
- Document Findings

OUTPUTS

- Capability Scorecard

- Identified Key Root Causes for Gaps

- Recommendations for Improvement / Prioritized Improvement Plan

- Capability Development Plan Final Brief and Report

Process to build an SE Capability Development Plan

Systems Engineering Capability Development

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Integrated Acquisition Capability™

Leadership Capability
1. Program Strategy
2. Program Authorities
3. Program Operating Model
4. Institutional Knowledge Capture and Dissemination

Acquisition Capability
1. Concept Development
2. Acquisition Strategy
3. Acquisition Process
4. Major Restructuring
5. Acceptance & Transfer
6. Follow-on Business Development

Program Capability
1. Program Planning
2. Performance Mgmt
3. Supplier M
4. Logistics
5. Schedule
6. Financial
7. Risk Man

Technical Capability
Stakeholder Requirements Definition
7. Transition
8. Validation

Core Capabilities

IAC Definitions

Capability	Definition
Architectural Design	Synthesize a system solution that satisfies the requirements.

Capability: Architectural Design

Tailoring of the IAC for DoD Programs

5. People Development and
7. Life Cycle Approach

8. Program Organization Contract Management
0. Mission & Info Assurance
1. Program Review Process
2. Configuration Data Mgmt
3. Infrastructure Management

9. Technical Performance Management
10. Modeling & Simulation
11. Technology Mgmt Development

Governance | People | Process | Technology & Infrastructure

DoD Systems Engineering Processes

Technical Management Process		Technical Processes	
Decision Analysis	Risk Management	Requirements Development	Integration
Technical Planning	Configuration Management	Logical Analysis	Verification
Technical Assessment	Technical Data Management	Design Solution	Validation
Requirements Management	Interface Management	Implementation	Transition

Source: Defense Acquisition University

ology and trademark of Booz Allen Hamilton, Inc.

A complete capability requires the right **People** following a standard **Process** enabled by the proper **Technology & Infrastructure** in accordance with a defined **Governance** mechanism.
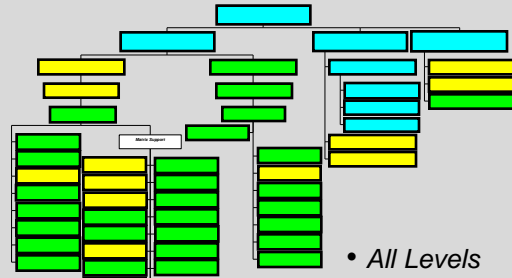
...table following a standard... ...0 programs... ...zes from a wide... ...range of high technology industries.

Interview Workflow

Capability Questionnaire

Interview Guide

- *All Levels*
- *Non-Attributional*
- *360° Perspective*

Interviewed
Not Available
Briefed

Interview List

Tailored Questions

Schedule Interviews

Setup Assessment Tool

Tailor Interview Questions & Document Review List

Schedule Interviews & Collect Documents

Document Review Workflow
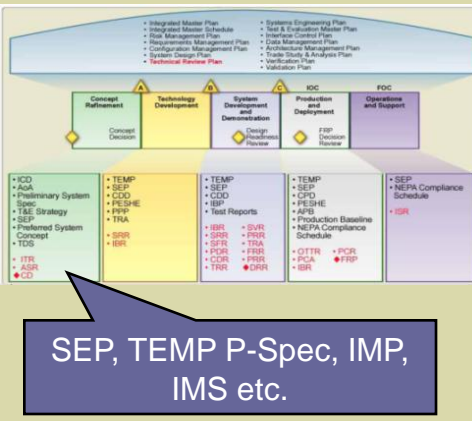
SEP, TEMP P-Spec, IMP, IMS etc.

