Australian Systems Engineering Workshop
28-30 October 2015, Sydney, NSW, Australia

Determining Return on Investment for MBSE, SE & SoSE

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Outline

- Rationale and background
- How much SE is needed
- When & where SE is most needed
- A RoI approach for capability investment decisions
- Towards a methodology for selecting an MBSE enterprise improvement options based on RoI
- The next steps

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RATIONALE AND BACKGROUND

Rationale

- It is generally accepted that continuous improvement are vital to organisational vitality
- Organisational interventions produce numerous proposals that compete for funding
- Need to select between the various proposals
- Selection basis:

  Potential value of each proposal to the organisation

Key Questions

- What are the organisational investment priorities?
- What is the appropriate amount of investment for any given activity?
- How should the investment effort be phased over time?

- Return on investment is often used to compare investment opportunities

Why Selection of Proposals is Challenging

- We are comparing apples and oranges
  - Marketing initiatives
  - IT infrastructure upgrades
  - Manufacturing infrastructure upgrades
  - MBSE initiatives
  - New buildings and facilities
- Socio-political process not just financial
- Each will have a different payoff window – which could be decades
- Each will pursue different aspects of the corporate strategic plan

The ‘Return on Investment’ Concept

- RoI comes from financial circles

RoI = Net profit / Investment cost

- Investment cost is fairly easy to quantify
- Net profit, less so:
  - For a Government department or not-for-profit organisation, the concept of “profit” is foreign
  - For a company, return on good engineering improvement:
    - takes some time to flow through
    - can be difficult to quantify in simple accounting terms

Solution: Let’s look at the value SE can add

Data on the value of Systems Engineering

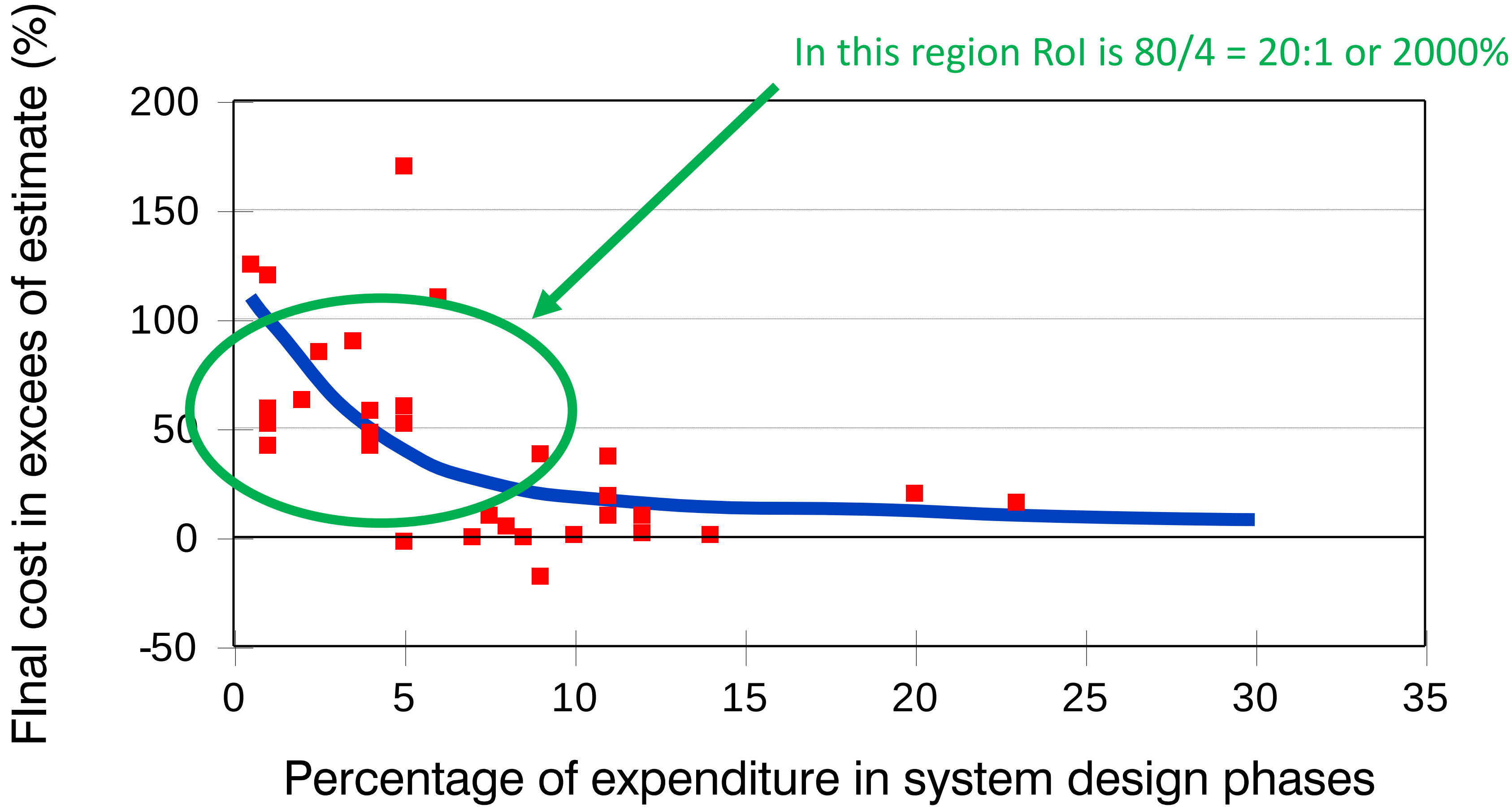
HOW MUCH IS NEEDED

International Perspective

- Pre 1995 NASA evidence shows that if less than 5% of the budget is spent before detailed design, the cost overruns are immense.
- UK MoD Downey procedures (1965, that cite a 1948 report) call for up to 15% expenditure on conceptual design.
- Australian Kinnaird report (2002) has the same finding.

NASA Experience: Overrun vs SE Effort

(NASA, 1995)



Standish Research Lessons Learned

(US Commercial Software Development, Standish, 1995)

- 365 organisations
- 8380 applications
- Some improvement reported in recent years

Outcome	Description	Percentage
Project success	Project completed on time, on budget, with all features and functions as initially specified.	16.2 %
Project challenged	Project completed but over budget, over time, with fewer features and functions than initially specified.	52.7 %
Project impaired	The project was cancelled at some point during the development cycle.	31.1 %

Standish Research Lessons Learned

Criteria cited for the fate of projects by percentage

Index	Success Criteria	Points	Good Systems Engineering covers
1	User involvement	19	✓
2	Executive management support	16	✓
3	Clear statement of requirements	15	✓
4	Proper planning	11	✓
5	Realistic expectations	10	✓
6	Smaller project milestones	9	✓
7	Competent staff	8	✓
8	Ownership	6	✓
9	Clear vision & objectives	3	✓
10	Hard-working, focussed staff	3	✓
TOTAL		100	

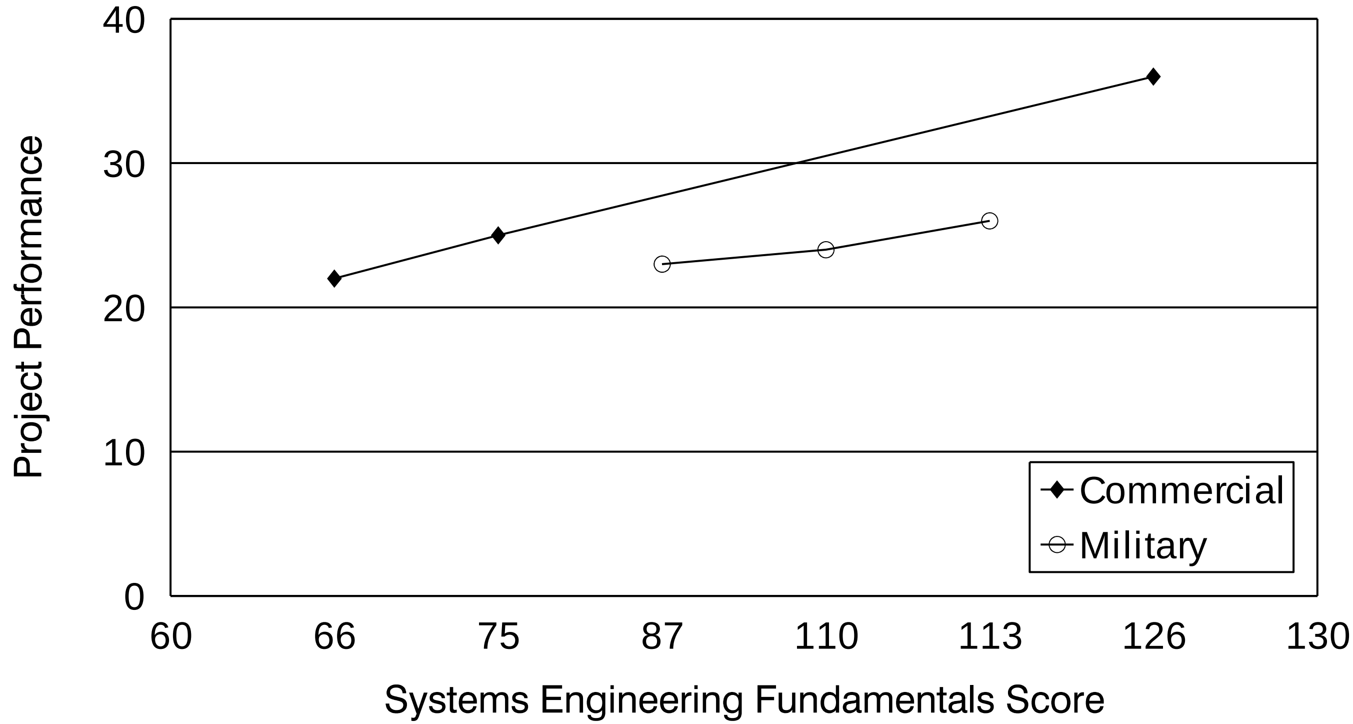
The Standish project success potential metric (The Standish Group, 1995).

"Following established SE/SwE practices would avoid around half of project failures."

Aerospace Industry Lessons Learned

(Moody *et al*, 2007

Project performance (technical, cost, schedule) …



… correlated with getting the SE fundamentals well established at the beginning of a project

IBM SE Effectiveness Study

(Barker, 2003)

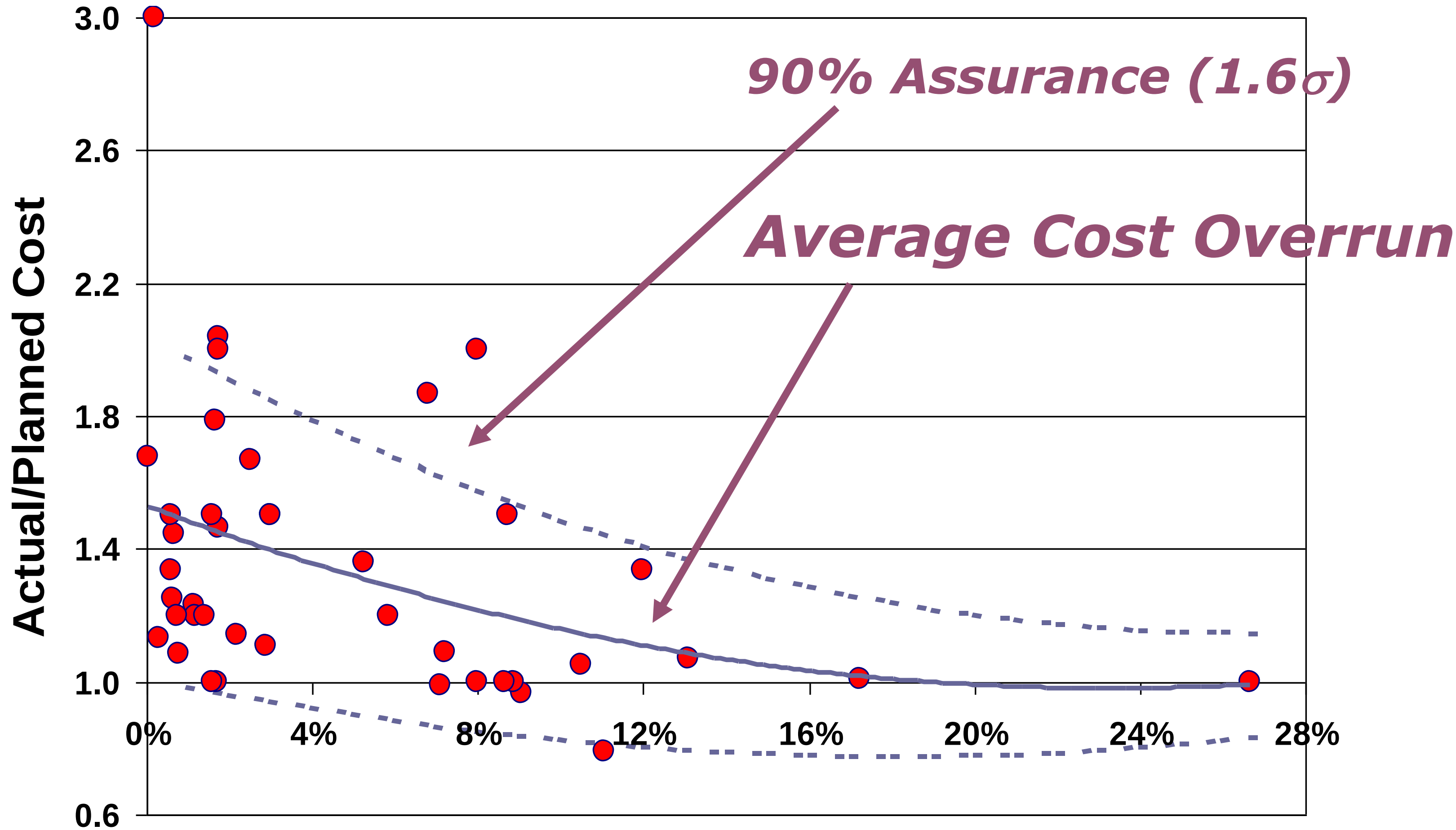
- Study of eight software product development projects during upgrade of SE processes
- Initial cost = $1350/point
- With improved SE cost = $944/point

INCOSE Center of Excellence and Value of SE WG Research Findings

- Eric Honour has been spearheading an INCOSE research program to identify the value of systems engineering.
- The work has been presented at INCOSE symposia from 2002 onwards
- Also work Joe Elm in NDIA/INCOSE Value of SE project

- **43 respondents**
- **1 project not completed**
- **Values $1.1M - $5.6B**
- **SE Cost 0.3% - 26%**

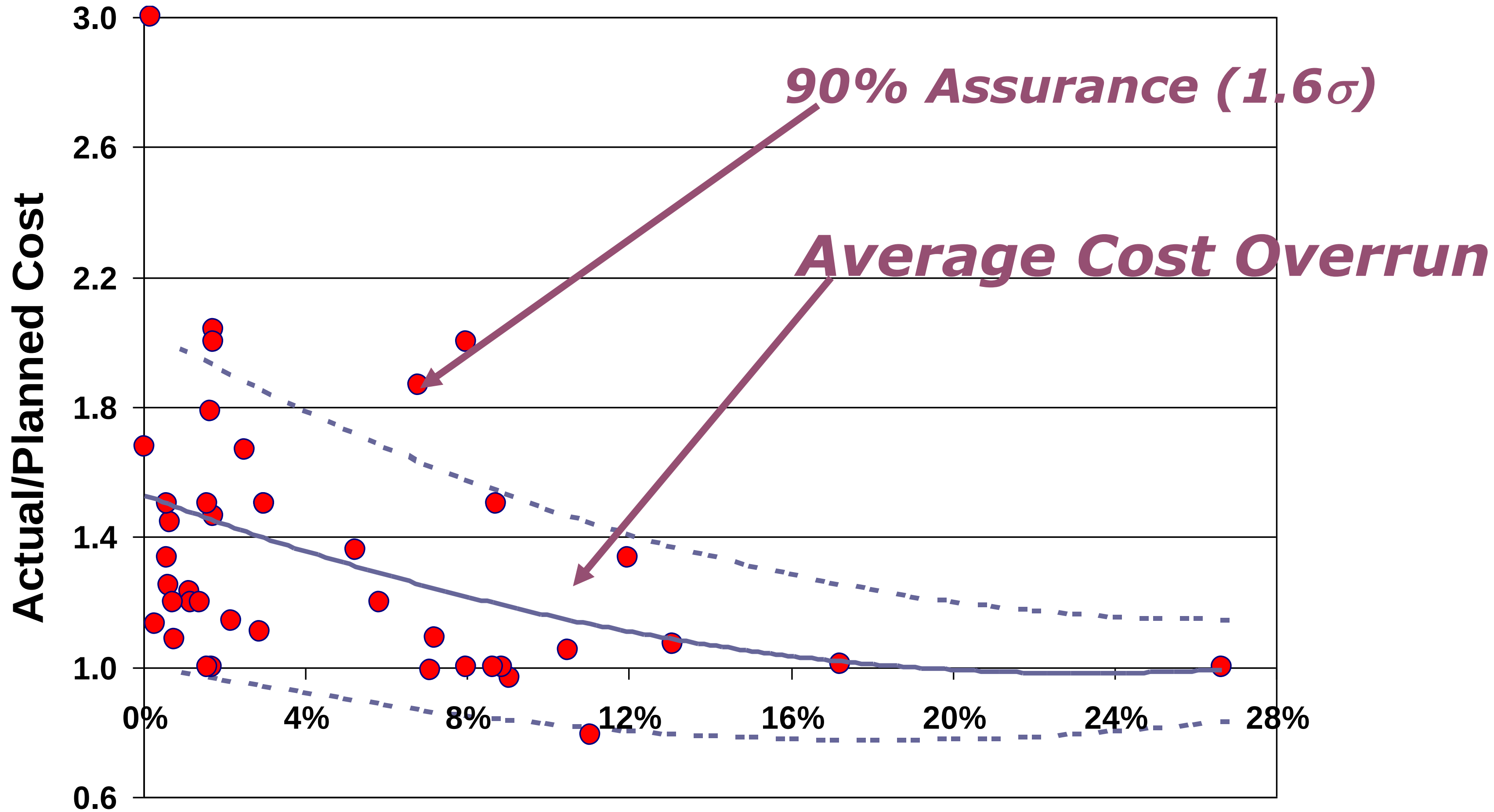
Honour's Value of SE Project: Cost Overrun versus SE Effort



SE Effort = SE Quality * SE Cost/Actual Cost

Source: SECOE 01-03 INCOSE 2003

Schedule Overrun versus SE Effort



SE Effort = SE Quality * SE Cost/Actual Cost

Source: SECOE 01-03 INCOSE 2003

Conclusions on the *Value of SE*

- Increasing SE effort improves development quality
  - Cost, schedule, and subjective system quality
- Optimum SE effort is 10-15% or more
- Quality of the SE effort matters
  - Lower quality SE reduces effectiveness

Data on when & where Systems Engineering should be applied

WHEN & WHERE MOST NEEDED

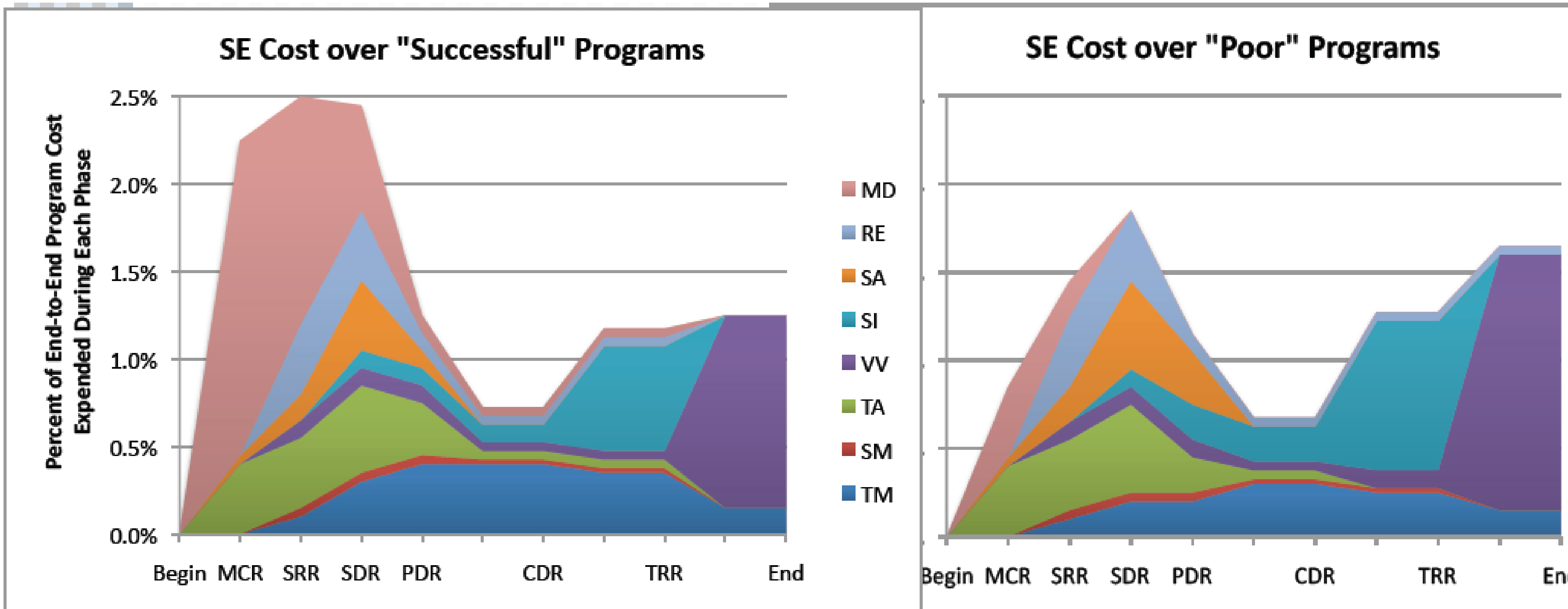
PhD Research

(Honour, 2010)

- New data set of 53 projects
- Expenditure on effective Systems Engineering Effort is very strongly correlated with project outcome
- Guidance is appearing on how this should be allocated.

  - The most successful programs, as measured in cost compliance, schedule compliance, and overall subjective success, appear to expend about 15%-20% of the development program cost in systems engineering efforts.
  - The most successful programs, measured in the same three areas, also seem to have optimum values for the eight defined systems engineering activities. When considered individually, the optimum value for each activity is:
    - Mission Definition – 1%
    - Requirements Engineering – 2.5%
    - System Architecting – 2.5%
    - System Implementation – 3%
    - Technical Analysis – 4%
    - Technical Management – 4%
    - Scope Management – 1%
    - Verification & Validation – 7%

SE Investment vs Project Success



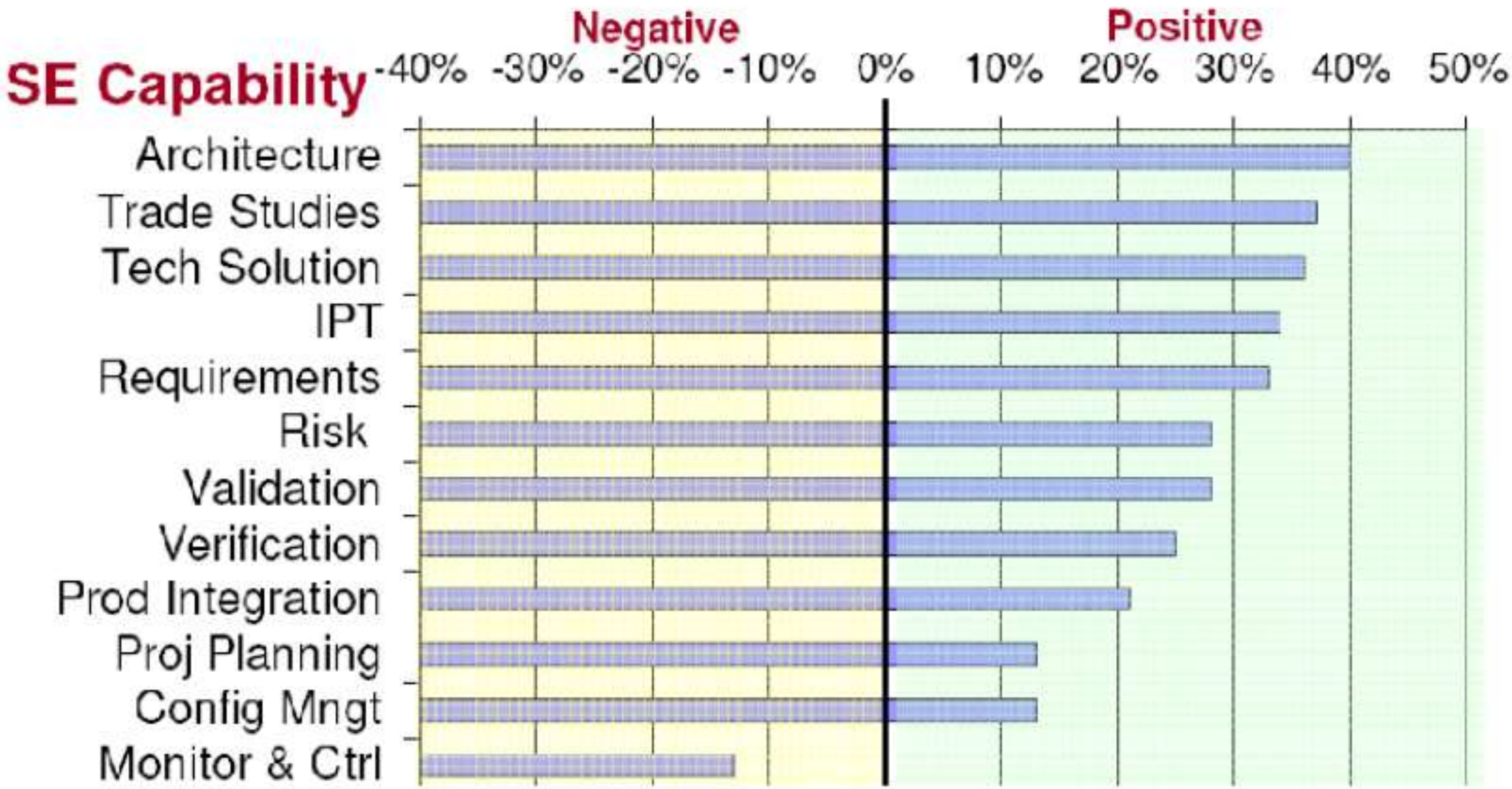
Successful *(~on cost)*
- More mission/purpose defn
- More tech leadership/mgmt
- More Systems Engineering

Poor *(overran cost)*
- More system integration
- More verif & valid
- Less Systems Engineering

Honourcode, Inc. Presentation for the INCOSE Symposium 2010 Chicago, IL USA

(Honour, 2012)

SE Capabilities that impact Project Success



SHOAL (Elm et al, 2008)

A RoI approach for capability investment decisions

MAKING CHOICES

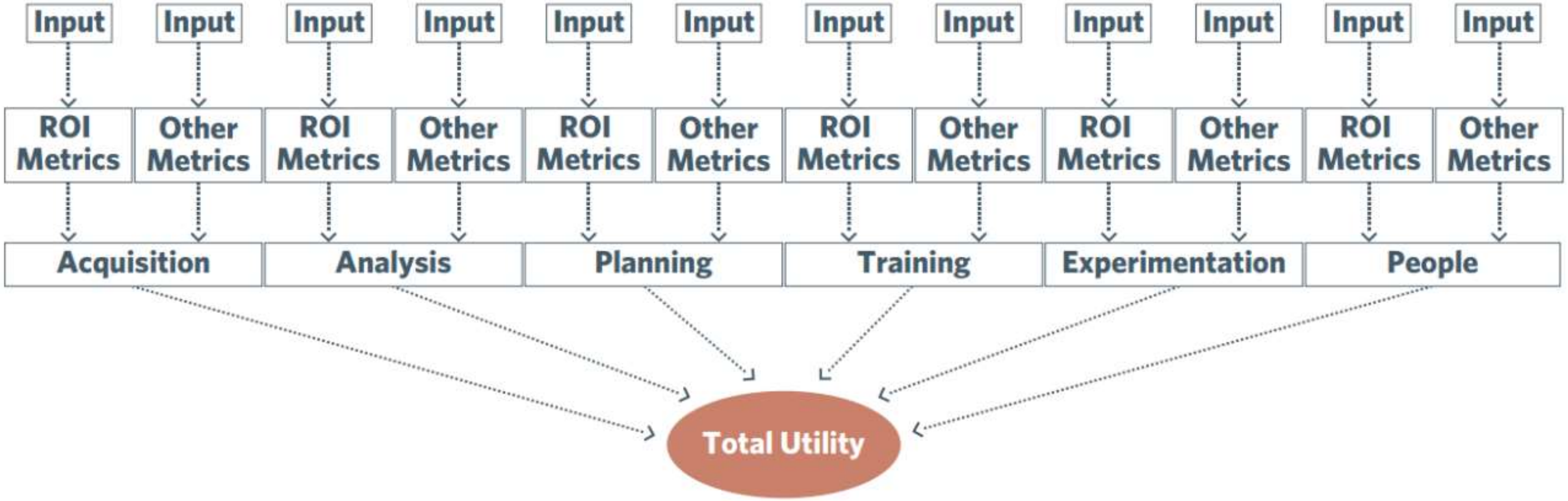
RoI on Modelling and Simulation (M&S)

(Oswalt et al 2012)

- Recognised that financial RoI is not helpful
- Performed comparative RoI against stakeholder value
- Looks at RoI across the communities of interest
- Choose to concentrate on relative benefit of different M&S options and choose the most attractive using Multi-Attribute Value Analysis (MADM)

RoI on M&S – Calculation

(Oswalt et al 2012)



RoI of Capability Investment Decisions

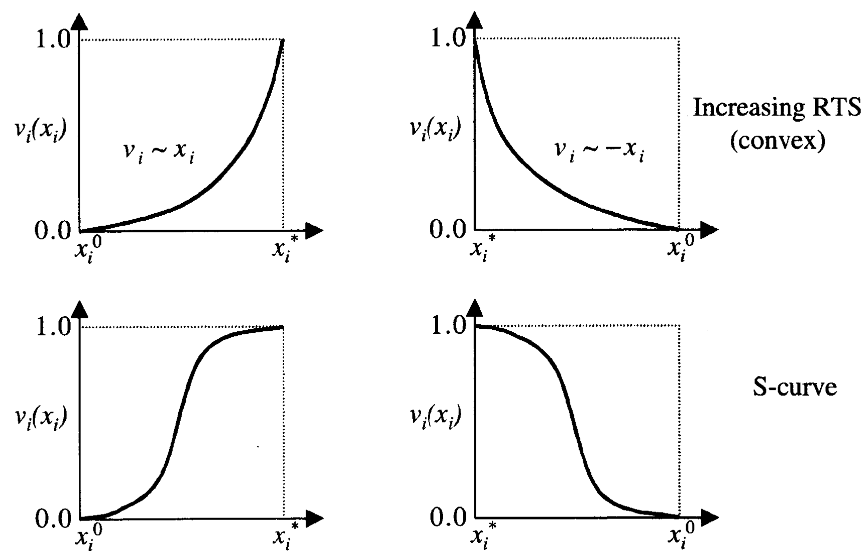
(Maude and Cook, 2015)

- Similar approach to RoI of M&S
- Used to select the best capability development option based on RoI
- Process
  - Identify key stakeholder improvement objectives (MoEs)
    - E.g. reduced project risk, cost, schedule; improved system performance
  - Select performance metrics (KPPs)
  - Estimate performance KPPs for each option
  - Normalise measures through value curves
  - Aggregate to determine change in value for each investment option based on the capability that it provides to users
- Implementation
  - Used project WSAF model that holds MoEs and key MoPs
  - Exported information to Excel
  - Weighted sum objective function implemented in Excel along with visualisation of decision space

Calculation for the Value of an Option

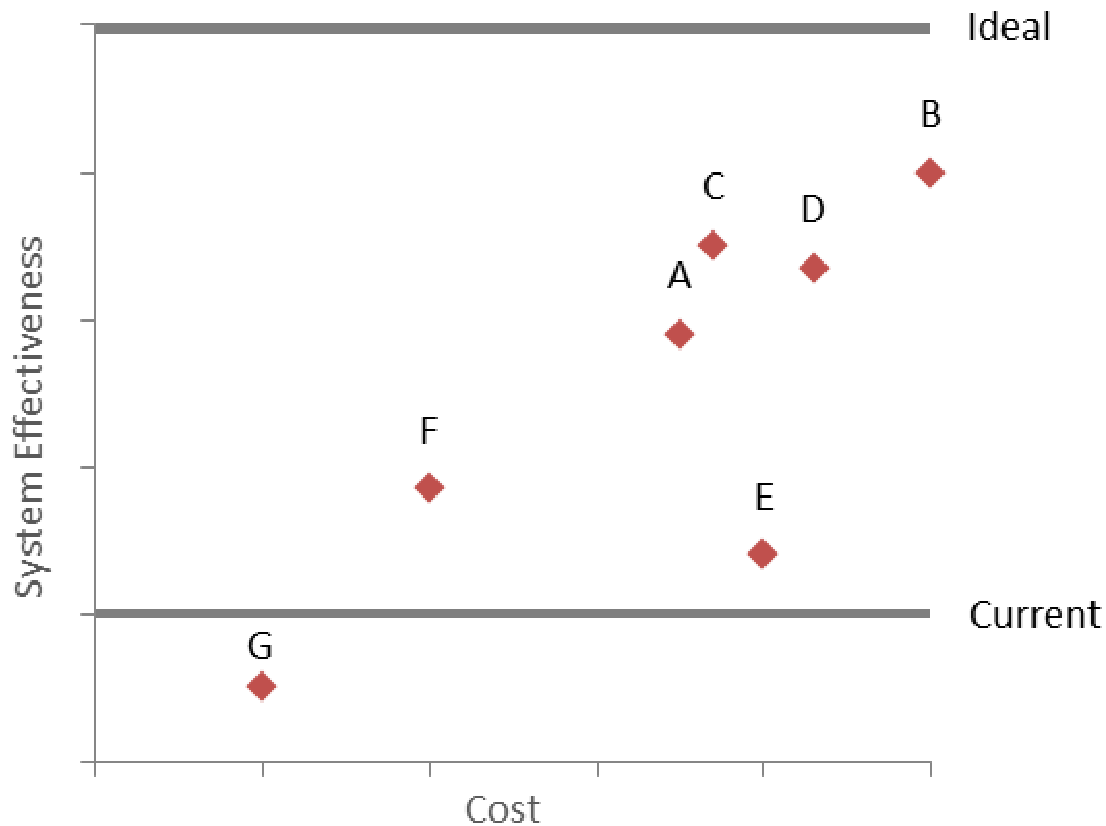
- Objective function: $$v(\mathbf{x}) = \sum_{i=1}^{n} w_i v_i(x_i)$$

- Where v(x) is the vector of values for i options given n weighted objectives wi and v(x) is the value change over the attribute range (Buede, 2000).



Display of Findings

- Display provides a comparison of systems effectiveness improvement provided for each option plotted against the cost increment associated with its implementation



- Different stakeholders have different perceptions of value. This can be accommodated by allowing each to define a set of weights. This produces different 'views' of value for each stakeholder.

Towards a methodology for selecting MBSE enterprise improvement options based on RoI

IMPROVING THE ENTERPRISE

Aim & Approach

- Aim – To select the best enterprise improvement option based on RoI

- Approach
  - Identify key stakeholder value attributes (MoEs, MoS)
  - Rank the attributes in order of importance and use this to determine the weighting

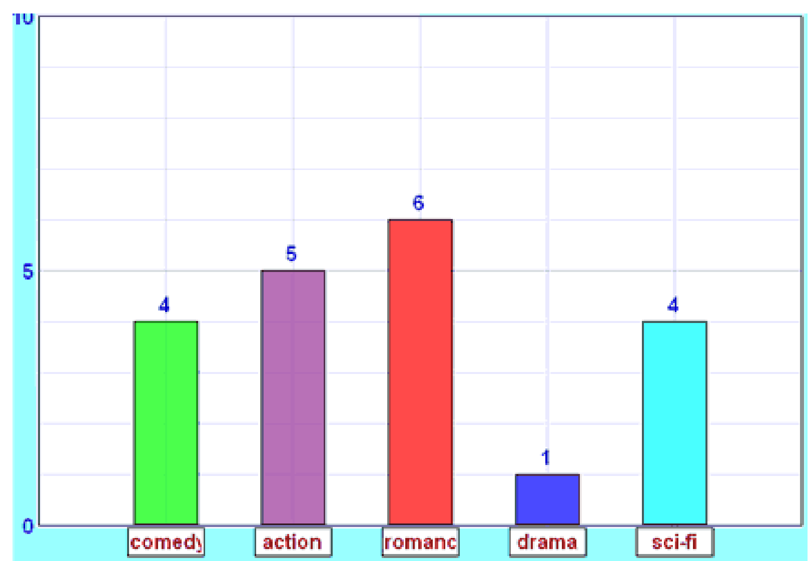
Example: MB-TRA Value Model

(Cook et al, 2015)

Rank	Value Attribute	Description	Weighting
1	**Insightfulness and Comprehensiveness**	The capability of a TRA Methodology to aid an MB-TRA practitioner to uncover a comprehensive set of risks and risk drivers (some of which would not be apparent to a PSTA without the methodology) and to assess the risks appropriately.	0.14
2	**Justifiability**	The degree and ease with which one can demonstrate that assertions made in the TRA can be substantiated.	0.13
3	**Effectiveness**	The capability of a TRA methodology to produce an insightful TRA that meets consumers' needs and addresses the basic TRA problem situation as stipulated in guidelines and instructions. (The methodology will be likely judged to be effective if it enables a suitably-qualified practitioner to be able to produce the desired set of outputs.)	0.13
4	**Adaptability and Scalability**	The ease with which a TRA methodology can be adapted for use in different situations including by teams of analysts, potentially at distributed sites. This includes supporting distributed work practices.	0.11
5	**Supportability**	The ease with which a TRA methodology is able to be supported once deployed. This includes the practicality of maintaining it in use, the resource cost of doing so and the ease with which the TRA methodology can deal with changes in guidance.	0.10
6	**Information accessibility**	The ease of searching for and retrieving TRA-related information, intermediate artefacts, and assessment rationale over time.	0.08
7	**Efficiency**	The capability of a TRA methodology to achieve results with minimum expenditure of time and effort. This attribute includes the degree to which the methodology focuses on those activities necessary to achieve a high-quality TRA.	0.07
8	**Learnability**	The ease with which a process user is able to learn how to perform the activities of a TRA methodology.	0.07
9	**Consistency**	The degree of consistency of the presentation of information and the application of techniques across projects; and the consistency of information with other artefacts within the same project.	0.07
10	**Acceptability**	The degree to which the methodology is likely to be taken on by the users and accepted by the key stakeholders.	0.05
11	**Manageability**	The ease with which a process manager is able to estimate the time and resources needed to complete a TRA, determine the status of a TRA task, and apply corrective actions to maintain a specified level of effort and task performance.	0.04

Approach (2)

- Produce value curves for each attribute
- Estimate the performance against each value attribute for each option, e.g.
  - No change
  - Incremental change
  - Invest in a structured, conventional process improvement initiative
  - Invest in a standardised MBSE approach
  - Invest in a novel MBSE approach
- Calculate overall value of each option
- Produce display for decision makers



Can we Quantify the RoI of the Options?

Yes!

- Use data above
- Refine using:
  - A set of project classifiers
  - Guide use of database of project case studies

Initial Estimate

- Place project or set of projects on the Honour curves based on:
  - Programmed SE spend
    - as a percentage of the project spend to the commissioning of the first working production example
  - The expected quality of the SE effort
    - MBSE is aligned with good SE so a mature MBSE approach will be accorded a high SEE score
- Estimate RoI from:

$$RoI = (-\Delta Actual\ Cost/Planned\ Cost)/(\Delta\ SE\ Effort)*\lambda$$

where λ is the multiple of project-specific adjustment factors

Adjustment Factors

- Project type, e.g. software, mechanical, electronic, civil engineering
- Project complexity
- Industrial domain, e.g. defence, rail, construction
- Historical project slippages for the industry
- The appropriateness of planned SE resource utilisation
- Initial organisational process maturity (much greater gains are seen when improving from a low base)
- Net present value of money
- etc.

Software Project Outcomes Versus Complexity

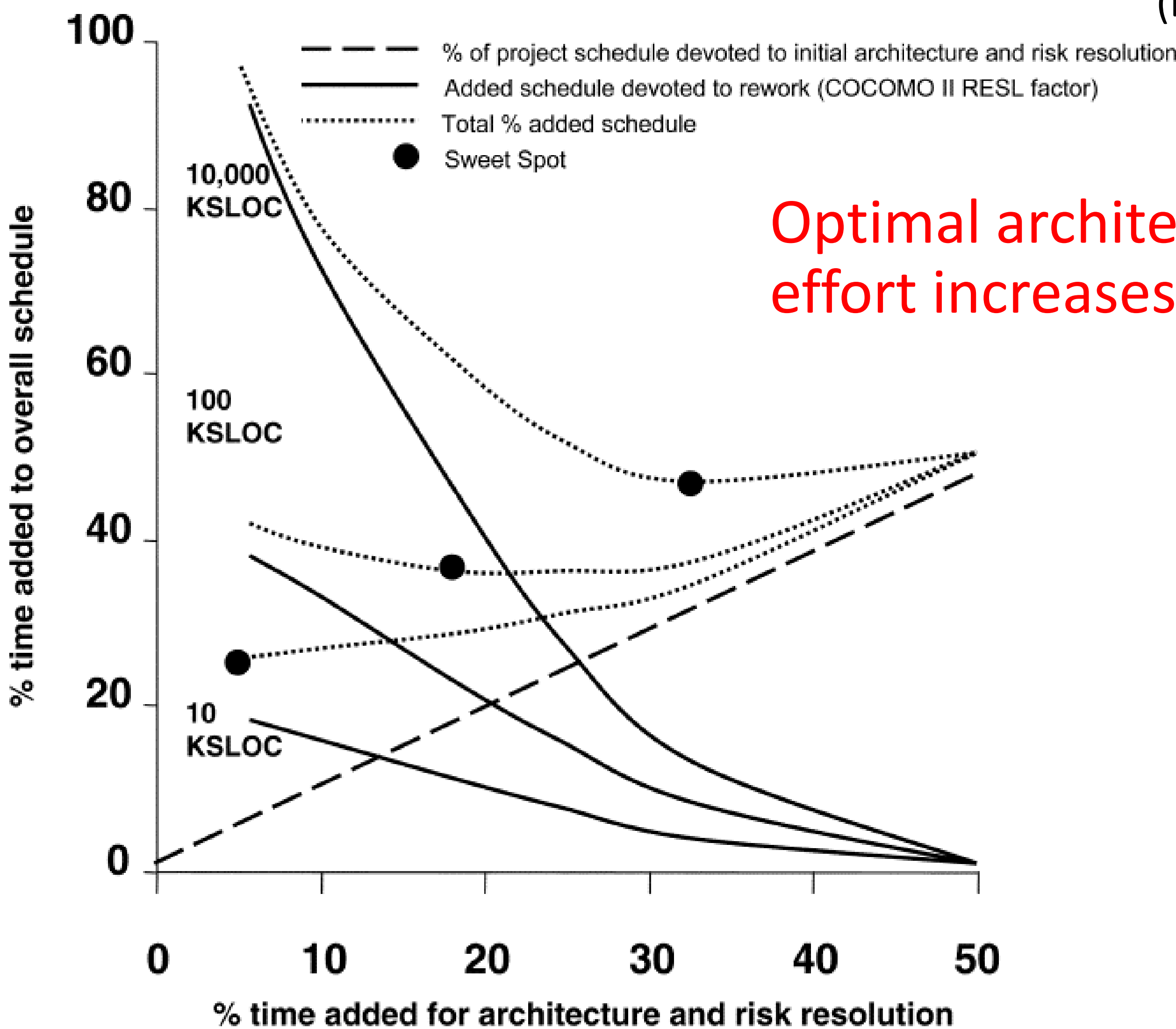
(Capers Jones, 1996)

	Early	On-Time	Delayed	Canceled
1 FP	14.68%	83.16%	1.92%	0.25%
10FP	11.08%	81.25%	5.67%	2.00%
100FP	6.06%	74.77%	11.83%	7.33%
1000FP	1.24%	60.76%	17.67%	20.33%
10,000FP	0.14%	28.03%	23.83%	48.00%
100,000FP	0.00%	13.67%	21.33%	65.00%
Average	*5.53%*	*56.94%*	*13.71%*	*23.82%*

