The Business Case to Requirements Engineering

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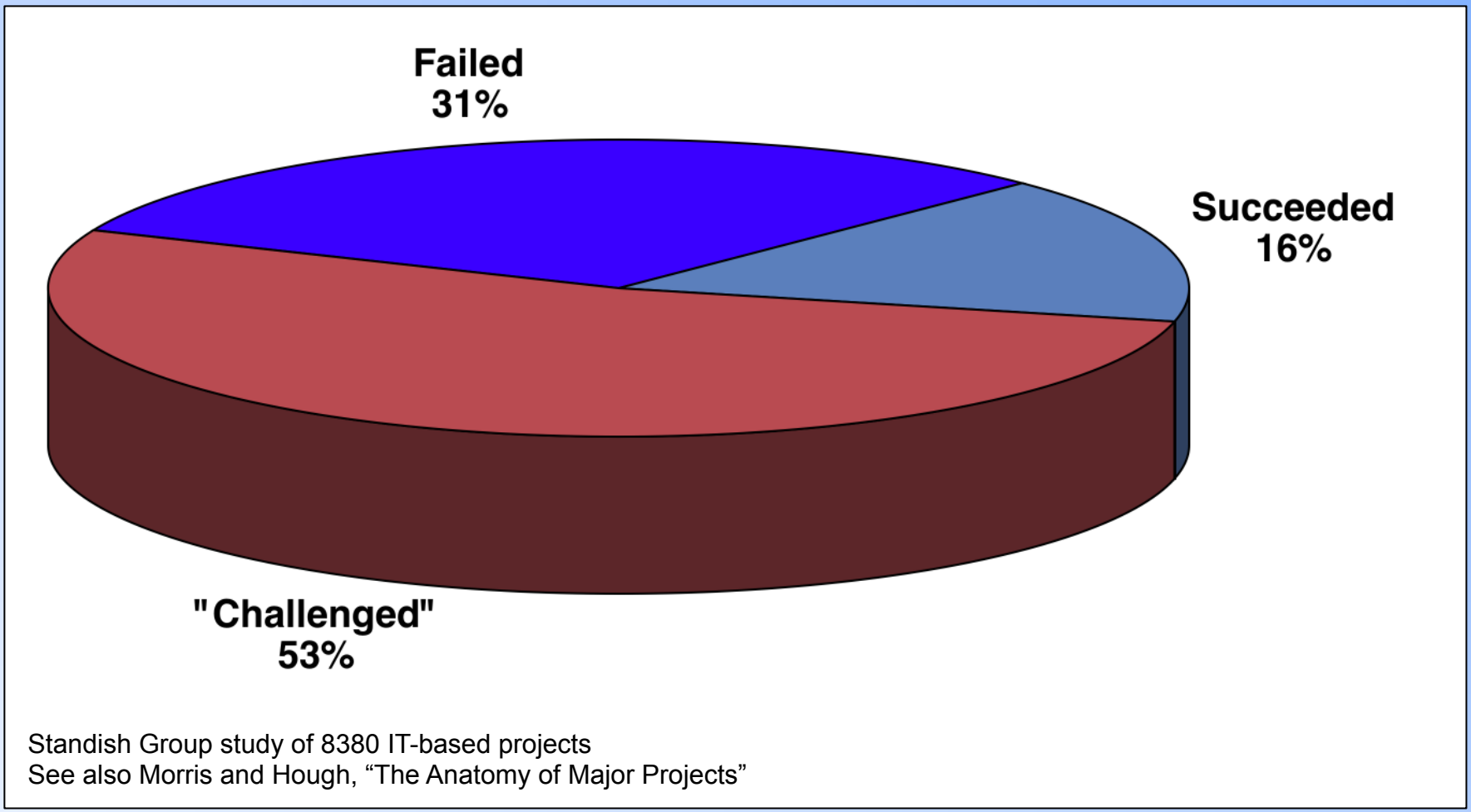
Impact of Requirements Defects

Organization/Project	Overruns Attributed to Requirements Problems
NASA over two decades (Werner Gruhl)	70% of overrun amount
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

The Problem in General



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

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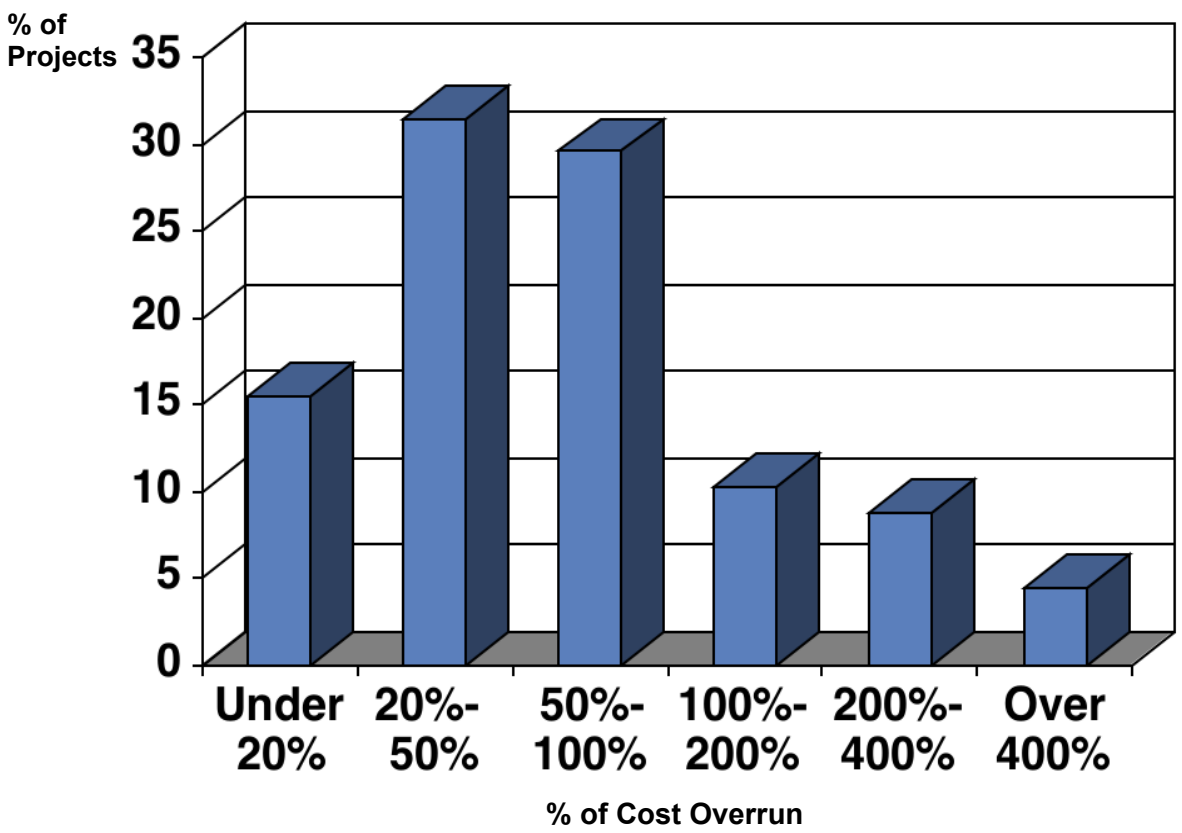
The Problem - Cost



