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# COCOTS Status

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**14th International COCOMO Forum**
**Los Angeles, CA**
**October 27, 1999**



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***USC Center for Software Engineering***

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**Presentation Outline**

- Model Overview
- Data Collection & Results: where we were last year
- Data Collection: where we are now
- Database Characteristics: selected summary facts
- Current Predictive Results
- Available Tool
- Issues That Need a Harder Look
- Next Steps



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# Model Overview

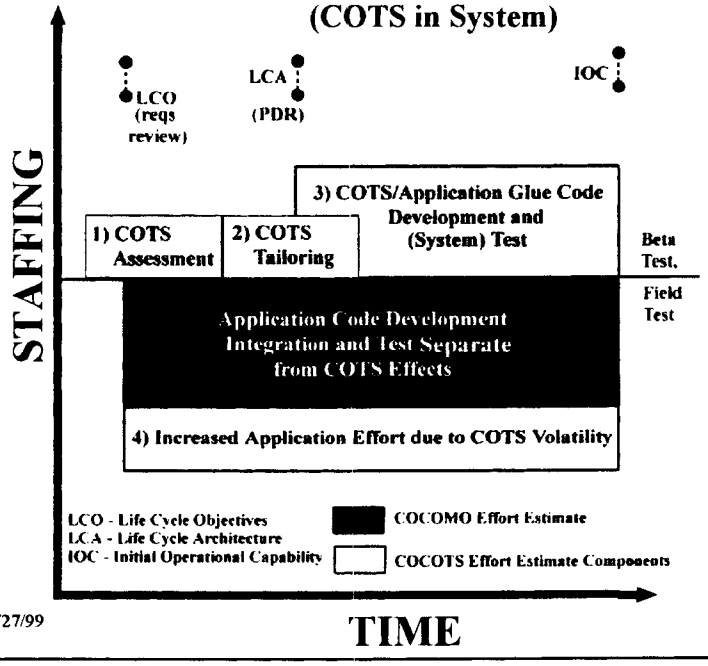
## COTS Definition

- "Commercial Off the Shelf" Software
- Commercial Software Products
  - sold, leased, licensed at advertised prices
- Source Code Unavailable
  - generally an application program interface (API)
  - frequently tailoring options
- Usually periodic releases with feature growth, obsolescence



## COCOMO vs. COCOTS Cost Sources

### (COTS in System)



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# *COTS Integration Cost Sources:*
# *1) Assessment*

## Initial Filtering Effort

$$\text{Total Effort} = \left(\#\ \text{COTS Candidates}\right)\left(\frac{\text{Average Filtering Effort}}{\text{Candidate}}\right)$$

## Final Selection Effort

$$\text{Total Effort} = \sum_{\substack{\text{Assessment}\\ \text{Attributes}}} \left(\#\ \text{COTS Candidates}\right)\left(\frac{\text{Average Assessment Effort for Attribute in Given Domain}}{\text{Candidate}}\right)_i$$

- *List of attributes refined in collaboration with Dr. Elizabeth Bailey*
- *Effort/candidate is project-dependent, within domain guidelines*



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# *COTS Integration Cost Sources:*
# *1) Assessment - Assessment Attributes*

**Correctness**
- Accuracy
- Correctness

**Availability/Robustness**
- Availability
- Fail safe
- Fail soft
- Fault tolerance
- Input error tolerance
- Redundancy
- Reliability
- Robustness
- Safety

**Security**
- Security (Access related)
- Security (sabotage related)

**Product Performance**
- Execution performance
- Information/data capacity
- Precision
- Memory performance
- Response time
- Throughput

**Understandability**
- Documentation quality
- Simplicity
- Testability

**Ease of use**
- Usability/Human Factors

**Version Compatibility**
- Downward compatibility
- Upward compatibility

**Inter-component Compatibility**
- Compatibility with other components
- Interoperability

**Flexibility**
- Extendability
- Flexibility

**Installation/Upgrade Ease**
- Installation Ease
- Upgrade/Refresh ease

**Portability**
- Portability

**Functionality**
- Functionality

**Price**
- Initial purchase/lease
- Recurring costs

**Maturity**
- Product Maturity
- Vendor Maturity

**Vendor Support**
- Response time for critical problems
- Support
- Warranty

**User Training**
- User training

**Vendor Concessions**
- Willingness to escrow source code
- Willingness to make modifications

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## *COTS Integration Cost Sources: 2) Tailoring*

$$\text{Total Effort} = \sum_{\substack{\text{Tailoring} \\ \text{Complexity} \\ \text{Levels}}} \left(\begin{matrix}\#\text{ COTS Candidates} \\ \text{Tailored at} \\ \text{Complexity Level}\end{matrix}\right)_i \left(\begin{matrix}\text{Average Effort at Tailoring} \\ \text{Complexity Level in Domain}\end{matrix}\right)_i$$

