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# **ADVANCE:** Implementing a Defect Model for Performance Prediction

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# **Overview of "ADVANCE"**

# Stochastic model

- Includes Defect Creation, Spread, and Detection
- Includes Effects of Rework
- " Based on Historic Company Performance
- " Uses Company-specific Key Process Attributes
- " Predicts Defects (mean, ) per phase & total



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# Outline

- " Basis and Previous Work
- " Implementation
- " Calibration
- Deployment
- " Conclusions and Future Work
- " References



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## Outline

# **"Basis and Previous Work**

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### Basis: Requirements

- OPP-SP 1.5 requires Process Performance Models (PPM) to estimate or predict the value of a process-performance measure from the values of other process, product, and service measurements
- *Chrissis, et.al., list four uses of PPMs:* 
  - 1. The organization uses them for estimating, analyzing, and predicting the process performance associated with the processes in the organization's set of standard processes.
  - 2. The organization uses them to assess the (potential) return on investment for process improvement activities.
  - 3. Projects use them for estimating, analyzing, and predicting the process performance for their defined processes.
  - 4. Projects use them for selecting processes or subprocesses for use.



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# **Basis: Summary of Approach**

- The technical approach is based on established methodologies for reliability prediction of software defect densities:
  - . Historical data is used to produce a process performance baseline
  - . The process performance baseline is characterized by key process attributes
    - <sup>"</sup> Specific attributes are defined for each lifecycle stage
  - . At the beginning of the project, the model will predict process performance based on the defined attribute values
  - . At the end of each lifecycle phase, predicted phase attributes are replaced by actual phase attributes, actual phase results are entered, and the remaining lifecycle performance is updated



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### **Basis: Previous Work**

- "Rout and Abel 1993 % Model for Defect Insertion and Detection in Software Development+
- Chulani 1999 Constructive Quality Modeling for Defect Density Prediction: COQUALMO+
- " Others (see paper or References)



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# Basis: Rout & Abel Framework

- 1. % Firrors are introduced into a software component at each stage of development, the rate of insertion being dependent on a number of factors+
- 2. % Firrors are detected and removed during all stages of development, at a rate which is primarily dependent on the detection technique employed+
- % Frors that are not detected during one stage of development may result in multiple errors in succeeding stages+



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# Basis: Rout & Abel Framework

- When an error which results from an error in a preceding stage is detected, all related errors are not necessarily detected+
- 5. %When an error is corrected, there is a non-zero probability that new errors will be introduced+



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# **Basis: Rout & Abel Framework**

Difficulty: Rout and Abel were unable to represent framework points 4 and 5 in an analytic equation.

Solution: use a discrete-event model to represent processes without an analytic equation

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# Basis: Chulani COQUALMO

Chulani utilized the COCOMO production function:

# $E = a(S)^{b}$

#### where S = size (SLOC), a and b are empirically derived, a is a product of Quality Adjustment Factors+



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# Basis: Defect Model (Per Phase)

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#### **Basis: Three Factors per Phase**

- Defect Creation:
   Dc = Fc\*f(P)
- <sup>"</sup> Defect Inheritance:  $Di_{adi} = Di^*Fs$
- " Defect Detection:  $Dd = Fd^{*}(Dc + Di^{*}Fs)$
- " 3 Factors x 5 Phases = 15 Factors



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### mplement: 3 Parts

- " Extendi Discrete-Event model
- " User Interface (Microsoft Excel)
- " Calibration Grid (Microsoft Excel)



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#### Implement: Drive Factors

$$F_{n}[i] = F_{nom}[i] \prod_{j=0}^{k} M_{jn}[i] \qquad n = \{C, I, D\}$$

#### Where:

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- M<sub>jn</sub>[i] is the Model Drive Factor for attribute j as applied to factor n for phase i.
- "  $F_{nom}[i]$  is a nominal value for  $F_n[i]$
- " Similar to use by Chulani in COQUALMO



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## mplement: Extend Model

- Commercial processmodelingtool
- " Graphical, Hierarchical
- DiscreteEvent





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### mplement: e.g. Defect Creation

- *i* Items flow through process network
- " Queuing, time delay, decisions
- "Numeric calculations, statistical distributions





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### mplement: User Interface