For "challenged" and cancelled projects:

Cost Overrun %

Average cost overrun: 89%

Standish Group study of 8380 IT-based projects

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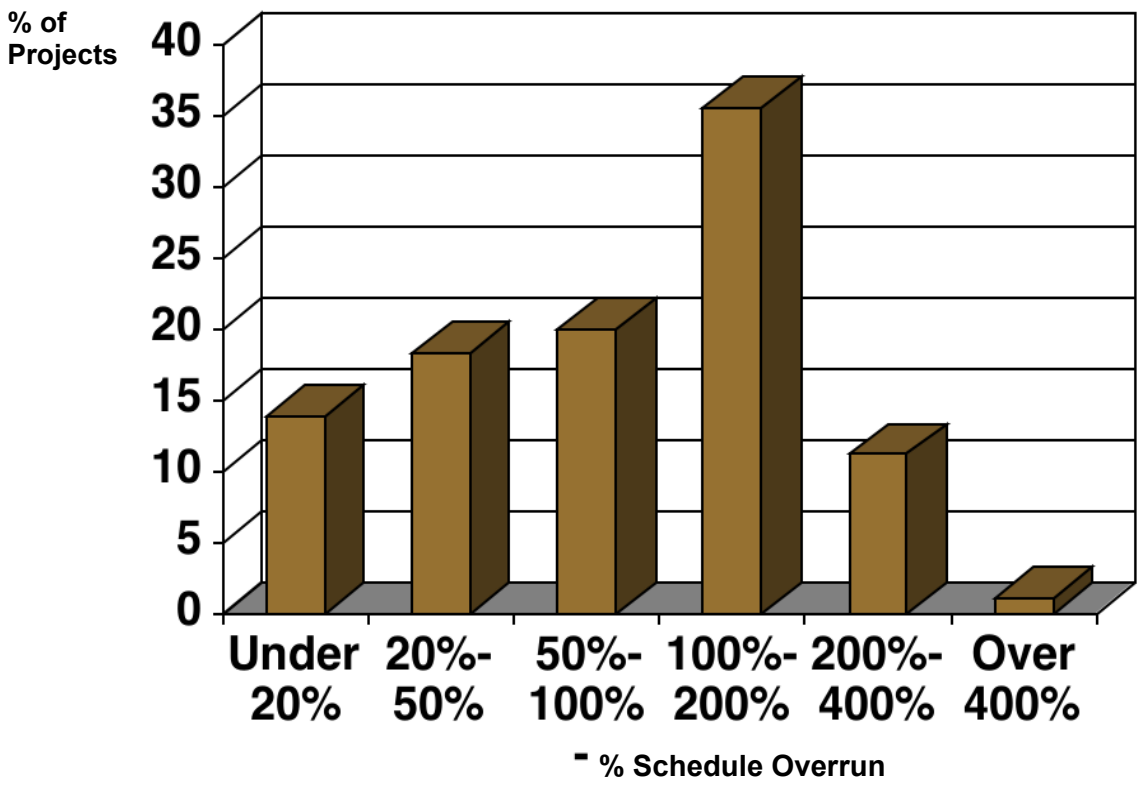
The Problem - Schedule

