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Quantitative Intelligence

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

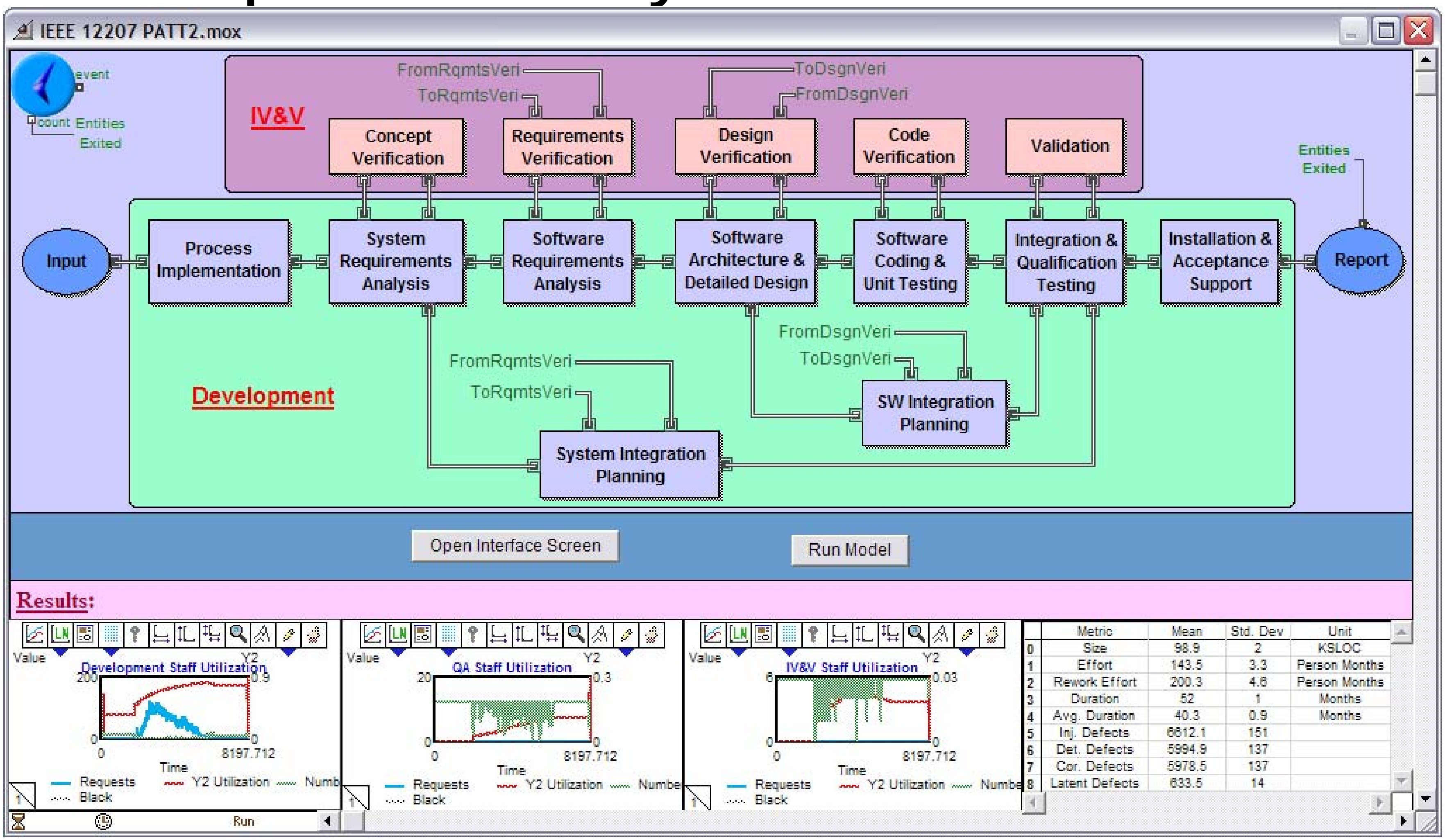
Applying Process Simulation = High Value Add

- 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

Notebook - IEEE12207_Baseline.mox

IV&V Profile: Silap-Unmanned

Save IV&V Profile

Load IV&V Profile:

Delete IV&V Profile:

		Concept Verification		Requirements Verification		Design Verification		Code Verification		Validation	
ID	IV&V Technique	Consequence	Error Potential	Consequence	Error Potential	Consequence	Error Potential	Consequence	Error Potential	Consequence	Error Potential
1.1	Management and Planning of Independent Verification and Validation	1	1	1	1	1	1	1	1	1	1
1.2	Issue and Risk Tracking	2	2	2	2	2	2	2	2	2	2
1.3	Final Report Generation	2	2	2	2	2	2	2	2	2	2
1.4	IV&V Tool Support	2	2	2	2	2	2	2	2	2	2
1.5	Management and Technical Review Support	1	1	1	1	1	1	1	1	1	1
1.6	Criticality Analysis	1	1	1	1	1	1	1	1	1	1
1.7	Identify Process Improvement Opportunities in the Conduct of IV&V	2	2	2	2	2	2	2	2	2	2
2.1	Reuse Analysis	3	None								
2.2	Software Architecture Assessment	3	None								
2.3	System Requirements Review	3	4								
2.4	Concept Document Evaluation	None	None								
2.5	Software/User Requirements Allocation Analysis	None	None								
2.6	Traceability Analysis	None	None								
3.1	Traceability Analysis – Requirements			2	4						
3.2	Software Requirements Evaluation			3	4						
3.3	Interface Analysis – Requirements			4	3						

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IV&V Layer – Select Criticality Levels for IV&V Techniques using pull-down menus

Notebook - IEEE12207_Baseline.mox

2.3	System Requirements Review	None	None								
2.4	Concept Document Evaluation	None	None								
2.5	Software/User Requirements Allocation Analysis	None	None								
2.6	Traceability Analysis	None	None								
3.1	Traceability Analysis - Requirements			None	None						
3.2	Software Requirements Evaluation			None	None						
3.3	Interface Analysis - Requirements			None	None						
3.4	System test Plan Analysis			None	None						
3.5	Acceptance Test Plan Analysis			None	None						
3.6	Timing and Sizing Analysis			None	None						
4.1	Traceability Analysis - Design					None	None				
4.2	Software Design Evaluation					None	None				
4.3	Interface Analysis Design					None	None				
4.4	Software FQT Plan Analysis					None	None				
4.5	Software Integration Test Plan Analysis					None	None				
4.6	Database Analysis					None	None				
4.7	Component Test Plan Analysis					None	None				
5.1	Traceability Analysis - Code							None	None		
5.2	Source Code and Documentation Evaluation							None	None		
5.3	Interface Analysis - Code							None	None		
6.1	Traceability Analysis - Test									None	None
8.15	Project Management Oversight Support	None	None	None	None	None	None	None	None	1	1

