PROJECT PERFORMANCE INTERNATIONAL

THE BUSINESS CASE FOR SYSTEMS ENGINEERING

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SEI/AESS/NDIA 2012 STUDY RESULTS

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Driver	Relationship to Performance (Gamma)		
	All Projects	Lower challenge	Higher challenge
SEC-Total – total deployed SE	+0.49	+0.34	+0.62
SEC-PP – project planning	+0.46	+0.16	+0.65
SEC-REQ – reqts. developt. & mgmt.	+0.44	+0.36	+0.50
SEC-VER – verification	+0.43	+0.27	+0.60
SEC-ARCH – product architecture	+0.41	+0.31	+0.49
SEC-CM – configuration management	+0.38	+0.22	+0.53
SEC-TRD – trade studies	+0.38	+0.29	+0.43
SEC-PMC – project monitor & control	+0.38	+0.27	+0.53
SEC-VAL – validation	+0.33	+0.23	+0.48
SEC-PI – product integration	+0.33	+0.23	+0.42
SEC-RSKM – risk management	+0.21	+0.18	+0.24
SEC-IPT – integrated product teams	+0.18	-0.12	+0.40

Gamma	Relationship
-0.2 <| *Gamma* | ≤ 0	Weak negative
0 ≤ | *Gamma* | < 0.2	Weak positive
0.2 ≤ | *Gamma* | < 0.3	Moderate
0.3 ≤ | *Gamma* | < 0.4	Strong
0.4 ≤ | *Gamma* |	Very strong

http://resources.sei.cmu.edu/asset_files/specialreport/2012_003_001_34067.pdf

Source: "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012

OUR JOURNEY:

- What are our challenges?
- What is systems engineering?
- Why systems engineering?
- Studies on the value of systems engineering
- ROI for one facet: Requirements Analysis

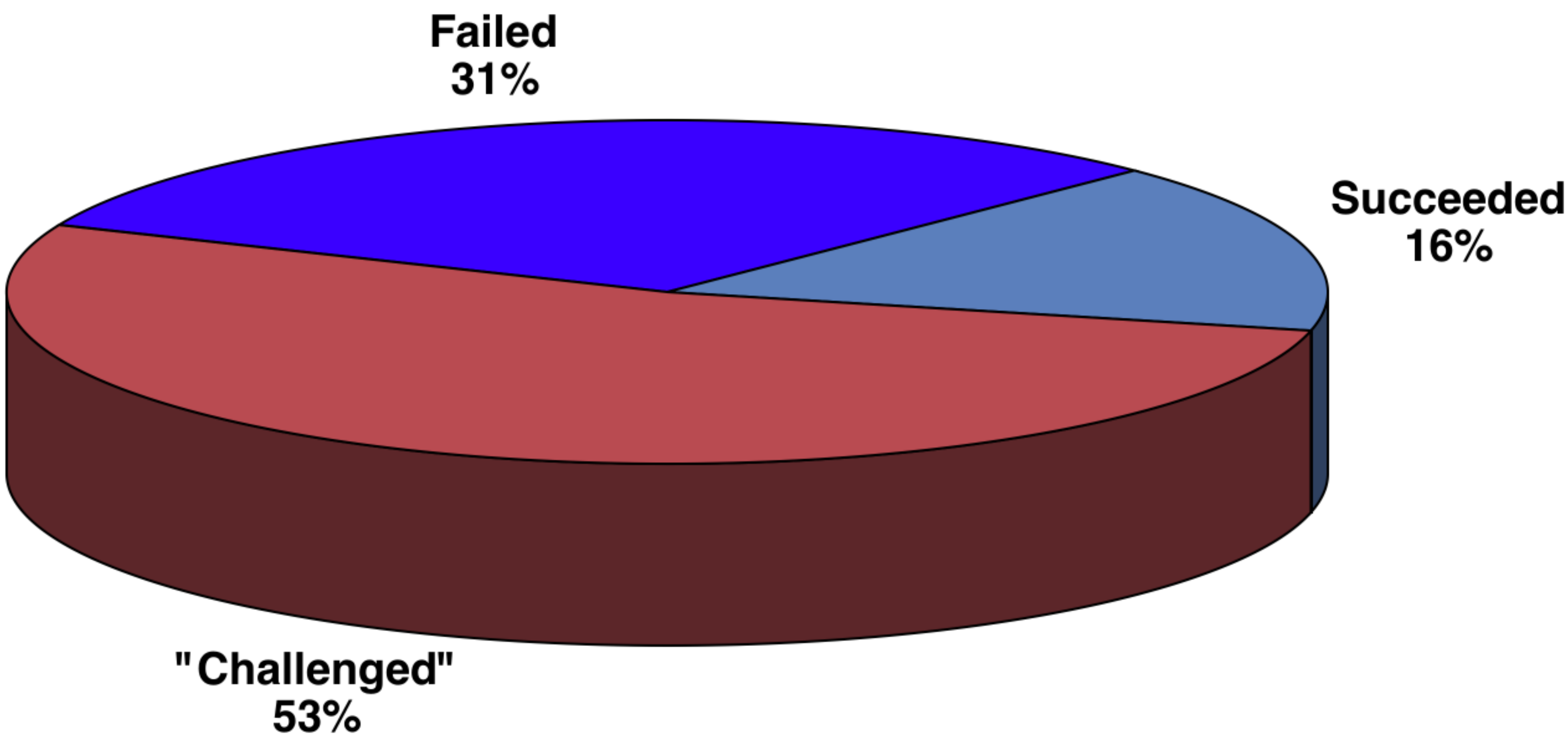
KICK-OFF EXERCISE:

In groups of 3-4 people, consider the question "what are the greatest challenges that we (you) face in your engineering"? List as many challenges as you can, in the time designated.

WHERE WE HAVE COME FROM – OOPS GOT THAT WRONG!

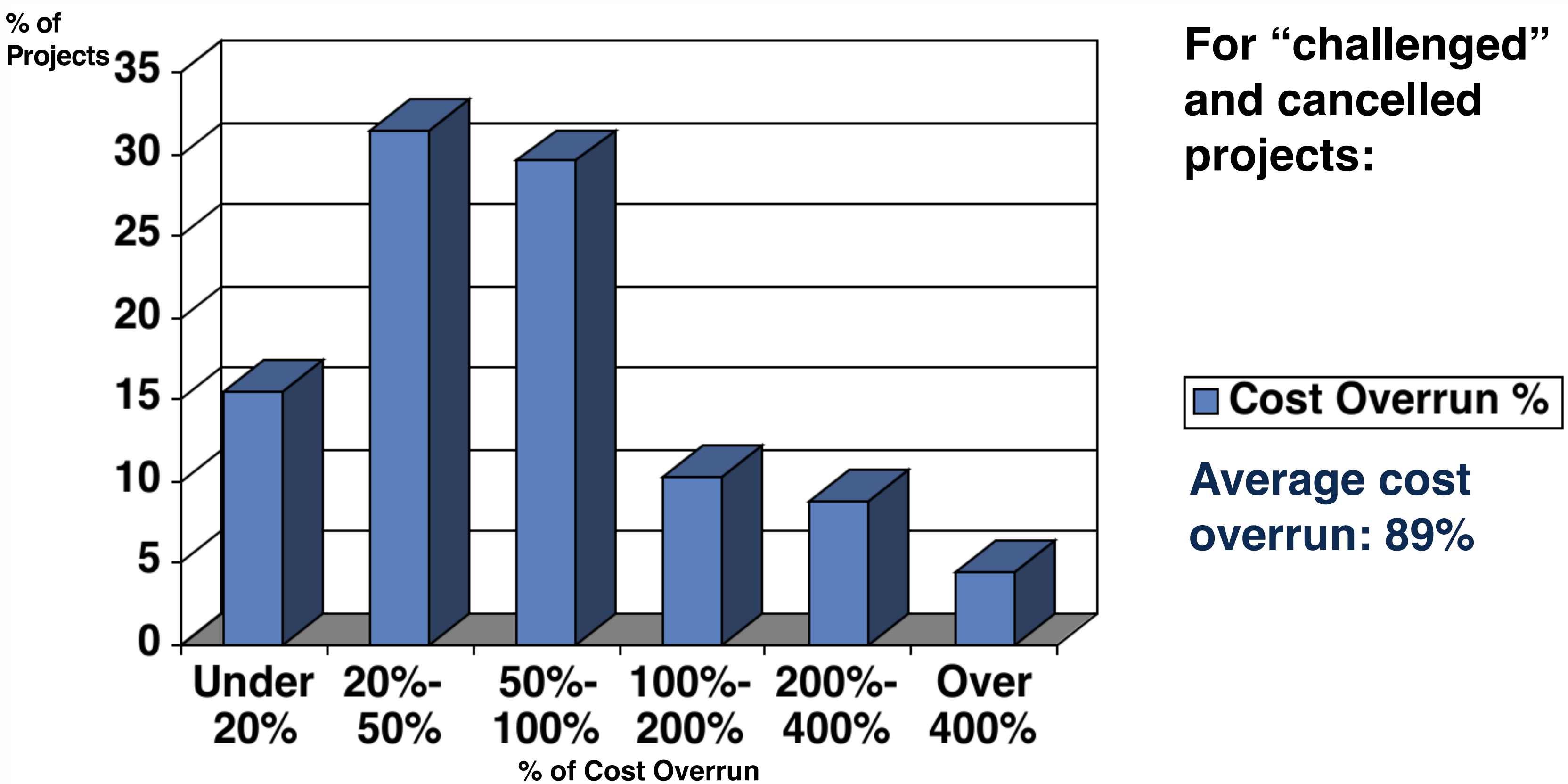
TODAY, AND NOT JUST IN KABUL!

