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Return on Investment for Systems Engineering Tools

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Return on Investment for Systems Engineering Tools

Paper #: 123

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A Masters Degree Research Project
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Agenda

Purpose

- Purpose
- Objectives

Scope

- Scope
- User Inputs

Methods

- Background
- Approach

Calculations

- Data
- Calculations

Results

- Financial
- Value

Findings

- Findings
- Conclusions

SE Tools ROI – Research Purpose

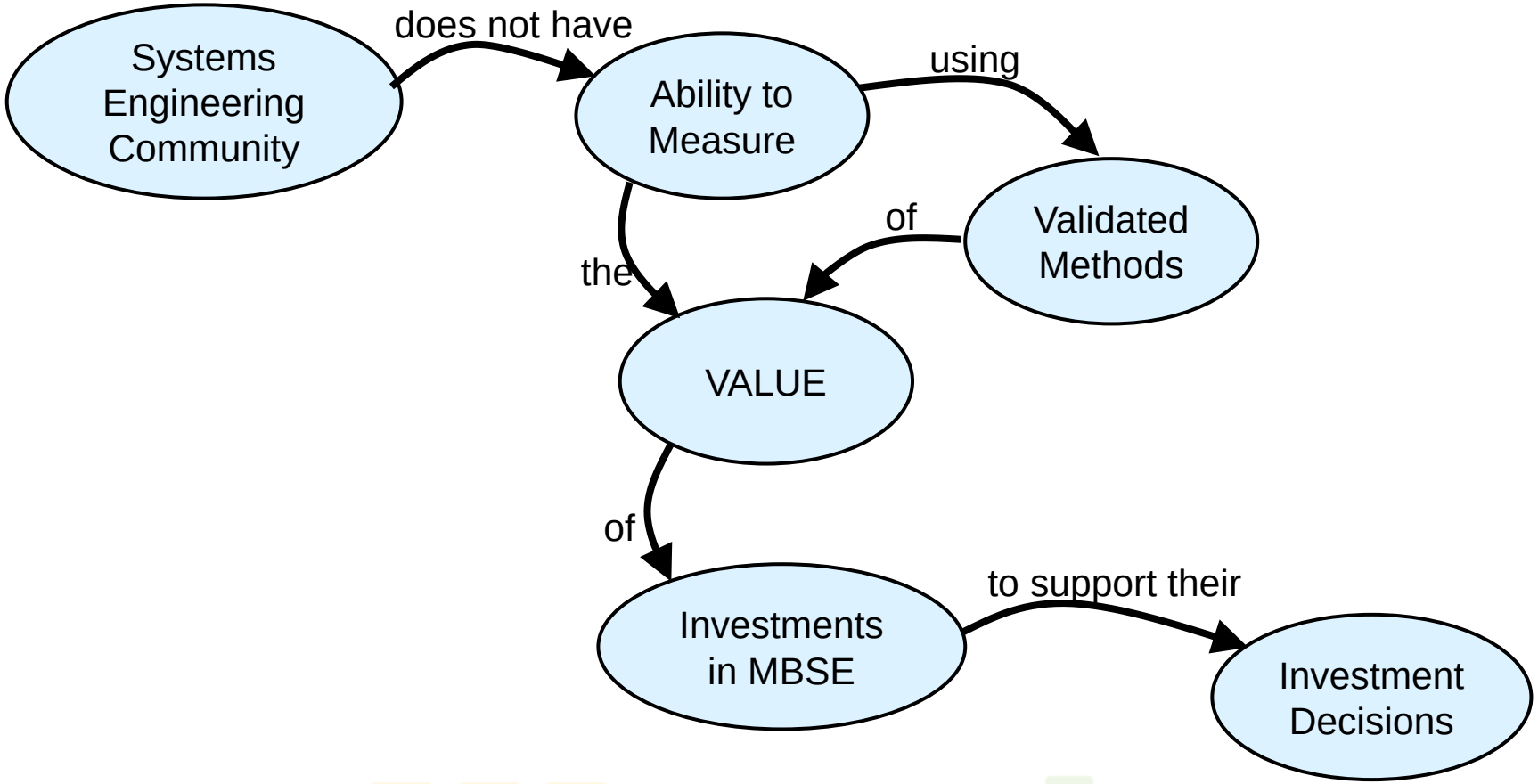
INCOSE Value Proposition Initiative

- VPI seeks to create value propositions based on characteristics that are important to customers, providers, and decision makers

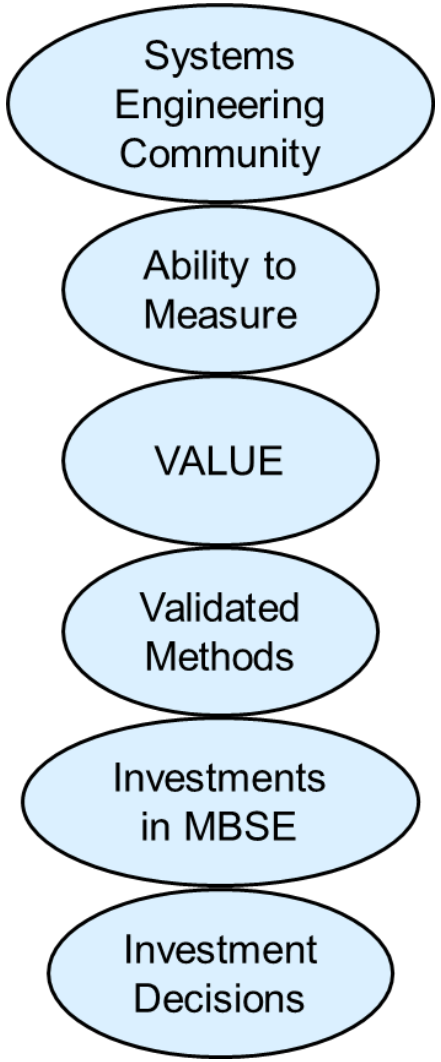
- This research attempts to provide numerical data for measuring the value proposition of system engineering software tools

SE Tools ROI - Problem Statement

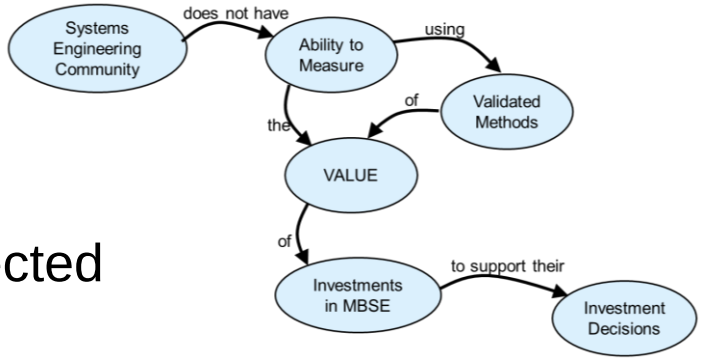
Systems Engineering community does not have the ability to measure, using validated methods, the value of investments in model-based systems engineering to support their investment decisions.



SE Tools ROI - Research Objectives



Commercial or non-commercial organizations of different sizes, varying objectives, varying amounts of SE tasks



Estimated ROI and ROA ($$) for investment ($$) in a selected SE tool (individual or category)

Value to the organization as determined by Profitability, Productivity, Capability, and Project Performance (weighted)