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

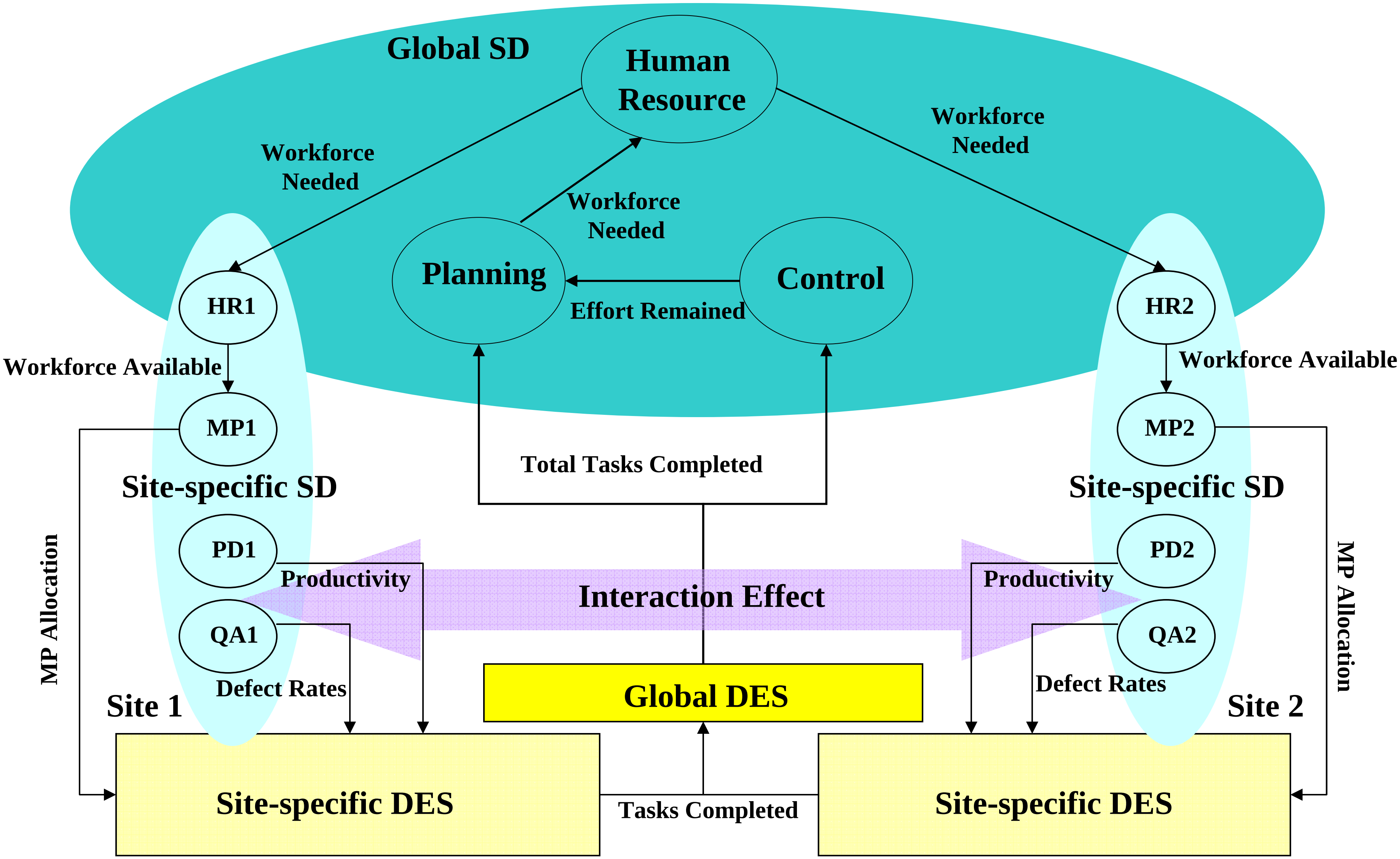
Result Comparison

Case	Configuration	Total Effort Mean (Person Months)	Rework Effort Mean (Person Months)	Duration Mean (Months)	Corrected Defects Mean (Number of Defects)	Latent Defects Mean (Number of Defects)
1	Baseline	346.26	201.65	58.42	6,038.26	629.48
2	IV&V at Validation	355.35	210.75	59.95	6,113.79	574.17
3	IV&V at Code	334.13	189.53	57.38	6,134.84	573.49
4	IV&V at Design	327.93	183.33	56.56	6,123.11	581.27
5	IV&V at Requirements	326.82	182.21	56.40	6,078.87	600.04

% Improvement Compared to the Baseline

Case	Configuration	Total Effort Mean	Rework Effort Mean	Duration Mean	Corrected Defects Mean	Latent Defects Mean
1	Baseline					
2	IV&V at Validation	-2.63%*	-4.51%*	-2.63%*	+1.25%	+8.79%*
3	IV&V at Code	+3.50%*	+6.01%*	+1.77%	+1.60%	+8.90%*
4	IV&V at Design	+5.29%*	+9.09%*	+3.17%*	+1.41%	+7.66%*
5	IV&V at Requirements	+5.62%*	+9.64%*	+3.46%*	+0.67%	+4.68%*

GSD Model Structure



HR = Human Resource MP = Manpower Allocation PD = Productivity QA = Quality Assurance

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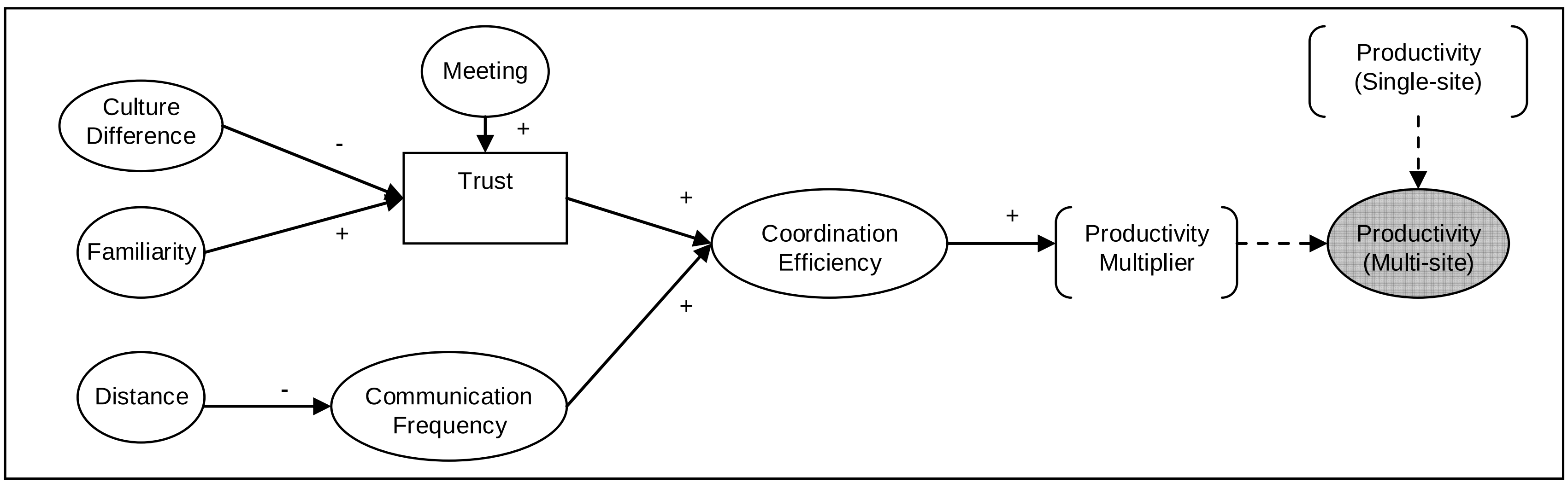
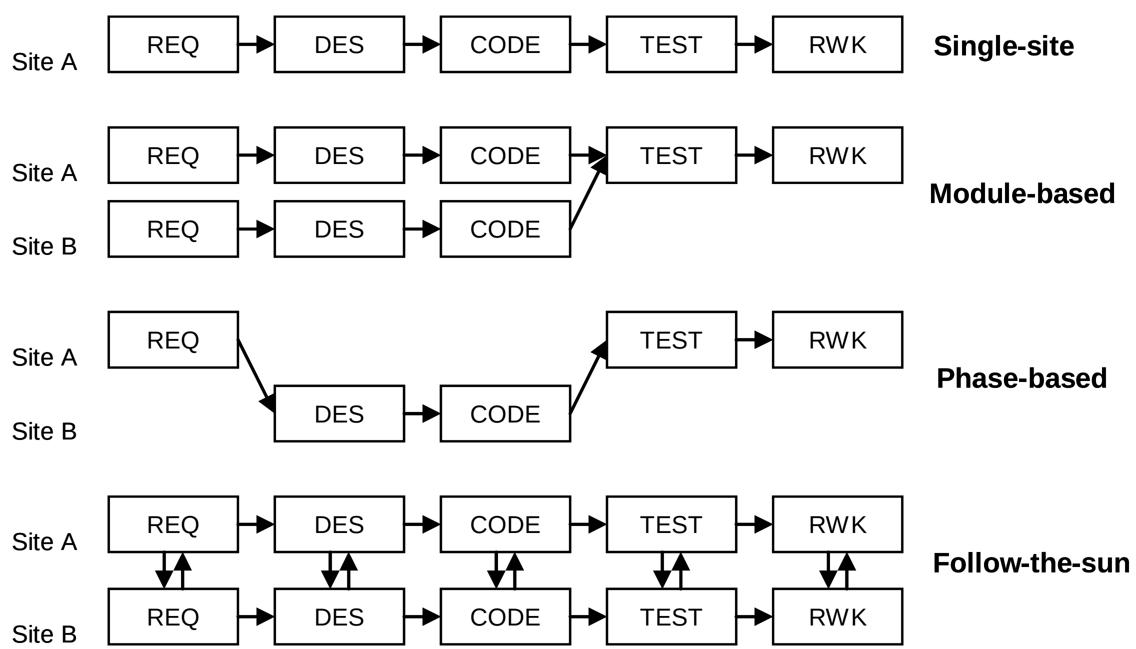
Interaction Effects (IE)