THE PROBLEM IN GENERAL:



Standish Group study of 8380 IT-based projects
See also Morris and Hough, “The Anatomy of Major Projects”

THE PROBLEM – COST:

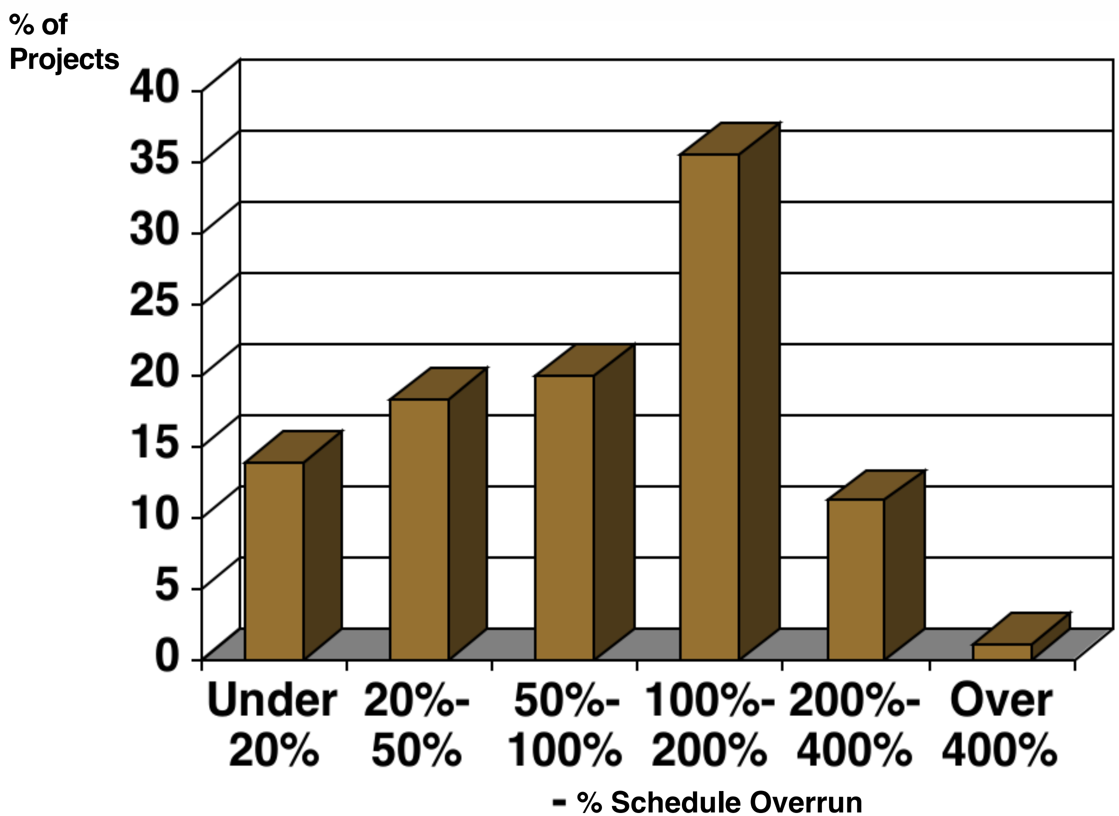


For "challenged" and cancelled projects:

Average cost overrun: 89%

Standish Group study of 8380 IT-based projects

THE PROBLEM – SCHEDULE:



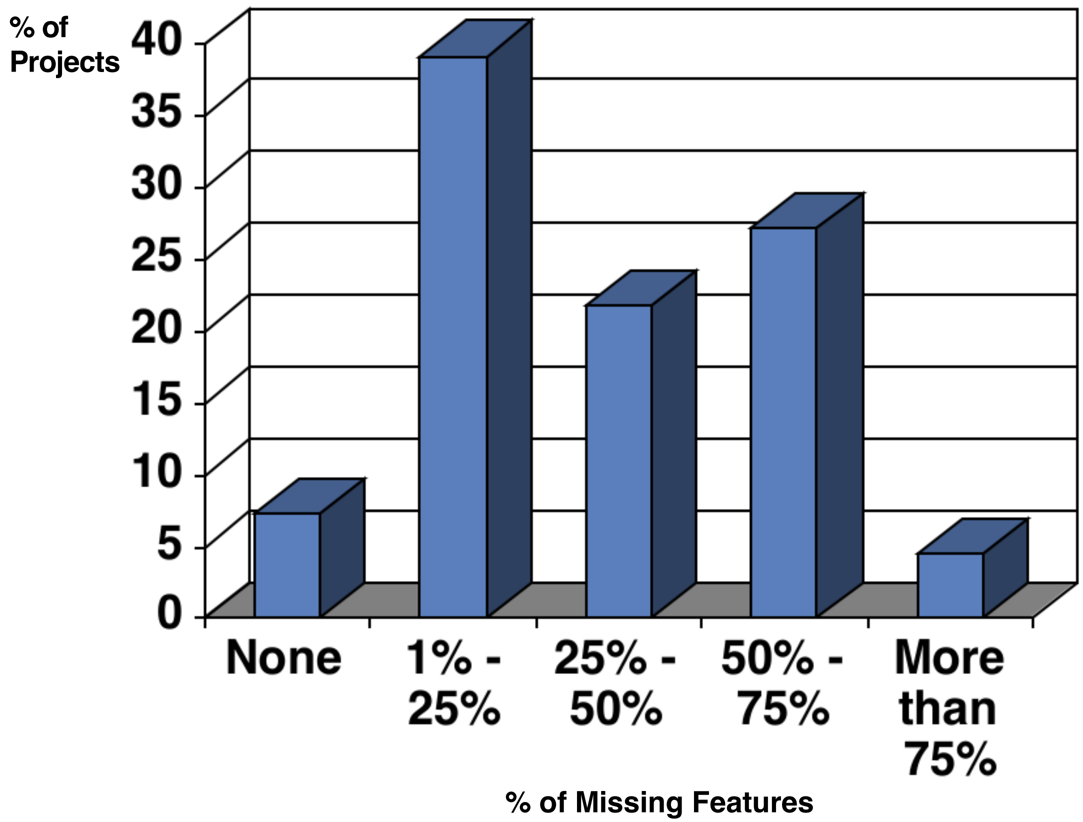
For "challenged" and cancelled projects:

Time Overrun %

Average schedule overrun: 122%

Standish Group study of 8380 IT-based projects

THE PROBLEM – QUALITY:



For “challenged” projects:

Missing Features %

Average missing features: 39%

Standish Group study of 8380 IT-based projects

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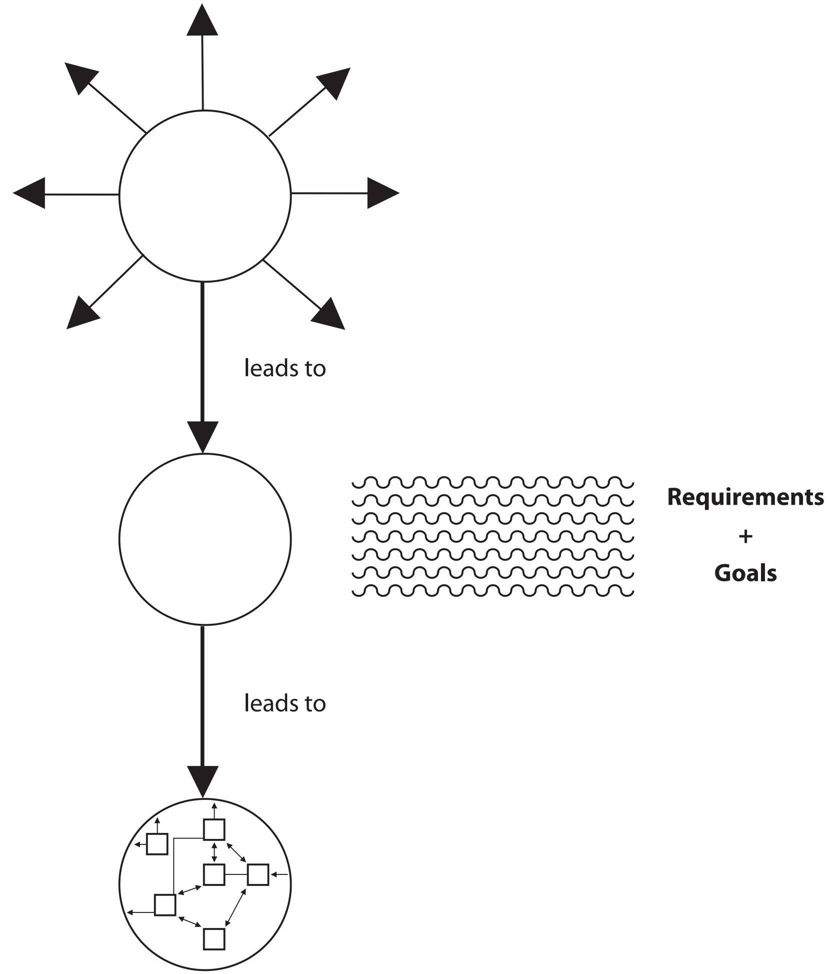
System Views

Outward and Upward Looking View
(part of one or more bigger systems)

Object View
(object with required and desired characteristics)

Inward Looking View
(seeing the system destined to become a set of interacting objects, the properties of the whole coming from the objects and their interactions)



