



Honourcode, Inc.

Systems Engineering Return on Investment

**SE-ROI Research
Interim Results Sep 08**

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**Centre of Excellence in
Defence & Industry Systems Capability**

Funding provided by

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



Agenda

- Background – concepts
- Prior research results
- Current SE-ROI project
- Research scientific basis

- **SE-ROI interim results**
PROPRIETARY DATA, SE-ROI PROJECT
Not to be released beyond participant organizations

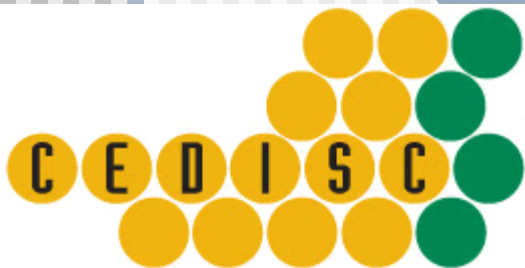




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Background

Concepts: value of SE
Prior results



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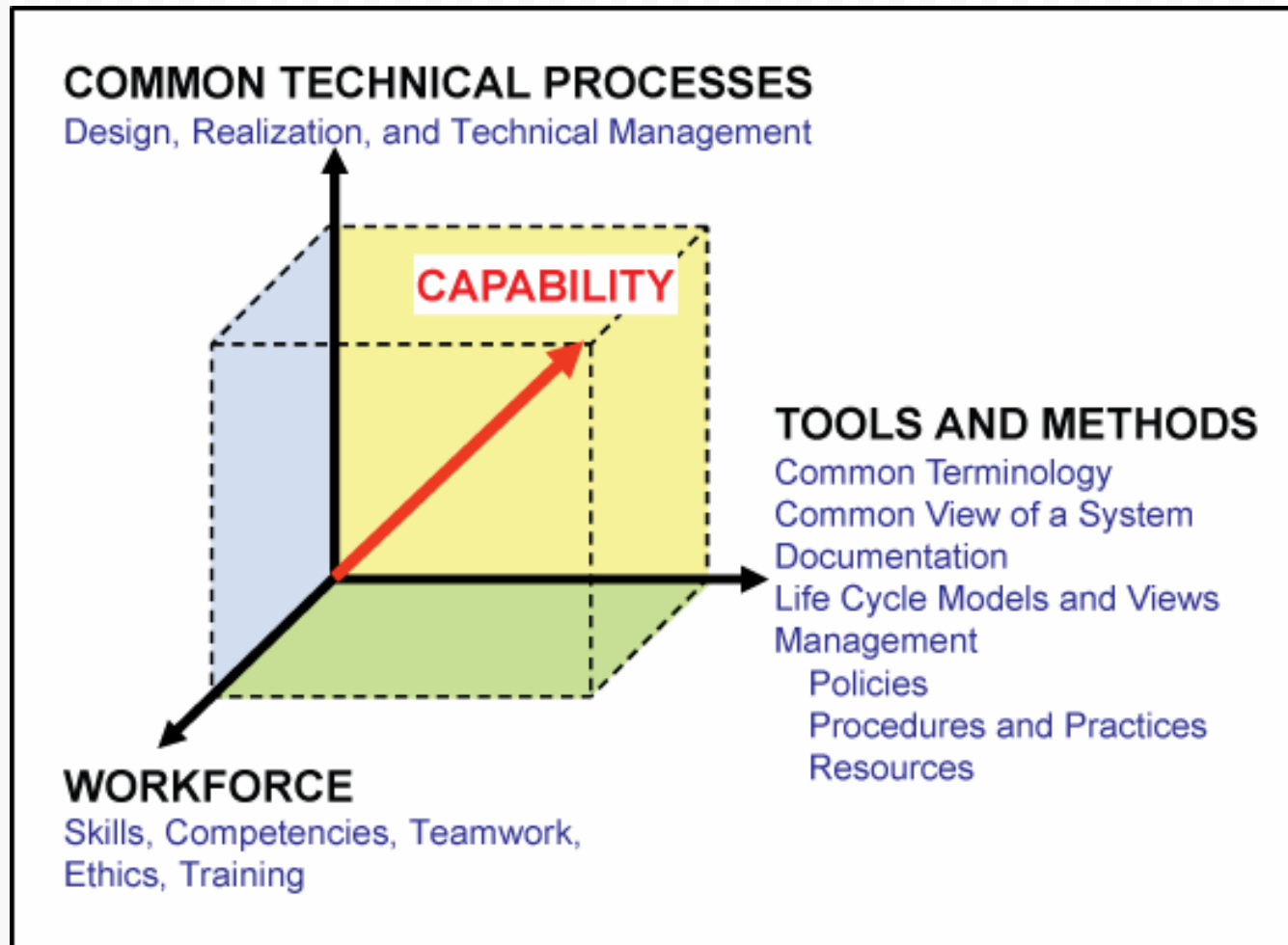
Systems Engineering

- ***Interdisciplinary approach and means to enable the realization of successful systems***
 - Defining customer needs and required functionality early in the development cycle
 - Documenting requirements
 - Proceeding with design synthesis and system validation
- ***Considers the complete problem:*** Operations, Cost & Schedule, Performance, Training, Support, Test, Disposal, Manufacturing
- ***Integrates all disciplines*** and specialty groups into a team effort, structured development from concept to production to operation
- ***Considers both business and technical needs*** of all customers with the goal of providing a quality product that meets the user needs.