Method to determine Value from organization and SE tool attributes

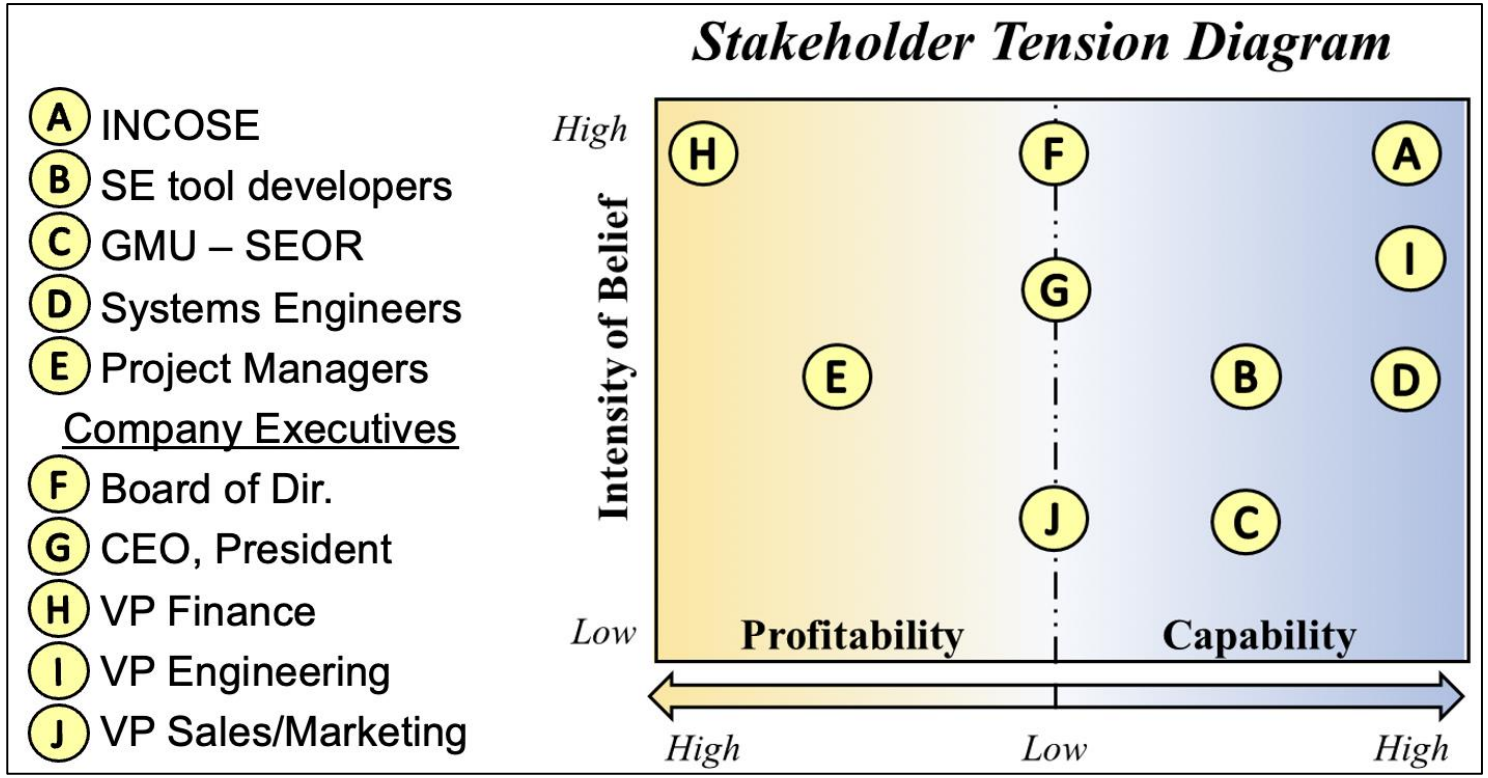
- SE Tool Productivity, Ease of Use, Proficiency levels
- Organization Productivity

Amount ($$) of financial investments in SE tool acquisition and training

Determination of value over a several year period for alternative SE tools (individual or category)

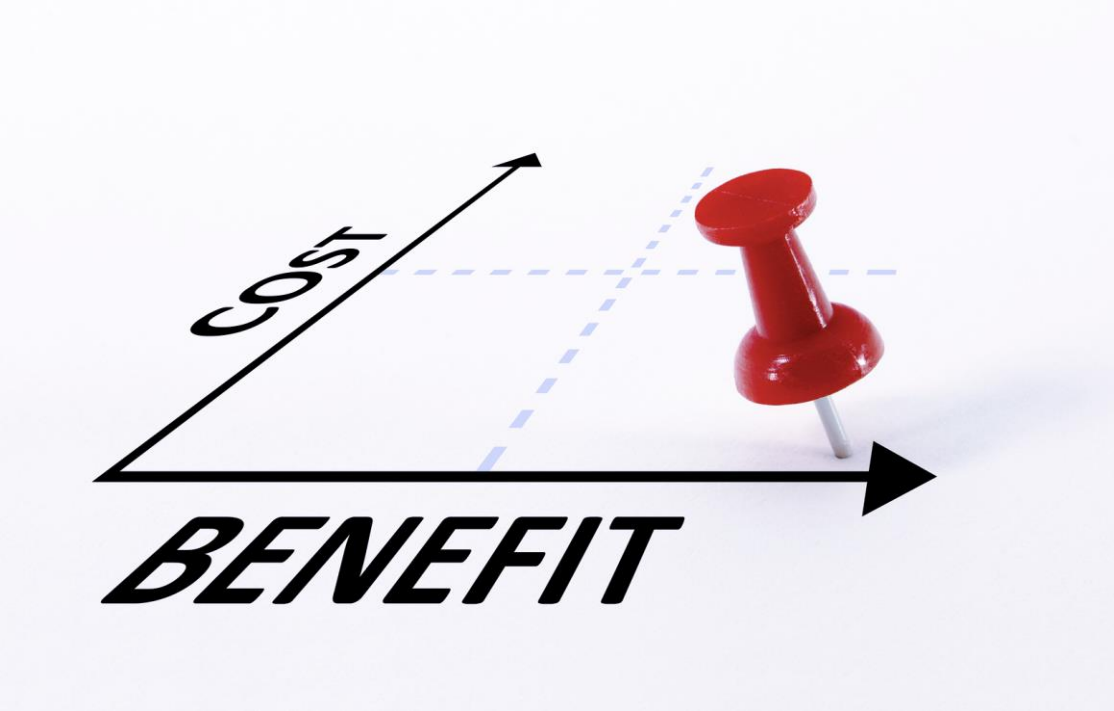
Organization Stakeholders – Varying Priorities

- Different stakeholders have different priorities
- We need a method that informs the DM based upon *their* priorities



Research Goal for the ROI Tool

To provide information to inform a decision maker regarding the value of changes to their current level of systems engineering capability

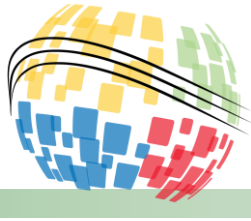


Bhanot, Pradeep. “Cost/Benefit.” *Actian. 4 June 2019,* https://www.actian.com/company/blog/a-cost-benefit-guide-to-the-data-warehouse/.

Metrics Provided for a Decision

- Profitability
- Productivity
- Capability
- Project Success

Agenda



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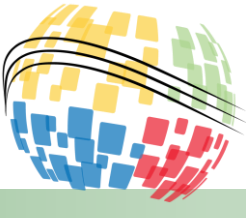
SE ROI Tool – User Considerations



Method

- Information only as needed to make an investment decision
  - ***not for predicting the future***
- Range of organization types (Commercial and Government)
- Range of organization sizes (S, M, L, XL, User Specified)
  - SE labor: ranges from 1 to 100 man-years of effort ($100K to $10M)
- Account for organization priorities and desired SE capability
- Consider current and future SE workloads plus degree of difficulty for the SE work (challenge)

SE ROI Tool – User Inputs

Organization Characteristics

- Type, Size, Priorities, Objective

Organization Capabilities

- Current Systems Engineering capabilities
- Desired Systems Engineering capabilities

Organization Workload

- Current workload, Future workload, SE Challenge Level

SE ROI Tool User Inputs Worksheet

Organization type
choose from type categories listed
select Commercial, Govt, Education

Commercial | 1

Organization Size
choose from size categories listed

Medium | 2
S, M,L,XL

Organization Primary Objective

Profitability | 1
select Profit, Product, Capab, or Project

Organization Priorities (weightings)
rank these 1st, 2nd, or 3rd
(one tie in ranking is allowed)

1st	2nd	3rd	4th

must be low# to high#		Weighting Rank	Adjusted
1	Capability	0.521	**0.521**
2	Productivity	0.271	**0.271**
3	Project Performa	0.146	**0.146**
4	Profitability	0.063	**0.063**

must all be different — Rank-Sum method

SE current workload 75 **in man-years**

SE forecast workload
enter number as %, relative to current SE workload =100%

Value is % of Current workload			
minimum	expected	maximum	
100	100	120	current year
120	140	170	next 2 years
125	160	230	next 3 to 5 years

SE Challenge level
choose level of challenge
1 = easy, 4 = hard
= a "degree of difficulty index"
Ref. Joseph Elm (2013)

current	future
2	4

System Engineering Capability
choose SE capability level,
% of full SE functions

	current	desired
Sys Engrg Planning	100	100
Requirements Management	100	100
Design Synthesis	100	100
Functional Analysis	100	100
Design Documentation (CM)	100	100
Technical Risk Mgt	100	100
Technical Performance Mgt.	100	100
System Operations	100	100
Specialty Engrg. Disciplines	100	100
Design Integration	100	100
IVV	100	100
Project Mgt	100	100