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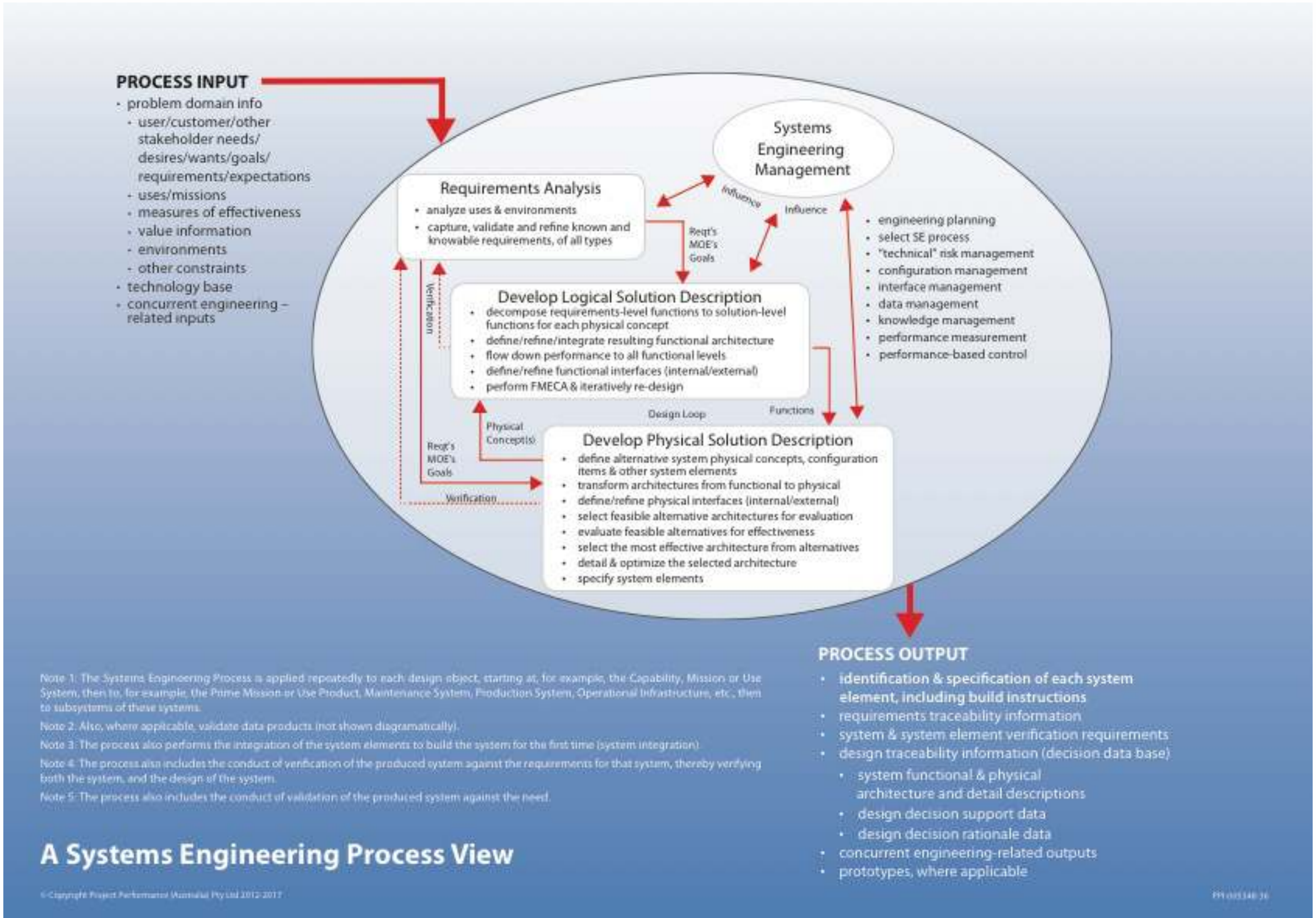
WHAT IS SYSTEMS ENGINEERING?



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INTEGRATE VERIFICATION & VALIDATION

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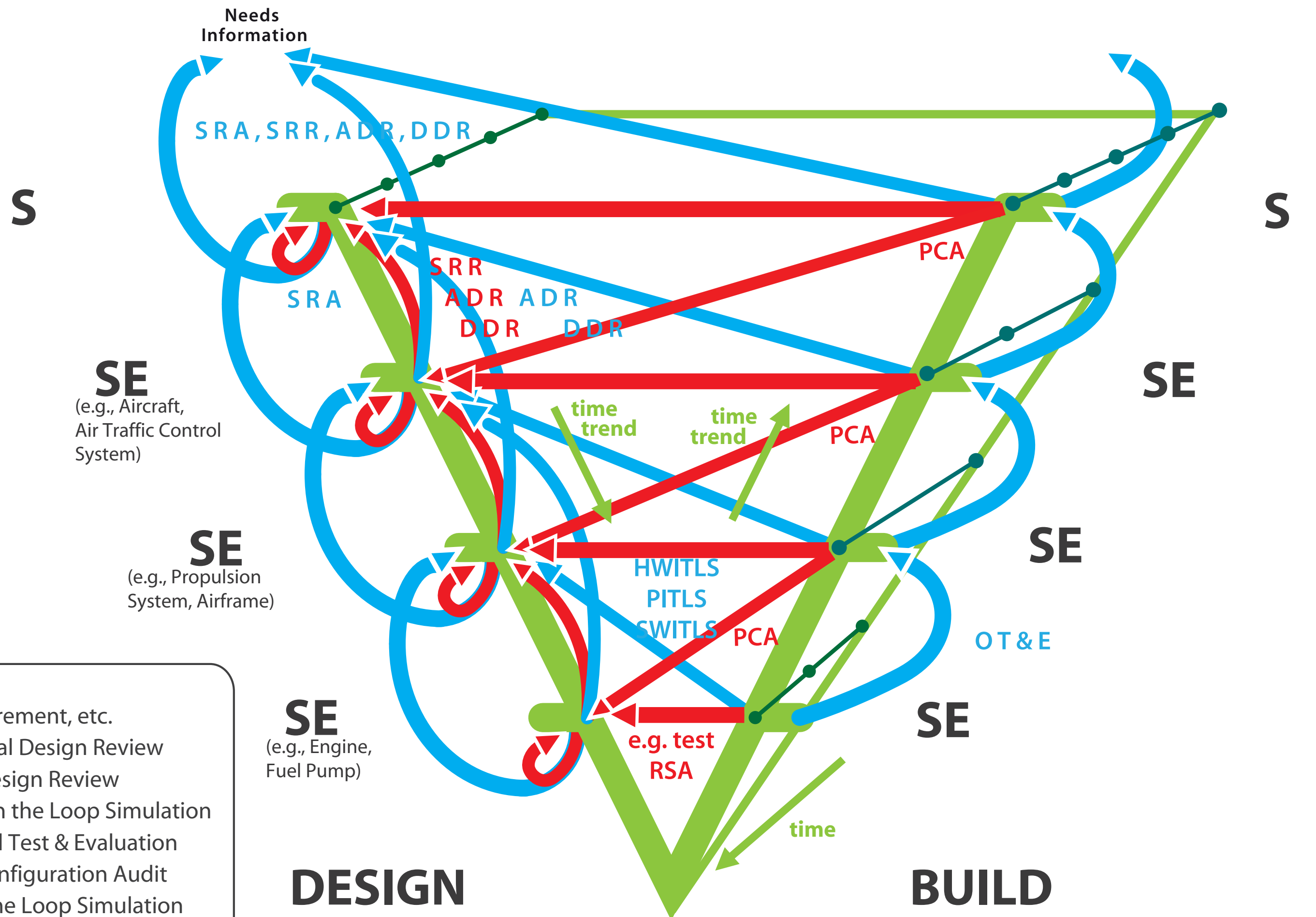

Legend :

●	A Build, increment, etc.
ADR	Architectural Design Review
DDR	Detailed Design Review
HWITLS	Hardware in the Loop Simulation
OT&E	Operational Test & Evaluation
PCA	Physical Configuration Audit
PITLS	People in the Loop Simulation
RSA (FCA)	Requirements Satisfaction Audit
S	Top-Level System
SE	System Element
SRA	System Requirements Analysis
SRR	System Requirements Review
SWITLS	Software in the Loop Simulation

Verification:
Is the work product correct-meets requirements?

Validation:
Does the work product satisfy the need for the work product?

WEDGE MODEL™

PPI-006003-9

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THE ESSENCE OF SE:

- ensure adequate problem definition
- define possible solution alternatives
- qualify solution alternatives for feasibility & effectiveness
- develop qualified alternatives
- use logical design as an aid in developing physical design (model-based design)
- design through levels of abstraction – architecture and detail
- maintain a clear distinction between problem and solution

AND MORE …

- conduct trade-off studies and optimization to maximize overall effectiveness
- specify solution elements to objective adequacy
- integrate engineering specialties with technology expertise
- verify work products (correct – the product right)
- validate work products (needed – the right product)
- employ configuration management
- do only work that adds value
- manage the engineering – plan, organize, inspire, assess, control.

WHEN IS SYSTEMS ENGINEERING APPLIED?

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- Solution development phase
  - New Systems/Products
  - Families of Products
- Solution build/production phase
  - To correct design deficiencies
- Sustainment/operations and support phase
  - Modifications to track changing need
  - Incremental/competitive improvements for business reasons
  - Response to obsolescence

WHAT IS SYSTEMS ENGINEERING APPLIED TO?

- The enterprise
- Capability/business/enterprise systems
- End-use products
- Production systems
- Maintenance systems
- Training systems
- Project systems
- Engineering systems
- Anything else for which a solution does not already exist, and is sought!

IN WHAT BUSINESS MODELS?

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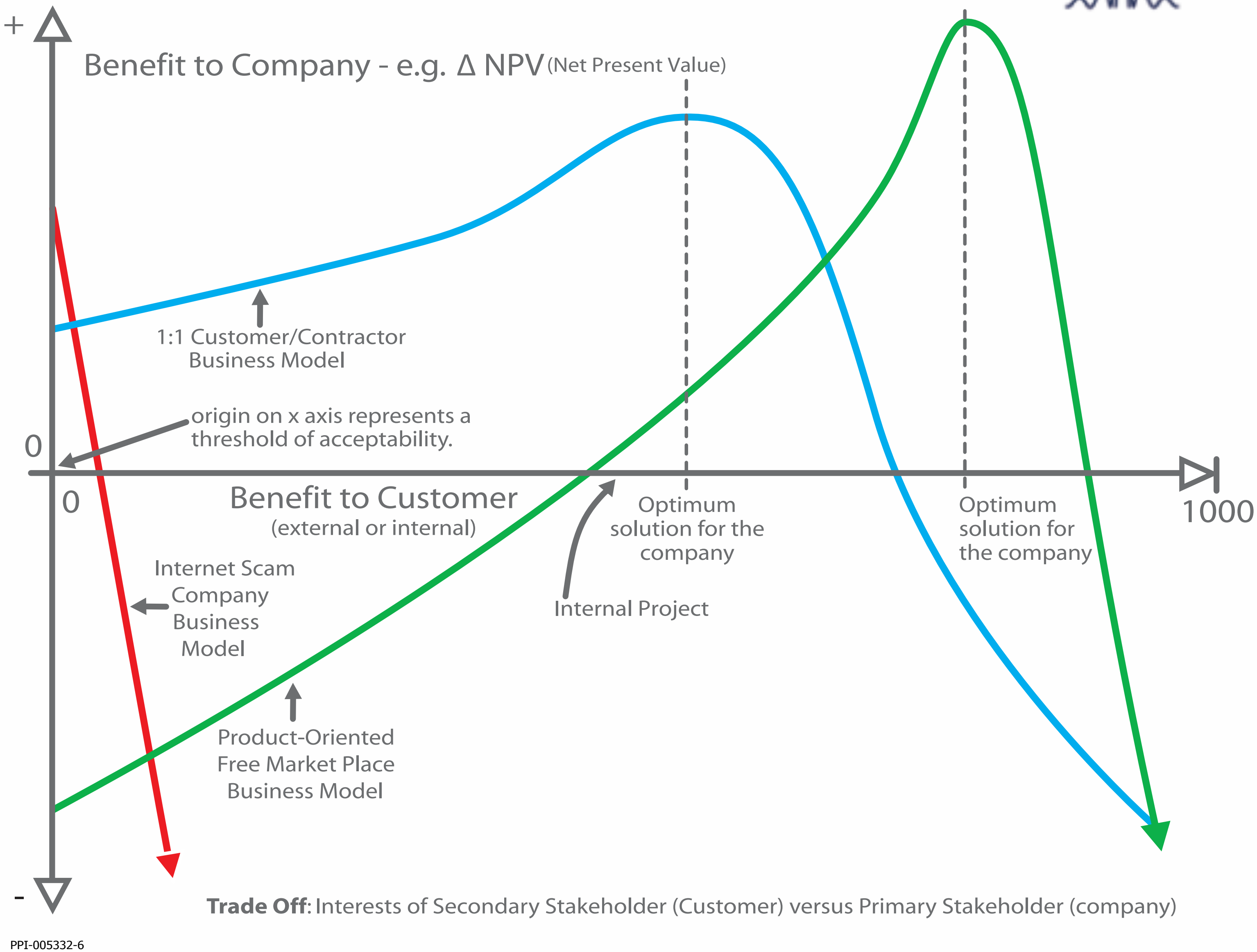

