THE BUSINESS CASE FOR SYSTEMS ENGINEERING

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THE PROBLEM SPACE

- Opportunities/threats
- User needs
  - What the solution must do (functions)
  - How well it must do it (performance)
  - Utilization environments (natural, induced)
  - Other constraints (cost, schedule, physical characteristics, other qualities, laws, policies, standards)
- Supplier needs
  - Cash Flow
  - Profit
  - Reputation

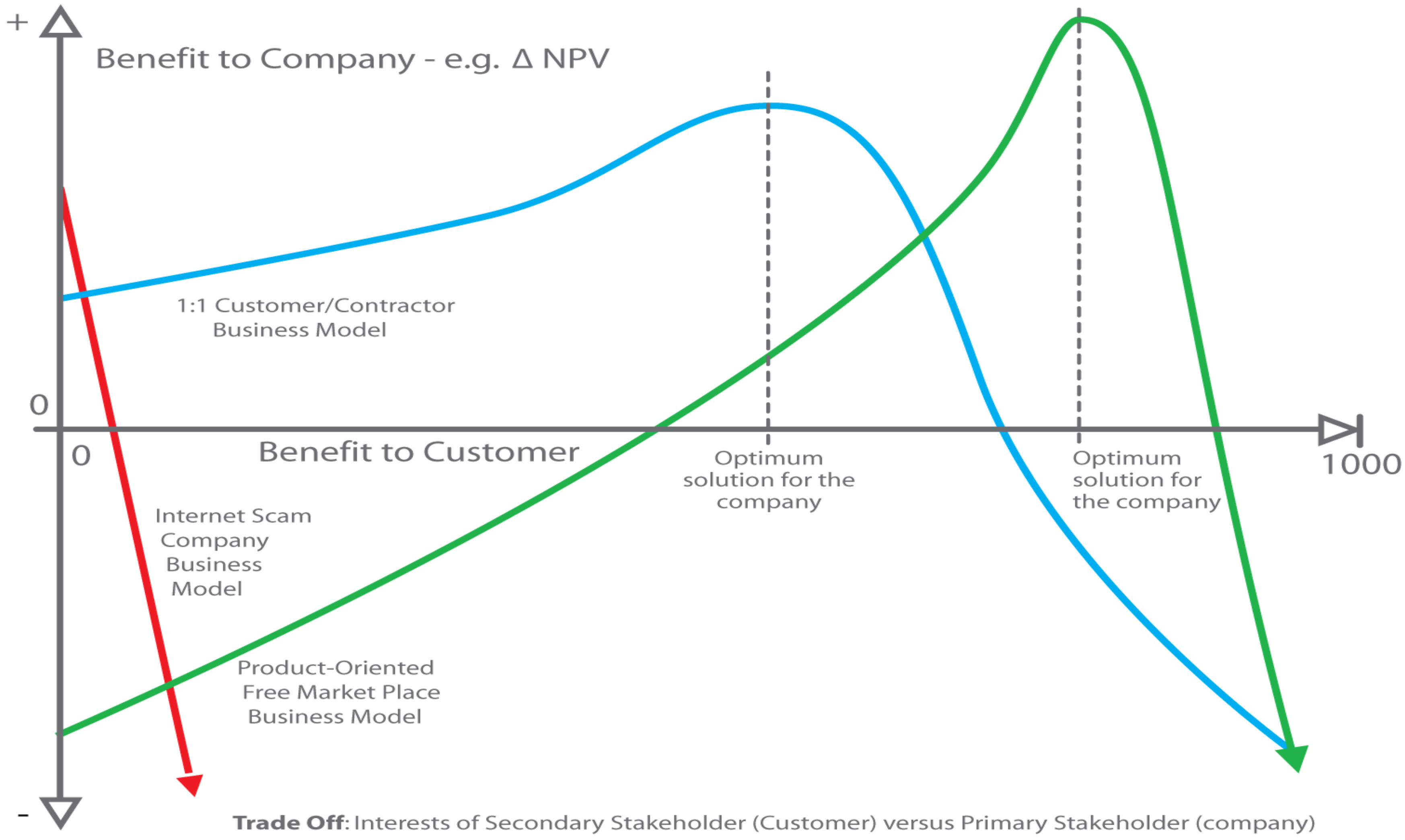
THE SOLUTION SPACE

- Complete, life-cycle based solution:
  - Development, production, verification, validation, marketing, distribution, sales, use, support, disposal, as applicable
- Correct solution:
  - All imperatives (requirements) are satisfied
- Optimal solution
  - Of feasible solution alternatives, the best is chosen
- Must reconcile customer and supplier imperatives
- Must consider changing problem, the changing pool of solution technologies, and uncertainty (risk and opportunity)

Maximise value delivery in accordance with the values of the primary stakeholders

GOALS OF ENGINEERING MANAGEMENT

1. Quality products and services
   - Customer needs satisfied throughout the life cycle
2. Profitable companies
3. Timely delivery of products and services
   - Predictable development schedule
4. Affordable products and services
   - Downstream processes designed in up front
   - Cost of engineering changes and recalls substantially reduced
   - Cost considered a design driver



+
Benefit to Company - e.g. Δ NPV
0
0
Benefit to Customer
1000
1:1 Customer/Contractor Business Model
Optimum solution for the company
Optimum solution for the company
Internet Scam Company Business Model
Product-Oriented Free Market Place Business Model
-
Trade Off: Interests of Secondary Stakeholder (Customer) versus Primary Stakeholder (company)

WORLD CLASS CONCEPTS

World class suppliers

- Prosper through pursuit and achievement of customer satisfaction
- Are reliable by being ahead of the game in every respect – in management, in engineering, in production, in marketing, in delivery, in support

World class customers

- Help suppliers solve problems
- Serve on multi-disciplinary product teams
- Do not over-specify their requirements
- Clearly distinguish between requirements and goals

DEMONSTRATED BENEFITS OF A SYSTEMS APPROACH - MORE

1. Shorter time to market
2. Lower product development costs
3. Higher product quality
4. Lower manufacturing costs
5. Lower testing costs
6. Reduced service/support costs
7. Enhanced competitiveness
8. Improved profit margins