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

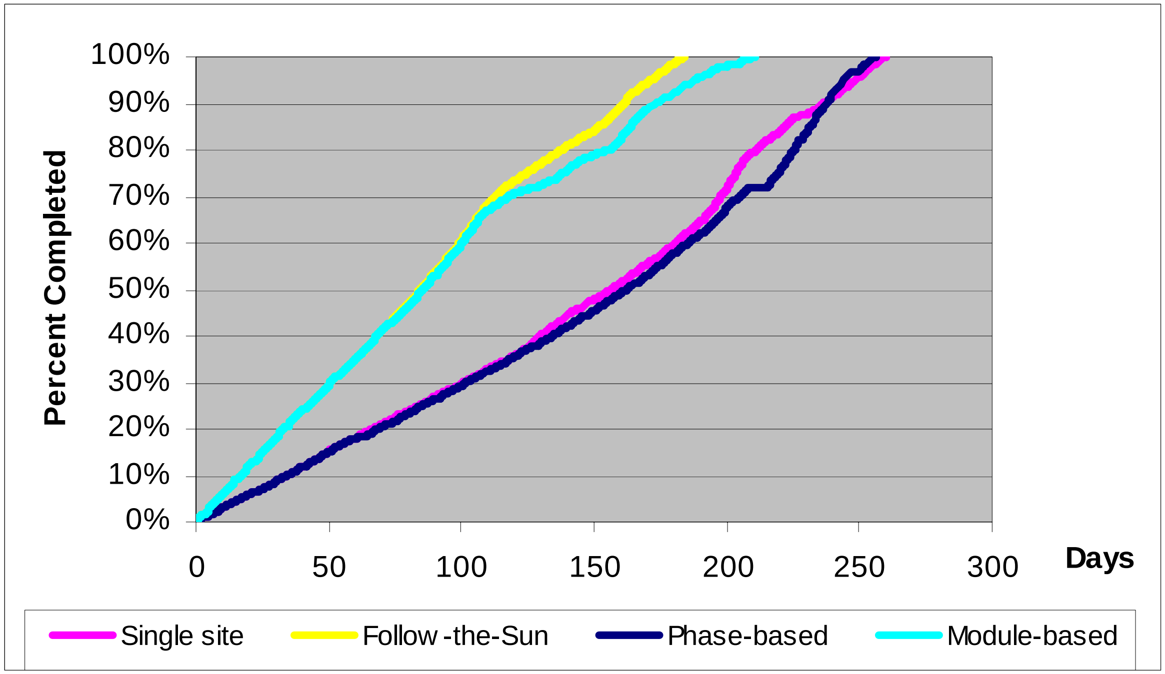


Evaluate Process Tradeoffs

- 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

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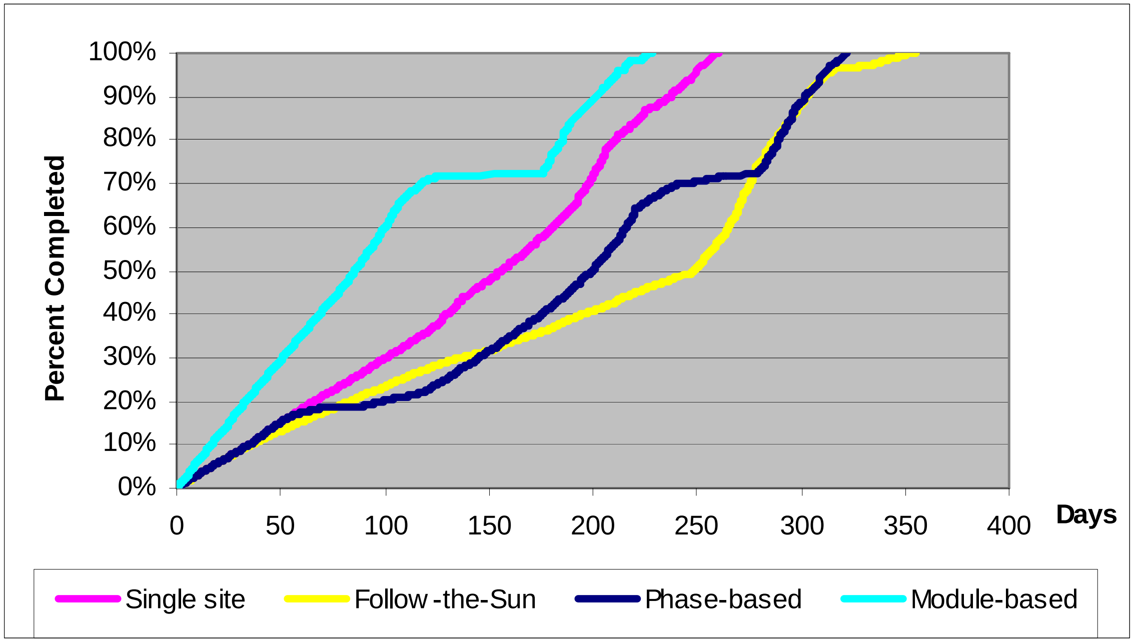
Real World Situation



- 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

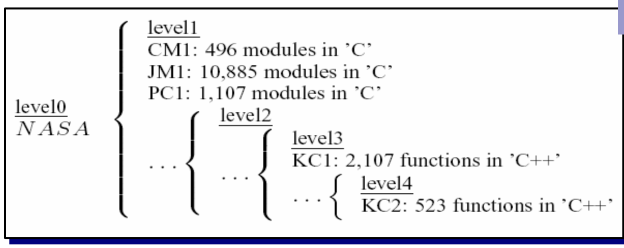
- Can assess impact of using prime with collection of subcontractors at different sites (i.e. software acquisition model)
- Impact of short funding government projects

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

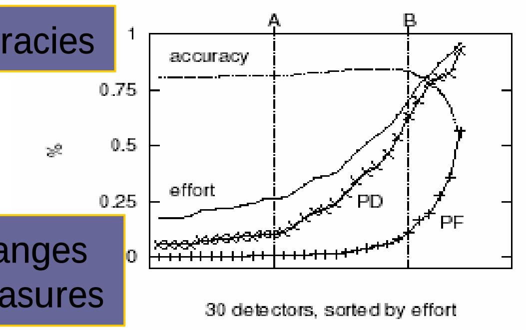


7 level 4 sub-systems

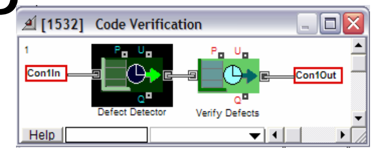
a
b
c
d
e
f
g

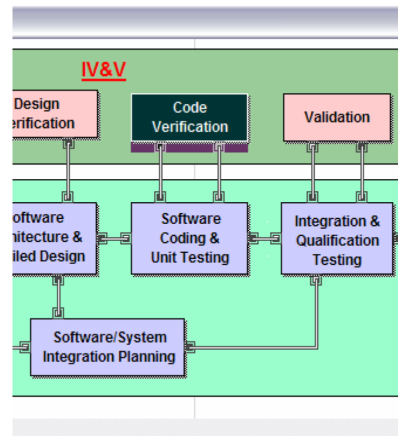
Stable accuracies

Massive changes in other measures

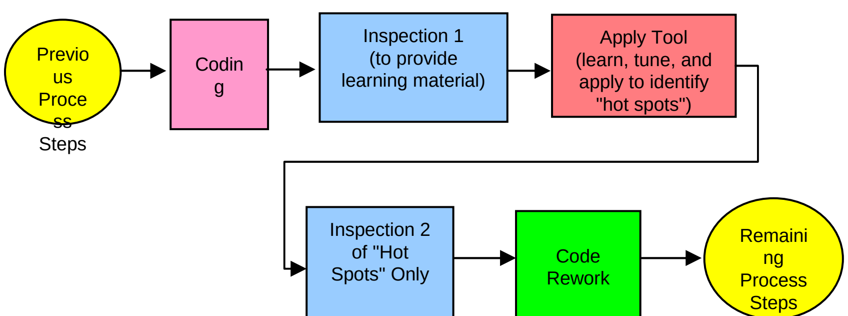


Changes to Model Reflecting Modified Process





Changes to Process



Results Showing Impact on NASA Projects

Total Size (KLOC)	Total Effort + IV&V (PM)	Total Effort (PM)	Total Rework Effort (PM)	Total Duration (Month)	Average Duration
50% V&V					
99.79	815.75	815.75	198.30	33.80	29.48
4.00	27.97	27.97	8.58	1.48	1.26
reinspect 50% detcap IV&V = 0.05 & inspect 10% with detcap = 0.50					
99.79	813.16	807.16	190.02	34.24	29.32
4.00	27.89	27.89	8.35	1.46	1.26
	2.59	**8.59**	**8.28**	**-0.44**	**0.16**
reinspect 50% detcap IV&V = 0.05 & inspect 10% with detcap = 0.70					
99.79	810.79	804.79	187.74	34.20	29.27
4.00	27.81	27.81	8.13	1.46	1.25
	4.96	**10.96**	**10.56**	**-0.39**	**0.20**
reinspect 50% detcap IV&V = 0.02 & inspect 10% with detcap = 0.50					
99.79	814.93	808.93	191.73	34.28	29.35
4.00	27.87	27.87	8.30	1.46	1.26
	0.82	**6.82**	**6.57**	**-0.47**	**0.12**

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
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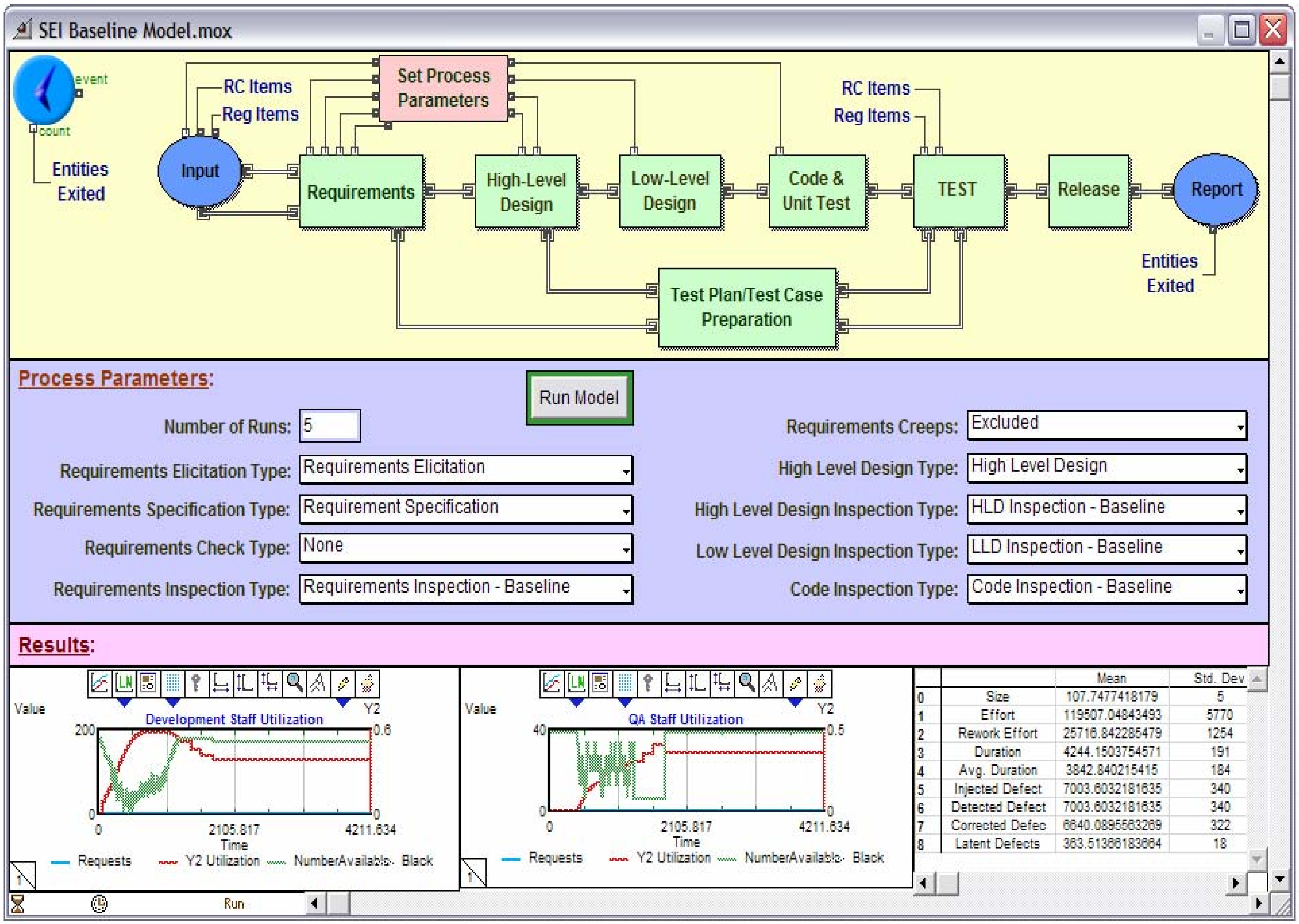
  - IV&V Strategy
- Assess the Costs and Benefits of Applying New Tools and Technologies
- ***Plan Processes and Make Better Tradeoff Decisions***
- ***Evaluate Process Improvement Opportunities***