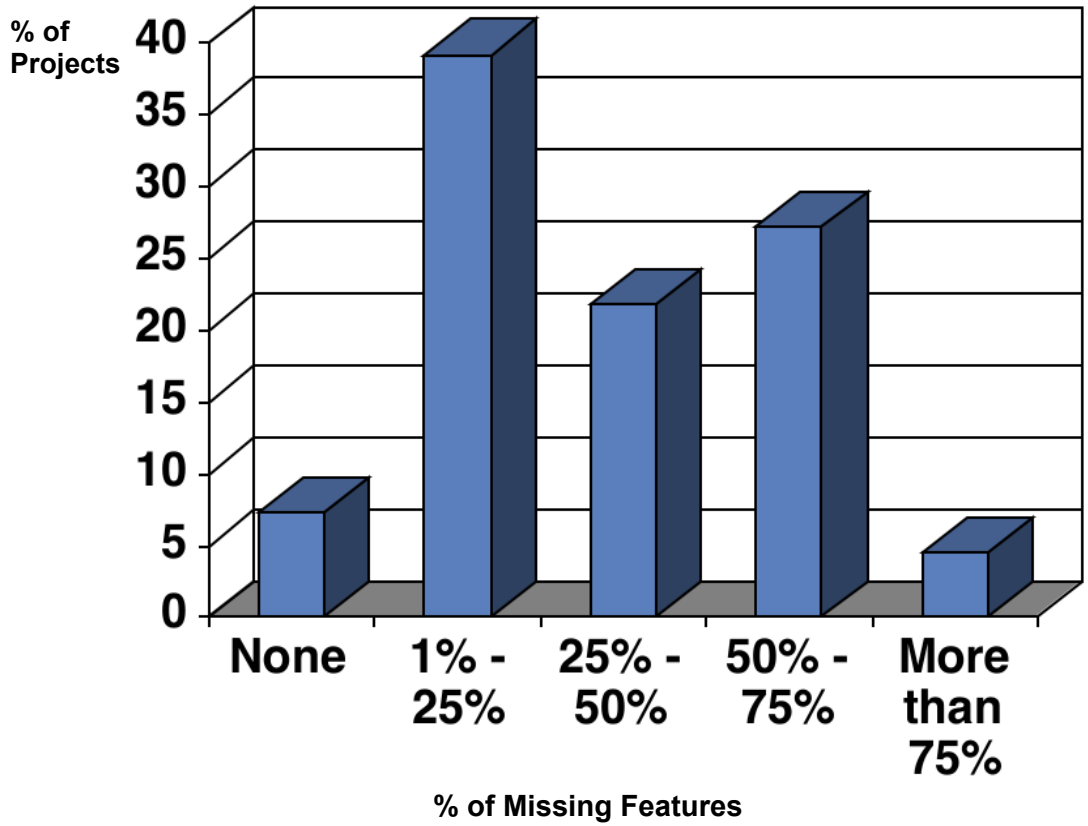


For "challenged" and cancelled projects:

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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Some Indicators of Ineffective RE

- Significant issues with customers, marketing, product management, or system/software developers over requirements
- Significant redevelopment due to requirements issues
- Cannot measure or express requirements quality in quantitative terms
- Requirements issues arise during testing
- Customers prefer competitors' products

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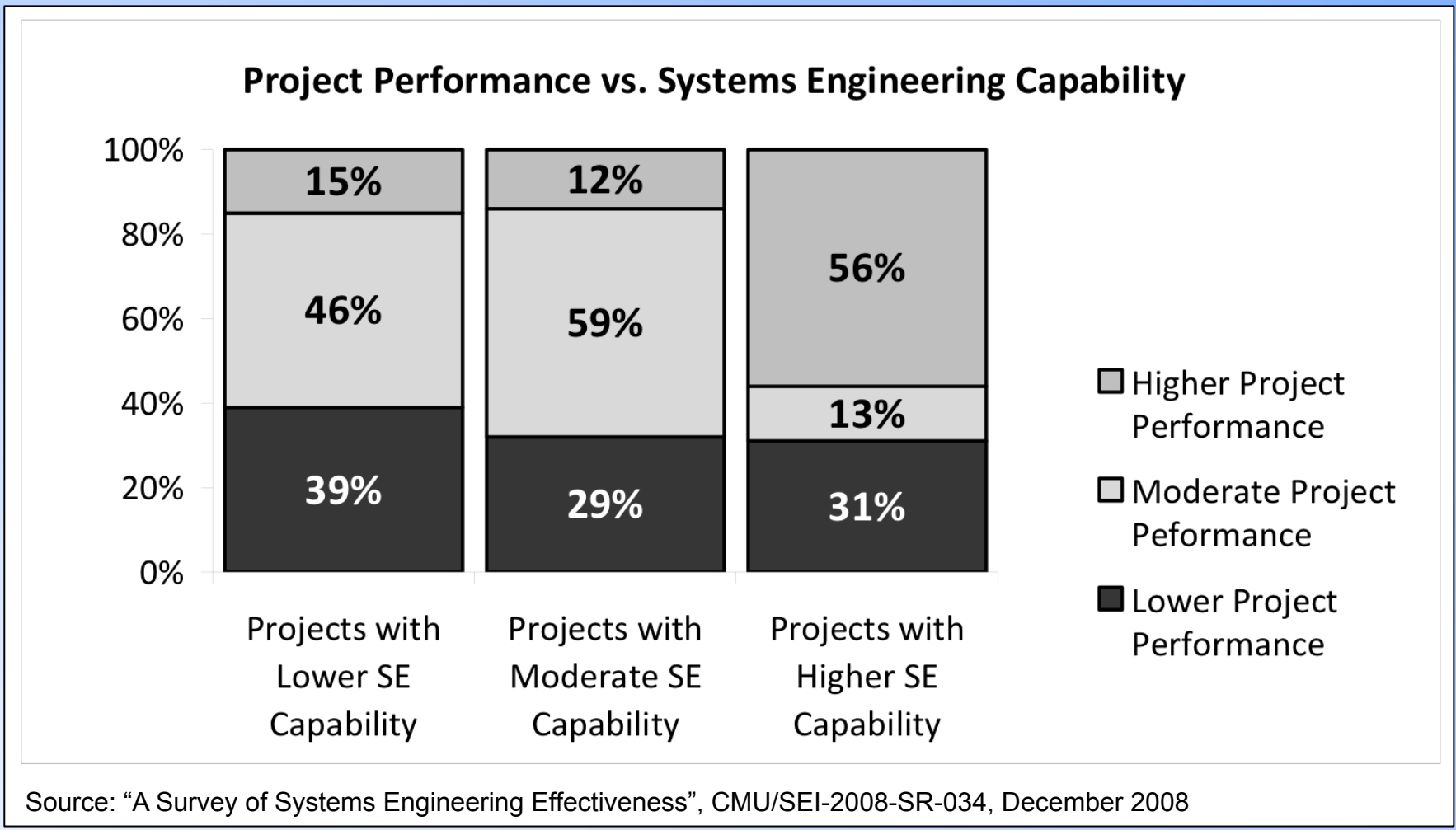
Where does the money go?

Cost component	Ideal %	Actual %
What proportion of development cost is spent due to genuine requirements changes?	There is no ideal.	?
What proportion of development cost is spent due to defective requirements?	0%	?
What proportion of development cost is spent due to system/software design errors undetected in design reviews? Coding errors?	0%	?
What proportion of development cost is spent due to system/software design errors undetected in system testing? Coding errors?	0%	?
What proportion of cost in a system integration phase is spent on system integration as opposed to rework?	100%	?

