Why Can’t We All Just Get Along?
Lessons In Reconciling Cost Estimates

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The authors are veterans of many Independent Cost Estimates (ICEs) and Very Few Program Office Estimates (POEs) by Choice!
The authors are grateful to the following fellow ICEmen for their contributions:

Ray Covert
John Neatrour
Nathan Menton
Outline

• “Reconcile”
• A Brief History of Cost Reconciliation
• Why Do We Reconcile Cost Estimates?
• Why We Should Expect Problems
• What Are the Problems?
• What Can We Do About It?
• Tips for Presenting the Outcome of a Reconciliation
• Summary
• Why Can’t We All Just Get Along?
Main Entry: **reconcile**

Pronunciation: 're-k&n-"sI(-&)l

**Function:** *verb*

Inflected Form(s): -ciled; -cil·ing

**Etymology:** Middle English, from Anglo-French or Latin; Anglo-French reconcile, from Latin reconciliare, from re- + conciliare to conciliate

**transitive verb**

1a: to restore to friendship or harmony <reconciled the factions>  
b: SETTLE, RESOLVE <reconcile differences>

2: to make consistent or congruous <reconcile an ideal with reality>

3: to cause to submit to or accept something unpleasant <was reconciled to hardship>

4a: to check (a financial account) against another for accuracy

b: to account for

**intransitive verb:** to become reconciled

Source: Merriam-Webster's Online Dictionary, 10th Edition
A Brief History of Cost Reconciliation: In The Beginning…

• ........ there was only one estimate…
  – Generated by managing engineers, sometimes with the help of those who would do the work
  – Examples: John Roebling & Brooklyn Bridge, Steve Bechtel & Hoover Dam

• The results were generally good:
  – Quick
  – Responsive
  – Generated by the those who would have to live with the costs
  – Provided a basis for financing…and assigning blame if costs rose

• But they were not perfect:
  – Only as good as the estimators’ experience…and sometimes made bad by their personal biases
  – Inconsistent across projects
  – Frequently incomplete
  – Reflective of the risk aversion of entrepreneurs in search of funds
A Brief History of Cost Reconciliation: Later On…

• Seeing this, the bill payers said, 

Let the project office create a “formal” estimate.

• “Formal” = “procedural”, more inclusive, involving more departments and more experts...

• And the results were better:  
  – More documentation for the financers & oversight groups  
  – Easier to identify biases, missing costs

• But still not perfect:  
  – Still success driven (still biased)  
  – Always precisely wrong at the end…and sometimes way wrong early on
A Brief History of Cost Reconciliation: Still Later…

• So the bill payers said,

Let there be a second, independent estimate.

• “Independent” = “unbiased”*
• And the results were more → twice as many estimates
• But not always better: What happens when the two estimates disagree?

* In fact, a different set of biases
A Brief History of Cost Reconciliation: Today

• So, finally, the bill payers said,

  Let the two estimates be reconciled.

• And the results were better still:
  – Arithmetic errors were identified and fixed
  – Sometimes the totals of the two estimates equal each other (within some error bounds)

• Except for two small problems:
  – The estimates typically never agree completely below the top line
  – Neither estimate is ever exactly right
Why Do We Reconcile Cost Estimates?

• Reconciliation is necessary when there are:
  – Other estimates of the program
  – Changes in the technical and programmatic inputs during the course of the estimating process

• For Independent Cost Estimates (ICEs), reconciliation with the Program Office Estimate (POE) is typically needed

• Reconciliation is not “target practice”
  ▪ Goal is not replication
  ▪ May need to agree to disagree about risks, ground rules, assumptions
Why We Should Expect Problems (Philosophical)

- Cost estimation deals with forecasting, not foretelling; hence any cost estimate is always exactly wrong.
- A cost estimate is not “real;” you cannot observe an estimated cost in the real world.
- The cost estimator/analyst must build an estimate from the engineers’ model of a yet unrealized program.
- In other words, every cost estimate is a \((model, \text{estimate}, \text{incomplete characterization}, \text{copy})\) of a \((model, \text{estimate}, \text{incomplete characterization}, \text{copy})\) which is reminiscent of....
“‘Four’ is cloned from ‘Two’, and has the mentality of an overly-curious child. Unfortunately since he is a clone-of-a-clone, his IQ is considerably lower than that of his predecessors, since the personality defects are more pronounced when a clone is cloned (The analogy from the movie refers to how a copy of a copy may not be as 'sharp' as the original).”

http://en.wikipedia.org/wiki/Multiplicity_(film)
Why We Should Expect Problems (Practical)

