



Cost Estimate Credibility

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ICEAA So Cal Workshop
September 26, 2018
Redondo Beach, CA

Earlier versions of this paper have been presented at:

- AIAA Space Economics Workshop & Panel– Rand (2016)
- Defense Analysis Exchange – Seoul (2016)
- ICEAA International Training Symposium – Bristol (2016) and Portland (2017)
- Naval Postgraduate School - Monterey (2017)

So, What is *Cost Estimate Credibility*?

Early definition: **Rod Stewart's*** 1991 (2nd Edition), first published in 1982 textbook on “Cost Estimating” advises (page 83) that “The credibility, accuracy, and supportability of the cost estimate for any work output will depend to a large degree on the care, knowledge, and time spent on developing a detailed Work Breakdown Structure (WBS) [MIL-STD-881] dictionary...Each element in the structure must be fully described [complete] to allow the specialist to estimate accurately the resources to do the job.”

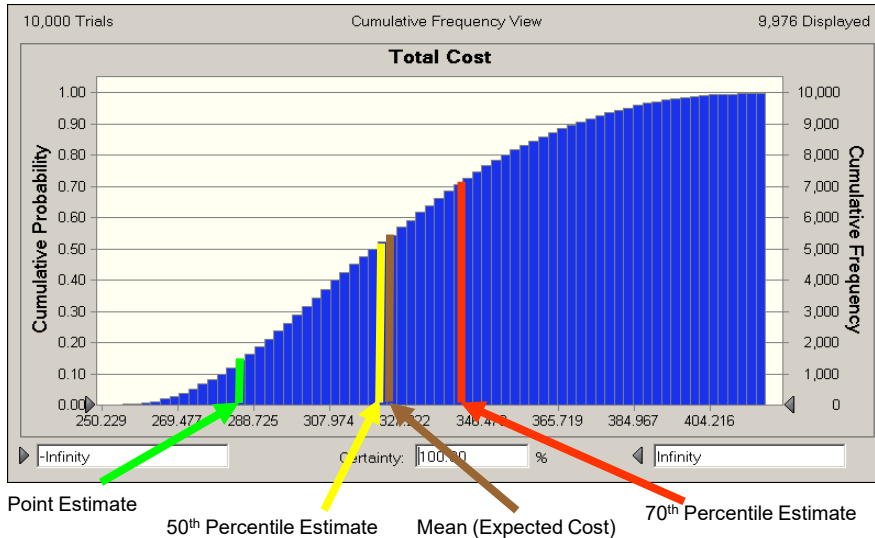
- Is this where many estimates, and new models, turn bad?
- Are there rational synonyms for credibility, such as confidence level, realism, reasonableness?
- Would our definition be based on perception (the right stuff) or reality (statistics)?
- Is this the case where “you know it when you see it?”
- How can I convince you that my estimate is a credible prediction of a future event?
- Let's ask our peers
- Remember the 2005 book, “The Wisdom of Crowds” by James Surowiecki who convinced us that “...*under the right circumstances, it's the crowd that's wiser than even society's smartest individuals.*”

***Rod Stewart** was Manager of Cost Analysis at NASA/MSFC, Associate Fellow AIAA, and National Estimating Society (NES) President (forerunner of ISPA, ICA, SCEA and ICEAA).



Is Confidence Level a Proxy for Credibility?