CMU/NDIA Study Results



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

CMU/NDIA Study Results – 2

Supplier's Systems Engineering Capability	Relationship to Project Performance	Relationship (Gamma)	Section Reference
Project Planning	Weak positive relationship	+0.13	5.1.3.2
Project Monitoring and Control	Weak negative relationship	-0.13	5.1.3.3
Risk Management	Moderately strong positive relationship	+0.28	5.1.3.4
Requirements Development and Management	**Moderately strong positive relationship**	**+0.33**	**5.1.3.5**
Trade Studies	Moderately strong positive relationship	+0.37	5.1.3.6
Product Architecture	Moderately strong to strong positive relationship	+0.40	5.13.7
Technical Solution	Moderately strong positive relationship	+0.36	5.1.3.8
Product Integration	Weak positive relationship	+0.21	5.1.3.9
Verification	Moderately strong positive relationship	+0.25	5.1.3.10
Validation	Moderately strong positive relationship	+0.28	5.1.3.11
Configuration Management	Weak positive relationship	+0.13	5.1.3.12
IPT-Related Capability	Moderately strong positive relationship	+0.34	5.1.3.1

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

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CMU/NDIA Study Results - 3

Supplier Systems Engineering Capability	Relationship to Project Performance	Relationship (Gamma)	Section Reference
Total Systems Engineering Capability	Moderately strong positive relationship	+0.32	5.1.3.13
Combined Requirements and Technical Solution Capability	Strong positive relationship	+0.49	5.2.3.14
Requirements and Technical Solution Combined with Project Challenge	Very strong positive	+0.63	5.3.1.3

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

SEI/AESS/NDIA 2012 Study Results

Driver	All Projects	Lower Challenge Projects	Higher Challenge Projects
Total Deployed SE	+0.49 Very strong positive	+0.34 Strong positive	+0.62 Very strong positive
Project Planning	+0.46 Strong positive	+0.16 Weak positive	+0.65 Very strong positive
Requirements Development and Management	**+0.44 Very strong positive**	**+0.36 Strong positive**	**+0.50 Very strong positive**
Verification	+0.43 Very strong positive	+0.27 Moderate positive	+0.60 Very strong positive
Product Architecture	+0.41 Very strong positive	+0.31 Moderate positive	+0.49 Very strong positive
Configuration Management	+0.38 Strong positive	+0.22 Moderate positive	+0.53 Very strong positive
Trade Studies	+0.38 Strong positive	+0.29 Moderate positive	+0.43 Very strong positive
Project Monitoring and Control	+0.38 Strong positive	+0.27 Moderate positive	+0.53 Very strong positive
Validation	+0.33 Strong positive	+0.23 Moderate positive	+0.48 Very strong positive
Product Integration	+0.33 Strong positive	+0.23 Moderate positive	+0.42 Very strong positive
Risk Management	+0.21 Strong positive	+0.18 Weak positive	+0.24 Moderate positive
Integrated Product Team Utilization	+0.18 Strong positive	-0.12 Weak negative	+0.40 Very strong positive

