Honourcode, Inc.

Systems Engineering Return on Investment

SE-ROI Research
Interim Results Aug 09

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Funding provided by
- ***Honourcode, Inc.***
- ***CEDISC (Univ of South Australia)***

Agenda

- **Background**
  - Motivation for the topic
  - Quick summary of anecdotal prior works
- **SE-ROI Project**
  - Goals and methodology
- **SE-ROI Research Interim Results**
  - Demographics results
  - Interim correlation results

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Background

Concepts: Value of SE

Prior results

- **Boeing - Franz data**
- **IBM – Barker data**
- **Value of SE 2004 data**
- **EIA SE Effectiveness Study**
- **SEROI-COCOMO 2008 data**

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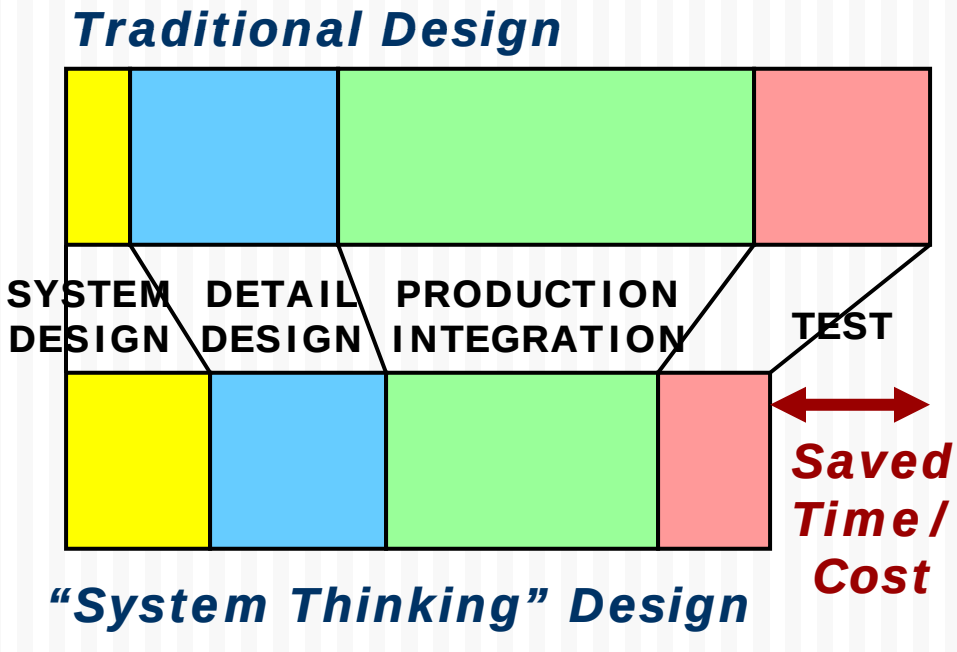
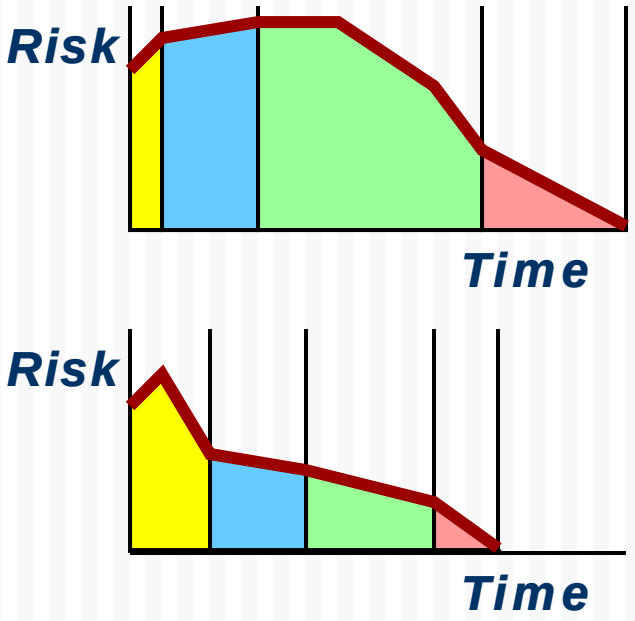
Heuristic Claim of SE

- **Better systems engineering leads to**
  - **Better system quality / value**
  - **Lower cost**
  - **Shorter schedule**





Not Known: How Much Is Enough?

Impact of Systems Engineering on Quality and Schedule

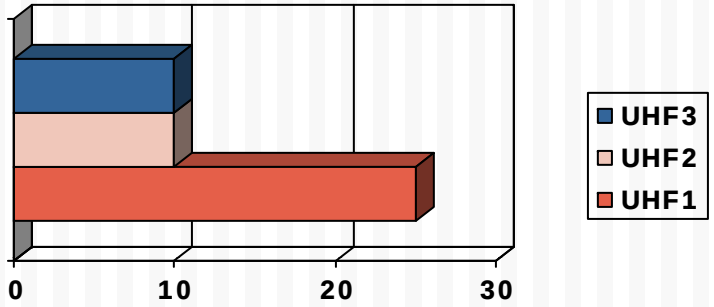
- **Empirical evidence obtained from three parallel (same time) projects**
  - **Each developed a complex, robotic Universal Holding Fixture (UHF)**
  - **Each used a different level of SE**
  - **Results are compared**

Trait	UHF1	UHF2	UHF3
Size	10' x 40'	8' x 50'	6' x 14'
Accuracy	±0.005"	±0.003"	±0.003"
Contact Sensors	None	57	108
Vacuum Sensors	1	70	108
Real-time checks	No	Yes	Yes
Probe contours	No	Yes	Yes
NC interface	No	Yes	Yes

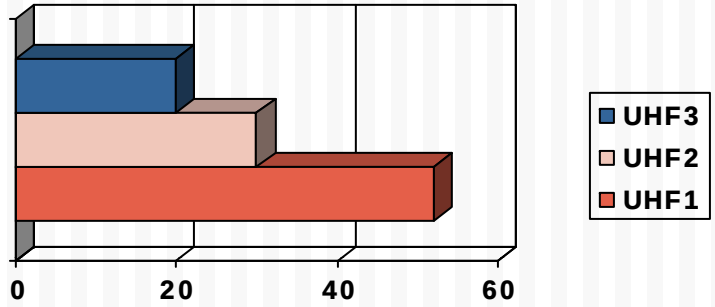
…W. Forrest Frantz, Impact of Systems Engineering on Quality and Schedule – Empirical Evidence, Boeing, INCOSE 1995

Impacts

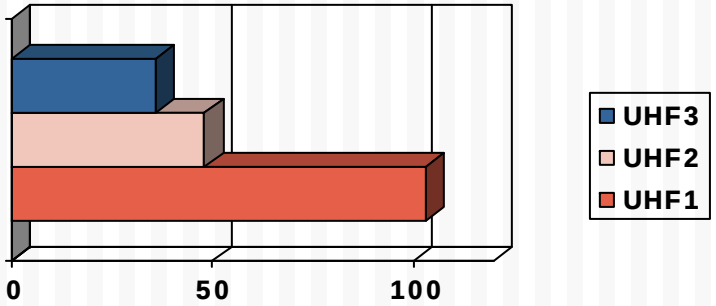
Requirements to RFP (weeks)



Design to Production (weeks)



Overall Development Time (weeks)



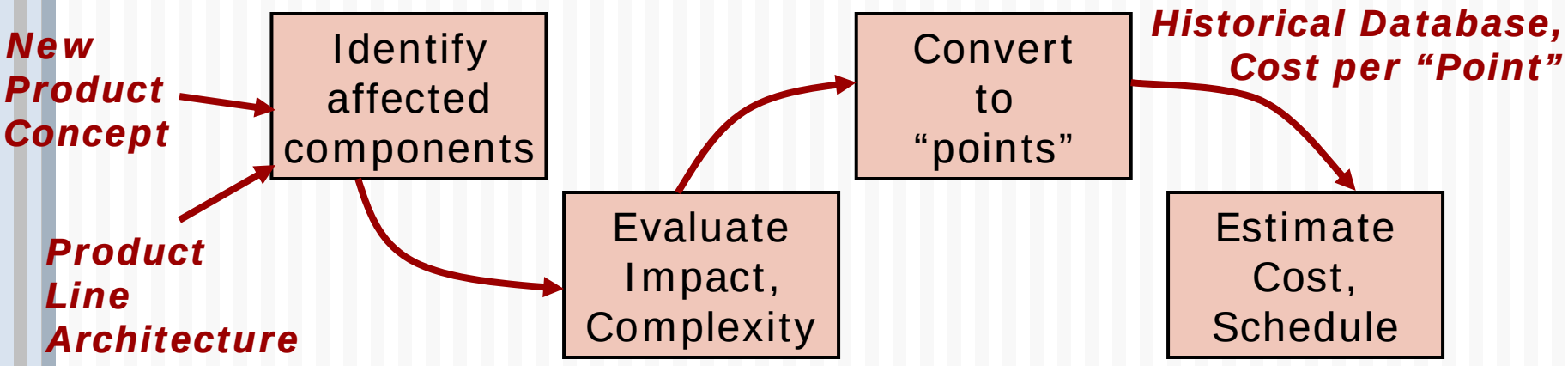
- **Use of better SE reduced**
  - **Overall cycle time**
  - **Time to create req's**
  - **Time to design / produce**
  - **Time to test**

...even in the face of more complex, higher quality systems!

