Applying Process Simulation to Achieve High-Value Benefits

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Agenda: Part I

1. Introduction: What is Process Simulation?
2. Motivation: What can be done with Process Simulation Models?
3. Examples of High Value Add Ways the Process Simulation Can be applied within an organization
4. Wrap-Up/ Conclusions
What Is a Simulation Model?

- A simulation model is a computerized model (not a maturity model) designed to display significant features of the dynamic system it represents.

- Simulations are generally employed when
  - behavior over time is of particular interest or significance, and
  - the economics or logistics of manipulating the system being modeled are prohibitive

- Common purposes of simulation models are:
  - to provide a basis for experimentation,
  - to predict behavior,
  - to answer “what if” questions,
  - to teach about the system being modeled.
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 for a project
  - Globally Distributed Software Development
- Assess the Costs and Benefits of Applying New Tools and Technologies
- Plan Processes and make better Tradeoff Decisions
- Evaluate Process Improvement Opportunities
- Architect, Design, and Document Processes
- Estimate Project Costs from the Bottom Up
- Manage Projects Quantitatively
- Train Project Managers
Applying Process Simulation = High Value Add

- **Evaluate Strategic Issues**
  - Quality Assurance, V&V, and IV&V Strategy for a project
  - Globally Distributed SW Development
NASA Model – IEEE 12207 Software Development Lifecycle
# IV&V Layer – Select Criticality Levels for IV&V Techniques using pull-down menus

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# Impact of IV&V at Different Points in the Development Process

## Result Comparison

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<th>Case</th>
<th>Configuration</th>
<th>Total Effort Mean (Person Months)</th>
<th>Rework Effort Mean (Person Months)</th>
<th>Duration Mean (Months)</th>
<th>Corrected Defects Mean (Number of Defects)</th>
<th>Latent Defects Mean (Number of Defects)</th>
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## % Improvement Compared to the Baseline

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GSD Model Structure

Global SD

Planning

Control

Workforce Needed

Site-specific SD

Site 1

Site 2

Interaction Effect

Global DES

Site-specific DES

Site-specific DES

HR = Human Resource

MP = Manpower Allocation

PD = Productivity

QA = Quality Assurance
Interaction Effects (IE)

- Capture the impact of GSD factors on productivity and defect generation rate.
- Interaction effect on productivity rate
Evaluate Process Tradeoffs

- Task Allocation Strategy Alternatives
Ideal Situation

- Duration when using follow-the-sun is 70% of the time it takes using single-site.
- Module-based took a little longer than follow-the-sun.
Real World Situation

- Follow-the-sun took about 37% longer than single-site
- Module-based is the shortest
Key Questions GSD Models Can Address

- Impact of moving to multi-site development
- Impact of adding a new development site
- Task allocation strategy
- Multi-site QA strategy
- Impact of different development sites using different processes, people and technology
- Deals with issues due to cultural, language, time zone, productivity and cost differences
- Examines impact of personnel turnover and skills development
Applications for System Acquisition

- Can assess impact of using prime with collection of subcontractors at different sites (i.e. software acquisition model)
- Impact of short funding government projects
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
  - Quality Assurance/ V&V Strategy for a project
  - IV&V Strategy
  - Globally Distributed Software Development

- Assess the Costs and Benefits of Applying New Tools and Technologies
Cost/Benefit of New Technologies

New LDD Technology

- 7 level 4 sub-systems
- Stable accuracies
- Massive changes in other measures

Changes to Process

1. Previous Process Steps
2. Coding
   - (to provide learning material)
3. Inspection 1
   - (to provide learning material)
4. Apply Tool
   - (learn, tune, and apply to identify "hot spots")
5. Inspection 2 of "Hot Spots" Only
6. Code Rework
7. Remaining Process Steps

Results Showing Impact on NASA Projects

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<th>Total Effort + IV&amp;V (PM)</th>
<th>Total Effort (PM)</th>
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reinspect 50% detcap IV&V = 0.05 & inspect 10% with detcap = 0.50

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reinspect 50% detcap IV&V = 0.02 & inspect 10% with detcap = 0.50
General Business Case Questions

