Evaluating the Impact Of Requirements Analysis Tools On Large-Scale NASA Projects

David M. Raffo, Ph.D., Portland State Univ.
Robert Ferguson, SEI
Siri-on Setamanit, Ph.D., Quantel, Inc.

© 2006 Carnegie Mellon University

Agenda

Motivation

What are Automated Req. Analysis Tools?

What is Process Simulation?

What are the Benefits?

Discussion

Conclusions

© 2006 Carnegie Mellon University

Motivation

Good new technologies are wasted unless there is a compelling business case to use them

Without such a case:

- Managers not convinced
- No reallocation of scarce resources

Good technology: Requirements Analysis Tools

- Increased PDs (probability of detection) (enables better detection capability during human inspection)
- Low cost

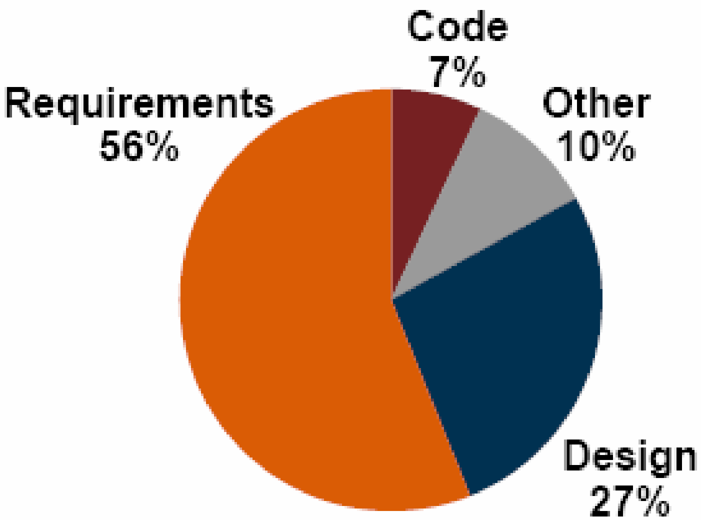
This talk:

- Present the business case
- Developed using process simulation

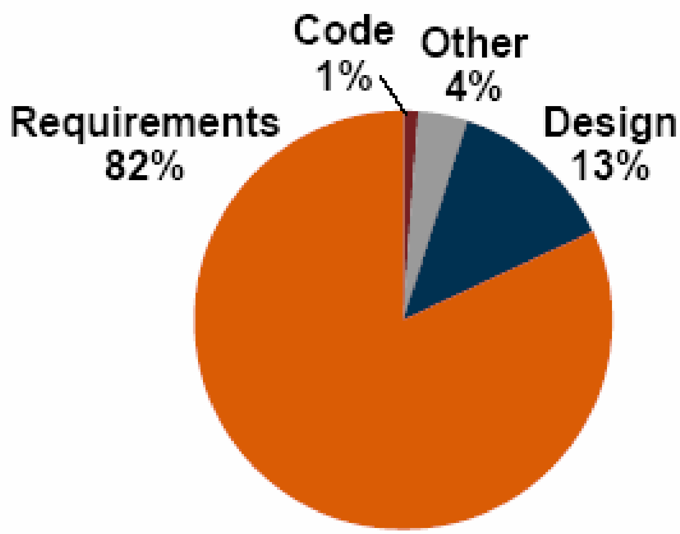
© 2006 Carnegie Mellon University

Requirements Best Illustrate Our Challenge

Distribution of Defects



Distribution of Effort to Repair Defects



Over half of software defects are attributed to requirements problems

Source: James Martin

Over 80% of rework effort is spent on requirements-related defects

Source: Dean Leffingwell

12 | Copyright © 2005 Borland Software Corporation. All rights reserved. | 3 June 2005

© 2006 Carnegie Mellon University

Analyzing Requirements$_1$

An endemic and enduring problem

- Vague requirements with unstated performance criteria

Automated Requirements Checkers:

— TEKChecker (www.clearspecs.com)

— Requirements Assistant (Sunny Hills Consultancy http://www.requirementsassistant.nl/index.htm)

— Specification Analysis Tool - SAT (http://www.cassbeth.com/)

— QuARS (SEI/CNR) - http://citeseer.ist.psu.edu/634143.html

— E-Smart/ARM (GSFC) - http://satc.gsfc.nasa.gov

— Lexior http://www.cortim.com

© 2006 Carnegie Mellon University

Analyzing Requirements$_2$

Why use Requirements Analysis tools?

- Reduce cycle time and effort while producing better results than possible with tedious manual review
- Early detection and correction of often costly errors
  - Captures most common classes of errors
  - Often missed in inspections and quality assurance
  - Allowing analysts to focus on more difficult problems