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INDICATORS OF EFFECTIVE SE – PRODUCT-ORIENTED ENTERPRISE:

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- On, under, or close to development budget
- On, ahead of, or close to development schedule
- High Return on Sales
- Market leadership
- Low warranty costs
- Repeat business is the norm
- High staff satisfaction and retention

INDICATORS OF EFFECTIVE SE – CONTRACT-ORIENTED ENTERPRISE:

- On, under, or close to development budget
- On, ahead of, or close to development schedule
- High contract gross margin
- High customer satisfaction
- Low warranty costs
- Repeat business is the norm
- High staff satisfaction and retention

INDICATORS OF EFFECTIVE SE – INTERNAL PROJECTS:

- On, under, or close to development budget
- On, ahead of, or close to development schedule
- High internal customer satisfaction
- No desire to outsource
- High staff satisfaction and retention

INDICATORS OF EFFECTIVE SYSTEMS ENGINEERING MANAGEMENT:

- Effective systems engineering
- Harnessing of creativity
- A learning environment
- Growing intellectual capital within the enterprise
- High staff satisfaction and retention
- Shared vision of the outcome and a related focus on quality, cost, time

INDICATORS OF NO SE OR INEFFECTIVE SE:

- Milestones missed
- Significant dispute with stakeholders over requirements
- Many problems and delays occuring during system integration
- Significant dispute with customers over testing
- Significant problems occuring in released or fielded systems/products
- Engineering effort tends to be back-end loaded during development

WHERE DOES THE MONEY GO?

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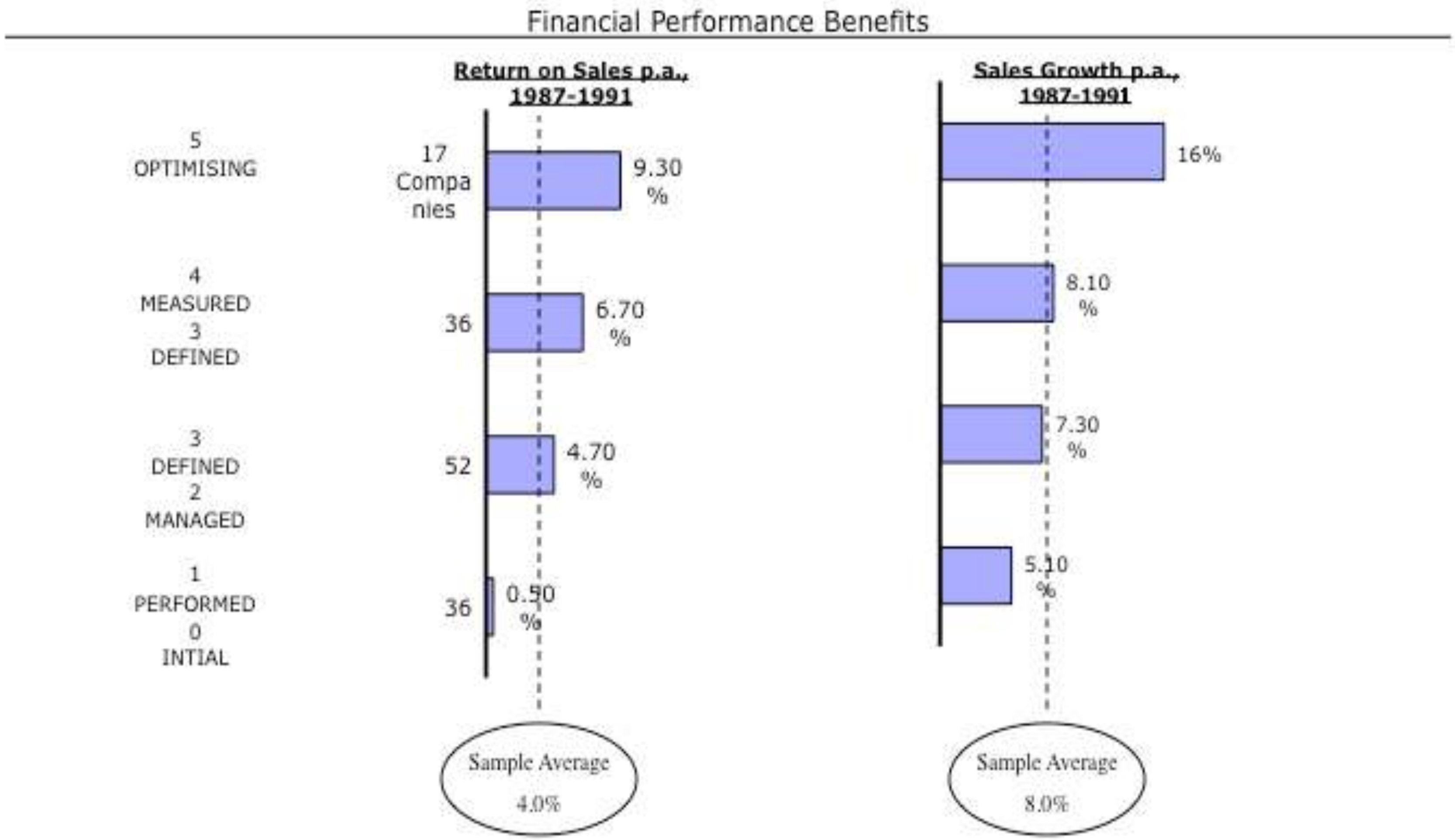
Cost component	Ideal %	Actual %
What proportion of development cost is spent due to genuine system requirements changes?	There is no ideal.	?
What proportion of development cost is spent due to defective system requirements?	0%	?
What proportion of development cost is spent due to system design errors undetected in design reviews?	0%	?
What proportion of development cost is spent due to system design errors undetected in system testing?	0%	?
What proportion of cost in a system integration phase is spent on system integration as opposed to rework?	Close to100%	?

McKINSEY STUDY (1)



SOURCE: Excellence in Quality Management, McKinsey & Company, Inc

McKINSEY STUDY (2)

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Quality Benefits

Equivalent to CMMI Maturity Level	Design Quality Market Share %	Process Quality Scrap%	Process Quality Rework%	Service Quality
5 OPTIMISING	>35	<0.8	<0.5	CUSTOMER SERVICE
4 MEASURED 3 DEFINED	>25	<2.0	<2.0	
3 DEFINED 2 MANAGED	>20	<4.0	<3.0	ERROR CORRECTION
1 PERFORMED 0 INITIAL	<20	>4.0	>3.0	

SOURCE: Excellence in Quality Management, McKinsey & Company, Inc.

OTHER OLD CLAIMS

1. Improved Quality of Designs
   - *Resulted in reduced Change Orders (> 50%)*
2. Product Development Cycle
   - *Reduced as much as 40-60% by concurrent rather than sequential design of products and processes*
3. Manufacturing Costs
   - *Reduced by as much as 30-40% by having integrated product teams integrate product and process designs*
4. Scrap & Rework
   - *Reduced by as much as 75% through product and process design optimization*

Data based on a study of 14 companies that had applied concurrent engineering - Institute for Defense Analysis (IDA), 'The Role of Concurrent Engineering in Weapons System Acquisition', December 1988