The probability that the actual cost will not exceed the estimated cost is the cumulative probability (**confidence level**)



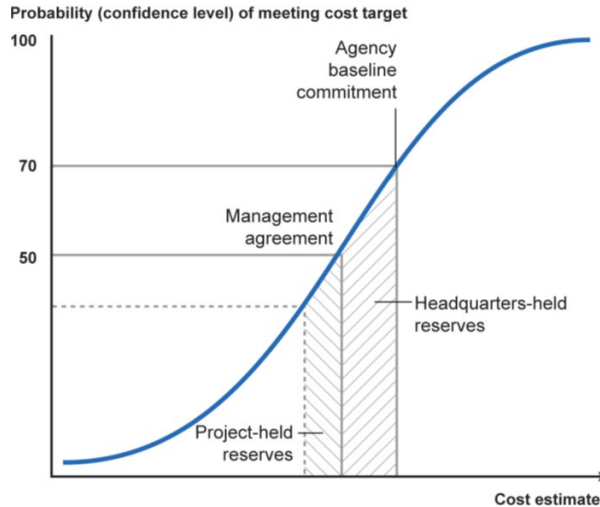
Graphic courtesy of **Steve Book**, mentor to many of us. (Crystal Ball product)

- Yes
- No

← Estimated Cost

Is it good (convincing) enough to just cite a range of estimates or a point estimate with a probability?

What about Joint Confidence Level (JCL)?



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-18-280SP

- NASA adopts JCL process which develops joint cost and schedule confidence level (considering risk) to quantitatively assess the likelihood that the project can be completed within the predicted budget (y-axis) and on time (x-axis).
- Supports risk-adverse and risk-tolerant decision makers.
- Supports portfolio cost policy implementation analysis for projects > \$250M
- Baselined and budgeted at 70 % confidence level and funded at 50 % confidence level

However, June 2018 GAO report identifies causes for NASA cost and schedule overruns:

- Overruns might be linked to using JCL for cost and schedule estimates, and
- Awaiting NASA Inspector General recommendation on continued JCL use.

MDA Cost Estimating & Analysis Handbook

- In 2012, **Dr. Christian Smart, Chief of Cost Estimating, Missile Defense Agency (MDA)** published his Cost Estimating and Analysis Handbook, based partly on the 1972 Government Accountability Office (GAO) definition* of what is required for a credible cost estimate:
 - Clear identification of the task (system description, ground rules, technical characteristics)
 - Broad participation in preparing estimates (include all stakeholders)
 - Availability of valid data (especially relevant historical data)
 - Standardized estimate structure (WBS)
 - Provision for program uncertainties (allow for unknowns)
 - Recognition of inflation
 - Independent review
 - Estimate revision as program changes



* [“Theory and Practice of Cost Estimating for Major Acquisitions, “page 31-32](#)

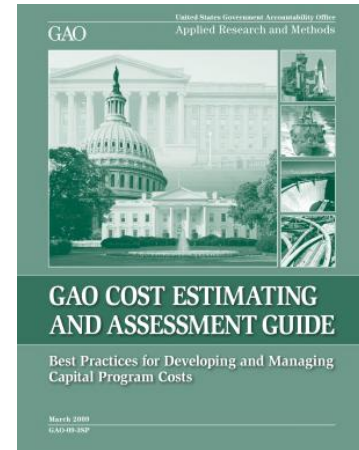
GAO Cost Estimating and Assessment Guide

Best Practices for Developing and Managing Capital Program Costs

Created Nov 2009; updated May 2013



- Incorporating its own “Theory and Practice of Cost Estimating for Major Acquisitions,” GAO 1972 (previous slide).
- To establish a consistent methodology based on best practices [includes a checklist] and that can be used across the federal government for developing, managing, and evaluating capital program cost estimates.
- Linking cost estimating and EVM (performance-based program management) considering differences between estimated and actual costs.
- Integrate cost estimating, system development oversight, and risk management.
- A guide for use in conjunction with Government Auditing Standards; primary audience is federal audit community.
- After major industry survey (2006), including NASA and Customs Service case studies, GAO developed a process for developing credible cost estimates.