INCOSE Definition



SE Framework



Graphic from NASA NPR 7123.1 Figure 1-1



SE Ontology for Measurement

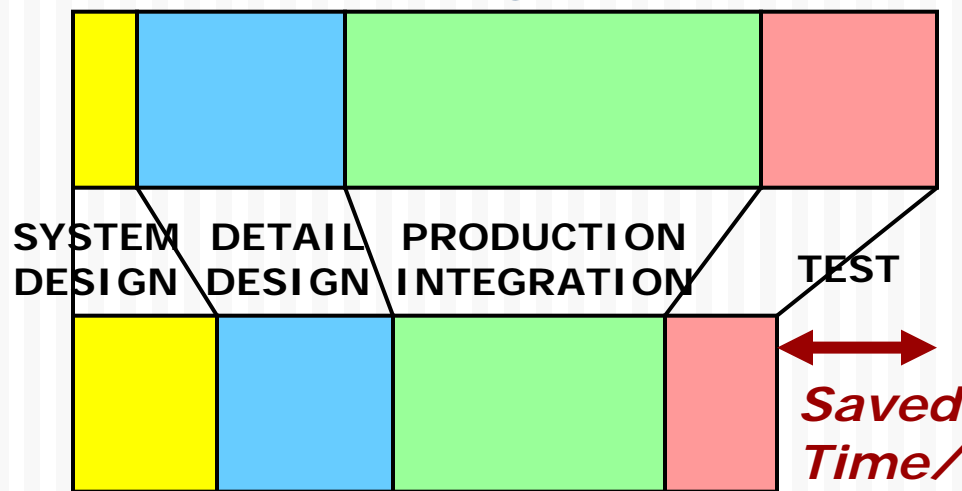
SE Categories	EIA-632	IEEE-1220	ISO-15288	CMMI	MIL-STD-499C
Mission/purpose definition	Not included	▪Def customer expectations	▪Stakeholder needs defn	▪Dev customer requirements	Not included
Requirements engineering	▪Requirements definition	▪Requirements analysis / track	▪Requirements analysis	▪Requirements dev / mgmt	▪Requirements analys / valid'n
System architecting	▪Solution definition	▪Synthesis	▪Architectural design	▪Select solutions ▪Dev design	▪Req'ments allocation ▪Design rep
System implementation	▪Implemntat'n ▪Trans to Use	Not included	▪Implemntat'n ▪Integration ▪Transition	▪Impl product design ▪Prod intgrat'n	Not included
Technical analysis	▪Systems analysis	▪Funct analysis ▪Trade studies	▪Requirements analysis	▪Decision analys / reslt'n	▪Funct analysis ▪Assess effectv ▪Trade analysis
Technical management/ leadership	Tech Mgmt ▪Plan/Assess/ Control	▪Tech mgmt ▪Track perf ▪Track metrics ▪Update	▪Plan/Assess/ Control ▪Decision/risk/ resource/config mgmt	▪Plan/Monitor/ Control ▪Qual/config/ risk mgmt ▪Project mgmt	▪Plan/Monitor ▪Decisi'n/control ▪Risk/baseline/ intfc/data mgmt ▪Tech reviews
Scope management	▪Supply ▪Acquisition	Not included	▪Acquisition ▪Supply	▪Supplier agree mgmt	▪Tech mgmt of sub/vendors
Verification & validation	▪Req validation ▪Sys verif ▪End prod valid	▪Req verif ▪Funct verif ▪Design verif	▪Verification ▪Validation	▪Verification ▪Validation	▪Design verif & validation

Honour 2006, "Advancing an Ontology for SE to Allow Consistent Measurement"

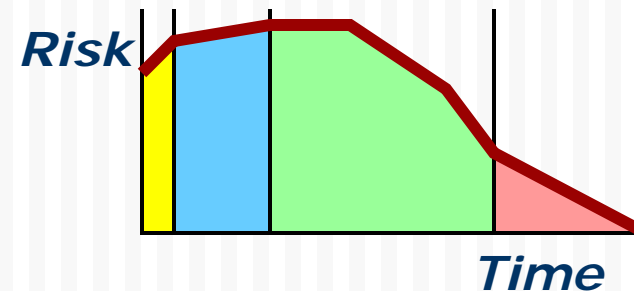
Heuristic Claim of SE

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

Traditional Design



"System Thinking" Design



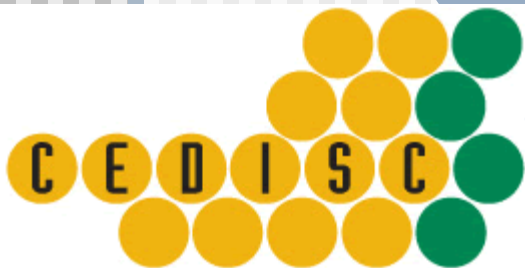
Not Known: How Much Is Enough?