NASA AND THE VALUE OF SE

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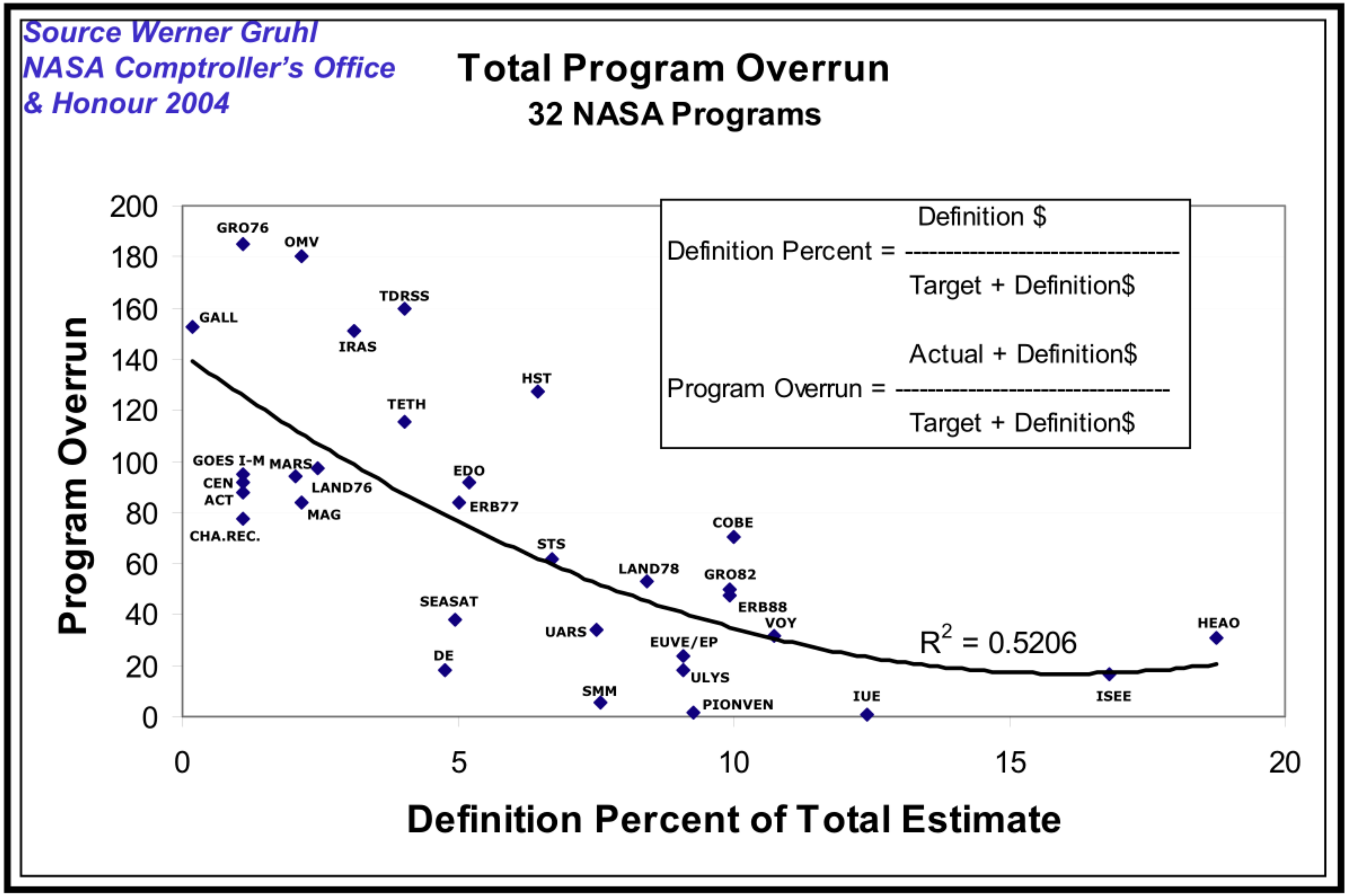

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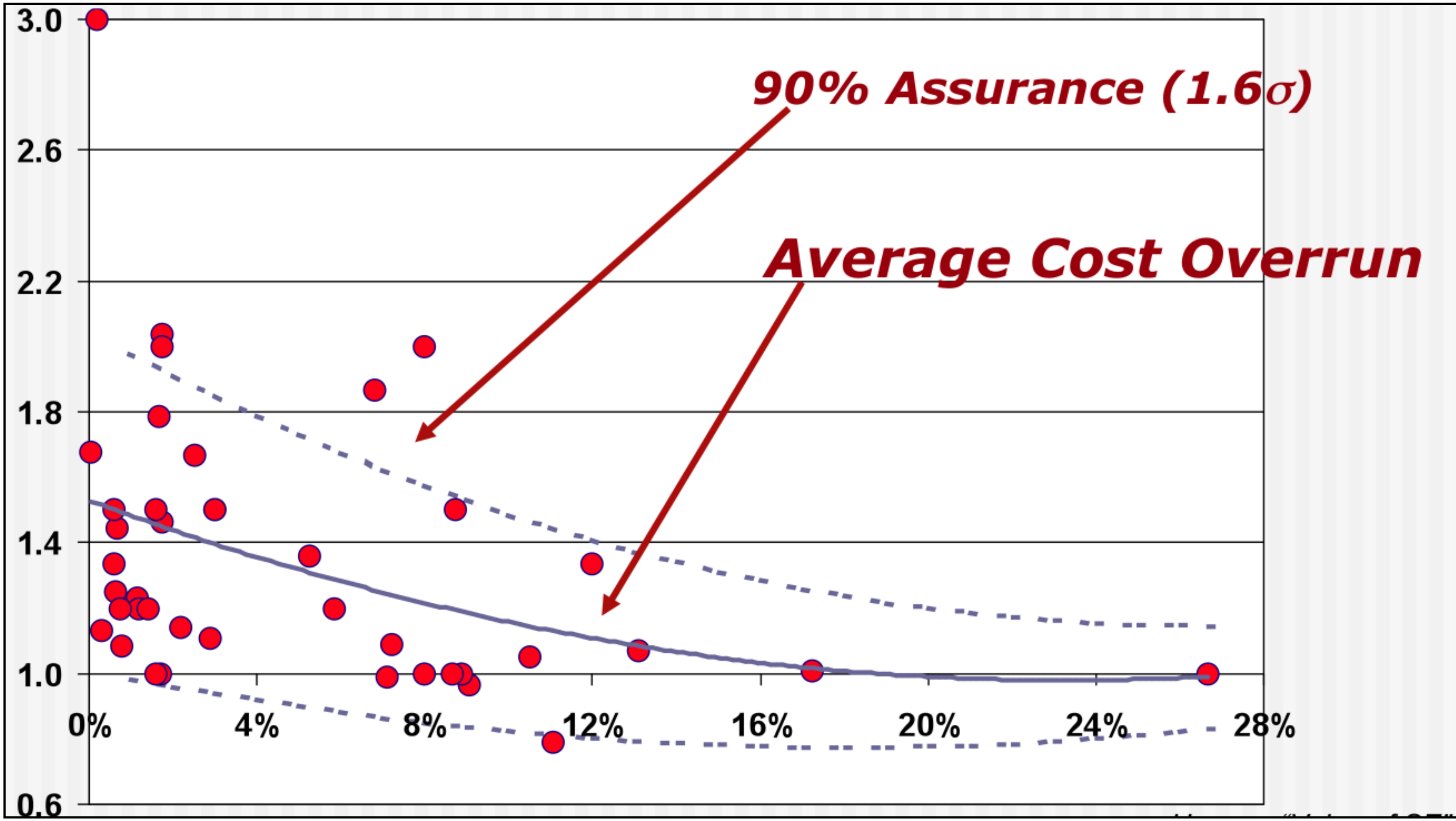
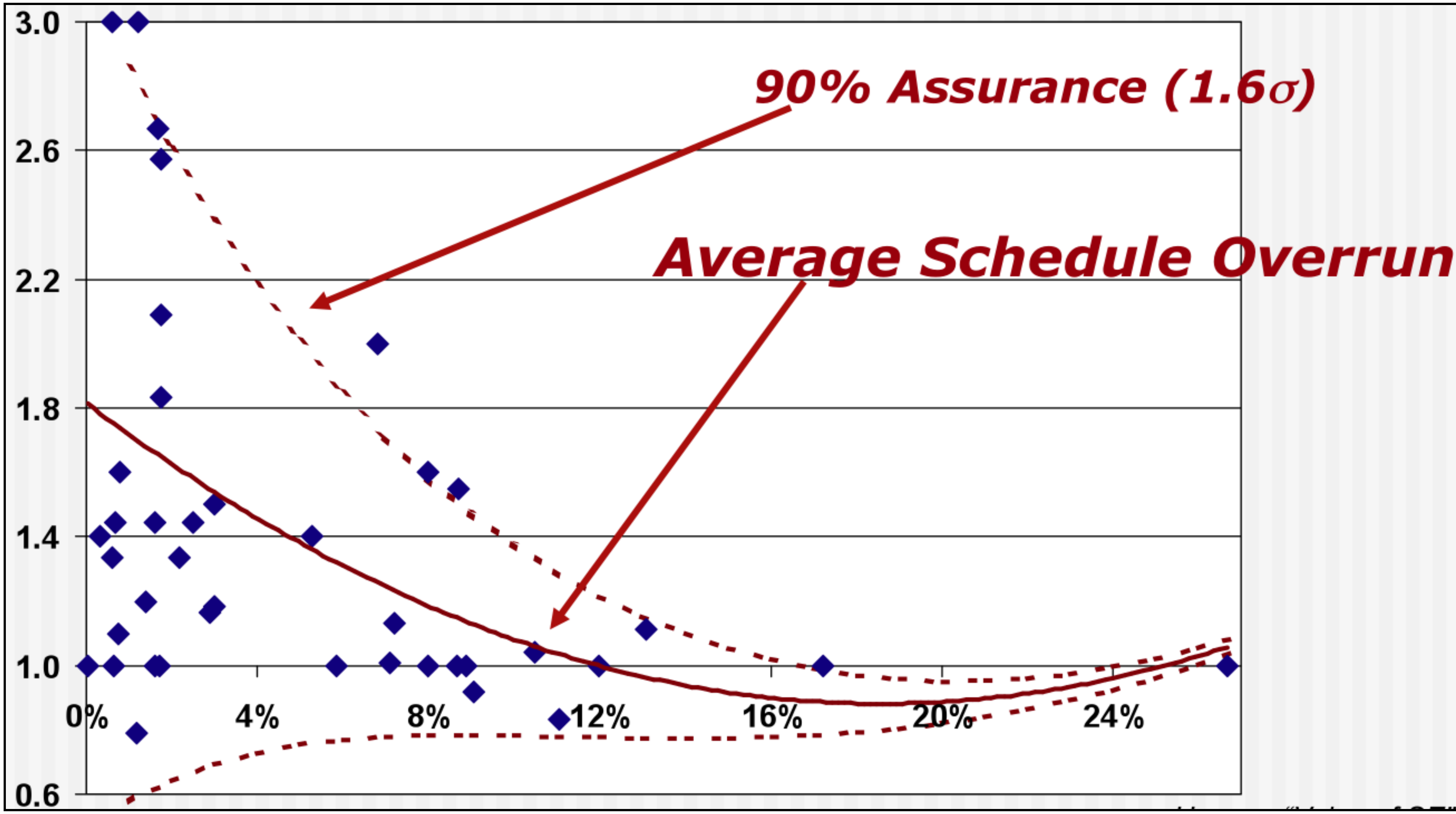
INCOSE STUDY - COST



SE Effort = SE Quality * (SE Cost/Actual Cost)