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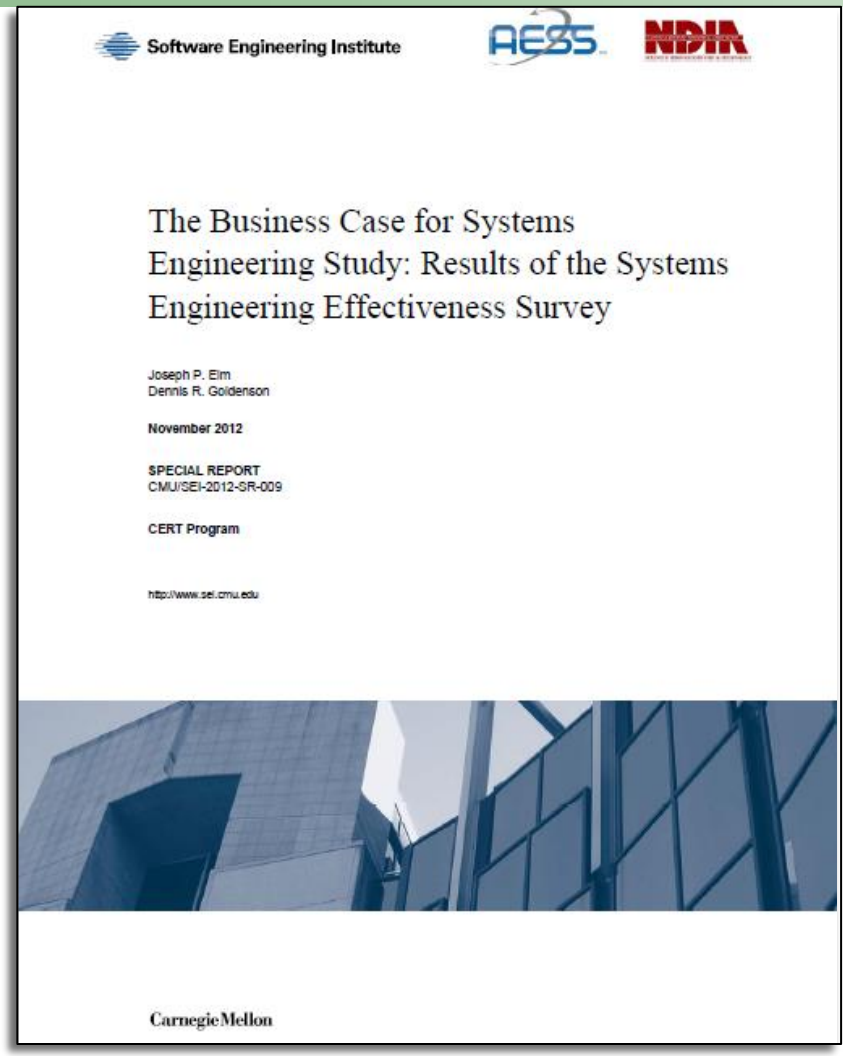
Systems Engineering Effectiveness Survey (2012)

Conducted by Software Engineering Institute (Joseph Elm)

- Finding: Investments in SE improves project performance
  - If <10% of project budget spent on SE, expect ≈100% budget overrun
- Project challenge is a key factor in SE benefit determination
  - High challenge projects require SE investment to succeed
  - Low challenge projects: success is feasible without SE investment
- Showed relationship of 11 SE categories (capabilities) to the overall benefit of SE to project success

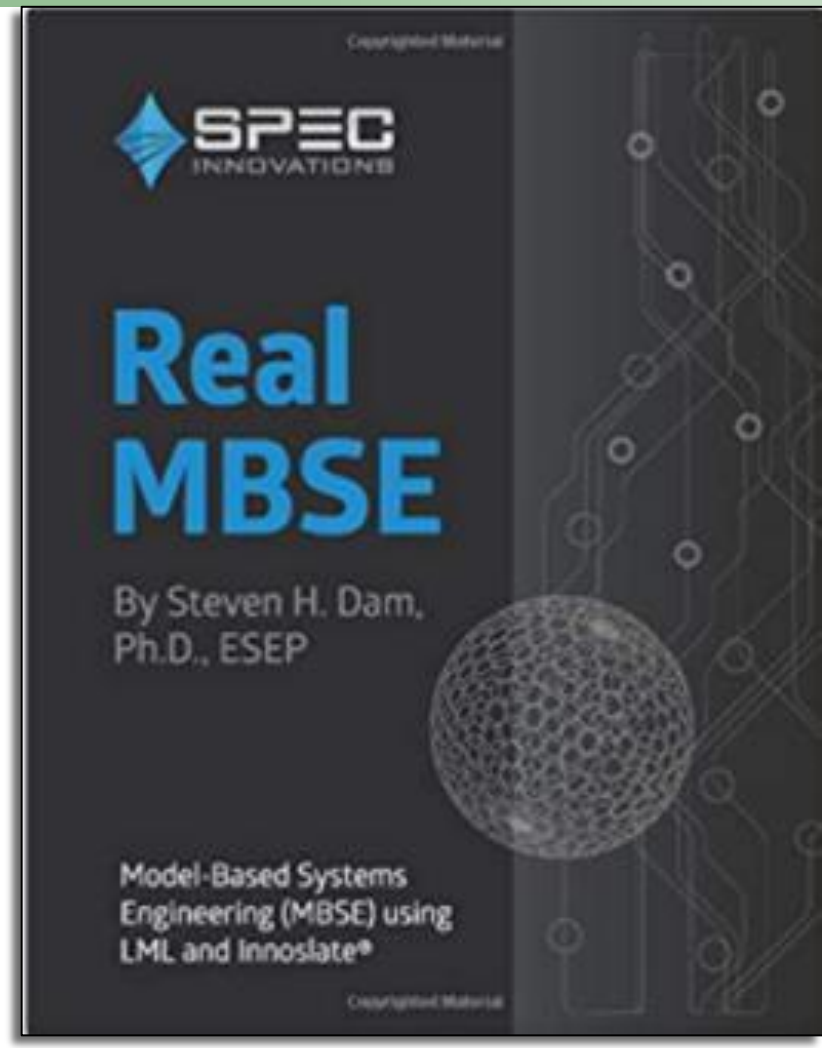


Recent SE Tools ROI Assessment

Performed by SPEC Innovations (Steve Dam)

- Built upon the SEI survey to estimate an ROI for MBSE
  - 10% of project budget in SE functions produces an ROI of 1,000%
  - . . . but only if you are performing all of the SE functions (capabilities)
- Examined three types of SE tools (ad hoc, SysML, LML)
  - Ease of Use
  - Productivity (time to perform SE tasks)
  - Cost (acquisition and training)
- MBSE tools produce a very high ROI
  - As much as 100% ROI for LML* tools (via 2X productivity increase)

