Honourcode, Inc.

Why Systems Don't Measure Up

SE-ROI Research

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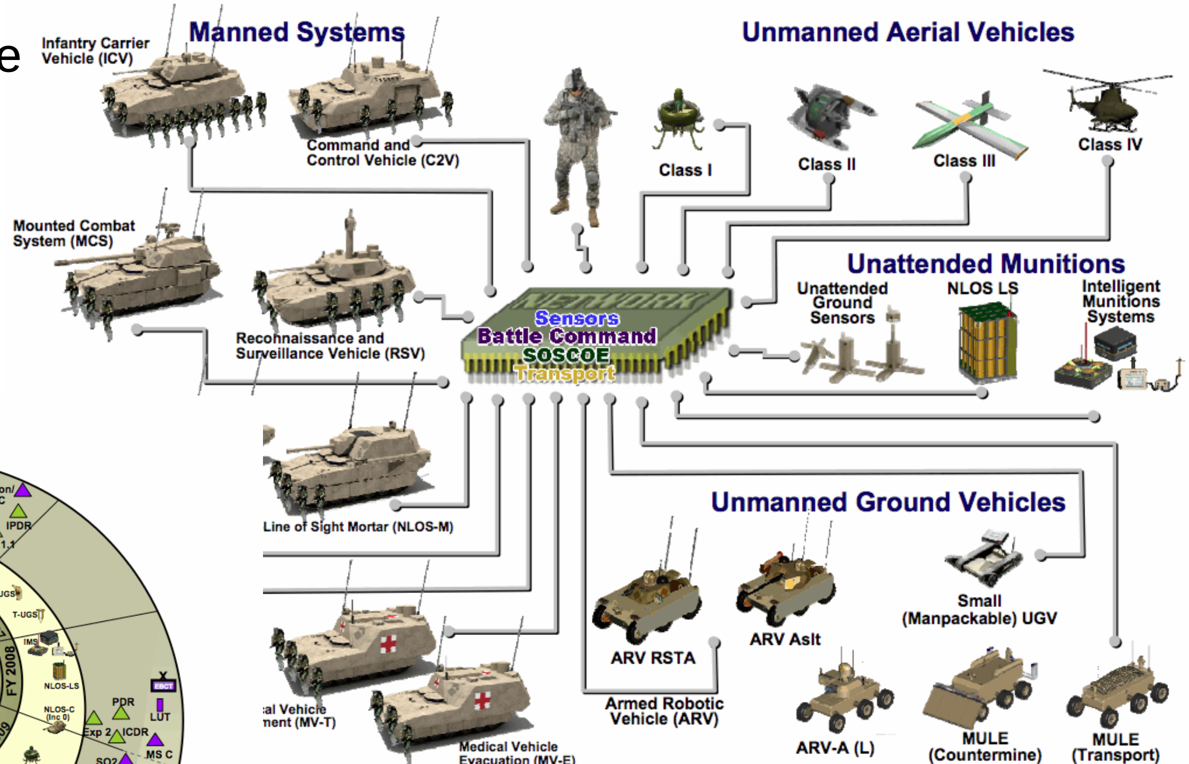
- ***Honourcode, Inc.***
- ***DASI (Univ of South Australia)***

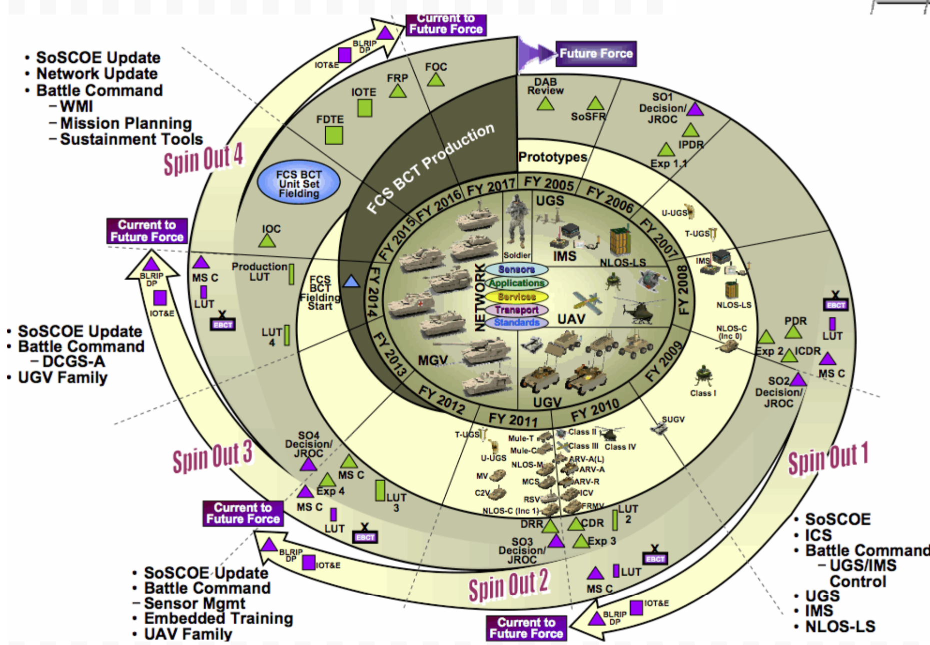
University of South Australia
Defence and Systems Institute

US Army Future Combat Systems

- Build the Army of the future
- Network centric design
- Planned as a Directed SoS



Decades-long Schedule



Component Systems

- The single largest acquisition program ever attempted by US DoD

FCS Approach and Results

- Technical approach 2003-2009
  - Single contractor to plan, integrate entire SoS
  - Layered, networked architecture
  - Worked to develop SoS Common Operating Environment (SOSCOE) to standardize interfaces
  - Task Integration Networks as a Service-Oriented Architecture
  - Extensive use of DoDAF to manage information
- Program cancelled after six years of work
  - Unable to meet goal of first FCS unit by 2008 (target was moved outward to 2015)
  - Too expensive to continue
  - All component systems growing in cost and complexity

Agenda

- SE-ROI Project
  - Goals and methodology
  - Primary results
- Systems Don’t Measure Up
  - Measures of Effectiveness (MOE)
  - Research data about relationship SE vs. MOEs
- How to Measure Up
  - Research-indicated causes
  - Known effective methods that aren’t typically used

SE-ROI Project

Methodology

Primary results

- SE correlates strongly with cost and schedule compliance
- Target SE level = 14.4%

SE-ROI Research Bottom Line

- Better programs expend
  - more SE effort overall
  - more mission definition, more tech leadership
- Nearly all SE activities correlate well with
  - Cost/schedule control
  - Stakeholder overall success
- No SE activities correlate with
  - System technical quality

SE today leads to better programs

– but does not lead to better systems.

- Results can be used to right-size SE
  - Right-sizing cost estimation method

SE-ROI Project

Interviews

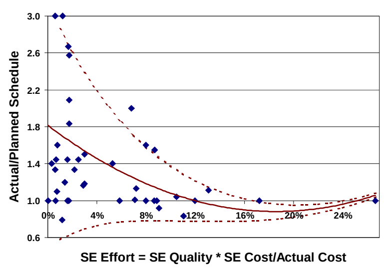
- **Just-completed programs**
- **Key PM / SE / Admin**
- **Translate program data into project structure**

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

Desired Results

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

Statistical correlation



Basic Demographics

Characteristic	ValueSE Data Set	SE-ROI Data Set
Number of organizations	Unknown	16
Number of data points	44	48
Funding method	Unknown	39 contracted, 9 amortized
Program total cost	\$1.1M - \$5.6B Median \$42.5M	\$600K - \$1.8B Median \$14.4M
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 35 mo.
Schedule compliance	(0.8):1 – (4.0):1 Median (1.2):1	(0.3):1 – (2.5):1 Median (1.1):1
Percent of program used in systems engineering effort, by cost	0.1% - 27% Median 5.8%	0.1% - 80% Median 17.4%
Subjective assessment of systems engineering quality (1 poor to 10 world class)	Values of 1 to 10 Median 5	Values of 1 to 10 Median 7

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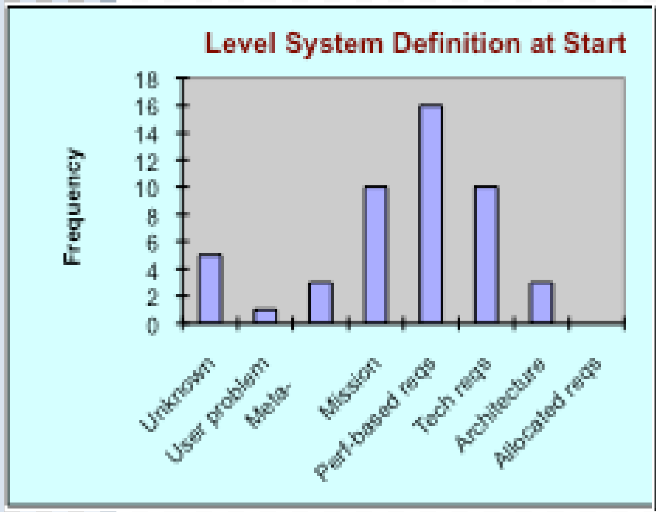
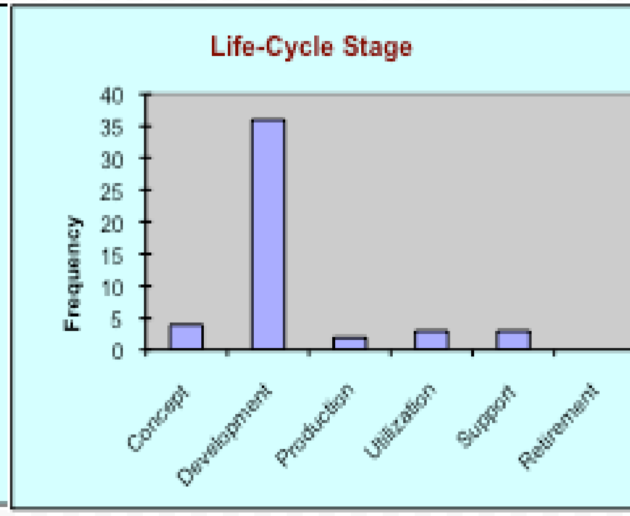
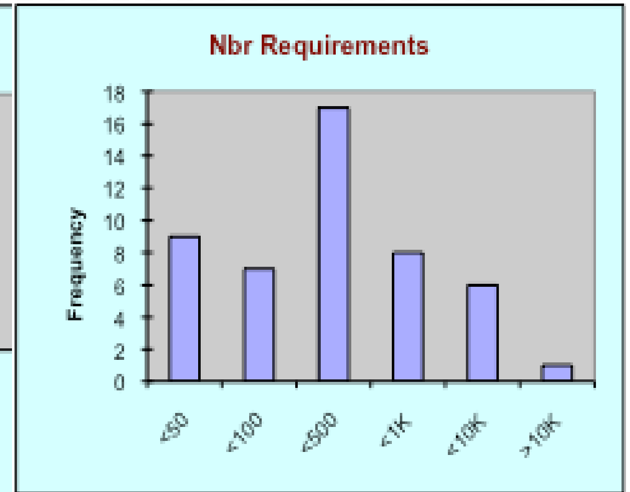
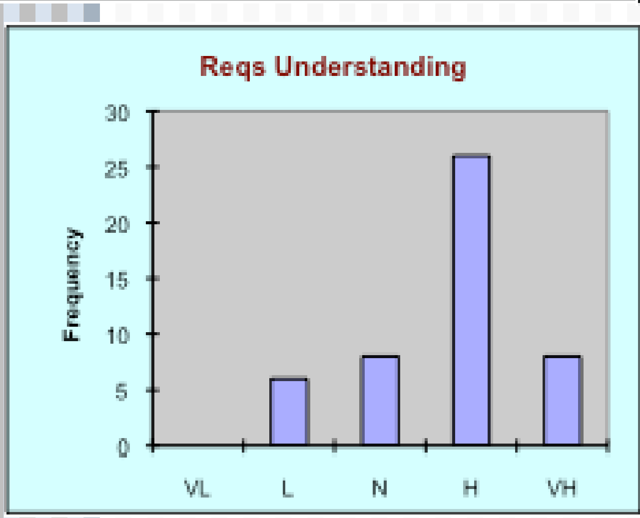
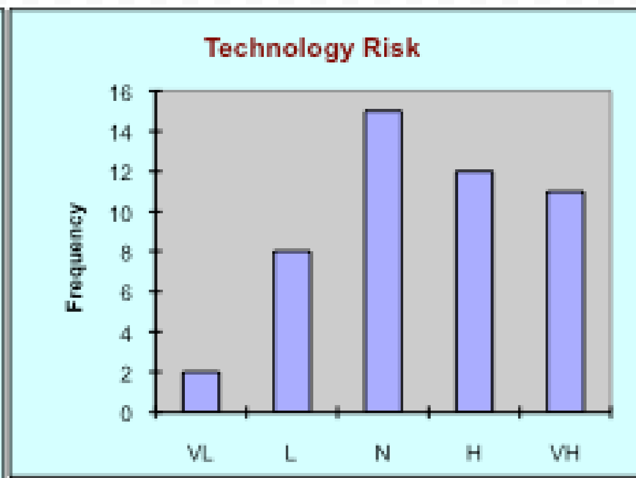
Variety of Programs

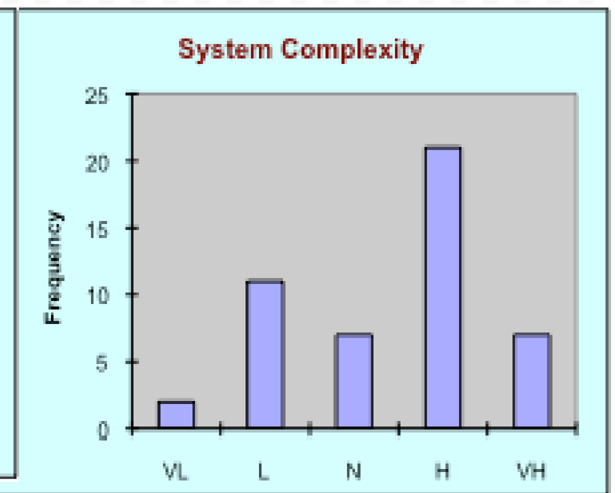




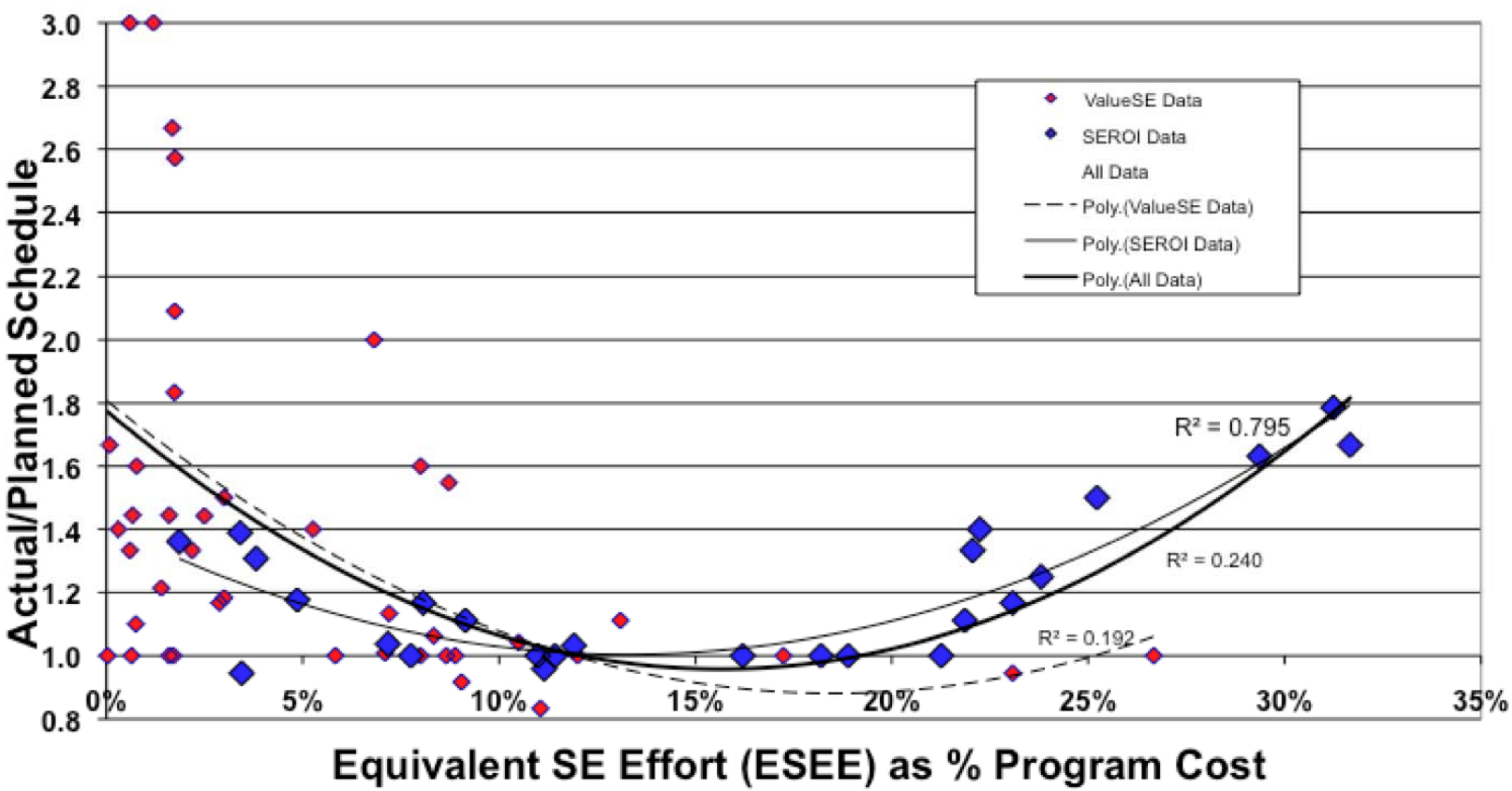




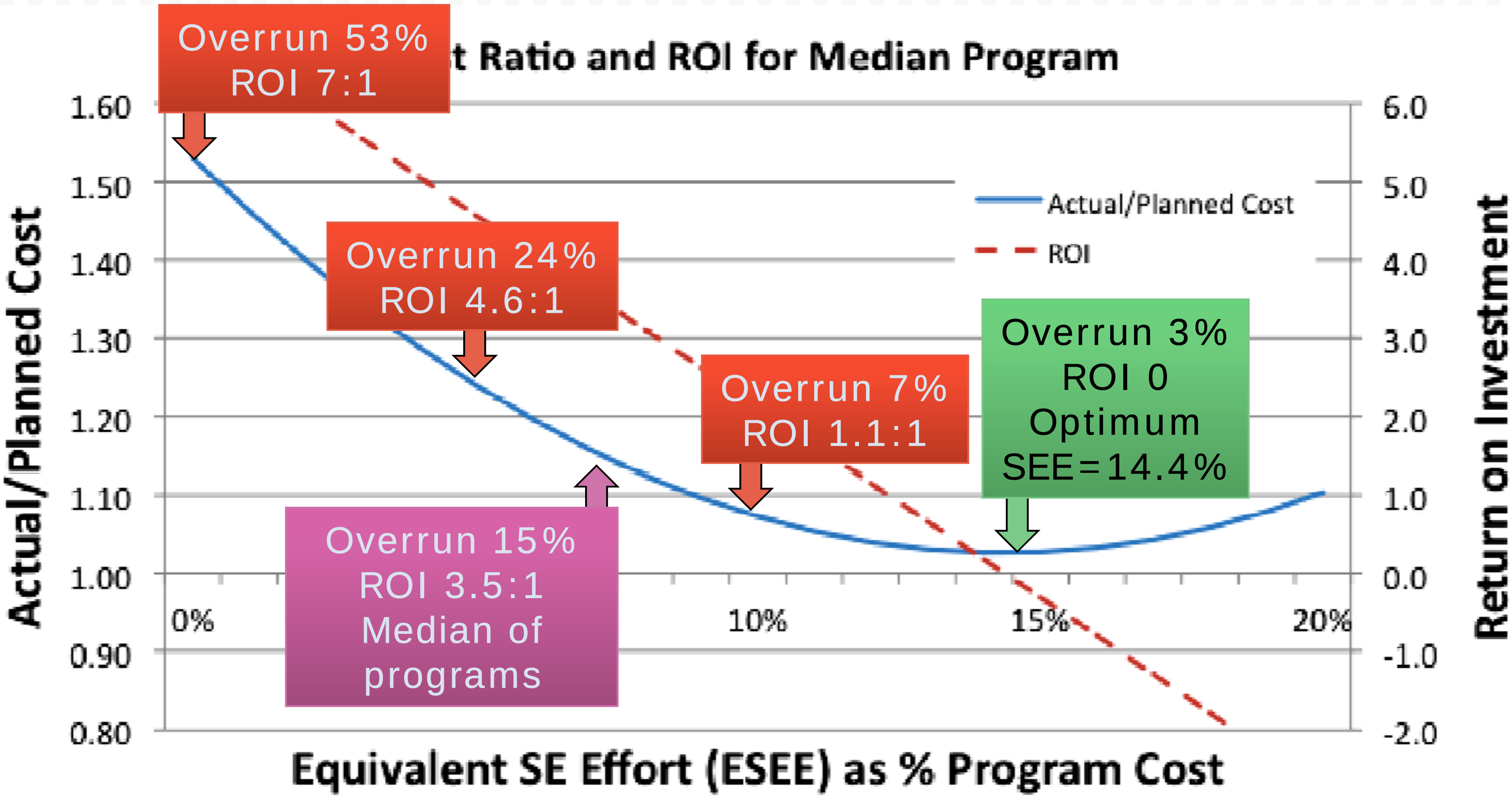




Schedule vs. SE Effort



Return on Investment



Systems Don't Measure Up

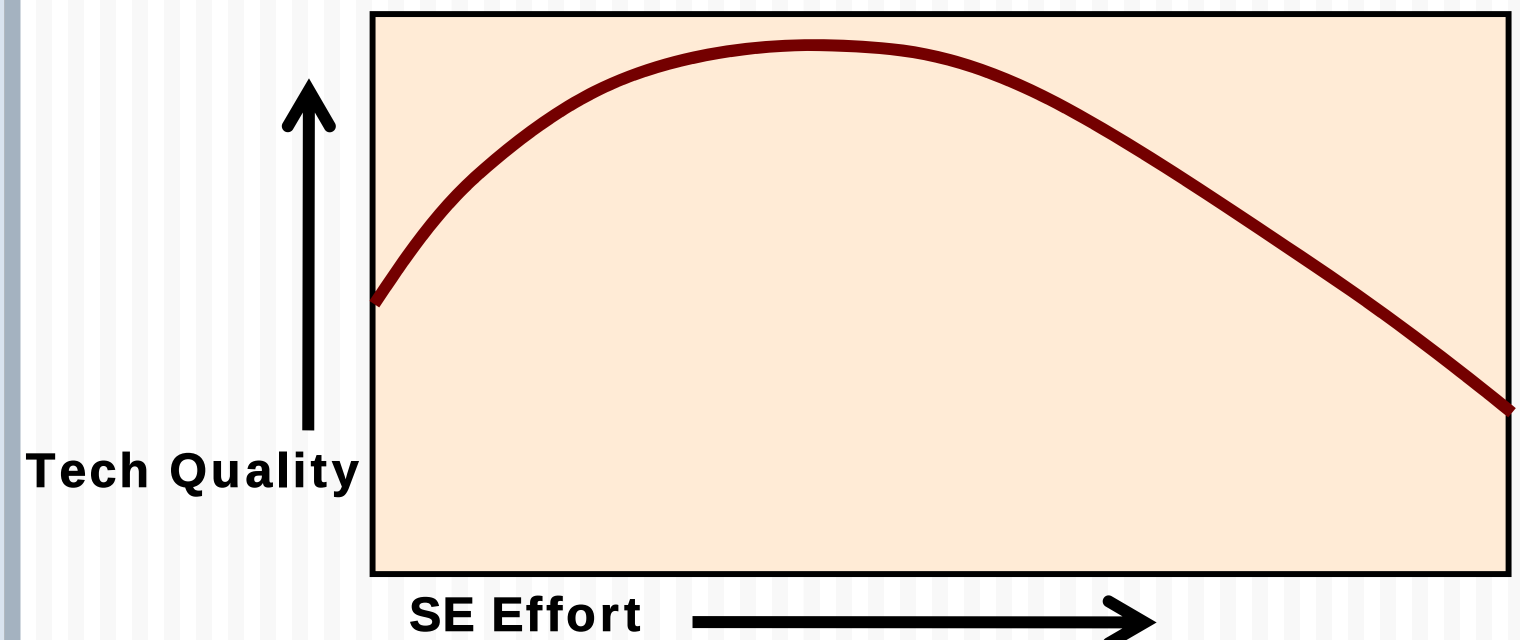
SE does not correlate with MOE quality

No SE activity correlates with MOE quality

Widely-Believed Hypothesis

There should be a significant correlation between the amount of SE effort and the technical quality of the system

Expected behavior



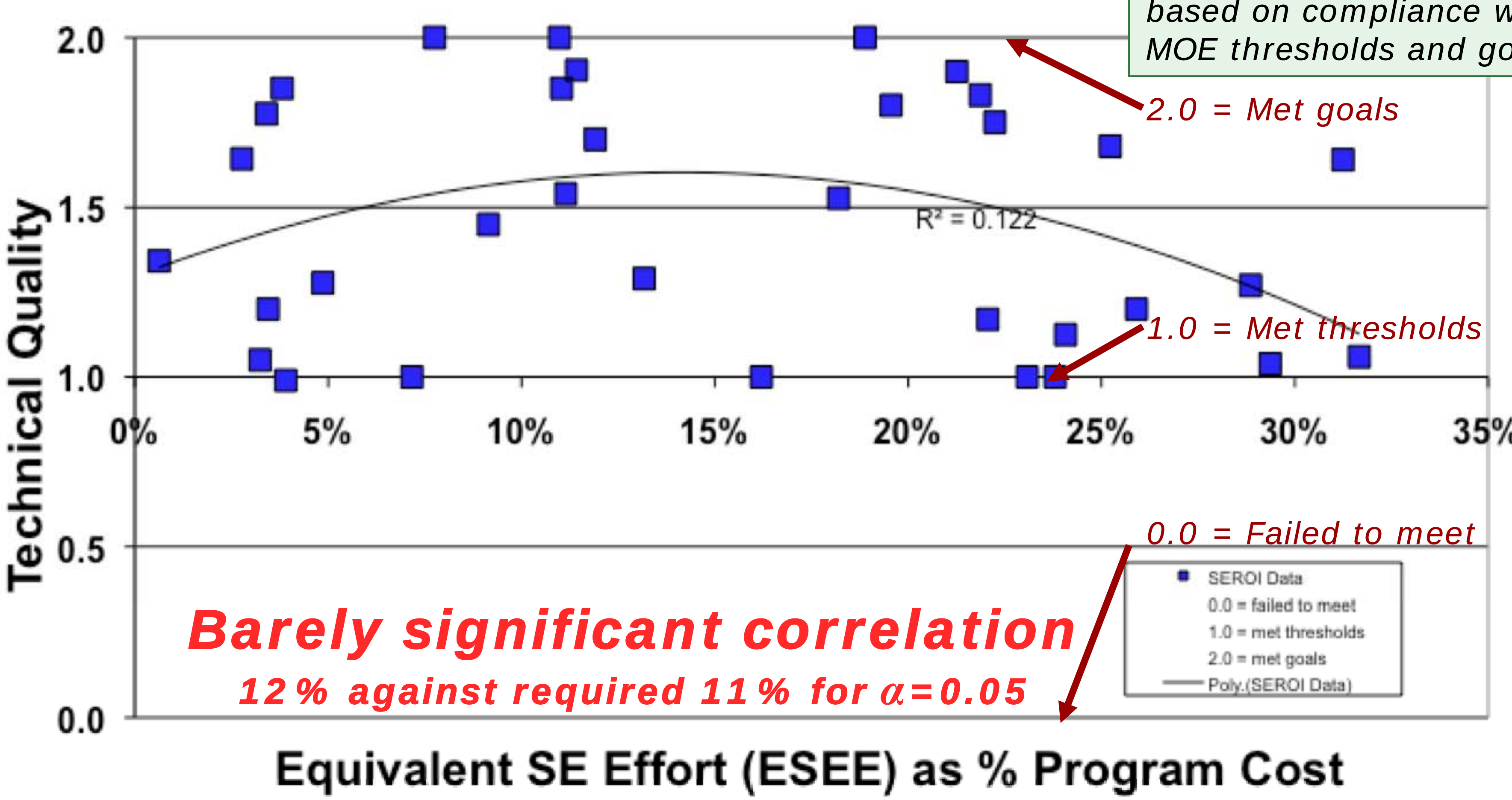
Honour (2002) "Quantitative Relationships in Effective SE"

Technical Quality based on MOEs

- Measures of Effectiveness (MOE) – quantifiable operational parameters that measure value to the stakeholders
- Interview method: interviewees are PM+LSE
  - Identify parameters that matter to the stakeholders
  - Describe threshold level, objective level as perceived by the stakeholders
  - Describe level actually achieved
  - Identify weights of the MOEs
- Calculation method
  - Scale all MOEs to common linear scale:
    "2" = objective; "1" = threshold; "0" = failure
  - Calculate Technical Quality = weighted sum

Tech Quality vs. SE Effort

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

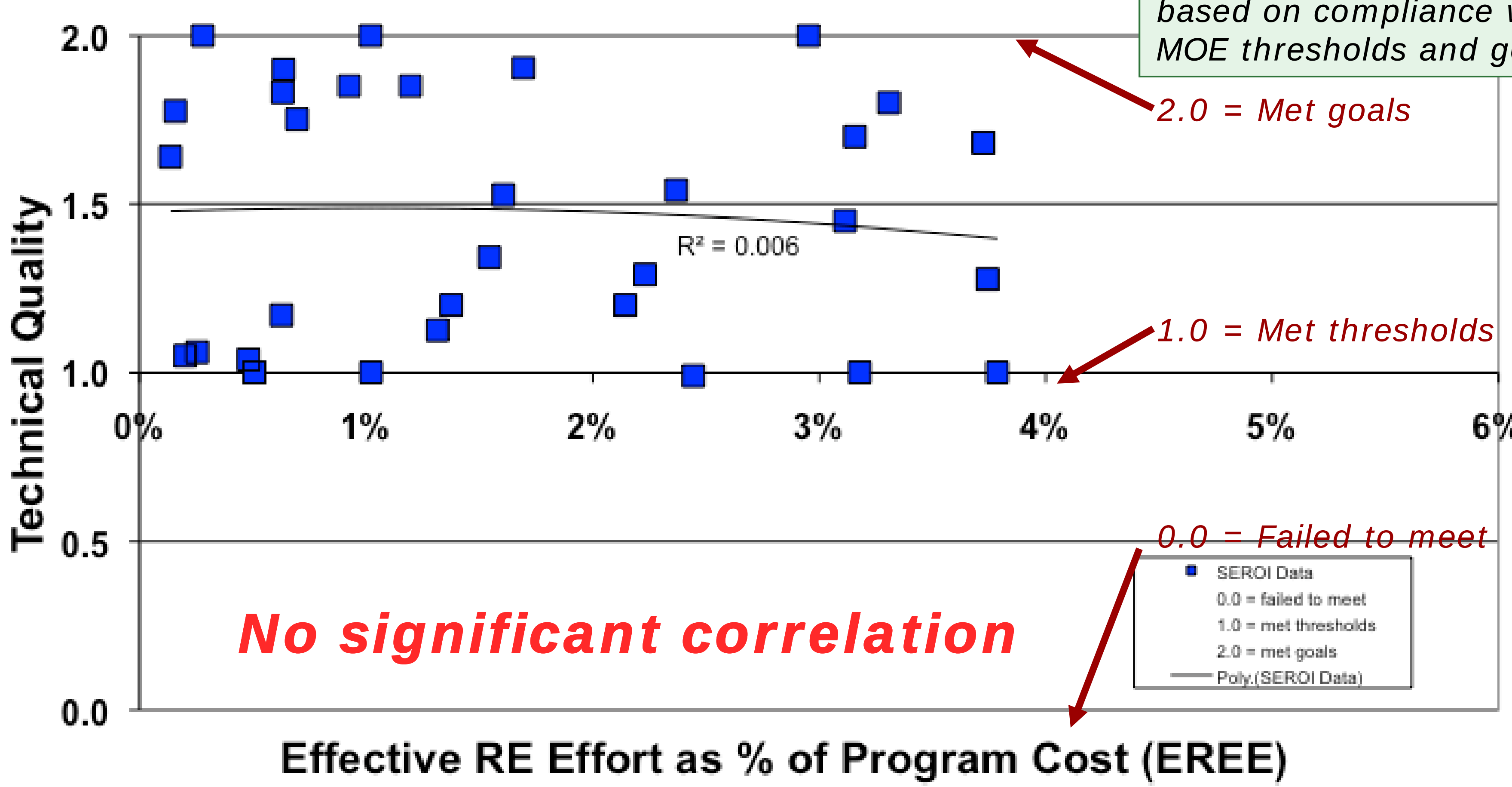


Barely significant correlation

12% against required 11% for $\alpha = 0.05$

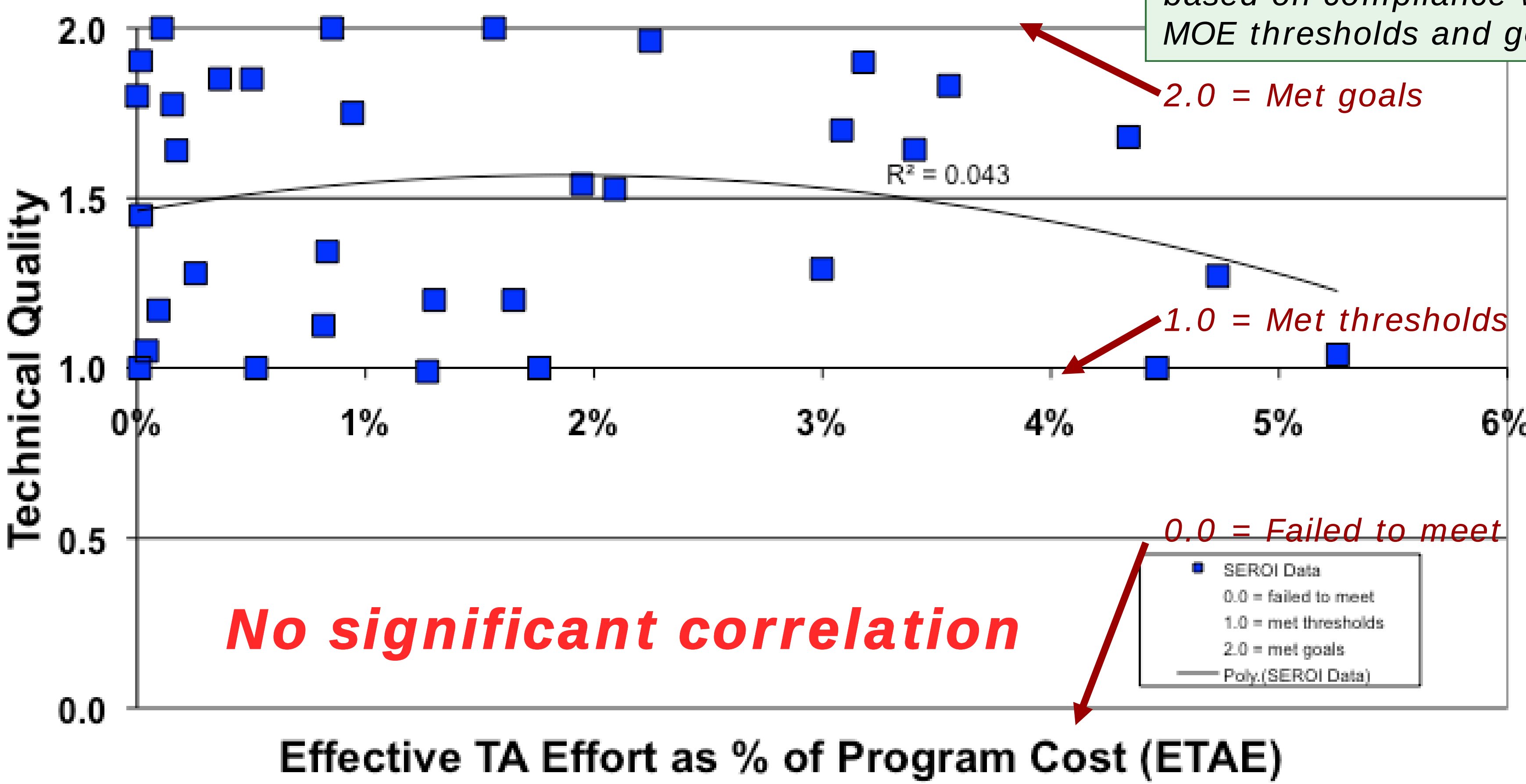
Tech Quality vs. Reqs Effort

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



Tech Quality vs. Tech Analysis

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



Effect of SE Activities

Activity	Code	Quantifiable Correlation Exists With			
		Cost Compliance	**Schedule Compliance**	**Overall Success**	**Technical Quality**
Total Systems Engineering Effort	SE	Yes	Yes	Yes	Perhaps
Mission/Purpose Definition Effort	MD	Yes	Yes	No	No
Requirements Engineering Effort	RE	Yes	Yes	Yes	No
System Architecting Effort	SA	Yes	Yes	Yes	No
System Integration Effort	SI	Yes	Yes	Yes	No
Verification & Validation Effort	VV	Yes	Yes	No	No
Technical Analysis Effort	TA	Yes	Yes	Perhaps	No
Scope Management Effort	SM	Yes	No	Yes	No
Technical Management/ Leadership Effort	TM	Yes	Yes	Yes	No

Results in the Real World

- Program runs smoothly
  - Cost overrun "not too bad"
  - Schedule overrun "not too bad"
- DT&E successful
  - System meets acquisition requirements (mostly)
- OT&E is a "shot in the dark"
  - Might be successful
  - Might be abject failure
  - Seemingly random program cancellations
    (But those in the program knew it was coming...)
- Post-analysis of failures
  - Lots of variability, but some common threads
  - "Inadequate front-end systems engineering"

How to Measure Up

Commonly known methods are typically not used

There are solutions

Finding Cause

- Correlation does not show cause
  - Does SE effort have no effect on MOEs? OR
  - Does working toward MOEs cause variability in SE?
- Can only determine cause from root cause analysis
  - Identify correlating factors
  - Examine underlying data for possible reasons
  - Develop theoretical hypotheses for cause-and-effect
  - Test the hypotheses

Observed Information

- From the SE-ROI data
  - Only two slight correlations with TQ
    - Lead SE experience level
    - Level of requirements understanding
  - Theory: *experience and deep understanding lead to better TQ*
- From the SE-ROI interviews
  - Requirements control was well known and universal
  - Few PM/LSE pairs were immediately aware of the MOEs
  - But PM/LSE pairs were able to identify the MOEs
  - Few teams used numeric methods
  - Theory: *over-focus on requirements acts to the detriment of TQ*

Testing the Hypotheses

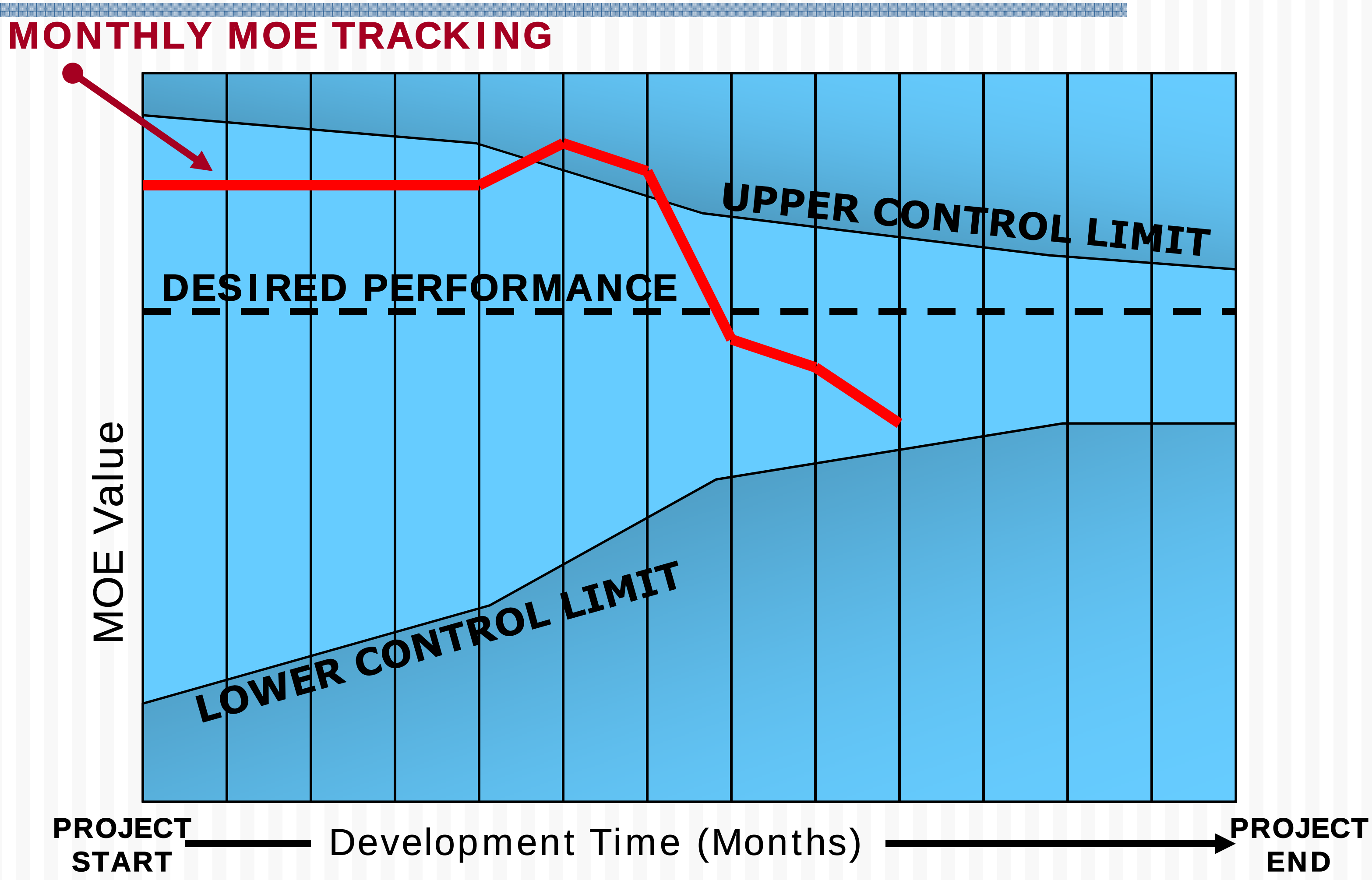
- *Experience and deep understanding lead to better TQ*
  - Theoretical: experienced LSEs have learned the importance of working with stakeholders; leads to better understanding of requirements and of the factors that matter
  - Data: teams with experienced LSEs were more likely to use numeric methods to track MOEs
- *Over-focus on requirements acts to the detriment of TQ*
  - Theoretical: vast number of requirements overwhelms development teams; binary requirements lead to a mindset contrary to quantifiable MOEs
  - Data: amortized (commercial) programs (with less focus on reqs) were much more likely to use numeric methods to track MOEs

Performance-Based Acquisition

- Performance-based specifications
  - Focus on key parameters that matter to stakeholders
  - Identify ranges of acceptable and desired values
  - Reduce significantly the total number of requirements (and thereby reduce cost to track & verify)
- Compatible contracting methods
  - Incentive fee contracts based on technical quality
  - Developer identifies the detailed requirements
    - Verification proof by developer
    - Acquirer oversight and certification
    - (Model: FAA, FDA certifications)

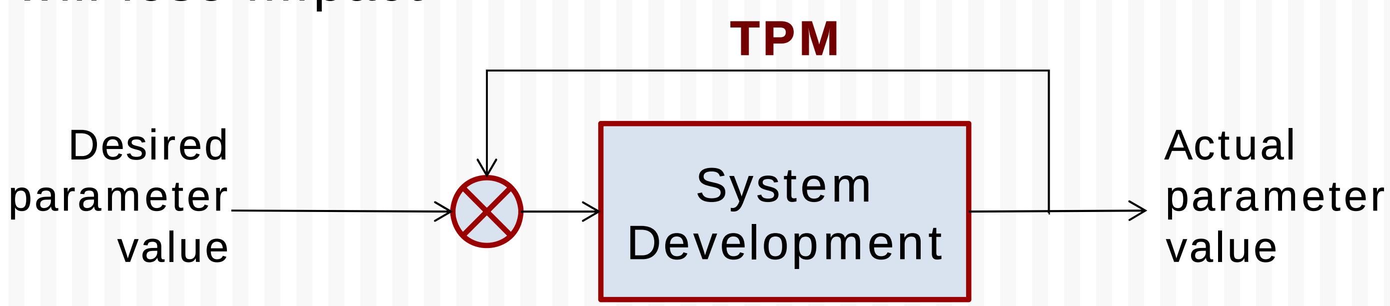
Known Numeric Methods to Control TQ

Tech Performance Measurement



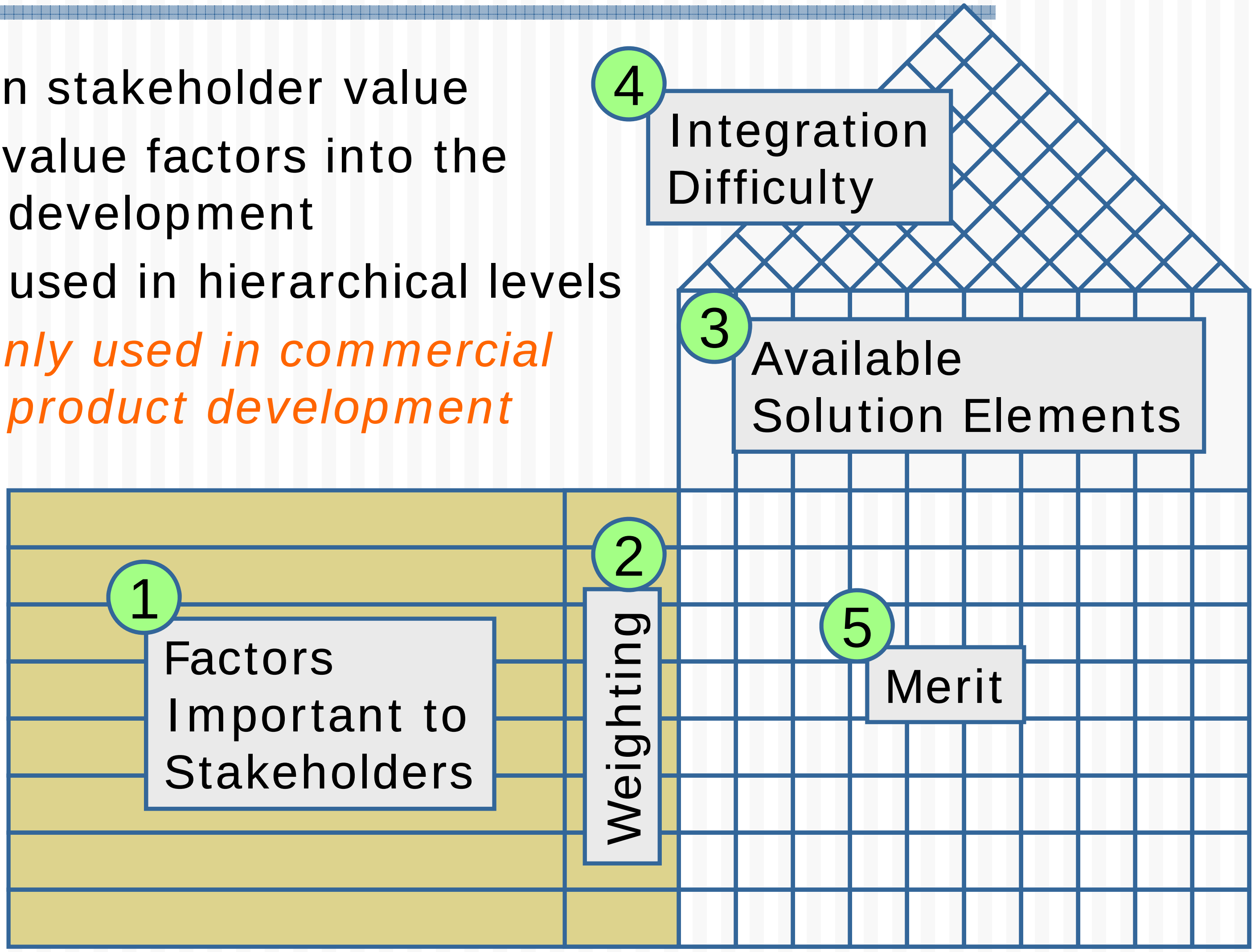
TPM Power

- Power of TPM is in what you do with the tracking!
  - TPM charts do nothing in themselves
- Create feedback loops
  - Affect the people who can affect the parameter
  - Use leadership methods
- Restrict TPM to just a few key parameters
  - Can track many more
  - Only have 4-5 visible at any time
  - More will lose impact



Quality Function Deployment

- Focus on stakeholder value
- Deploy value factors into the system development
- May be used in hierarchical levels
- *Commonly used in commercial system product development*

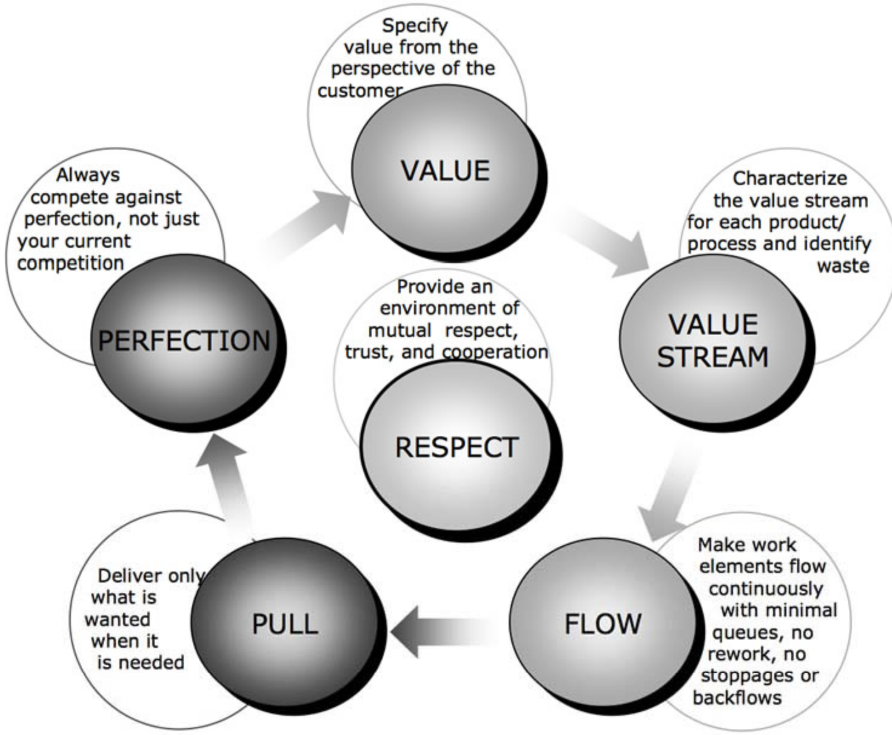


Known Numeric Methods to Control TQ

Six Sigma

Focused on Value Measures

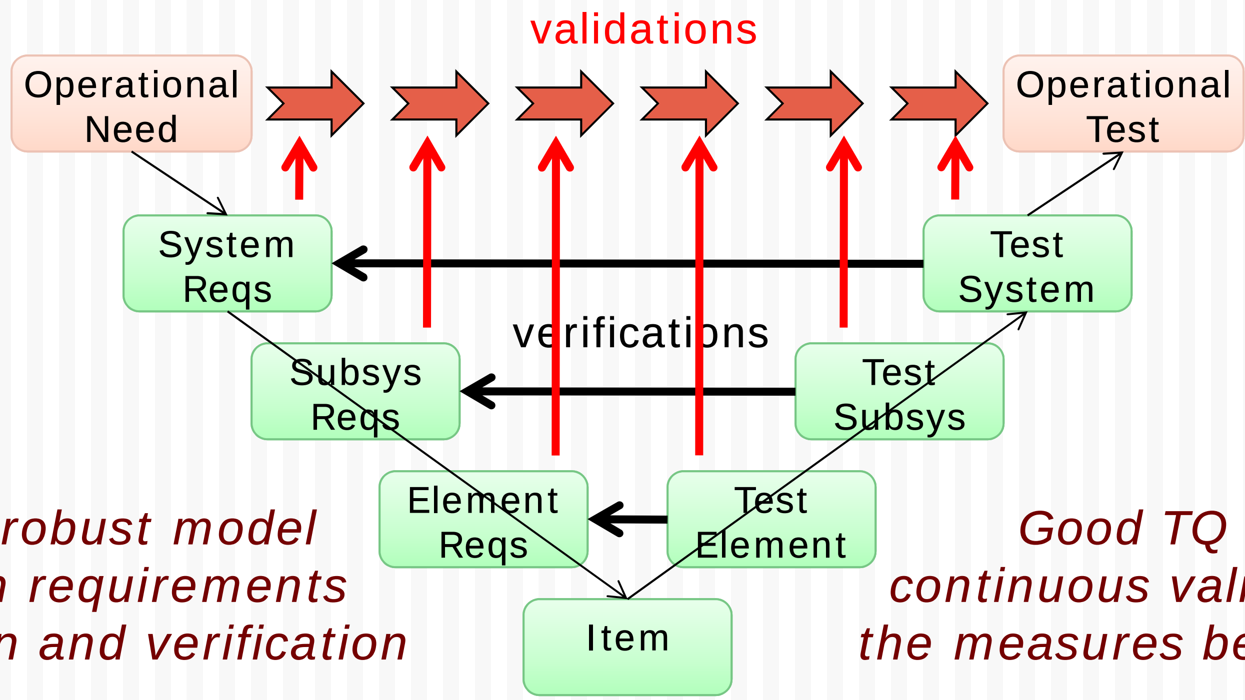
- Identify what brings value to the stakeholders
- Determine measures that quantify that value
- Create calculation and presentation methods
- Repetitively gather, calculate, and present the measures
- *Commonly used in commercial system product development*



Often coupled with Lean approaches

Continuous Operational Validation

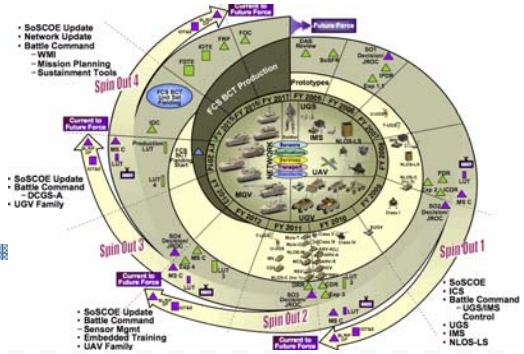
- Stakeholder value function changes over time
  - New technologies, new perceptions, new ideas
- Measurement methods must track changing reality



Vee is a robust model based on requirements allocation and verification

Good TQ demands continuous validation of the measures being used

FCS Lessons



- The ORD was developed in a hurry, with too little technical analysis or understanding
- Requirements were not ranked hierarchically early enough
- System-level requirements were not effectively subordinated to SoS-level ones
- Large number and specificity of system-level requirements precluded trades to meet SoS-level requirements and constrained the structure of the architecture.
- Ultimately, [all requirements] were threshold requirements and had the same implicit level of prioritization.
- Revalidating operational concepts periodically will ensure that the capability being acquired remains relevant

RAND (2012) "Lessons from the Army's Future Combat Systems Program"

Summary

Bottom Line

- Systems today do not measure up
  - SE correlates well with cost and schedule compliance
  - Target SE level = 14.4%
  - No SE activities correlate with system technical quality

SE today leads to better programs

– but does not lead to better systems.

- Experience and deep understanding lead to better technical quality
- Emphasis on binary requirements is good for acquisitions, but acts to the detriment of technical quality
  - Numeric methods work better for technical quality
- Long-known methods to control system technical quality exist *but are rarely used*
  - PBA, TPM, QFD, Six Sigma, continuous validation

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Questions?

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