DEMONSTRATED BENEFITS MULTIPLIER EFFECT - NOT AN UNTRIED THEORY

1. Improved Quality of Designs
   - *Resulted in reduce 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

SYSTEMS ENGINEERING APPLIED IN A PRODUCT-ORIENTED COMPANY

Systems engineering is an interdisciplinary, collaborative approach to the engineering of systems which aims to capture stakeholder needs and objectives, and to transform these into to a description of a holistic, life-cycle balanced system solution, which aims to maximize value delivery to the company by means of satisfaction of product and programmatic requirements, and maximization of overall solution effectiveness according to the values of the company

Note: Although the SE process does not physically build the end system in a production sense, SE is also concerned with verification and validation in development of the built system

SYSTEMS ENGINEERING APPLIED IN A CONTRACT-ORIENTED COMPANY

Systems engineering is an interdisciplinary, collaborative approach to the engineering of systems which aims to capture stakeholder needs and objectives, both within and external to the company, and to transform these into to a description of a holistic, life-cycle balanced system solution, which aims to maximize value delivery to the company by optimising value delivery to the customer

Note: Although the SE process does not physically build the end system in a production sense, SE is also concerned with verification and validation in development of the built system

SYSTEMS ENGINEERING APPLIED IN INSIDE AN ENTERPRISE

Systems engineering is an interdisciplinary, collaborative approach to the engineering of systems which aims to capture stakeholder needs and objectives, both within and external to the enterprise, and to transform these into to a description of a holistic, life-cycle balanced system solution, which aims to maximize value delivery to the internal stakeholders

Note: Although the SE process does not physically build the end system in a production sense, SE is also concerned with verification and validation in development of the built system

SYSTEMS ENGINEERING – WHY SHOULD WE CARE?

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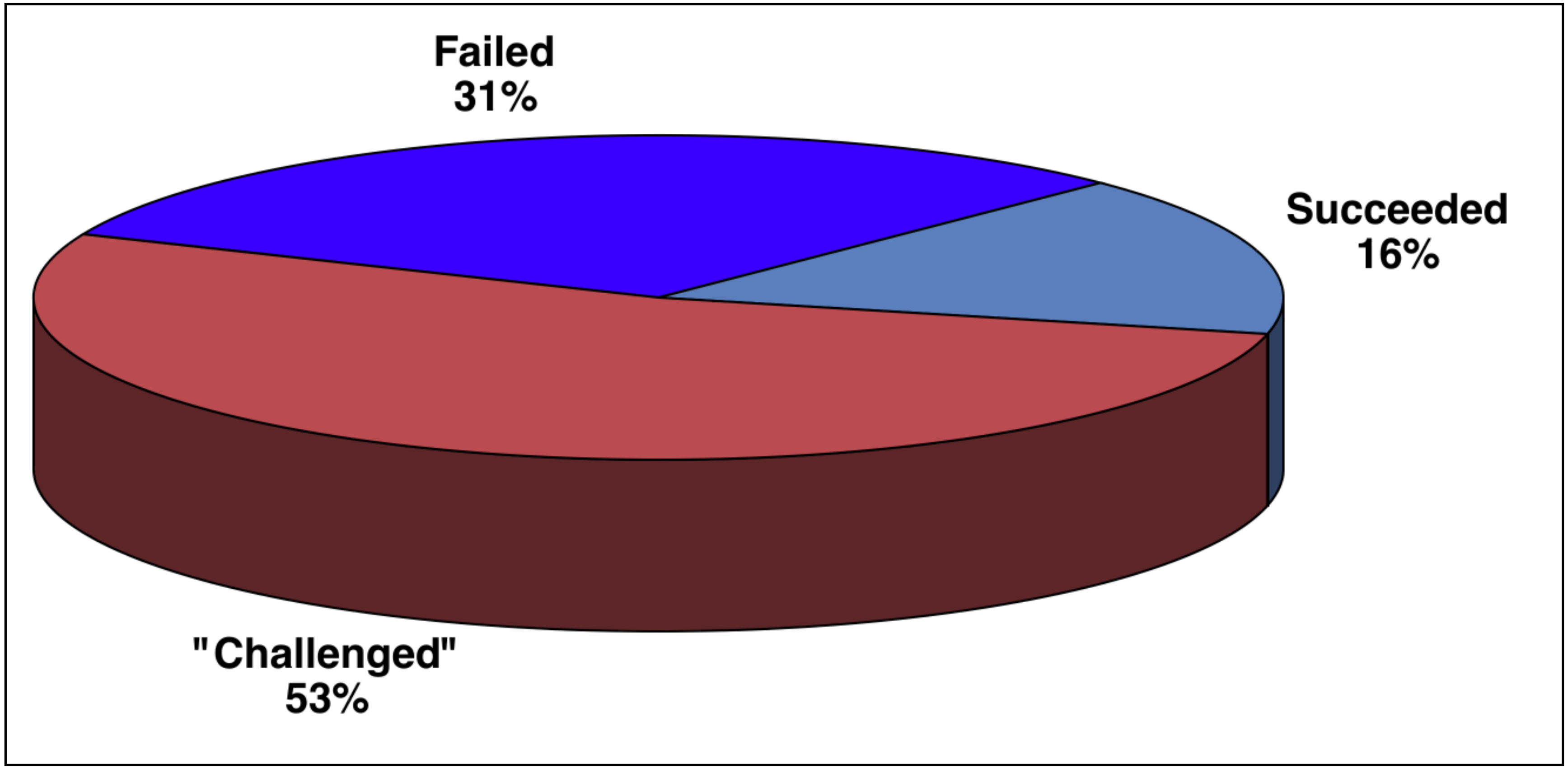
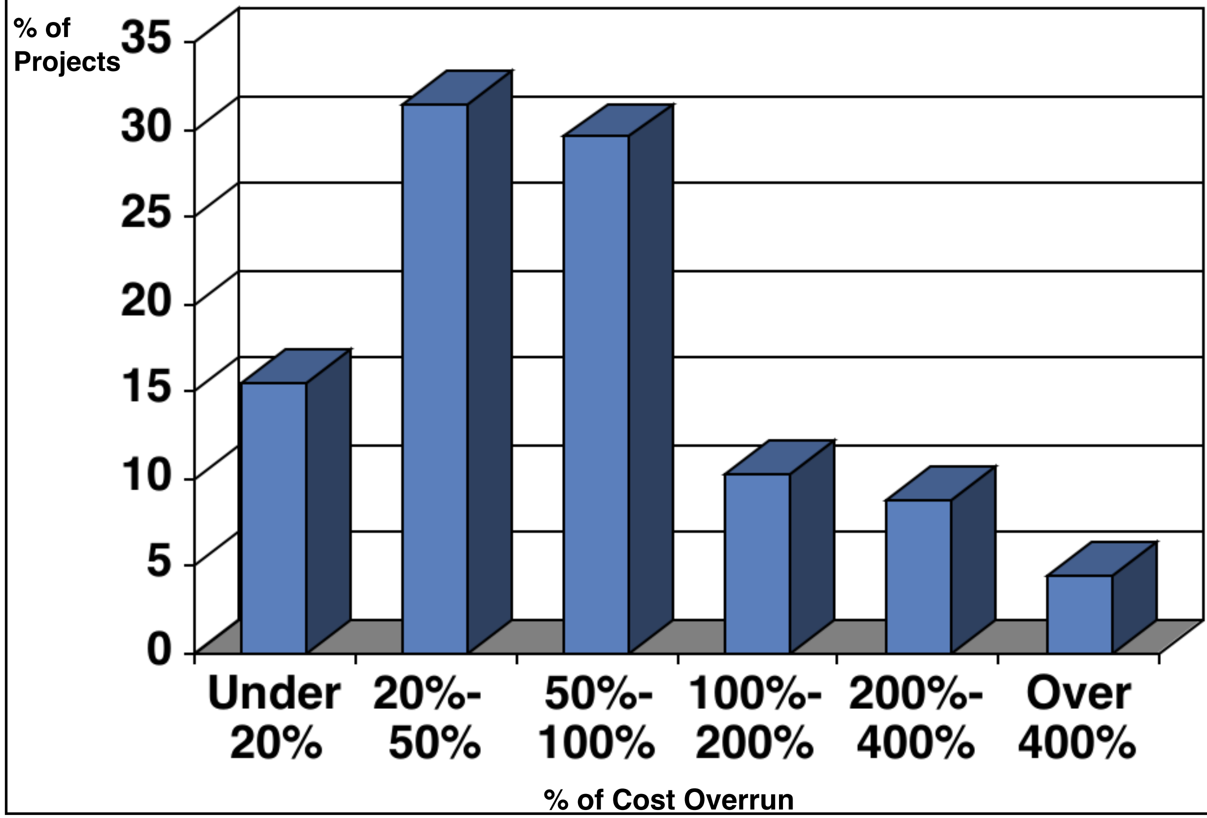
THE PROBLEM (1)