*–Five tailoring effort complexity levels:*

*Very Low, Low, Nominal, High, Very High*

*– Differentiated based on number tailored parameters, difficulty of needed scripts, API iterations, etc.*



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## *COTS Integration Cost Sources: 2) Tailoring - Dimensions of Tailoring Difficulty*

| | Individual Activity & Aid Complexity Ratings | | | | | |
|---|---|---|---|---|---|---|
| Tailoring Activities & Aids | Very Low (point value = 1) | Low (point value = 2) | Nominal (point value = 3) | High (point value = 4) | Very High (point value = 5) | Corresponding Points |
| Parameter Specification | Zero to 50 parms to be initialized | 51 to 100 parms to be initialized | 101 to 500 parms to be initialized | 501 to 1000 parms to be initialized | 1001 or more parms to be initialized | ____ |
| Script Writing | Menu driven, 1 to 5 line script, 1 to 5 scripts needed | Menu driven, 6 to 10 line scripts, 5 to 15 scripts needed | Hand written, 11 to 25 line scripts, 16 to 30 scripts needed | Hand written, 26 to 50 line scripts, 31 to 50 scripts needed | Hand written, 51 or more line scripts, 51 or more scripts needed | ____ |
| I/O Report & GUI Screen Specification & Layout | Automated or standard templates used, 1 to 5 reports/screens needed | Automated or standard templates used, 6 to 15 reports/screens needed | Automated or standard templates used, 16 to 25 reports/screens needed | Hand written or custom designed, 26 to 50 reports/screens needed | Hand written or custom designed, 51 or more reports/screens needed | ____ |
| Security/Access Protocol Initialization & Set-up | 1 security level, 1 to 20 user profiles, 1 input screen/user | 2 security levels 21 to 50 user profiles, 2 input screens/user | 3 security levels 51 to 75 user profiles, 3 input screens/user | 4 security levels 76 to 100 user profiles, 4 input screens/user | 5 or more security levels 101 or more user profiles, 5 or more input screens/user | ____ |
| Availability of COTS Tailoring Tools | No tools available | N/A | N/A | N/A | Tools are available | ____ |

Total Point Score = _____

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## *COTS Integration Cost Sources: 3) Glue Code Development and Test*

$$\text{Total Effort} = A \cdot [(\text{size})(1+\text{breakage})]^{B} \cdot \prod (\text{effort multipliers})$$

- **A - a linear scaling constant**
- **Size - of the glue code in SLOC or FP**
- **Breakage - of the glue code due to change in requirements and/or COTS volatility**
- **Effort Multipliers - 13 parameters, each with settings ranging VL to VH**
- **B - an architectural scale factor with settings VL to VH**



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## *COTS Integration Cost Sources: 3) Glue Code Development and Test - Glue Code Cost Drivers*

**Personnel Drivers**

1) ACIEP - COTS Integrator Experience with Product
2) ACIPC - COTS Integrator Personnel Capability
3) AXCIP - Integrator Experience with COTS Integration Processes
4) APCON - Integrator Personnel Continuity

**COTS Component Drivers**

5) ACPMT - COTS Product Maturity
6) ACSEW - COTS Supplier Product Extension Willingness
7) APCPX - COTS Product Interface Complexity
8) ACPPS - COTS Supplier Product Support
9) ACPTD - COTS Supplier Provided Training and Documentation

**Application/System Drivers**

10) ACREL - Constraints on Application System/Subsystem Reliability
11) AACPX - Application Interface Complexity
12) ACPER - Constraints on COTS Technical Performance
13) ASPRT - Application System Portability