NASA Cost Estimating Handbook

- “Documentation should include a reasonable description of each line item, along with **risk confidence levels** for many cost elements. The level of detail varies with the estimate, but the minimum amount of detail should be enough for another estimator to reconstruct the estimate.” (Ref: pages 30-32, version 4, 2014)
- “To verify the reasonableness and credibility of the estimate, estimators are encouraged to generate **secondary estimates [independent cost estimate (ICE)]** based on the same set of normalized data and inputs, but using different models and techniques.”
- The handbook was a partial response to the 2006 GAO survey of NASA cost estimating credibility (see pervious slides).
- ❖ “A **peer review** is another important part of completing an estimate. Once the estimate has been completed and documented, and before the estimate is presented to decision makers, it is important for the estimator to get an outside review. This “sanity check” can provide an outside perspective and a fresh view of the estimate, which can catch any issues with the estimate before presentation.”



NASA/Marshall Space Flight Center

- **Andy Prince**, Cost Estimating Director, NASA/MSFC, “The Credibility of NASA Cost Estimates” (2011) Paper, argues that:
 - Credibility is a quality metric (not an accuracy metric):
 - Degrees of independence of the estimator
 - Sound technical and program baseline
 - Risk analysis
 - Sufficient estimate contingency [what if?]
 - Reliable and auditable historical data
 - Cross-checks
 - Linkage to schedule
 - Clear and effective communication
 - Management culture with desire to know the truth
- Andy’s predecessor, **Dr. Joe Hamaker**, then Director Hq NASA Cost Analysis Division, ISPA Journal (2007) “... accuracy is important; but we can’t know the accuracy until the project is complete...”
 - Estimators think like engineers; an engineer differs from the mathematician in believing that a prediction of “7”, rather than “6.999,” is good enough (and maybe more realistic).”



Cost Estimation, Methods And Tools

(Wiley Textbook 2015)

- **Dr. Dan Nussbaum** - past Director, Naval Center for Cost Analysis; past SCEA President; and current NPS, Energy Academic Group Chair
- **Greg Mislick** - NPS Cost Analysis Chair, Operations Research Dept; and NPS Associate Dean, Graduate School of Operational and Information Sciences
- **Characteristics of a good estimate** (more than precision):
 - Completeness
 - Reasonableness
 - **Credibility**
 - Defensibility

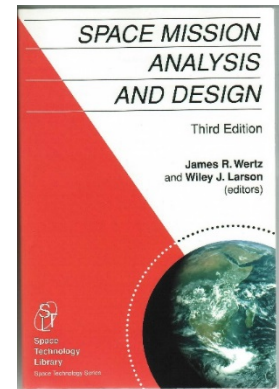
In post-publication interview, Greg expanded on what makes a good estimate; he said: *“So you are not going to prove your estimate is ‘correct,’ but what you want to prove is that your estimate is reasonable and credible. You show this by using sound mathematical techniques and people then understand how you came to these conclusions.”*



2016 ICEAA Educators of the Year

Space Mission Engineering (Handbook)

- **Jim Wertz**, David Everett, and Jeffrey Puschell (editors) Microcosm Press “Space Mission Engineering, the new SMAD” (2011); derived from “Space Mission Analysis and Design” (latest version 1999 shown here)
- Chapter 11, Cost Estimating (**Hank Apgar**) defines cost realism (not accuracy or precision) as the perception of the estimate, i.e., how likely is the estimate to closely predict the future event; more than statistical correctness; conveys inherent quality of prediction:
 - Applied accepted estimating procedures
 - Proven (and calibrated) estimating tools
 - Demonstrates estimating cross-checks and second opinions
- So, if not accuracy or precision, then what is estimate credibility?