INCOSE STUDY - SCHEDULE

PROJECT PERFORMANCE INTERNATIONAL



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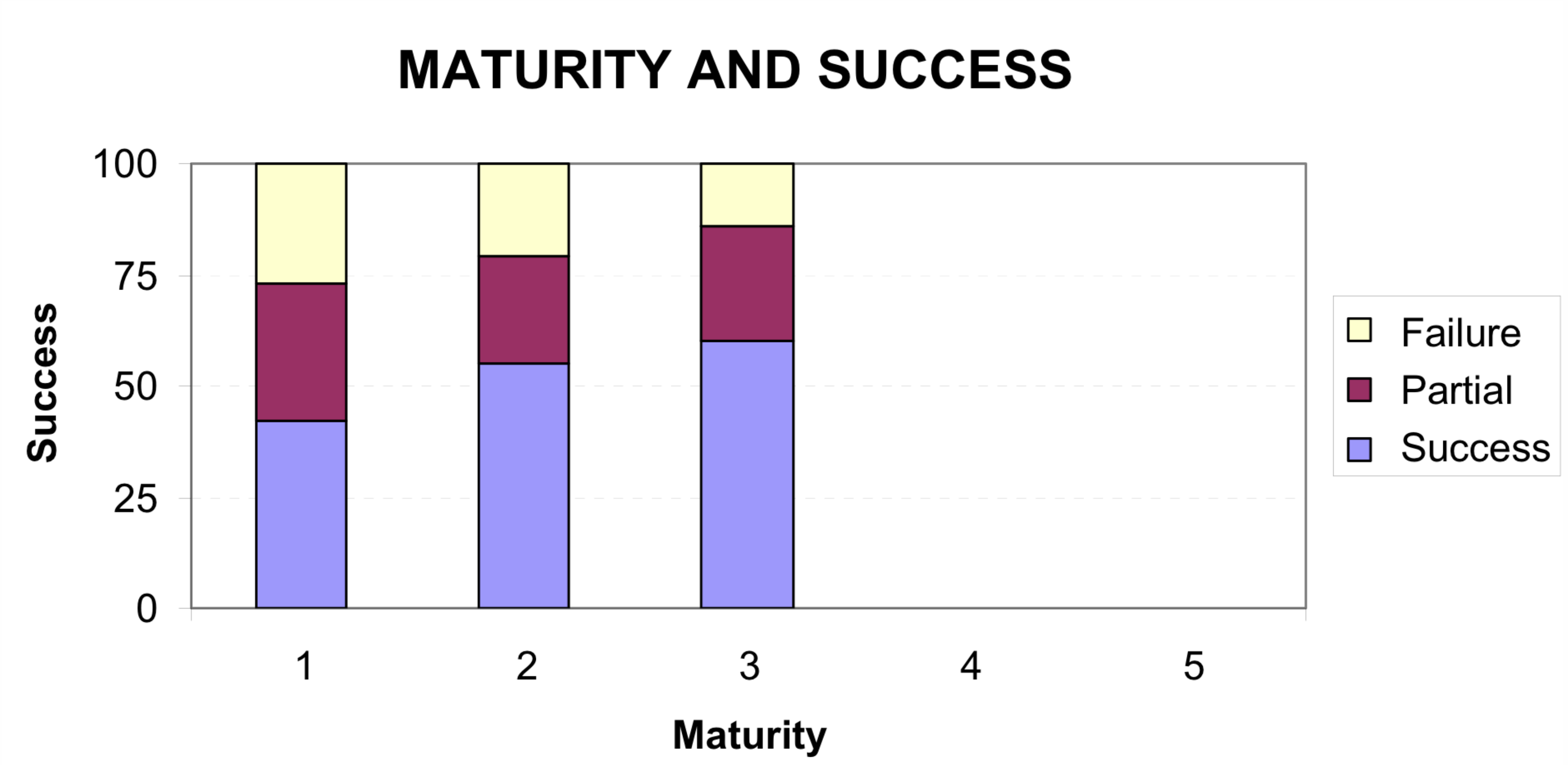
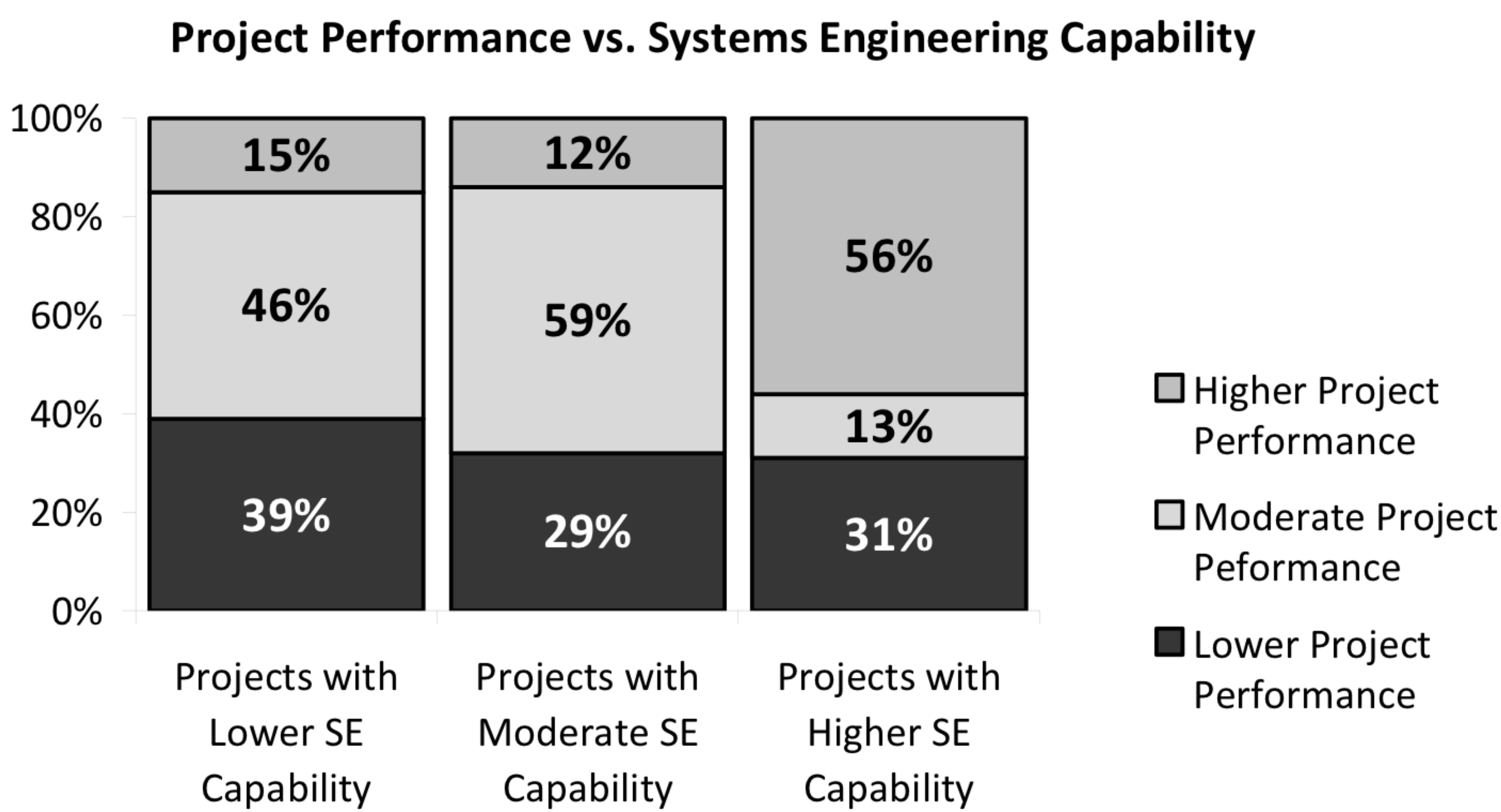
MCPM – MATURITY BY PROJECT CATEGORY MODEL, BRAZIL



Archibald & Prado, "PM Maturity 2006 Research –Maturity and Success in IT", March, 2007

CMU/NDIA 2007 STUDY RESULTS



Source: "A Survey of Systems Engineering Effectiveness", CMU/SEI-2008-SR-034, December 2008