**Nonlinear Scale Factor**

1) AAREN - Application Architectural Engineering

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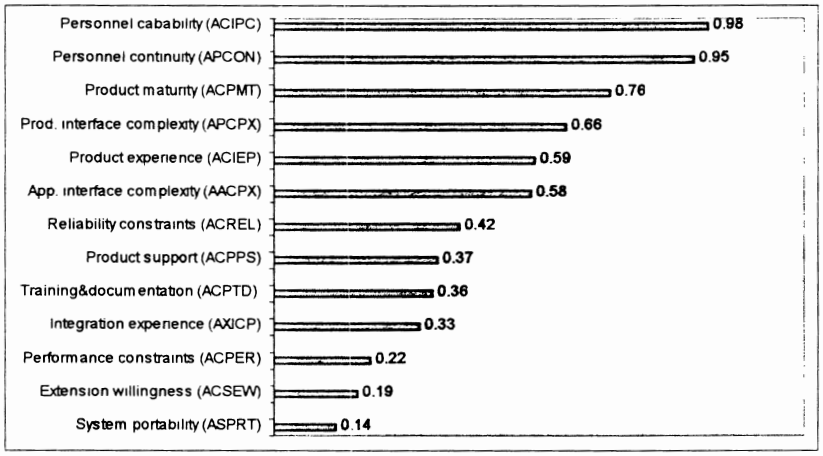
## *Glue Code Cost Drivers Productivity Ranges*



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## *COTS Integration Cost Sources:*
## *4) Increased Application Effort Due to COTS Volatility*

**Approximate Model:**

$$\text{Total Effort} = (\text{Application Effort}) \cdot \left[\frac{\text{BRAK COTS}}{100}\right] \cdot (\text{EAF})_{\text{COTS}}$$

**Detailed Model with COCOMO II Parameters:**

$$\text{Total Effort} = (\text{Application Effort}) \cdot \left[\left(1+\frac{\text{BRAK COTS}}{1+\text{BRAK}}\right)^{1.01+\Sigma} - 1\right] \cdot (\text{EAF})_{\text{COTS}}$$

**BRAK COTS:** % application code breakage due to COTS volatility
**BRAK** : % application code breakage otherwise
$\Sigma$ : COCOMO II scale factor
**EAF** : Effort Adjustment Factor (product of effort multipliers)

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## *Total COTS Integration Cost Estimate*

**Total Integration Effort (in Person-Months) =**

**Assessment Effort + Tailoring Effort + Glue Code Effort + Volatility Effort**

***where***

**Assessment Effort = Filtering Effort + Final Selection Effort**

**Total integration Cost =**

**(Total Integration Effort) • ($$/Person-Month)**



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## Data Collection & Results: where we were a year ago

**October 1998 - Database**

- **6 Student Digital Library projects**
- **4 Industrial FAA projects**

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## October 1998 - Results

*Experiences with Library Project Data*

*Initial Model*

| Project | A | Size (UFP) | B | xEAFs | Estimate (P-hr) | Actual (P-hr) | Relative Error |
|---|---|---|---|---|---|---|---|
| 3 | 1.00 | 12 | 1.00 | 0.68 | 8.16 | 61.36 | -87% |
| 5 | 1.00 | 10 | 1.00 | 2.39 | 23.90 | 79.60 | -70% |
| 6 | 1.00 | 3 | 1.00 | 4.35 | 13.05 | 14.54 | 10% |

A = 1.00 => one UFP/P-hr



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## February 1999 - Results

*Experiences with Library Project Data*

*Revised Glue Code Submodel*

| Project | A | Size (SLOC) | B | xEAFs | Estimate (P-hr) | Actual (P-hr) | Relative Error | Original Error |
|---|---|---|---|---|---|---|---|---|
| 3 | 0.009 | 500 | 1.04 | 1.82 | 10.50 | 11.50 | -9% | -87% |
| 5 | 0.009 | 400 | 1.12 | 2.25 | 16.62 | 17.10 | -3% | -70% |
| 6 | 0.009 | 218 | 1.16 | 10.42 | 48.38 | 39.50 | 22% | 10% |

A = .009 => 111 SLOC/P-hr

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# Data Collection: where we are now

**October 1999 - Database**

- **20 Industrial projects collected to date**
  - **data entry continuing (13+ points or ~65% already entered)**
- **Data collection continuing**
  - **(COCOMO 81 debuted with 63 calibration data points)**
- **Following summaries based on the interim database**
  - ***they show enough of the picture to characterize the gross nature of the projects we are collecting***



