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26th annual INCOSE international symposium

Edinburgh, UK
July 18 - 21, 2016

SPOTing best approaches to enable SE in Enterprises

Prioritizing improvements in the practice of SE to get better results

Richard Beasley, Andrew Pickard, Andy Nolan and Frank Hull

Introduction

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- Systems Engineering applies to complex and complicated systems and provides value by increasing the probability of success
- INCOSE has led the way in defining Systems Engineering Process and Practice and in developing Systems Engineers
- But – the purpose of doing Systems Engineering is not to do Systems Engineering but to get better outcomes from the whole socio-technical enterprise
- Better results can be obtained by better application of Systems Engineering
- **But what is the route to getting better at Systems Engineering?**

What is SPOT?

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- A databank of practices and a composite model that shows their interactions and their individual and combined influence on the performance of product development systems
- Built to enlarge and replicate results from an initial study for product development in 100 US manufacturers sponsored by the US Defense Advanced Research Projects Agency (DARPA)
- Over 116 strategic business units from a diversity of major corporations principally in the USA, but also from Japan and Europe
- S = Strategy; P = Process; O = Organization; T = Tools and Technologies

Tandem Socio-Technical Systems

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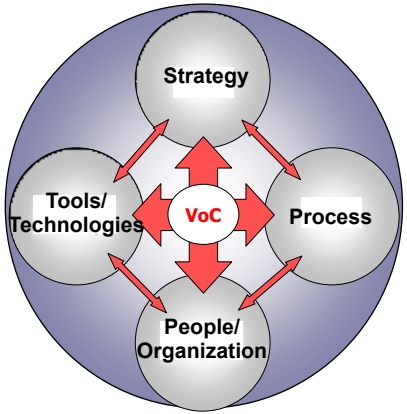
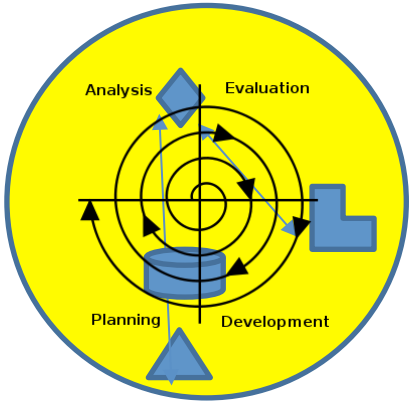
Enterprise Systems Engineering

Social System



Technical System



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What is SPOT?

Strategy, Processes, Organization, Tools/Technologies; 147 questions.

Formulated in collaboration with a dozen leading companies in a Concurrent Engineering User Group based on earlier research 9 Hull, F. M., Collins, P. D. and Liker, J. (1996) *Composite Forms of Organization as a Strategy for Concurrent Engineering Effectiveness*, IEEE Transactions on Engineering Management, Vol., 43, Number 2, May 1996)

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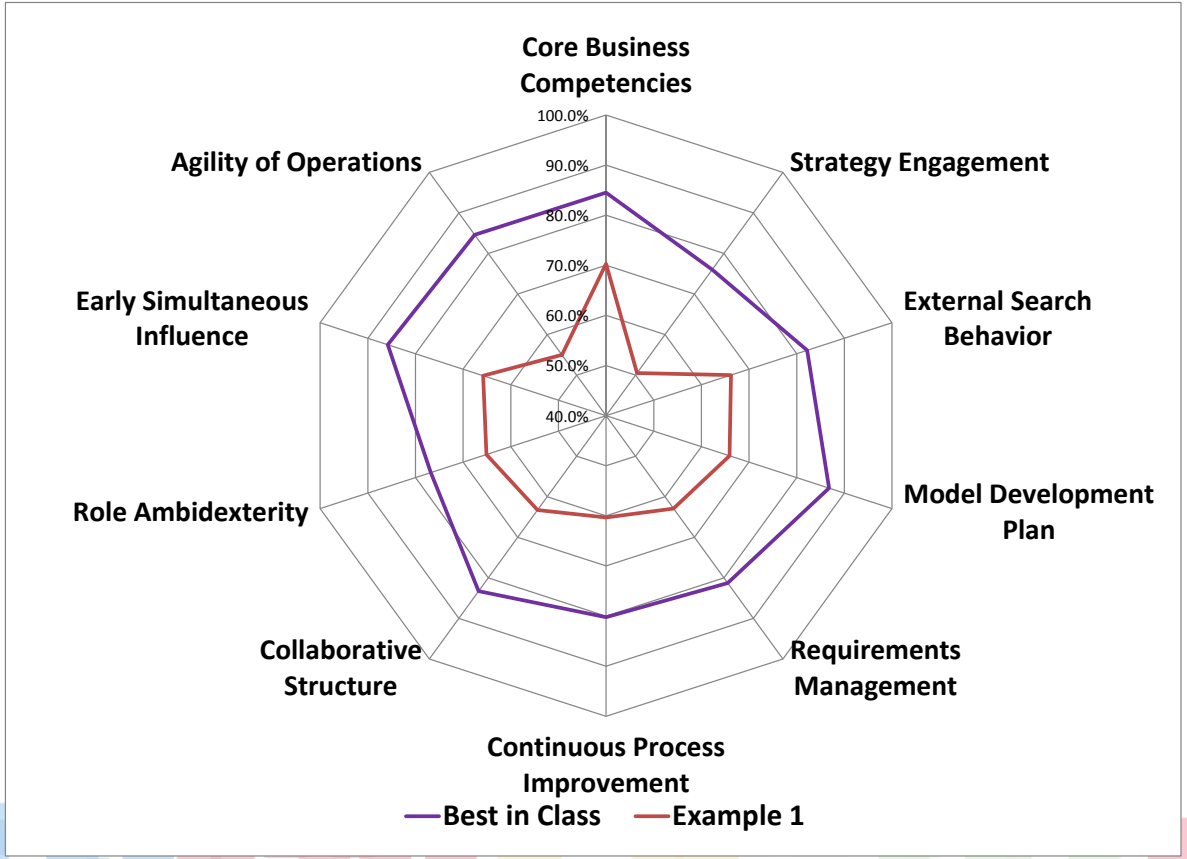
SPOT Area	Sub-Area	#
Strategy	Integrated PD Strategy	4
	Clear Strategic Objectives	3
	Core Business Competencies	2
	Core Technical Competencies	3
	Adaptive Strategy	2
	Strategy Engagement	3
	External Search Behavior	6
Processes	Benchmarking & Industry Analysis	2
	Voice of Customer	4
	Model Development Plan	4
	Staged Development Process	2
	Standard Design and Parts	2
	Design Documentation and Conformance	2
	Requirements Management	4
	Product Design Reviews	3
	Continuous Process Improvement	7