* LML = Lifecycle Modeling Language



System Engineering Tool Categories

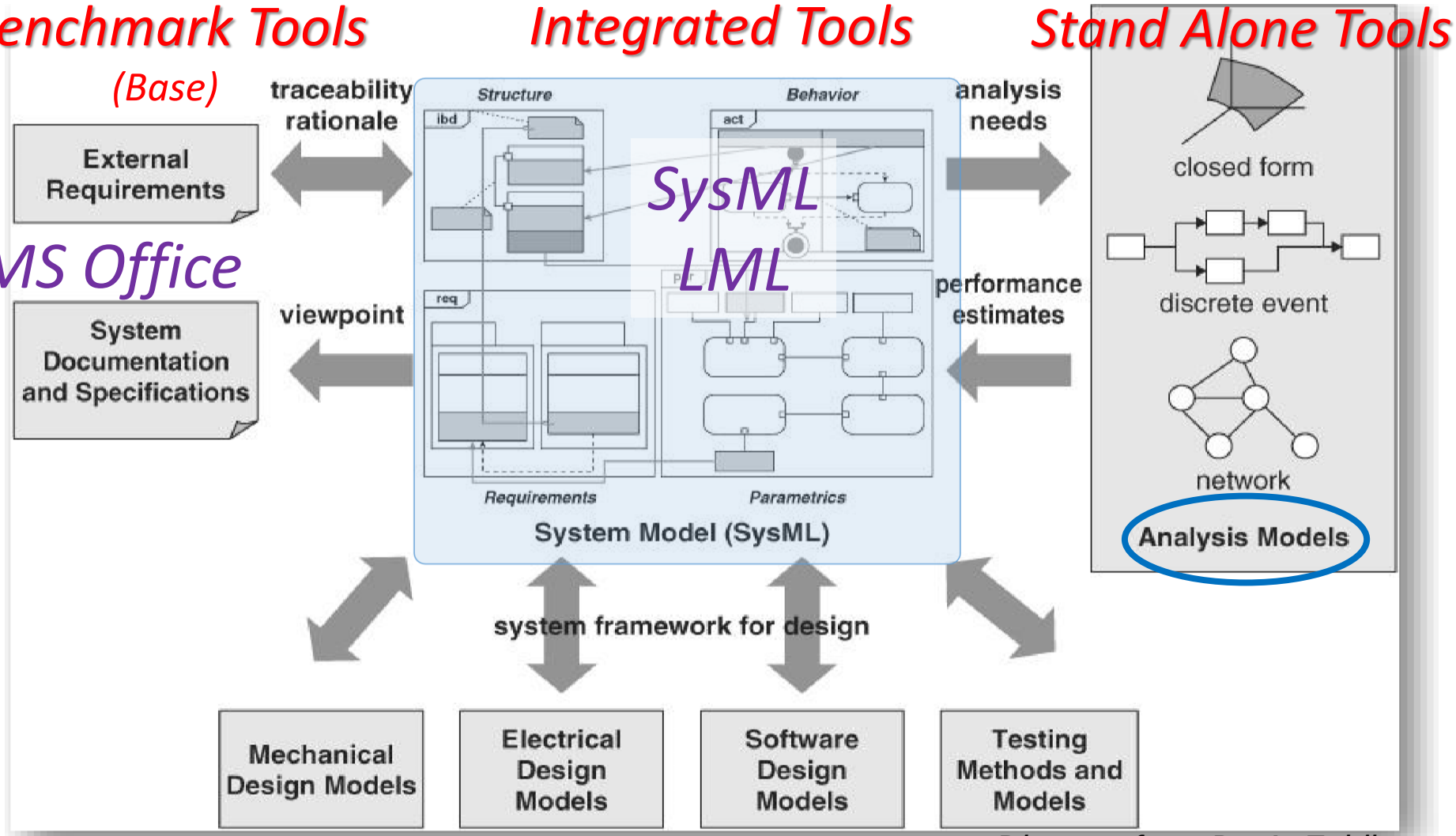


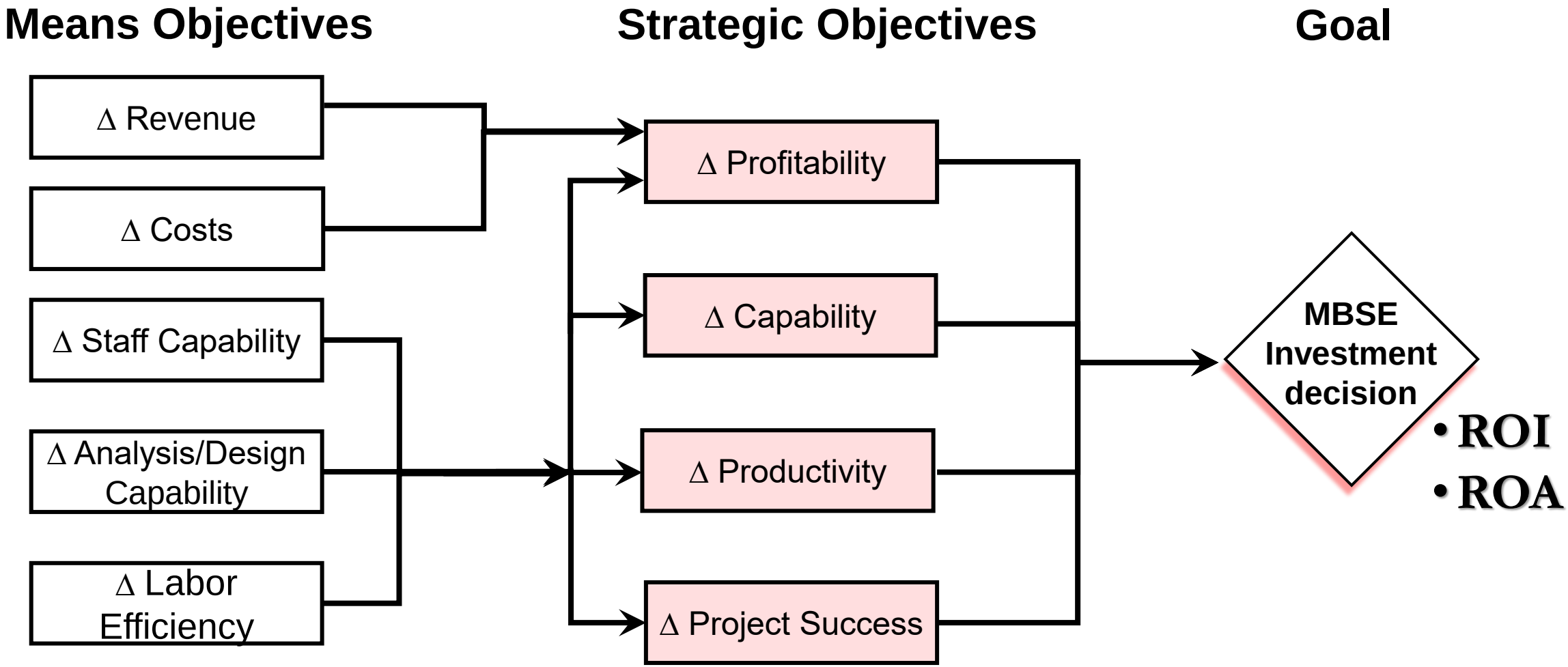
Diagram from Dr. A. Zaidi

SE Tools Evaluated

SE Tools For Evaluation

- **Benchmark (Base):** MS Office Pro (Word/PowerPoint), Access, Excel (Analytic Solver), Publisher, Project Pro
- **Stand Alone:** StarUML, Analytica, Vensim, Logical Decisions, Matlab/Simulink, Deltek (Compass),
- **Integrated:** Innoslate, MagicDraw, Enterprise Architecture, Cradle, Core

Calculation of ROI - Schematic of Approach



User Inputs Allow Tailored Results

% now, % need

Growth
Competition

S, M, L, XL

Profitability
Productivity
Capability
Proj. Perform.

now, future

now, future

User Inputs

- System Engineering Capability
- Organization Objectives
- Organization Size
- Organization Priorities (wts)
- Project Challenge
- Market Forecast

Organization Capabilities

	Systems Engineering Capability and Related Tasks	Current	Future
1.0.	Sys Engrg Planning	%	%
1.1.	Requirements Management	%	%
1.2.	Design Synthesis	%	%
1.3.	Functional Analysis	%	%
1.4.	Design Documentation (CM)	%	%
1.5.	Technical Risk Mgt	%	%
1.6.	Technical Performance Mgt.	%	%
1.7.	System Operations	%	%
1.8.	Specialty Engrg. Disciplines	%	%
1.9.	Design Integration	%	%
1.10.	IVV	%	%
1.11.	Project Mgt	%	%

Tool Capabilities

Basic	Stand-alone	Integrated
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%
%	%	%

Organization & Tool Evaluations

Productivity & Profitability

Tools Reviewed

Basic	Stand-alone	Integrated
MS Word	Analytica	CORE
MS Excel	Deltek	Cradle
MS Project	Logical Decision	Doors
MS Access	Matlab/Simulink	Ent. Architect
Frontline Solver	StarUML	Innoslate
	Vensim	MagicDraw

SE ROI Tool Data – Capability Matrix

			Integrated MBSE Tools					SE Standalone tools						Benchmark/Base Tools					
Systems Engineerin Capability	Systems Engineering Capability and Related Tasks	Concordance Factor (power)	Innoslate	MagicDraw w/ SysML Plugin	Enterprise Architecture	Cradle	Core	Deltek (Compass)	StarUML	Analytica	Vensim	Logical Decisions	Matlab/Simulink	MS Office	Word/Powerpoint	Access	Excel	Analytic Solver Comprehensive	Project Professional
1.0.	Sys Engrg Planning	1.000	100%	0%	0%	40%	0%	40%	0%	0%	40%	0%	0%	100%	100%	0%	40%	0%	40%
	SEMP		X											X	X				
	WBS Preparation		X			X		X			X			X	X		X		X
	WBS Maintenance		X			X		X			X			X	X		X		X
	RAM		X											X	X				
	Maintain/Evolve SE Mgt Plan		X											X	X				
1.1.	Requirements Management	1	100%	100%	17%	100%	100%	0%	0%	0%	0%	0%	0%	100%	100%	33%	50%	0%	0%
	Import Requirements Documents		X	X		X	X							X	X				
	Analyze Requirements		X	X		X	X							X	X		X		
	Manage Requirements		X	X	X	X	X							X	X	X	X		
	Trace Requirements		X	X		X	X							X	X	X	X		
	Allocate Requirements		X	X		X	X							X	X				
	Import & Allocate Standards		X	X		X	X							X	X				
1.2.	Design Synthesis	1	100%	100%	83%	67%	67%	0%	83%	0%	0%	0%	17%	50%	33%	0%	17%	0%	0%

