COCOTS
Software Integration
Cost Model: Insights & Status

Dr. Barry Boehm (USC)
Mr. Chris Abts (USC)
Dr. Betsy Bailey (Software Metrics)

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University of Southern California
USC Center for Software Engineering

Points of Contact at USC-CSE in Los Angeles

Mr. Chris Abts (primary graduate researcher) .........................(213) 740-6470
Ms. Ladonna Pierce (CSE Office Administrator) ......................(213) 740-5703
Dr. Barry W. Boehm (CSE Director) ......................................(213) 740-8163
USC Center for Software Engineering  FAX line .....................(213) 740-4927
COCOTS E-Mail .......................................................... cots-info@sunset.usc.edu
World Wide Web page ..............................................http://sunset.usc.edu/COCOTS/cocots.html

Additional Contact at Software Metrics, Inc. in Virginia (near D.C.)

Dr. Elizabeth (Betsy) Bailey .............................................. (703) 754-0115
FAX line ................................................................. (703) 754-0115
E-Mail ................................................................. bkbailey@erols.com
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
Rationale for Using COTS Products

- Significant change in s/w development practice over past 20 years:
  - building systems with pre-existing software to keep development & maintenance costs as low as possible
  - One such source: COTS

- Rationale for COTS based systems:
  - involve less development time by taking advantage of existing, market proven, vendor supported products, thus lowering overall development costs
# COTS Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Available now; earlier payback</td>
<td>• Licensing and intellectual property procurement delays</td>
</tr>
<tr>
<td>• Avoids expensive development &amp; maintenance</td>
<td>• Up front license fees</td>
</tr>
<tr>
<td>• Predictable license costs &amp; performance</td>
<td>• Recurring maintenance fees</td>
</tr>
<tr>
<td>• Rich in functionality</td>
<td>• Reliability often unknown/ inadequate; scale often difficult to change</td>
</tr>
<tr>
<td>• Broadly used, mature technology</td>
<td>• Unnecessary features compromise usability, performance</td>
</tr>
<tr>
<td>• Frequent upgrades often anticipate organization’s needs</td>
<td>• Functionality, efficiency constraints</td>
</tr>
<tr>
<td>• Dedicated support organization</td>
<td>• No control over upgrades/maintenance</td>
</tr>
<tr>
<td>• Hardware/software independence</td>
<td>• Dependency on vendor</td>
</tr>
<tr>
<td>• Tracks technology trends</td>
<td>• Efficiency sacrifices</td>
</tr>
<tr>
<td></td>
<td>• Integration not always trivial; incompatibilities among vendors</td>
</tr>
<tr>
<td></td>
<td>• Synchronizing multiple-vendor upgrades</td>
</tr>
</tbody>
</table>
Caveat to Using COTS Products

- Two main characteristics of COTS:
  - source code not available to developer
  - evolution not under control of developer
- Results in trade-off:
  - development time can be reduced, but often at cost of increased s/w component integration work
- Unique risks associated with COTS:
  - cost of licensing and redistribution rights, royalties, effort needed to understand the COTS software, pre-integration assessment and evaluation, post-integration certification of compliance with mission critical or safety critical requirements, indemnification against faults or damage caused by vendor supplied components, and costs incurred due to incompatibilities with other needed software and/or hardware
When are COTS Products the “Right” Solution?

• When they lie at the intersection of the three determinants of feasibility, *and do so demonstrably better than could original code*: 

- Technical Constraints
- Economic Constraints
- Strategic Constraints
Constraints on COTS Solution Feasibility

- **Technical**
  - ability to supply the desired functionality at the required level of reliability

- **Economic**
  - ability to be incorporated and maintained in the new system within the available budget and schedule

- **Strategic**
  - ability to meet needs of the system operating environment--including technical, political, and legal considerations--now, and as environment is expected to evolve in the future
COTS Integration Sources of Effort

- COTS Assessment (pre- and post-commitment)
  - Of functionality, performance, interoperability, etc.
- COTS Tailoring and Tuning
  - Effects of platform, other COTS products
- Glue Code Development
  - Similar to other COCOMO II estimation
- Application Volatility Due to COTS
  - COTS volatility, shortfalls, learning curve
- Added Application V&V Effort
  - COTS option and stress testing
  - Debugging complications, incorrect fixes
COCOMO vs. COCOTS Cost Sources
(COTS in System)