- What is the impact of applying new tools and technologies?
- What is the economic benefit or value of the tool or technology? What is the Return on Investment?
- When is it useful and when might it be useless?
- Under what conditions does the tool or technology perform best?
- What performance standards does the tool need to achieve in order to have a positive return?
- Are there better ways to apply the tool?
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
  - Quality Assurance/ V&V Strategy for a project
  - IV&V Strategy
- Assess the Costs and Benefits of Applying New Tools and Technologies
- **Plan Processes and Make Better Tradeoff Decisions**
- **Evaluate Process Improvement Opportunities**
Incremental Development Model
# Benefits of Process Simulation

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<th>Projected Cost or Revenue delta due to Duration Change</th>
<th>Total Injected Defects</th>
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Add QuARS Tool: Eliminate Additional Process
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
  - Quality Assurance/ V&V Strategy for a project
  - IV&V Strategy
  - Globally Distributed Software Development
- Assess the Costs and Benefits of Applying New Tools and Technologies
- Plan Processes and Make Better Tradeoff Decisions
- Evaluate Process Improvement Opportunities
- *Architect, Design, and Documenting Processes*
Architect, Design and Document Processes

Process Simulation Model

Life Cycle Model Templates

Generic Process Model Blocks

Generalized Process Components

Req1: Use Case Analysis
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
  - Quality Assurance/ V&V Strategy for a project
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  - Globally Distributed Software Development
- Assess the Costs and Benefits of Applying New Tools and Technologies
- Plan Processes and Make Better Tradeoff Decisions
- Evaluate Process Improvement Opportunities
- Architect, Design, and Documenting Processes
- *Estimate Project Cost from the Bottom-Up*
Using Process Simulation to perform early stage project cost estimation

- Study Conducted by Mizell, in the Engineering Assessment Directorate at KSC
- Applied Process Simulation to provide bottom-up cost and schedule estimates at multiple stages of the project (i.e. from Concept of Operations forward)
- Utilized real project data from KSC and SEL
- Developed estimates that incorporated effects for
  - Incremental Spiral processes
  - Impact of short funding projects
NASA Model – Incremental Spiral Lifecycle

Adapted from Mizell, 2006
Accomplishments of Mizell’s Research

- Methodology to use simulation to provide interval estimates
- Developed probability distributions for size, productivity, and defects using organization specific data
- Provided confidence intervals for project estimates
- Combined system dynamics model with DES process model to analyze effects of turnover on project effort and duration
- Adapted incremental spiral process model
- Complete NASA project case study

© Mizell, 2006
Process Models Used

- IEEE 12207 being used by NASA IV&V
- Adapted for incremental development
- Adapted for spiral development
- Incorporated system dynamics portions into model
- Model development supported by Quantel
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
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- Architect, Design, and Documenting Processes
- Estimate Project Costs from the Bottom-Up
- Manage Processes Quantitatively
Are You on Target?

Original Plan

Actual Data

Corrective Action

Current Trajectory
NASA SW Project and IV&V

Project and IV&V Data

SW Process Simulation Model

Better IV&V Decisions

Track and Replan Improved Outcomes

Process Performance Cost, Quality, Schedule

Outcome Based Control Limits
PROMPT Control and Feedback Loop

1. **Process and Project Data**
2. **Updated Model Parameters**
3. **SW Process Simulation Model**
4. **Metrics Repository**
5. **Outcome Based Control Limits**
6. **Performance Predictions from Model**
7. **Primary Loop**
   - **Is the Process In Control?**
     - Yes: Continue to Execute Process
     - No: Yes, Use Simulation to evaluate corrective action alternatives
8. **Secondary Loop**
   - **Is corrective action necessary?**
     - Yes: Identify Possible Process Improvements
     - No: Implement Best Corrective Action

---

PROMPT Control and Feedback Loop

- **SW Development Process**
- **Performance Predictions from Model**
- **Outcome Based Control Limits**
- **Updated Model Parameters**
- **Metrics Repository**
- **Process and project data**
- **Primary Loop**
  - **Is the Process In Control?**
    - Yes: Continue to Execute Process
    - No: **Secondary Loop**
      - **Is corrective action necessary?**
        - Yes: Identify Possible Process Improvements
        - No: Implement Best Corrective Action
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
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- Evaluate Process Improvement Opportunities
- Architect, Design, and Documenting Processes
- Estimate Project Costs from the Bottom-Up
- Manage Processes Quantitatively