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

THE PROBLEM - COST

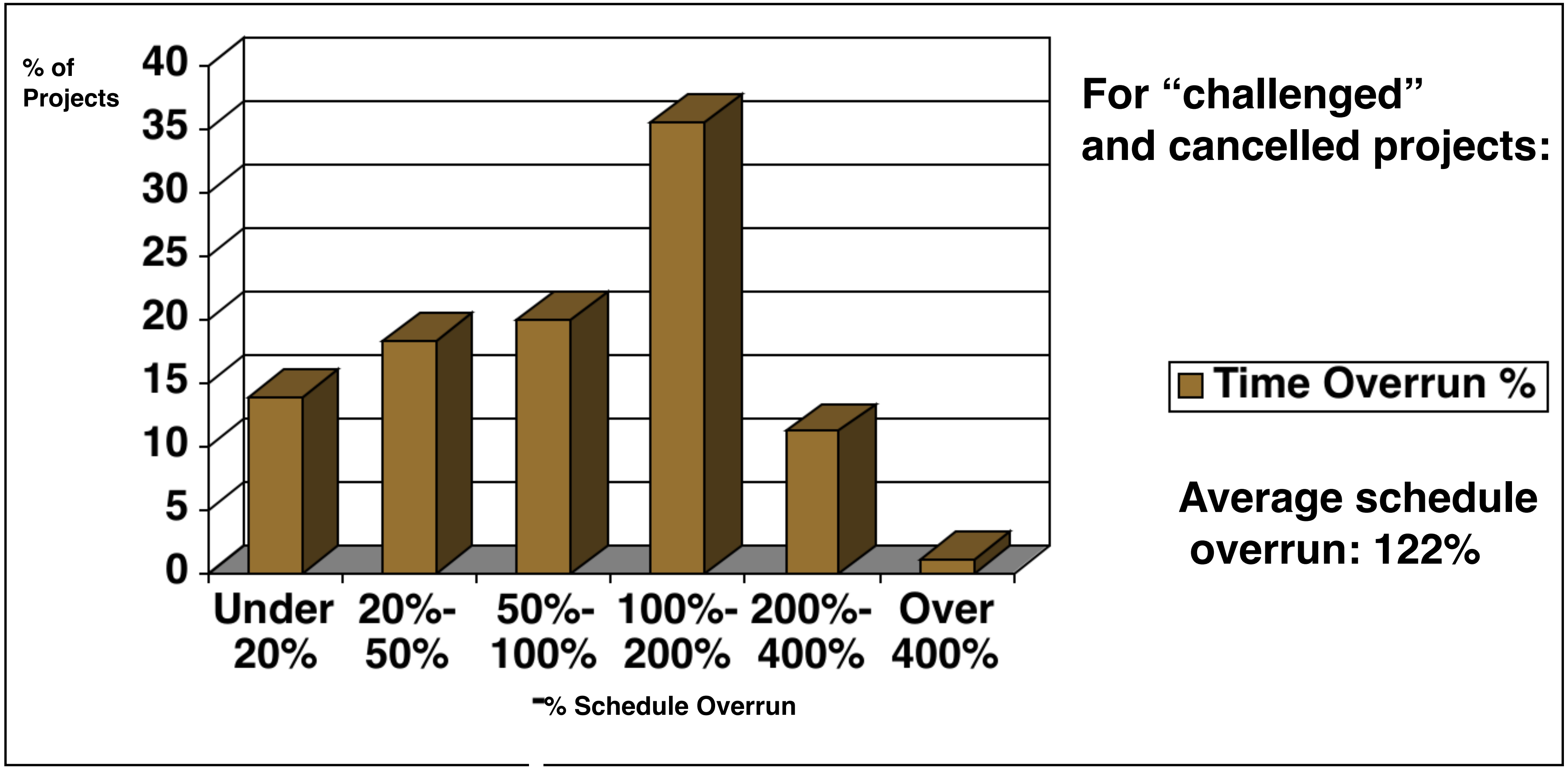


For "challenged" and cancelled projects:

Average cost overrun: 89%

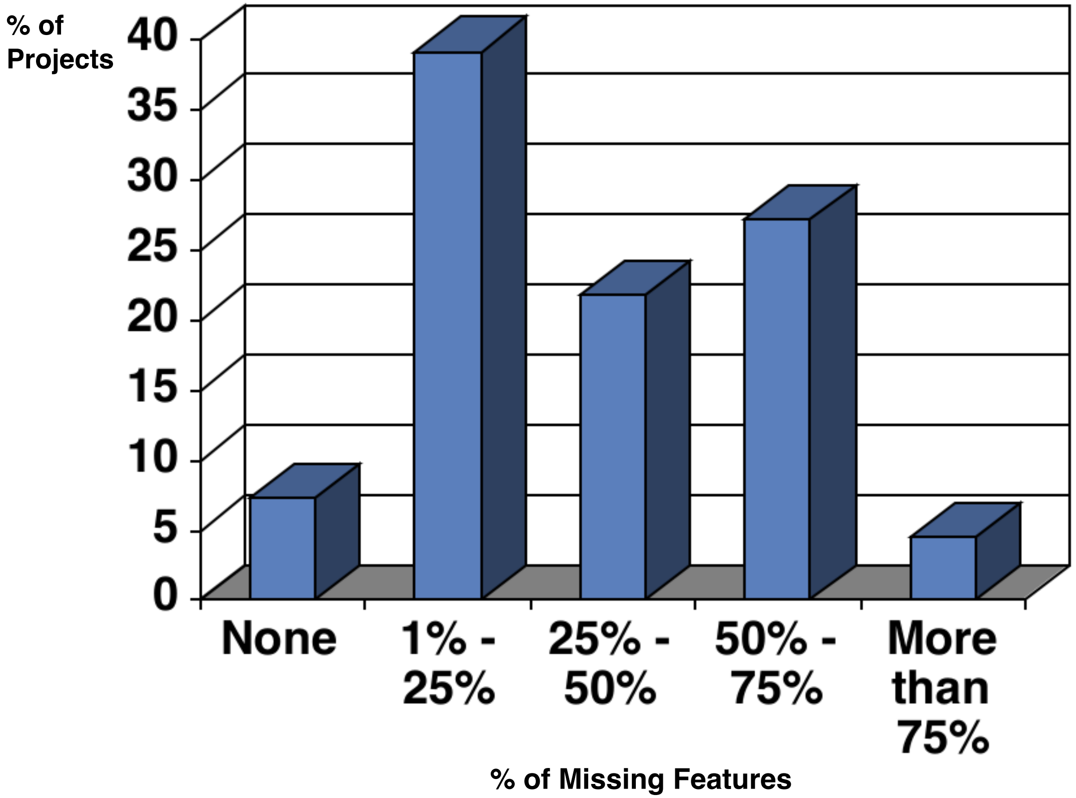
Standish Group study of 8380 IT-based projects

THE PROBLEM - SCHEDULE



Standish Group study of 8380 IT-based projects

THE PROBLEM - QUALITY



For “challenged” projects:

Average missing features: 39%

Standish Group study of 8380 IT-based projects

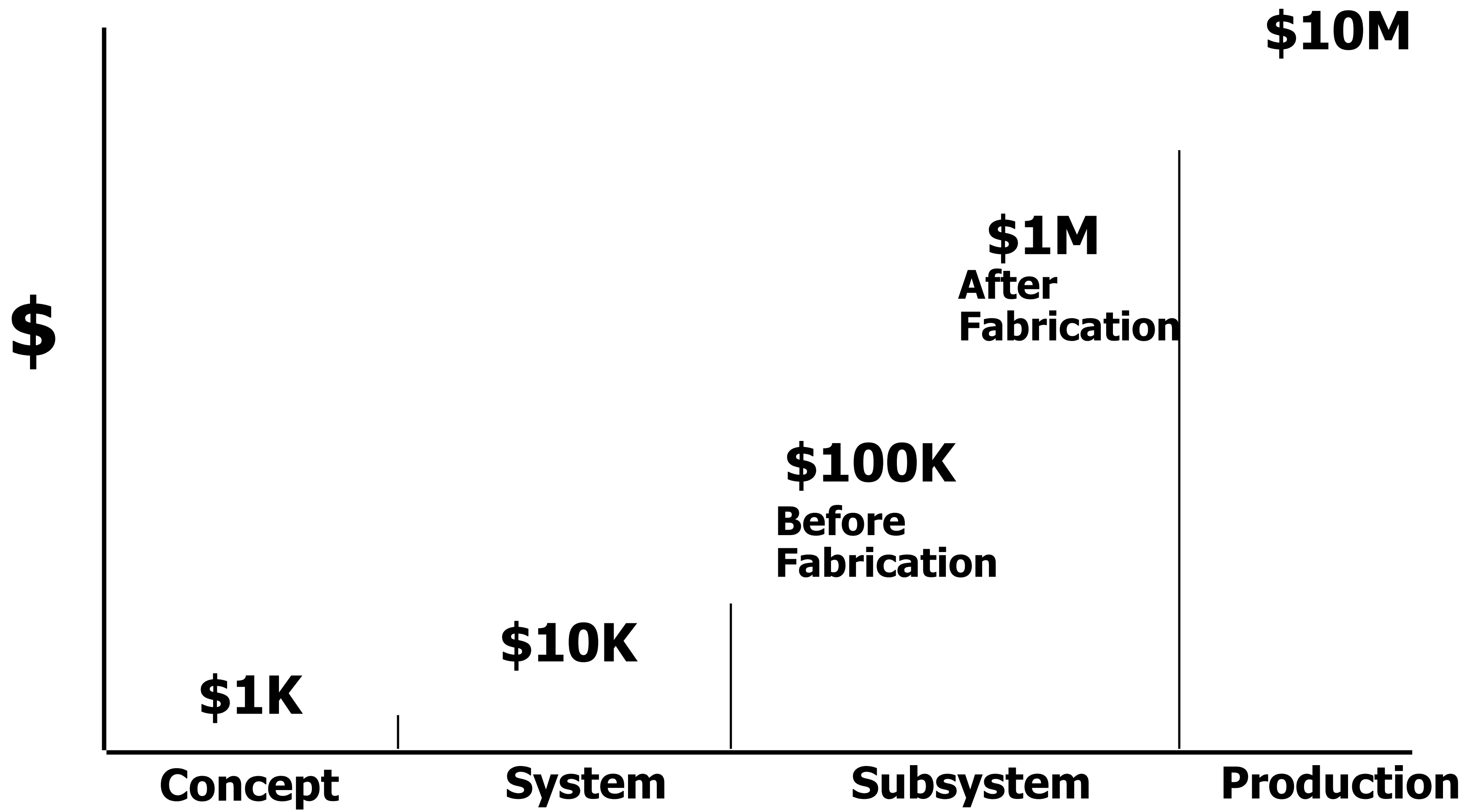
WHEN IS SYSTEMS ENGINEERING APPLIED?