© 2006 Carnegie Mellon University

Analyzing Requirements$_3$

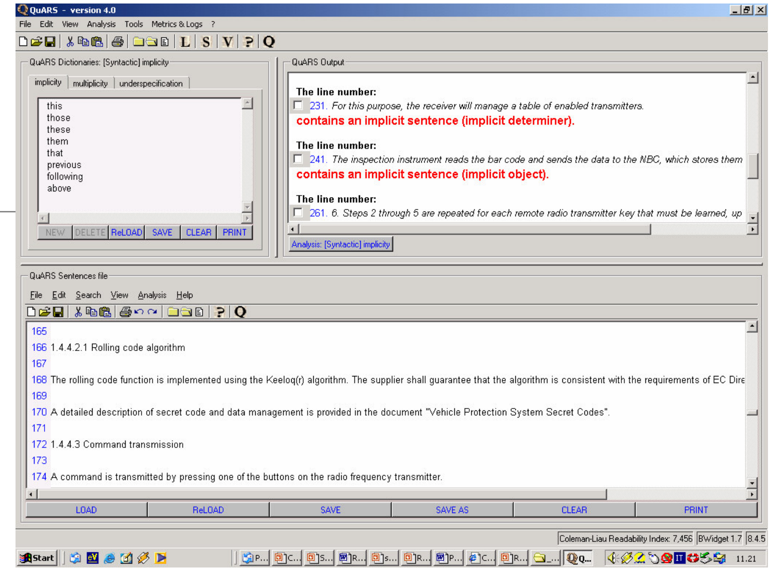
How do these tools work?

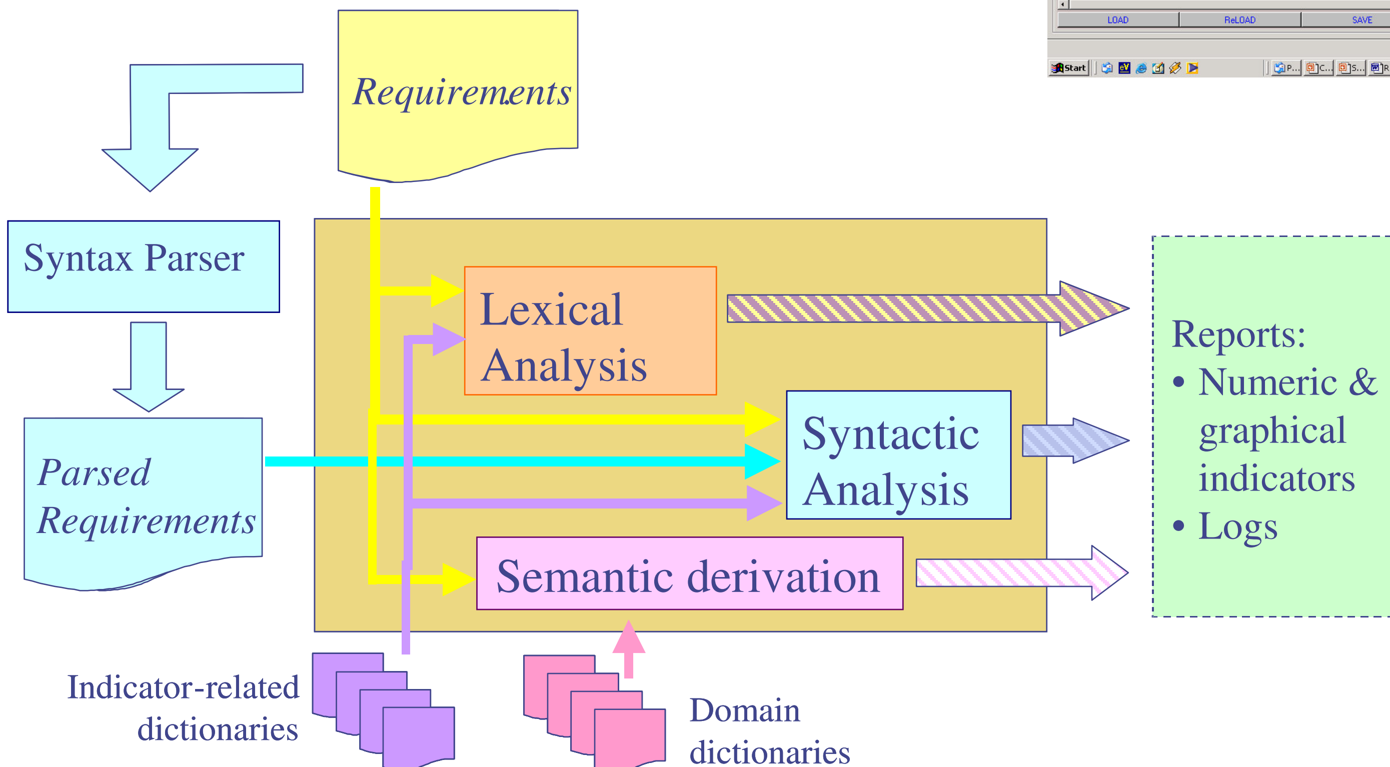
- Natural language analysis of requirements text
- Lexical: vague, weak, optional, subjective, other terms
- Syntactic: multiple, implicit, under specified statements
- Semantic:
  - Allows screening for consistency, completeness, etc
  - Arbitrary combinations of domain, component, functionality, product quality attributes and so on

© 2006 Carnegie Mellon University

QuARS

Quality Analysis for Requirements Specification





QuARS was selected for this study because field study evidence is available in the literature

© 2006 Carnegie Mellon University

What is Process Simulation?