*Train Project Managers*
Teaching Software Project Management through Modeling (Navarro, et. al., 2006)
Benefits of Process Simulation

- Decision Support and Tradeoff Analysis
- Sensitivity Analysis – “What if”
- Supports Industry Certification and process improvement programs including CMMI, Six Sigma, and others
- Benchmarking
- Design and Define Processes/Metrics
- Bring Lessons Learned Repositories Alive
- Can save cost, effort, and expertise
- Many ways to achieve High Value-Add by using process simulation
Bottom-Line

- Process Simulation can make an impact on your business.
  - Improving QA strategies (defect containment, COQ, COPQ)
  - Achieving higher CMMI Levels (Fulfilling CMMI L4)
  - Implementing 6 Sigma practices
  - Adopting new technologies
  - Plan/replan projects
  - Bottom-up cost estimation

- Enables an organization to adapt to change and improve processes more quickly – beating the competition, win contracts

- Enables an organization to design processes better, train employees, implement more quickly = better performance, higher quality, faster
The End

Questions?
Applying Process Simulation to Achieve High-Value Benefits

David M. Raffo, Ph.D.
Quantel, Inc.
Software Engineering Institute
Portland State University
Agenda: Part II

- Overview of Simulation Types
- Process Tradeoff Analysis Method
  - Data
  - Model Templates
  - Model Database
  - Analysis of Results
- Incremental Model tour
- Conclusions
Alternative Process Simulation Approaches

- Modeling Paradigms
  - Knowledge-Based Systems
  - Agent Based
  - State-Based
  - Discrete Event
  - System Dynamics
  - Hybrid

- Research Outlets
  - Software Process: Improvement and Practice
  - Journal of Systems and Software

- Tools
  - Arena
  - ProModel
  - Extend
  - Stella
  - VenSim
  - Research tools

- Conferences
  - Winter Simulation Conference
  - SPW/ ProSim
  - SEPG
  - SSTC
Alternative Process Simulation Approaches

- Knowledge Based Systems
  - Person-in-the loop
  - Fine level of granularity
  - Supports process enactment

- Agent Based Systems
  - Fine level of granularity
  - Supports detailed work interactions

- State Based Systems
  - Captures flow of control (work activities, parallelism) well
  - Multi-view graphical representations
  - Difficult to capture task, work package and resource details
Alternative Process Simulation Approaches

- **Discrete Event Simulation**
  - Able to represent richness of processes, work packages and resources
  - Good for modeling quantitative process performance
  - Good tool support

- **System Dynamics**
  - Captures feedback well
  - Often used for high level qualitative issues

- **Hybrid**
  - Captures best aspects of Discrete Event and System Dynamics
  - Models are complex
  - Being used to predict performance of multi-site development
# Common Applications of Each Approach

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<th>STRAT</th>
<th>PLAN</th>
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**Development Projects**

**Project and Process Data**

- Organizational
- Site and Project
- Industry Standard

**SW Process Simulation Model**

**Financial Benefits**
- NPV, ROI

**Better Process Decisions**

**PATT Project Database**

**Project Performance**
Where does the data come from?  (1 of 2)

- Input data are used to predict the performance measures.

- Can be derived from the organization
  - Current baseline
  - Exemplary projects
  - Pilot data

- Can also be derived from
  - Expert opinion
  - Industry data from comparable organizations

- Best judgments to describe the state of your organization
Input Data (2 of 2)

- **Examples:**
  - process documents and assessments
  - amount of incoming work
  - effort based on size (and/or other factors)
  - defect detection efficiency
  - effort for rework based on size and number of defects
  - defect injection, detection and removal rates
  - decision point outcomes; number of rework cycles
  - hiring rate; staff turnover rate
  - personnel capability and motivation, over time
  - resource constraints
  - frequency of product version releases
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
- Development
- Inspection
- Testing
- Rework
- IV&V
- Joint Reviews

Generalized Process Components
- Req1: Use Case Analysis

- IEEE 12207
- Spiral
- Incremental
- Product Line
- Rapid Prototyping
Customizing PATT
Multiple block types implement SW development techniques

- Development blocks develop product and inject defects
- Inspection blocks detect defects
- Testing blocks detect defects
- Rework blocks correct and inject defects
- Joint Review blocks detect and correct defects.
- IV&V blocks detect defects.
Project Data Base

- Inputs
  - Size, productivity, error potential, consequence, defect injection, detection, and correction rates, cost, duration, etc.