VBA controls for user inputs

ReceivesExtendmodeloutputs

	A	В	С	D	E	F	G	Н	1	J	К	L	MN	1 0	P	Q	R	S	T	U	V	W	X
1			_			DEVELOPMENT TOOLS				DEVELOPMENT TOOLS				TAILORING MATRIX			Defect Actuals		3				
2	Proj:	200406					Design Tool?	Г		iireme its	Requirements Management Tool?	Г		Participated in a peer review of the SRS	1		Phase	In- Phase	P-1	P-2	P-3	P-4	
3						Tool	Integrated with Editor?	Г		Requ	Hequirements Traceability Tool?	Γ		the SDD and	Informal 💌		Req 🗵	33		-			
4		CPLX1	0.7			Design	Code Generation?	Г		il User ace	GUI Interface?	V		Participated in a Preliminary Design Review			Des 🗵	21	11		_		
5		CPLX2	1.0				Automated Document Generation?	<b>v</b>		Graphica Interfi	Integrated with Editor?	Π		Peer reviewed the SDD and SDTM for most detailed designs	Informal 💌		Code ┌─ &UT						
6	•	Product Expert	25%				GUI interface?	•		uare ding	Software Build tool?	M		Participated in a Critical Design Review	N		S¥ Int FT¥						
7	VTIARI.	Product Experienced	25%	Total		t Tools	Integrated with Editor?	Г		Softy Built	GUI interface for tool?	Г		Conducted Formal Code Inspection	none (0%) 💌		Sys 🗖 Int						
8	CT FAMII ngineers)	Product Normal	0%	100%		tion Mgm	Module ¥ersion Merge Capability?	ম		vare ion (on jet)	Software Installation tool (i.e., Install Shield)	R		Informal Unit Tests	ঘ								
9	M PRODU	Product Intermediate	50%			Configura	Multi-Level User Access Capability?	ম		Softv Installat Targ	GUI interface for tool?	Г		Formal Unit Tests	Г								
10	TEA	Product Novice	0%				¥ersioning Capability?	<b>v</b>			Automated Unit Test tool?	Г		FTV	ব								
11	5	Technical Expert	25%			10	Language Syntax Highlighting?	ঘ			Automated GUI Test tool?												
12	DPMEN	Technical E <b>z</b> perienced	25%	Total		Editors	Intelli-Sense?	Π			Automated Regression Test Tool?	Γ			Product Size	6							
13	DEVEL	Technical Normal	0%	100%			Any wizards?	Γ		ĝ	Memory Leak Detection Tool?	4		Phase	# of products	Start	End						
14	TEAM	Technical Intermediate	50%			Com piler	Integrated with Editor?	Π		Tes	Timing Profile Tool?	Г		Requirements	383	C	20						
15		Technical Novice	0%			ugger	Debugger?	9			Coverage Tool?			Design	766	20	40						
16						Deb	Integrated with Editor?				Path Coverage Tool?	Г		Code & Unit Test	54737	40	60						
17					1.12					Code Analyze Tool?	Code Analyzer Tool?	Г		S¥ Int & FT¥	54737	60	80						
18 19		version S₩_1_0 8/16/2007									Specialized test tool/simulator	П		System Integration	54737	80	95						
20																							
-94 14 - 4	+ +	UserInterfa	ce / Re:	sults /	Mul	tirunStatis	itics /							[+]									•



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# mplement: Calibration Grid

- Converts UI settings to Model Drive Factors
- Isolates Extend model from calibration
- Does not contain actual historical data





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## mplement: Results (per-run)

- " In-Phase Defects
- " Out-of-Phase Defects
- " Cumulative per Phase
- " Estimated Remaining

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		Model	Results	]				
		Result	s This I	Run				
Total Phase Det	fects Found		Bre	akdowr	n By Pł	nase		
			р р.	-1 P-2	Р-3	P-4	Actuals?	Created
Requirements	2		2				0	6
Design	7		4 3				0	6
Code & Unit Test	17		17 0	0		_	0	50
SW Int & FTV	45		26 1	7 1	1		0	45
System Int	59		25 1	7 16	1	0	0	25
	Cı	ımulati	ve D	efect	s Fo	und		
120 -								
100 -				+				
80-				_				
60 -				-		_		
40-								
20 -								



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# mplement: Results (statistical)

- Mean, Variance,Std. Deviation
  - . Per phase
  - . Total
- Lower & UpperConfidence limits
  - . Per phase
  - . Total





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$$F_{n}[i] = F_{nom}[i] \prod_{j=0}^{k} M_{jn}[i] \qquad n = \{C, I, D\}$$

- <sup>"</sup> Determine the values of M<sub>jn</sub>[i], F<sub>nom</sub>[i]
- "From 53 User Interface inputs, 10 best were selected for initial calibration
- " 10 inputs mapped into 21 drive factors
- Multiple settings per input factored into 55 values requiring calibration



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# Cal: Fitting the Curve

- Curve fitting was used to determine the f(P) (F<sub>nom</sub>[i]) for the Defect Creation function
- Several different curve functions were evaluated



#### COCOMO-type power equation was the best fit $E = a(S)^{b}$



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# Cal: Running the Calibration

- Linear regression and iteration were used to optimize M<sub>jn</sub>[i]
- 55 values calibrated to 72 (later, 66) historical datasets
- Approximately 500,000 model runs required
- Final correlation 0.984, improvement of .109





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# Deployment: Pilot

- "Pilot deployment to SW Engineering Organization
- " Feedback positive
  - . minor changes to UI
  - . Identified and removed 11 ‰utliers+and recalibrated



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# Deployment: Application

- SW Engineering runs model
- Initial recalibration each year with new data
- " Organization use:
  - . Evaluate organization process performance
  - . Assess quantitative return-on-investment for potential process improvement impact
  - . Establish organizational objectives



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# Deployment: Application

#### Project use:

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- Run to establish realistic and achievable project objectives
  - Establishes quantitative basis for negotiations
- . Run to estimate or predict the projector performance of selected subprocesses
  - Ensure projector success by predicting future outcomes based on current performance
  - <sup>7</sup> Establish corrective actions today to alter the future course of the project
  - <sup>7</sup> Proactive process performance risk identification
- . Run to assess progress and evaluate corrective action
- . Compare predicted vs. actual
- . Update calibration only if project rebaselines



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### Conclusions

- Significant Effort to Develop
  - But, completely fitted to our process
- Development Effort helped refine metric collection
- " Development helped organizational buy-in



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#### Future Work

- " SW Model:
  - . Calibrate additional UI attributes
  - . Calibrate internal distribution spreads
  - . Add defect type categories
- " Others:
  - . Family of models to include other Engineering disciplines: Aero, Systems, HW
- " Integrated Product Model

Technique is adaptable to all disciplines



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