- Actors have different perceptions
- Motives of one’s client vary sometimes even over the course of the reconciliation effort
  - Political pressure builds
  - Expected outcome replaced by feared one
- Stakeholders have conflicting and changing expectations about the process and outcome:
  - No collusion!
  - How can we use the best of the information to come up with a single number to budget to?
What Are the Problems?
Here Are A Few

• Different Motives
• Different Methodologies
• Time Lag
• Lingering Vagueness
• Different Ground Rules and Assumptions
Different Motives

• The POE generally reflects a success-oriented outlook and a plan the way the program office wants it to be. It may
  – Be in a buy-in mode
  – Uncritically accept contractor claims
  – Ignore history

“Who are you going to believe, me or your own eyes?”...Chico Marx

• The ICE generally
  – Tries to account for the worst that can happen
  – Comes from a nonadvocate, honest broker perspective and reflects lessons of multiple historical programs
  – May be required to ensure adequate funding to cover risks
  – May be perceived or actually intended to kill a program.
Different Methodologies

• **POE**
  – Parametric models calibrated to a particular environment
  – Engineering judgment
  – Contractor data and estimates
  – Vendor quotes
  – Bottom up
  – Extrapolation from Actuals

• **ICE**
  – Parametric models that produce estimates based on industry averages
  – Historical data
  – Industry trends
Time Lag

• ICE relies on compiled information representing a snapshot of the program at a given time
  – Technical Description (CARDs, Technical Specifications) documentation updated infrequently
  – Access to functional specialists limited

• POE benefits from close and continuous contact with engineers and program management and thus may lead the ICE by several months

• Each may be estimating a different program
Lingering Vagueness

• Requirements still volatile
  – Designs immature
  – Quantities undecided
  – Manufacturing readiness uncertain
  – Payloads in flux

• Potential players not all identified (both sponsors and contractors)

• Schedule
  – Actual need date
  – Availability of essential technology

• Program office and ICE Team may simply end up with different views
Different Ground Rules and Assumptions

- Perceptions of Uncertainty and Risk
  - Weight growth
  - Code growth
  - GFE
  - COTS
  - Heritage of hardware
  - Reliance on other programs
- Headcounts
- Inflation rates
What Can We Do About It?
Sanity Checks

• Let history into the discussion
• Better, faster, cheaper: you can’t get all three and are lucky to get just one
• The contractor community is not Lake Wobegon: they are not all above average
  – Neither are most program offices
• New ways of doing business generally aren’t

“In an insane world, a sane man looks insane”
……..Ray Covert
Space Vehicle Comparisons: Cost per kilogram (FY06$)

DDT&E and First Unit for Space Vehicle Including Payload

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Agree to Disagree

• Since the only certainty is that neither the POE nor the ICE will be correct, humility on both sides is appropriate
• Choice of methodology is usually a matter of opinion
  – Can expect different results
  – Each will have a different error associated with the estimate
• Future trends of inflation, cost, technology, etc. are open to differing viewpoints
• Should NOT agree to disagree to avoid doing diligence, for example......
When Not to Agree to Disagree

- Handling of program level item (system engineering, program management, integration and test)
- Objectively verifiable information
  - Mass and mass growth potential
  - Software size
  - Code reuse and growth potential
  - Demonstrated performance
  - Technology Readiness Level (TRL)
- Computational and algorithmic errors
  - “You are entitled to your own opinion but not to your own mathematics”........NDH

“Your insistence does not relieve our requirement for due diligence”....Ray Covert
Tips for Presenting the Outcome of a Reconciliation
Highlight Differences in Ground Rules and Assumptions

• **ICE**
  - Uncertainty is applied to all WBS elements
  - Estimates are presented in FY06$ through G&A but without fee
  - DoD Inflation factors are used to escalate cost
  - O&S estimated through 2030
  - Pessimistic assessment of potential code growth is a factor of 2.5
  - Most likely estimate of software assumes 20% code reuse
  - Most likely schedule estimate includes 6 month delay in delivery of Hemiflexer from The Twinkler program
  - COTS hardware and software will be upgraded every 3 years

• **POE**
  - Uncertainty is applied to all WBS elements except the payloads
  - Estimates are presented in FY03$ with fee
  - NASA inflation factors are used to escalate cost
  - O&S estimated through 2025
  - Pessimistic assessment of potential code growth is a factor of 1.5
  - Most likely estimate of software assumes 90% code reuse
  - Hemiflexer will be delivered from The Twinkler program 3 months before launch
  - COTS hardware and software will be updated every 5 years
## Compare Methodologies By WBS Elements at a Suitable Level

<table>
<thead>
<tr>
<th>Level 2 Elements</th>
<th>ICE</th>
<th>POE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Program Management</td>
<td>Factor</td>
<td>Staffing by analogy</td>
</tr>
<tr>
<td>2.0 Systems Engineering</td>
<td>Factor</td>
<td>Staffing by analogy</td>
</tr>
<tr>
<td>3.0 Safety and Mission Assurance</td>
<td>Factor</td>
<td>Staffing by analogy</td>
</tr>
<tr>
<td>4.0 Science/Technology</td>
<td>Space Operations Cost Model (SOCM)</td>
<td>Staffing by analogy</td>
</tr>
<tr>
<td>5.0 Payload</td>
<td>NASA Instrument Cost Model</td>
<td>Extrapolation from Actuals</td>
</tr>
<tr>
<td>6.0 Spacecraft</td>
<td>Hardware: Top-level models such as AMCM and QuickCost; Analogy; Dollars per kg comparison; Software: Lines of code per staff month comparisons, Aerospace CERs</td>
<td>Hardware: NAFCOM or other subsystem level parametric models; Software: COCOMO II Early Design version</td>
</tr>
<tr>
<td>7.0 Mission Operations</td>
<td>SOCM; Software: COCOMO II Early Design version</td>
<td>Staffing by analogy</td>
</tr>
<tr>
<td>8.0 Launch Vehicle/Services</td>
<td>Look up tables, historical data adjusted as necessary</td>
<td>NASA Pricing Quotations</td>
</tr>
<tr>
<td>9.0 Ground Systems Development</td>
<td>Hardware: Ground Station Rules of Thumb; Software: COCOMO II Early Design version, Aerospace CERs</td>
<td>Hardware: Vendor Quotes; Software: Lines of code per staff month comparisons</td>
</tr>
<tr>
<td>10.0 System Integration Assembly &amp; Test</td>
<td>Factor</td>
<td>Staffing by analogy</td>
</tr>
<tr>
<td>11.0 Education &amp; Public Outreach</td>
<td>Factor</td>
<td>Analogy</td>
</tr>
</tbody>
</table>
Compare Estimates

Statistic | ICE | POE
--- | --- | ---
Trials | 10,000 | 10,000
Mean | 6052 | 5219
Median | 5984 | 5212
Standard Deviation | 806 | 270
Variance | 649915 | 72884
Skewness | 0.5213 | 0.1518
Kurtosis | 3.42 | 3
Coeff. of Variability | 0.1332 | 0.0517
Minimum | 3934 | 4329
Maximum | 10509 | 6285

Percentile | ICE | POE
--- | --- | ---
10% | 5,073 | 4,878
20% | 5,359 | 4,990
30% | 5,583 | 5,072
40% | 5,780 | 5,144
50% | 5,984 | 5,212
60% | 6,187 | 5,281
70% | 6,429 | 5,355
80% | 6,705 | 5,444
90% | 7,129 | 5,569
Compare Distributions

- ICE entirely overlaps POE
  - POE mean (5,211) falls below the ICE 20th percentile
  - All scenarios in POE are in ICE
  - POE significantly understates the risk of total program cost overruns
Compare Estimates at an Appropriate WBS Level

<table>
<thead>
<tr>
<th>WBS</th>
<th>POE</th>
<th>ICE</th>
<th>Delta (ICE-POE)</th>
<th>% Difference (ICE-POE)/ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>50th</td>
<td>80th</td>
<td>80/50</td>
</tr>
<tr>
<td>Total</td>
<td>2,606</td>
<td>2,606</td>
<td>2,722</td>
<td>4%</td>
</tr>
<tr>
<td>1.1 System Level Segment</td>
<td>214 n/a n/a 460 446 531 16% 247</td>
<td>54%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2 Space Segment</td>
<td>781 n/a n/a 933 904 1,099 18% 151</td>
<td>16%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.1 Space Segment SE/PM</td>
<td>140 155 67 58 91 36% (73)</td>
<td>-109%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.2 Space Segment Al&amp;T</td>
<td>60 - 66 50 44 68 36% (10)</td>
<td>-20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.3 Payload 1</td>
<td>172 168 198 15% 244 225 302 25% 73</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.4 Payload 2</td>
<td>32 32 32 0% 32 32 32 0% (0)</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.5 Payload 3</td>
<td>36 36 40 9% 103 93 134 31% 67</td>
<td>65%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.6 Payload 4</td>
<td>100 98 114 14% 129 120 163 26% 28</td>
<td>22%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.7 Payload 5</td>
<td>31 31 35 11% 31 29 39 27% 0</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2.8 Spacecraft/Bus (including AGE and LOOS)</td>
<td>209 207 243 14% 278 268 329 19% 68</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3 Ground Segment</td>
<td>150 149 163 9% 244 239 272 12% 94</td>
<td>39%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3.1 Ground Segment SE/PM</td>
<td>23 23 25 9% 49 45 63 29% 26</td>
<td>52%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3.2 Ground Segment Al&amp;T</td>
<td>4 3 4 9% 33 30 42 29% 29</td>
<td>89%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3.3 Ground Sites</td>
<td>114 113 125 10% 137 135 149 9% 22</td>
<td>16%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3.4 Terrestrial Communication</td>
<td>0 0 0 14% 5 5 6 15% 5</td>
<td>94%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3.5 Training, Simulators and Spares</td>
<td>8 8 10 16% 21 20 25 20% 12</td>
<td>60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4 Off Contract Effort</td>
<td>86 85 95 10% 131 128 153 16% 46</td>
<td>35%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 Software Segment</td>
<td>303 299 360 17% 335 295 496 41% 32</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6 Launch Segment</td>
<td>201 198 228 13% 225 221 259 14% 25</td>
<td>11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7 Operations &amp; Support Segment</td>
<td>322 321 346 7% 372 367 417 12% 51</td>
<td>14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8 Government Costs</td>
<td>500 497 538 8% 329 324 371 13% (171)</td>
<td>-52%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined 1.1 and 1.8</td>
<td>714</td>
<td>790</td>
<td>76</td>
<td>10%</td>
</tr>
</tbody>
</table>