Incremental Development Model



Benefits of Process Simulation

		Project										
	Option	Total Effort (PM) Dev Eff + Dev Rwk	Rework Effort Devel Defects (PM)	Project Duration *(Calendar Months)*	Projected Cost or Revenue delta due to Duration Change	Total Injected Defects	Corrected Defects	Escapted Defects	Rework Effort for Field Defects *(PM)*	Impleme ntation Costs *($)*	NPV	ROI
0	Base Case	200	90	18	$0.00	1150	990	160	40	$0.00	n.a.	n.a.
1	Implement QFD	190	75	17.5	$0.00	1150	1020	130	30	$100,000	$165,145	15%
2	Implement VOC	185	75	17	$ 100,000	1150	1050	100	20	$120,000	$185,231	29%
3	Add QuARS Tool	175	65	16	$ 300,000	1150	1090	60	10	$ 80,000	$289,674	88%
4	Eliminate	230	130	22	$(400,000)	1150	900	250	80	$0.00	-$378,043	-129%
5	Additional Process											

Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
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  - Globally Distributed Software Development
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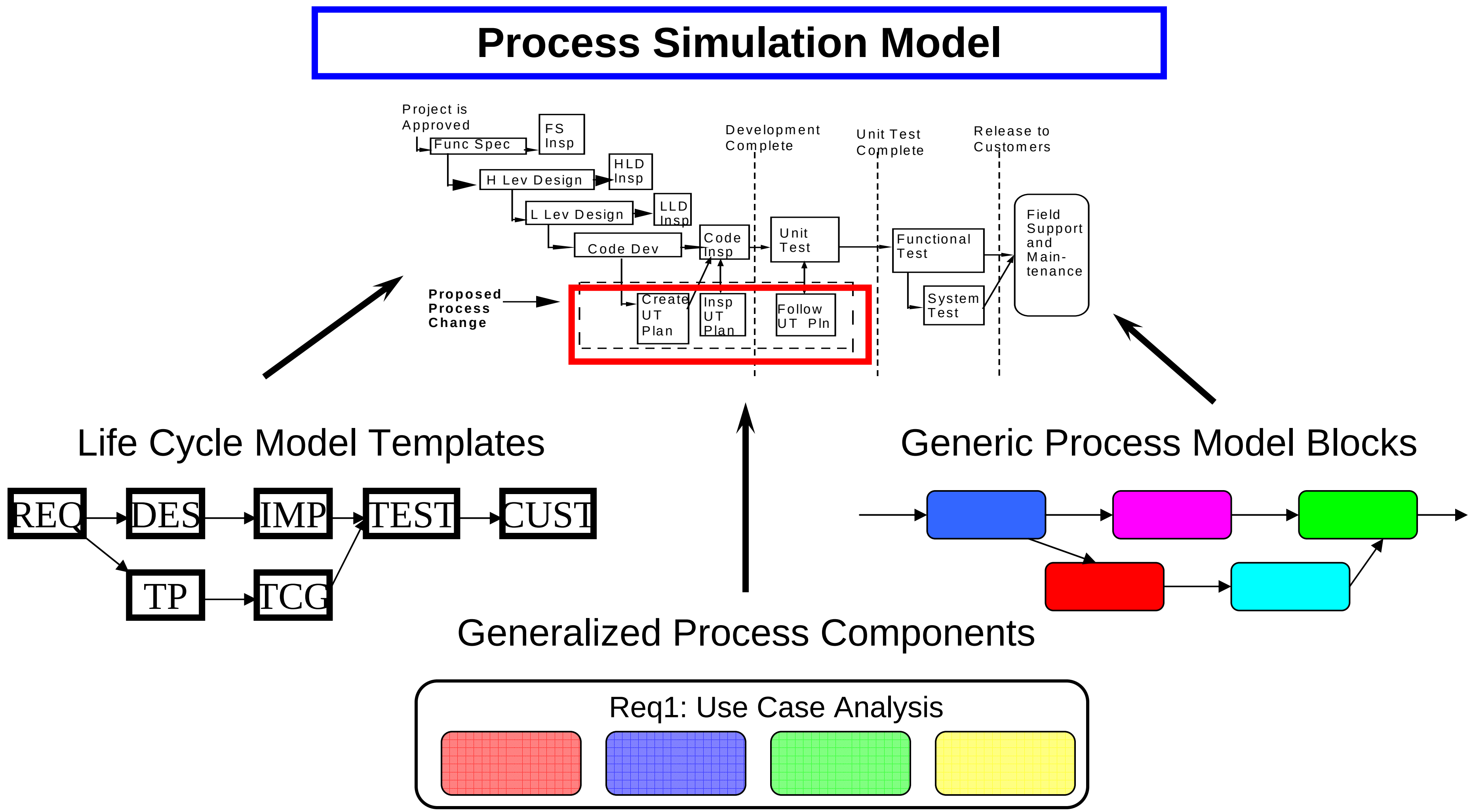
- ***Architect, Design, and Documenting Processes***

Architect, Design and Document Processes



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- 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

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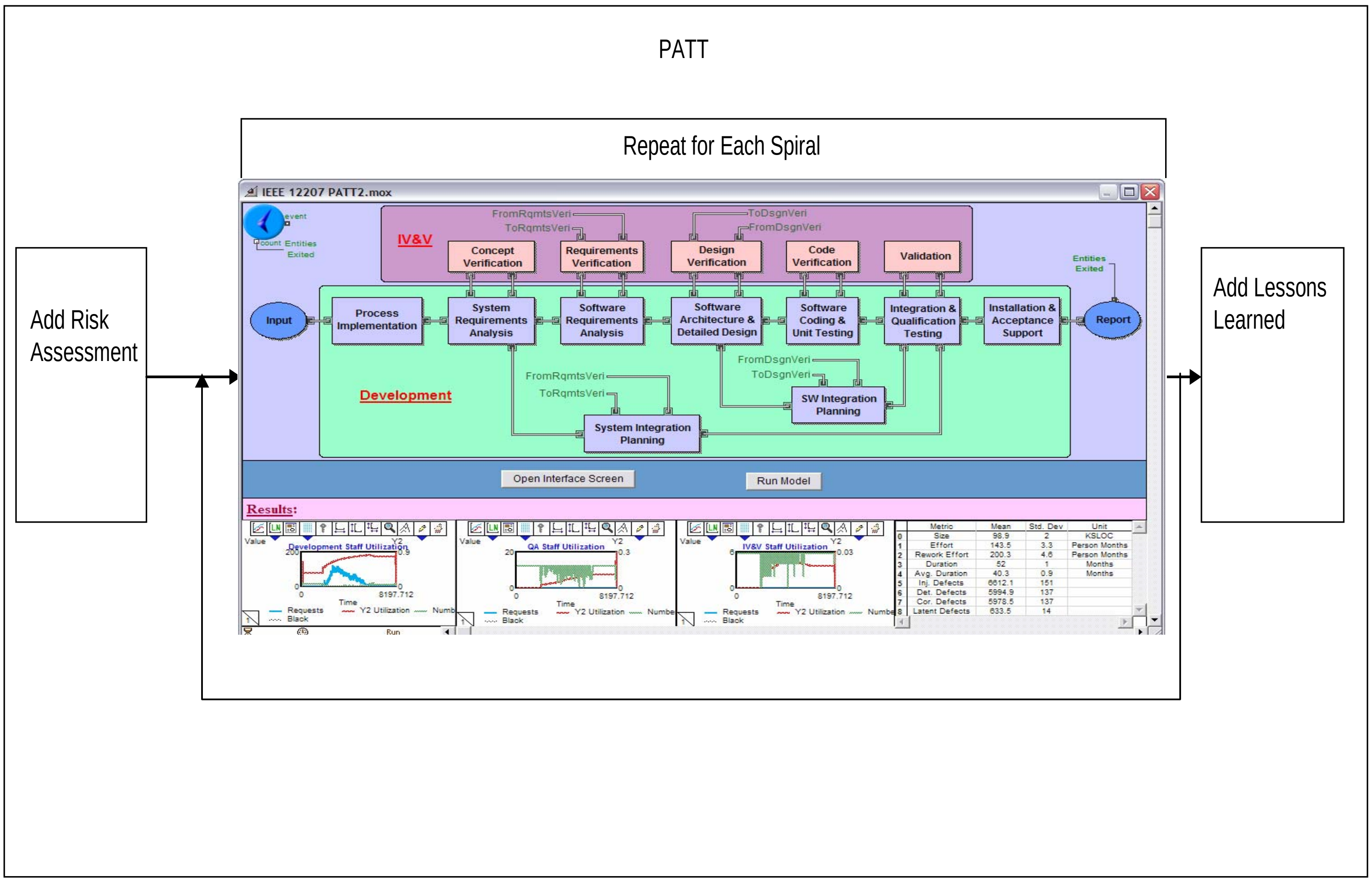
NASA Model – Incremental Spiral Lifecycle