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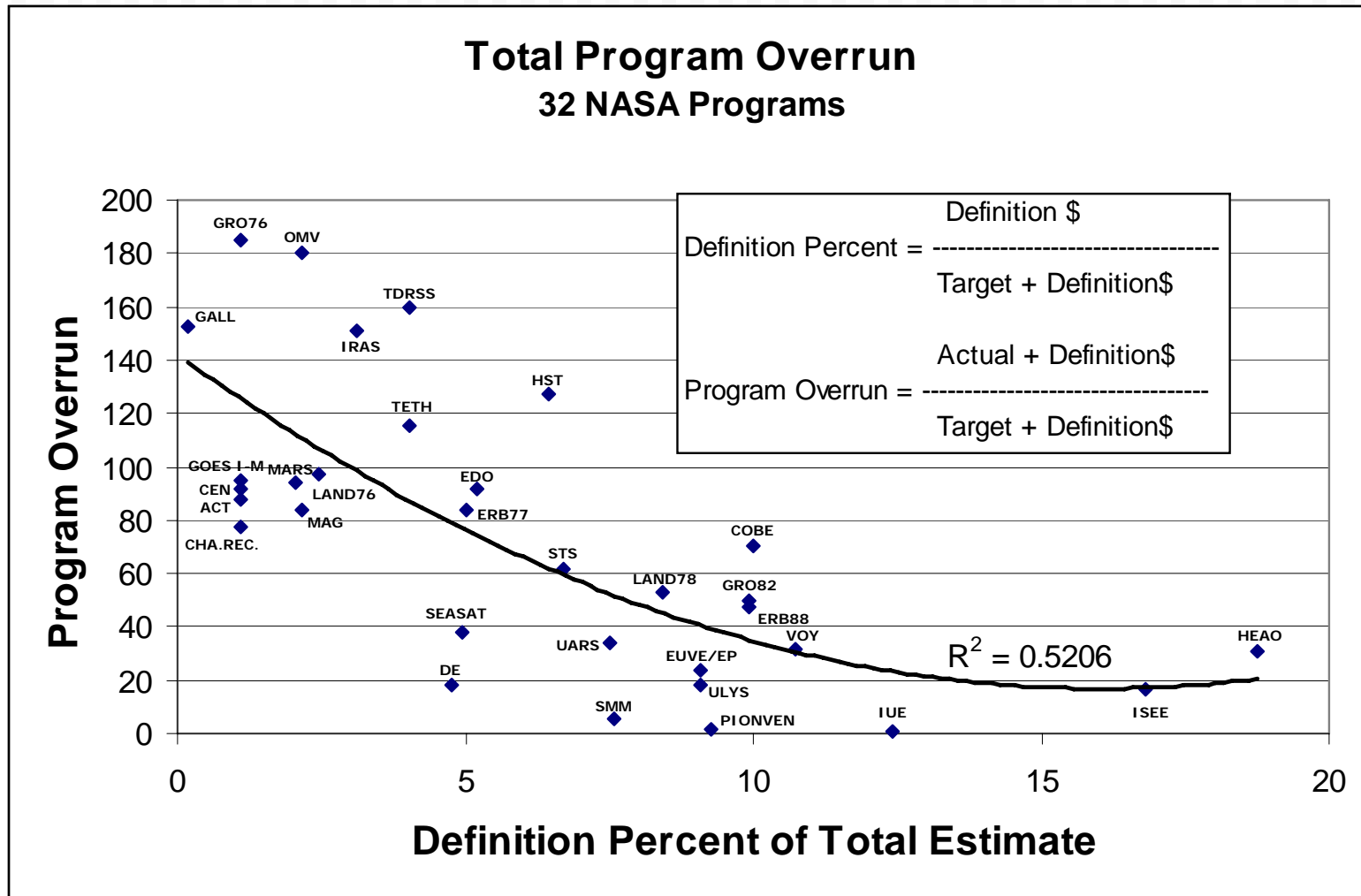
Prior Research Results

**What do we have in
hand that proves the
value of SE?**



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NASA Tracking 1980s



Source Werner Gruhl 1992
NASA Comptroller's Office



“Boundary Management” Study

- Study of 45 high-tech new product development teams
- Significant portion of time is spent at team boundaries