From Capers Jones, *Patterns of Software Systems Failure and Success* (International Thomson Computer Press, 1996)

Optimal Architectural Design

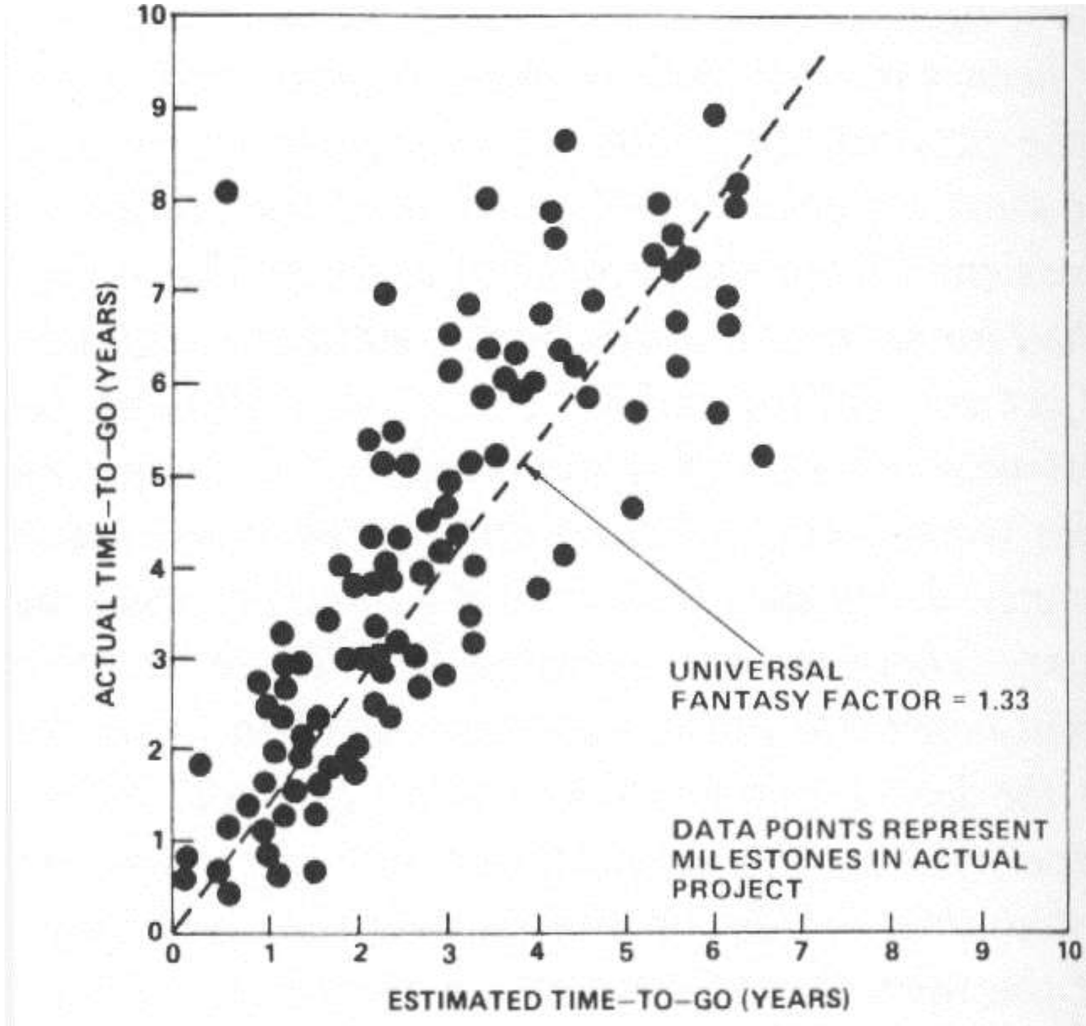
(Boehm et al, 2008)



Optimal architectural design effort increases with project size

US Congress Data On Defence Project Over-runns

(Augustine 1984, later data similar)



THE NEXT STEPS

The Next Steps

- Honour (INCOSE), Elm (NDIA/INCOSE) and others have shown that it is possible to elicit this sensitive data and to produce quantitative findings
- Additional research is needed to establish the adjustment factors for the unique Australian project environment
- It would be ideal if this could be a joint venture between
  - SESA/INCOSE
  - An acquiring organisation, prime contractor or a consulting firm
  - A university through academics and one or more PhD students
- Extend to MBSE and SoSE using additional data

Some RoI Data for MBSE

- Adoption of MBSE effectively forces many systems engineering activities to be performed more thoroughly and through this MBSE inherently promotes good systems engineering (Logan, 2011).
- Hause (2009) stated that MBSE saved Westinghouse 70% on verification using auto-generated testing for railway switching systems
- Saunders (2011) stated that Raytheon reduced specification defects by 68% following the introduction of MBSE practices.
- Need to process various data sources – see following

MBE Benefits Across the Acquisition Life Cycle

(NDIA, 2011)

- More complete evaluation of trade space [8, Boeing 787]
- Improved communications across stakeholders [6, 8]
- Earlier evaluation of manufacturing feasibility [2]

- Rapidly evaluate changing threats and explore solution space [8]
- Design Reuse [6, 7]
- Lower costs with complex product families [5]

- Reduced manufacturing related costs and schedule [2]

- Improved requirements [3, 4, 6, 7]
- Earlier risk identification and mitigation [2, 4, 7]
- Early evaluation of manufacturing processes [2]
- More complete evaluation of trade space [8, Boeing 787]

- Earlier risk identification and mitigation [2, 4, 7]
- Concurrent and collaborative engineering [2, 3, 4, 7]
- Reduced defects and re-work costs [1, 3, 4, 7])
- Accelerated development schedule [1, 6, 7]
- Improved system and software reliability and quality [6, 7, 8]
- Design Reuse [6, 7]

(5) Complex Product Family Modeling for Common Submarine Combat System MBSE

(Hause, 2012)

- A Product Family is a group of products derived from a common product platform.
  - Chrysler K-cars, Boeing 747
- LMCO Used MBSE to define product families, manage complexity, leverage reuse, and document commonality
- **Expect 13% additional savings to SE from MBSE**
  - **25% in Capability Definition**
  - **Another 10% over DOORS in Baseline Management**
- Savings won't be seen until 4th year
  - 2 years to implement model
  - 1 year transition overlap with current process

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QUESTIONS
&
VOLUNTEERS?