Tailored Doc List

Capability Artifacts

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Interview Workflow

Conduct Interviews

Subjective Data

Store Data

Access Controlled

Require ments Analysis	02.01 Are all types of requirements (functional, performance, design constraints, regulatory, etc) captured in a consistent manner?

| Definition | and that was realized and corrected? | occasionally knowing the source of the requirement. |
| Requirements Analysis | 02.01 Are all types of requirements (functional, performance, design constraints, regulatory, etc) captured in a consistent manner? | No, our team uses an MS Word document for regulatory requirements and a spreadsheet for new user requirements. The DOORS database is updated after test. |

Notional Example: **Team uses a text document for regulatory requirements and a spreadsheet for new user requirements. Requirements tools are available but not used, RTM used by test did not include most recent changes.**

Explore Cross References

Record Findings

Team Database

Store Data

Notional Example: 02.01 **"The established reqmnts. database shall be the authoritative requirements management tool for capture and recording of new requirements to provide full traceability….changes must be approved.."**

Document Review Workflow

Perform Document Reviews

Objective Data

Doc	Docu...				SEP	Systems Engineering
P Spec	P...			2.01		"The established reqmnts database shall be the autoritative requirements management tool for capture, recording and to provide full traceability."
SEP	Systems		5			
TEMP	Test & E	−	6	TEMP	Test & Evaluation Management Plan
ICD	Initial Ca	+	8	ICD	Initial Capabilities Document
AoA	Analysis	+	10	TP	Test Report (Results)
TP	Test Rep	+	12	IMP	Integrated Master Plan
IMP	Integrated Master Plan					
IMS	Integrated Master Schedule					

Synthesize Data & Identify Strengths & Weaknesses

Interview Data

Document Reviews Data

	Q #	Document Review Notes
1		
2	P Spec	Performance Specification
4	SEP	Systems Engineering Plan
	2.01	"The established reqmts database shall be the autoritative requirements management tool for capture, recording and to provide full traceability."
5		
6	TEMP	Test & Evaluation M...
8	ICD	
10	TP	Test Report (Results)
12	IMP	Integrated Master Plan

Score Capabilities

Category	Question	#	Criteria:	Justification:
Stakeholder Requirements Definition	01.01 Who are the stakeholders for the system?	4	Stakeholders are identified and understood across the program	Stakeholders were identified in the Acquisition Plan, SEP and Communication Plan consistently
	01.02 Do stakeholders feel that their requirements are captured effectively?		Stakeholder requirements are documented and available to stakeholders	Documented in multiple locations and documents not in accordance with SEP
	01.07 How are new requirements or changes in requirements vetted for approval?		New requirements and c... for approval	No formal vetting process with engineering staff and ...ere changed
	01.04 How are requirements problems, such as conflicting stakeholder requirements, identified and resolved?			
	01.05 Is there a formally documented and approved Concept of Operations?		Requirem...	...ution for
	01.08 ** How are stakeholder desires for interfaces and interoperability with external systems captured?		CONOPS is documented... Requirements for interfa... external systems are do...	
	01.06 Are methods such as use cases, mission threads, etc. used to help develop and derive requirements? Are use cases developed in coordination with the system architects?			
			Used cases (scenarios) ... requirements	...uirements
Requirements Analysis	02.02 What tool is used for storing and managing requirements?	3		
	02.06 Can you provide an example of how poorly defined requirements (e.g., un-testable, poorly defined) have been identified and resolved?		Requirements are documented and stored in a central repository	
	02.01 Are all types of requirements (functional, performance, design constraints, regulatory, etc) captured in a consistent manner?		Issues with requirements are identified and resolved	
			Requirements are captured in consistent format	Limited evidence of this
	02.05 Can you give an example of any requirements that do not have top-down traceability?		Lower level requirements are all traceable to higher level requirements	No traceability reported

Fully Capable	5
Strong Capability	4
Moderate Capability	3
Weak Capability	2
No Capability	1