Successful teams spent more time in boundary management

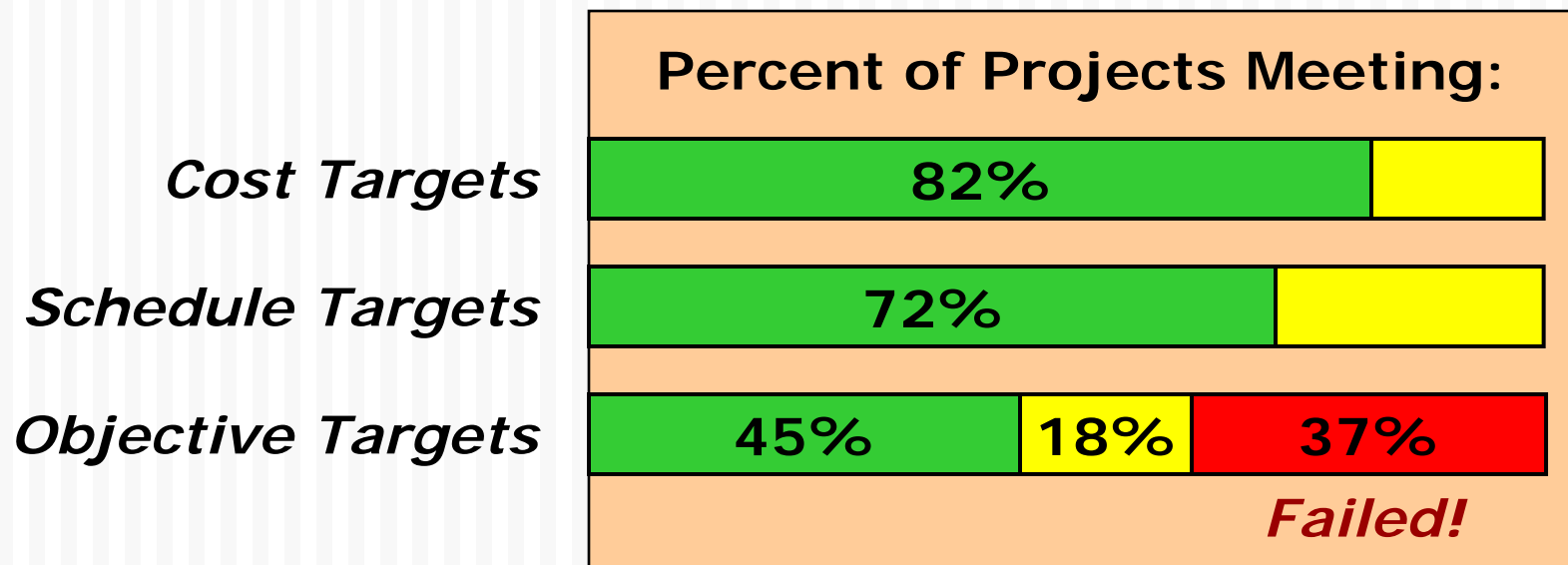
Processes used did not correlate with success

<u>Individual Time Spent</u>	
■ Outside Team	14%*
* Typically limited to few individuals	
■ Within Team	38%
■ Alone	48%



"Large Engineering Projects"

- Study of 60 LEPs (power generation, transportation, oil production, technology)
- Evaluation by interviews and by objective and subjective quality measures.



...Miller & Lessard, Strategic Management of Large Engineering Projects, MIT 2000



"Large Engineering Projects"

Significant Findings:

- Most important determinant was a coherent, well-developed organizational/team structure
A structure of leadership creates greater success
- Technical difficulties, social disturbance, size were not statistically linked to performance
 - *All projects had turbulent events*
- Technical excellence could not save a socially unacceptable project
Process definition is important but not sufficient.



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

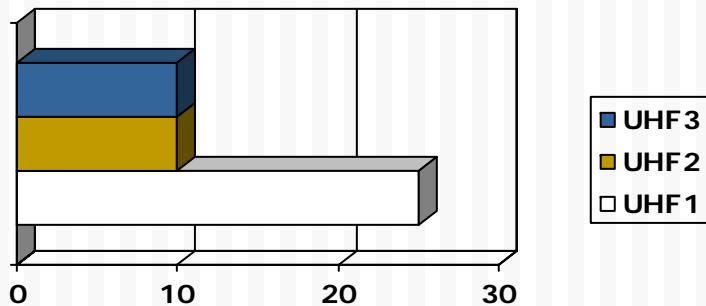
Trait	UHF1	UHF2	UHF3
Size	10' x 40'	8' x 50'	6' x 14'
Accuracy	±0.005"	±0.003"	±0.003"
Contact Sensors	None	57	108
Vacuum Sensors	1	70	108
Real-time checks	No	Yes	Yes
Probe contours	No	Yes	Yes
NC interface	No	Yes	Yes

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

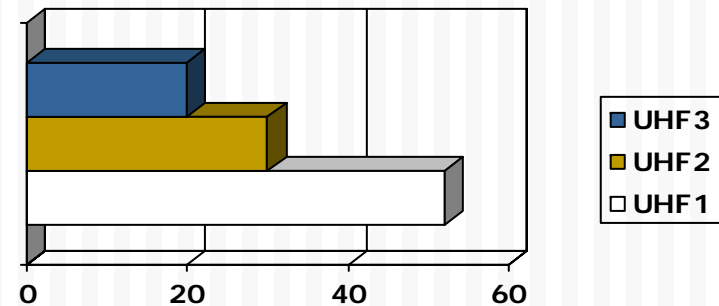


Impacts

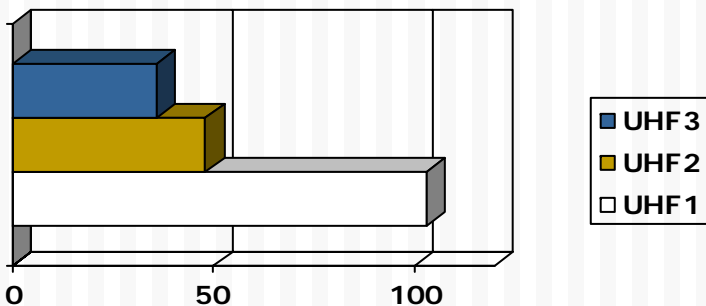
Requirements to RFP (weeks)