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# Database Characteristics: selected summary facts

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## Project Domains

*(project sources: Army, Navy, FAA)*

- Air Traffic Management 6+
- Business (including databases) 3+
- Communication, Navigation, & Surveillance 3+
- Mission Planning 2
- Logistics 1



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## Classes of COTS Products Used

- databases
- data conversion packages
- GUIs
- operating systems
- network managers
- device drivers
- report generators
- back office retail

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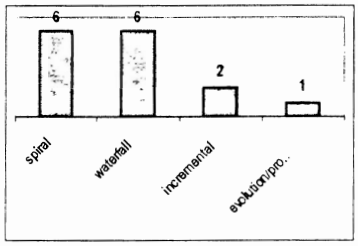
## Development Processes

- **Spiral 6+**
- **Waterfall 6+**
- **Incremental 2+**
- **Evolution/Prototype 1+**




***(most projects currently in maintenance)***



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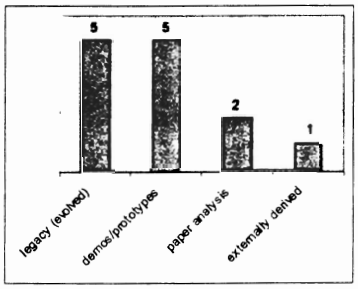
## Architectures & Architecting Processes

- Architectures
  - *all over the map but with one common element: "distributed"*
- Process
  - 1- (evolved) legacy 5+
  - 2- demos/prototypes 5+
  - 3- paper analysis 2+
  - 4- externally developed 1



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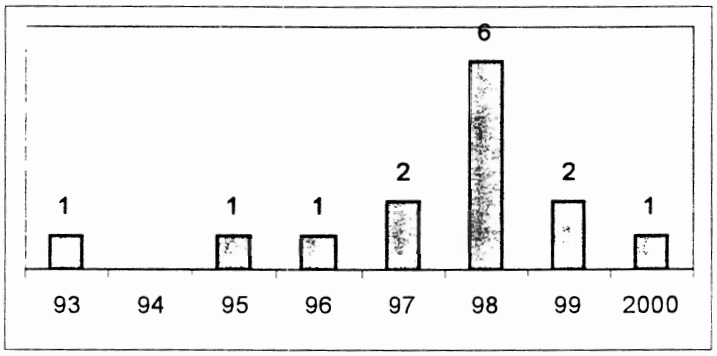
## Delivery Dates



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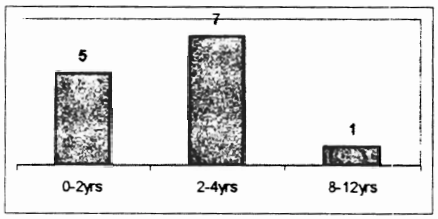
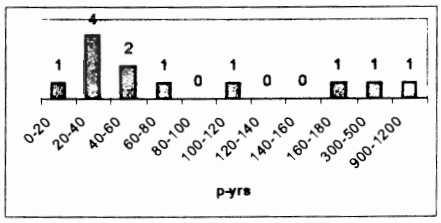
## Total Duration




## Total Effort



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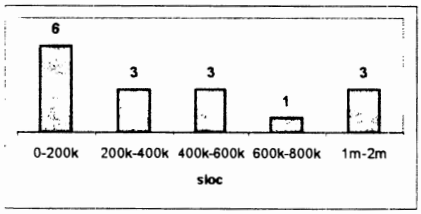
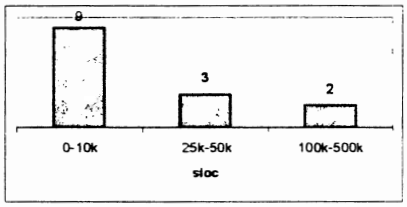
## Total SLOC




## Glue SLOC



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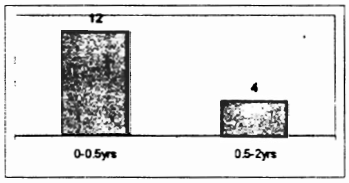
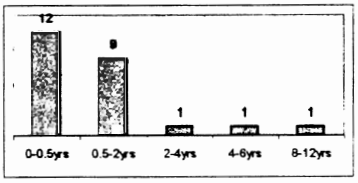
## Schedule Duration by Activity