1) COTS Assessment
2) COTS Tailoring
3) COTS/Application Glue Code Development and (System) Test
4) Increased Application Effort due to COTS Volatility

LCO - Life Cycle Objectives
LCA - Life Cycle Architecture
IOC - Initial Operational Capability

Beta Test, Field Test

COCOMO Effort Estimate
COCOTS Effort Estimate Components
COTS Integration Cost Sources:

1) Assessment

Initial Filtering Effort

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

Final Selection Effort

Total Effort = \( \sum \left( \text{# COTS Candidates} \right) \left( \frac{\text{Average Assessment Effort for Attribute in Given Domain}}{\text{Candidate}} \right)^i \)

- List of attributes refined in collaboration with Dr. Elizabeth Bailey
- Effort/candidate is project-dependent, within domain guidelines
### COTS Integration Cost Sources:
#### 1) Assessment - Assessment Attributes

<table>
<thead>
<tr>
<th>Correctness</th>
<th>Understandability</th>
<th>Portability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>Documentation quality</td>
<td>Portability</td>
</tr>
<tr>
<td>Correctness</td>
<td>Simplicity</td>
<td></td>
</tr>
<tr>
<td>Testability</td>
<td>Functionality</td>
<td>Functionality</td>
</tr>
<tr>
<td>Availability/Robustness</td>
<td>Ease of use</td>
<td>Price</td>
</tr>
<tr>
<td>Availability</td>
<td>Usability/Human Factors</td>
<td>Initial purchase/lease</td>
</tr>
<tr>
<td>Fail safe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fail soft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault tolerance</td>
<td>Version Compatibility</td>
<td>Recurring costs</td>
</tr>
<tr>
<td>Input error tolerance</td>
<td>Downward compatibility</td>
<td></td>
</tr>
<tr>
<td>Redundancy</td>
<td>Upward compatibility</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>Inter-component Compatibility</td>
<td></td>
</tr>
<tr>
<td>Robustness</td>
<td>Compatibility with other components</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Interoperability</td>
<td>Vendor Support</td>
</tr>
<tr>
<td>Security</td>
<td>Security (Access related)</td>
<td>Response time for critical problems</td>
</tr>
<tr>
<td></td>
<td>Security (sabotage related)</td>
<td>Support</td>
</tr>
<tr>
<td>Product Performance</td>
<td>Flexibility</td>
<td>Extendability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexibility</td>
</tr>
<tr>
<td>Execution performance</td>
<td>Installation/Upgrade Ease</td>
<td>User Training</td>
</tr>
<tr>
<td>Information/data capacity</td>
<td>Installation Ease</td>
<td>User training</td>
</tr>
<tr>
<td>Precision</td>
<td>Upgrade/Refresh ease</td>
<td></td>
</tr>
<tr>
<td>Memory performance</td>
<td></td>
<td>Vendor Concessions</td>
</tr>
<tr>
<td>Response time</td>
<td></td>
<td>Willingness to escrow source code</td>
</tr>
<tr>
<td>Throughput</td>
<td></td>
<td>Willingness to make modifications</td>
</tr>
</tbody>
</table>
COTS Integration Cost Sources:
2) Tailoring

Total Effort = \[
\frac{\text{# COTS Candidates Tailored at Complexity Level}^i}{\text{Tailoring Complexity Levels}} \times \left( \frac{\text{Average Effort at Tailoring Complexity Level in Domain}^i}{i} \right)
\]

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

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

Total Point Score = _________
COTS Integration Cost Sources:
3) Glue Code Development and Test

Total Effort = A \times [(size)(1+breakage)]^B \times \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
**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
COTS Integration Cost Sources:
4) Increased Application Effort Due to COTS Volatility

Approximate Model:

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

Detailed Model with COCOMO II Parameters:

Total Effort = (Application Effort) \times \left[ \left( \frac{1 + \frac{\text{BRAK COTS}}{1 + \text{BRAK}}}{1.01 + \ldots} \right)^{-1} \right] \times (\text{EAF})

BRAK COTS: % application code breakage due to COTS volatility
BRAK : % application code breakage otherwise
S : COCOMO II scale factor
EAF : Effort Adjustment Factor (product of effort multipliers)
**COTS Integration Cost Sources:**