Earlier version (SMAD)

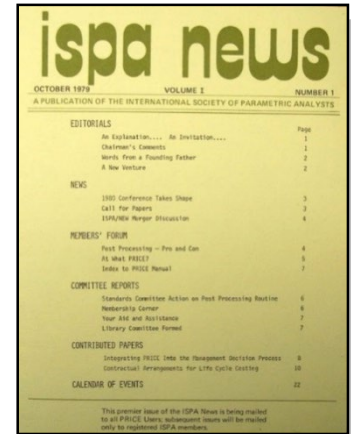
RAND (Report)

- <http://www.rand.org/pubs>
- **Bernie Fox**, et al, RAND (2008), “Guidelines and Metrics for Assessing Space System Cost Estimates”
- How to assure your estimate is credible [more about the process]:
 - Government program estimates typically reviewed by independent review agencies to verify the estimate is
 - Complete (all program elements)
 - Consistent (with directed program)
 - Reasonable (appropriate estimate methods and assumptions)
 - Typically use a Cost Analysis Requirements Description (CARD)
 - System description and operating scenario, acquisition schedule, quantities
 - Assessment of risk
 - Using
 - High cost and high risk elements
 - Cost crosschecks
 - Risk assessment



DCAA Auditor's Perspective

- The August 1991 ISPA Journal reprinted that year's **Conference Keynote Address** by **Larry Uhlfelder**, Assistant Director for Policy and Plans, Defense Contract Audit Agency (**DCAA**), who explained DCAA's policy regarding **audits of parametric cost estimating models**. [Note: this was impetus for founding of ISPA]
- Larry referred to a previous article in the October 1979 ISPA News by **Chuck Starrett**, then the **DCAA Director**, who identified the five **cost model auditing criteria** to be verified before submitting a parametric estimate to the government, and still valid (according to DCAA manuals), to be:
 1. Logical relationships,
 2. Verifiable data,
 3. Significant statistical relationships (high r-squared),
 4. Reasonably accurate predictions, and
 5. Proper systems monitoring.



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DCAA Director's Perspective

- The ISPA Journal of Parametrics reprinted the **1993 ISPA Conference Keynote Address** by **Bill Reed, DCAA Director**. After referring (again) to the 1979 cost **modeling** article, entitled, "Parametric Cost Estimating – An Audit Perspective" (previous slide) by the then-Director of DCAA, Bill reiterated DCAA's support to parametric estimating for contractor proposals and went on to identify where parametric cost **estimates** were failing the credibility test.
- Typical contractor **parametric cost estimate** failures were judged to be:
 - Estimates not based on actuals or updated data.
 - Estimates over time varied significantly.
 - Estimators and accountants not communicating with each other.
 - Lack of written policies and procedures.
 - Estimates made by persons not responsible for performing the work.
- Note: an impetus to the founding of ISPA was the perception that parametric estimates could not be audited; here was contrary evidence that they could be.



Beginning a Series of ISPA Journal Articles:

1. Air Force CAIG

- The Summer 2006 Journal featured our first of a series of invited articles from **Rich Hartley** representing his multiple positions as Chief, Cost Analysis Improvement Group; Deputy Assistant Secretary of the Air Force for Cost and Economics; and Chief, Air Force Cost Analysis Improvement Group Support Division, (AFCAIG), entitled “What are Quality Cost Estimates?”
- Hartley identifies the following areas to ‘watch out for’ when preparing government and contractor cost estimates:
 - Lack of transparency associated with data sources or estimating methods used - failure to establish a clear track from actuals to estimates.
 - Use of, for cost estimating or cross-check purposes, piecemeal (partial) data or data that otherwise cannot be traced to auditable program cost data.
 - Use of select data and estimating models from multiple sources - raises suspicion of “cherry-picking” to get pre-desired results.
 - Unrealistic risk-analysis results, not defining risk inputs precisely, or not tracing them to historical experience, not linking risks to potential cost impacts.
 - Excessively detailed briefings to decision makers or inclusion in such briefings of information extraneous to the decision to be made.
 - Failure to integrate schedule and time with the cost estimate.
 - Lack of, or improper, calibration.
 - Omitting cost elements (i.e., systems-of-systems level, systems engineering, and program management).