SPOT Area	Sub-Area	#
Organization	Open Communication	3
	Customer Focus	4
	Decentralized Decision-Making	4
	Shared Assessment	3
	Cross-Functional Teaming	3
	Early Simultaneous Involvement/Influence	3
	Downstream Engagement	2
	Role Ambidexterity	3
	Bounded Empowerment	5
	Coaching Culture	4
Tools and Technologies	Product Data Management	4
	Project Management Tools	4
	Decision Support System	7
	Operational Flexibility/Agility of Operations	3
	Computer-Aided Operations	2
	Computer-Aided Design	3
Firm & Industry Characteristics	N/A	37

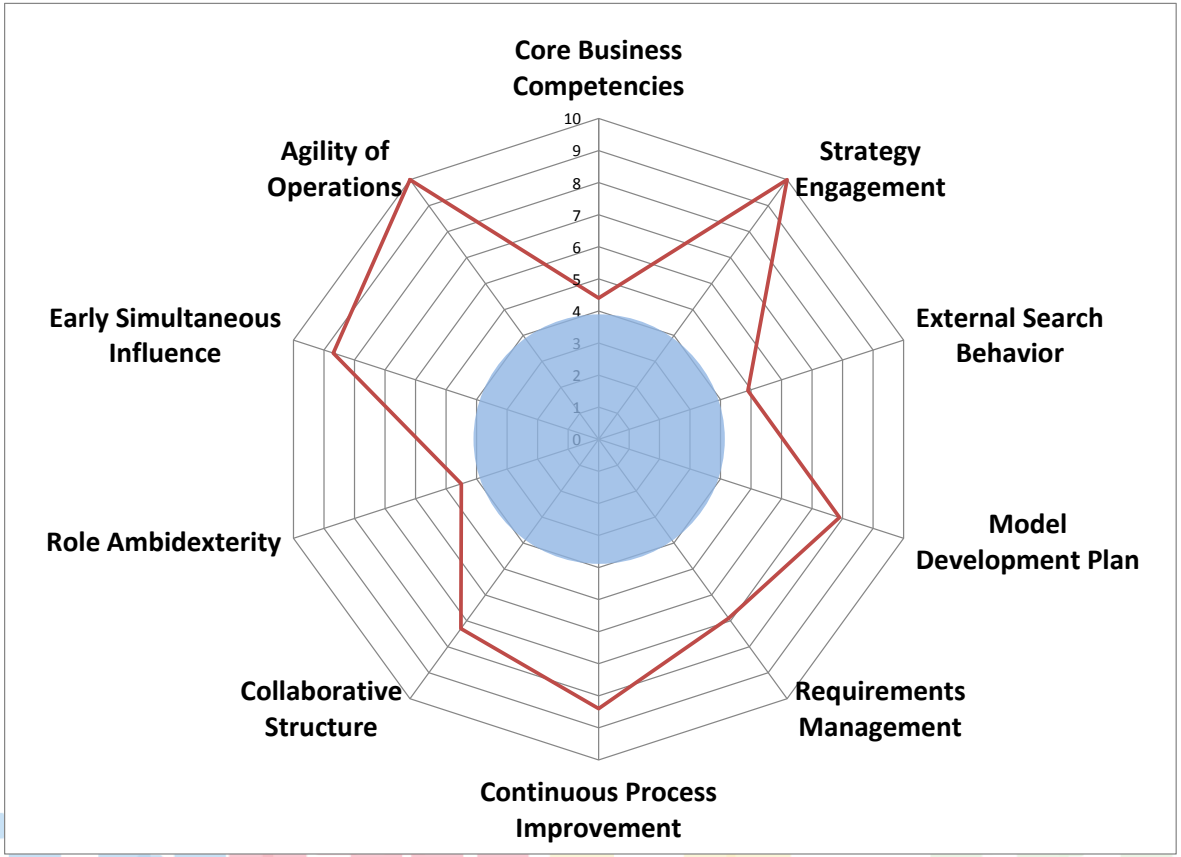
Gaps vs. Best in Class



Birdseye view of gaps vs. Best-in-Class practices

Radial axis = % time respondents observed deployment of development practices in these 10 sets of behavior