- Data gathered from research, team members' tool experience, and SME input
- Includes 11 core Systems Engineering + 1 Project Management tasks + subtasks
- Indicates each tool's capability to support specific SE process tasks & subtasks

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SE ROI Tool Data – Software Cost

- Data gathered from research and vendor interaction
- Includes acquisition, training (cost and labor), + annual maintenance cost for each tool

Average Acquis Cost	TOOLS	Acquisition Cost for ROI tool	Training Time (Hrs)	Training Cost	Renewal Cost (Yearly $)	Average Maint Cost
$ 3,588	Integrated Tools	Acquire	Time	Course Fee	Maintain	$ 1,840
minimum	Innoslate	$ 2,000.00	74	$ 567.00	$ 2,000.00	minimum
$ 639	MagicDraw	$ 1,299.00	40	$ 1,600.00	$ 200.00	$ 200
	Enterprise Architecture	$ 2,000.00	28	$ 1,600.00	$ 2,000.00	
maximum	Cradle	$ 639.00	56	$ 1,890.00	$ 2,500.00	maximum
$ 12,000	Core	$ 12,000.00	56	$ 1,890.00	$ 2,500.00	$ 2,500
$ 1,913	Stand-alone Tools	Acquire	Time	Course Fee	Maintain	$ 143
minimum	Deltek (Compass)	$ 2,350.00	24	$ 1,950.00	$ 500.00	minimum
$ 99	StarUML	$ 129.00	12	$ 100.00	$ -	$ -
maximum	Analytica	$ 2,495.00	32	$ 1,500.00	500	maximum
$ 3,895	Vensim DSS	$ 1,195.00	64	$ 500.00	$ -	$ 860
	Logical Decisions	$ 3,895.00	6	$ 750.00	$ -	
	Matlab/Simulink	$ 2,150.00	24	2000	$860	
$ 820	Base Tools	Acquire	Time	Course Fee	Maintain	$ 263
minimum	MS Office Professional	$ 144.00	0	$ -	$ 144.00	minimum
$ 144	Excel	$ 144.00	8	$ 15.00	$ 144.00	$ -
	Word/Powerpoint	$ 144.00	0	$ -	$ 144.00	
maximum	Access	$ 144.00	4	$ 20.00	$ 144.00	maximum
$ 1,030	Excel + Anal.Solver	$ 2,139.00	56	$ 510.00	$ 644.00	$ 144
	FL Analytic Solver	$ 1,995.00	48	$ 495.00	$ 500.00	
	Project Professional	$ 1,030.00	8	$ 95.00	$ 120.00	

SE ROI Tool Data – SE Capability

Tool Effectiveness scores

Score	0	2	4	6	8	10
Meaning	You cannot get the outcomes (0%) you want with this tool	You can get the few outcomes (50%) you want with this tool	You can get the most outcomes (80%) you want with this tool	You can get all outcomes (100%), but in multiple steps	You can get all outcomes (100%), but in few steps	You can get all outcomes (100%) directly with this tool

Time to Become Proficient scores

Score	0	2	4	6	8	10
Meaning	> 40 hours	30-40 hours	20-30 hours	12-20 hours	8-12 hours	< 8 hours

- Data gathered through survey
- Outlines the user's ability to achieve their desired outcomes (graphs, data, documents, requirements) while using each tool

SE ROI Tool Data – Labor Efficiency

Tool Proficiency scores

Score	0	2	4	6	8	10
Meaning	Beginner Applied 10% of the features	Novice Applied 11-20% of the features	Competent Applied 21-30% of the features	Experienced Applied 31-40% of the features	Advanced Applied 41-50% of the features	Proficient Applied >50% of the features

System Engineering Productivity scores

Score	0	2	4	6	8	10
Meaning	No Time Savings	Job Completed 10% faster	Job Completed 25% faster	Job Completed 35% faster	Job Completed 50% faster	Job Completed 66% faster

- Data gathered through a survey
- Estimates how productive each user felt using the software and if the tool allowed them to complete their tasks *faster*

Assumptions Used for ROI and ROA

Company size:	S	M	L	XL	Company X
(in man-years)	2	5	25	100	user entered

- SE labor cost: $104,000 per man-year *(Indeed.com, Nov 4, 2020)*
- Base profit level: 10% of SE labor expense
- NPV Cost of Capital: 8 %
- ROI = sum of Net Cash Flows (yrs 0-2) divided by sum of tool Investments
- ROA = Sum of Net Cash Flow (yrs 3 to 5) divided by SE staff headcount (EP). Annual Net Cash flow is Investments (tool costs) minus Benefits (increased project profit + reduction in labor costs)
- Project Performance = "Challenge" adjusted improvements in base profit level

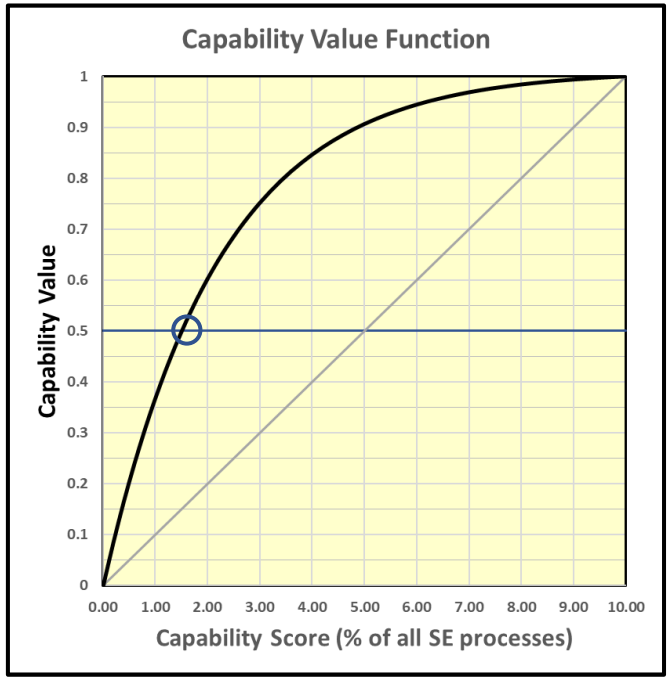
Sample ROI and ROA Calculations

SE Tools ROI calculations	INDIVIDUAL	selected tool =	Innoslate					
4	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total	
SE task required labor	150,000	150,000	150,000	210,000	210,000	210,000	**1,080,000**	
Cost to perform SE tasks	$ 7,283,654	$ 7,283,654	$ 10,197,115	$ 10,197,115	$ 10,197,115	$ 10,197,115	**$ 55,355,769**	
Cost of new SE tools	$ 150,000	$ -	$ 85,717	$ 68,226	$ -	$ -	**$ 303,943**	
Cost of SE tool training	$ 34,020	$ -	$ 19,441	$ 15,474	$ -	$ -	**$ 68,934**	
Cost of SE tool maint/renew	$ -	$ 150,000	$ 85,717	$ 68,226	$ 68,226	$ 68,226	**$ 440,394**	
Reduction in SE labor costs	$ 4,260,937	$ 4,260,937	$ 5,965,313	$ 5,965,313	$ 5,965,313	$ 5,965,313	**$ 32,383,125**	
Improve in Project Perform	$ 2,890,392	$ 2,890,392	$ 3,002,885	$ 3,002,885	$ 3,002,885	$ 3,002,885	**$ 17,792,325**	
Base Profit (SE base hrs)	$ 728,365	$ 728,365	$ 1,019,712	$ 1,019,712	$ 1,019,712	$ 1,019,712	**$ 5,535,577**	
Assumed Base SE profit %	0.10							
	$ 4,552,283.65	$ 3,823,918.27						