- Development
  - New Systems/Products
  - Families of Products
- Build/Production
  - Correct Design Deficiencies
- Sustainment/Operations and Support
  - Modifications
  - Incremental/Competitive Improvements

WHAT IS SYSTEMS ENGINEERING APPLIED TO?

- End-use items
- Production systems
- Maintenance systems
- Training systems
- Project systems
- Engineering systems
- Anything else for which a solution does not already exist and is sought

COST OF AN ENGINEERING CHANGE



SOURCE: *"A Smarter Way to Manufacture". April 30, 1990 issue of Business Week*

INDICATORS OF EFFECTIVE SE – PRODUCT-ORIENTED ENTERPRISE:

- 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 product and a related focus on quality, cost, time

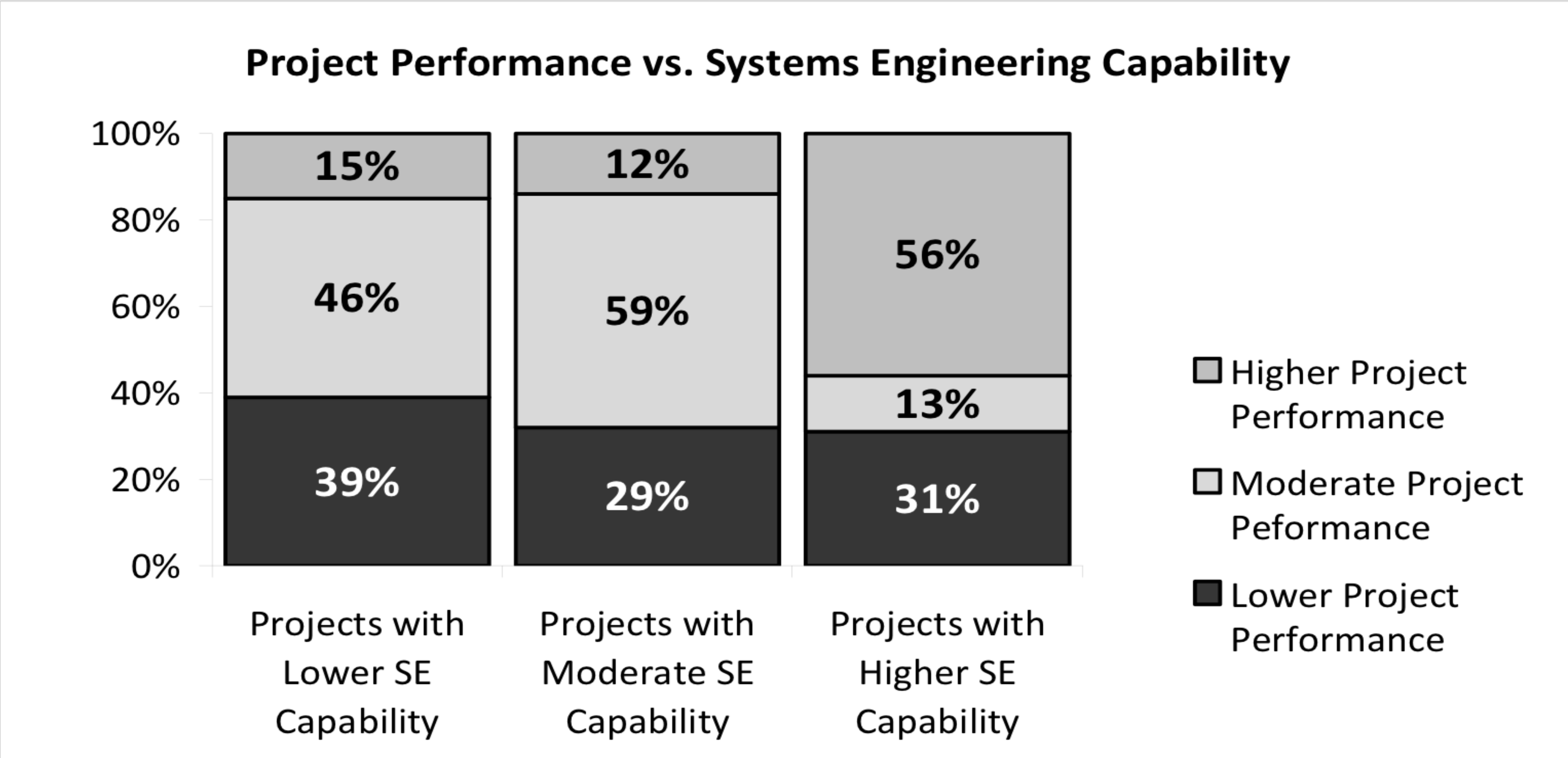
INDICATORS OF NO SE OR INEFFECTIVE SE

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

WHERE DOES THE MONEY GO?

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?	100%	?