...W. Forrest Frantz, Impact of Systems Engineering on Quality and Schedule – Empirical Evidence, Boeing, INCOSE 1995

Systems Engineering Effectiveness

- **Study of 8 software product development projects during upgrade of SE processes**
- **Evaluation by cost and schedule against a standard estimating method.**



Costing method applies only to project management, business management, systems engineering, system integration, and delivery into production. Application development costs are not included.

…Barker, Determining Systems Engineering Effectiveness, IBM Commercial Products, CSER 2003

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Systems Engineering Effectiveness

Significant Findings:

- Impact and complexity provide an effective method to perform parametric costing.

  Early parametric costing works.

- Preliminary data indicates that the use of Systems Engineering will improve project productivity when effectively combined with the Project Management and Test Processes.

  Systems engineering improves productivity.

$/Point Averages

Without SE	**$1,350/pt**
With SE	**$944/pt**

2000	**$1,454/pt**
2001	**$1,142/pt**
2002	**$818/pt**

…Barker, Determining Systems Engineering Effectiveness, IBM Commercial Products, CSER 2003

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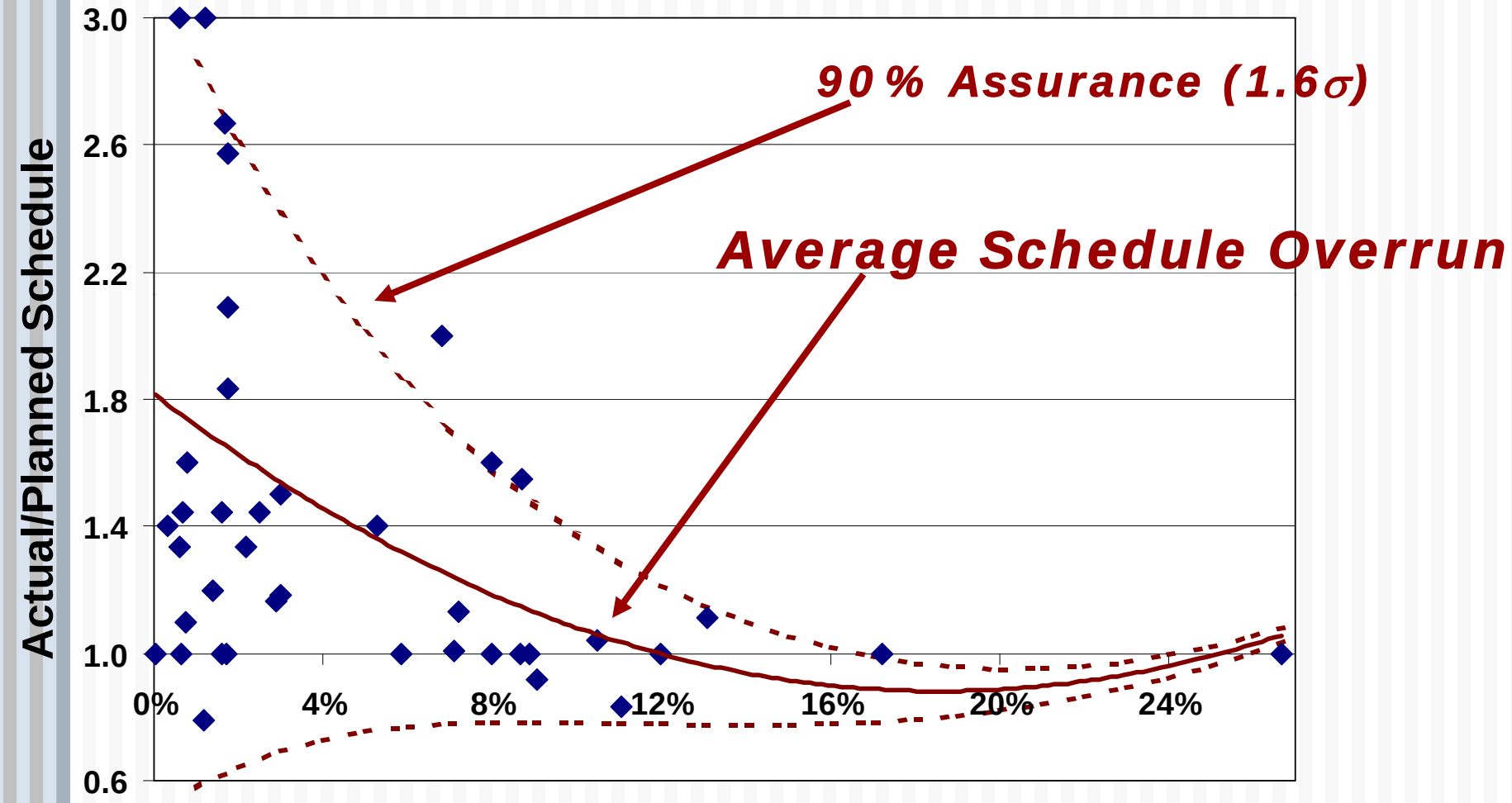
Schedule Overrun vs. SE Effort



SE Effort = SE Quality * SE Cost/Actual Cost

...Honour, Understanding the Value of Systems Engineering, INCOSE 2004

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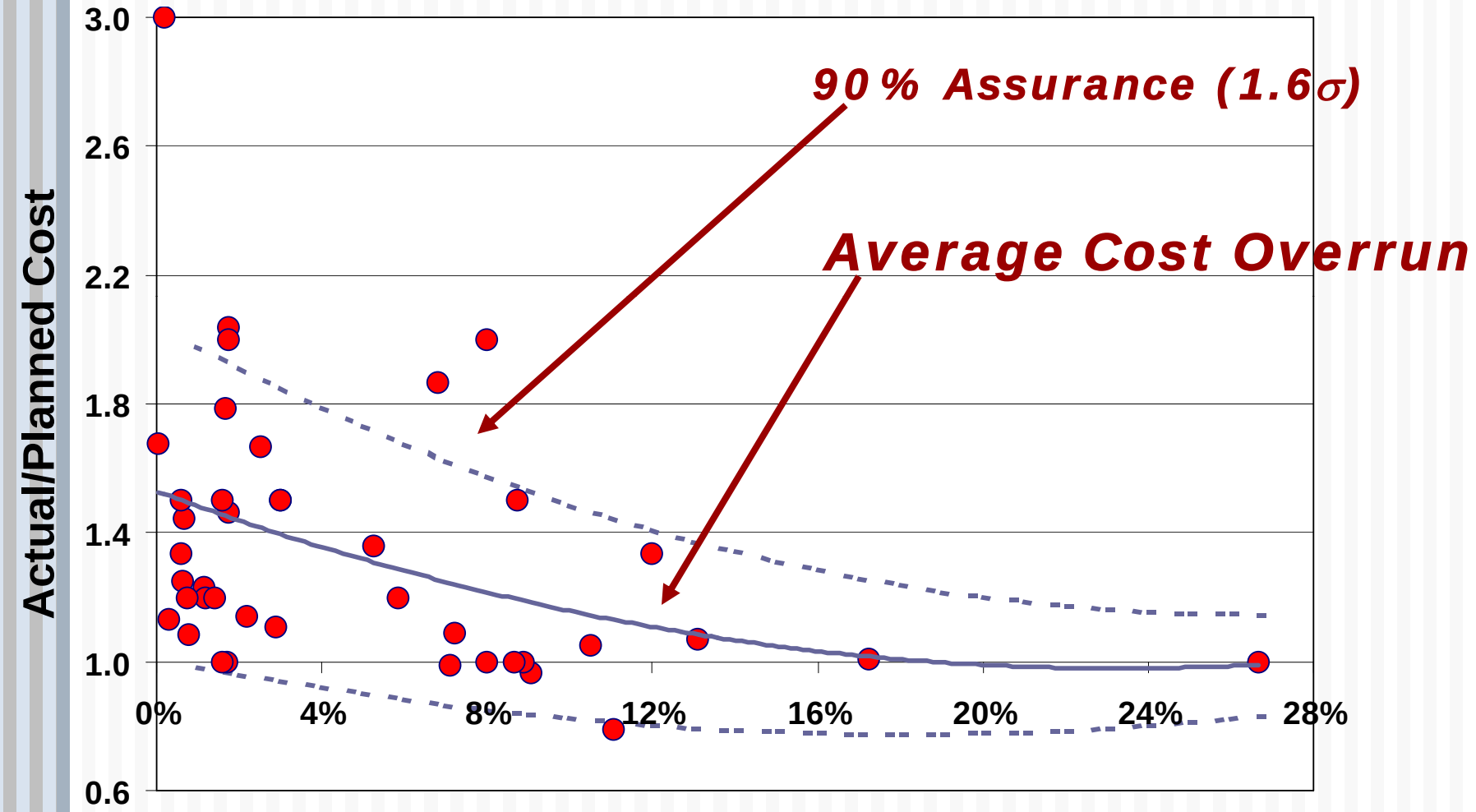
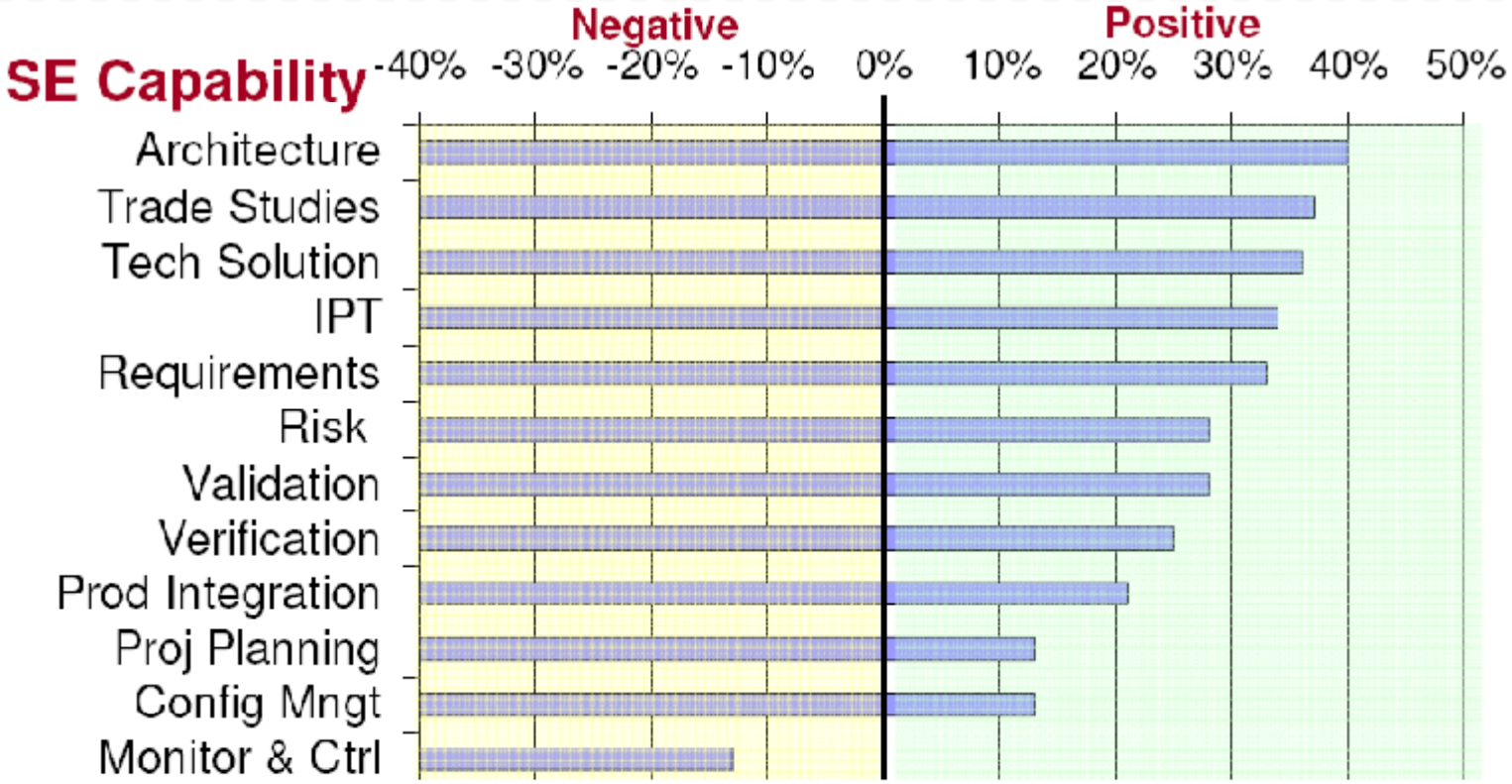
Cost Overrun vs. SE Effort