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

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

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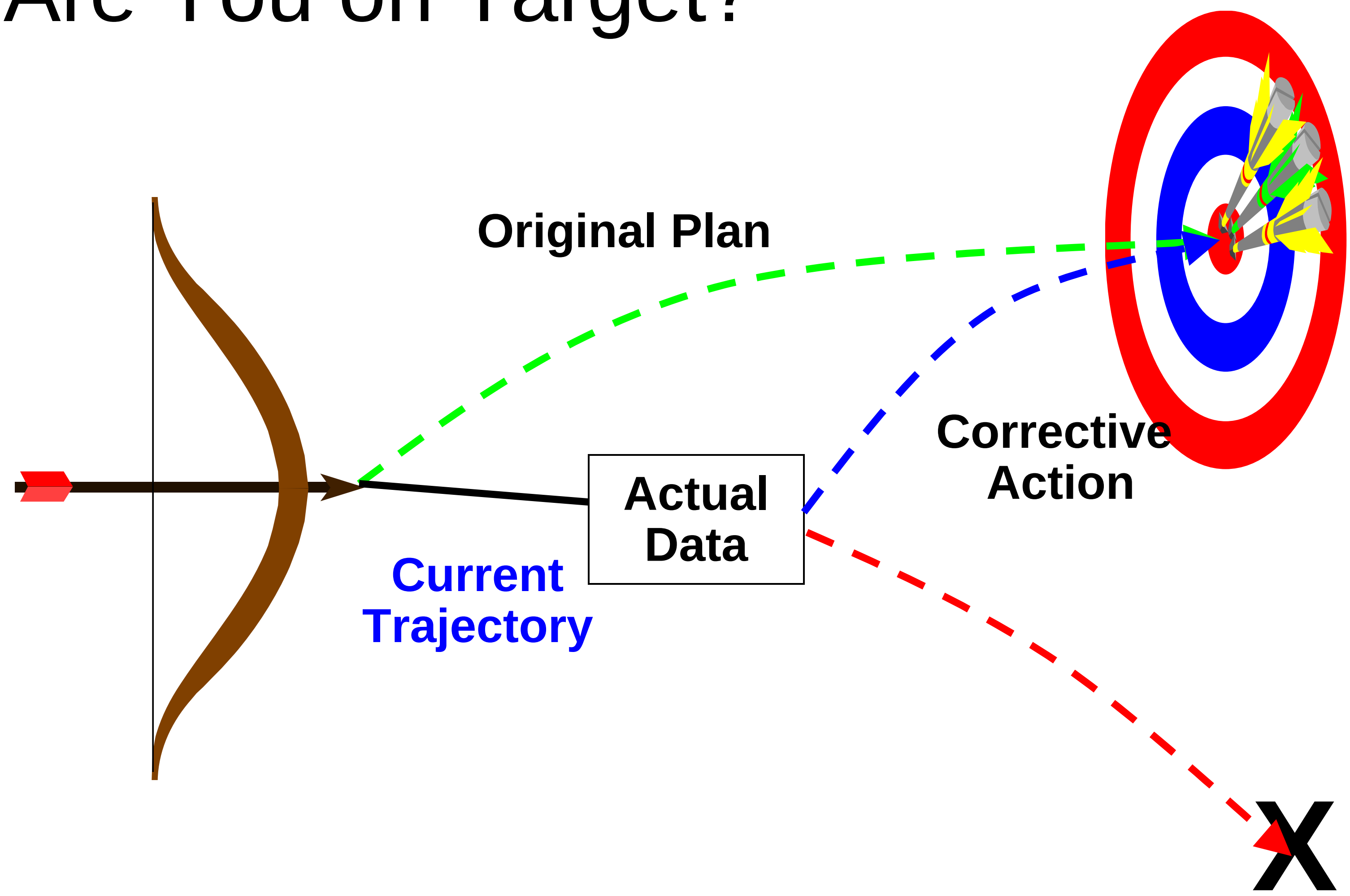
- ***Manage Processes Quantitatively***

Are You on Target?



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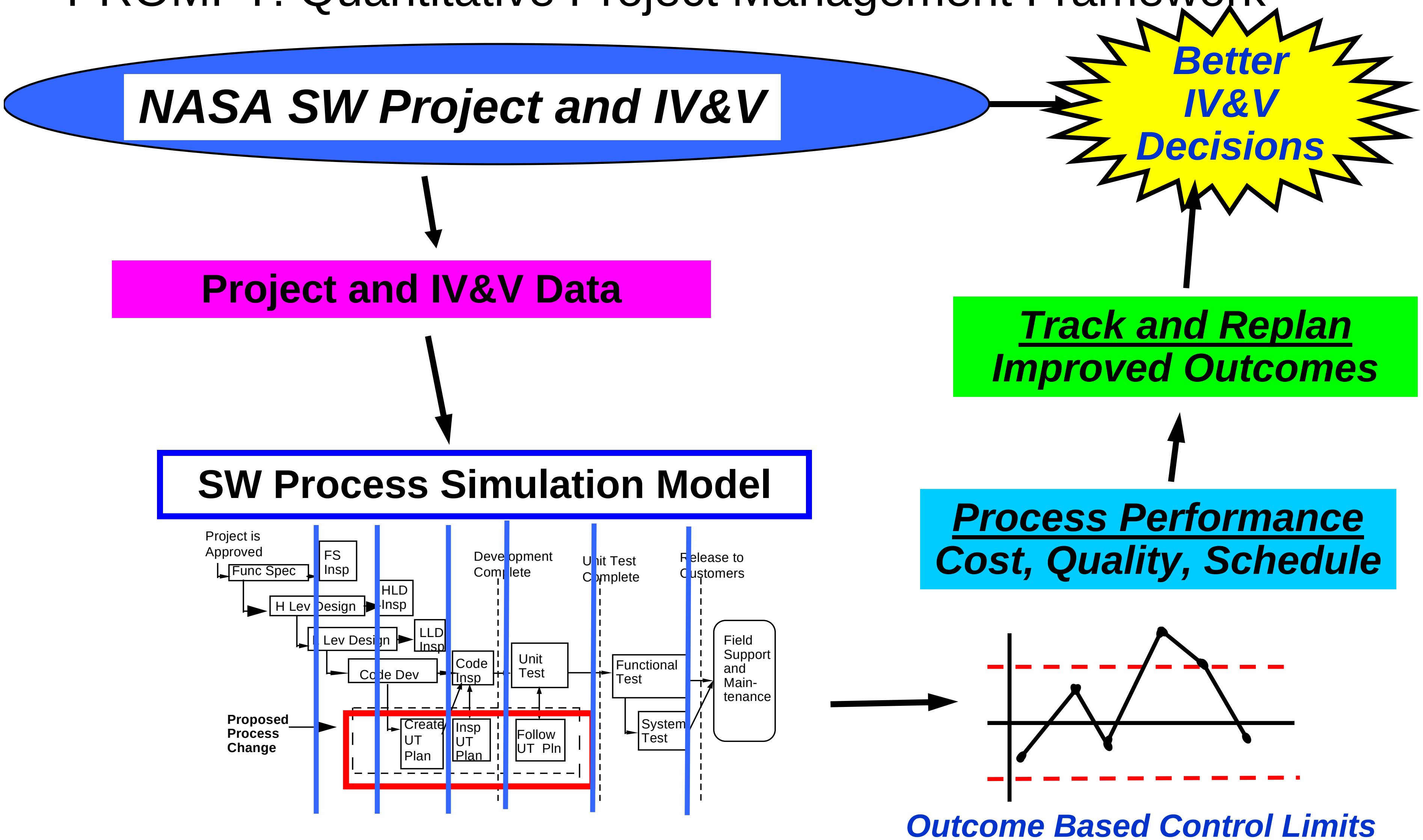
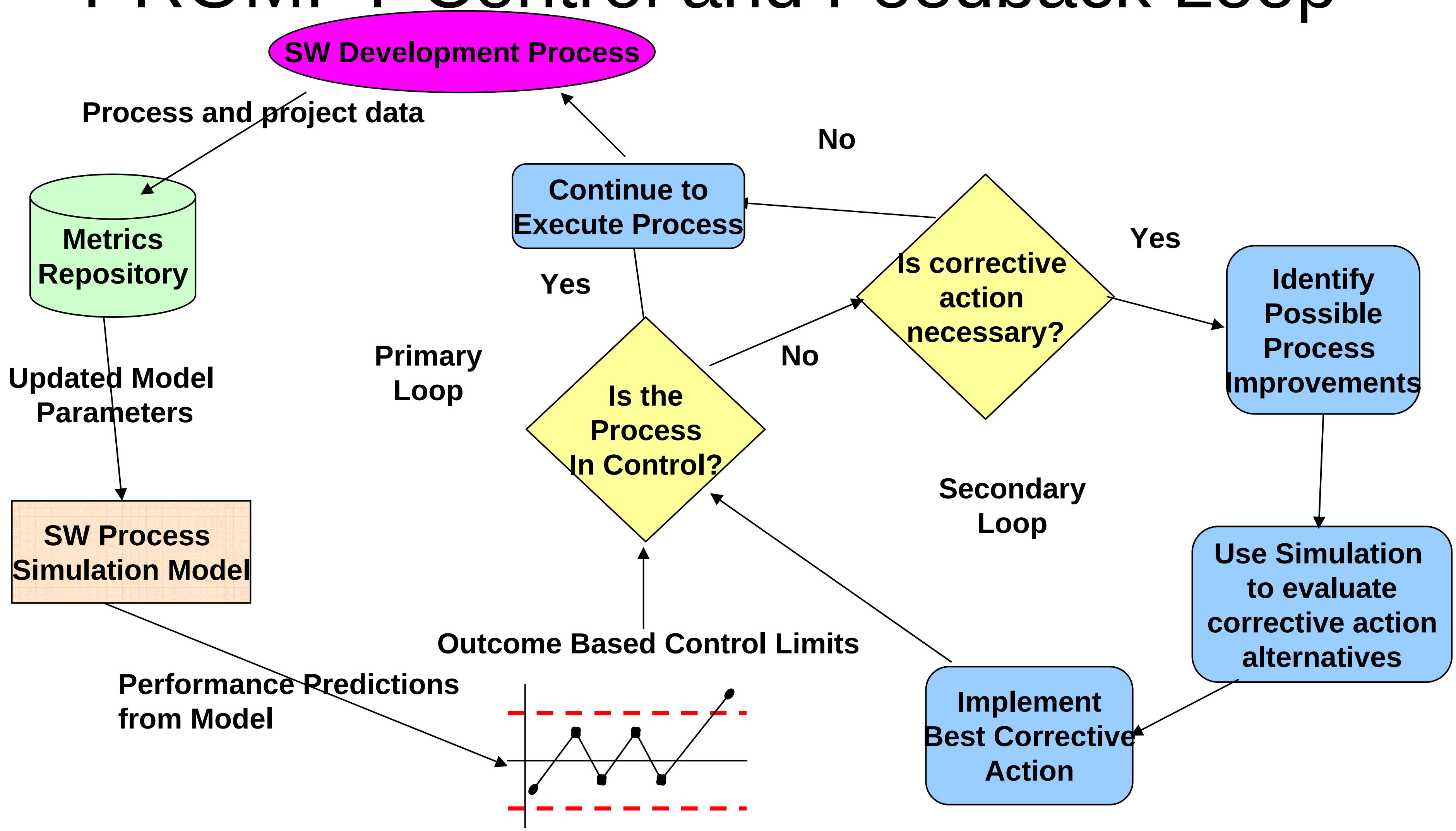
PROMPT: Quantitative Project Management Framework