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

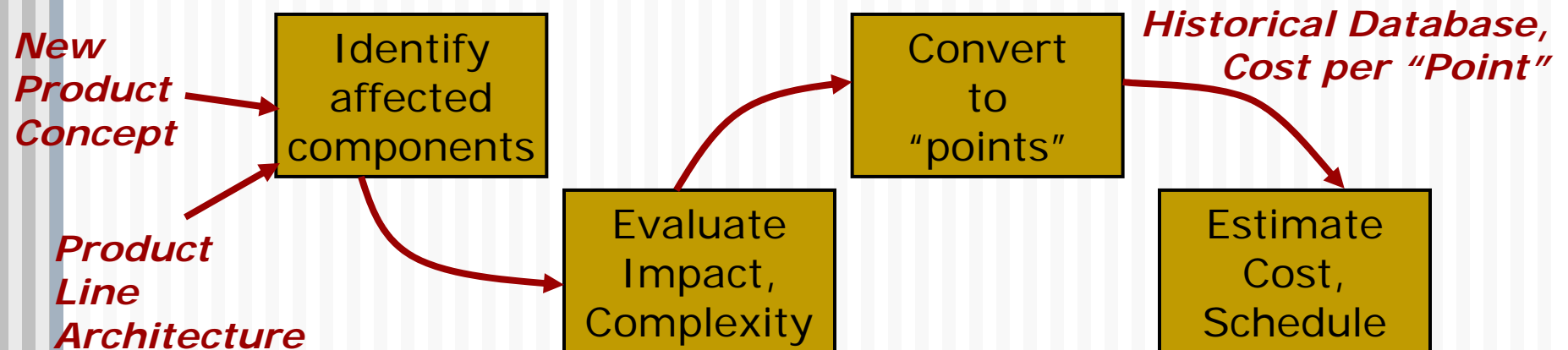
...even in the face of more complex, higher quality systems!

...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





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	2000	\$1,454/pt
		2001	\$1,142/pt
With SE	\$944/pt	2002	\$818/pt

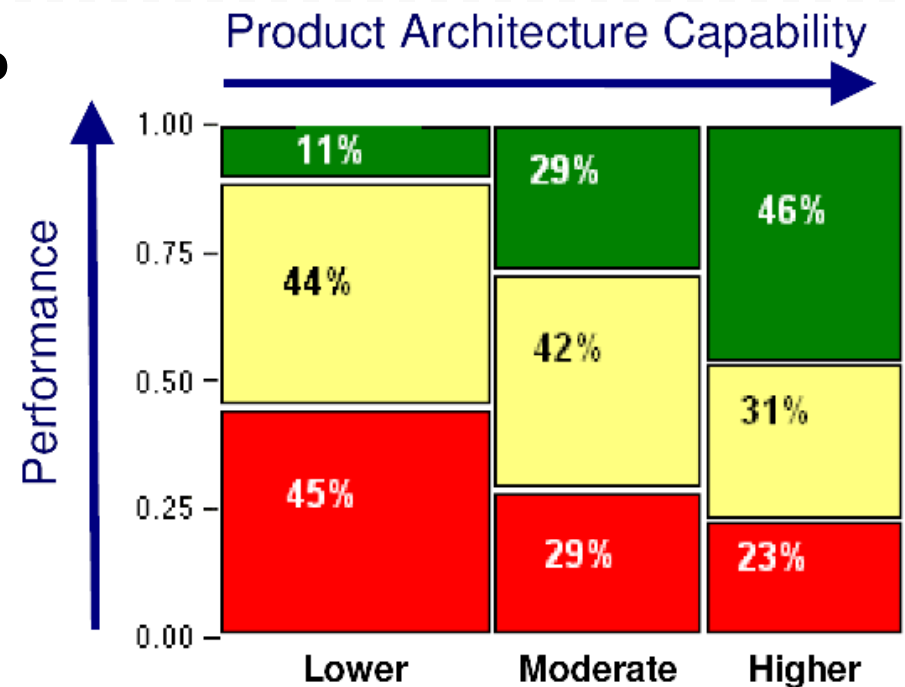
...Barker, Determining Systems Engineering Effectiveness,
IBM Commercial Products, CSER 2003





NDIA SE Effectiveness - 2007

- Survey of SE practices with ~140 questions, 60+ program responses
- Results analyzed statistically for correlations between SE practices and program performance
- Questions grouped into 18 categories
- Typical result: **Better product architecture capability shows a "strong" correlation with performance** ($\text{Gamma} = +40\%$)