SE Effort = SE Quality * SE Cost/Actual Cost

...Honour, Understanding the Value of Systems Engineering, INCOSE 2004

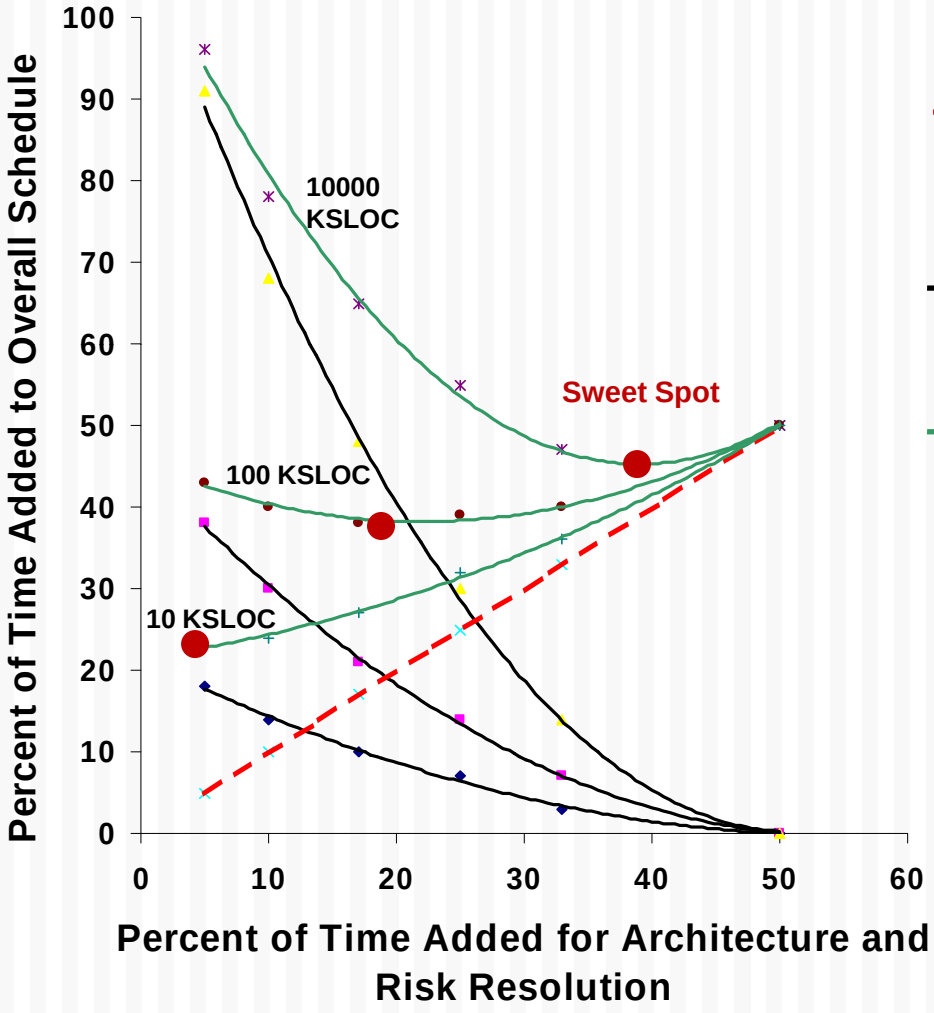
Effect of SE Activities on Projects



- **Gamma relationship to project performance**

...Elm, A Survey of Systems Engineering Effectiveness, NDIA, CMU/SEI 2007

COCOMO II: How Much Architecting is Enough?



Percent of Project Schedule Devoted to Initial Architecture and Risk Resolution

Added Schedule Devoted to Rework (COCOMO II RESL factor)

Total % Added Schedule

Sweet Spot Drivers:

Rapid Change: leftward

High Assurance: rightward

Basis: 161 projects in COCOMO II database since implementation of RESL factor

...Boehm/Valerdi/Honour, The ROI of Systems Engineering: Some Quantitative Results, USC/MIT, INCOSE 2007

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SE-ROI Project

Methodology

Industry support

Project Goals

- **Research objectives**

  How Much Is Enough?

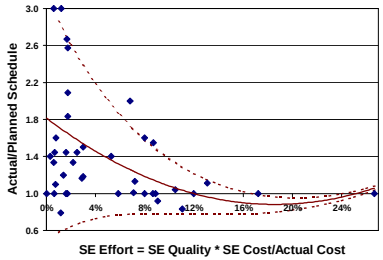
  - ***Find out how much of what type of SE correlates with project success***
    - **What SE practices are appropriate under what conditions.**
  - ***Leading indicators***
    - **Used during a project to assess the project's expected future success and risks based on SE practices used.**
  - ***Identification of good SE practices***
    - **Appropriate to generate success under different conditions.**
- **Schedule**
  - **'05-'07 – Technical structuring and definitions**
  - **Late '07 – Started data gathering**
  - **Internal reports '08–'09**
  - **Final reports '10**

SE-ROI Project

Interviews
- Just-completed programs
- Key PM/SE/Admin
- Translate program data into project structure

- *Program characterization*
- *Program success data*
- *SE data (hours, quality, methods)*

Statistical correlation



Desired Results
1. Statistical correlation of SE practices with project success
2. Leading indicators
3. Identification of good SE practices

Company Participation

- **Data gathering** – ***minimal impact***
  - **Select 2 to 4 programs**
  - **One day of interviews**
  - **2-hour sessions with PM+SE of each program**
  - **Strong protection of proprietary data**
- **Reports** – ***effective program benchmarking***
  - **Benchmark report within 30 days of session**
    - **Compares your programs against prior data**
  - **Quarterly reports from all prior data, all sources**
    - ***Correlations found***
    - ***Leading indicators proven***
    - ***SE practices proven***

Current Status – August 2009

SE ontology from SE standards – wide-spread, acceptable terminology	Completed Oct 05
Develop interest base from possible interview sources (currently ~65)	Completed, Ongoing
Create interview data sheets and vet them through sample interviews	Completed Oct 06
Start program interviews	Started 3/07
Gather data from 40+ programs	In process
– Interviews held	34
– Programs ready for interview	7
– Active program contacts	10?
– Other known possibilities	15?
Report benchmark results to participating organizations	In process
Public reports on research results	In process