- Process simulation models focus on the dynamics of ***systems*** development, maintenance and acquisition projects
- They represent the process
  - as currently implemented (as-is, as-practiced, as-documented), or
  - as planned for future implementation (to-be)
- Simulation Features
  - Use Graphical interfaces
  - Utilizes actual data/ metrics
  - Predict performance
  - Supports “What if” Analyses
  - Support business case analyses
  - Reduces risk

© 2006 Carnegie Mellon University

Applying Process Simulation = High Value Add

Evaluate Strategic Issues

- Quality Assurance, V&V and IV&V Strategy
- Distributed Software Development
- Supply Chain Design

Plan Processes

- Identify better process alternatives
- **Assess the Costs and Benefits of New Tools**
- Evaluate Impact of Process Improvements

Architect, Design, and Document Processes

Manage Projects Quantitatively

Estimate Project Costs from the Bottom Up

Train Project Managers

© 2006 Carnegie Mellon University

How do we use Process Simulation?

Architect the Process Model

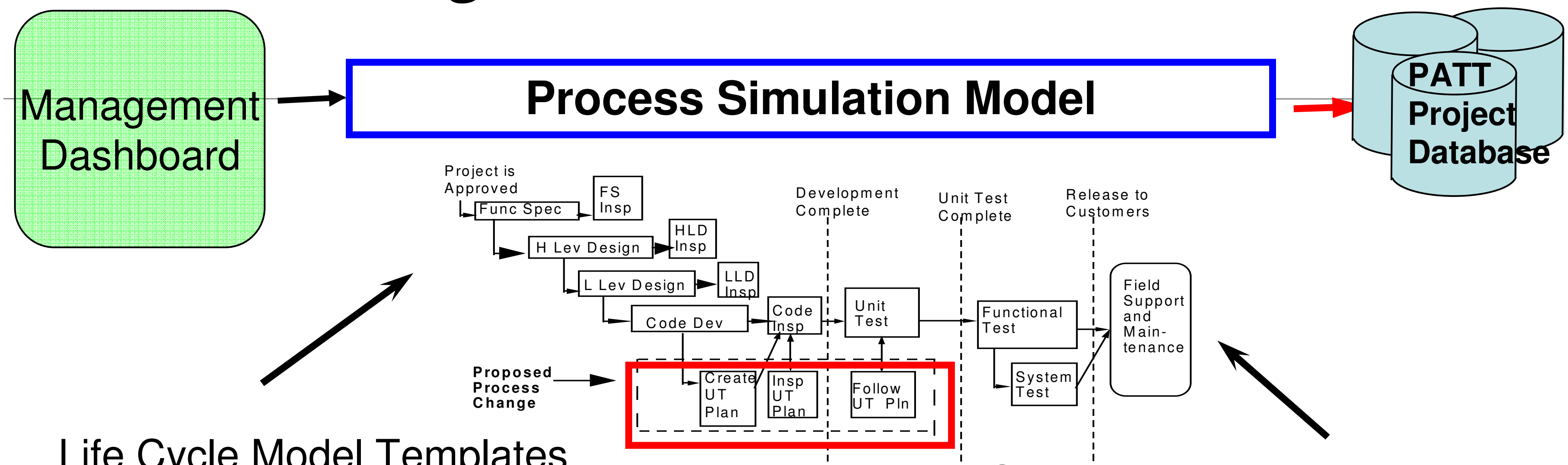
Calibrate the Data Set

Run Options

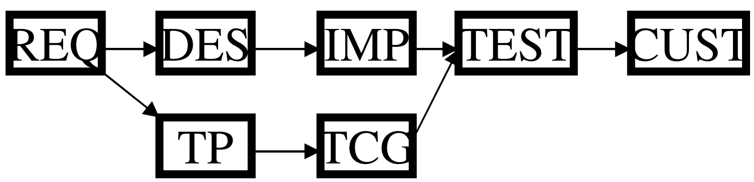
See the Return on Investment

© 2006 Carnegie Mellon University

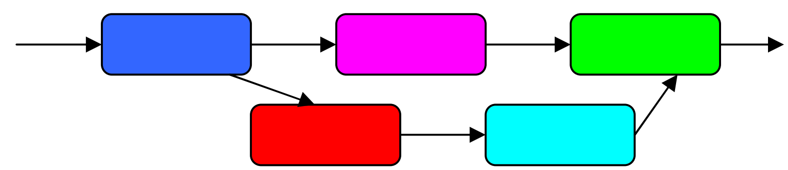
Creating Process Simulation Models



Life Cycle Model Templates

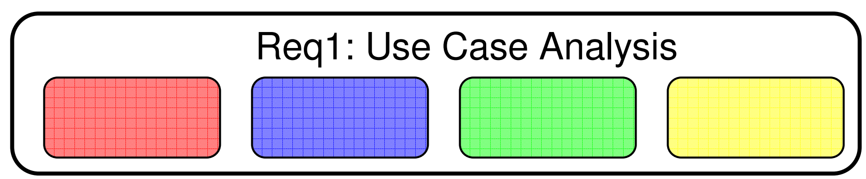


Generic Process Model Blocks



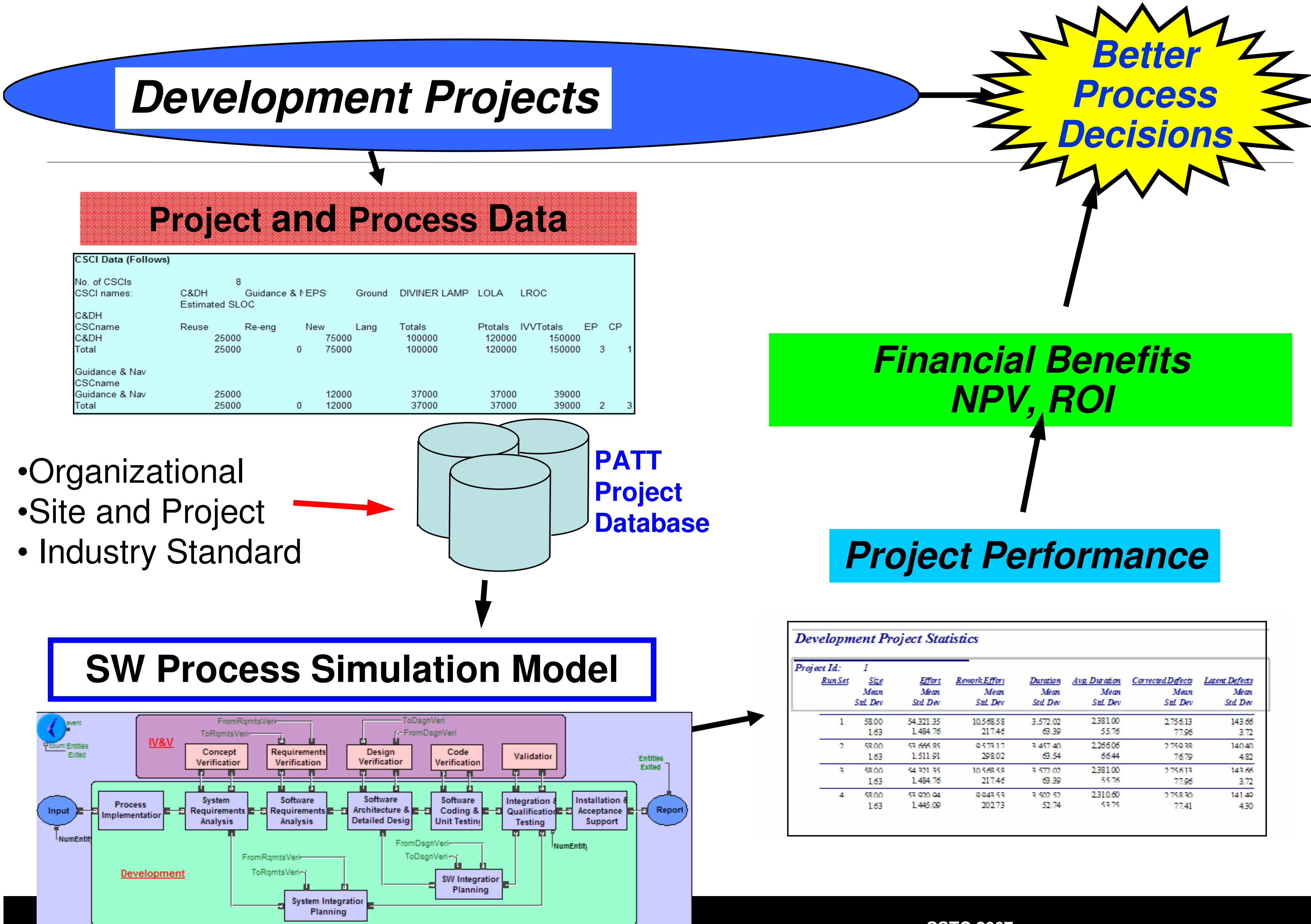
- IEEE 12207
- Spiral
- Incremental
- Product Line
- Rapid Prototyping

Generalized Process Components



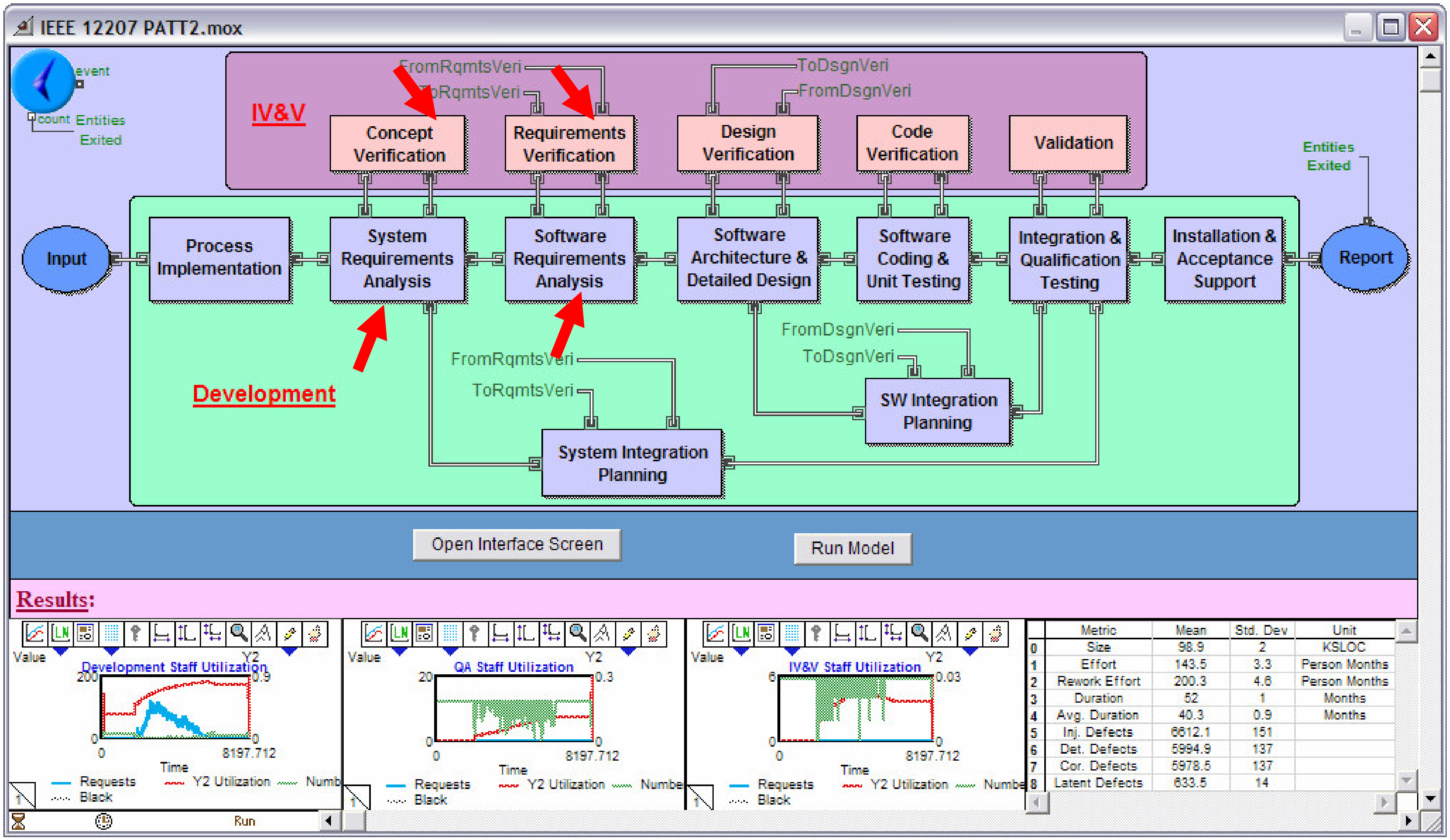
- Development
- Inspection
- Testing
- Rework
- IV&V
- Joint Reviews