Analyze Underlying Dimensions of Capability

2.0 Requirements Analysis Findings (Notional)

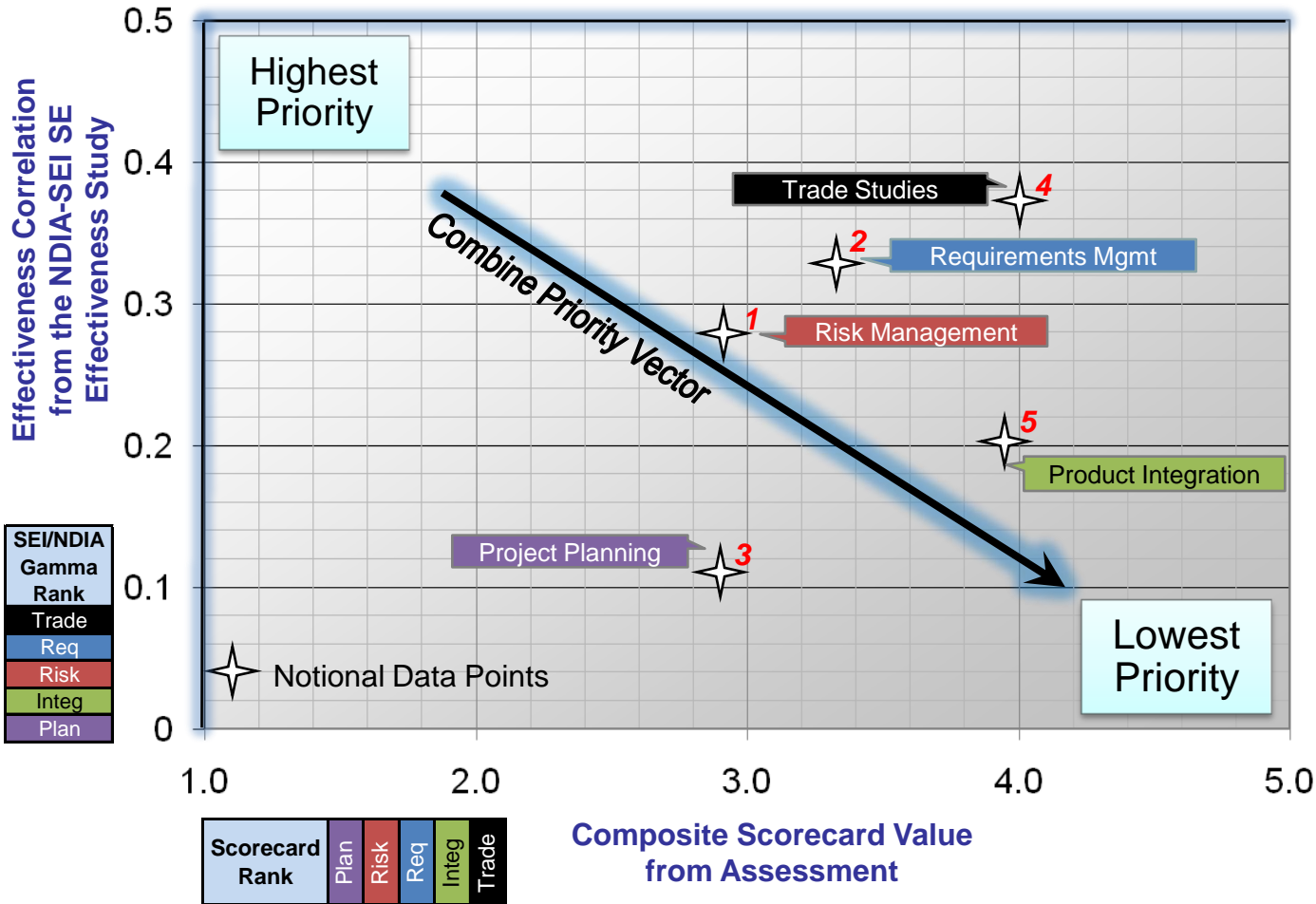|	
Governance	While the program SEP calls for use of a req mgmt tool to manage requirements no governance mechanisms are in place for oversight. Requirements are changed without notifying key stakeholders
People	Some individuals who need access to the latest requirements on programs do not know how to access or use the tools.
Process	No formal overarching requirements management process was identified, team members create ad hoc methods across programs and do not follow processes within program SEPs.
Technology & Infrastructure	The Requirements Management tools available to the team are comprehensive and no issues with access for those trained in use of the tool

Document Findings

Interview Summary
Cross Reference
Underlying Issues
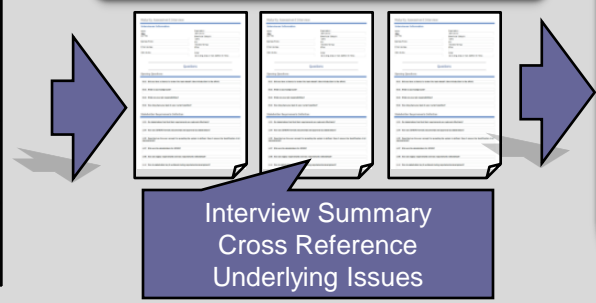
Formulate Recommendations

Based upon underlying dimensions, capability interdependencies & characterize impact

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Plot of NDIA-SEI SE Effectiveness Study & Notional Independent Assessment Findings

Plot of NDIA-SEI SE Effectiveness Study & Notional Independent Assessment Findings. Y-axis: Effectiveness Correlation from the NDIA-SEI SE Effectiveness Study (0 to 0.5). X-axis: Composite Scorecard Value from Assessment (1.0 to 5.0). Data points: Risk Management (1), Requirements Mgmt (2), Project Planning (3), Trade Studies (4), Product Integration (5). Combine Priority Vector from Highest Priority to Lowest Priority.