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SE-ROI Research Interim Results

- Demographics
- Continued additions to "Value of SE" results
- Histograms of SE activities
- Indications about effectiveness of SE activities

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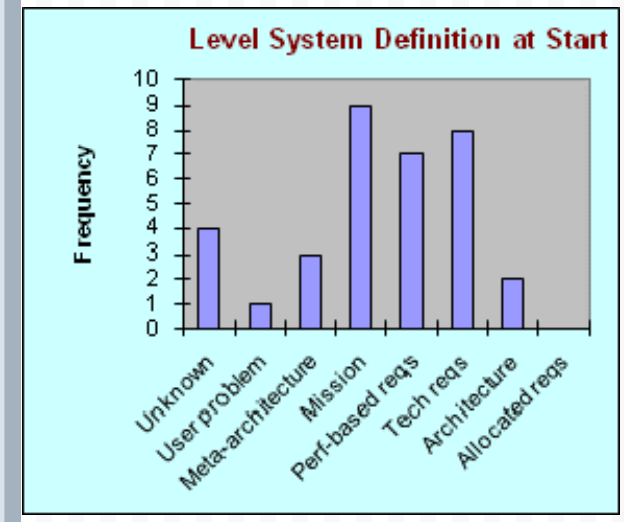
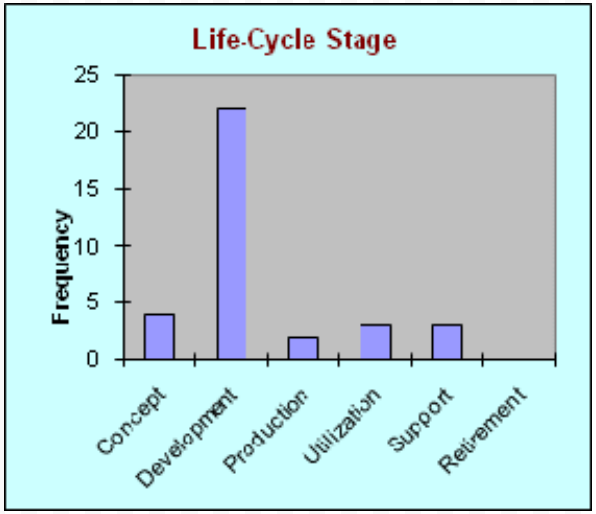
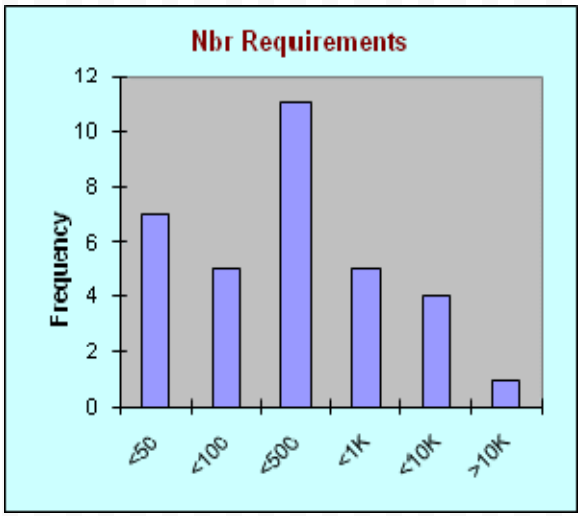
Basic Demographics

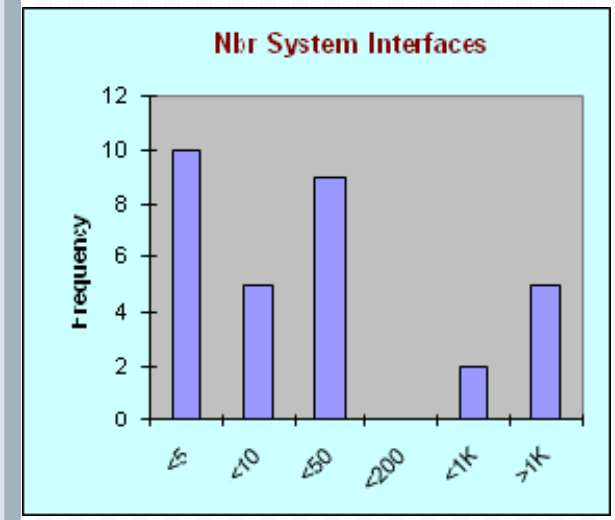
Characteristic	ValueSE Data Set	SE-ROI Data Set
Number of organizations	Unknown	12
Number of data points	44	34
Funding method	Unknown	24 contracted, 10 amortized
Program total cost	$1.1M - $5.6B Median $42.5M	$600K - $1.8B Median $12.0M
Cost compliance	(0.8):1 – (3.0):1 Median (1.2):1	(0.6):1 – (10):1 Median (1.0):1
Development schedule	2.8 mo. – 144 mo. Median 43 mo.	2 mo. – 120 mo. Median 32 mo.
Schedule compliance	(0.8):1 – (4.0):1 Median (1.2):1	(0.3):1 – (2.5):1 Median (1.0):1
Percent of program used in systems engineering effort, by cost	0.1% - 27% Median 5.8%	4% - 80% Median 14.8%
Subjective assessment of systems engineering quality (1 poor to 10 world class)	Values of 1 to 10 Median 5	Values of 1 to 9 Median 7

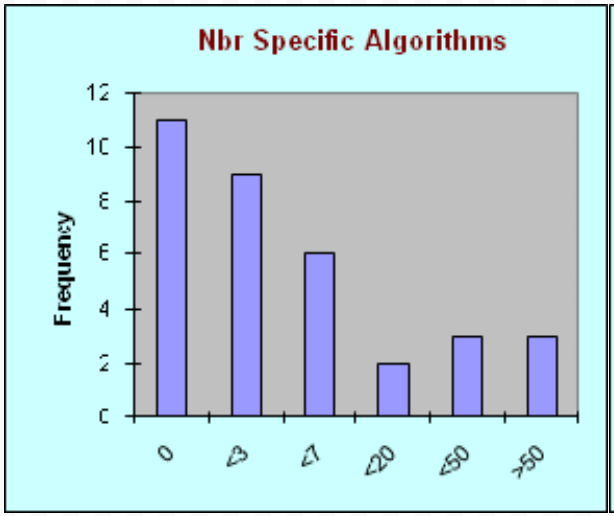
Program "Size"