© 2006 Carnegie Mellon University



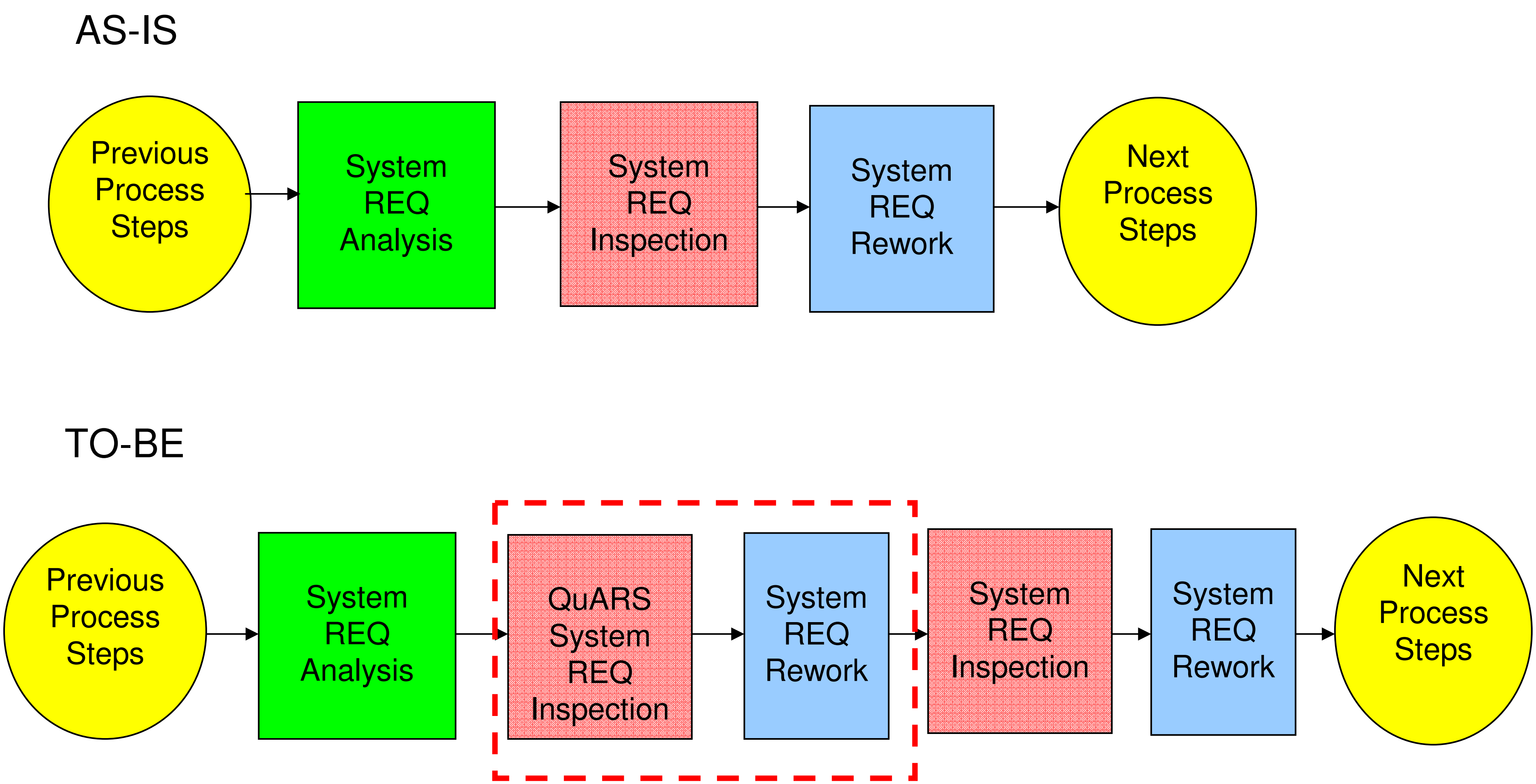
© 2006 Carnegie Mellon University

NASA Model – Includes IV&V Layer with IEEE 12207 SW Development Lifecycle



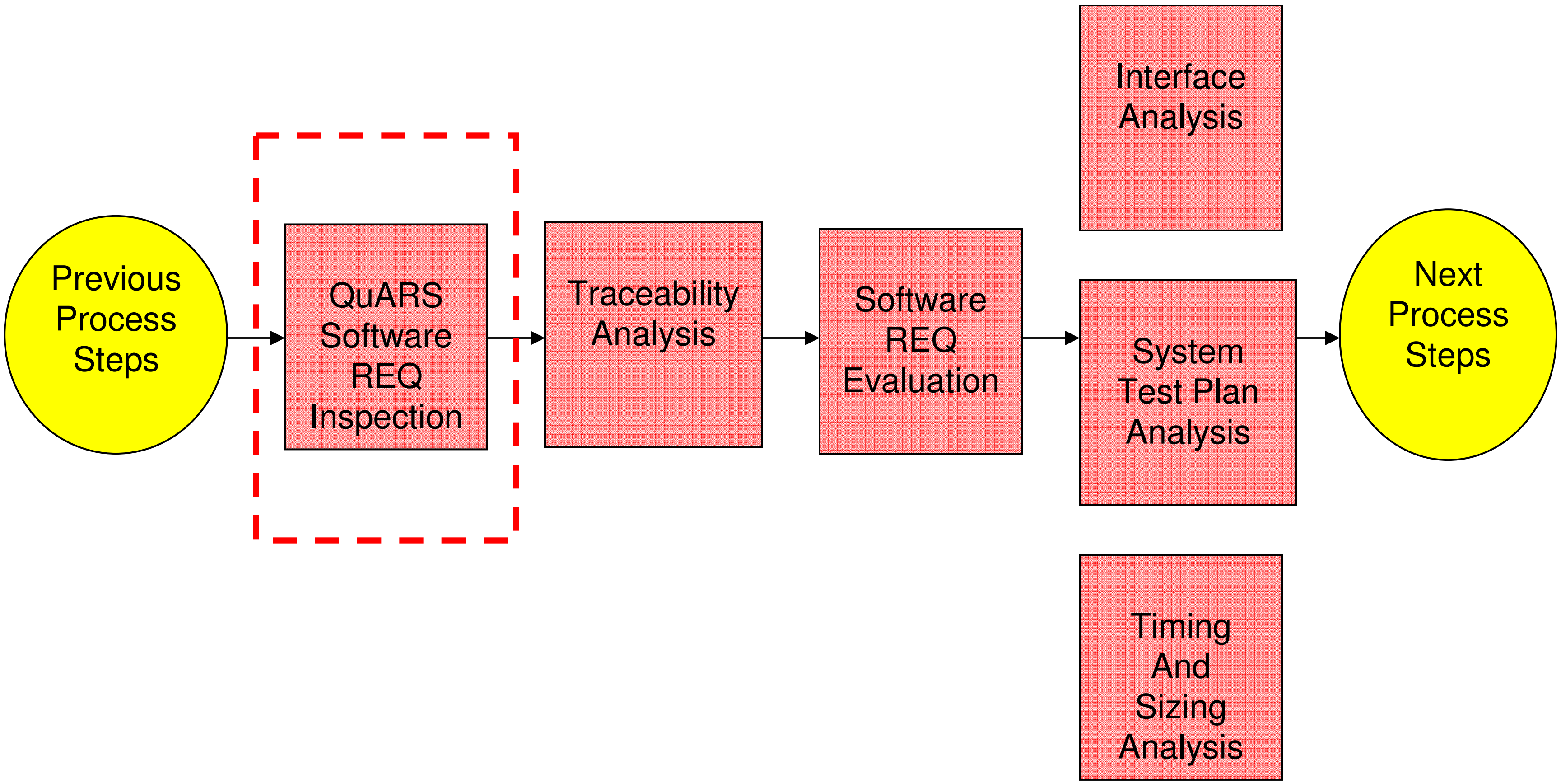
© 2006 Carnegie Mellon University

System and SW Requirements Processes



© 2006 Carnegie Mellon University

IV&V at Requirements Verification



© 2006 Carnegie Mellon University

Impact of QuARS - Assumptions

Have the ability to look at a variety of insertion points

Assumptions:

- Typical Manned Mission using IEEE 12207 Process
- Includes IV&V
- 100 KSLOC Project
- Industry standard data for Earned Value, defect detection rates
- Organizational data for productivity, defect injection rates
- Project specific data for IV&V
- Pilot study data for capabilities of QuARS

© 2006 Carnegie Mellon University

Impact of QuARS - Assumptions

In the case of QuARS

1. Productivity of the tool => 10 KLOC/ Person hour
2. QuARS type defects => 37% of Requirements Defects
3. QuARS detects 100% of lexical and (i.e. QuARS detectable defects)
4. Improves defect detection capability at Requirements Inspections (+5 to10%)
5. Cost of training and associated SEPG activities 1 person-month
6. Cost of tool TBD

Secondary Effects of Using QuARS

1. Improves clarification of requirements (i.e. improves productivity in design of + 5%
2. Improves Engineering design decisions (reduced injection of design defects of - 5%
3. Improves test planning and test case generation productivity + 5%)
4. Improves test case generation (i.e. less investigation and rework -5%)

© 2006 Carnegie Mellon University

Cases Looked at

QuARS as a V&V activity within the project.