“Big Bang” Gaps



Big Bang gaps of high leverage opportunities Algorithm: Gap vs. BIC multiplied by correlation coefficient with performance: Time, cost, quality & innovation

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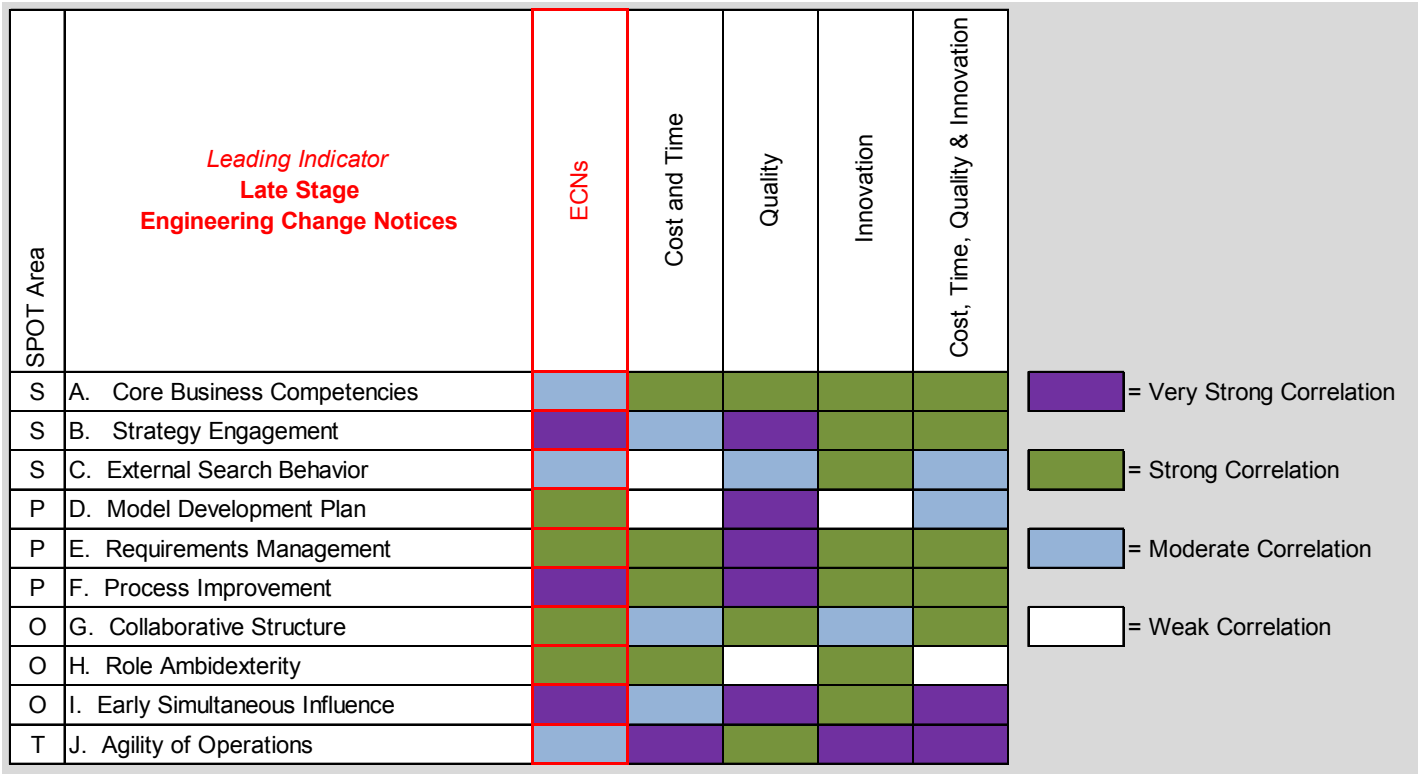
Leading Indicator Correlation



SPOT Area	*Leading Indicator* **Late Stage Engineering Change Notices**	ECNs	Cost and Time	Quality	Innovation	Cost, Time, Quality & Innovation
S	A. Core Business Competencies					
S	B. Strategy Engagement					
S	C. External Search Behavior					
P	D. Model Development Plan					
P	E. Requirements Management					
P	F. Process Improvement					
O	G. Collaborative Structure					
O	H. Role Ambidexterity					
O	I. Early Simultaneous Influence					
T	J. Agility of Operations					

= Very Strong Correlation

= Strong Correlation

= Moderate Correlation

= Weak Correlation

Leading Indicator (Late Stage Engineering Change Notices, ECN) and Ten SPOT Practices (from the SPOT evaluation)

INCOSE Recommended Practice

- INCOSE has publicized/produced three important sets of information about what influences project outcomes
  - SE Effectiveness
  - Lean SE Enablers
  - COCOMO II