- Outputs
  - Customizable reporting
  - All levels - Project, phase, activity levels
  - Costs reported using COQ format
  - Defect containment statistics
  - Special reports for IV&V
Project Database

IEEE12207Data: Database (Access 2000 file format)

Objects

Tables

- Create table in Design view
- Create table by using wizard
- Create table by entering data
- Entity_Info
- Entity_List
- Fan_Out
- Input_Parameters
- Ivv_Activity_Statistics
- Ivv_Input
- Ivv_Phase_Data
- Ivv_Phase_Statistics
- IVV_Profiles
- Ivv_Statistics

- Ivv_Step_Data
- Ivv_Totals
- Parameter_Information
- Parameter_Names
- Project_Activity_Efforts
- Project_Activity_Statistics
- Project_Data
- Project_Level_Info
- Project_Phase_Data
- Project_Phase_Statistics
- Project_Statistics
- Project_Step_Data
- Project_Totals
### Development Project Total Effort/Duration Statistics

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<th>Duration</th>
<th>Avg. Duration</th>
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<th>Latent Defects</th>
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PATT Architecture

Model Engine
- PATT Model
  - Simulation Model
  - LC Templates
  - Phases
  - Blocks
  - Connectors
  - Libraries and Extensions

Database Engine
- PATT Database
  - Tables
  - Custom Reports
  - Model Specific
  - PATT DB Structure

Analysis Engine
- PATT Output Analyzer
  - Sensitivity Analysis
  - Design of Experiments
  - Configuration Analysis
## Benefits of Process Simulation

<table>
<thead>
<tr>
<th>Option</th>
<th>Project</th>
<th>Total Effort (PM)</th>
<th>Rework Effort (Dev)</th>
<th>Project Duration (Calendar Months)</th>
<th>Projected Cost or Revenue delta due to Duration Change</th>
<th>Total Injected Defects</th>
<th>Corrected Defects</th>
<th>Escaped Defects</th>
<th>Rework Effort for Field Defects (PM)</th>
<th>Implementation Costs ($)</th>
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Computations and Tradeoffs

- Sensitivity Analysis
- Design of Experiments
- Business Case – ROI, NPV
- Methods in use and available
Demonstration of the Incremental Model
Simulation User-Levels

- Level 1: Manager - Runs simulations based on pre-determined options
- Level 2: Analyst - Able to add or change the process to study the impact of process changes
- Level 3: Expert - Able to create new models from scratch
- Level 4: Developer - Able to program new block and/or modify the logic of existing blocks, as allowed by the security model
- Level 5: Originator – Establishes security model
Process Tradeoff Analysis Method (PTAM)

- Based on extensive research into Software Process Modeling conducted in academia, SEI and industry.
- Graphical user interface and models software processes
- Integrates SEI methods to define processes and supports CMMI PAs (CMMI L4 QPM)
- Supports Industry Certification Programs including CMMI, Six Sigma, and others
- Benchmarking
- Integrates metrics related to cost, quality, and schedule into understandable project performance picture.
- Predicts project-level impacts of process improvements in terms of cost, quality and cycle time
Process Tradeoff Analysis Method (PTAM)

- **Support business case analysis** of process decisions - ROI, NPV and quantitatively assessing risk.
- **Reduces risk** associated with process changes by predicting the probability of improvement
- **Saves time, effort and expertise** over other methods
Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
  - Quality Assurance, V&V and IV&V Strategy for a project
  - Globally Distributed Software Development
- Assess the Costs and Benefits of Applying New Tools and Technologies
- Plan Processes and make better Tradeoff Decisions
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- Architect, Design, and Document Processes
- Estimate Project Costs from the Bottom Up
- Manage Projects Quantitatively
- Train Project Managers

*Process Simulation can make a positive impact on your business!*
The End

Questions?