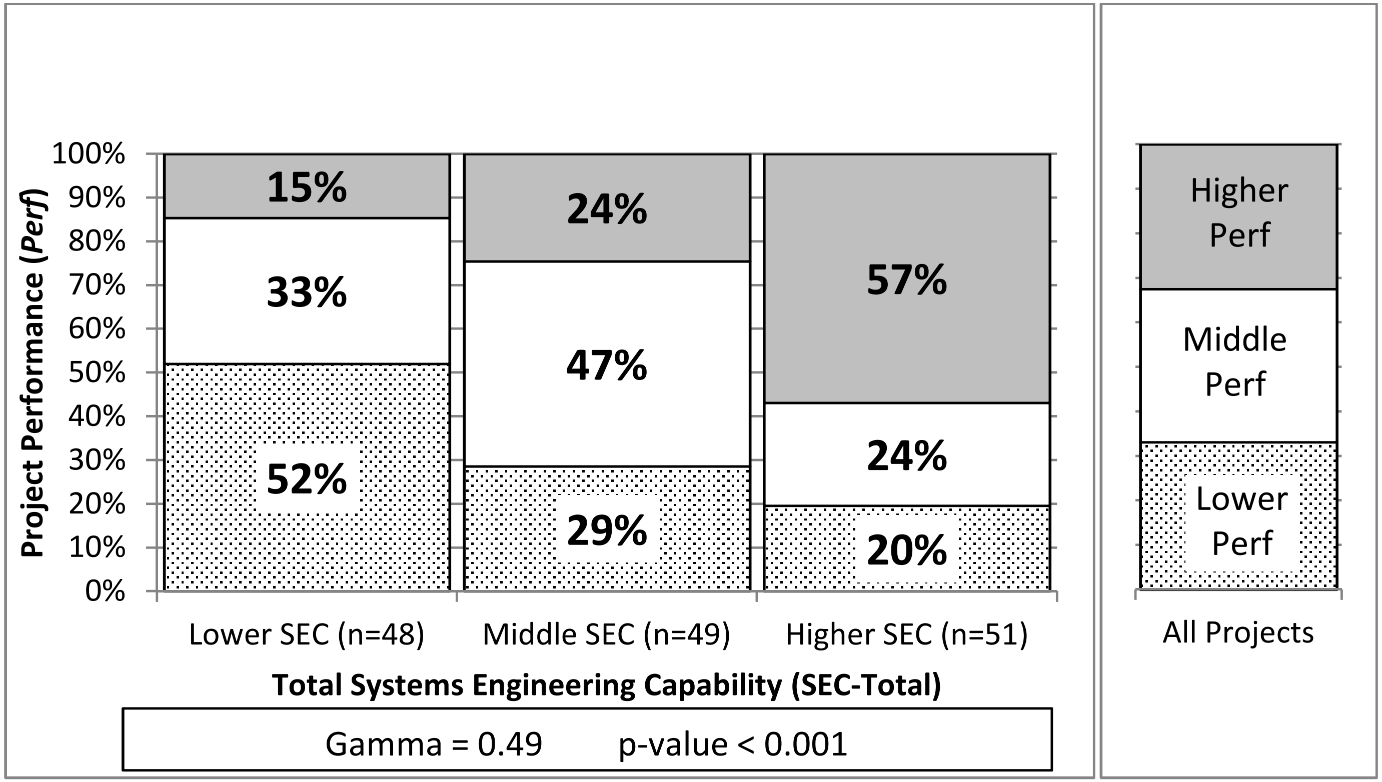
PROJECT ENGINEERING MATURITY MATRIX

Maturity Level	Characteristics	Key Process Areas
5 OPTIMIZING	**Feedback:** Process Continuously Improved	System problem prevention Technology innovation Process management
4 MANAGED	**Quantitative:** Process Measured **Focus on metrics**	Process mapping/variation Process improvement database Quantitative quality plans
3 DEFINED	**Qualitative:** Process defined and institutionalized **Focus on process org.**	Enterprise process definition Education and training Review and testing Interdisciplinary teamwork Life cycle engineering Integrated systems management
2 REPEATABLE	**Intuitive:** Process depends on individuals	System requirements mgmt Project planning and tracking System configuration mgmt Quality management System risk management
1	**Ad hoc/chaotic:** Unpredictable	

Increased Customer and Producer Satisfaction

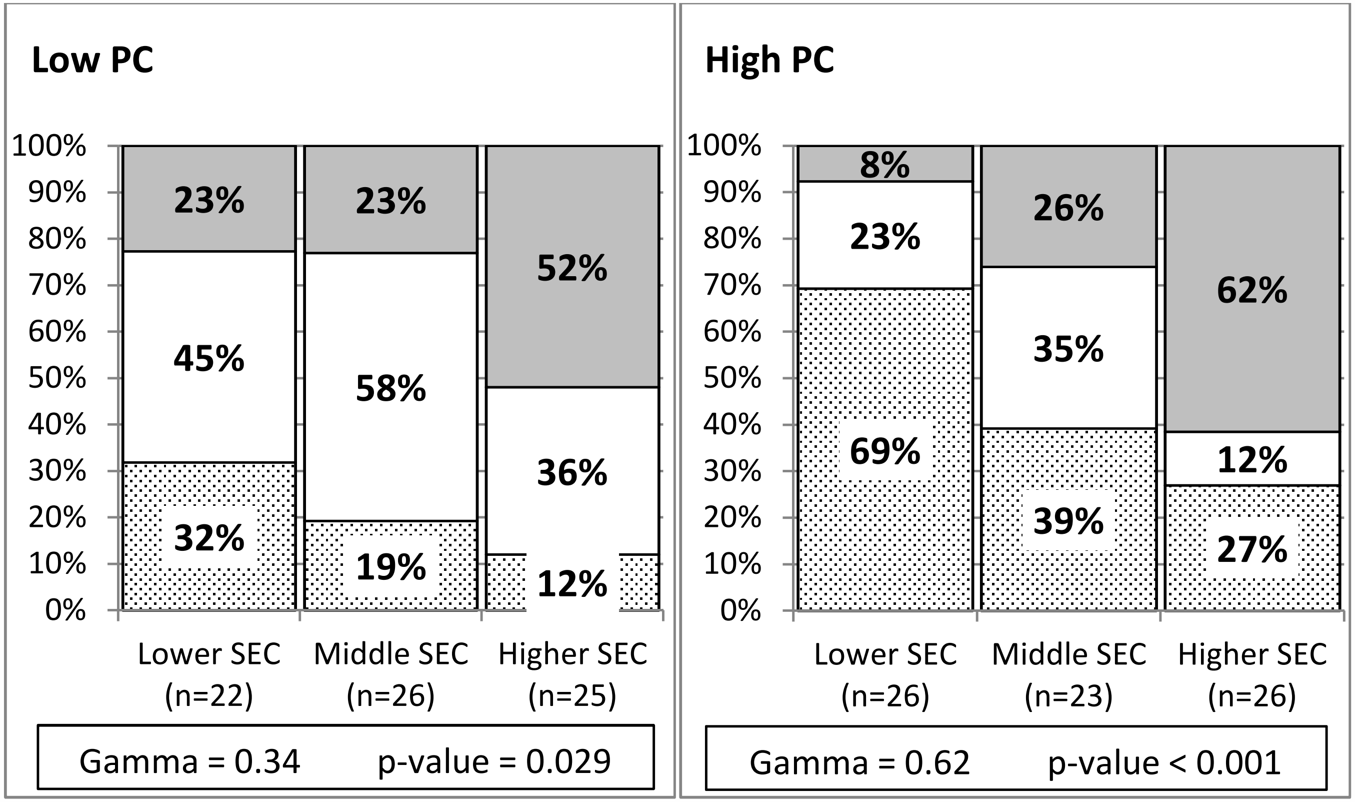
Increased Risk

SEI/AESS/NDIA 2012 STUDY RESULTS (1)



Source: "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012

SEI/AESS/NDIA 2012 STUDY RESULTS (2)



Legend: PC Project Challenge

Source: "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012

SEI/AESS/NDIA 2012 STUDY RESULTS (3)

Driver	Relationship to Performance (Gamma)		
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0 ≤ | *Gamma* | < 0.2	Weak positive
0.2 ≤ | *Gamma* | < 0.3	Moderate
0.3 ≤ | *Gamma* | < 0.4	Strong
0.4 ≤ | *Gamma* |	Very strong

http://resources.sei.cmu.edu/asset_files/specialreport/2012_003_001_34067.pdf

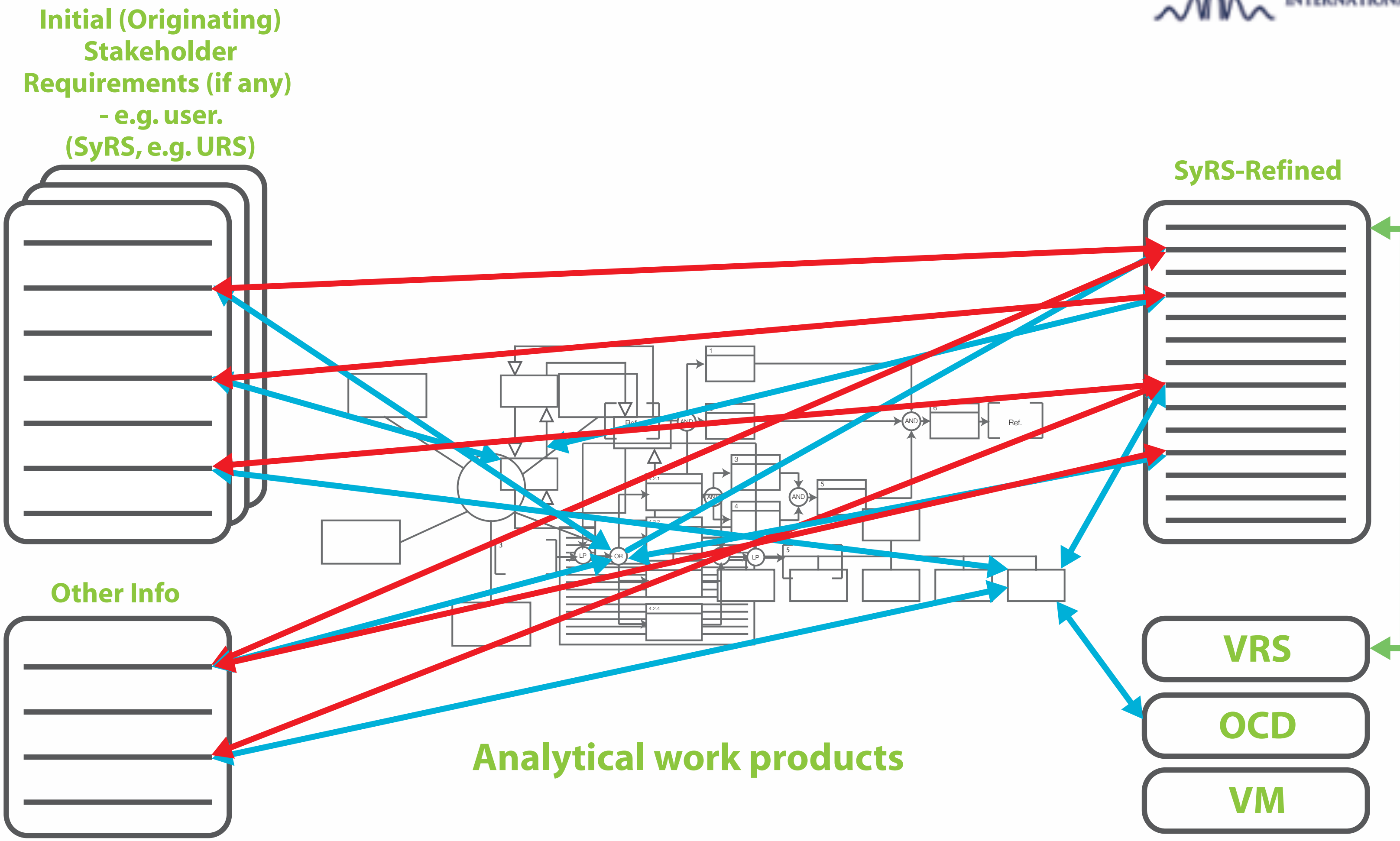
Source: "The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey", CMU/SEI-2012-SR-009, November 2012

SEI/AESS/NDIA 2012 STUDY RESULTS (4)