SE Effectiveness Study

Section	Subject	# Questions	Content
A	About this Project	17	Challenges & project environment
B	About this Contract	13	Nature of the contract
C	About the Organization	5	Location, domain & past experience
D	Project Planning	22	Process, WBS, Integrated Master Plans & Schedules, SE Involvement
E	Integrated Product Teams	5	IPT formation & participation
F	Risk Management	8	Risk management process
G	Requirements Development & Management	14	Documentation & management process
H	Trade Studies	3	Performance & documentation
I	Product Architecture	5	High level structure & interface management
J	Product Integration	1	Documentation of the integration process
K	Verification	9	Review process, test/verification procedures & acceptance criteria
L	Validation	2	Validation procedures & acceptance criteria
M	Configuration Management	4	Configuration management process
N	Project Performance: Earned Value Measurement	10	Earned Value Management approach, current project status & estimate at completion
O	Other Performance Indicators	14	Schedule performance, customer satisfaction, award fees, fielded product feedback
P	In Conclusion	1	Any other relevant information about the Project

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Systems Engineering Effectiveness Study: 133 Questions

Elm, J., & Goldenson, D., (2012) *The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey* (CMU/SEI-2012-SR-009). Accessed 15th September, 2014, from the Software Engineering Institute, Carnegie Mellon University website: http://resources.sei.cmu.edu/library/asset-view.cfm?AssetID=34061

Lean Enablers for SE

Lean Principle	Lean Enablers Area	# of enablers
Value	Establish the value of the end product or system to the customer	6
	Frequently involve the customer	4
Map the Value Stream	Map the Systems Engineering and Product Development value streams and eliminate non-value-added elements	13
	Plan for frontloading the program	4
	Plan to develop only what needs developing	5
	Plan to prevent potential conflicts with suppliers	4
	Plan leading indicators and metrics to manage the program	5
Flow	Clarify, derive, prioritize requirements early and often during execution	6
	Front load architectural design and implementation	5
	Systems Engineers to accept responsibility for coordination of product development activities	4
	Use efficient and effective communication and coordination	9
	Promote smooth Systems Engineering flow	6
	Make program progress visible to all	4
	Use lean tools	5
Pull	Pull tasks and outputs based on need, and reject others as waste	9
Perfection	Strive for excellence of Systems Engineering process	8
	Use lessons learned from past programs for future programs	5
	Develop perfect communication, coordination and collaboration policy across people and processes	8
	For every program use a Chief Engineer role to lead and integrate the program from start to finish	5
	Drive out waste through design standardization, process standardization and skill-set standardization	3
	Promote all three complementary continuous improvement methods to draw best energy and creativity from all employees	3
Respect for People	Build an organization based on respect for people	14
	Expect and support engineers to strive for technical excellence	4
	Nurture a learning environment	8
	Treat people as most valued assets, not as commodities	1
Use the INCOSE Systems Engineering Handbook	Requirements capture and development (Value)	1
	Planning the progran (Map the Value Stream)	1
	Executing the program (Flow)	1
	Tailoring for a given program (Pull)	1
	Continuous improvement (Perfection)	1
	People management (Respect for People)	1

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Lean Enablers for Systems Engineering; 154 Enablers (148 considered in the correlation)

Oppenheim, B., Murman, E. and Secor, D., (2010) *Lean Enablers for Systems Engineering,* Journal of Systems Engineering, DOI 10.1002/sys, Wiley

COCOMO II

COCOMO Factor Type	COCOMO Factor	# Questions
Scale Factor	Precedentedness	5
	Development Flexibility	4
	Architecture/Risk Resolution	7
	Team Cohesion	4
	Process Maturity	2
Effort Multiplier	Product Related	5
	Platform Related	3
	Personnel Related	6
	Project Related	3

COCOMO II Factors; 39 Questions

Boehm, B., Abts, C., Brown, W., Chulani, S., Clark, B., Horowitz, E., Madachy, R., Reifer, D. and Steece, B., (2000) *Software Cost Estimation with COCOMO II*, Prentice-Hall, ISBN 0-13-026692-2