Continuing Journal Series:

2. NASA

Then, in the Spring 2007 ISPA Journal, **Dr. Joe Hamaker**, then **Director of the Hq NASA Cost Analysis Division**, provided his response to the first “What are Quality Cost Estimates?” article but adding his own most important attributes of quality in cost estimating to be:



- Sufficient reserve to cover the “up morphs” [risk adders] that most projects undergo.
- Independent cost estimates performed by non-advocates.
- Top-level sanity checks.
- A management culture that desires good estimating.

Continuing Journal Series:

3. Lockheed Martin

- These two quality-focused articles by government executives quickly followed, in the Fall 2008 issue of the **ICEAA** Journal of Cost Analysis and Parametrics (successor to the ISPA Journal of Parametrics) by a contractor perspective written by **Richard Janda**, Vice President of **Program Assessment and Evaluation, Lockheed Martin**.
- Richard believes the following characteristics assure a quality cost estimate:
 - Is the estimate based on objective data?
 - Is the analysis honest? [the honest broker]
 - Are the data and analysis relevant?
 - Is the basis of the cost estimate logical?
 - Is the estimate accurate?
 - Is the estimate holistic? Integrated? Complete?
 - How well is the estimate communicated?



Continuing Journal Series:

4. Army CEAC

- Then, in June 2009, **Stephen Bagby**, Deputy Assistant Secretary of the Army for Cost and Economics and the **Director of the Army Cost and Economic Analysis Center (CEAC)** entered the debate on estimating quality to describe the Army process to ensure the probable costs of its programs are adequately reflected in a limited budget.
- Established Army Cost Review Board (CRB) to combine multiple cost estimates (program office, independent estimate) into single Army Cost Position (ACP)
- Increased focus when lacking adequate program and technical information, such as relying on the Initial Capability Document (ICD) when a Cost Analysis Requirements Description (CARD) is not available.
- Attempted to link capability to cost.



Continuing Journal Series:

5. European Space Agency

- In 2011, the European Space Agency (ESA) published (ICEAA Journal 2011): **Herve Joumier, Chief of Cost Estimating, ESA, “Quality Cost Estimates ...”**
 - Build on published work by Hartley, Hamaker, Janda, and Bagby (published in journals)
 - European aerospace lacks mega-estimating groups (as in US) except for ESA, Airbus, and UK MOD.
 - Define estimate quality (not lowest cost and shortest schedule)
 - Forget the magic number concept
 - Dangers of the “initial poor or naïve cost estimate” paradigm
 - The value of accountability [who prepared the estimate]



ICEAA Denver: 2015 Best Conference Paper

- **Andy Prince**, “The Psychology of Cost Estimating,” near the end of this well-researched and intuitive paper are his signs of a (possibly) overtly-biased estimate and “things to look out for;”
 - Discarding or ignoring applicable data
 - Placing too much emphasis on a single datapoint or opinion
 - Tenuous analogies or extrapolations
 - An estimate that deviates significantly from **the historical trend or reasonable analogs**
 - Any estimate that depends on changes in historical business practices [unverified new ways to do business]
 - Falling in love with a subjective assessment



So, Is There Consensus on What Assures Credibility in the Cost Estimating?

The wisdom of the crowd (our peers) suggests that consistent with enough time, qualified estimating tools and resources, and relevant information, the **estimate credibility** can be assured by five attributes:

1. A state-of-the-art, transparent, clearly defined estimating process. (Leidos Hase Approved CESM and Mgmt Review Process)
2. Calibrated cost models or statistically-qualified CERs with relevant and verified data. (This Depends on Availability of and Use of Leidos Historical Data)
3. Peer reviews, sensitivity analyses, and independent crosschecks. (This Is Part of Leidos SOP)
4. A defined baseline, sound assumptions, and suitable estimate structure. (Refers to Leidos BOE Quality)
5. Logical, reasonable, and repeatable cost and schedule predictions with risk [and schedule] assessment. (Under Purview of Leidos EVMS and Risk Mitigation Process)