Composite Ranking
- Risk Management
- Requirements Mgmt
- Project Planning
- Trade Studies
- Product Integration

SEI/NDIA Gamma Rank: Trade, Req, Risk, Integ, Plan

Scorecard Rank: Plan, Risk, Req, Integ, Trade

Plot provides interesting insight into rankings, however other factors must be considered for prioritization

- Underlying causal factors from capability dimensions of People Process, Technology and Governance
- Balance of organizational risks and trades to optimize ROI
- Project, program or portfolio Phase(s), Schedule(s), Funding

The Capability Development Plan:

- Leverages data and actual performance from the diagnostic to create tangible and actionable recommendations

- Hones in on underlying causes providing synergy in improvement efforts for greatest Return on Investment (ROI)

- Accounts for interdependencies between capabilities and provides necessary insight to prioritize efforts for rapid and immediate impact

- Lays our the necessary prioritized tasks Is a detailed and prioritized work plan

Findings & Recommendations

Underlying Dimensions

2.0 Requirements Analysis Findings (Notional)	
Governance	While the program SEP calls for use of DOORs to manage requirements no governance mechanisms are in place for oversight. Requirements are changed without notifying key stakeholders
People	Some individuals who need access to the latest requirements on programs do not know how to access or use the tools.
Process	No formal overarching requirements management process was identified, team members create ad hoc methods across programs and do not follow processes within program SEPs.
Technology & Infrastructure	The Requirements Management tools available to the team are comprehensive and no issues with access for those trained in use of the tool

Core & Supporting SE Capabilities

Prioritized Plan
1. Requirements Mgmt
2. Risk Management
3. Project Planning
4. Product Integration
4. Trade Studies

Plan & Schedule

Systems Engineering Capability Development Plan

Tank Automotive Research Development & Engineering Command

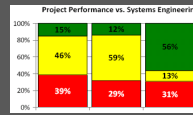October 14, 2008
Prepared By: Booz Allen Hamilton, Inc.

Plan creates a catalyst for change to institutionalize Systems Engineering

Summary

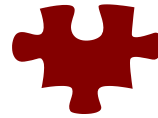| Premise:		
⬆ SE Capability = ⬆ Program Performance	*Project Performance vs. Systems Engineering*	SE Capability is arguably one of the most important for companies that develop and integrate complex systems

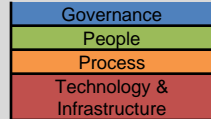| **Challenges** *Typically Seen in Organizations*		**Benefits**
Building a ***comprehensive view*** of capability with an understanding of ***interdependencies*** to create a high performing organization		***Integrated Acquisition Capability*** a comprehensive framework to assess and build the capabilities essential for a successful system acquisition program
Obtaining unhindered and unbiased feedback and applying a ***proven approach for improvement***		Tailored, ***independent and objective review*** based upon industry standards and best practices. Dual path (two-way) verification ensures ***integrity of results***
Leverage resources to implement improvement efforts in lieu of core mission and Identifying key areas to ***improve performance***	Governance / People / Process / Technology & Infrastructure	Diagnostic ***identifies underlying causes*** of capability inhibitors and offers insight to provide ***rapid and synergistic improvements***
Establishing a concrete baseline from which to ***measure performance*** to appropriately adapt make course corrections	Fully Capable 5 / Some Capability 4 / Limited Capability 3 / Very Little Capability 2 / No Capability 1	Identifies ***improvement opportunities & strengths to leverage.*** Creates a ***Current State Baseline*** from which to track improvement.
Breaking down organizational barriers and ***building integrated capabilities***		Prioritized plan provides ***realistic and tangible recommendations*** and creates a catalyst for change ***to institutionalize Systems Engineering***

Conclusion:
Approach enables SE Maturation for *Increased Program Performance*