Comparisons

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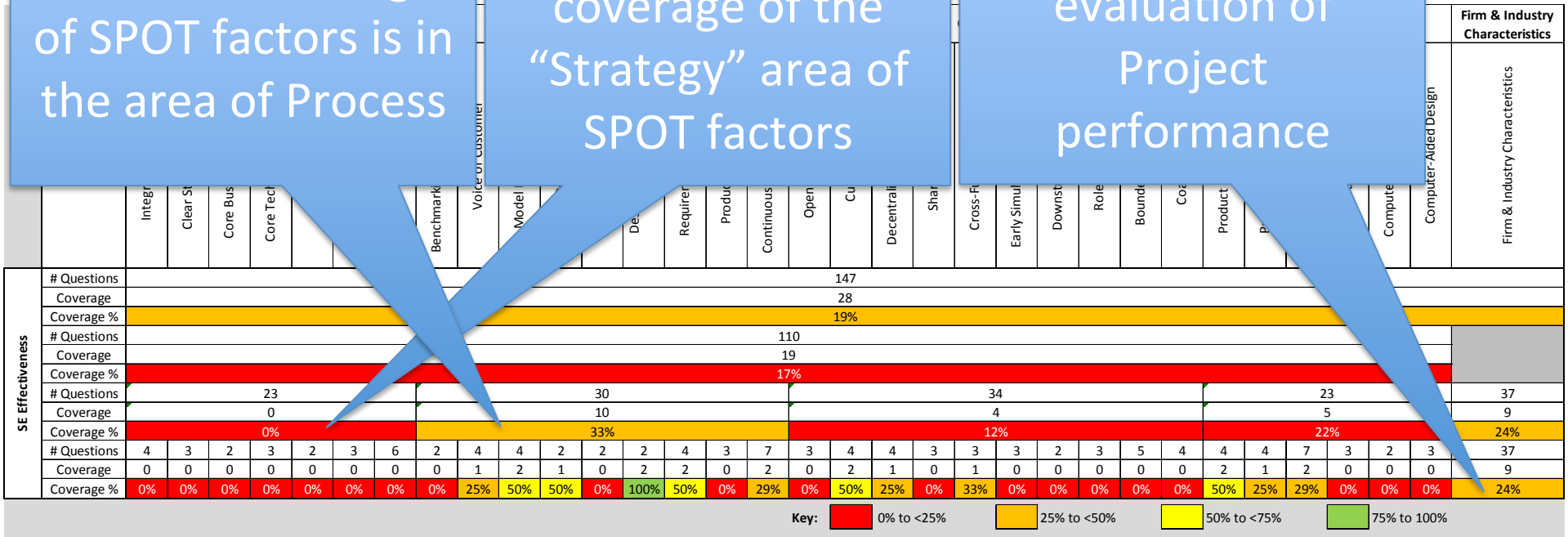
- The next slides show comparisons between the coverage of the four different assessment methods
- Each was derived from six correlation matrices, the largest of which contained over 21,000 cells
  - SPOT (147 factors) vs. Lean SE Enablers (148 factors)
- Shown are 4 of 12 possible comparisons of coverage of the factors from one method by the factors from the other method
  - Coverage of SPOT factors by SE Effectiveness factors
  - Coverage of SPOT factors by Lean SE Enablers factors
  - Coverage of SPOT factors by COCOMO II factors
  - Coverage of Lean SE Enablers factors by SPOT factors

SPOT and SE Effectiveness

The best coverage of SPOT factors is in the area of Process

There is no coverage of the "Strategy" area of SPOT factors

Both have some evaluation of Project performance



		Firm & Industry Characteristics
SE Effectiveness	# Questions	147
	Coverage	28
	Coverage %	19%
	# Questions	110
	Coverage	19
	Coverage %	17%
	# Questions	23 / 30 / 34 / 23	37
	Coverage	0 / 10 / 4 / 5	9
	Coverage %	0% / 33% / 12% / 22%	24%

# Questions	4	3	2	3	2	3	6	2	4	4	2	2	2	4	3	7	3	4	4	3	3	3	2	3	5	4	4	4	7	3	2	3	37
Coverage	0	0	0	0	0	0	0	0	1	2	1	0	2	2	0	2	0	2	1	0	1	0	0	0	0	0	2	1	2	0	0	0	9
Coverage %	0%	0%	0%	0%	0%	0%	0%	0%	25%	50%	50%	0%	100%	50%	0%	29%	0%	50%	25%	0%	33%	0%	0%	0%	0%	0%	50%	25%	29%	0%	0%	0%	24%

Key: 0% to <25% | 25% to <50% | 50% to <75% | 75% to 100%

SPOT and Lean SE

This evaluation looks at the coverage of SPOT factors by Lea

The Lean SE Enablers are best practice advice and do not include an assessment method for Project performance, so have poor coverage of the SPOT area gathering this information

coverage in Tools and Technologies

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| | SPOT Area | | |

SPOT and COCOMO II

This evaluation loc … by COCOMO II factor…

COCOMO is focused on predicting Project performance, so there is less focus on enterprise strategy

…verage of SPOT factors by COCOMO factors is in the area of Process

| | SPOT Area | Strategy | | |

Lean SE and SPOT

This evaluation looks at the coverage of Lean SE Enabler factors by SPOT fa

The best coverage of the Lean SE Enablers factors are in the "Value" and "Pull

the Lean SE

Overall coverage is generally good

		1.2 Estab	1.3 Fr	2.2 Map Elimin	2.3 Pla	2.4 Pla	2.5 Plan t	an	3.7 Mak	5.2 S	5.3 Use Progra	5.4 Devel Coordinat across	5.5 For Every Role to Lea f	5.6 Drive Standardiza and S	5.7 Promote A Continuous Impr Best Energy	6.2 Build an Orga	6.3 Expect and S for Tec	6.4 Nurture a
																6: Respect for People		
SPOT	# Questions								160									
	Coverage								8									
	Coverage %																	
	# Questions	10		31					45				9	39		26		
	Coverage	10		19					25				8	20		16		
	Coverage %	100%		61%					56%				89%	51%		62%		
	# Questions	6	4	13	4	5	4	5	6	5	4	9	12	4	5	9	15	5	8	5	3	3	14	4	8
	Coverage	6	4	8	4	3	2	2	3	0	4	6	6	3	3	8	7	4	6	0	3	0	11	1	4
	Coverage %	100%	100%	62%	100%	60%	50%	40%	50%	0%	100%	67%	50%	75%	60%	89%	47%	80%	75%	0%	100%	0%	79%	25%	50%

Key: 0% to <25% | 25% to <50% | 50% to <75% | 75% to 100%

Overall Correlation

Overall Correlation
- With SPOT Firm & Industry Characteristics

How well does the row item correlate with the column item?	SPOT	Lean SE	COCOMO II	SE Effectiveness
SPOT		61%	67%	35%
Lean SE	66%		64%	26%
COCOMO II	50%	49%		38%
SE Effectiveness	19%	23%	44%	

