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.
Agenda

Motivation
What are Automated Req. Analysis Tools?
What is Process Simulation?
What are the Benefits?
Discussion
Conclusions
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
Requirements Best Illustrate Our Challenge

Distribution of Defects

- Requirements: 56%
- Design: 27%
- Code: 7%
- Other: 10%

Over half of software defects are attributed to requirements problems
Source: James Martin

Distribution of Effort to Repair Defects

- Requirements: 82%
- Design: 13%
- Code: 1%
- Other: 4%

Over 80% of rework effort is spent on requirements-related defects
Source: Dean Leffingwell
Analyzing Requirements

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
Analyzing Requirements

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
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
QuARS

Quality Analysis for Requirements Specification

Syntax Parser

Parsed Requirements

Lexical Analysis

Semantic derivation

Syntactic Analysis

Reports:
- Numeric & graphical indicators
- Logs

Indicator-related dictionaries

Domain dictionaries

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

QuARS 2007
Raffo, Ferguson and Setamanit
© 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
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
How do we use Process Simulation?

Architect the Process Model
Calibrate the Data Set
Run Options
See the Return on Investment
Creating Process Simulation Models

Management Dashboard

Process Simulation Model

PATT Project Database

Life Cycle Model Templates

REQ → DES → IMP → TEST → CUST

TP → TCG

Generic Process Model Blocks

Genericized Process Components

Req1: Use Case Analysis

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

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

Software Engineering Institute | Carnegie Mellon

SSTC 2007
Raffo, Ferguson and Setamanit
© 2006 Carnegie Mellon University
Better Process Decisions

Financial Benefits NPV, ROI

Organizational
Site and Project
Industry Standard

Development Projects

Project and Process Data

Financial Benefits
NPV, ROI

SW Process Simulation Model

PATT Project Database

Project Performance
NASA Model – Includes IV&V Layer with IEEE 12207 SW Development Lifecycle
System and SW Requirements Processes

AS-IS

Previous Process Steps → System REQ Analysis → System REQ Inspection → System REQ Rework → Next Process Steps

TO-BE

Previous Process Steps → System REQ Analysis → QuARS System REQ Inspection → System REQ Rework → System REQ Rework → System REQ Inspection → System REQ Rework → Next Process Steps
IV&V at Requirements Verification

Previous Process Steps

- QuARS Software REQ Inspection
- Traceability Analysis
- Software REQ Evaluation

Next Process Steps

- Interface Analysis
- System Test Plan Analysis
- Timing And Sizing Analysis
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
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%)
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%)
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?
Results - Applying QuARS in V&V Mode at Different Phases

<table>
<thead>
<tr>
<th></th>
<th>Effort incl. IV&amp;V</th>
<th>Effort</th>
<th>RWK Effrt</th>
<th>IV&amp;V Effrt</th>
<th>Duration</th>
<th>Avg. Dur</th>
<th>Crctd Dfcs</th>
<th>Ltnt Dfcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuARS at Sys Req</td>
<td>1,659</td>
<td>1,670</td>
<td>1,312</td>
<td>(11)</td>
<td>103</td>
<td>49</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>p value</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>QuARS at Sw Req</td>
<td>5,142</td>
<td>5,128</td>
<td>4,779</td>
<td>14</td>
<td>377</td>
<td>72</td>
<td>(10)</td>
<td>55</td>
</tr>
<tr>
<td>p value</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>QuARS at Sys &amp; Sw Req</td>
<td>5,268</td>
<td>5,285</td>
<td>4,926</td>
<td>(17)</td>
<td>362</td>
<td>81</td>
<td>(10)</td>
<td>59</td>
</tr>
<tr>
<td>p value</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

- 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
Results – Less Than 100% of Project is Inspected

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

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
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%
Results – QuARS Under Different Defect Injection Rates