PROMPT Control and Feedback Loop



Applying Process Simulation = High Value Add

- Evaluate Strategic Issues
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  - Globally Distributed Software Development
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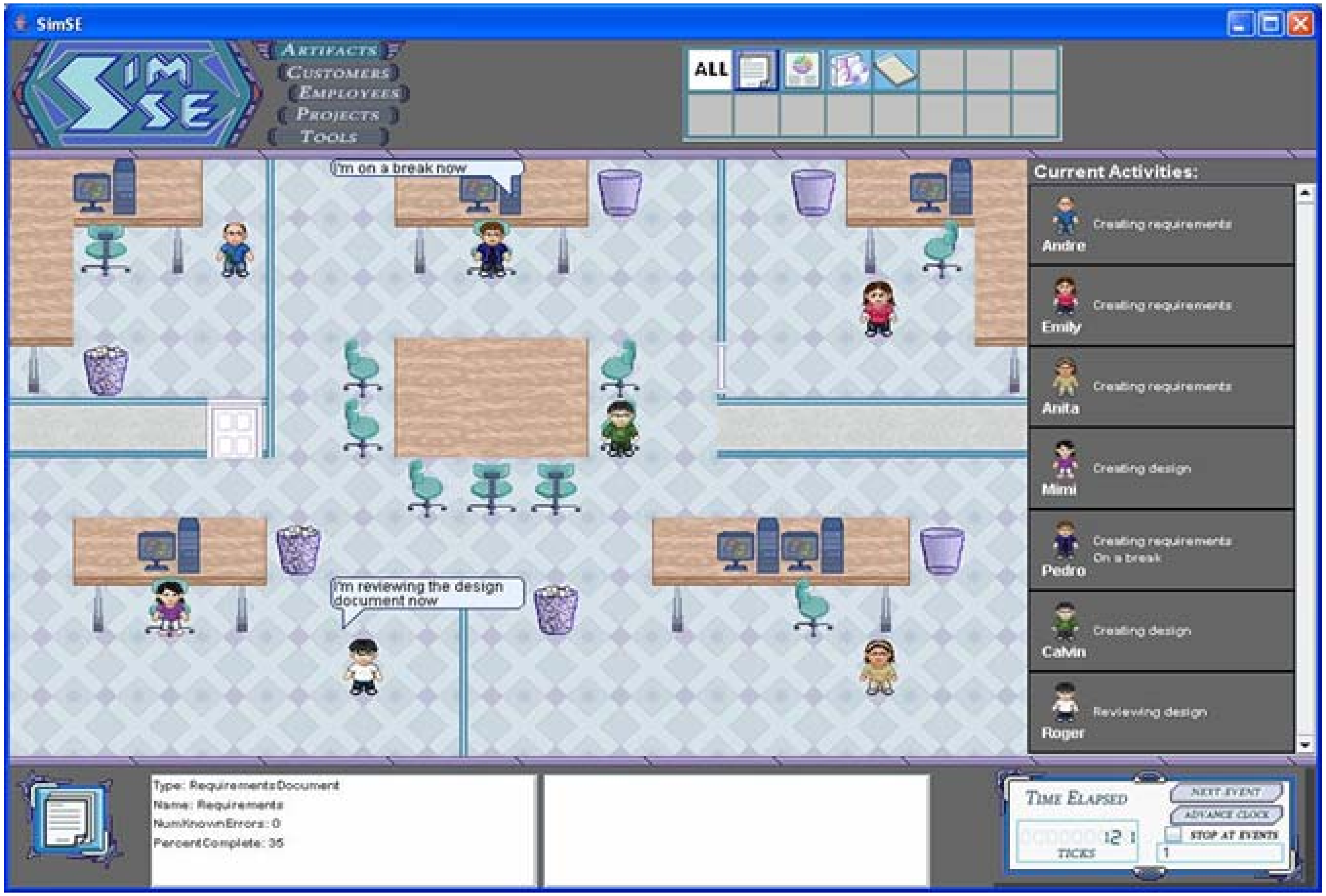
- Plan Processes and Make Better Tradeoff Decisions
- Evaluate Process Improvement Opportunities
- Architect, Design, and Documenting Processes
- Estimate Project Costs from the Bottom-Up
- Manage Processes Quantitatively
- ***Train Project Managers***

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

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Applying Process Simulation to Achieve High-Value Benefits

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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

	STRAT	PLAN	MGMT	IMPR	UNDR	TRAIN
KBS					X	X
Agent Based					X	X
State-Based		X		X	X	X
Discrete Event	**X**	**X**	**X**	**X**	**X**	**X**
System Dynamic	X	x		x	X	X
Hybrid	X	X	X	X	X	X

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Development Projects

Better Process Decisions

Project and Process Data

CSCI Data (Follows)

No. of CSCIs		8								
CSCI names:	C&DH	Guidance & N	EPS	Ground	DIVINER	LAMP	LOLA	LROC		
	Estimated SLOC									
C&DH										
CSCname	Reuse	Re-eng	New	Lang	Totals		Ptotals	IVVTotals	EP	CP
C&DH	25000		75000		100000		120000	150000		
Total	25000	0	75000		100000		120000	150000	3	1
Guidance & Nav										
CSCname										
Guidance & Nav	25000		12000		37000		37000	39000		
Total	25000	0	12000		37000		37000	39000	2	3

Financial Benefits NPV, ROI

- Organizational
- Site and Project
- Industry Standard

PATT Project Database

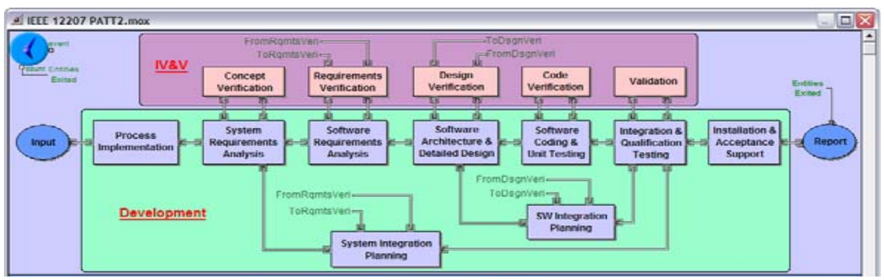
Project Performance

Development Project Statistics

Project Id: 1

RunSet	Size Mean / Std Dev	Effort Mean / Std Dev	Rework Effort Mean / Std Dev	Duration Mean / Std Dev	Avg. Duration Mean / Std Dev	Corrected Defects Mean / Std Dev	Latent Defects Mean / Std Dev
1	58.00	54,321.35	10,568.58	3,572.02	2,381.00	2,756.13	143.66
	1.63	1,484.76	217.46	63.39	55.76	77.96	3.72
2	58.00	53,666.85	9,573.17	3,457.40	2,266.06	2,759.38	140.40
	1.63	1,511.91	298.02	63.54	66.44	76.79	4.82
3	58.00	54,321.35	10,568.58	3,572.02	2,381.00	2,756.13	143.66
	1.63	1,484.76	217.46	63.39	55.76	77.96	3.72
4	58.00	53,920.94	9,943.53	3,502.52	2,310.60	2,758.30	141.49
	1.63	1,445.09	202.73	52.74	53.75	77.41	4.30