CMI/NDIA STUDY RESULTS



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

CMI/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

CMI/NDIA STUDY RESULTS - 3

Project Challenge Factor	Relationship to Project Performance	Relationship (Gamma)	Section Reference
Project Challenge	Moderately strong negative relationship	-0.31	5.1.1

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

CMI/NDIA STUDY RESULTS - 4

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

MCPM – MATURITY BY PROJECT CATEGORY MODEL, BRAZIL

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

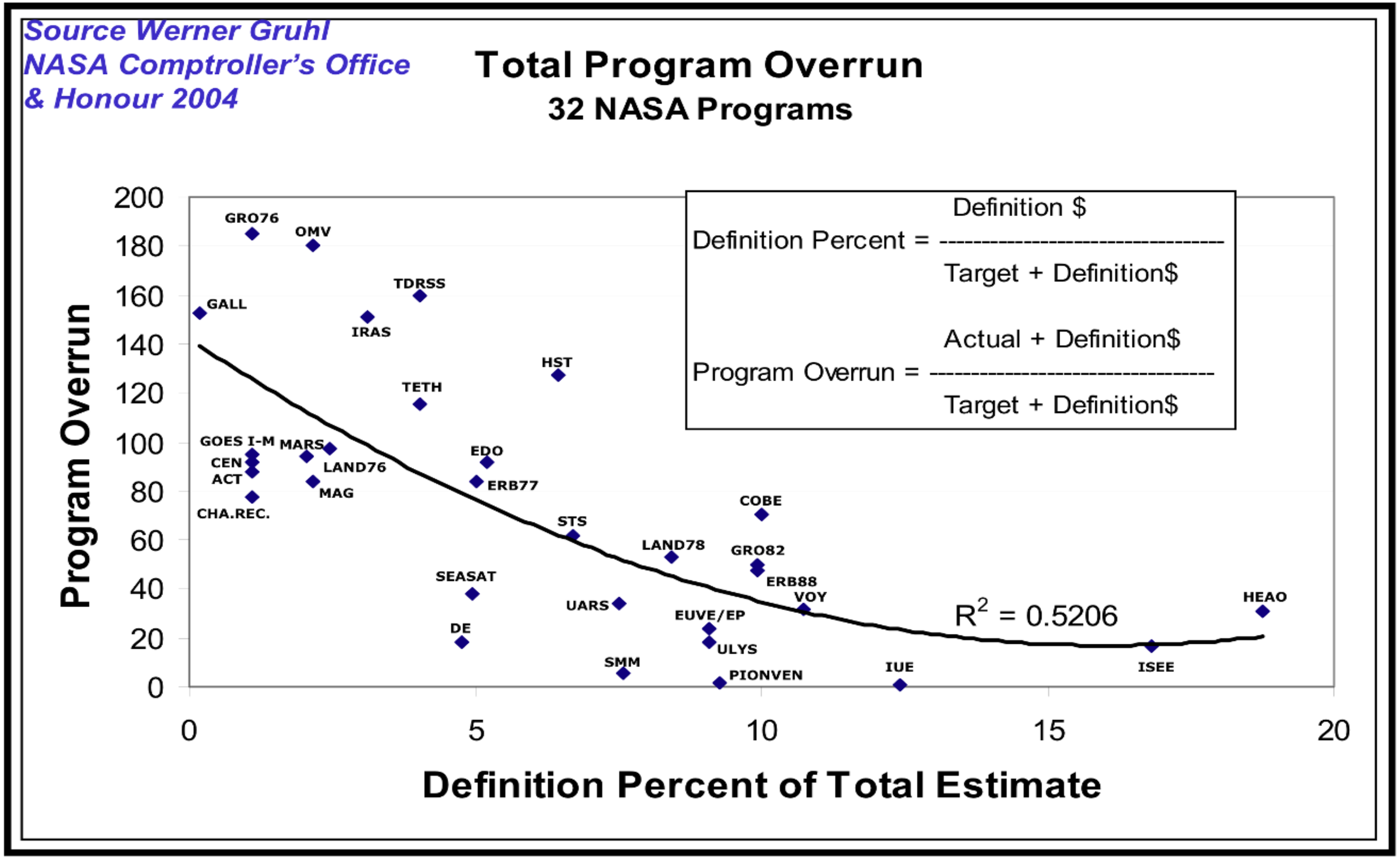
PROJECT ENGINEERING MATURITY MATRIX

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	

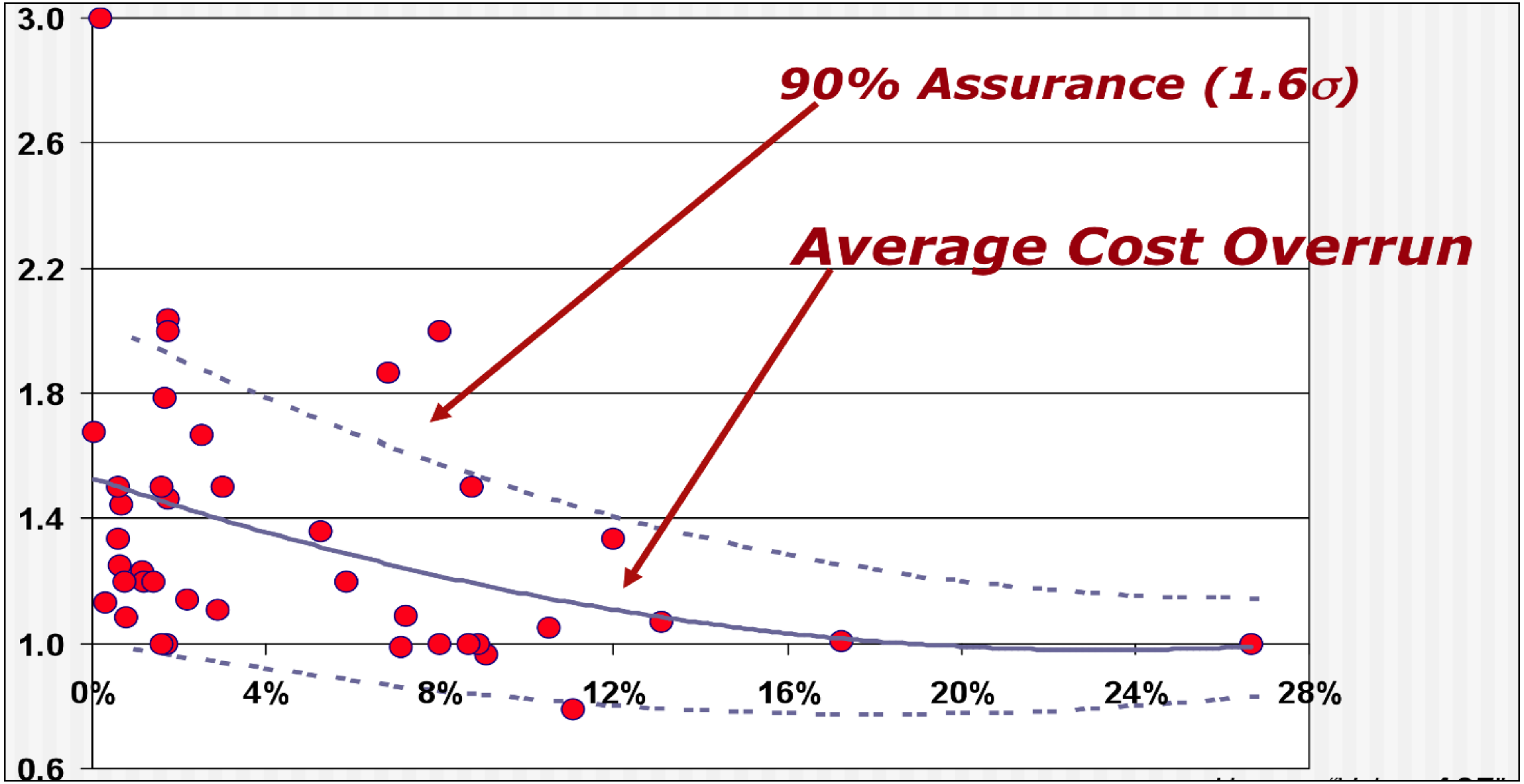
Increased Customer and Producer Satisfaction