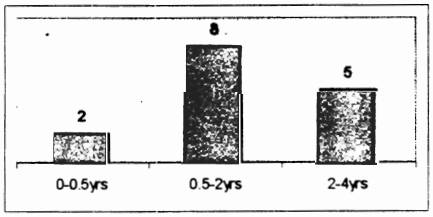
### Assessment




### Tailoring




### Glue Code



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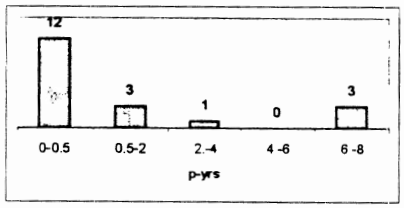
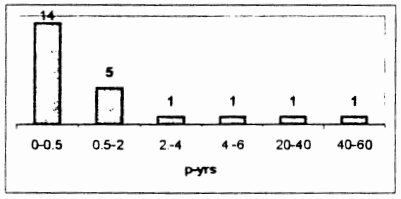
## Effort by Activity

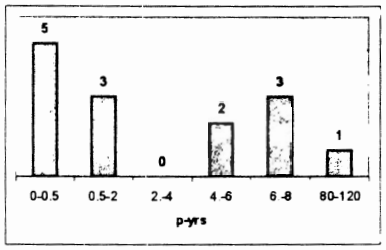
**Assessment**




**Tailoring**




**Glue Code**



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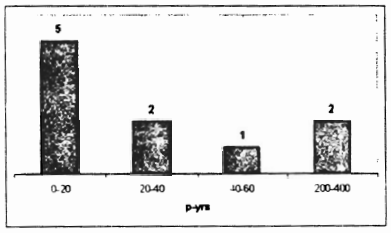
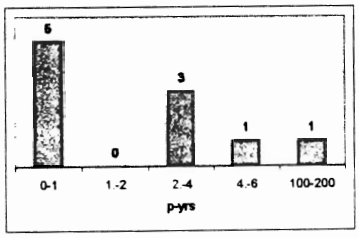
## Effort by Activity (cont'd) - *volatility*

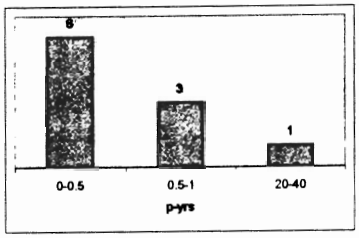
**Total System Effort excluding COTS integration**




**System Effort due to REVL**




**System Effort due to COTS volatility**



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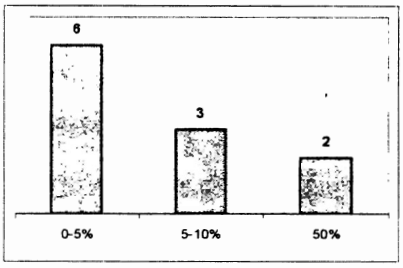
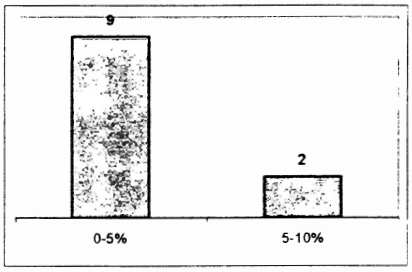
## Effort by Activity (cont'd) - *volatility*

**Percentage system rework due to REVL**




**Percentage system rework due to COTS volatility**



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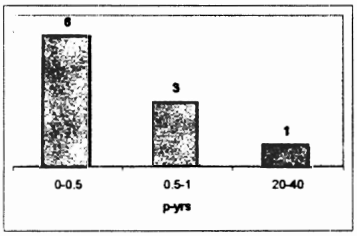
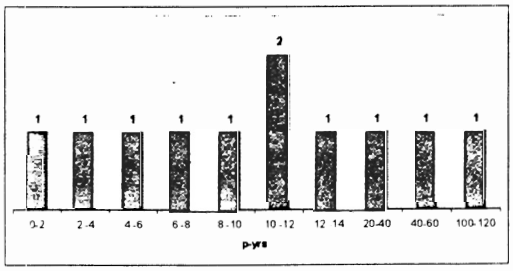
## Effort by Activity (cont'd) - *volatility*