Need to be prepared to explain each major discrepancy!
## List Unresolved Issues

<table>
<thead>
<tr>
<th>Issue</th>
<th>WBS Element(s) Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable TRLs for high-cost items unavailable in time for the ICE</td>
<td>1.2.3, 1.2.4, 1.2.5, 1.2.6, 1.2.7</td>
</tr>
<tr>
<td>Math error in POE suspected</td>
<td>1.2.8</td>
</tr>
<tr>
<td>Code count used in ICE lower than the one used for the POE</td>
<td>1.5</td>
</tr>
<tr>
<td>About 40% of the POE comes from contractors with unproven track records</td>
<td>1.2</td>
</tr>
<tr>
<td>ICE disregards significant heritage of platform</td>
<td>1.2.8</td>
</tr>
</tbody>
</table>
Summary

- Any cost estimate is a prediction and predictions are always precisely wrong!
- There are any number of reasons why cost estimates differ
- Recognize that reconciliation means identifying the valid reasons for the differences, not unnaturally forcing two estimates closer to each other
- Use relevant history as a source of sanity checks
- The POE represents more of a policy as to how much management is willing to pay and what the head count will be
- The ICE is more likely to represent how much the program actually could cost
Why Can’t We All Just Get Along?

Because we’re really not supposed to!
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AI&amp;T</td>
<td>Assembly, Integration and Test</td>
</tr>
<tr>
<td>AMCM</td>
<td>Advanced Mission Cost Model</td>
</tr>
<tr>
<td>B</td>
<td>billion</td>
</tr>
<tr>
<td>CARD</td>
<td>Cost Analysis Requirement Description</td>
</tr>
<tr>
<td>CER</td>
<td>Cost Estimating Relationship</td>
</tr>
<tr>
<td>COCOMO</td>
<td>Constructive Cost Model</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off the Shelf</td>
</tr>
<tr>
<td>Dem/Val</td>
<td>Demonstration/Validation</td>
</tr>
<tr>
<td>DDT&amp;E</td>
<td>Design, Development, Test and Evaluation</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>ESLOC</td>
<td>Executable Source Lines of Code</td>
</tr>
<tr>
<td>FY</td>
<td>Fiscal Year</td>
</tr>
<tr>
<td>GFE</td>
<td>Government Furnished Equipment</td>
</tr>
<tr>
<td>ICE</td>
<td>Independent Cost Estimate</td>
</tr>
<tr>
<td>K</td>
<td>thousand</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram</td>
</tr>
<tr>
<td>M</td>
<td>million</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NDH</td>
<td>Neal David Hulkaner</td>
</tr>
<tr>
<td>NICM</td>
<td>NASA Instrument Cost Model</td>
</tr>
<tr>
<td>NRE</td>
<td>Nonrecurring Engineering</td>
</tr>
<tr>
<td>O&amp;S</td>
<td>Operations and Support</td>
</tr>
<tr>
<td>POE</td>
<td>Program Office Estimate</td>
</tr>
<tr>
<td>ROM</td>
<td>Rough Order of Magnitude</td>
</tr>
<tr>
<td>SEE</td>
<td>Standard Error of Estimate</td>
</tr>
<tr>
<td>SM</td>
<td>Staff months</td>
</tr>
<tr>
<td>SOCM</td>
<td>Space Operation Cost Model</td>
</tr>
<tr>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>WBS</td>
<td>Work Breakdown Structure</td>
</tr>
</tbody>
</table>