Increased Risk

NASA AND THE VALUE OF SE

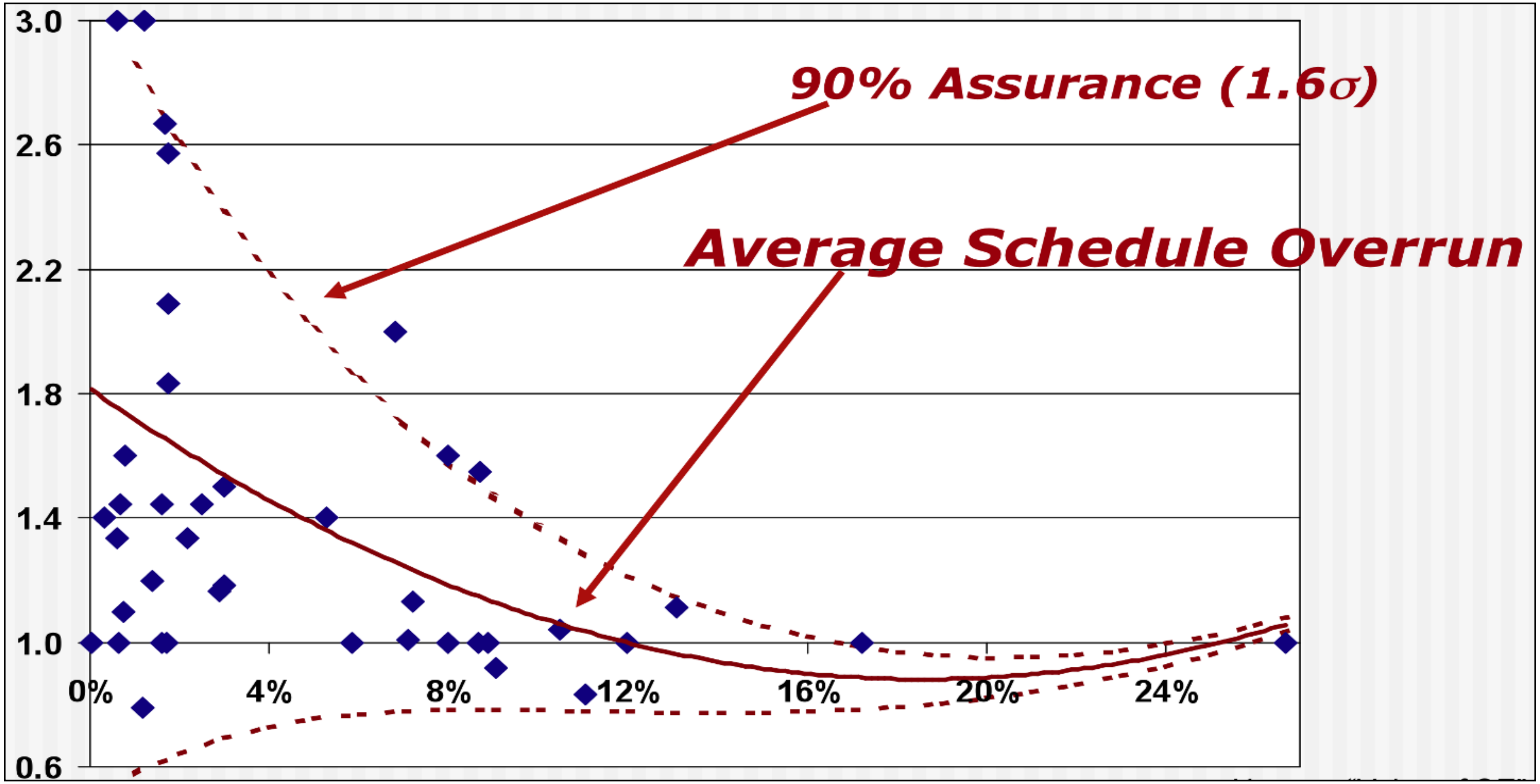


INCOSE STUDY - COST



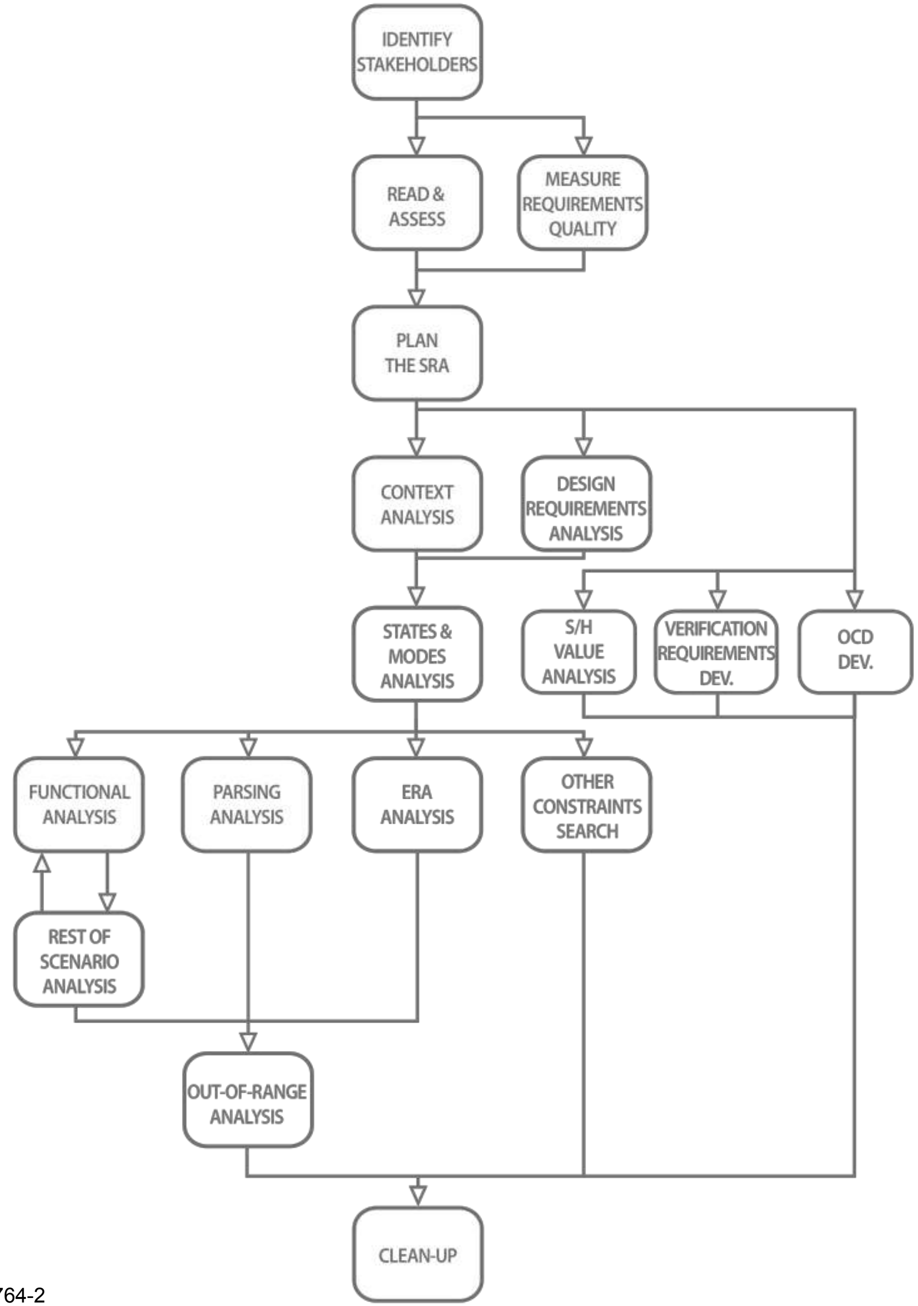
SE Effort = SE Quality * (SE Cost/Actual Cost)

INCOSE STUDY - SCHEDULE



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

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



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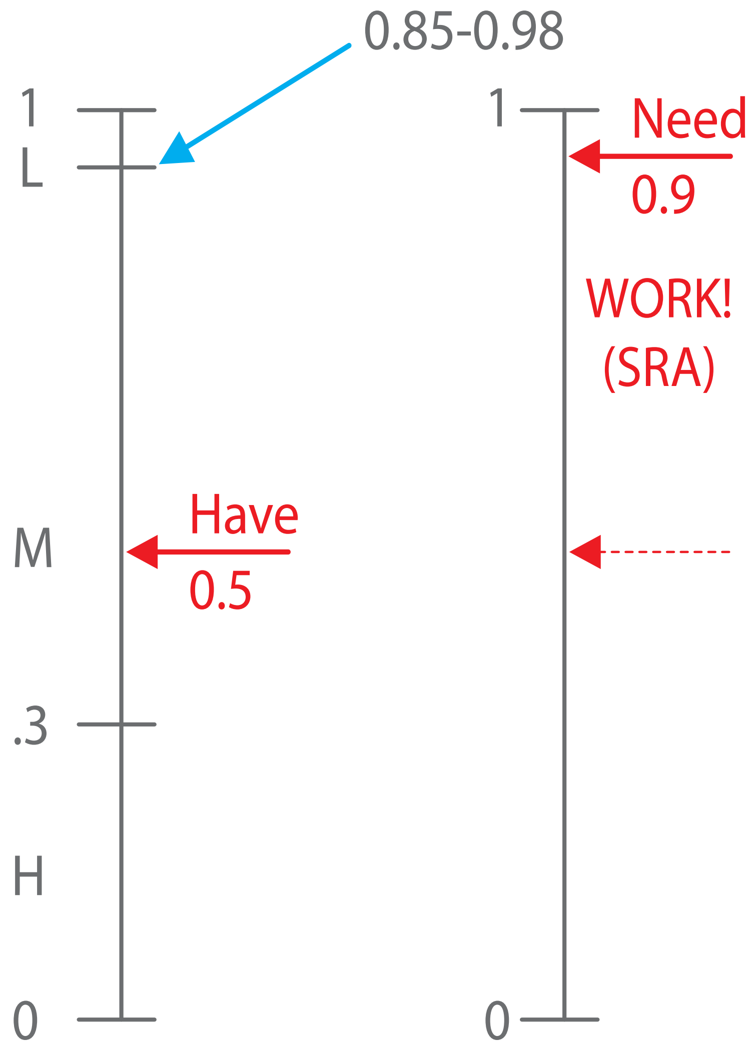
REQUIREMENTS QUALITY AND REQUIREMENTS ANALYSIS EFFORT



Requirements Quality Metric

WORK = f(

Have
Need
Number of Requirements
Skills
Tech-Environment
Access & Cooperation)

Document Number: P007-004138-2

IMPACT OF REQUIREMENTS DEFECTS

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 - 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 - CONTRACTOR

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

KEY MESSAGES, CHAPTER 1

1. **The practice of engineering can be immature**
   - Sometimes ad hoc and chaotic – that is destructive to profit and capability
2. **For prosperity, a management and technical approach is needed that provides:**
   - High quality products and services
   - On-time delivery of products and services
   - Affordable products and services
3. **The evidence is now compelling that the practice of systems engineering contributes enterprise success in terms of:**
   - High quality products and services
   - On-time delivery of products and services
   - Affordable products and services

ADDITIONAL KEY POINTS FOR YOU

List any additional key points: