National Defense Industrial Association
6th Annual CMMI Technology Conference
November 2006

The Value of Systems Engineering

What do we know about it?

How do we discover more?

Al Mink
Systems Value / GMU

Value of SE
Overview

1. **The Problem**
2. **What We Know Today**
3. **The Race to Discover More**
4. **Conclusions**

Value of SE

The Problem (Stakeholder Analysis)

What – and how much – SE is appropriate for a particular system development program?

- **Customers**
  - Unsure of how to evaluate bids
  - May not receive best value for the systems they acquire
  - DoD #1 SE Issue – "Inconsistent SE Practices across life cycle"
- **Industry (System Developers & Integrators)**
  - Unsure of what to bid, and later loath to add SE costs
- **Associations & Academia**
  - Unable to fully satisfy their members and students
- **SE professionals**
  - Lack rigorous justification for their recommendations

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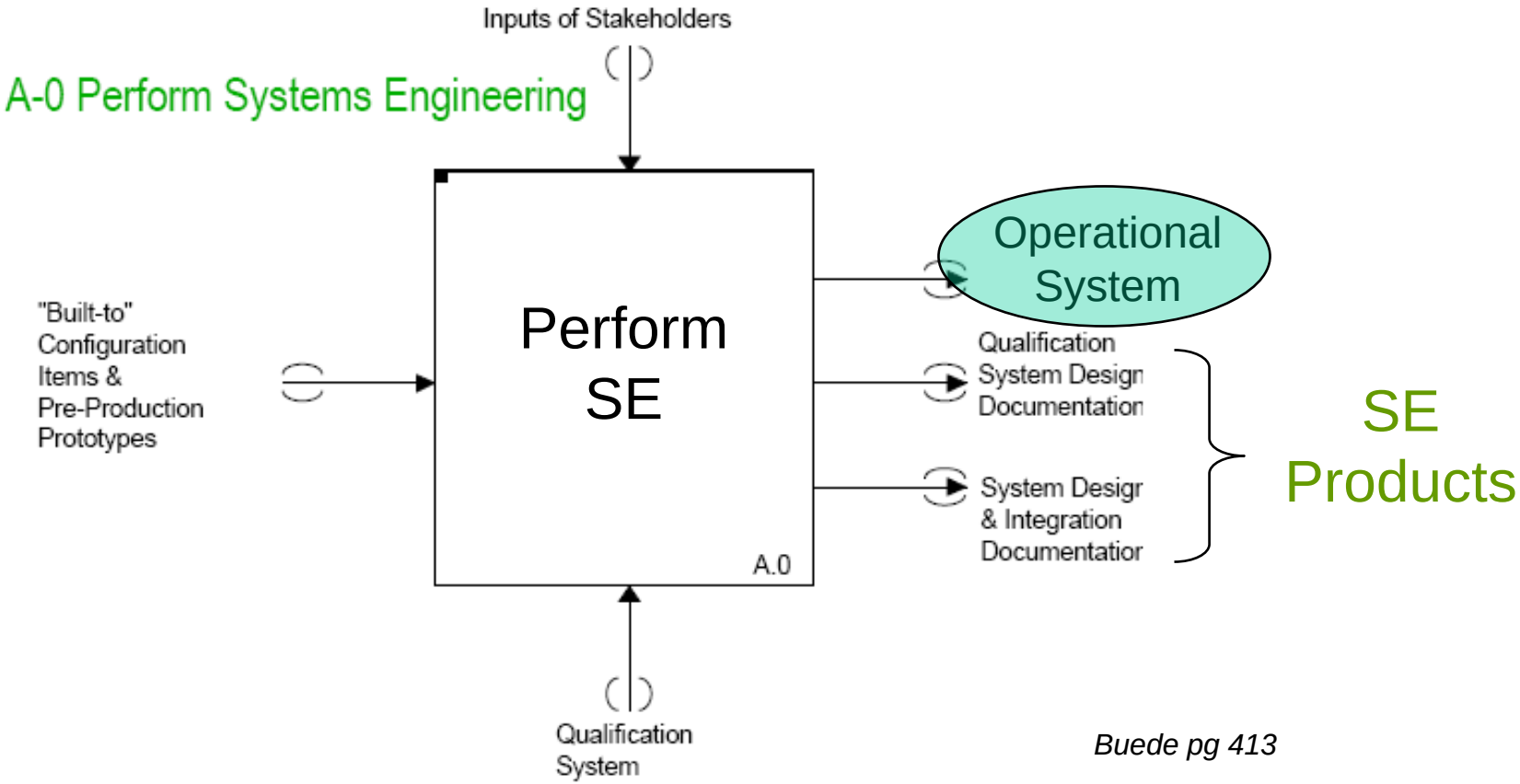
The Problem (IDEF 0 View)



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SE produces more than products -- It affects the value of operational system produced

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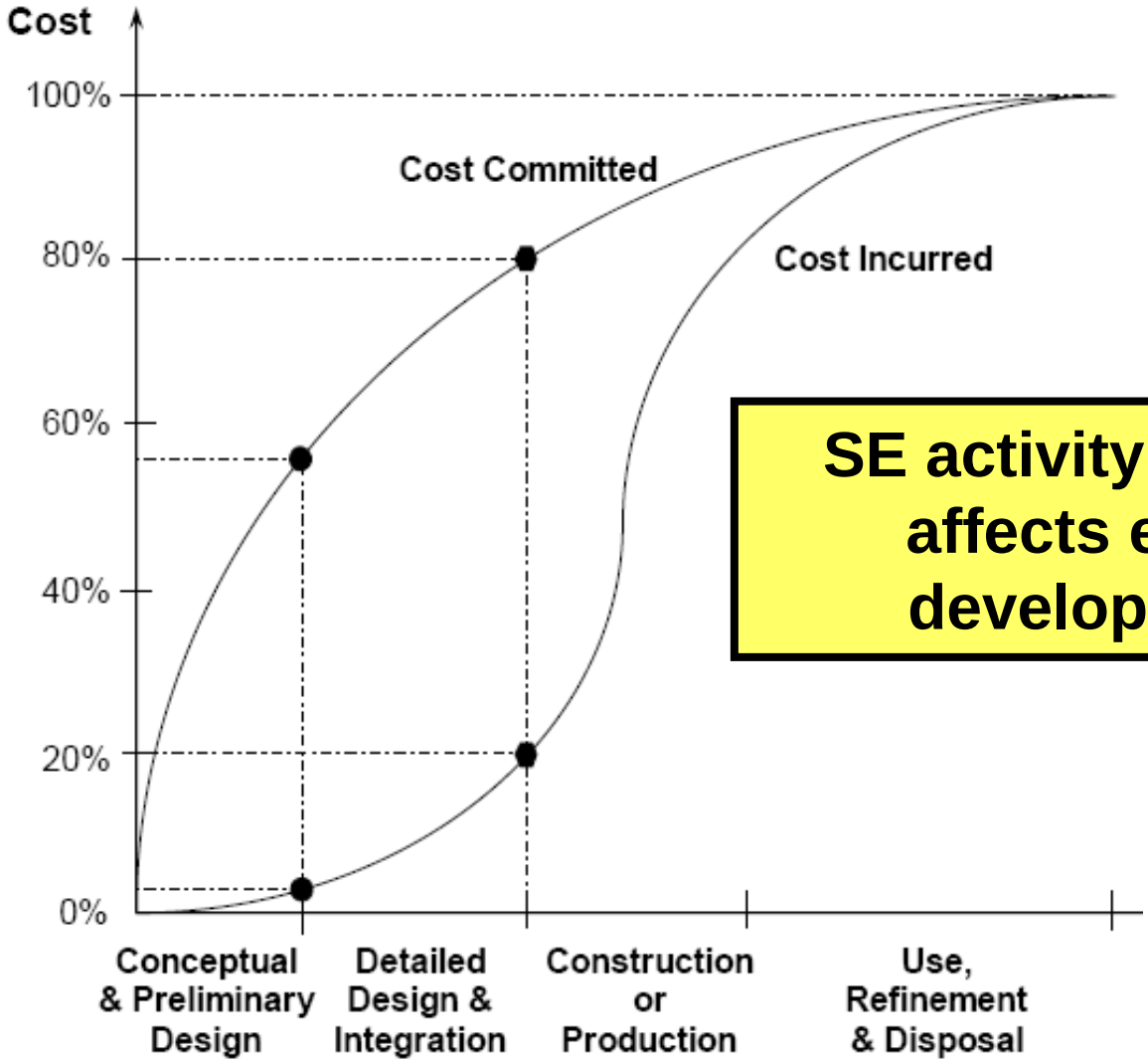
The Problem (Pareto View)



SE activity upfront affects entire development

Buede, Figure 1.2

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What we know today – Studies & Models

Gruhl, National Avionics and Space Administration (NASA), 1992

Compared upfront expenditures to eventual cost growth

Herbsleb, Software Engineering Institute (SEI), 1994

Studied ROI on process improvement in software

Honour, International Council on Systems Engineering (INCOSE), 2002

Surveyed industry to compare SE Effort to cost & schedule

Boehm & Valerdi, SE ROI (COCOMO), 2006 (Draft)

Analyzed SE activities from COCOMO II

Valerdi & Boehm, Constructive System Engineering Cost Model (COSYSMO), 2004

Developed parametric estimation model similar to COCOMO

Others…

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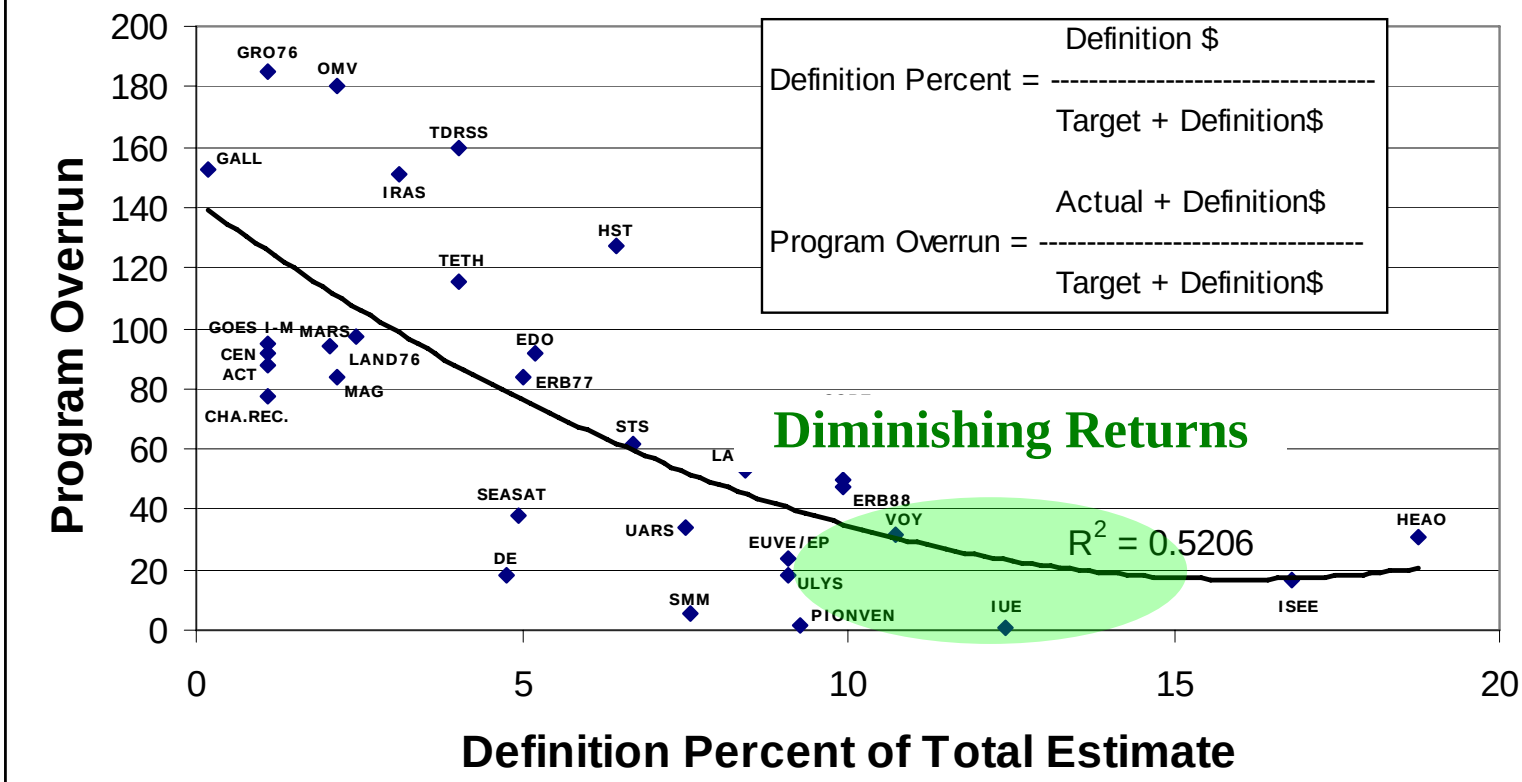
What we know today – NASA Study

Source Werner Gruhl
NASA Comptroller's Office
& Honour 2004



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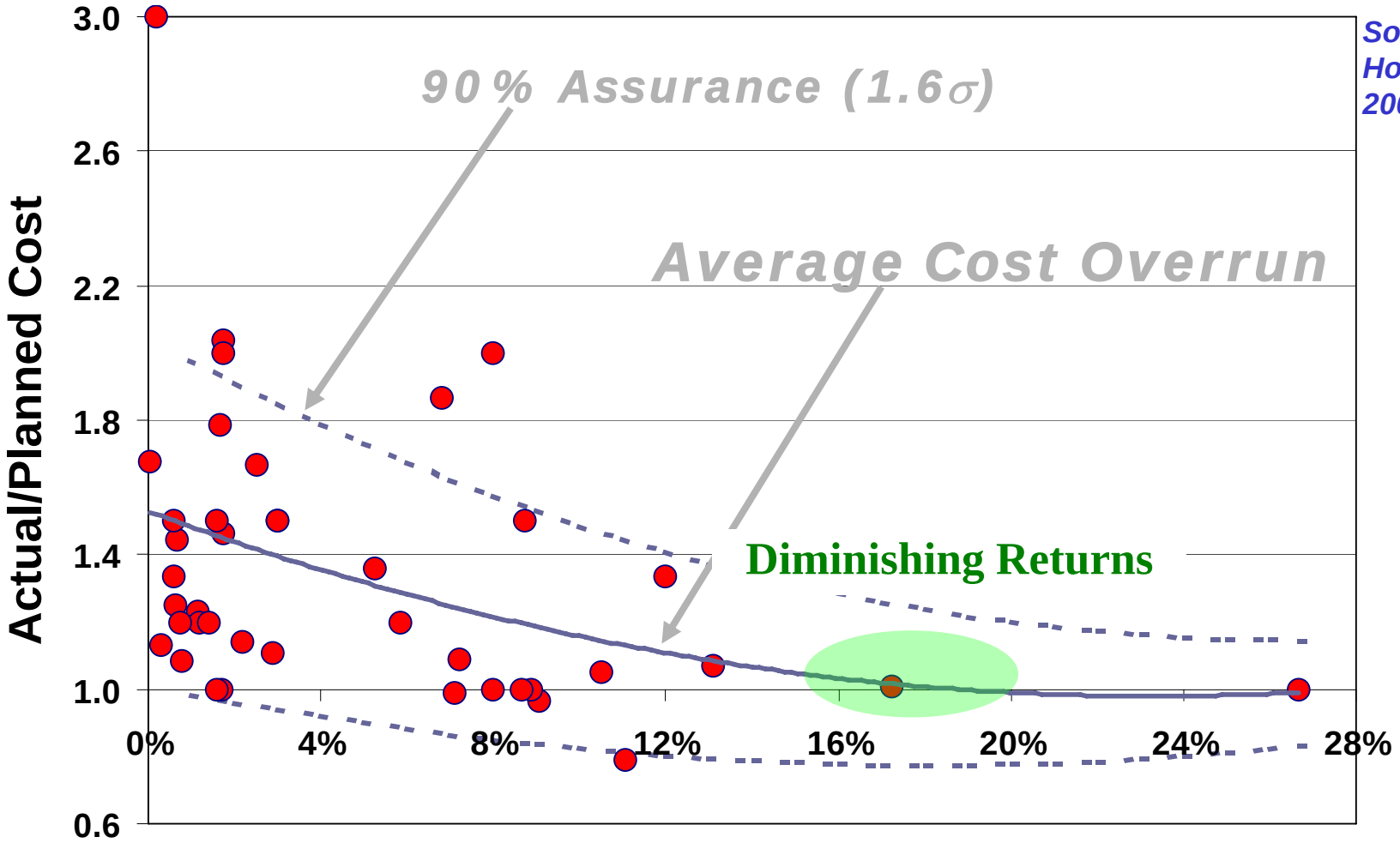
What we know today – INCOSE Study



SE Effort = SE Quality * SE Cost/Actual Cost

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What we know today – ROI of SE

SE ROI by Software Size of System

KSLOC	Very Low	Low	Nominal	High	Very High	Extra High
10	-	52%	-20%	-45%	-58%	-77%
100	-	248%	80%	18%	-10%	-54%
1,000	-	512%	204%	91%	42%	-30%
10,000	-	840%	356%	177%	99%	-4%

Boehm & Valerdi, 2006

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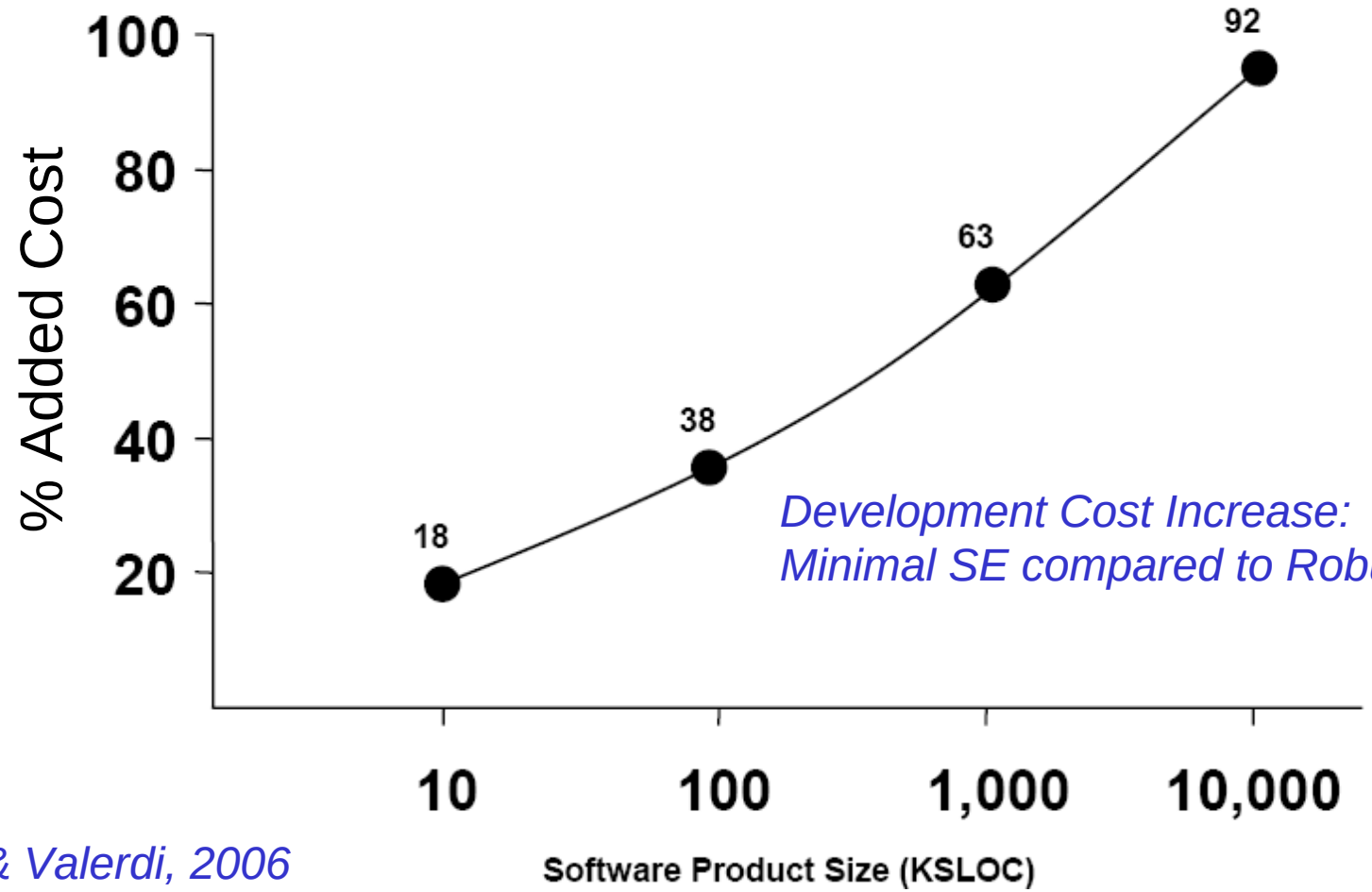
What we know today – ROI of SE

SE Activities Affect Software Development



Boehm & Valerdi, 2006

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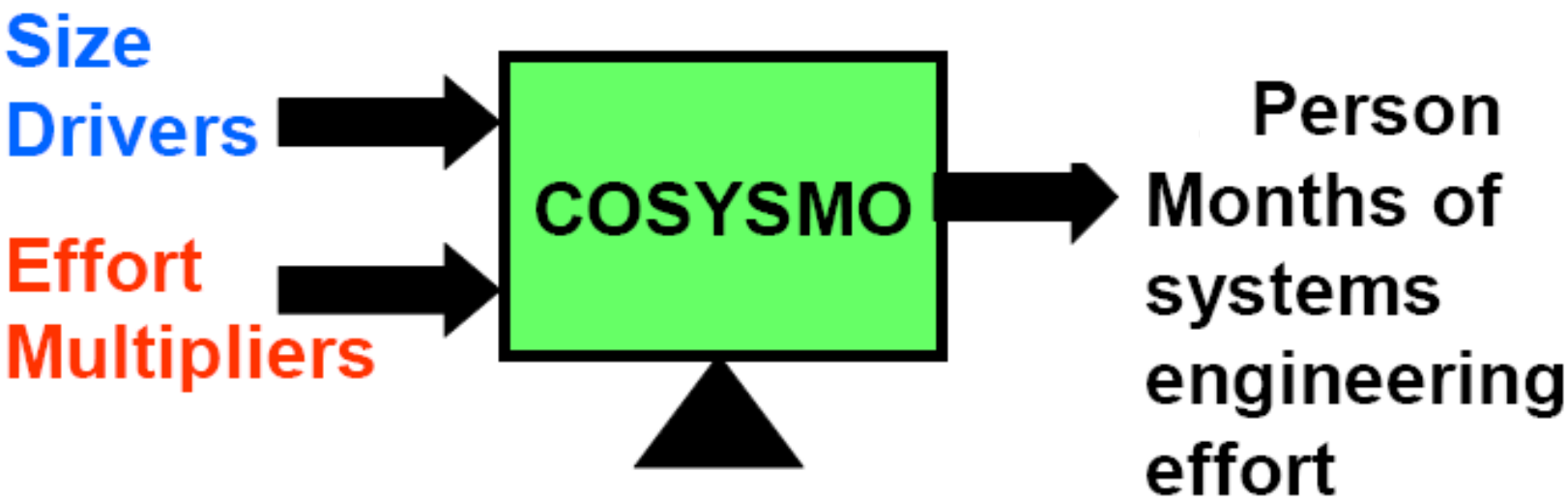
What we know today – COSYSMO

Limited ability to estimate "effort"



Pred(30) 50% uncalibrated

Pred(30) 70% calibrated

Valerdi, 2005

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What we know today – COSYSMO

SE Effort Across ANSI/EIA 632 Fundamental Processes

ANSI/EIA 632 Fundamental Process	Average	Standard Deviation
Acquisition & Supply	7%	3.5
Technical Management	17%	4.5
System Design	30%	6.1
Product Realization	15%	8.7
Technical Evaluation	31%	8.7

Valerdi & Wheaton 2005

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What we know today – COSYSMO

SE Effort Across IOS/IEC 15288 Lifecycles

23%	36%	27%	14%	%Effort
12	16	13	9	STDEV

Valerdi & Wheaton 2005

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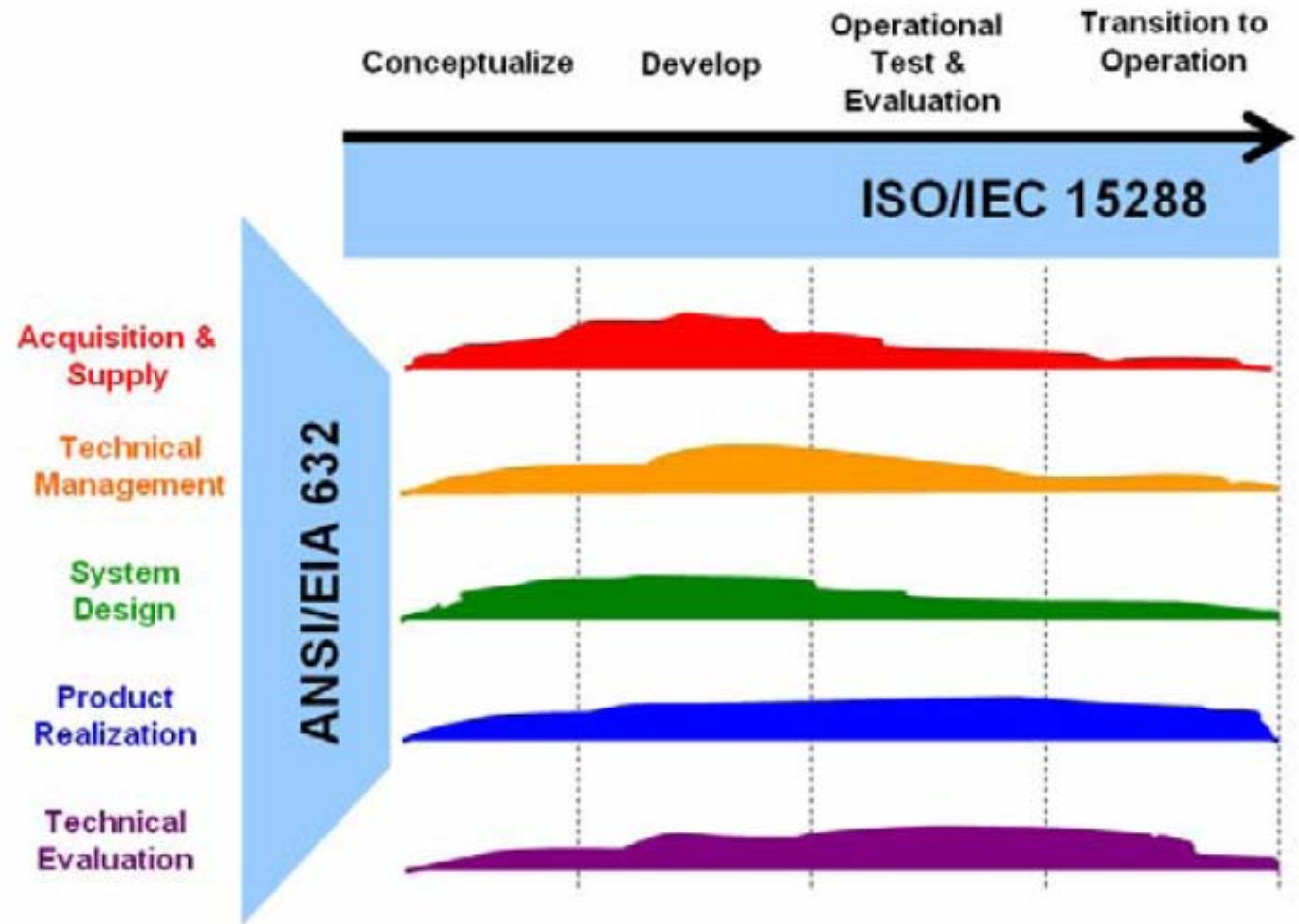
What we know today – COSYSMO

SE Effort Across IOS/IEC 15288 Lifecycles



Valerdi & Wheaton 2005

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What we know today – Summary

STUDY		APPLICABILITY		
Author & Background	**Findings**	**SE Activities**	**Definition of Success**	**Characteristics of Project**
Gruhl (1992) 32 NASA Pgms	8-15% Upfront Best	First two of five development phases	Cost (Less cost overrun)	Large; Complex; all NASA
Herbsleb (1994) 13 CMM Companies	Process Improvement ROI 4.0 – 8.8	CMM Process Areas	Cost (Cost reduction through SE investment)	Various; federal contracting
Honour (2004) Survey INCOSE SEs	15-20% of project should be SE	Overall SE level of effort (Cost) & related SE quality	Cost & Schedule	Various sizes (measured by total project cost)
Boehm & Valerdi (2006) COCOMO II	SE importance grows with project size	COCOMO II RESL (Architecture and Risk)	Cost	Various sizes, but software systems only
Boehm & Valerdi (2004) COSYSMO	Estimate within 30% effort 50% - 70% of time	33 activities defined by EIA 632	Cost	Mostly successful projects from federal contractors
Ancona & Caldwell (1990) Boundary Management	Managing team boundary 15%; more is better	Team boundary activities – interface between team and external	Product Performance (Successfully marketed products)	Technology products
Frantz (1995) Boeing side-by-side projects	More SE yielded better quality & shorter duration	Defined by Frantz	Product Performance & Schedule (Quality of product and duration of project)	Three similar systems for manipulating airframes during assembly

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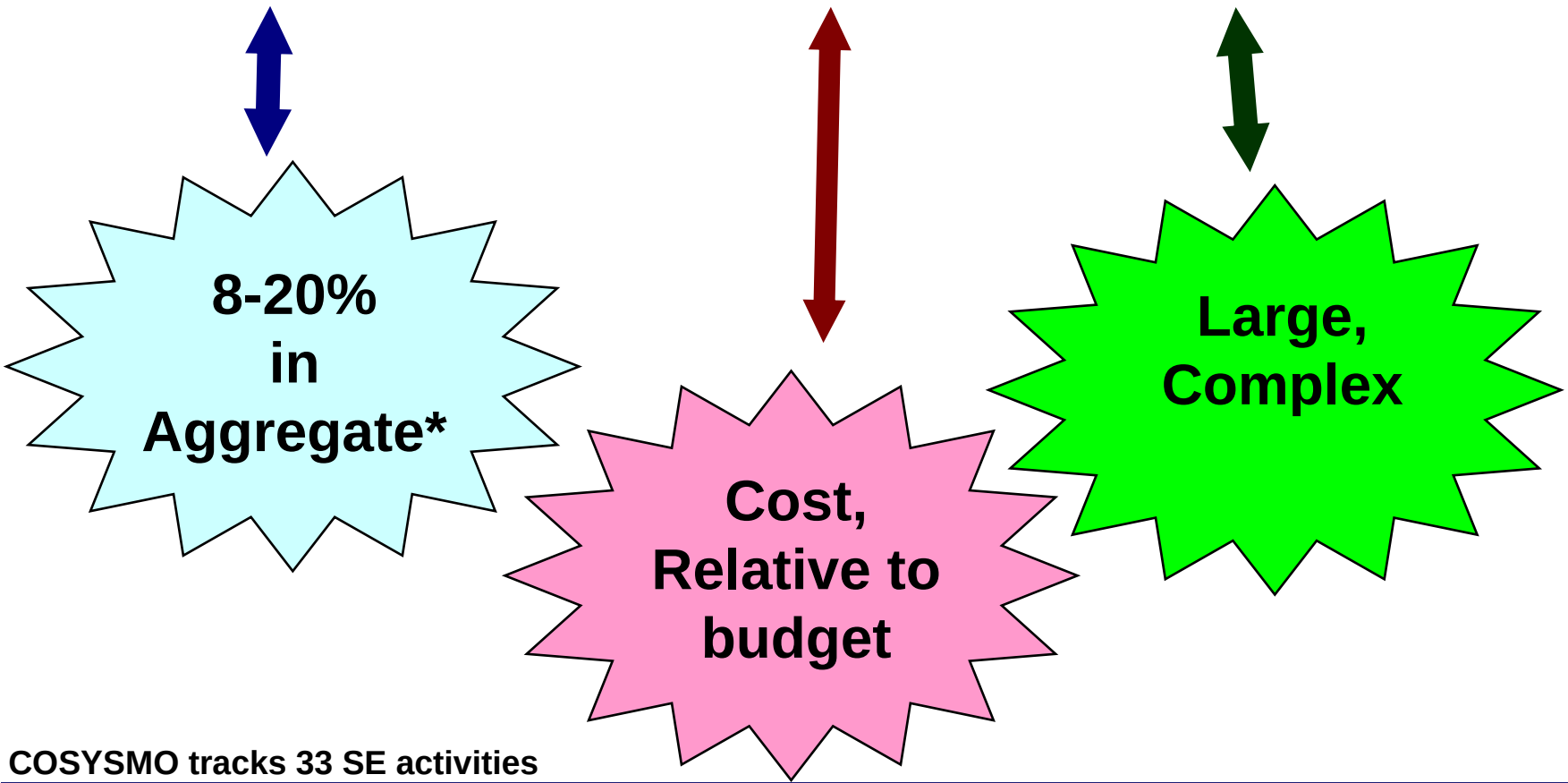
What we know today – Summary

Today we posses a *limited* understanding of the SE effort required for success of a project



* COSYSMO tracks 33 SE activities

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The Race to Discover More

Four Separate Efforts Underway

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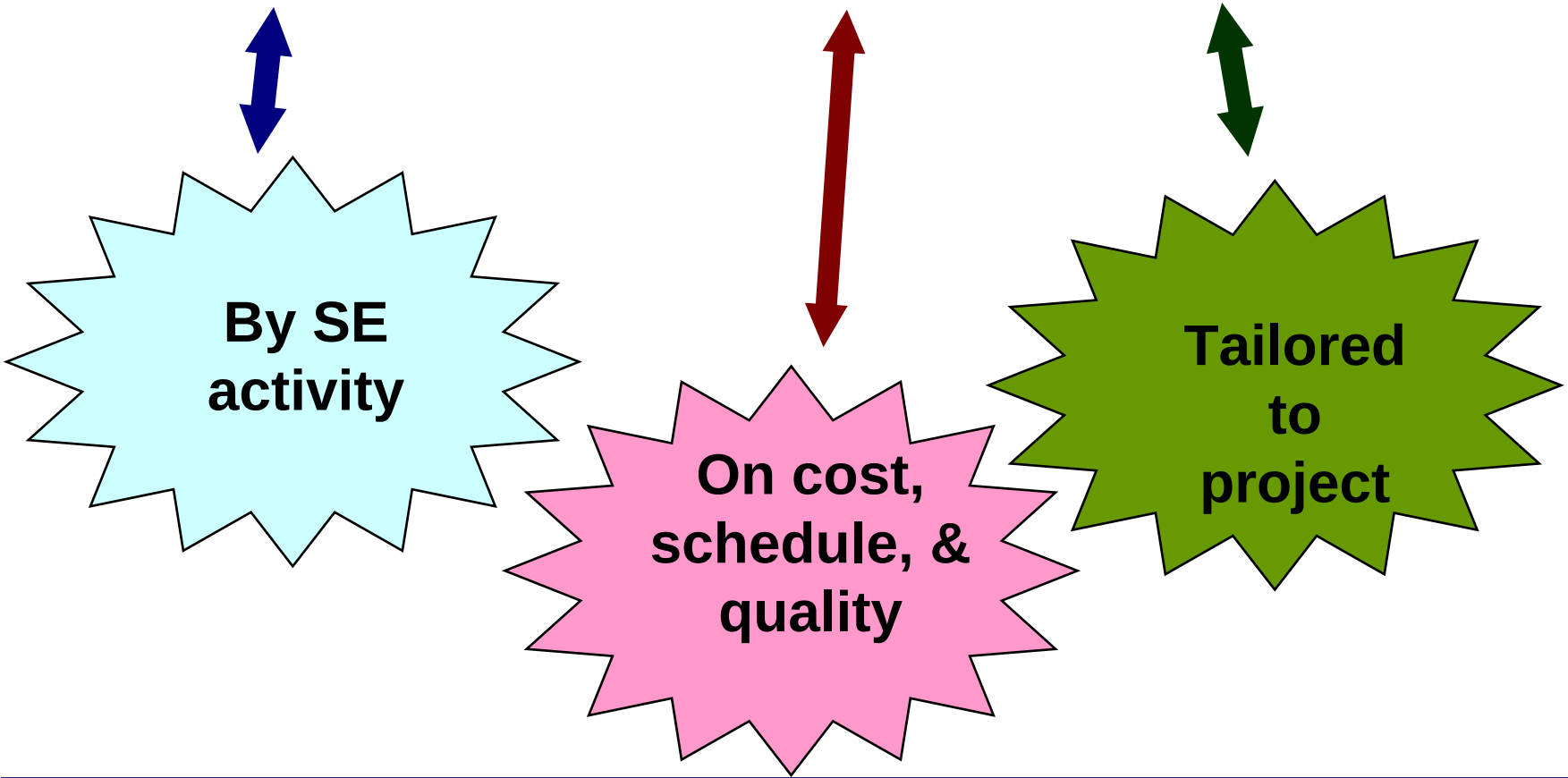
The Race to Discover More

All four should increase our understanding of the SE effort required for success of a project



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The Race to Discover More - Methodology

All Four Appear to Follow a General Approach

1. **Form Team**
2. **Develop Approach**
3. **Identify Projects**
4. **Collect Data**
5. **Analyze Data**
6. **Publish Results**

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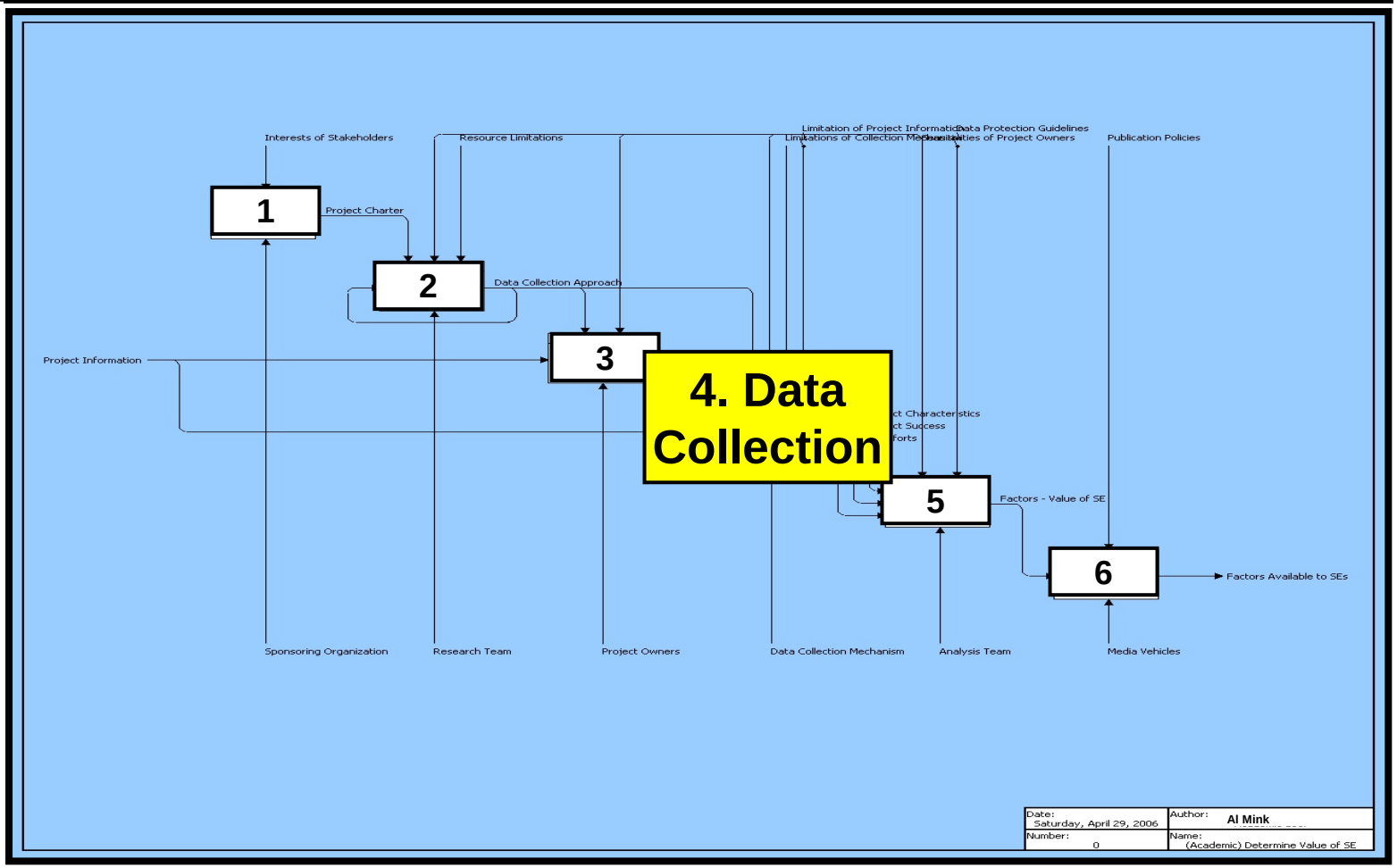
The Race to Discover More - Methodology

How the pieces fit together



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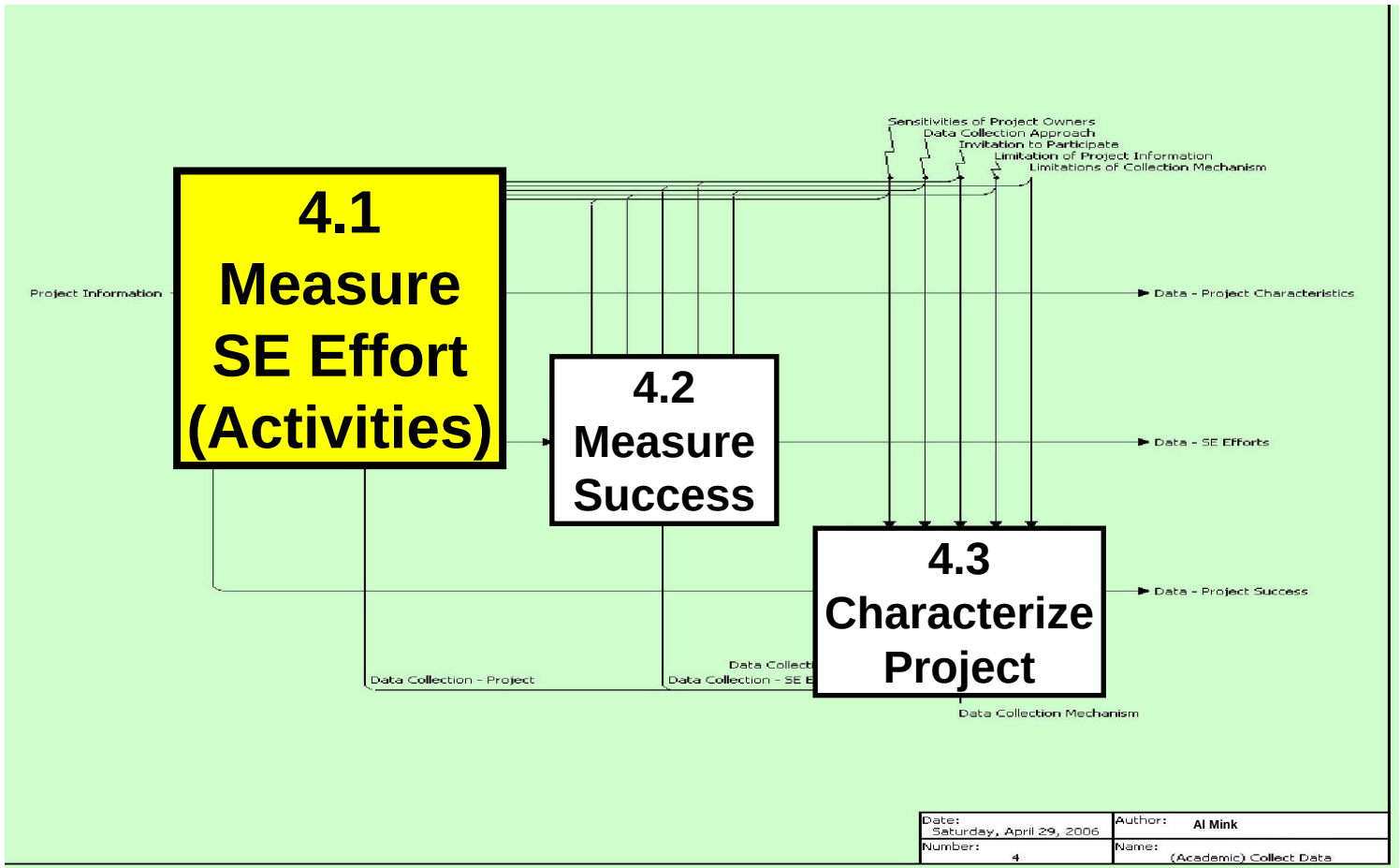
The Race to Discover More

Capturing Data – Three Categories



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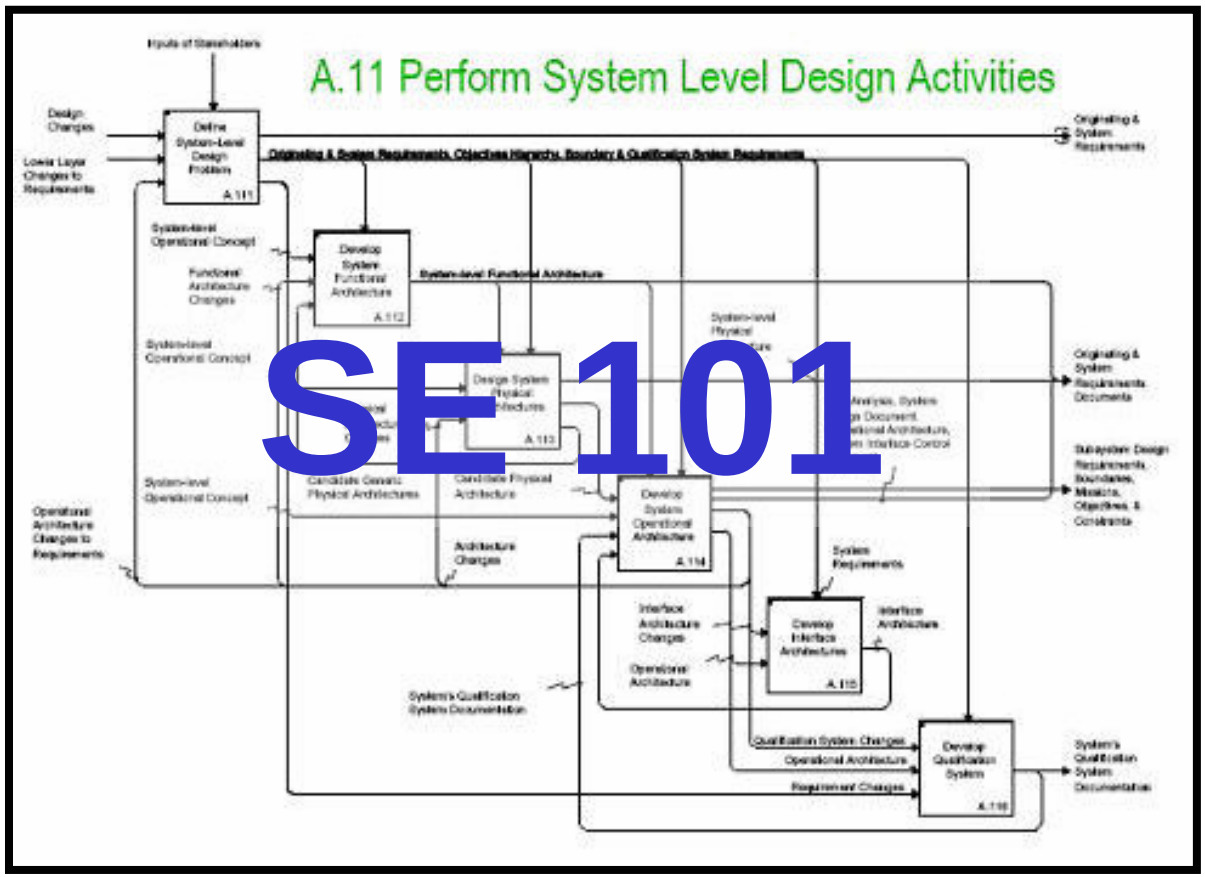
The Race to Discover More – Define SE Activities

Defining "SE Activities" – One View



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The Race to Discover More – Define SE Activities

Defining "SE Activities" – Many Views

Fragmented by domain opinions

- Military – DOD/MOD
- Space - NASA/ESA
- Commercial products
- Aircraft
- Automobiles
- Nuclear waste
- Process engineering
- Tool vendors
- Etc. Etc. Etc.

Fragmented by discipline opinions

- Technical leaders
- System architects
- System analysts
- Requirements engineers
- Operations analysts
- Design engineers

Fragmented by standards

- ANSI/EIA-632
- IEEE-1220
- ISO-15288
- CMMI
- MIL-STD-499C

Honour 2005

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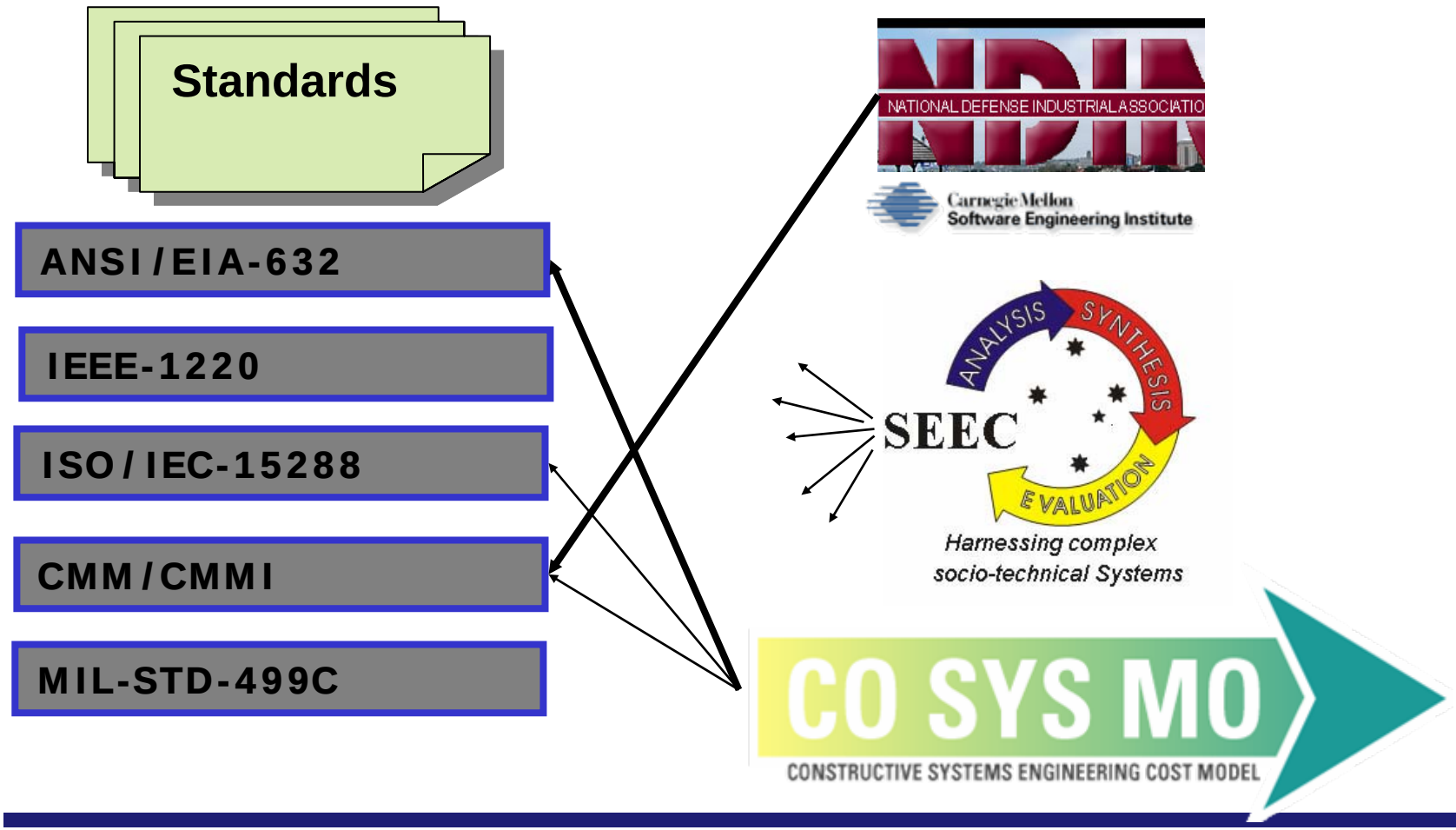
The Race to Discover More – Define SE Activities

How the Different Efforts Define "SE Effort"



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Emerging Approaches to Move Forward – Define Other Measures