Overall Correlation
- Without SPOT Firm & Industry Characteristics

How well does the row item correlate with the column item?	SPOT	Lean SE	COCOMO II	SE Effectiveness
SPOT		61%	67%	35%
Lean SE	82%		64%	26%
COCOMO II	51%	49%		38%
SE Effectiveness	17%	23%	44%	

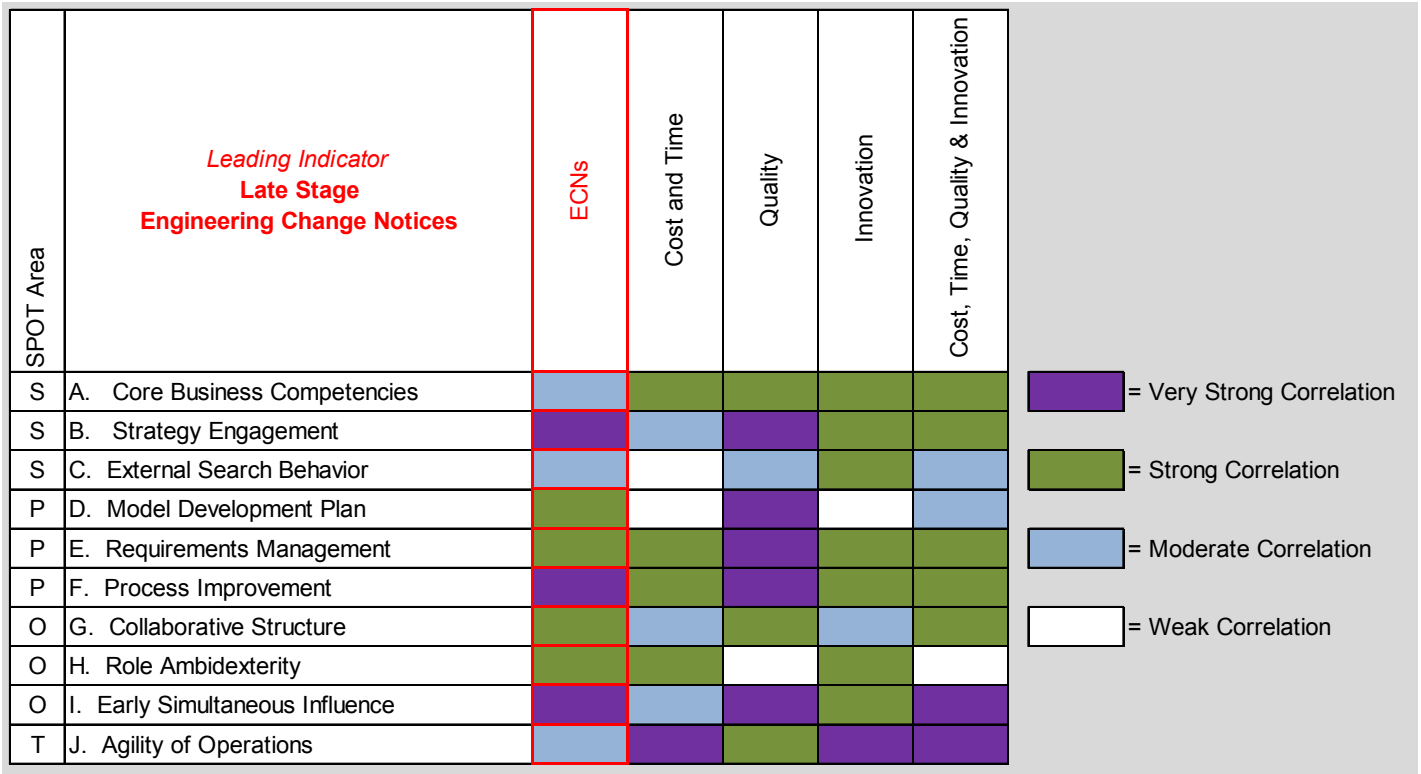
Key:
- 0% to <25%
- 25% to <50%
- 50% to <75%
- 75% to 100%

Interim conclusions:

- *SPOT aligns best to Lean SE Enablers*
- *More value to be got out of SE than just process*