Innoslate	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Total	
Sum Investments	$ 184,020	$ 150,000	$ 190,875	$ 151,925	$ 68,226	$ 68,226	**$ 813,270**	
Sum Benefits (Return)	$ 7,151,329	$ 7,151,329	$ 8,968,198	$ 8,968,198	$ 8,968,198	$ 8,968,198	**$ 50,175,450**	
Net Cash Flow	$ 6,967,309	$ 7,001,329	$ 8,777,323	$ 8,816,273	$ 8,899,972	$ 8,899,972	**$ 49,362,180**	
		3yr ROI	**4333%**			**$ 191,589**	**3yr ROA**	
		SUM Benefits	**$ 23,270,857**		**SUM Benefits**	**$ 26,904,593**	**per m-year**	
Rate for NPV (%)	**8**						**$80,630.21**	**NPV**

Innoslate	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Yr 0-2 Total	Yr 3-5
Cost of SW Tool	$ (184,020)						$ (184,020)	$ -
Depreciation of SW Tool		$ 7,363	$ 7,363	)	$ 7,363	$ 7,363	$ 14,726	$ 14,726
Operating Expense of SW Tool		$ (82,800)	$ (82,800)	$ (82,800)	$ (82,800)	$ (82,800)	$ (165,600)	$ (248,400)
NPV cashflow	$ (184,020)	$ (75,437)	$ (75,437)	$ (82,800)	$ (75,437)	$ (75,437)	$ (334,894)	$ (233,674)
Total Benefits	$ 7,151,329	$ 7,151,329	$ 8,968,198	$ 8,968,198	$ 8,968,198	$ 8,968,198	$ 23,270,857	$ 26,904,593
Net Cash Flow	$ 6,967,309	$ 7,075,893	$ 8,892,761	$ 8,885,398	$ 8,892,761	$ 8,892,761	$ 22,935,963	$ 26,670,920

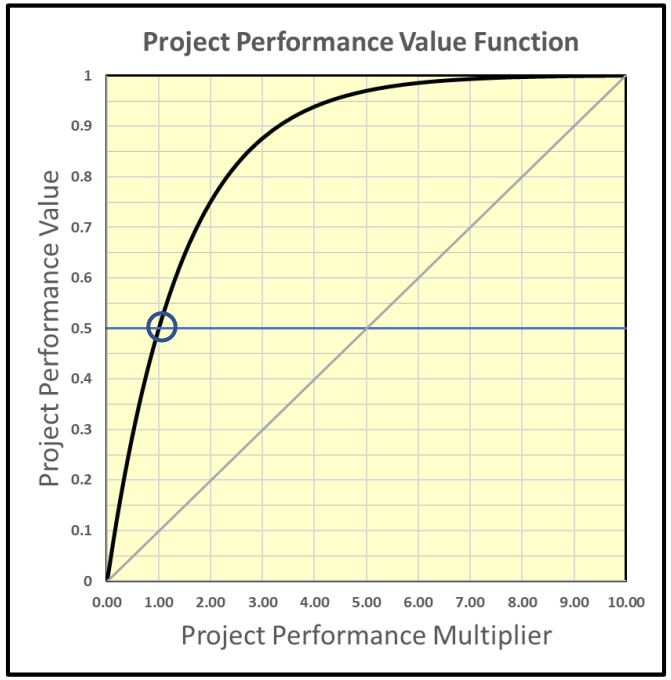
Value Function Calculations (1/2)



Capability Value

Score (x-axis) is percent of all SE processes performed by SE tool

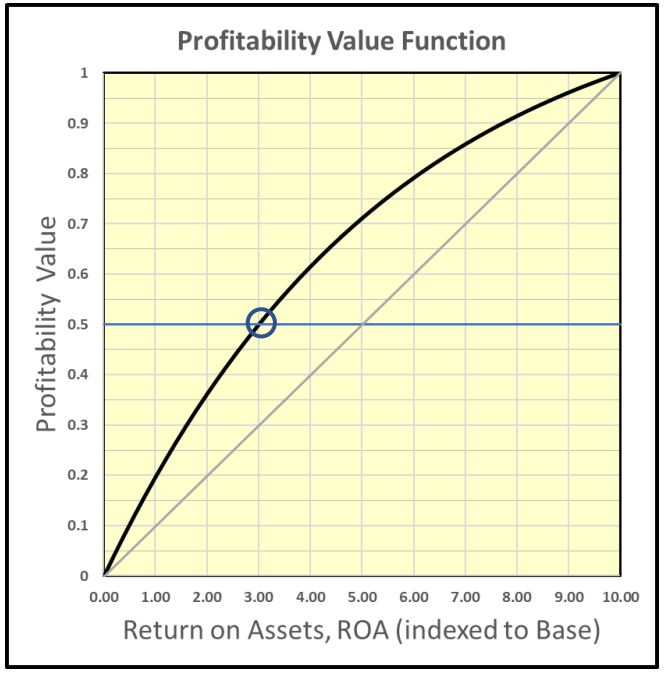
($Z_{0.5}$ = .85)



Project Performance Value

Score (x-axis) is "SE challenge" weighted net profit from SE tool

($Z_{0.5}$ = .90)