SW Process Simulation Model



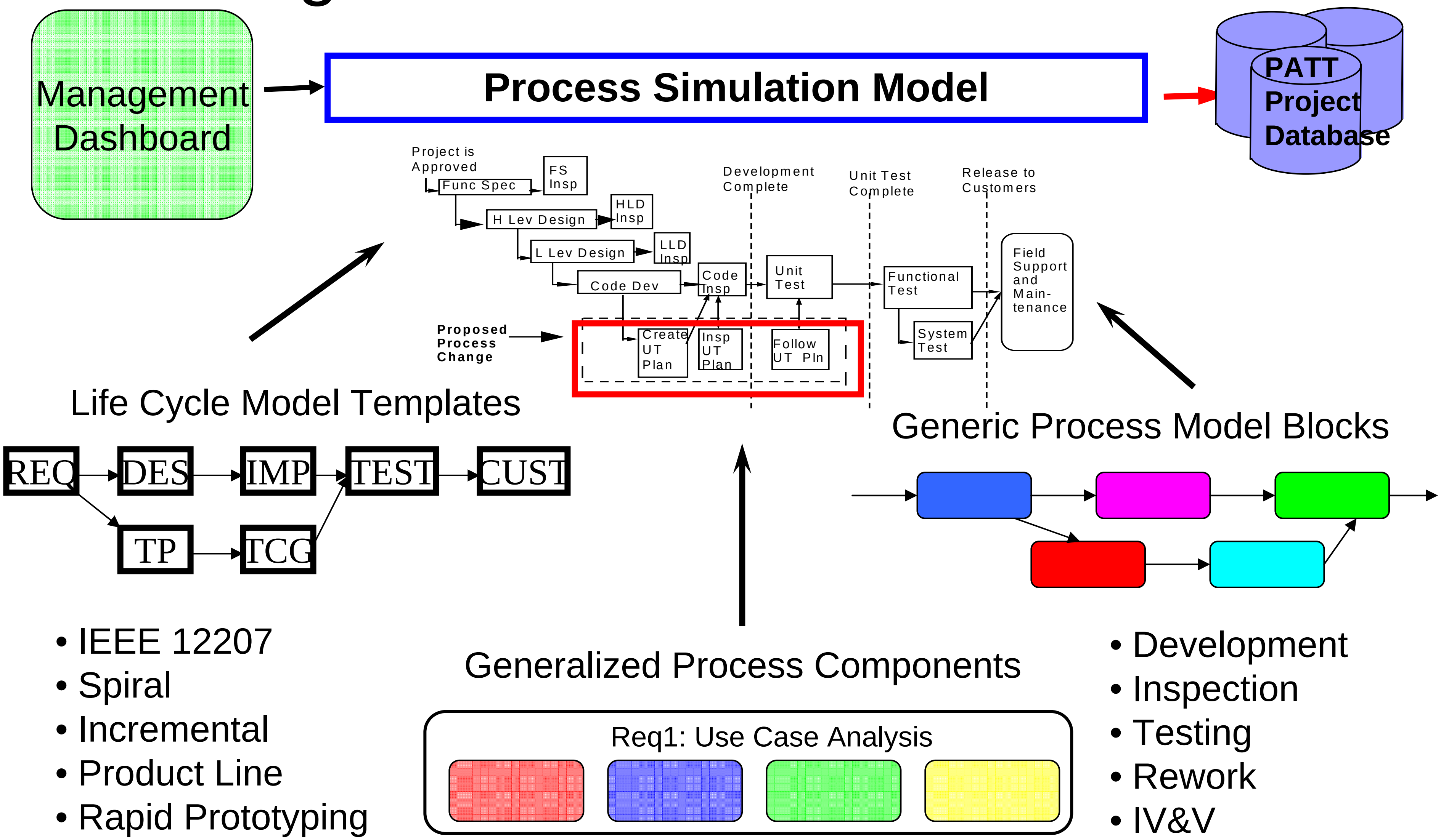
Where does the data come from? (1 of 2)

- 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



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

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

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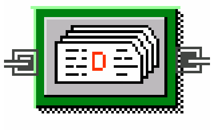
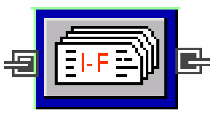
Customizing PATT

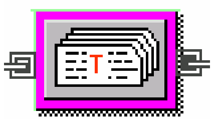
Multiple block types implement SW development techniques



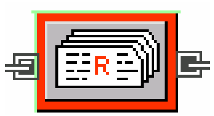
- Development blocks develop product and inject defects



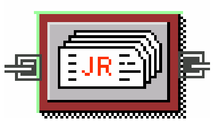
- Inspection blocks detect defects



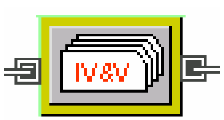
- Testing blocks detect defects



- Rework blocks correct and inject defects



- Joint Review blocks detect and correct defects.



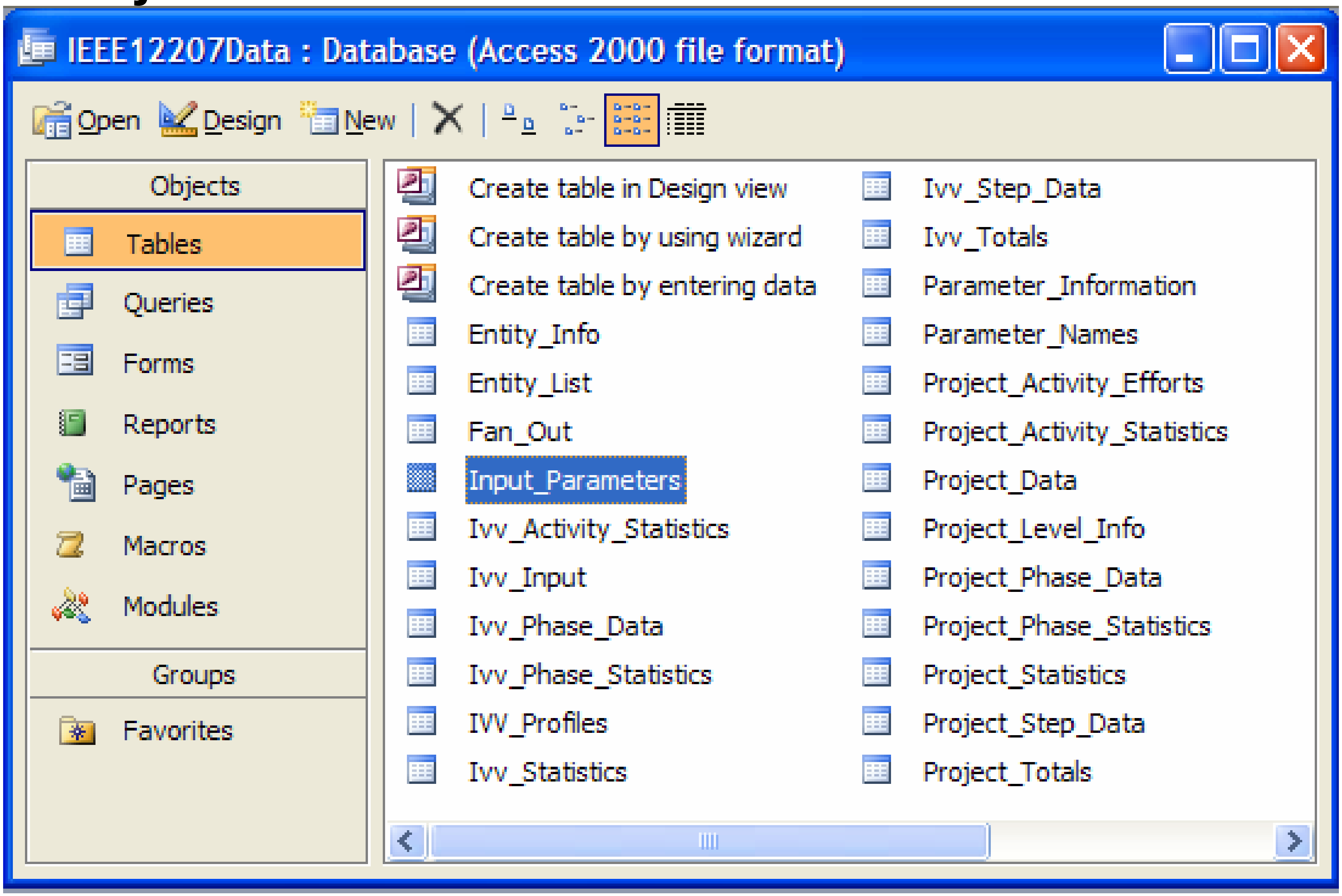
- IV&V blocks detect defects.