Driver	Relationship to Performance		
	All projects	Lower challenge projects	Higher challenge projects
PC – Project challenge	-0.26 ⇒ Moderate negative	-0.26 ⇒ Moderate negative	-0.23 ⇒ Moderate negative
EXP – Prior experience	+0.36 ⇒ Strong positive	+0.51 ⇒ Very strong positive	+0.19⇒ Weak positive

Source: “The Business Case for Systems Engineering Study: Results of the Systems Engineering Effectiveness Survey”, CMU/SEI-2012-SR-009, November 2012

A Look at Return on Investment for One Facet of Systems Engineering: Requirements Analysis



OCD:	operational concept description (CONUSE)
URS:	SyRS of user requirements
SyRS:	system requirements specification
VM:	value (or system/software effectiveness) model
VRS:	verification requirements specification

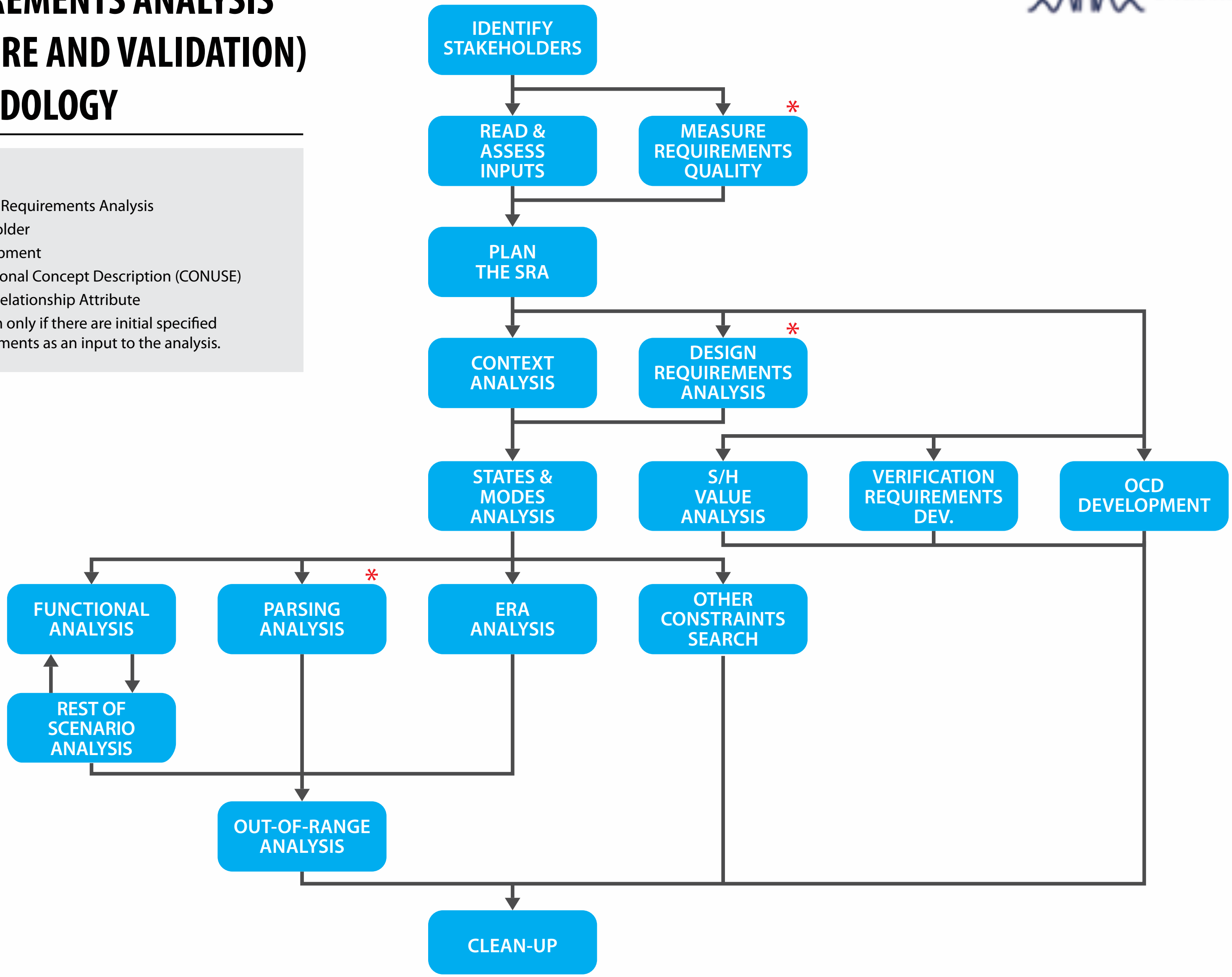
is a restatement of
traces to/from

PPI-005499-4

REQUIREMENTS ANALYSIS (CAPTURE AND VALIDATION) METHODOLOGY

Legend:

SRA System Requirements Analysis
S/H Stakeholder
DEV Development
OCD Operational Concept Description (CONUSE)
ERA Entity Relationship Attribute
* Perform only if there are initial specified requirements as an input to the analysis.



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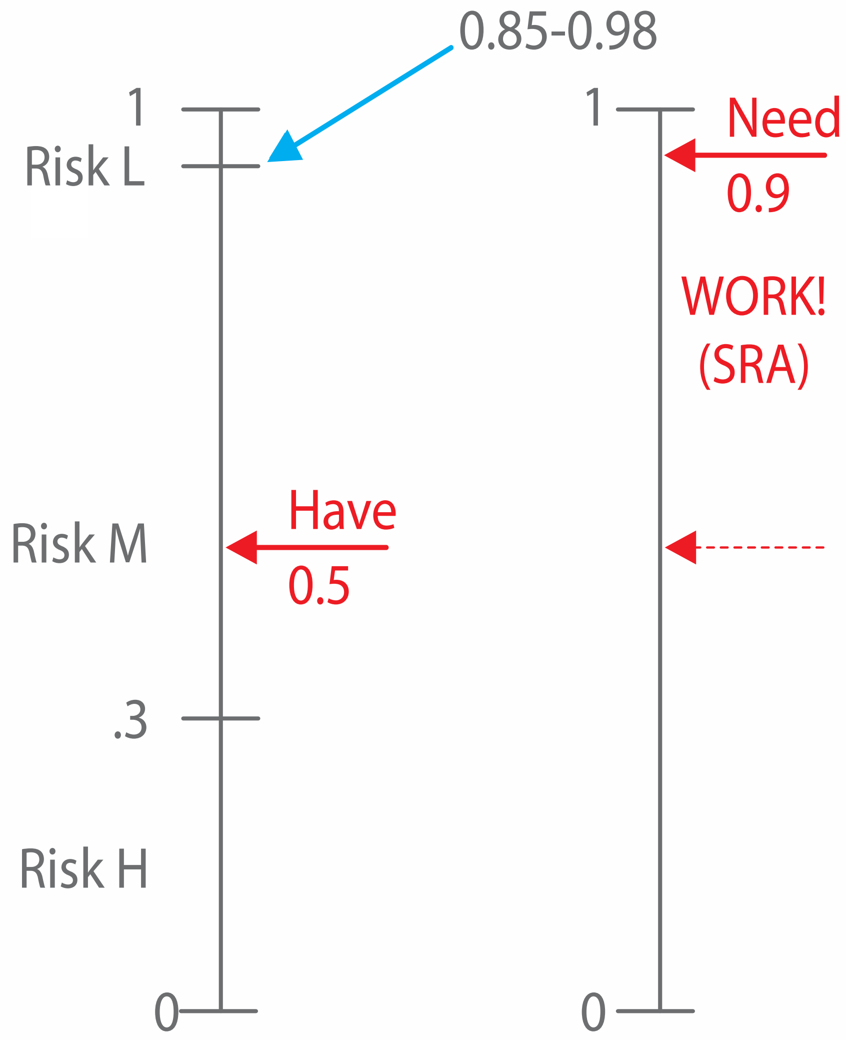
REQUIREMENTS QUALITY AND REQUIREMENTS ANALYSIS EFFORT



WORK = f(

Have

Need

Number of Requirements

Skills

Tech-Environment

Access & Cooperation)

IMPACT OF REQUIREMENTS DEFECTS

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Organization/Project	Overruns Attributed to Requirements Problems
NASA over two decades (Werner Gruhl)	70% of overruns
U.S. Census Bureau project 2009	80% cost overrun locked in solely due to poor requirements
Marine One Helicopter Program	83% cost overrun attributed by Lockheed to requirements problems
Schwaber, 2006; Weinberg, 1997; Nelson et al, 1999	"Requirements errors are the single greatest source of defects and quality problems"
Hofmann and Lehner, 2001	"Deficient requirements are the single biggest cause of software project failure"
Standish Group, The Chaos Report on 8300 IT projects	60.9% of an average 89% cost overrun

REQUIREMENTS ANALYSIS ROI TO CUSTOMER

Parameter	Value
Contract value	$4B
Requirements on the Ship	27,000, only fair in quality
Consequence if uncorrected	At least 20% loss of capability, costing at least $800M; or Rework costs exceeding 20%
Cost of fixing the requirements	$8M (0.2% of contract value)
Return on Investment	Approximately 100:1

REQUIREMENTS ANALYSIS ROI FOR A CONTRACTOR

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Paramater	Value
% Sales spent on marketing	12.5%
% Sales spent on bidding	9-10%
Win ratio for the more successful companies	1 in 2 to 1 in 4
Typical cost/bid, % Total Contract Value	2-3% TCV
Cost of winning business from a new customer vis-à-vis a satisfied existing customer	5:1
Cost of preserving customer satisfaction through requirements analysis	0.2% TCV

TCV: Total Contract Value

CONCLUSIONS:

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1. ***The practice of engineering can be immature***
   - *Sometimes ad hoc and chaotic – that is destructive to success via satisfaction of users and other stakeholders.*

2. ***The evidence is now compelling that the practice of systems engineering contributes to enterprise success in terms of:***
   - *reduced costs*
   - *shorter timeframes*
   - *increased value achieved in using the system.*

CHALLENGES – HOW DID WE GO?

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We will review the list of challenges from earlier, and the contributions made by "a systems approach to the engineering of systems".

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THE QUESTION IS NO LONGER, “SHOULD WE BE PRACTICING SYSTEMS ENGINEERING?” "YES" IS BEYOND DOUBT.

TODAY'S QUESTION IS, “HOW BEST DO WE DO IT?”

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