AP

Leading Indicator Correlation



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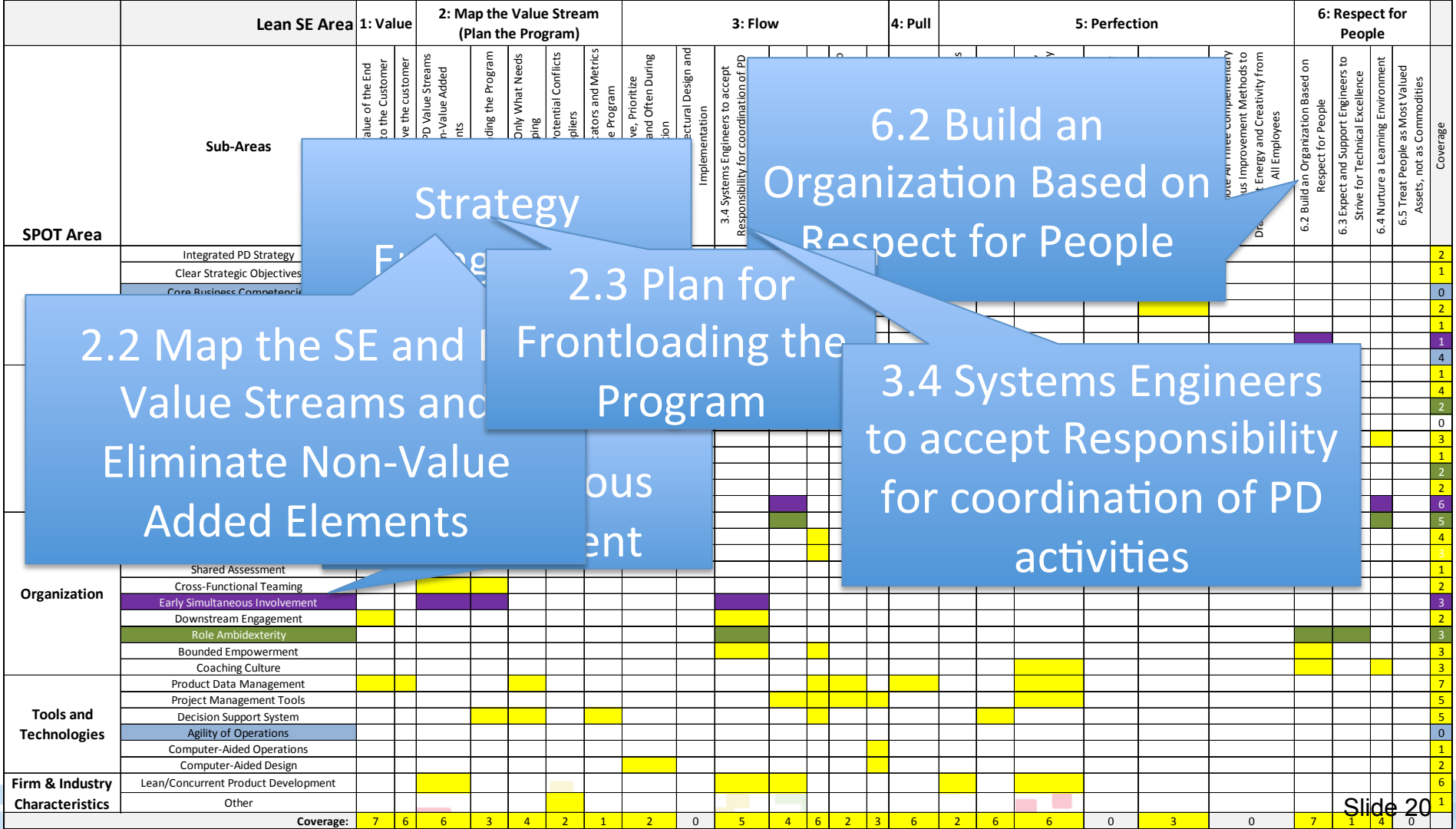
Leading Indicator (Late Stage Engineering Change Notices, ECN) and Ten SPOT Practices (from the SPOT evaluation)