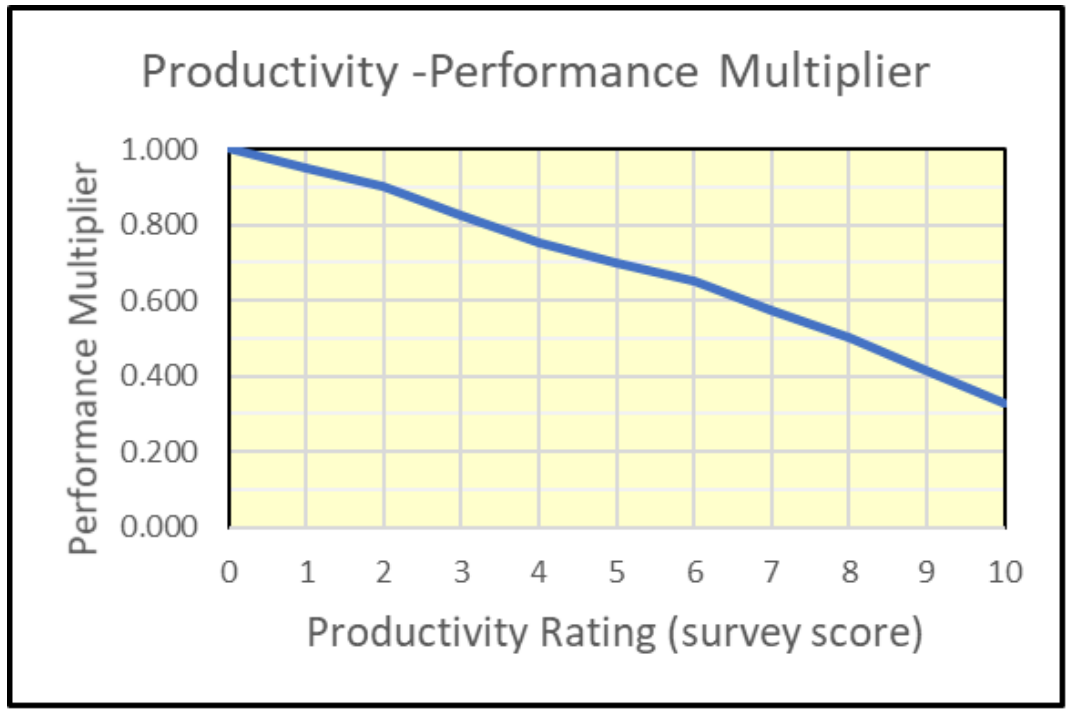


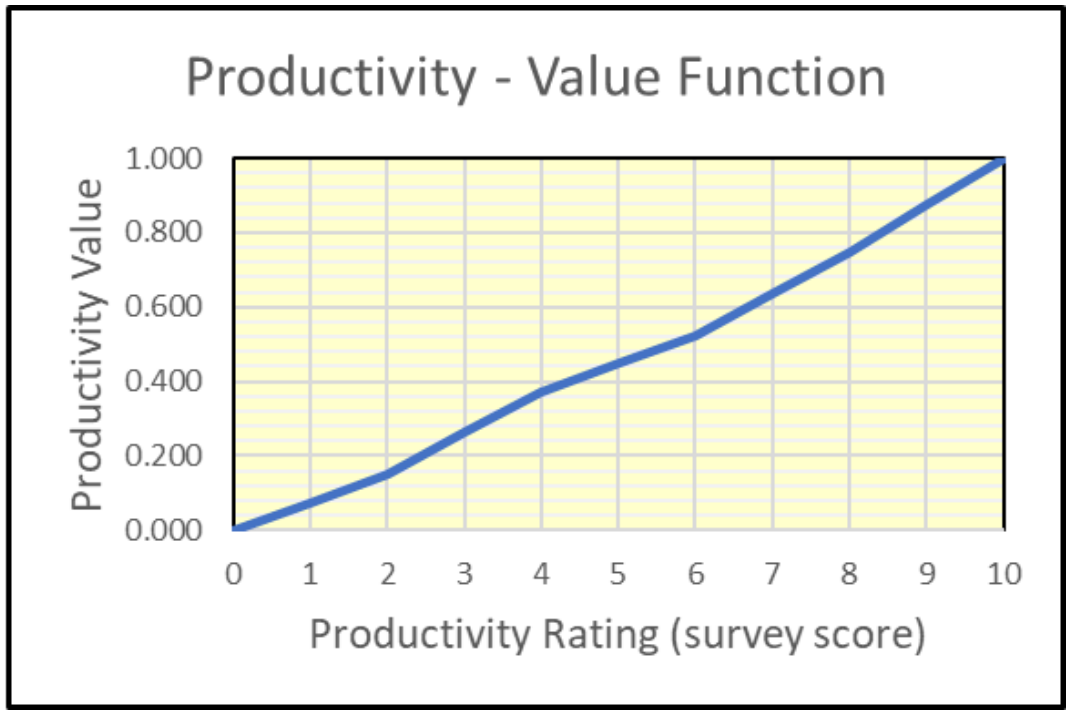
Profitability Value

Score (x-axis) is ratio of ROA_{tool} / ROA_{base}

($Z_{0.5}$ = .70)

Value Function Calculations (2/2)





Productivity Value

Score (x-axis) is results (rating) from SE tool productivity survey

- Survey indicated labor reduction values from 0 to 67 percent of benchmark values
- 67% performance reduction used as Value = 1.0

Concordance – How It Saves Labor

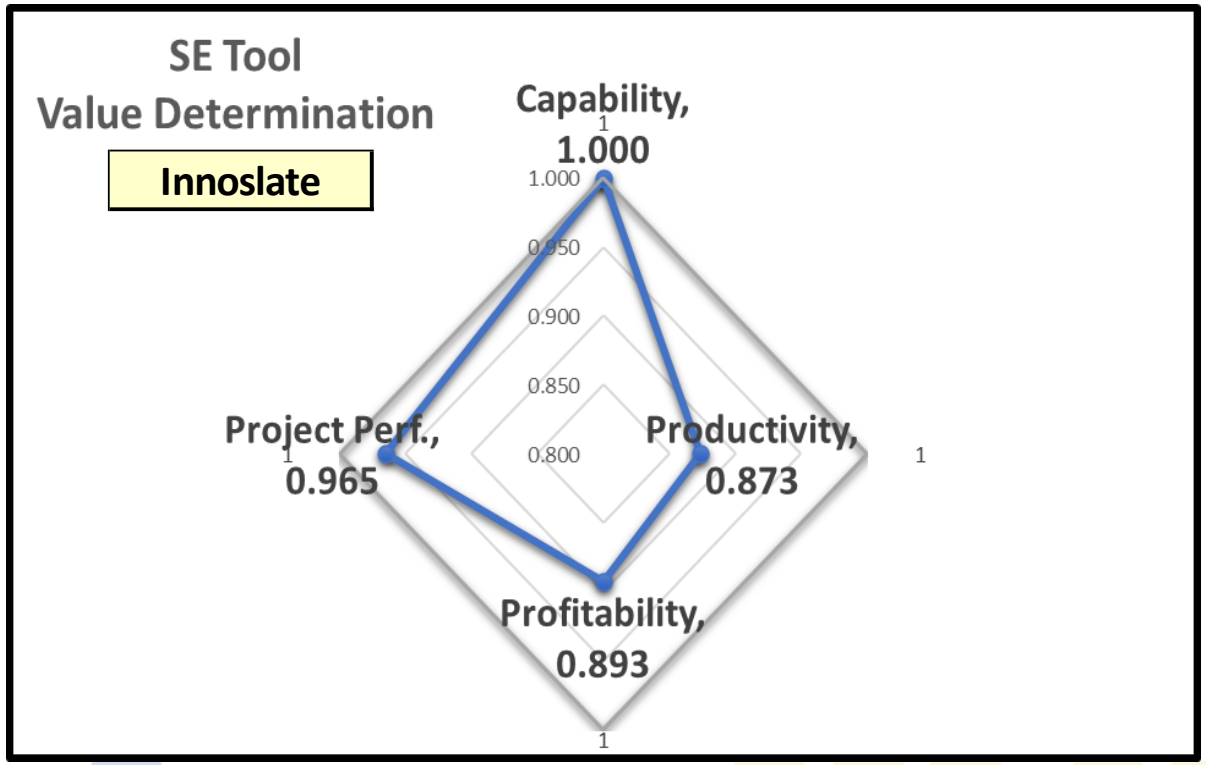
Productivity Improvement	0.0%	0.0%	34.2%	weighting
Concordance Factors	**Basic**	**Stand-alone**	**Integrated**	**factor**
fewer errors	100	100	75.00	0.2
faster processes	100	100	60.00	0.2
auto-generated products	100	100	75.00	0.2
tasks eliminated	100	100	80.00	0.2
shared information	100	100	75.00	0.1
communication efficiency	100	100	90.00	0.1
weighted average	**100.00**	**100.00**	**74.50**	*1.00*

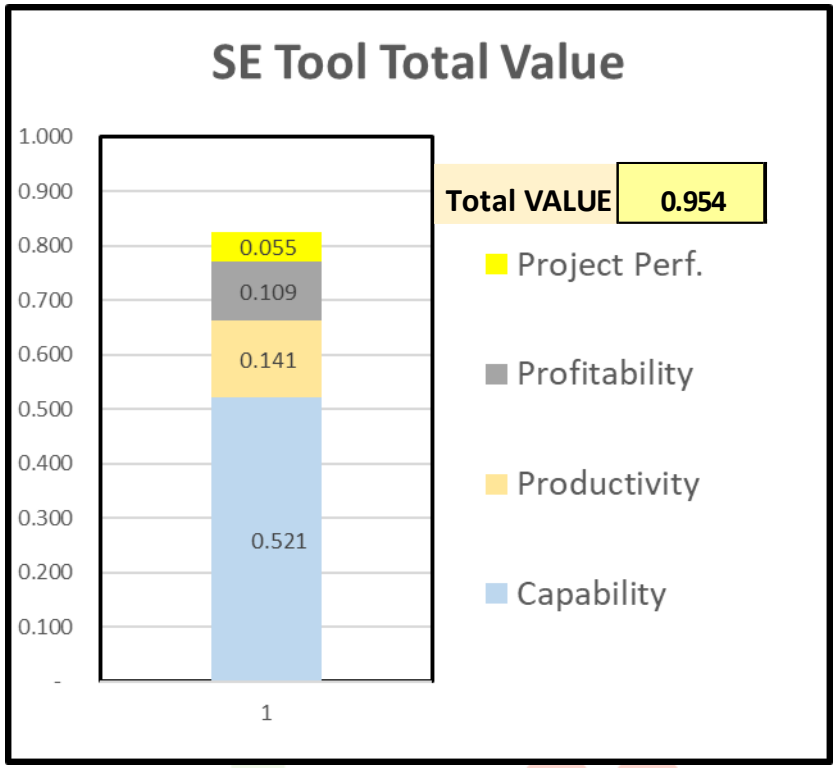
- Factors to apply Integrated tool concordance benefits are in the ROI model
  . . . . but these additional productivity factors are not used
- There is no data to measure or justify these very real benefits

Selected SE Tool – Value Assessment

Total Value of selected SE tool is automatically calculated from User Input parameters

- Company size, objectives, SE workload, SE task challenge, etc.
- Value by category (Capability, Productivity, Profitability, Project Performance)
- Total Value (sum of category values weighted by user priorities)





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ROI Tool Financial Results

Investments (Years 0 to 2)	Small	Medium	Large	X-Large
Base (benchmark)	$ 4,963	$ 16,507	$ 82,533	$ 330,130
Stand Alone	$ 13,447	$ 33,616	$ 168,082	$ 672,329
Integrated	$ 23,857	$ 59,642	$ 298,212	$ 1,192,847