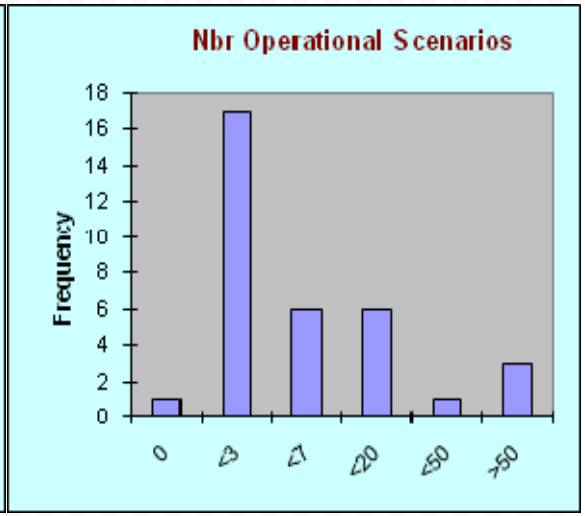




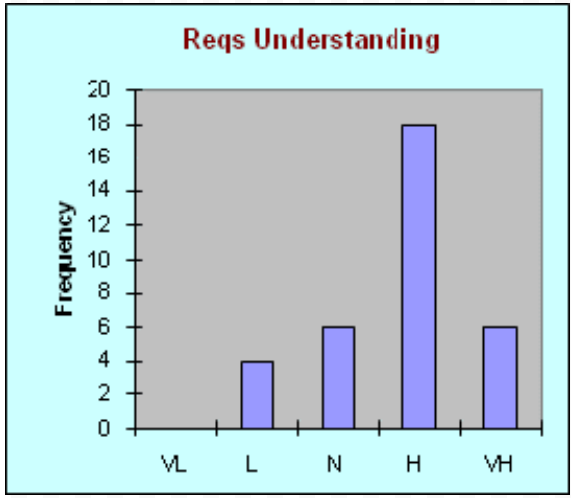


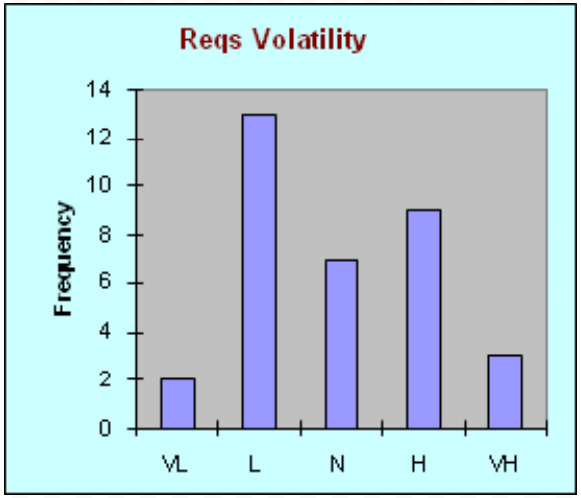


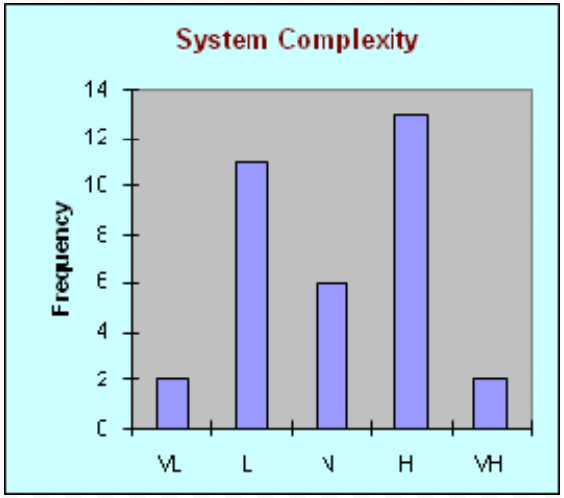


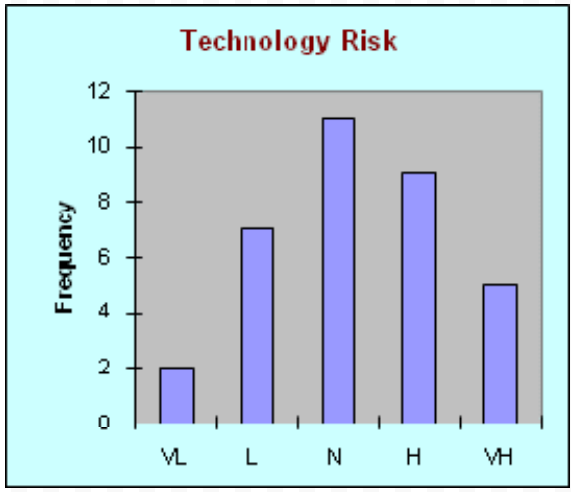


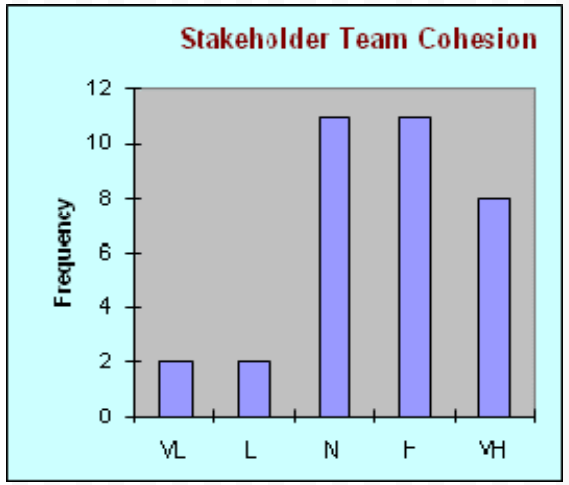
Program / Team Parameters

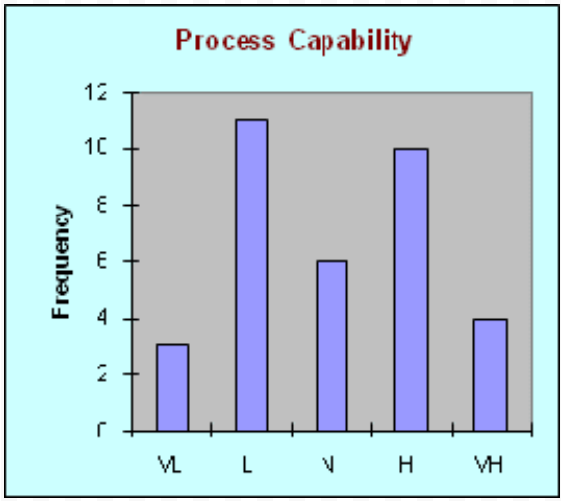




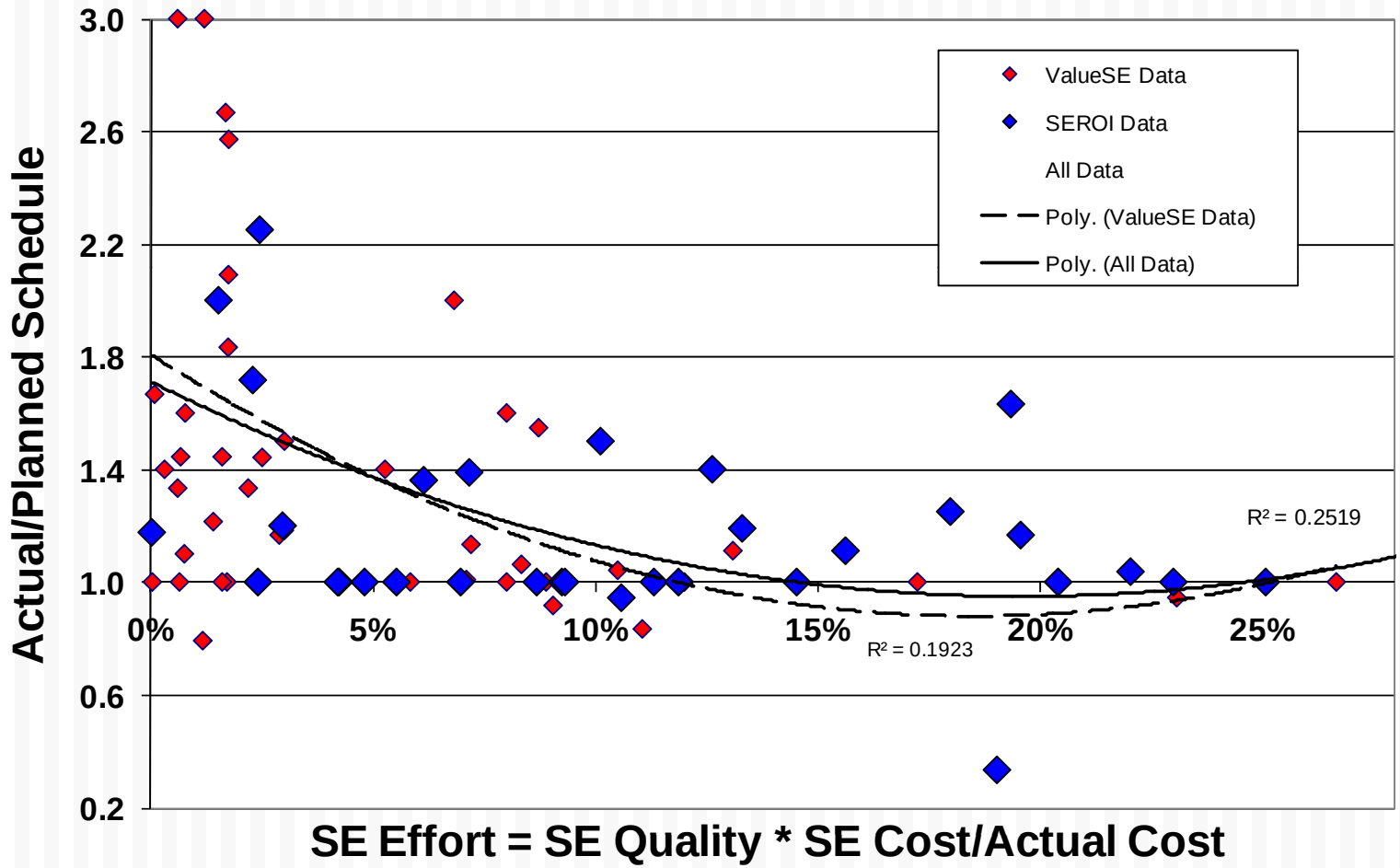






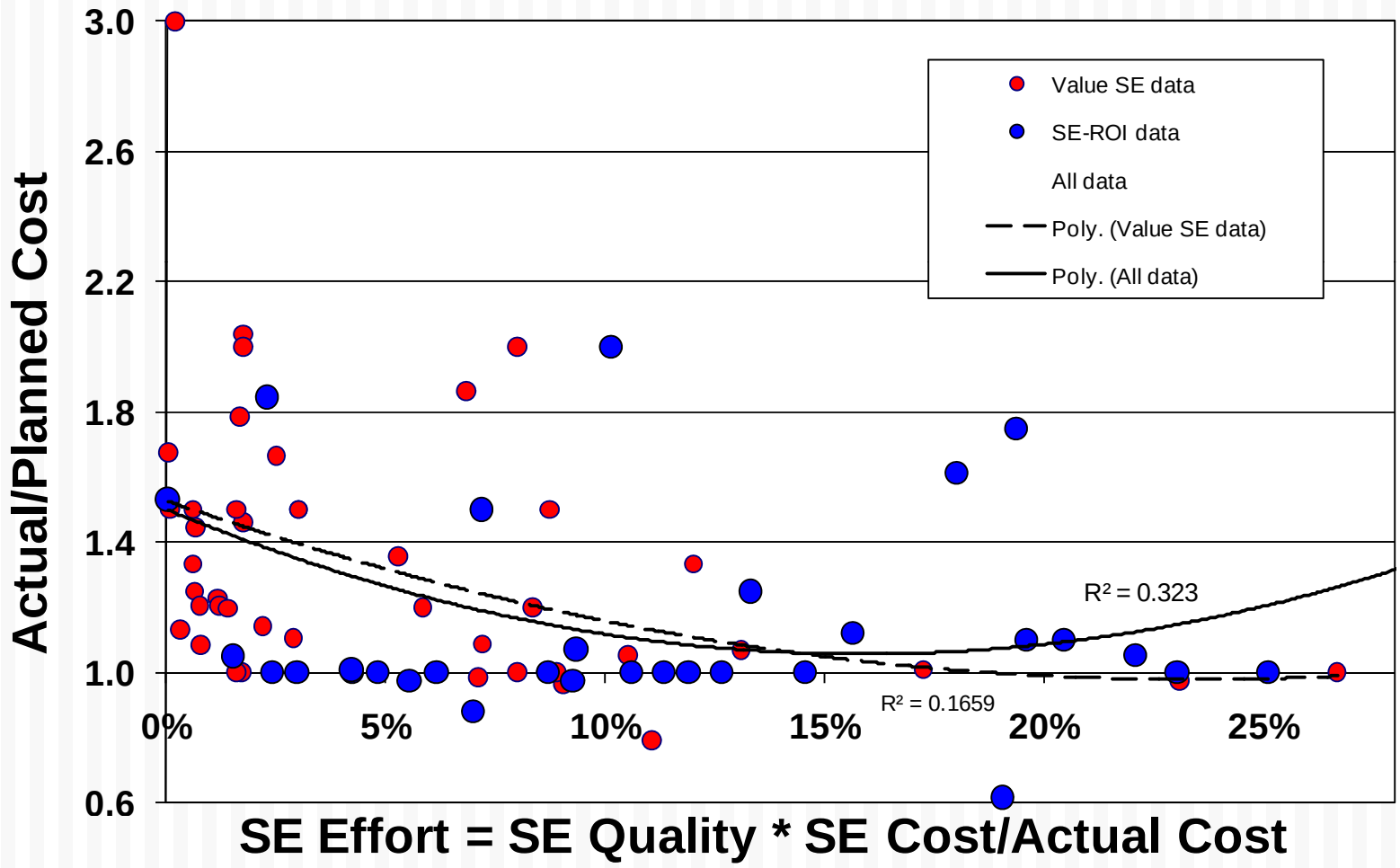


Schedule vs. SE Effort



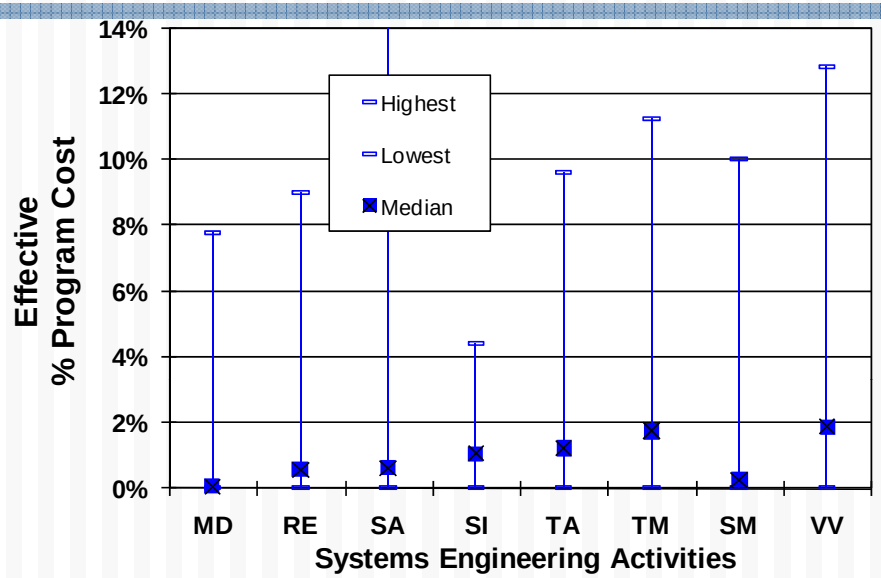