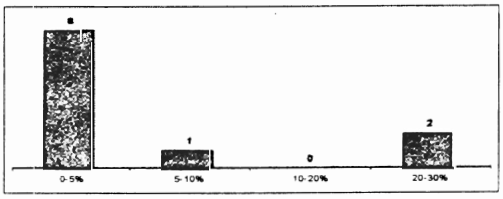
**System effort due to COTS volatility**




**COTS integration effort (assessment+tailoring+glue code)**




**Percentage (System effort due to COTS volatility)/ (COTS integration effort)**



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# Current Predictive Results:

## *Glue Code Effort*

| Proj. No. | A | size SLOC | KSLOC | %brak | effSize | ScaleParm | ScaleFactor | B | EAF | PM(est) | PM(act) | %RelError |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.8 | 100 | 0.1 | 100 | 0.2 | H | 1 | 1.04 | 0.46 | 0.2 | 6 | -96.8% |
| 2 | 2.8 | 6150 | 6.15 | 1 | 6.2115 | VH | 0 | 1 | 0.2 | 3.5 | 74 | -95.3% |
| 3 | 2.8 | 500 | 0.5 | 100 | 1 | N+0.25 | 4 | 1.16 | 0.34 | 1.0 | 6 | -84.1% |
| 4 | 2.8 | 125000 | 125 | 25 | 156.25 | VH | 0 | 1 | 1.63 | 713.1 | 1411 | -49.5% |
| 5 | 2.8 | 7000 | 7 | 15 | 8.05 | N+0.50 | 4 | 1.16 | 0.2 | 6.3 | 12 | -47.6% |
| 6 | 2.8 | 30000 | 30 | 0 | 30 | H | 1 | 1.04 | 0.42 | 40.4 | 60 | -32.6% |
| 7 | 2.8 | 10000 | 10 | 0 | 10 | H | 1 | 1.04 | 0.38 | 11.7 | 12 | -2.8% |
| 8 | 2.8 | 1200 | 1.2 | 0 | 1.2 | H | 1 | 1.04 | 0.29 | 1.0 | 1 | -1.8% |
| 9 | 2.8 | 5000 | 5 | 0 | 5 | H | 1 | 1.04 | 1.01 | 15.1 | 12 | 25.7% |
| 10 | 2.8 | 50000 | 50 | 0 | 50 | VH | 0 | 1 | 0.67 | 93.8 | 72 | 30.3% |
| 11 | 2.8 | 3000 | 3 | 0 | 3 | H | 1 | 1.04 | 0.96 | 8.4 | 6 | 40.4% |
| 12 | 2.8 | 25000 | 25 | 0 | 25 | H | 1 | 1.04 | 1.85 | 147.3 | 75 | 96.4% |
| 13 | 2.8 | 390000 | 390 | 20 | 468 | H | 1 | 1.04 | 0.11 | 184.3 | 60 | 207.2% |



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# Current Predictive Results:

## *Glue Code Effort*

**At 13 pts, COCOTS glue code model within:**
**50% of actuals 62% of the time**
**33% of actuals 38% of the time**

**At 83 pts, USC COCOMO II.1997 within:**
**30% of actuals 52% of the time**

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# Current Predictive Results:

## *Glue Code Schedule = 10*(Effort)$^{0.28+0.2*(B-1.0)}$*

| Proj. No. | B | PM(est) | *B-const* | *Bxconst* | *B+const* | *PMxconst* | TDEV(est) | TDEV(act) | %RelError |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.04 | 0.241538886 | 1 | 0.15 | 0.28 | 10 | 6.7 | 36 | -81.5% |
| 3 | 1.16 | 0.952 | 1 | 0.15 | 0.28 | 10 | 9.9 | 48 | -79.5% |
| 8 | 1.04 | 0.98153214 | 1 | 0.15 | 0.28 | 10 | 9.9 | 30 | -66.8% |
| 11 | 1.04 | 8.426269968 | 1 | 0.15 | 0.28 | 10 | 18.4 | 24 | -23.3% |
| 2 | 1 | 3.47844 | 1 | 0.15 | 0.28 | 10 | 14.2 | 18 | -21.2% |
| 7 | 1.04 | 11.66652801 | 1 | 0.15 | 0.28 | 10 | 20.2 | 24 | -15.9% |
| 9 | 1.04 | 15.08023848 | 1 | 0.15 | 0.28 | 10 | 21.7 | 24 | -9.5% |
| 12 | 1.04 | 147.2947843 | 1 | 0.15 | 0.28 | 10 | 41.7 | 42 | -0.7% |
| 6 | 1.04 | 40.42159316 | 1 | 0.15 | 0.28 | 10 | 28.8 | 24 | 20.0% |
| 4 | 1 | 713.125 | 1 | 0.15 | 0.28 | 10 | 62.9 | 48 | 31.1% |
| 10 | 1 | 93.8 | 1 | 0.15 | 0.28 | 10 | 35.7 | 24 | 48.6% |
| 13 | 1.04 | 184.334406 | 1 | 0.15 | 0.28 | 10 | 44.5 | 12 | 270.5% |
| 5 | 1.16 | 6.293775511 | 1 | 0.15 | 0.28 | 10 | 17.5 | 4 | 337.3% |