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

A Look at Return on Investment for Requirements Analysis

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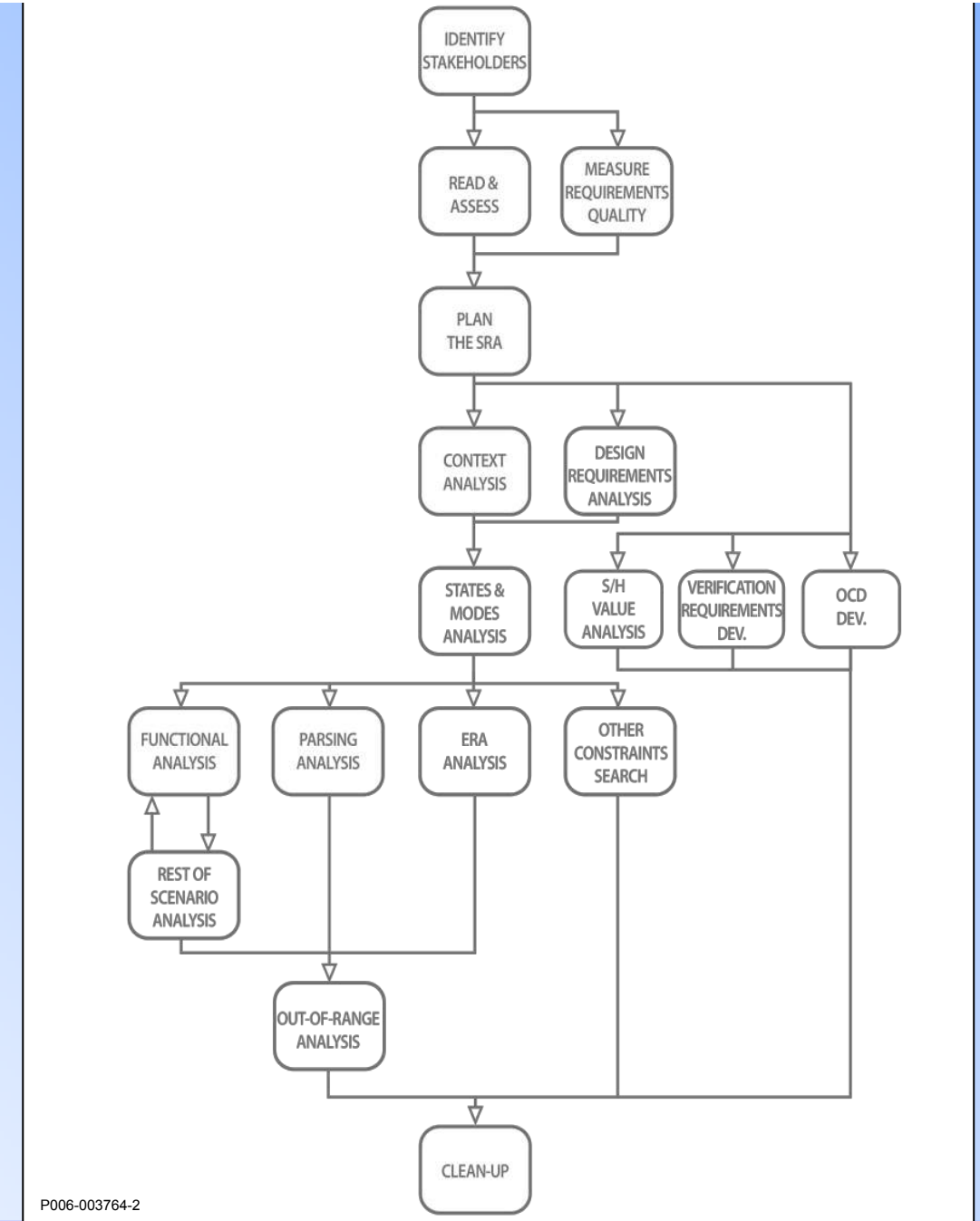
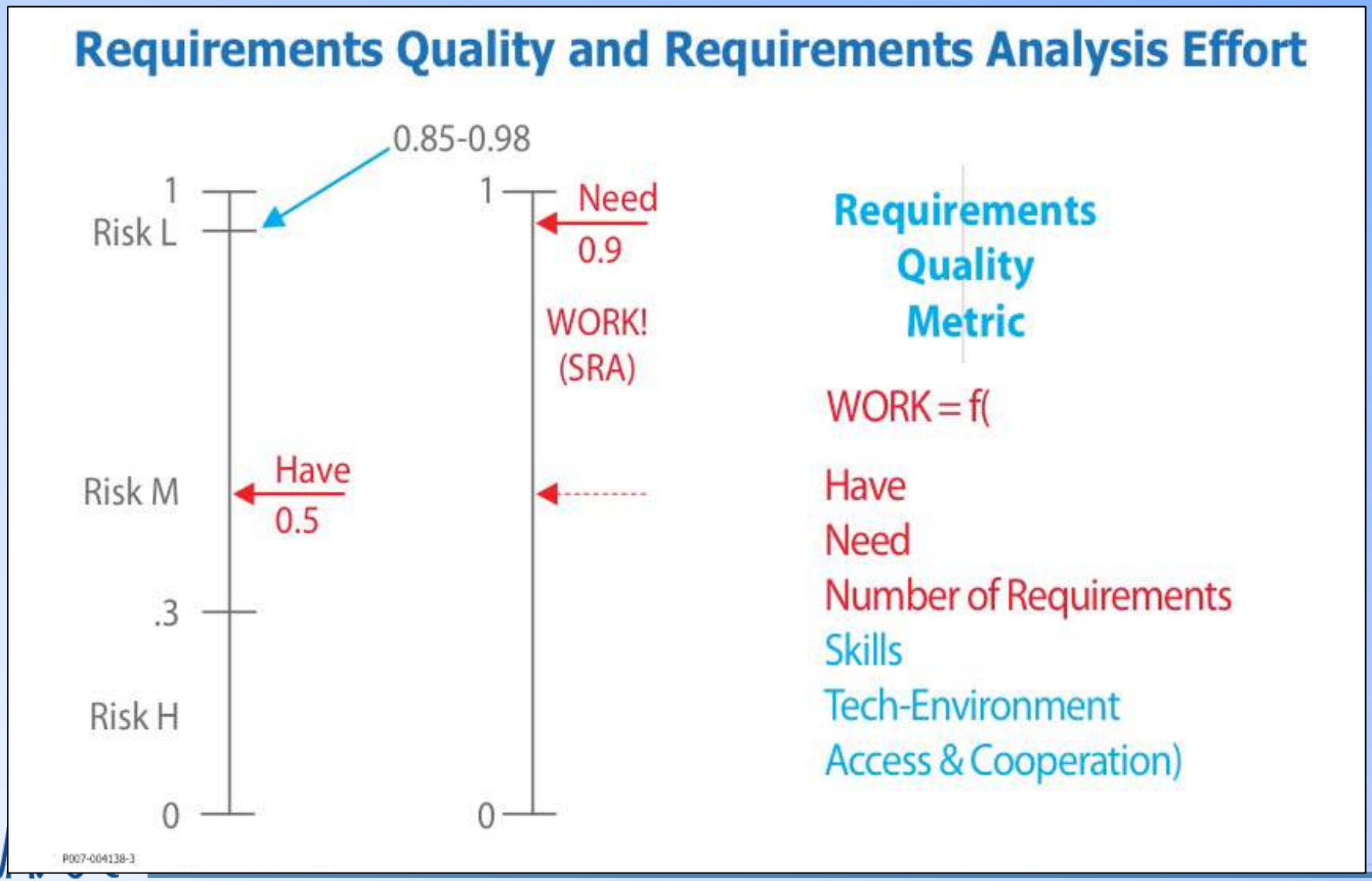


Requirements Quality and Requirements Analysis Effort



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

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Requirements Analysis ROI for Contractor

Parameter	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

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Requirements Engineering: Some Basic Concepts and Principles