4) **Increased Application Effort Due to COTS Volatility**

- **COCOMO II Scale Factors**

<table>
<thead>
<tr>
<th>Scale Factor</th>
<th>Very Low</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
<th>Very High</th>
<th>Extra High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precedentedness</td>
<td>thoroughly unprecedented</td>
<td>Largely unprecedented</td>
<td>somewhat unprecedented</td>
<td>generally familiar</td>
<td>largely familiar</td>
<td>thoroughly familiar</td>
</tr>
<tr>
<td>Development Flexibility</td>
<td>rigorous</td>
<td>Occasional Relaxation</td>
<td>some relaxation</td>
<td>general conformity</td>
<td>some conformity</td>
<td>general goals</td>
</tr>
<tr>
<td>Architecture/Risk Resolution</td>
<td>little (20%)</td>
<td>some (40%)</td>
<td>often (60%)</td>
<td>generally (75%)</td>
<td>mostly (90%)</td>
<td>full (100%)</td>
</tr>
<tr>
<td>Team Cohesion</td>
<td>some difficult interactions</td>
<td>Basically cooperative interactions</td>
<td>largely cooperative</td>
<td>highly cooperative</td>
<td>seamless interactions</td>
<td>N/A</td>
</tr>
<tr>
<td>Process Maturity</td>
<td>Chaos</td>
<td>CMM Level 1</td>
<td>CMM Level 2</td>
<td>CMM Level 3</td>
<td>CMM Level 4</td>
<td>CMM Level 5</td>
</tr>
</tbody>
</table>

*percentage of module interfaces specified, percentage of significant risks eliminated.*
**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)
Two Models, Differing Fidelity in Development
(Parallels COCOMO II modeling)

Early Design COCOTS model

- roll up of parameters in Assessment, Glue code submodels into fewer, more aggregated factors; inclusion of only the approximate Volatility model.

- less fidelity but requires fewer data points to calibrate.

- intended for more “what if” kind of estimating, earlier in the development process.

Post-architecture COCOTS model

- the full model as presented in preceding charts
Calibration Data Collection Status

• 6 Student Digital Library Projects
  – 8 more by end Spring ‘99 semester

• 12 Industrial Projects
  – FAA & aerospace contractors
  – 8+ additional projects anticipated by mid ‘99
  – will allow calibration of Early Design version

• Other Sources Being Explored
  – NASA, DoD, Commercial
  – USC-CSE Affiliates, GSAW & ICSE conferences
Experiences with Student Data
Raw Project Data