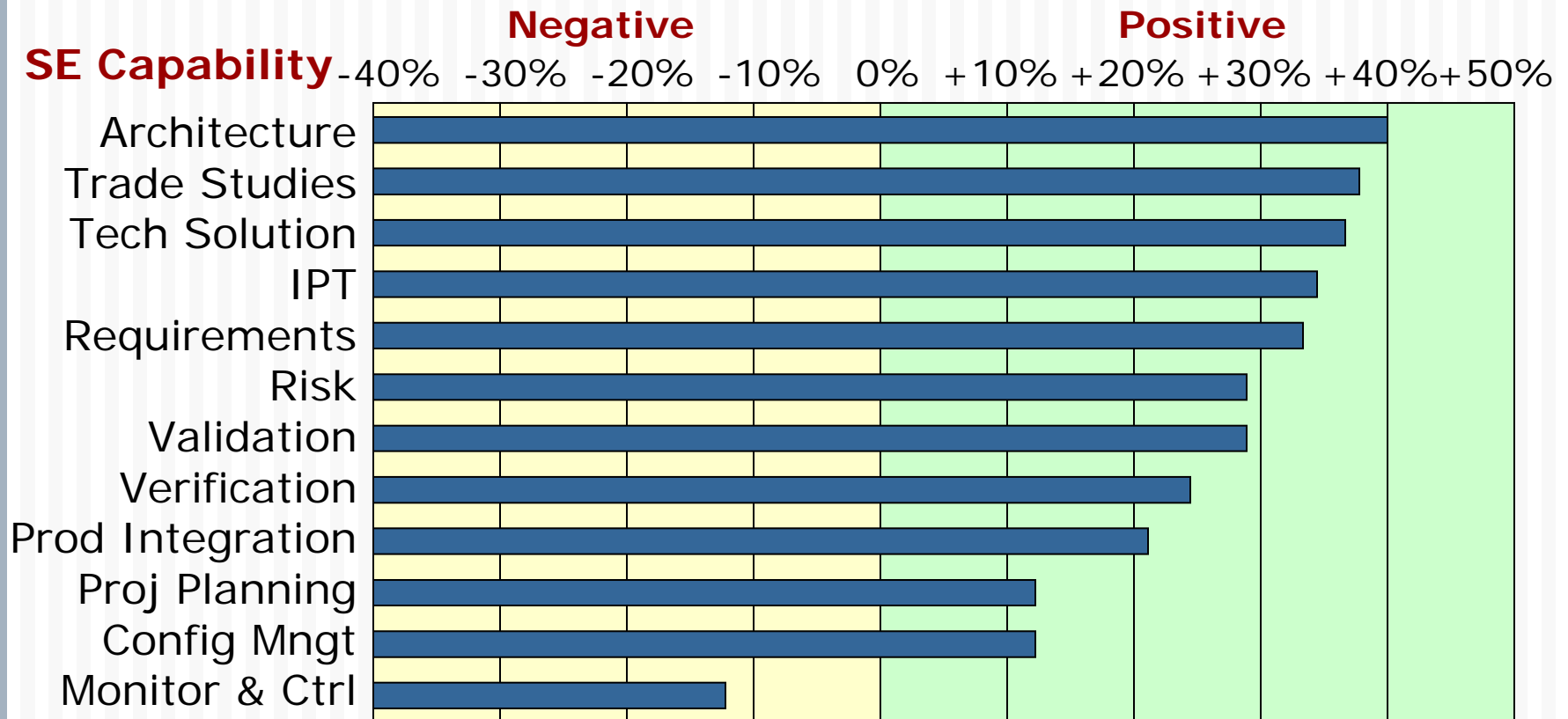
...Elm, *A Survey of Systems Engineering Effectiveness*,
NDIA, CMU/SEI 2007





Effect of SE Activities on Projects

Relationship to Performance (Gamma)