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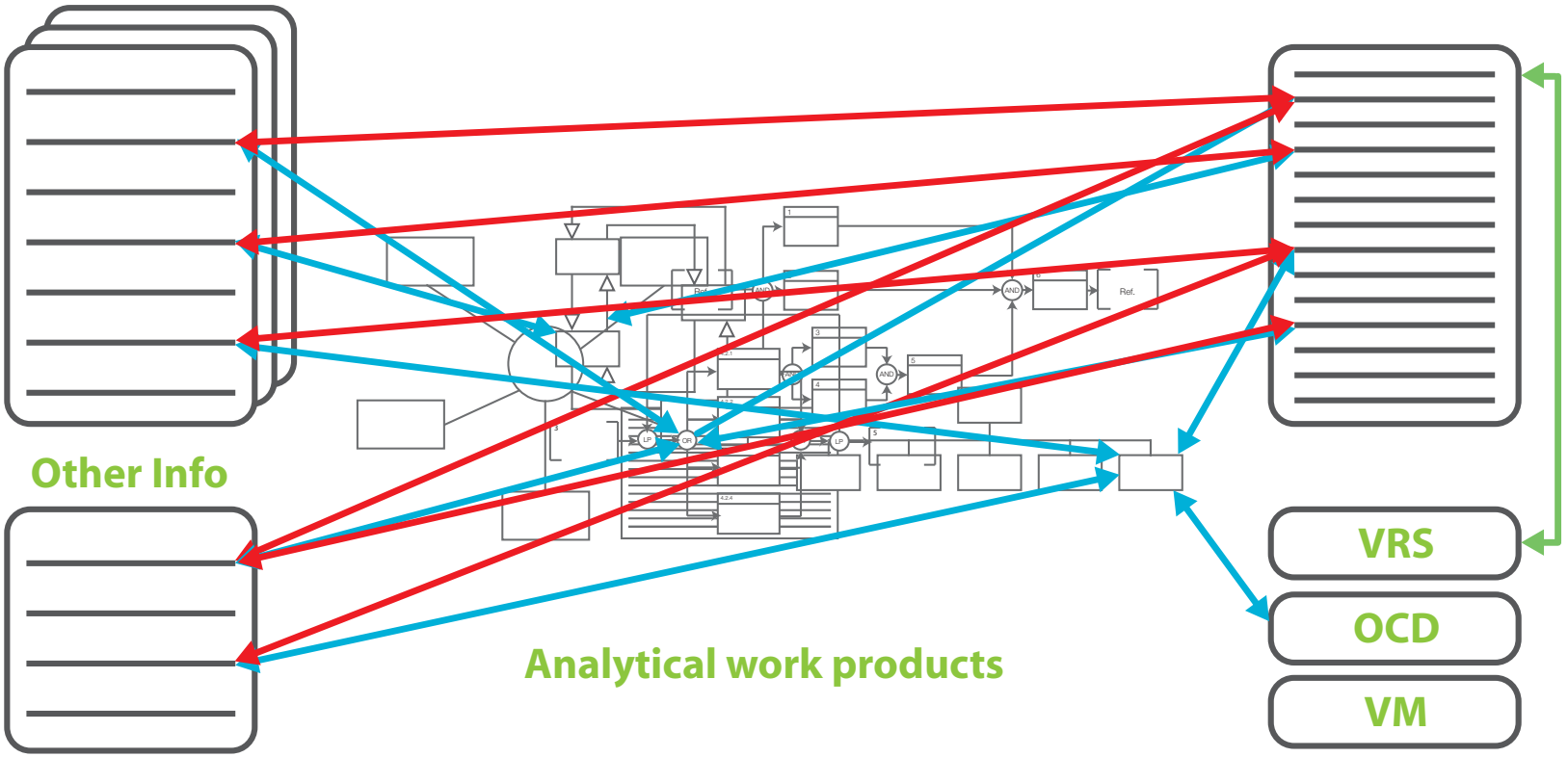
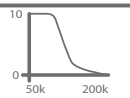
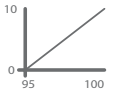
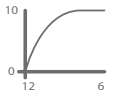
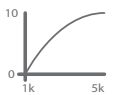
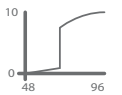
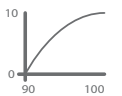


SRS: system or software requirements specification
VRS: verification requirements specification
OCD: operational concept description (CONUSE)
VM: value (or system/software effectiveness) model

PPI-005227-5

Value (System Effectiveness) Model

MOEs	Worst	Best	Pri	Pts	Weight %	UF
Cost, $k's per unit	200	50	1	100	25	
Reliability, %	95	100	1	100	25	
Interoperability	0	17	7	14	4	
Size(A/B/C)	C	A	8	3	1	
Schedule (Months)	12	6	3	40	10	
Visible Optical Range	1000	5000	5	30	7	
Duration of Transmission, hr	48	96	6	27	6	
Readiness, %	90	100	4	39	10	
OS & D Cost, $k pu/10 years	300	10	2	50	12	
				403	100	