<table>
<thead>
<tr>
<th>Comparison to Baseline</th>
<th>Effort incl. IV&amp;V</th>
<th>Effort</th>
<th>Rwrk_Eft</th>
<th>IV&amp;V Effort</th>
<th>Duration</th>
<th>Avg. Dur</th>
<th>Crtct_Dfcts</th>
<th>Lntn_Dfcts</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuARS at Sys Req</td>
<td>1,186.78</td>
<td>1,199.64</td>
<td>858.23</td>
<td>(12.86)</td>
<td>58.17</td>
<td>42.36</td>
<td>39.21</td>
<td>13.08</td>
</tr>
<tr>
<td>p value</td>
<td>0.02</td>
<td>0.02</td>
<td>0.00</td>
<td>0.84</td>
<td>0.25</td>
<td>0.08</td>
<td>0.51</td>
<td>0.04</td>
</tr>
<tr>
<td>QuARS at Sw Req</td>
<td>3,179.53</td>
<td>3,187.55</td>
<td>2,890.71</td>
<td>(8.02)</td>
<td>212.62</td>
<td>44.53</td>
<td>13.00</td>
<td>34.37</td>
</tr>
<tr>
<td>p value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.90</td>
<td>0.00</td>
<td>0.05</td>
<td>0.83</td>
<td>0.00</td>
</tr>
<tr>
<td>QuARS at Sys &amp; Sw Req</td>
<td>3,354.04</td>
<td>3,295.10</td>
<td>2,994.34</td>
<td>58.94</td>
<td>235.76</td>
<td>62.62</td>
<td>13.69</td>
<td>36.25</td>
</tr>
<tr>
<td>p value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.33</td>
<td>0.00</td>
<td>0.01</td>
<td>0.82</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparison to Baseline</th>
<th>Effort incl. IV&amp;V</th>
<th>Effort</th>
<th>Rwrk_Eft</th>
<th>IV&amp;V Effort</th>
<th>Duration</th>
<th>Avg. Dur</th>
<th>Crtct_Dfcts</th>
<th>Lntn_Dfcts</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuARS at Concept IV&amp;V</td>
<td>874.24</td>
<td>1,174.63</td>
<td>833.20</td>
<td>(300.39)</td>
<td>17.48</td>
<td>41.67</td>
<td>36.16</td>
<td>12.66</td>
</tr>
<tr>
<td>p value</td>
<td>0.08</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td>0.71</td>
<td>0.08</td>
<td>0.54</td>
<td>0.05</td>
</tr>
<tr>
<td>QuARS at REQ IV&amp;V</td>
<td>1,571.89</td>
<td>1,747.96</td>
<td>1,396.61</td>
<td>(176.07)</td>
<td>123.17</td>
<td>45.22</td>
<td>30.78</td>
<td>17.48</td>
</tr>
<tr>
<td>p value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.06</td>
<td>0.60</td>
<td>0.01</td>
</tr>
<tr>
<td>QuARS at both</td>
<td>1,643.16</td>
<td>2,123.36</td>
<td>1,758.96</td>
<td>(480.20)</td>
<td>86.25</td>
<td>61.77</td>
<td>24.49</td>
<td>23.22</td>
</tr>
<tr>
<td>p value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.07</td>
<td>0.01</td>
<td>0.68</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Return on Investment Inputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Development Staff per Hour</td>
<td>$100.00</td>
</tr>
<tr>
<td>Cost of IV&amp;V Staff per Hour</td>
<td>$100.00</td>
</tr>
<tr>
<td>Implementation Cost (Tool Cost)</td>
<td>$ -</td>
</tr>
<tr>
<td>Increase in Revenue per Month</td>
<td>$ -</td>
</tr>
<tr>
<td>Cost to Correct Latent Defects</td>
<td>$25,500.00 per defect</td>
</tr>
<tr>
<td>Org internal investment rate cut-off (aka hurdle rate)</td>
<td>20.00%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Hours per Month</td>
<td>170</td>
</tr>
<tr>
<td>Work Hours per Year</td>
<td>2,040</td>
</tr>
<tr>
<td>Latent Defects will be corrected within the first 36 months</td>
<td></td>
</tr>
<tr>
<td>If releasing the system early by 3 months or more, there will be an increase in revenues (due to an effort saving occurs at time = duration)</td>
<td></td>
</tr>
<tr>
<td>Duration saving occurs at time = duration + 1 month</td>
<td>170 hours</td>
</tr>
<tr>
<td>Latent defect saving occurs at time = duration + 36 months</td>
<td>6120 hours</td>
</tr>
</tbody>
</table>
NPV and Risk Results Summary

- 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)
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
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.
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)
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
The End

Questions?