Most SE practices correlate positively to project performance

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





Prior Research Indications*

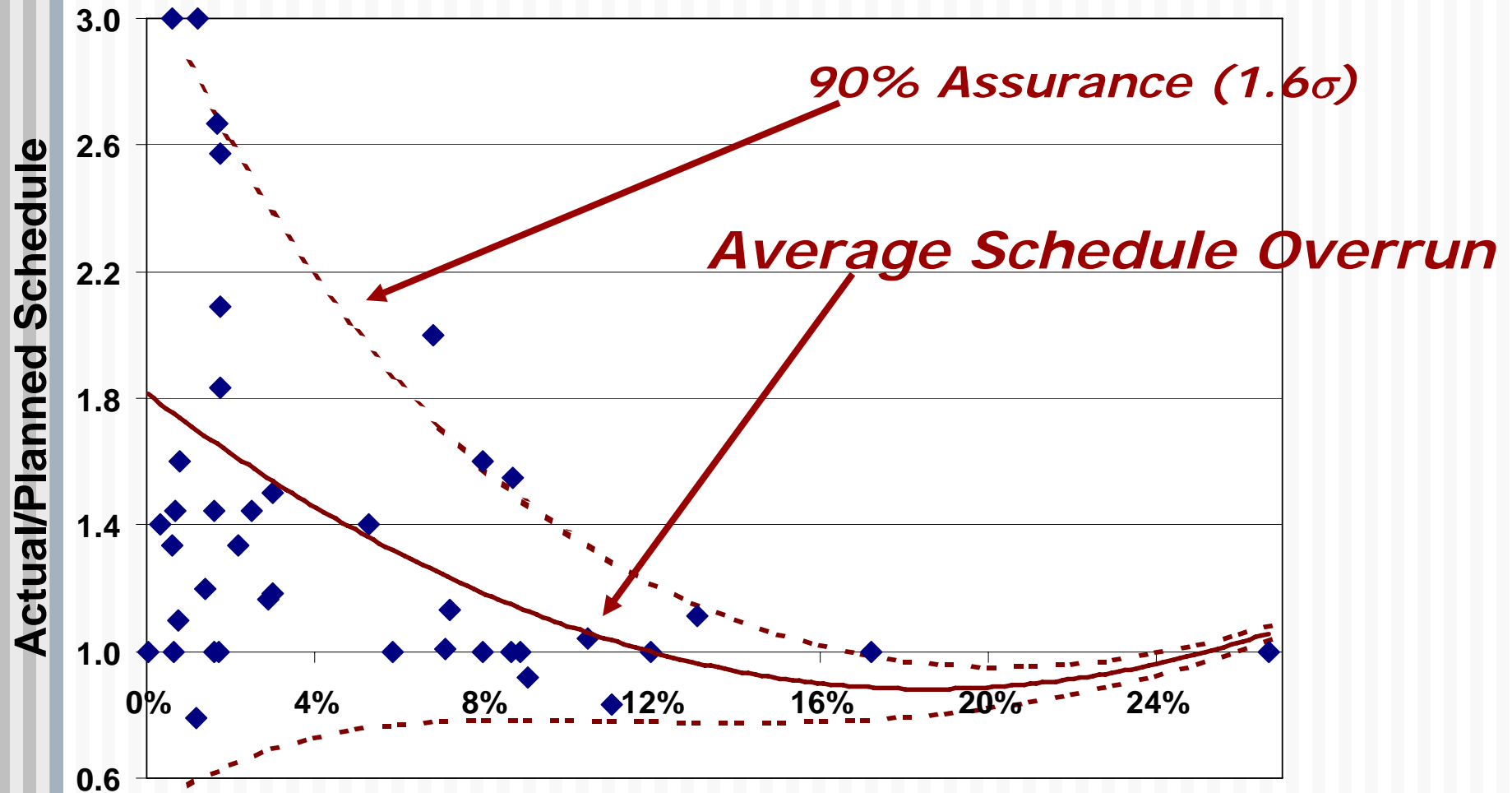
- Better technical leadership correlates to program success.
[Ancona 1990, Miller 2000]
- Better/more systems engineering correlates to shorter schedules by 40% or more, even in the face of greater complexity.
[Franz 1995, Honour 2004]
- Better/more systems engineering correlates to lower development costs, by 30% or more.
[Gruhl 1992, Barker 2003, Kludze 2004, Honour 2004, Boehm/Valerdi/Honour 2007]
- Programs typically operate at about 6% systems engineering.
[Kludze 2004, Honour 2004]
- Parametric cost estimation of systems engineering is possible.
[Valerdi 2004]
- SE practices correlate to program success, with different practices offering different correlations *[Gamgee 2006, NDIA 2007]*

But Still: How Much Is Enough?

- Optimum level of systems engineering is about 15% of a total development program.
[Gruhl 1992, Honour 2004, Boehm/Valerdi/Honour 2007]