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# Current Predictive Results:

## *Glue Code Schedule*

**At 13 pts, COCOTS glue code model within:**
**31% of actuals 54% of the time**

**At 83 pts, USC COCOMO II.1997 within:**
**30% of actuals 61% of the time**

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# Available Tool

- Adaptation of existing USC COCOMO II.2000 tool
- Performed by Mr. Wook Kim under guidance of
  Prof. Ellis Horowitz
- To date implements glue code submodel only;
  other submodels to follow soon...



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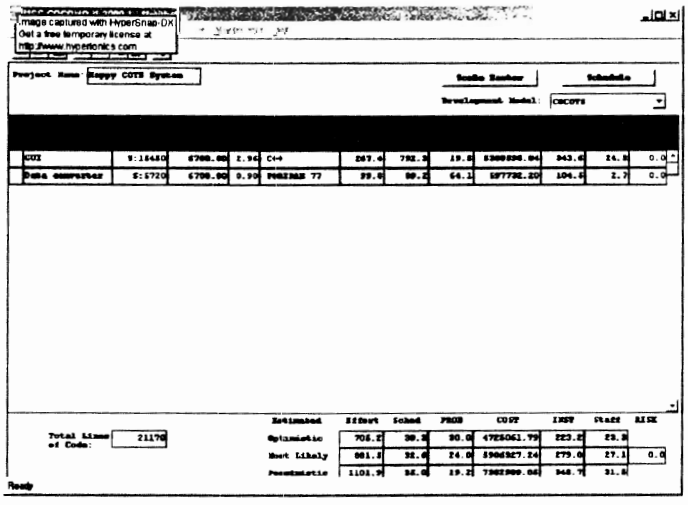

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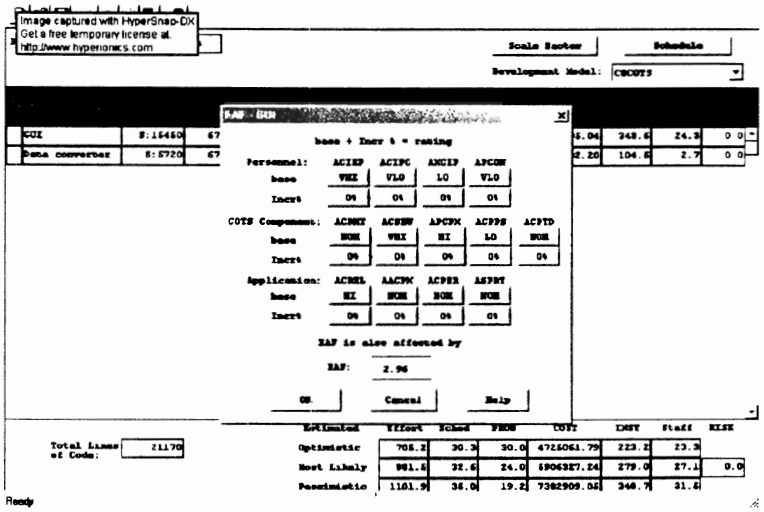




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# Issues That Need a Harder Look

- Volatility submodel?
- Schedule Equation?

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# Next Steps

- Expanding the model to cover total lifecycle
  - birds-of-the-feather session Wednesday eve
  - break-out group Thursday afternoon
- Continued data collection



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# USC-CSE Seven Step Modeling Methodology