Lean SE Area
1: Value
2: Map the Value Stream (Plan the Program)
3: Flow
4: Pull
5: Perfection
6: Respect for People
Sub-Areas
SPOT Area
Coverage
6.2 Build an Organization Based on Respect for People
6.3 Expect and Support Engineers to Strive for Technical Excellence
6.4 Nurture a Learning Environment
6.5 Treat People as Most Valued Assets, not as Commodities
Integrated PD Strategy
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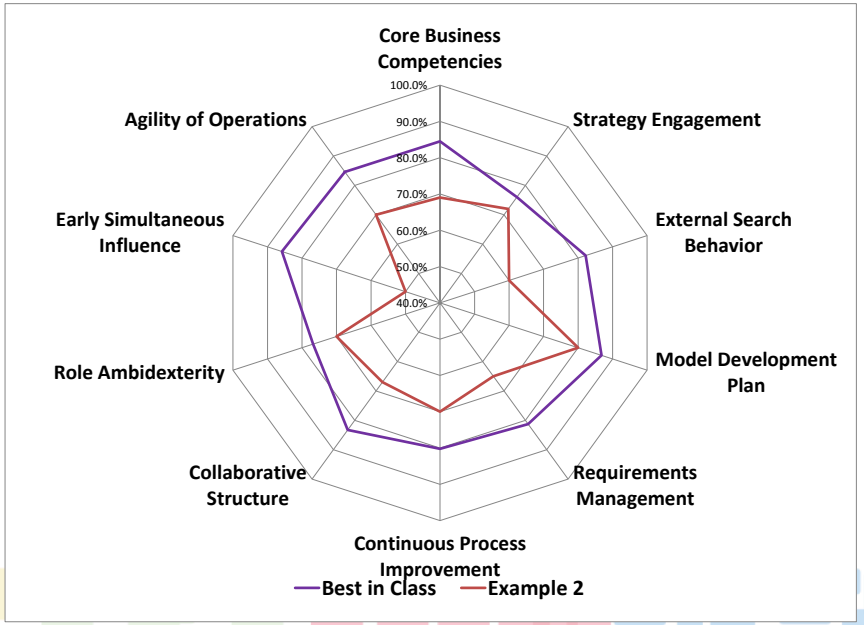
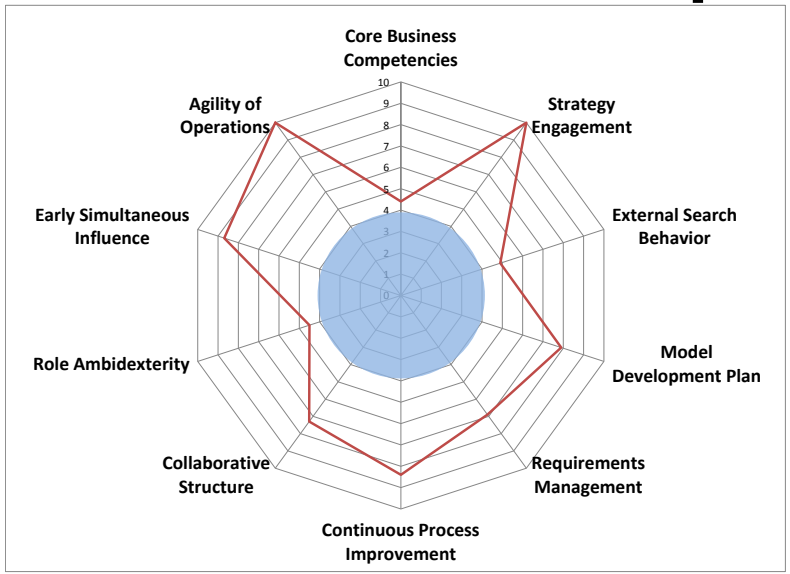
Bounded Empowerment
Coaching Culture
Organization
Product Data Management
Project Management Tools
Decision Support System
Agility of Operations
Computer-Aided Operations
Computer-Aided Design
Tools and Technologies
Lean/Concurrent Product Development
Other
Firm & Industry Characteristics
Coverage: 7 6 6 3 4 2 1 2 0 5 4 6 2 3 6 2 6 6 0 3 0 7 1 4 0
Strategy
6.2 Build an Organization Based on Respect for People
2.3 Plan for Frontloading the Program
2.2 Map the SE and I
Value Streams and
Eliminate Non-Value
Added Elements
3.4 Systems Engineers to accept Responsibility for coordination of PD activities

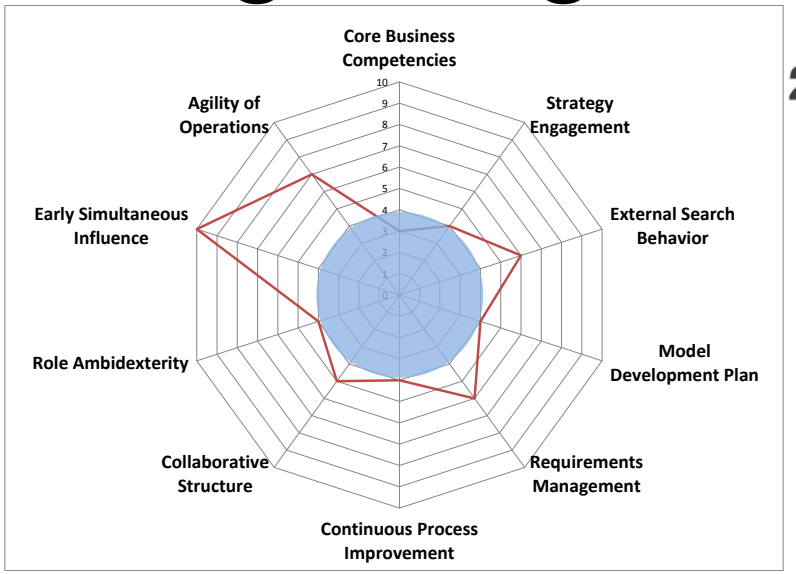
Relationship to GAP Chart

- 2 different fictitious Companies with different gaps relative to Best in Class
- Which lean SE enablers should be deployed?



Relationship to Big Bang





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Assessment Tool

Strategy Engagement (example)

- 6.2 Build an Organization Based on Respect for People
  - 6.2.1 Create a vision which draws and inspires the best people

Early Simultaneous Involvement (example)

- 2.3 Plan for Front-Loading the Program
  - 2.3.1 Plan to utilize cross-functional teams made up of the most experienced and compatible people at the start of the project to look at a broad range of solution sets

Conclusions

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- There's more than SE Process to give you SE value
- There is a gap in INCOSE material in helping an organization understand what to improve first
- The practices in the Concurrent Engineering SPOT databank are closely correlated to recognizable, recommended SE practice
- Therefore we propose that there is an opportunity to utilize the SPOT assessment and analysis capability to recommend to any given organization what aspect of SE capability to improve next to achieve the purpose of SE – and the answer isn't just process!

An Opportunity?

- To do this, INCOSE needs to validate the correlations, align the language and produce archetype organizational examples to show how to apply the approach.
- Work with SPOT and other behavioral drivers for optimizing technical and business features of design to produce an INCOSE guide for how an organization progressively improves its SE capability by broadening the scope of its application
- “The INCOSE Guide for Organizations to Improve Value Achieved from Doing Systems Engineering”?
- Which CAB Need was that?

Questions?

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  - Frank Hull frankmhull@gmail.com