In addition to defining & measuring SE Effort…

Cost, schedule, & quality

Success factors

- *EVMS*
- *Award Fee*
- *Requirements Trace*
- *Others…*

Tailored to project

Project characteristics

- *Size ($)*
- *Size (hours)*
- *Technology*
- *Complexity*
- *Others…*

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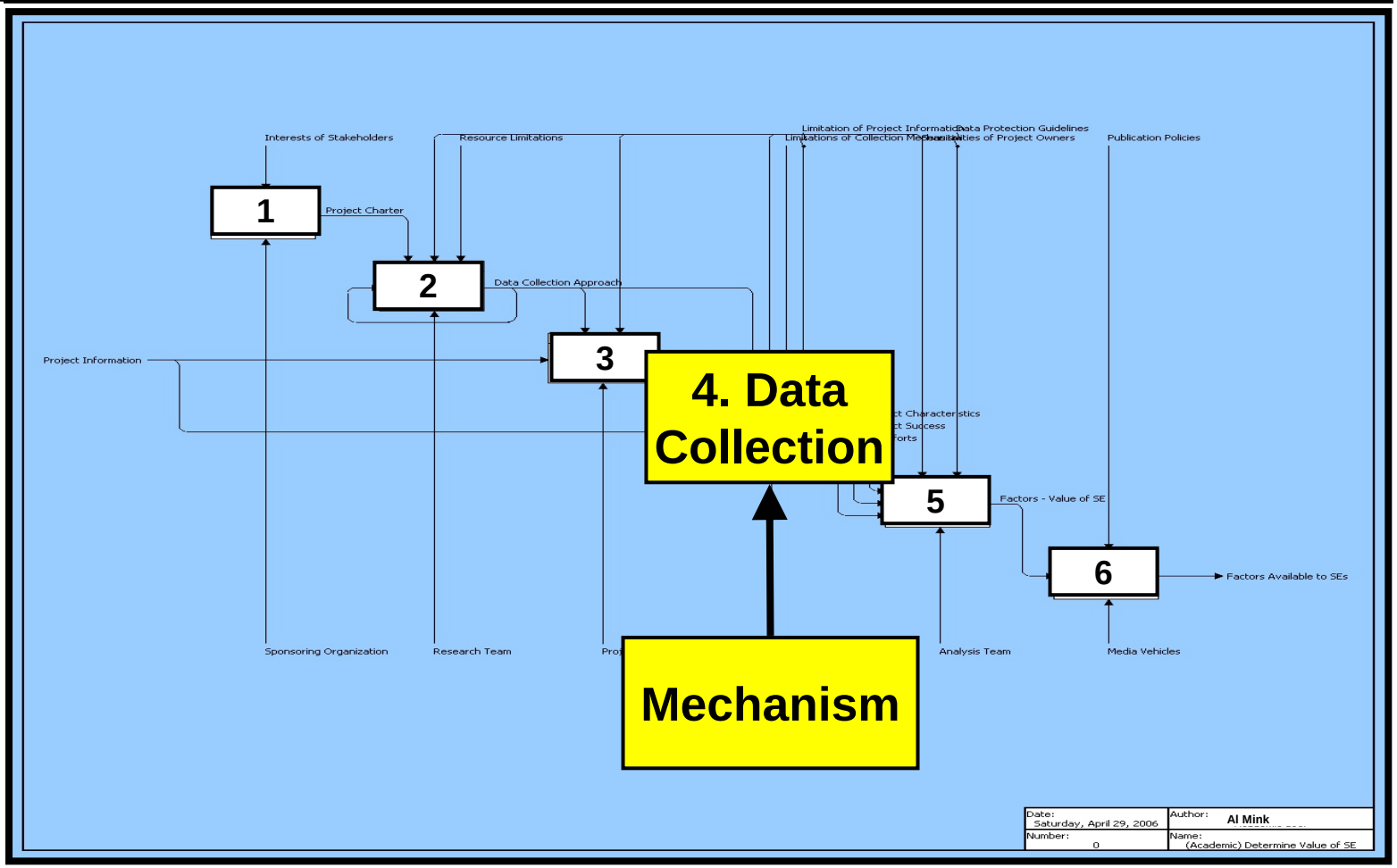
The Race to Discover More - Methodology

One Other Difference – Collection Mechanism



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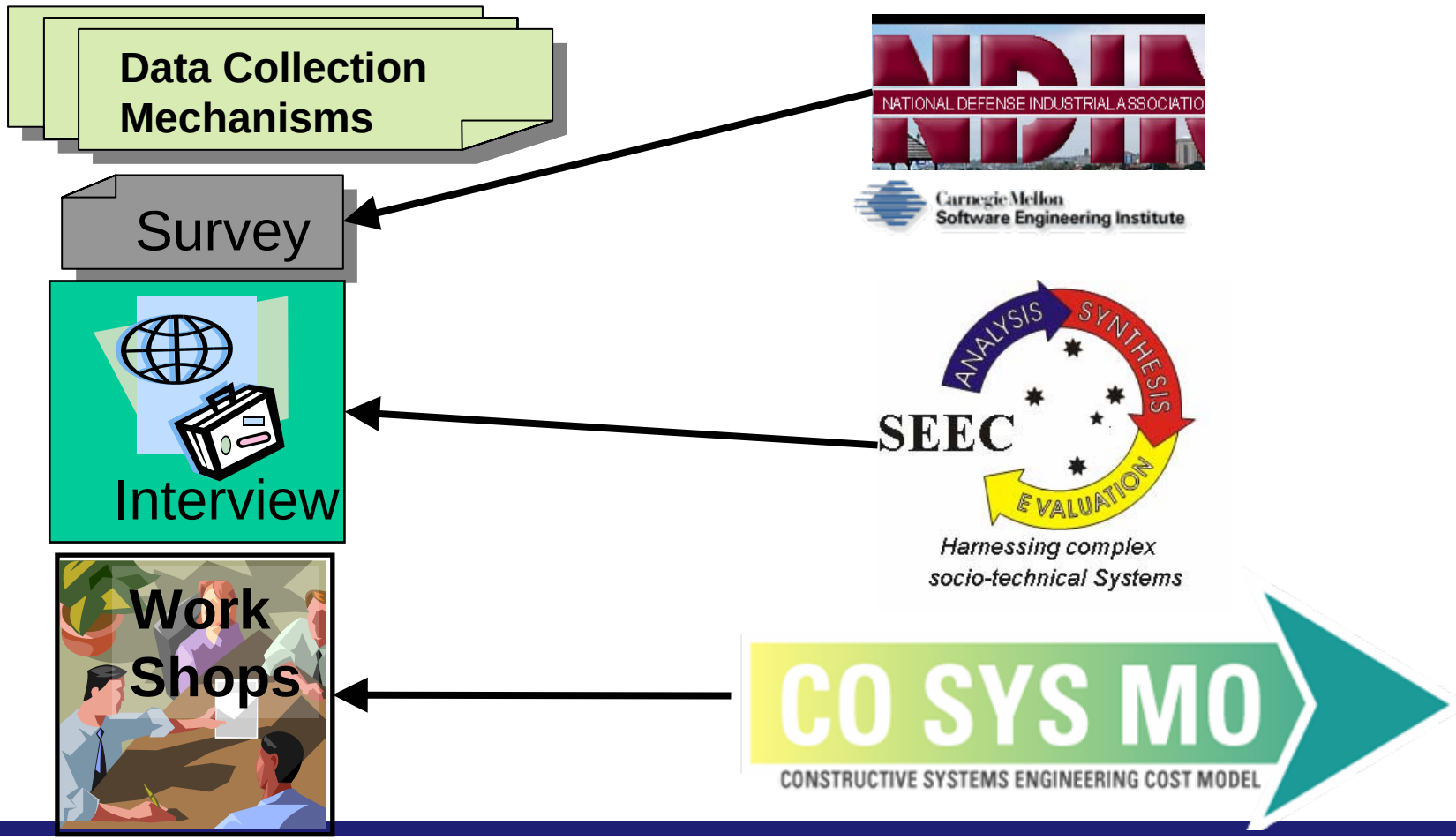
The Race to Discover More – Define SE Activities

How the Different Efforts Collect Data



Value of SE
Conclusions

- ***Value of SE***
  - **Remains fundamental to furthering SE as a respected discipline**
- **Four approaches underway to determine SE Value**
  - **With a fifth – Bob Bruff – on the horizon…**
- **They share commonalities, but also differ:**
  - **Differing types of projects**
  - **Differing SE Activities & Deliverables**
  - **Differing success factors (cost, schedule, quality, etc.)**
- **Challenges Remain**
  - **Useful project data – may not be widely available**
  - **Four separate projects – what if they report different results?**
  - **Success may be elusive – "The Shangri-La of ROI" (Sheard 2000)**
- **Make a difference! Support these approaches**

Value of SE
Conclusion

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