Pri: Priority
Pts: Points
UF: Utility Function

P007-005289-4

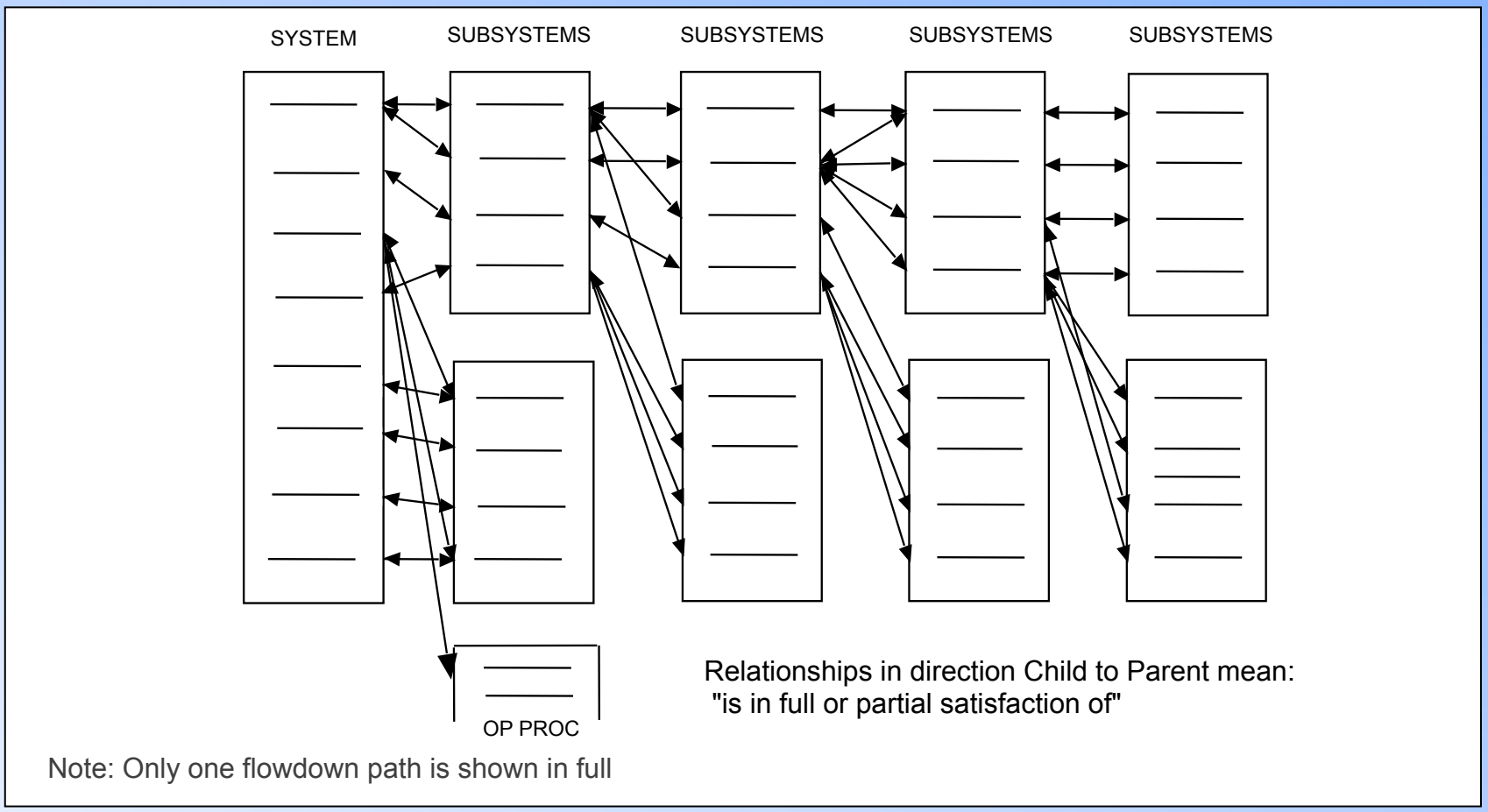
Example Requirement Traceability Tables

Customer Document		SyRS Para No
Para No	Title	
4.	REQUIREMENTS	Heading Only
4.1	General	4.2.1.1.2
4.2	Reserved	Not applicable
4.3	Radar Waveform Generator	Heading Only
4.3.1	Frequency Band	4.2.1.1.3
4.3.2	Waveform	4.2.1.1.4
		4.2.1.1.5
4.3.3	Start Frequency	4.2.1.1.6
4.3.4	Bandwidth	4.2.1.2.3
4.3.5	Bandwidth Reslolution	4.2.1.2.4

Customer Document		SyRS Para No	REQID No
Para No	Title		
4.	REQUIREMENTS	Heading Only	Nil
4.1	General	4.2.1.1.2	027141
4.2	Reserved	Not applicable	Nil
4.3	Radar Waveform Generator	Heading Only	Nil
4.3.1	Frequency Band	4.2.1.1.3	027143
			027144
4.3.2	Waveform	4.2.1.1.4	027145
		4.2.1.1.5	027073
4.3.3	Start Frequency	4.2.1.1.6	027146
			031001

Input **Output of RA**

Requirements Traceability in Design



Note: Only one flowdown path is shown in full

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Example Requirements Traceability Table in Design

PARENT REQID	CHILD REQID	ALLOCATED TO
013467	024579	HWCI 1
	024580	HWCI 1
	024581	HWCI 1
013468	027582	CSCI 3
	028003	CSCI 4
	025137	HWCI 2
013469	027583	CSCI 3
013470	NO CHILD	

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Benefits of Requirements Traceability

- Facilitates detection of requirements and design errors
- Prevents cost and schedule impact of spurious "requirements”
- Provides an effective mechanism for managing customer-introduced change
- Provides evidence that a requirement has been actioned
- Is an enabler for effective conduct of design verification
- Assists in requirements validation

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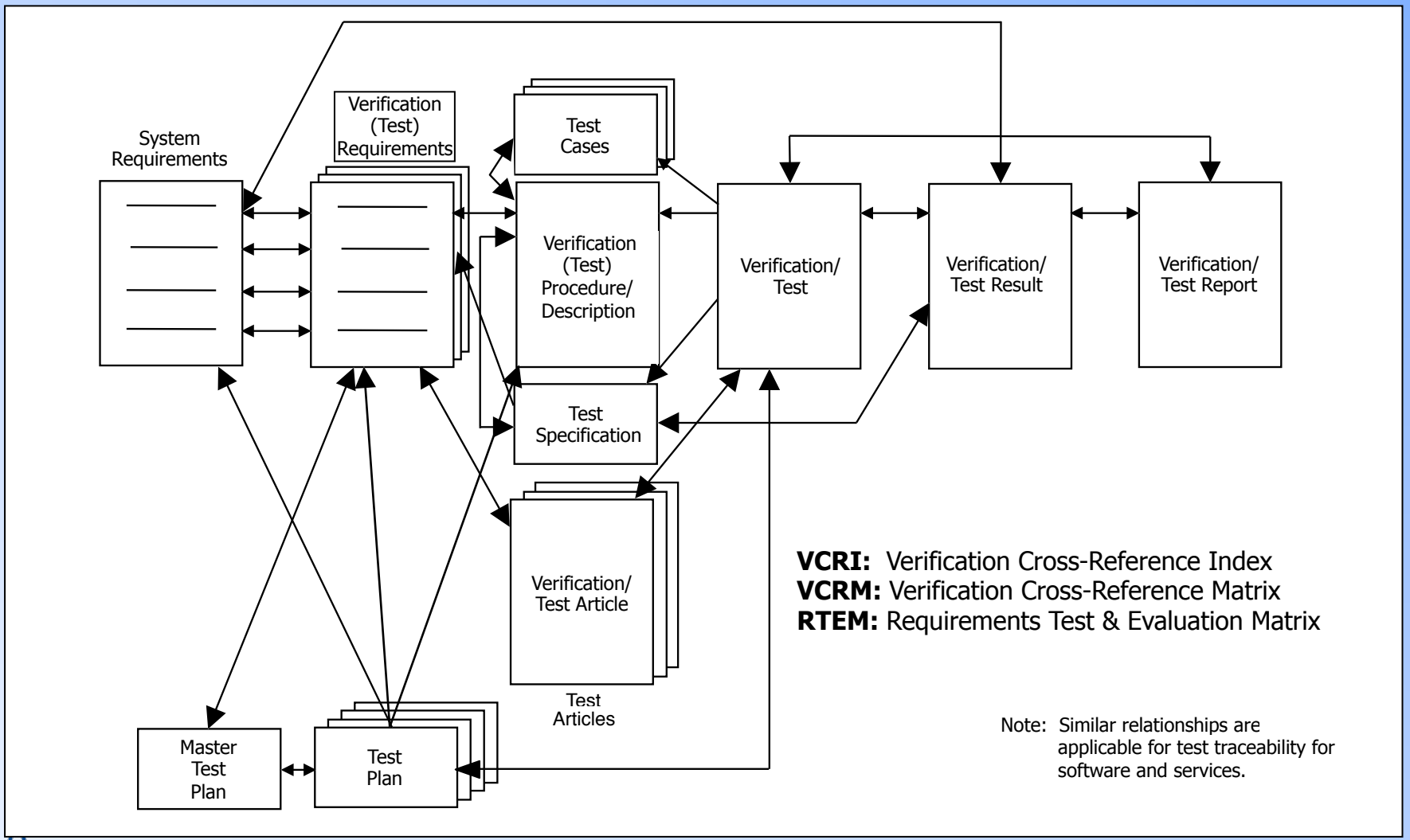
Verification Traceability