Caution: This is interim data.

Cost vs. SE Effort

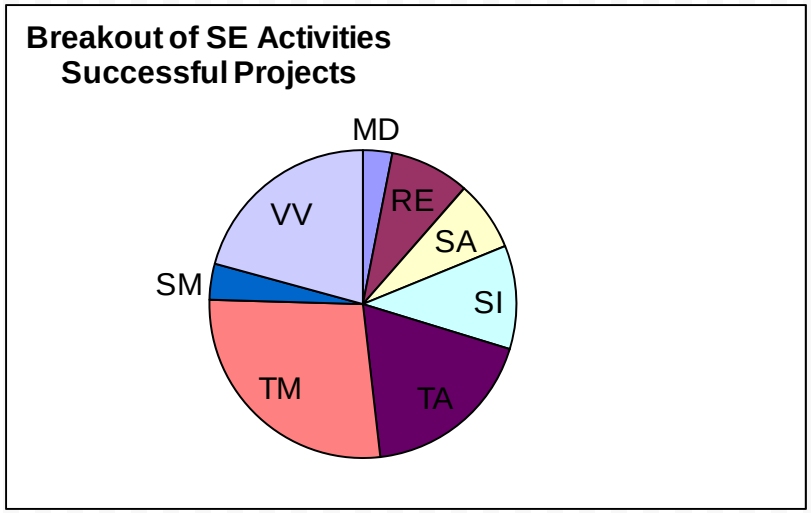


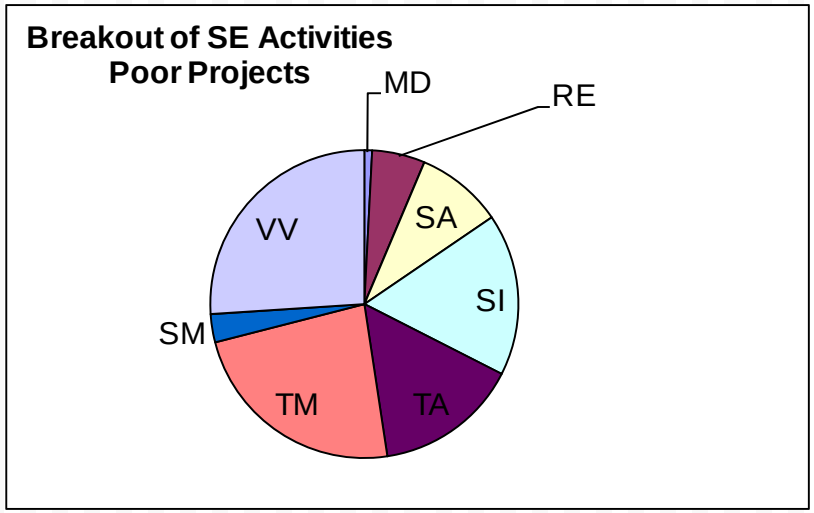
Caution: This is interim data.

Breakout by SE Activities



MD *Mission/Purpose Definition*
RE *Requirements Engineering*
SA *System Architecting*
SI *System Implementation*
TA *Technical Analysis*
TM *Technical Leadership/Management*
SM *Scope Management*
VV *Verification & Validation*

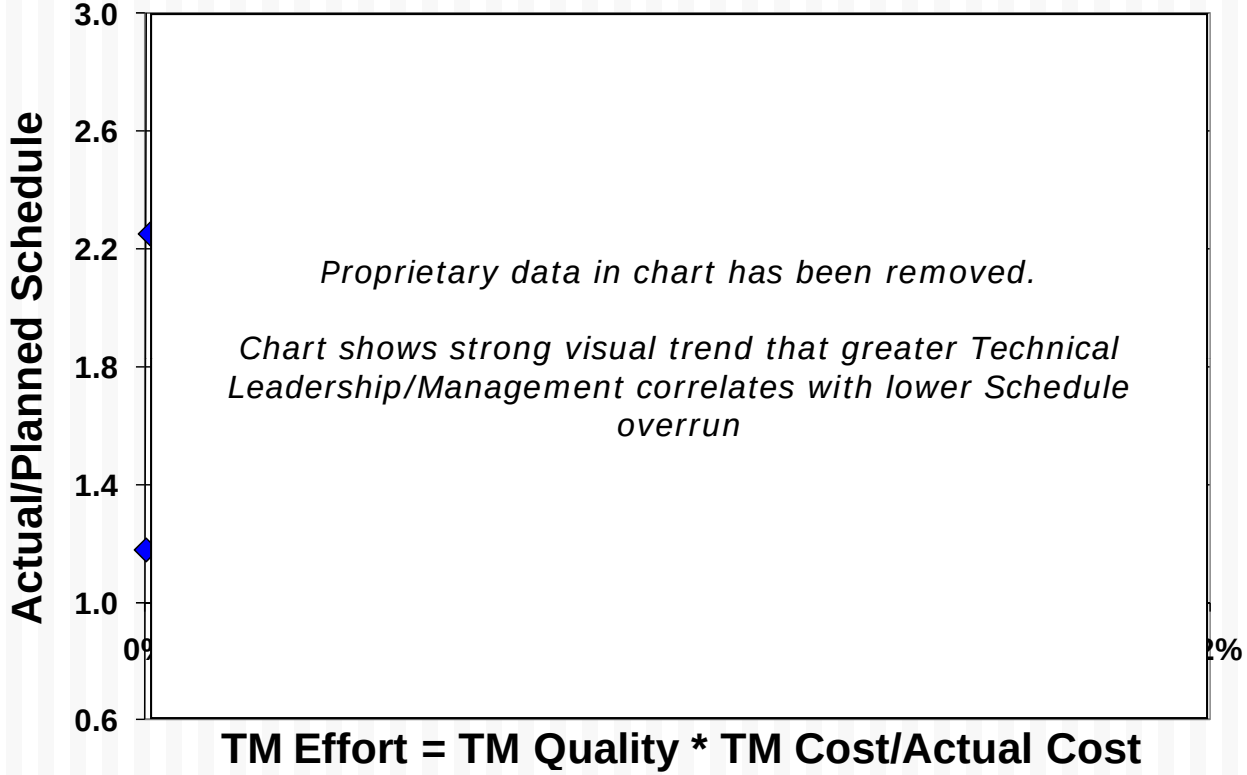




Caution: This is interim data.