Benefits - Labor Cost Savings (Years 0 to 2)	Small	Medium	Large	X-Large
Base (benchmark)	$ (0)	$ (0)	$ (0)	$ (0)
Stand Alone	$ 104,477	$ 261,194	$ 1,305,968	$ 5,223,874
Integrated	$ 324,373	$ 810,934	$ 4,054,668	$ 16,218,671

Benefits - Labor Hours Savings, man-months (Years 0 to 2)	Small	Medium	Large	X-Large
Base (benchmark)	(0)	(0)	(0)	(0)
Stand Alone	9	23	114	456
Integrated	30	76	379	1,515

Size	$$/yr
Small:	$200K
Medium:	$500K
Large:	$2.5M
X-Large:	$10M

Sys Engr salary
$104,000/yr
(Indeed.com)

ROI Tool Overall Results

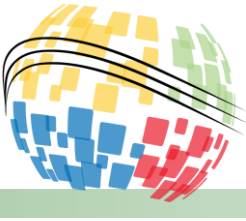
Summary of Research Results				
Return on SE Software Investments				**Total Value** (weighted)
	ROI	**ROA**	**Proj Perf.**	
Base (benchmark)	**0%**	**9%**	**100%**	**0.533**
Stand Alone	**677%**	**20%**	**113%**	**0.628**
Integrated	**1260%**	**45%**	**162%**	**0.851**

ROI = ∑ Net Profit / ∑ Investments for first 3-yr period

ROA = ∑ Net Profit / ∑ SE Headcount for second 3-yr period

ROI and ROA can also be calculated for an individual user-selected SE tool

Summary of ROI Tool Results



Stand Alone Tools

- Investment of 2% of SE annual salary: 17% labor savings, 677% ROI
  20% ROA (Net Profit/SE)
  +13% Project Performance

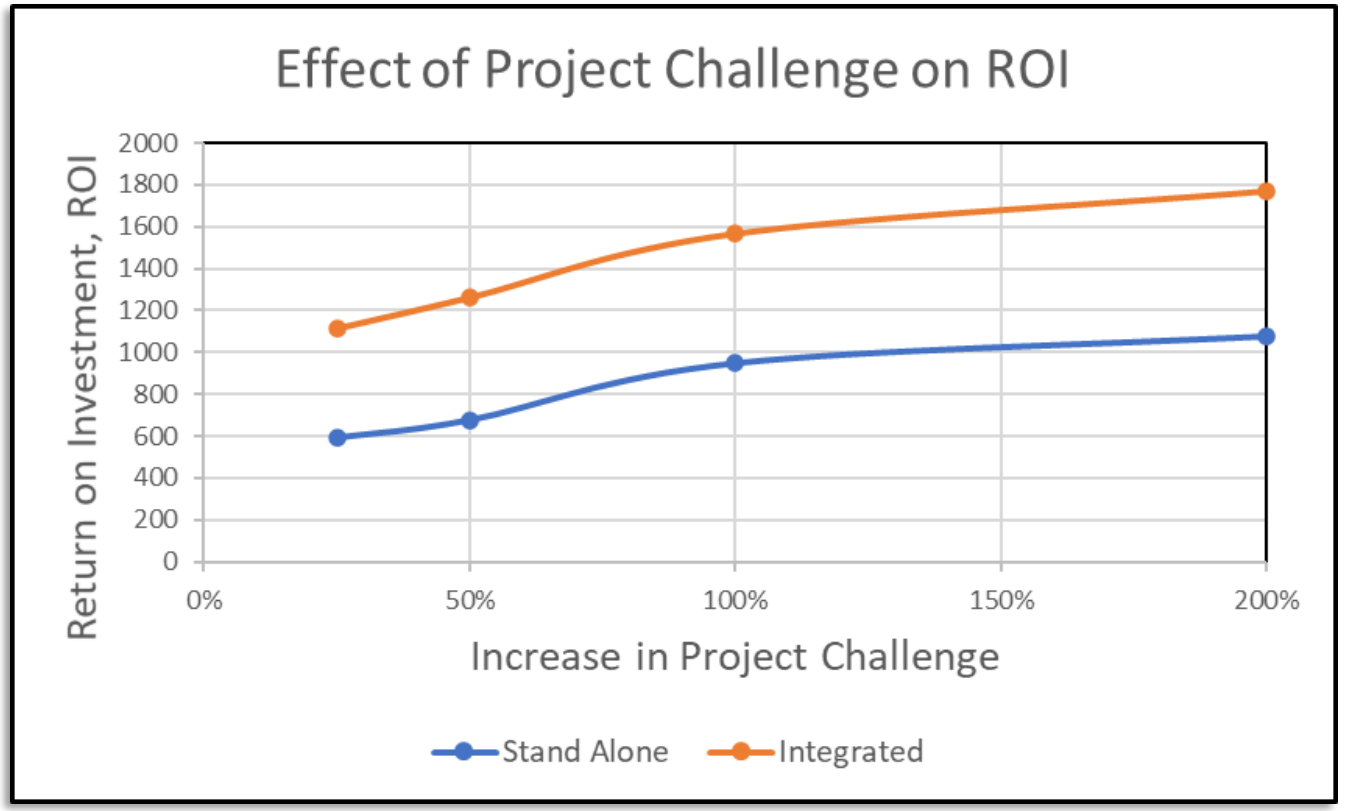
Integrated Tools

- Investment of 4% of SE annual salary: 54% labor savings, 1260% ROI
  45% ROA (Net Profit/SE)
  +62% Project Performance

- Engineering Headcount Reduction

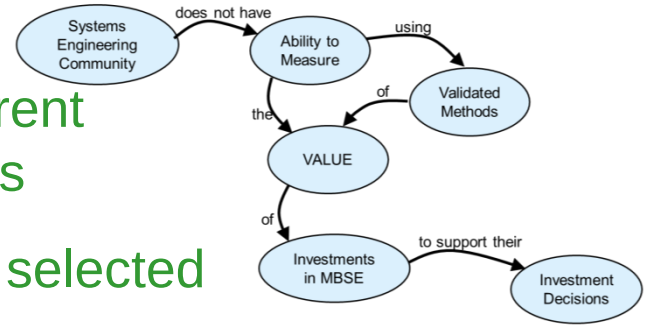
Company size:	Small	Medium	Large	X-Large
	3	7	38	150

Effect of Project Challenge on ROI



- Model results are all based on project challenge levels of Moderate/High
  - A 50% increase from current project to future projects

SE ROI Research Results



Systems Engineering Community	✓	Commercial or non-commercial organizations of different sizes, varying objectives, varying amounts of SE tasks
Ability to Measure	✓	Estimated ROI and ROA ($$) for investment ($$) in a selected SE tool (individual or category)
VALUE	✓	Value to the organization as determined by Profitability, Productivity, Capability, and Project Performance (weighted)
Validated Methods	X	✓ Method to determine Value from organization and SE tool attributes • Tool Productivity and Proficiency data is difficult to measure, not validated • Organization Productivity is very difficult to measure, not validated
Investments in MBSE	✓	Amount ($$) of financial investments in SE tool acquisition and training
Investment Decisions	✓	Determination of value over a several year period for alternative SE tools (individual or category)

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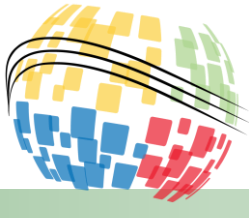
Summary of Research Findings



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Research Conclusions

- ROI and ROA for investments in SE tools can be estimated for a wide range of organizations, but cannot be validated
  - Empirical evidence of SE tool productivity, process applicability, and user proficiency levels does not exist (but is needed)
  - Anecdotal evidence of SE process benefits to project performance does exist
    - but extrapolation to general user experiences is speculative
- ROI and ROA estimates are much higher than expected
  - Dominant factor is SE labor savings (cost reductions) achieved from SE tool productivity benefits, far exceeding cost of SE tool investments
- Research studies from the INCOSE community to establish SE tool performance metrics can greatly improve confidence in ROI estimates

Future Research Topics

- Define and measure ***concordance*** offered by SE tools
- Develop aggregated Value Functions for SE ROI
- Perform subject matter expert analyses to determine:
  - Tool Effectiveness, time required to become proficient, etc.
  - Expected labor savings to perform SE tasks
  - Refine the definition of proficiency

Thank you for your attention !

Questions ?

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