- Look at applying QuARS at the Systems Requirements and Software Requirements phases, both.
- Assuming 100% and 50% Requirements inspections
- Before and after inspection
- When injection of QuARS type defects is at minimum (i.e. 20%)

QuARS as an IV&V activity outside of the project

- Look at applying QuARS at the Systems Requirements and Software Requirements phases, both.
- Assuming 100% and 50% Requirements inspections
- When injection of QuARS type defects is at minimum (i.e. 20%)

© 2006 Carnegie Mellon University

Key Questions Evaluated

Did QuARS provide a value?

Is the tool more effective in V&V or IV&V mode?

Under what project conditions is the tool most useful?

- Applying QuARS before or after Requirements Inspection
- Applying QuARS when different amount of requirements are inspected

Is QuARS still worth using when lexical defects are at a minimum? (max reduction through training achieved)

What is the amount that NASA should be willing to pay for the tool?

© 2006 Carnegie Mellon University

Results - Applying QuARS in V&V Mode at Different Phases

Comparison to Baseline

	Effort incl. IV&V	Effort	RWK_Efrt	IV&V Effort	Duration	Avg. Dur	Crctd_Dfcts	Ltnt_Dfcts
QuARS at Sys Req	1,659	1,670	1,312	(11)	103	49	34	18
p value	0	0	0	1	0	0	1	0
QuARS at Sw Req	5,142	5,128	4,779	14	377	72	(10)	55
p value	0	0	0	1	0	0	1	0
QuARS at Sys & Sw Req	5,268	5,285	4,926	(17)	362	81	(10)	59
p value	0	0	0	1	0	0	1	0

- Application of QuARS at Systems and Software Requirements offers a value
- Sweet spot is to apply QuARS after Software Requirements
- QuARS is approximately +10% to +15% benefit when applied before Requirements inspection rather than after
- QuARS has approximately +3% increased performance when project does not have IV&V

© 2006 Carnegie Mellon University

Results – Less Than 100% of Project is Inspected

Comparison to Baseline		Effort incl. IV&V	Effort	Rwrk_Efrt	IV&V Effort	Duration	Avg. Dur	Crctd_Dfcts	Ltnt_Dfcts
SC5.1		2133	2165	1800	-32	118	37	26	26
	p value	0	0	0	1	0	0	1	0
SC5.2		6590	6576	6208	13	503	57	-32	75
	p value	0	0	0	1	0	0	1	0
SC5.3		6287	6340	5973	-53	443	73	-23	71
	p value	0	0	0	0	0	0	1	0

- The value of QuARS increases when applied to projects that experience less than 100% inspections (this instance = 50%)
- At 50% inspection, +20% to +30% increased effort savings, +17% to +%42% reduction in latent defects

© 2006 Carnegie Mellon University

Results - Applying QuARS in IV&V Mode at Different Phases

Comparison to Baseline								
	Effort incl. IV&V	Effort	Rwrk_Efrt	IV&V Effort	Duration	Avg. Dur	Crctd_Dfcts	Ltnt_Dfcts
QuARS at Concept IV&V	1,448	1,679	1,322	(231)	114	69	32	17
p value	0	0	0	0	0	0	1	0
QuARS at REQ IV&V	2,427	2,717	2,341	(290)	191	64	19	29
p value	0	0	0	0	0	0	1	0
QuARS at both IV&V	2,900	3,374	2,976	(474)	237	98	11	36
p value	0	0	0	0	0	0	1	0

Value of QuARS is significantly reduced when applied in IV&V mode. 87%, 47%, 55% for effort; 94%, 52%, 61%

Secondary effects not experienced by the project

Slight make up on effort due to cost shift to IV&V

© 2006 Carnegie Mellon University

Results – QuARS Under Different Defect Injection Rates

Lexical defects reduced from 37% of Requirements defects to 20% (46% reduction)

Believed that even with training and other defect prevention measures, lexical defects will still exist at 20% level or greater

For V&V

- Effort savings reduced by 28% to 36%
- Quality savings reduced by 28% to 38%

For IV&V

- Effort savings reduced by 35% to 43%
- Quality savings reduced by 26% to 36%

© 2006 Carnegie Mellon University

Results – QuARS Under Different Defect Injection Rates

Comparison to Baseline	Effort incl. IV&V	Effort	Rwrk_Efrt	IV&V Effort	Duration	Avg. Dur	Crctd_Dfcts	Ltnt_Dfcts
QuARS at Sys Req	1,186.78	1,199.64	858.23	(12.86)	58.17	42.36	39.21	13.08
p value	0.02	0.02	0.00	0.84	0.25	0.08	0.51	0.04
QuARS at Sw Req	3,179.53	3,187.55	2,890.71	(8.02)	212.62	44.53	13.00	34.37
p value	0.00	0.00	0.00	0.90	0.00	0.05	0.83	0.00
QuARS at Sys & Sw Req	3,354.04	3,295.10	2,994.34	58.94	235.76	62.62	13.69	36.25
p value	0.00	0.00	0.00	0.33	0.00	0.01	0.82	0.00