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
<th>Group 6</th>
<th>Total Pers-hrs by Activity</th>
<th>% Total Pers-hrs by Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determine Requirements:</td>
<td>16.00</td>
<td>49.50</td>
<td>86.50</td>
<td>26.50</td>
<td>5.50</td>
<td>38.50</td>
<td>222.50</td>
<td>4.99</td>
</tr>
<tr>
<td>Prepare, update plans:</td>
<td>107.00</td>
<td>142.00</td>
<td>209.50</td>
<td>39.00</td>
<td>83.50</td>
<td>134.75</td>
<td>715.75</td>
<td>16.06</td>
</tr>
<tr>
<td>Design product:</td>
<td>99.00</td>
<td>3.00</td>
<td>103.50</td>
<td>63.50</td>
<td>13.00</td>
<td>96.00</td>
<td>378.00</td>
<td>8.48</td>
</tr>
<tr>
<td>Code product:</td>
<td>161.00</td>
<td>20.50</td>
<td>190.00</td>
<td>168.00</td>
<td>67.50</td>
<td>115.00</td>
<td>722.00</td>
<td>16.20</td>
</tr>
<tr>
<td>Participate in formal design/code reviews:</td>
<td>14.00</td>
<td>8.00</td>
<td>21.00</td>
<td>21.00</td>
<td>22.50</td>
<td>24.00</td>
<td>110.50</td>
<td>2.48</td>
</tr>
<tr>
<td>Integrate and test:</td>
<td>70.00</td>
<td>94.50</td>
<td>85.50</td>
<td>6.50</td>
<td>13.00</td>
<td>29.50</td>
<td>299.00</td>
<td>6.71</td>
</tr>
<tr>
<td>Fix defects found in testing:</td>
<td>60.00</td>
<td>27.50</td>
<td>61.00</td>
<td>2.00</td>
<td>15.00</td>
<td>71.00</td>
<td>236.50</td>
<td>5.31</td>
</tr>
<tr>
<td>COTS Related Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understand and qualify COTS:</td>
<td>2.00</td>
<td>6.00</td>
<td>98.50</td>
<td>10.00</td>
<td>61.00</td>
<td>19.50</td>
<td>197.00</td>
<td>4.42</td>
</tr>
<tr>
<td>Design COTS glue code:</td>
<td>0.00</td>
<td>0.00</td>
<td>7.50</td>
<td>0.00</td>
<td>0.30</td>
<td>9.00</td>
<td>16.80</td>
<td>0.38</td>
</tr>
<tr>
<td>Code COTS glue code:</td>
<td>0.00</td>
<td>0.00</td>
<td>4.00</td>
<td>0.00</td>
<td>16.80</td>
<td>30.50</td>
<td>51.30</td>
<td>1.15</td>
</tr>
<tr>
<td>Fix defects found in COTS testing:</td>
<td>5.00</td>
<td>0.00</td>
<td>2.50</td>
<td>1.00</td>
<td>1.50</td>
<td>4.00</td>
<td>14.00</td>
<td>0.31</td>
</tr>
<tr>
<td>Administrative Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management:</td>
<td>8.50</td>
<td>34.00</td>
<td>33.50</td>
<td>13.50</td>
<td>10.00</td>
<td>25.00</td>
<td>124.50</td>
<td>2.79</td>
</tr>
<tr>
<td>Documentation:</td>
<td>52.50</td>
<td>449.50</td>
<td>38.00</td>
<td>59.50</td>
<td>68.00</td>
<td>126.00</td>
<td>793.50</td>
<td>17.81</td>
</tr>
<tr>
<td>Other:</td>
<td>114.00</td>
<td>239.00</td>
<td>31.50</td>
<td>8.00</td>
<td>100.00</td>
<td>82.50</td>
<td>575.00</td>
<td>12.90</td>
</tr>
<tr>
<td>TOTAL WEEKLY Person-Hours</td>
<td>709.00</td>
<td>1073.50</td>
<td>972.50</td>
<td>418.50</td>
<td>477.60</td>
<td>805.25</td>
<td>4456.35</td>
<td>99.99</td>
</tr>
</tbody>
</table>

Table VIII.1- Effort hours by activity for graduate software engineering class projects incorporating COTS products.

Key: Group 1 - EDGAR Corporate Data
Group 2 - Medieval Manuscripts
Group 3 - Technical Reports
Group 4 - Latin American Pamphlets
Group 5 - CNTV Moving Image Archive
Group 6 - Hancock Photo Archive
Experiences with Student Data
COTS Assessment Effort Distribution
Groups 3 & 5 (search engines)

<table>
<thead>
<tr>
<th>Gross Attributes</th>
<th>Activities</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Functionality</td>
<td></td>
<td>20%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>2. Performance</td>
<td></td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>3. Dependability</td>
<td></td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>4. Usability</td>
<td></td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>5. Adaptability</td>
<td></td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>6. Operability</td>
<td></td>
<td></td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>7. Cost</td>
<td></td>
<td>50%</td>
<td>20%</td>
<td>30%</td>
</tr>
</tbody>
</table>

*Distribution of assessment effort by activity and attribute.*

I: nominal exercise - use COTS as intended by vendor
II: off-nominal exercise - adapt COTS to new use
III: reading and research
### Experiences with Student Data

**Glue Code Submodel Calibration**

<table>
<thead>
<tr>
<th>Project</th>
<th>A</th>
<th>Size (SLOC)</th>
<th>B</th>
<th>xEAFs</th>
<th>Estimate (P-hr)</th>
<th>Actual (P-hr)</th>
<th>Relative Error</th>
</tr>
</thead>
<tbody>
<tr>
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A = .009 => 111 SLOC/P-hr
Suggested COTS Classes

- database
- network management
- GUI builders
- operating systems
- report generators
- device drivers
- compilers
- decision support systems
- other???
Immediate COCOTS Follow-ons

• Modeling of schedule estimation and activity distribution
• Integration with COCOMO II estimation model
• More extensive tool implementation
In Conclusion: COCOTS’ Most Important Aspect

• COCOTS is completely open. Regardless of whatever estimates it provides, the descriptions of the elements that have gone into the model help highlight the most important factors that should be of concern to managers and developers of software systems using COTS software components.

• It’s the essence of a "constructive" cost model:
  – one that helps an estimator better understand the complexities of a given software job to be done
  – by being open permits the estimator to know exactly why a model gives the estimate it does