Project Data Base

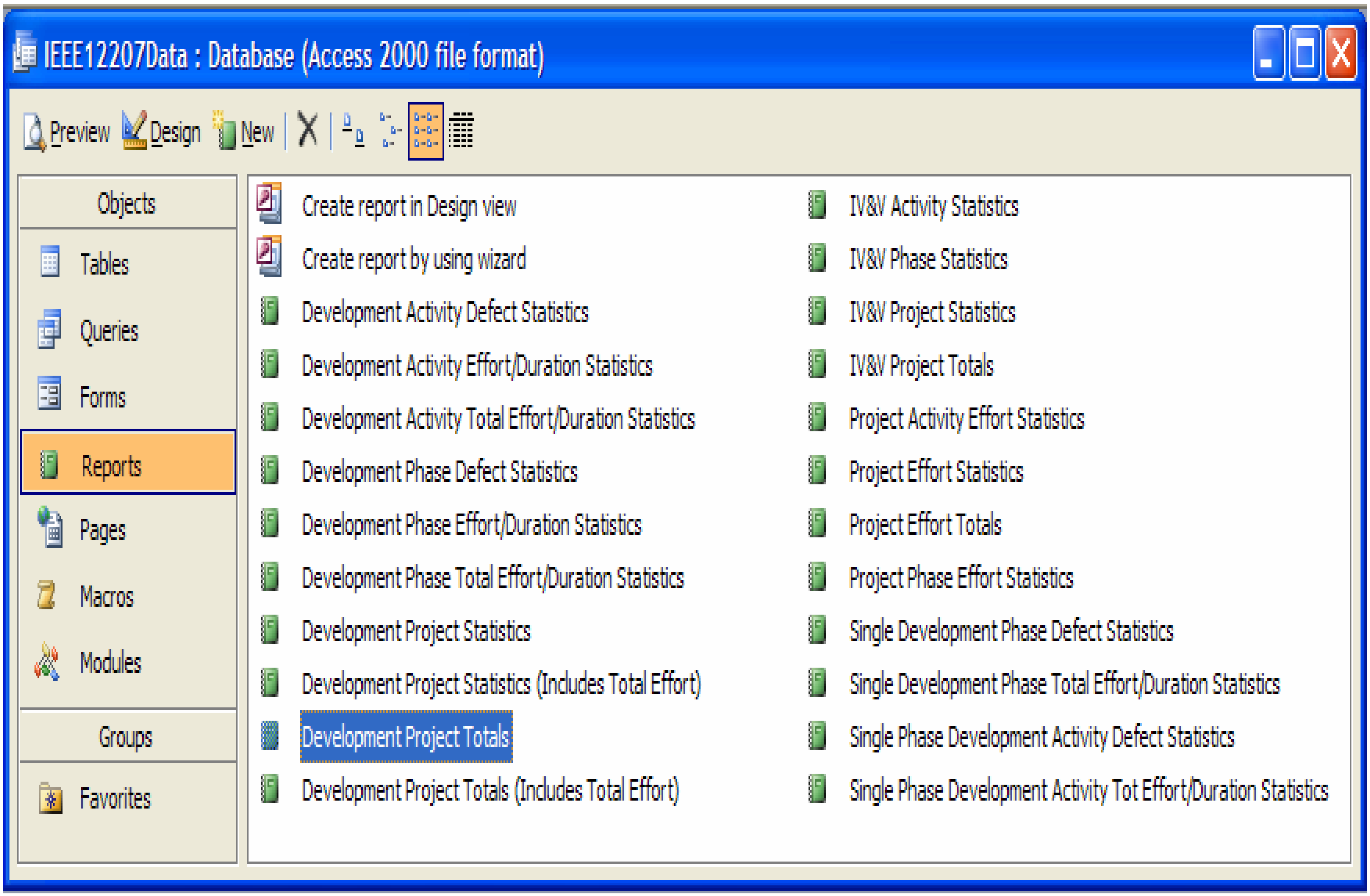
- Inputs
  - Size, productivity, error potential, consequence, defect injection, detection, and correction rates, cost, duration, etc.
- Outputs
  - Customizable reporting
  - All levels - Project, phase, activity levels
  - Costs reported using COQ format
  - Defect containment statistics
  - Special reports for IV&V

Quantel
Quantitative Intelligence

Project Database



Quantel
Quantitative Intelligence



Development Project Total Effort/Duration Statistics

Project Name: IEEE12207 SW Development Process Model

Run Set	Size	Total Effort	Rework Effort	Duration	Avg. Duration	Corrected Defects	Latent Defects
	Mean	Mean	Mean	Mean	Mean	Mean	Mean
	Std. Dev	Std. Dev	Std. Dev	Std. Dev	Std. Dev	Std. Dev	Std. Dev
1	98.59	57,876.16	30,541.63	5,364.34	2,631.64	5,878.40	518.02
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	98.59	58,052.90	30,541.63	5,351.82	2,575.64	5,878.40	518.02
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	98.59	60,804.74	33,233.51	5,545.17	2,557.96	5,804.28	586.63
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	100.48	61,794.80	33,756.25	5,256.44	2,335.78	5,901.19	596.30
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	98.59	58,632.66	30,541.63	5,452.80	2,645.37	5,878.40	518.02
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	98.59	58,632.66	30,541.63	5,452.80	2,645.37	5,878.40	518.02
	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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

Quantel
Quantitative Intelligence

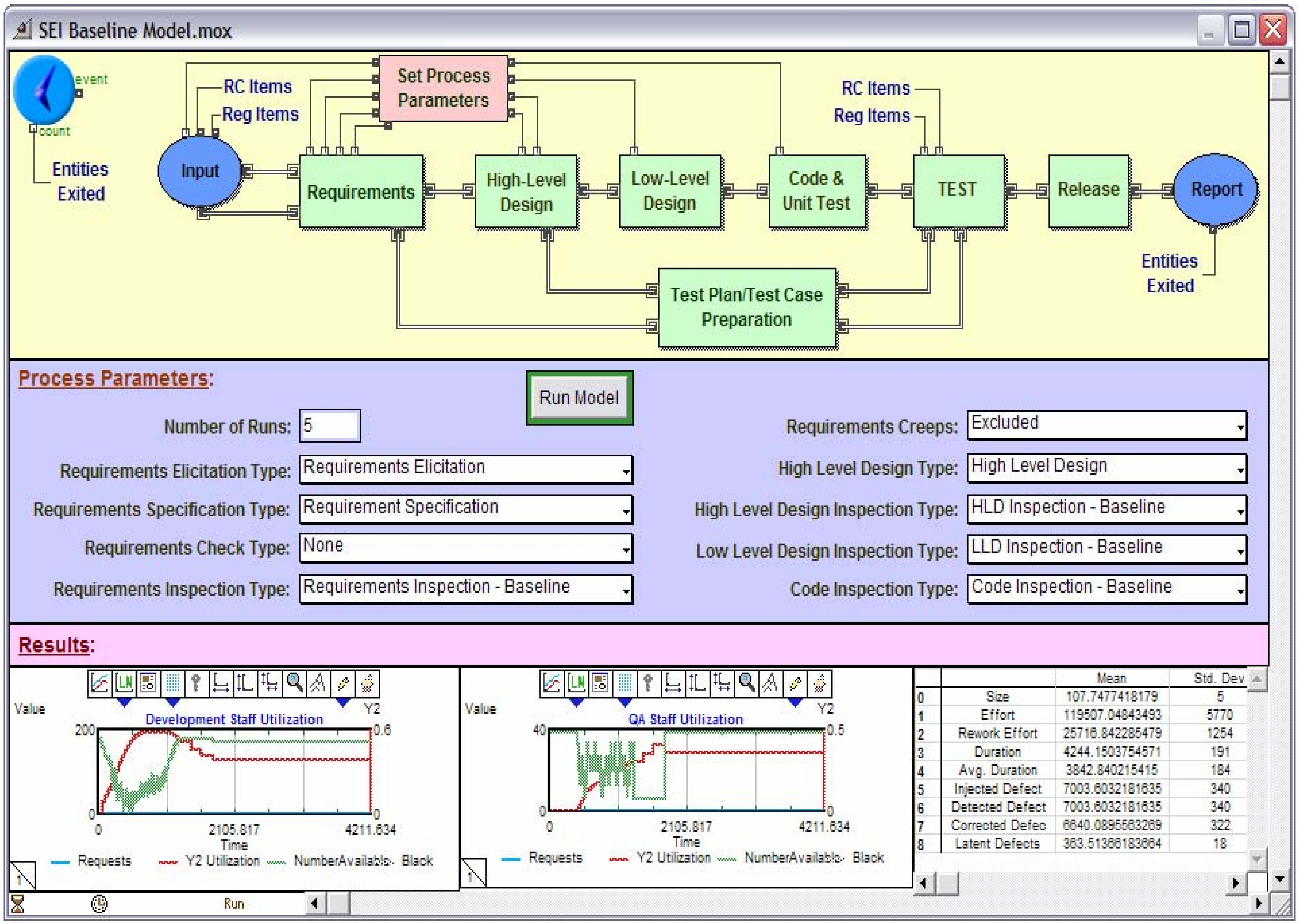
Benefits of Process Simulation

	Option	*Project* Total Effort (PM) Dev Eff + Dev Rwk	Rework Effort Devel Defects (PM)	Project Duration *(Calendar Months)*	Projected Cost or Revenue delta due to Duration Change	Total Injected Defects	Corrected Defects	Escapted Defects	Rework Effort for Field Defects *(PM)*	Impleme ntation Costs *($)*	NPV	ROI
0	Base Case	200	90	18	$0.00	1150	990	160	40	$0.00	n.a.	n.a.
1	Implement QFD	190	75	17.5	$0.00	1150	1020	130	30	$100,000	$165,145	15%
2	Implement VOC	185	75	17	$ 100,000	1150	1050	100	20	$120,000	$185,231	29%
3	Add QuARS Tool	175	65	16	$ 300,000	1150	1090	60	10	$ 80,000	$289,674	88%
4	Eliminate	230	130	22	$(400,000)	1150	900	250	80	$0.00	-$378,043	-129%
5	Additional Process											

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 allow 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
- Evaluate Process Improvement Opportunities
- 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