Comparison to Baseline	Effort incl. IV&V	Effort	Rwrk_Efrt	IV&V Effort	Duration	Avg. Dur	Crctd_Dfcts	Ltnt_Dfcts
QuARS at Concept IV&V	874.24	1,174.63	833.20	(300.39)	17.48	41.67	36.16	12.66
p value	0.08	0.02	0.00	0.00	0.71	0.08	0.54	0.05
QuARS at REQ IV&V	1,571.89	1,747.96	1,396.61	(176.07)	123.17	45.22	30.78	17.48
p value	0.00	0.00	0.00	0.00	0.01	0.06	0.60	0.01
QuARS at both	1,643.16	2,123.36	1,758.96	(480.20)	86.25	61.77	24.49	23.22
p value	0.00	0.00	0.00	0.00	0.07	0.01	0.68	0.00

© 2006 Carnegie Mellon University

Return on Investment Inputs

Input Parameters for Financial Calculation

Input					
Cost of Development Staff per Hour	$ 100.00		Org internal investment rate cut-off (aka hurdle rate)	20.00%	
Cost of IV&V Staff per Hour	$ 100.00				
Implementation Cost (Tool Cost)	$ -	**To be determined**			
Increase in Revenue per Month	$ -	if release early			
Cost to Correct Latent Defects	$ 25,500.00	per defect			
	1.5 person-month to fix 1 defect				
Assumptions					
Work Hours per Month	170		Work Hours per Year	2,040	
Latent Defects will be corrected within the first	36	months			
If releasing the system early by	3	months or more, there will be an increase in revenues (due to a			
Effort saving occurs at time = duration					
Duration saving occurs at time = duration +		1	month	170	hours
Latent defect saving occurs at time = duration +		36	month	6120	hours

© 2006 Carnegie Mellon University

NPV and Risk Results Summary

Config.	QuARS Value	
	Mean	Std Dev
SC1	$282,813	$24,649
SC2	$869,221	$45,055
SC3	$933,118	$54,769
SC4.1	$265,149	$20,884
SC4.2	$837,796	$48,780
SC4.3	$876,587	$46,510
SC6	$266,008	$19,413
SC7	$435,653	$29,121
SC8	$541,538	$34,524

SC 1: Turn on QuARS at System Requirments
SC 2: Turn on QuARS at Software Requirements
SC 3: Turn on QuARS at both Systems and Software
SC 4.1: Turn on QuARS after System Requirments Insp
SC4.2: Turn on QuARS after Software Requirments Insp
SC4.3: Turn on QuARS after both System and Software Requirments Insp
SC6: Turn on QuARS at Concept Verification
SC7: Turn on QuARS at Requirements Verification
SC8: Turn on QuARS at Concept Verification and Requirements Verification

- PR(NPV>0)=100%
- PR(NPV>$100K) = 100%
- Overall, QuARS shows a reduced NPV between -28% to -38% compared to higher defect injection rate (Lowest NPV = $182K)

© 2006 Carnegie Mellon University

Discussion

Straight forward and quick analysis (1 week)

- Main effects analysis
- Secondary effects analysis
- Sensitivity analysis
- Management Questions
- Results

NASA is currently engaged in conducting a 6 month trial of three different requirements analysis tools

Will use results of their study to validate the model

Still need to run simulation model to compute overall impact of the tool and perform business case analysis

© 2006 Carnegie Mellon University

Conclusions

QuARS is worth while

- Value to the project @ 20% hurdle rate ranges from $280K to $930K in V&V mode and $266K to 540K in IV&V mode
- Cost of tool is not set yet
- PR(NPV>100K) = 100%

Analysis showed that results were sensitive to

- % of project inspected
- % Lexical defects injected
- Labor rates, rework costs, hurdle rate

For these parameters, it is important to be clear about their values for projects that NASA plans to implement QuARS

Straight forward analysis took about 1 week.

© 2006 Carnegie Mellon University

Conclusions

Process Simulation is NOT a Silver Bullet

Many High Value Add Ways to Use Process Simulation

- Evaluate Strategic Issues - Quality Assurance Strategy
- Plan Processes
  - **Assess the Costs and Benefits of New Tools**
- Architect, Design, and Document Processes
- Manage Projects Quantitatively (CMMI L4)
- Estimate Project Costs from the Bottom Up
- Train Project Managers

See SEI Technical Report on Transitioning Process Simulation into Organizations (Summer 2007)

© 2006 Carnegie Mellon University

Contact Info

David M. Raffo, Ph.D.
Visiting Scientist, Software Engineering Institute
Professor, Portland State University
Chief Technologist, Quantel, Inc.
raffod@pdx.edu
c) 503-939-1720

Robert Ferguson, PMP
Senior Member, Technical Staff
Software Engineering Institute
rwf@sei.cmu.edu
412-268-9750

Siri-on Setamanit, Ph.D.
Consultant, Quantel, Inc.
Siri-on@quantelsystems.com

© 2006 Carnegie Mellon University

The End

© 2006 Carnegie Mellon University