Typical Data:

Schedule vs. Tech Lead'ship / Mgmt



Weaker visual correlation observed for:

MD Mission Definition

Strong visual correlation observed for:

ALL other activities

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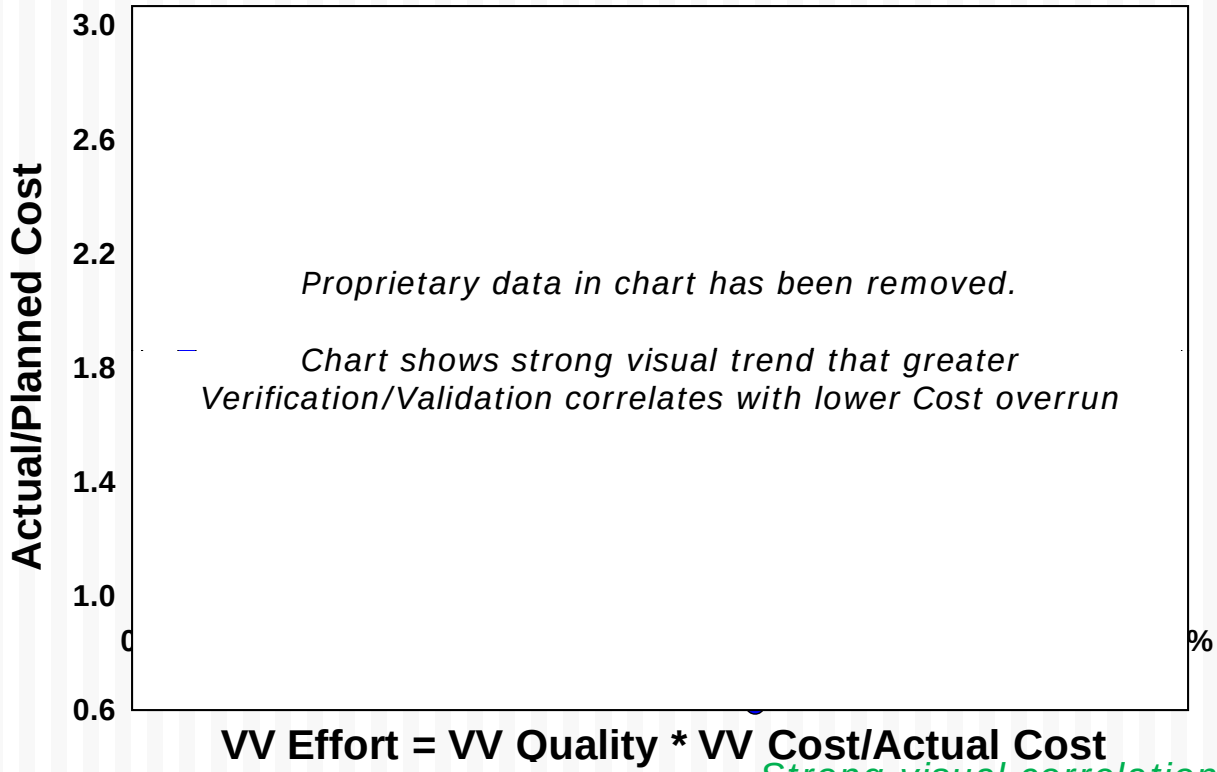
Caution: This is interim data, not yet reviewed and not ready for release.

Typical Data:

Cost vs. Verif/Valid



Weaker visual correlation observed for:

MD Mission Definition

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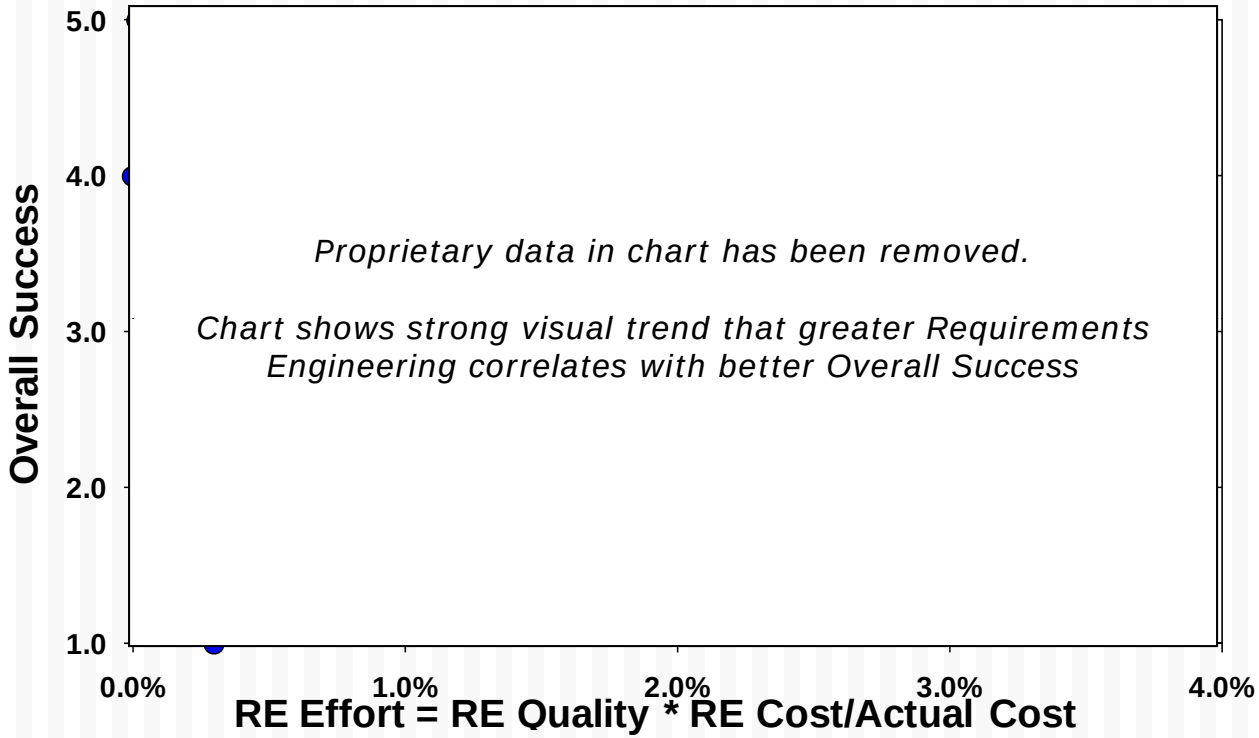
RE Requirements Engineering
SA System Architecting
TA Technical Analysis
TM Technical Leadership/Management
SM Scope Management
VV Verification & Validation

Caution: This is interim data, not yet reviewed and not ready for release.

Typical Data:

Overall Success vs. Reqs Engr



Weaker visual correlation observed for:

None

Strong visual correlation observed for:

MD	*Mission Definition*	*TM*	*Technical Leadership/ Management*
RE	*Requirements Engineering*		
SA	*System Architecting*	*SM*	*Scope Management*
TA	*Technical Analysis*	*VV*	*Verification/Validation*

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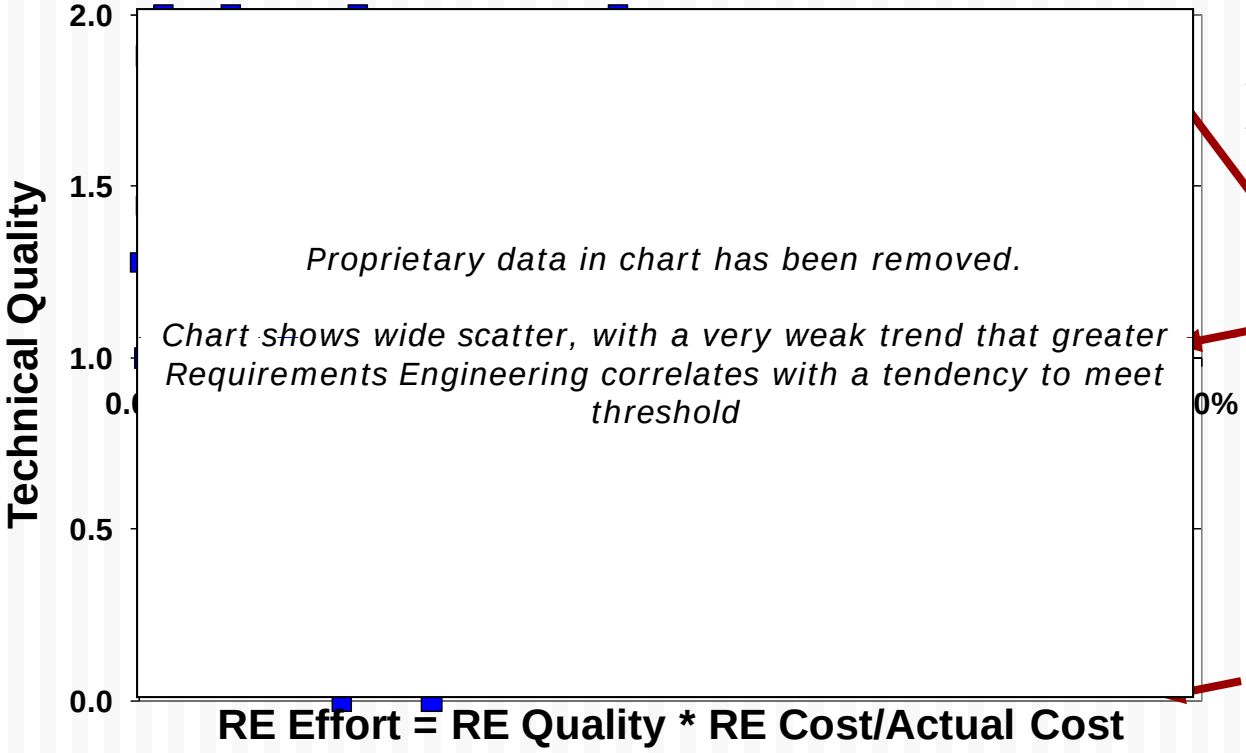
Typical Data:

Tech Quality vs. Reqs Engr



"Technical Quality" is based on compliance with KPP thresholds and goals

2.0 = Met goals

1.0 = Met thresholds

0.0 = Failed to meet

Weaker visual correlation observed for:

RE Requirements Engineering

Strong visual correlation observed for:

TA Technical Analysis

Correlation is toward threshold compliance versus goals. Perhaps calls into question lack of design or contractual emphasis on KPPs?

Caution: This is interim data, not yet reviewed and not ready for release.

Effect of SE Activities

- **Which activities correlate to better quality?**

Activity	Cost	Schedule	Overall	Technical[1]
Missn Defn[2]				
Reqs Engr				
Sys Arch	*Proprietary data in chart has been removed.* *Chart shows that nearly all systems engineering activities lead to better cost control, better schedule control, and better overall quality. Technical quality (as defined by KPP compliance) shows little correlation with most SE activities.*			
Sys Impl				
Tech Anlysis				
Tech Mgmt				
Scope Mgmt				
Ver & Val				

[1] *Projects aim at requirements compliance rather than goals*
[2] *For most projects, MD was performed in an earlier phase*

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Company Participation

- **Data gathering** – ***minimal impact***
  - **Select 2 to 4 programs**
  - **One day of interviews**
  - **2-hour sessions with PM+SE of each program**
  - **Strong protection of proprietary data**
- **Reports** – ***effective program benchmarking***
  - **Benchmark report within 30 days of session**
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    - ***Correlations found***
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Questions?

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Backup Slides SE-ROI Project

- Samples of SE-ROI interview data sheets
- Data security

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Program Characterization

GRADED QUANTITIES – Enter three specific numeric values for each.

	EASY	NOMINAL	DIFFICULT
Number of system requirements			
Number of system interfaces (external)			
Number of algorithms			
Number of operational scenarios			

OTHER QUANTITIES – Enter a specific numeric value for each.

	NUMBER		NUMBER
Number of unique components* in the system design		Number of developing organizations*	
Number of unique components* designed as part of the programme		Number of customer agencies* actively involved in the programme	
Number of components* integrated per system (multiple instances count)		System production quantity under this programme	
Number of documented trade studies* at the system level		Number of installation locations	
Number of formal tests* at the system level		CMMI level of parent organization (prime developer only)	
Number of formal test locations* at the system			

Subjective Parameters

SUBJECTIVE PARAMETERS - Evaluate each parameter on the scale given

Mission/purpose understanding	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Requirements understanding	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Requirements volatility (changes to requirements)	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Requirements growth (additions to requirements)	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Architecture understanding	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Overall system complexity	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Level of service requirements (environmental, safety, security, reliability, maintainability, etc.)	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Migration complexity			N ❑	H ❑	VH ❑	EH ❑
Technology risk	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Documentation	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Number and diversity of installations/platforms			N ❑	H ❑	VH ❑	EH ❑
Number of recursive levels in the design	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Stakeholder team cohesion	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Personnel/team capability	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Personnel experience/continuity	VL ❑	L ❑	N ❑	H ❑	VH ❑	
Lead system engineer experience level	VL ❑	L ❑	N ❑	H ❑	VH ❑	

Program Success

PROGRAMME SUCCESS MEASURES (COST/SCHEDULE/TECHNICAL)

Original planned cost ($ Total)	Original planned schedule (Months)	Original planned labor (Person-hrs)
Current projected cost ($ Total)	Current projected schedule (Months)	Current projected labor (Person-hrs)
Current cost expended ($ at time of interview)	Current schedule expended (Months after programme start)	Current schedule labor (Person-hrs)

Key Performance Parameter* (List the top 4 to 8)	Weight %	Threshold Value*	Goal Value*	Projected Value

STAKEHOLDER SUCCESS MEASURES

Amortized development – developer creates system product for a defined market segment	
Projected return on investment (%)	Projected period of return (Months after programme start)
Contracted development – customer creates contractual relationship with the developer	
Projected contract profit (% of cost)	

Systems Engineering

2. REQUIREMENTS ENGINEERING*

METHODS – REQUIREMENTS ENGINEERING What methods were used to perform requirements engineering? How well did they succeed?
TOOLS – REQUIREMENTS ENGINEERING What tools were used to perform requirements engineering? How well did they succeed?

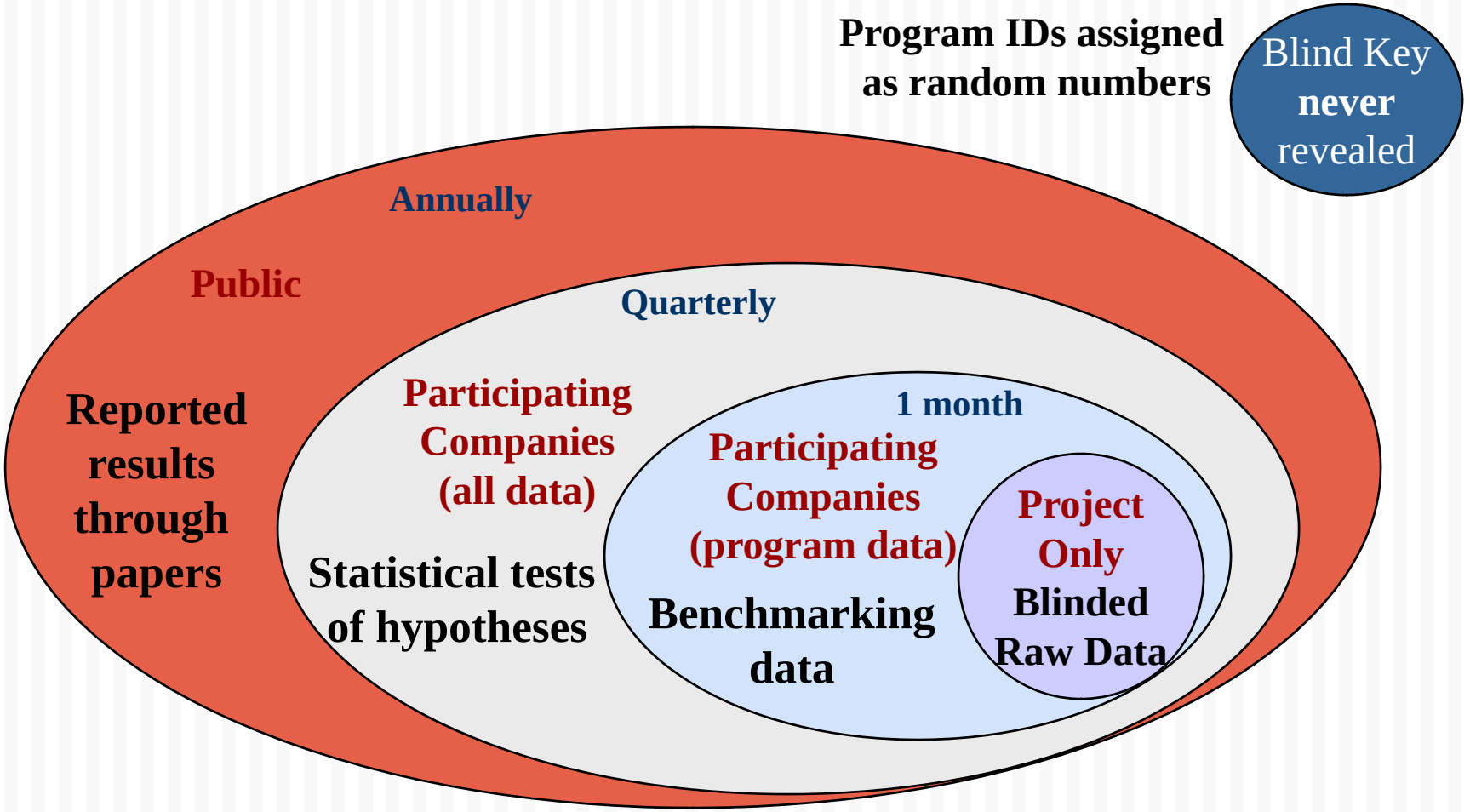
TOTAL EFFORT (PERSON-HR)	TOTAL COSTS ($)	QUALITY OF EFFORT VL L N H VH ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

METRICS – REQUIREMENTS ENGINEERING List any metrics used to evaluate the requirements engineering. Include the current value of each metric

One of the eight SE categories used

Honourcode, Inc.

Secure, Protective Data Layers



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Public data is statistical in nature, selected to protect sources