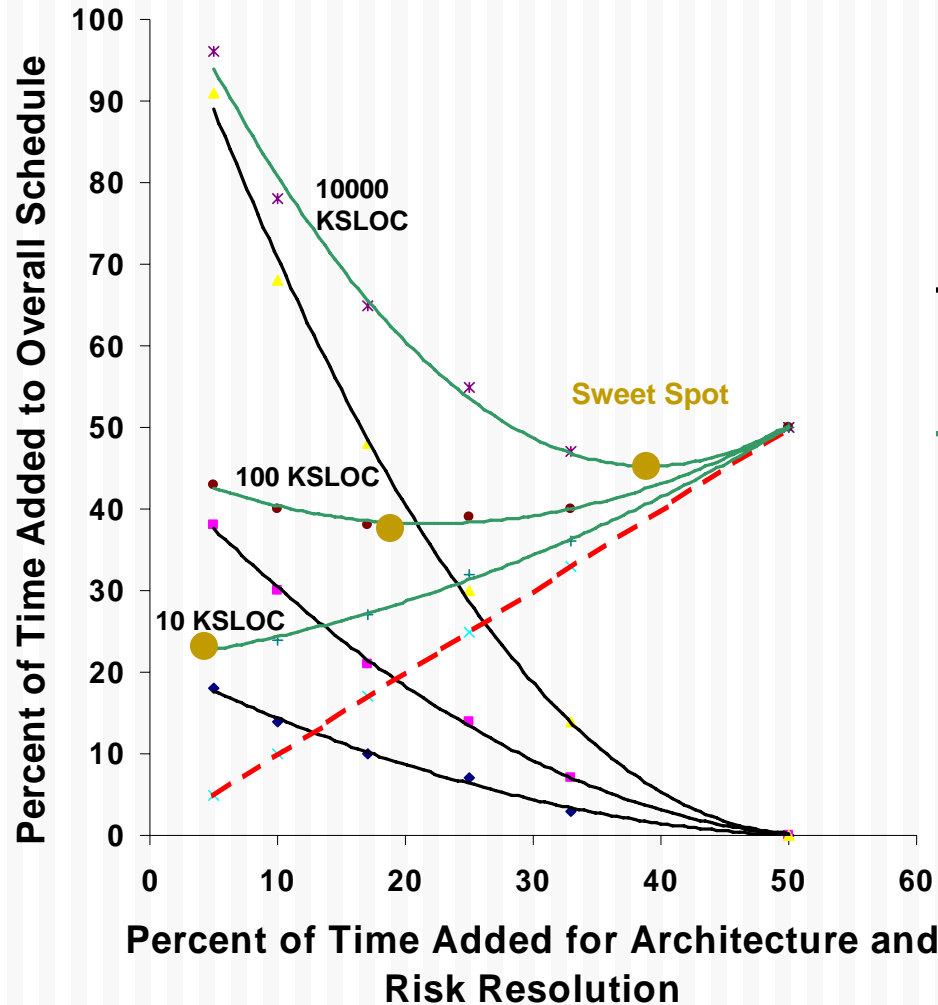
Schedule Overrun vs. SE Effort



SE Effort = SE Quality * SE Cost/Actual Cost

Source: SECOE 01-03
INCOSE 2003

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

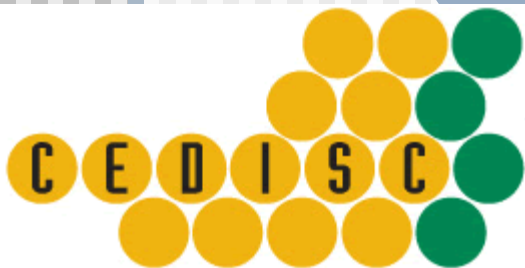
Basis: 161 projects in COCOMO II database since implementation of RESL factor



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SE-ROI Project

**Methodology
Industry support**



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SE-ROI Project

Interviews

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

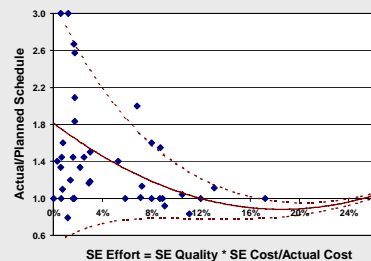
- *Program characterization*
- *Program success data*
- *SE data (hours, quality, methods)*

Desired Results

How Much Is Enough?

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

Statistical correlation





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 – Sep 08

- | | |
|---|-----------------------|
| ■ <u>SE ontology</u> from SE standards – wide-spread, acceptable terminology | Completed
Oct 05 |
| ■ <u>Develop interest base</u> from possible interview sources (currently 59) | Completed,
Ongoing |
| ■ <u>Create interview data sheets</u> and vet them through sample interviews | Completed
Oct 06 |
| ■ <u>Start program interviews</u> | Started 3/07 |
| ■ <u>Gather data</u> from 40+ programs | In process |
| ■ Interviews held | 21 |
| ■ Programs ready for interview | 13 |
| ■ Active program contacts | 15? |
| ■ Other known possibilities | 30? |
| ■ <u>Report benchmark results</u> to participating organizations | In process |
| ■ <u>Public reports</u> on research results | Target 2010 |

Need More Programs!





Acknowledgements

- Funding for the SE-ROI project provided by
 - Honourcode, Inc.
 - Centre for Excellence in Defence and Industry Capability (CEDISC)
 - University of South Australia
 - *Other funding sources are still needed*





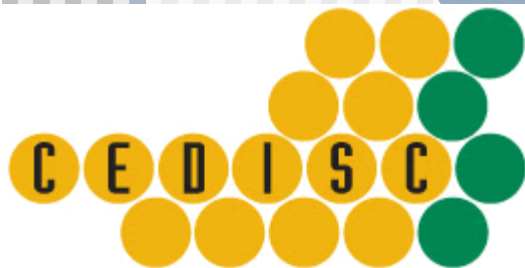
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SE-ROI Research Interim Results

**Continued additions to
"Value of SE" results**

**Histograms of SE
activities**

**Initial indications about
effectiveness of SE
activities**



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



Schedule vs. SE Effort

Proprietary data removed.
Contact author to participate and obtain data.



Cost vs. SE Effort

Proprietary data removed.
Contact author to participate and obtain data.



Breakout by SE Activities

Proprietary data removed.
Contact author to participate and obtain data.



Effect of SE Activities

Proprietary data removed.
Contact author to participate and obtain data.



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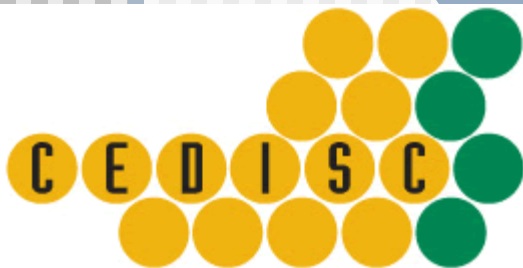
Systems Engineering Return on Investment

Questions?

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