Use of Requirements Issues Records (RIR's)

- **Provides:**
  - a structured method of tracking unresolved requirements issues
  - traceability of variations and clarifications to requirements
  - authorization by signature
  - a vehicle for customer/contractor dialog
  - a means of "pinning the customer down", when necessary to do so

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REQUIREMENTS ISSUE RECORD (RIR)

This form is used to record needs for clarification or raising of new requirements on a configuration item viewed as a "black box". Requirements, once resolved, may subsequently be entered into the Requirements Database, where applicable.

Responsibility for Resolution: ..... Target Date: ..... Originator: ..... Date: .....

CI: ..... Req Ref: ..... RC No: .....

1. Clarification/Information Required:

Distribution (by Requirements Manager): originator, designated resolver, Project Manager, other (add)

2. Clarification/Information Obtained:

Distribution (by Requirements Manager): originator, designated resolver, Project Manager, other (add)

3. Source of Clarification/Information (Documentary Where Possible):

Approved by (signature): TA Project Manager	Client Concurrence to Clarification/ Information (signature):	Closed by (signature): (TA Requirements Manager)
Date:	Date:	Date:

Distribution (by Requirements Manager): originator, designated resolver, Project Manager, other (add)

Action on Requirements Baseline (to be completed and initialled by Requirements Manager)	Not Required	Required	Performed
	.....	.....	.....

PPI-005608-1

Example Completed Requirements Issues Record (RIR)

This form is used to record needs for clarification or raising of new requirements on a configuration item viewed as a "black box". Requirements, once resolved, may subsequently be entered into the Requirements Database, where applicable.

Responsibility for Resolution: ASB	Target Date: 31/1/88	Originator: RJH	Date: 14/1/88
CI: System	Req Ref: REQID C001249		RC No: 194

1. Clarification/Information Required:

This requirement requires extensive clarification to produce a definitive testable requirement.

a. What does "externally noise limited" mean?

b. What has to be externally noise limited?

c. What assumptions shall be made about the distribution of external noise?

d. What about the treatment of combiner gain in considering and measuring system internal noise?

e. Is transmitter noise from the transmitter site to be considered in either external noise or internal noise?

f. What about locally generated receiver site noise?

Distribution (by Requirements Manager): originator, designated resolver, Project Manager, other (add)

2. Clarification/Information Obtained:

a. What does "externally noise limited" mean?

The criterion used is "internal noise equal to or less than external noise" – i.e, 3dB system noise figure degradation. There are precedents within defence for using 3dB and the customer has agreed to this. A lower figure, e.g. 0.5dB could have been used, however this would have resulted in an unrealisable requirement. It is yet to be established whether external noise limiting, based on a 3dB degradation definition is realisable at the higher end of the operational frequency range.

b. What has to be externally noise limited?

All system receive channels in the frequency range of operation.

c. What assumptions shall be made about the distribution of external noise?

It is assumed that external noise as specified in xxxx is isotropically distributed. This is a reasonable approximation to reality, and avoids any need to convolve the distribution in az-el of the noise with the polar pattern of the array.

d. What about the treatment of combiner gain in considering and measuring system internal noise?

Having specified the reasonable assumption that external noise is isotropically distributed, it follows that combine (beamforming) gain should also be considered to be zero in considering system internal noise figure.

PPI-005608-1

e. Is transmitter noise from the transmitter site to be considered in either external noise or internal noise?

It is evident that if the transmitter and receiver are on the same frequency, there are paths between them, and that any such paths will compromise system performance.

However, it can also be argued that propagation delay may minimise this problem, and that the path loss from other paths is variable and outside of the control of the designer, e.g. backscatter, high angle skywave, ground/surface wave, etc., and that inclusion of such noise would defeat the purpose of the specification. Thus there is a case that the system should be designed to be "externally noise limited" without considering transmitter noise, and the transmitter noise be considered as a separate design issue. This is acceptable to the customer

f. What about locally generated received site noise?

The intention would be that the system be designed to prevent degradation by locally generated noise of any type. The SSS should be drafted to include this aspect in the definition of the internal noise against which external noise is compared in defining "external noise limiting".

Distribution (by Requirements Manager): originator, designated resolver, Project Manager, other (add)

3. Source of Clarification/Information (Documentary Where Possible):

Meeting with customer, 26 January 1988. File xxxx Folio yy refers.

Approved by (signature): Project Manager	Client Concurrence to Clarification/ Information (signature):	Closed by (signature): (Requirements Manager)
Date:	Date:	Date:

Distribution (by Requirements Manager): originator, designated resolver, Project Manager, other (add)

Action on Requirements Baseline (to be completed and initialled by Requirements Manager)	Not Required	Required	Performed
	.....	.....	.....

PPI-005608-1

Internet-based Requirements Engineering Interest Groups

Yahoo Requirements Engineering Group
Description: Provides an environment for sharing experience in the scope of Software Requirements Engineering.
To join: http://groups.yahoo.com/group/Requirements-Engineering/

re-online@it.uts.edu.au
Description: An electronic forum for discussion and exchange of ideas among the Requirement Engineering researchers and practitioners around the world.
To join: http://discuss.it.uts.edu.au/mailman/listinfo/re-online

resg-admin@doc.ic.ac.uk
Description: Announcement email service of the Requirements Engineering Specialist Group of the British Computer Society.
To join: http://www.resg.org

Organizations:

Requirements Management Group of the International Council on Systems Engineering
Website: www.incose.org

Requirements Engineering Specialist Group of the British Computer Society
Website: www.resg.org.uk

Requirements Networking Group
Website: www.requirementsnetwork.com

Americas Requirements Engineering Association (AREA)
Website: www.A-RE-A.org

Polish Association for Requirements Engineering
To Join: http://pare.wymagania.org.pl/

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