Assuring Credibility in the Cost Estimate; Part II

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Abstract

This paper updates Part I, initiated in 2016, which traced the evolution of preferred cost estimating attributes, settling on **cost credibility**. Evidence was provided in the words of cost modelers, government executives, industry leaders, estimating and engineering handbooks, professional journals, and government auditing manuals. This update incorporates the impact of contemporary cost drivers such as program maturity, cost growth, and concept of operations. This paper reassesses the impact on the professional estimator.

The Challenge

In my thirty-five-year career as a cost engineer, I have persistently focused on the “goodness” of my estimates. Good estimates should display key attributes, such as precision, discipline, and relevance. But, the most challenging, and perhaps the most important, is **credibility**. How many estimators, or reviewers of estimates, really can define estimate **credibility** and, and more important, assure the estimate reviewer or customer that an estimate is credible?

In preparing this paper, I asked my peers how they would define “cost estimate credibility.” Few could recall an accepted definition of cost **credibility,** but several offered: “you will know it when you see it.”

I reflected back when I managed a group of new estimators with engineering backgrounds, dedicated to the new portents of parametric cost estimating. The mantra, then, was “to get a number” derived from the wonder tool set of commercial estimating models. Seeing yards of rolled heat-sensitive paper, printed from my Texas Instruments time-share terminal, my boss would annoy me by asking, “Hank, what does the model say” as if the whole estimating process was about to be automated with little human intervention.

Later, the emphasis seemed to focus on extrapolating “real world” cost data to develop proprietary cost estimating models. The mantra was to derive multi-variable CERs based on ZMPE, MUPE, or GRSQ, depending on how many degrees of freedom we liked. Our goal, then, was to develop estimates based on as many models or CERs as we could find and then defend our most favored estimate or a synthesis of estimates.

Ultimately, we strove to challenge the goodness or <u>quality</u> of every estimate as much as its pedigree. And, did it matter if the purpose was to budget, support an engineering trade, or to challenge a contractor’s proposal estimate? We wanted to know how to assure out clients that our estimate would be a faithful prediction of their future costs.

The Wisdom of Crowds

I developed this paper by consulting my peers (modelers and experts), a process assumed from my reading the 2005 book by James Surowiecki, “The Wisdom of Crowds,” which convinced me that “...under the right circumstances, it’s the crowd that’s wiser than even society’s smartest individuals.” A sampling of their opinions is deliberated in this paper.

My initial premise was that an estimate is a prediction of a future event – in this case predicting the cost and schedule to deliver a product or execute a program. I wondered, however, how well we can measure the estimate reality (statistics) or should we focus on perception (the right stuff). Would we know it when it when we see it, as a few of my peers suggested?

Rod Stewart, former president of the National Estimating Society and author of the 1982 book, "Cost Estimating" advised (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 WBS and dictionary…every element in the structure must be fully described to allow the specialist to estimate accurately the resources to do the job." And, this was in the day when estimators relied on calculators and paper handbooks.

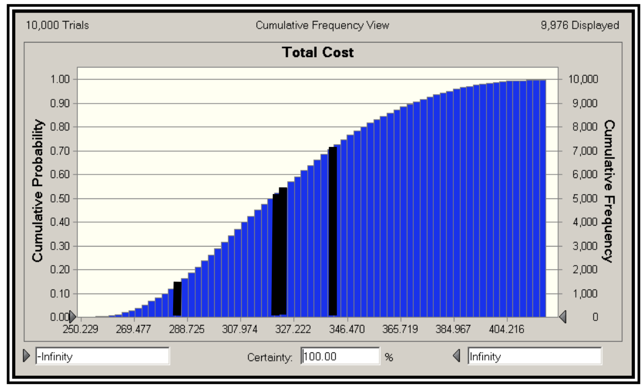


Figure1. What is the confidence level (cumulative probability) that the program can be completed for a budget set to a pre-determined cost estimate*? Ref: Book, S.; Private Papers.*

Estimators and cost model developers consider accuracy, completeness, and reasonableness as fundamental quality metrics. But the final "proof" of the estimate cannot be established until the program is complete and, by then, the estimate is no longer of interest. Perhaps, we should assure the **perception** of the "goodness" of every estimate, when judging the estimate as high on the metric "**credibility**."

What the modelers think

My mentor**, Steve Book,** convinced me that the answer was rooted in statistics - that the confidence level of the estimate is the logical proxy for its **credibility** (figure 1), *providing the input data, groundrules, and assumptions were valid and relevant*. In other words, what is the probability that my client will have enough budget to complete his project? It is here, also, that we consider **Joint Confidence level (JCL)** to assess the likelihood that the project can be completed within cost (budget) <u>and</u> schedule goals (figure 2). NASA applies this metric to entire portfolios to establish program level confidence levels. This approach supports both risk-adverse and risk-tolerant decision makers.

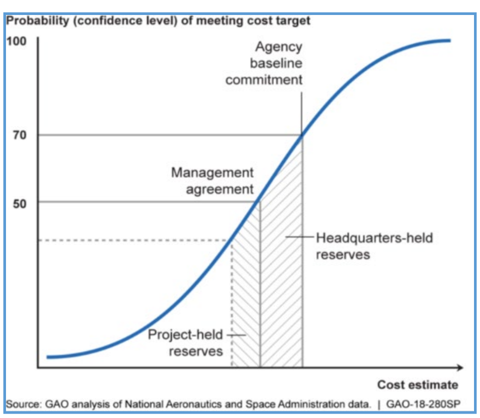


Figure 2. this S-Curve considers both cost and schedule uncertainty. Ref: NASA Cost Estimating Handbook; 2014.

From a practical aspect, programs typically can be baselined and budgeted at 70% confidence and funded at 50% confidence. When considering cost and schedule uncertainty, this metric ranks high on the candidate list of attributes which certify credibility.

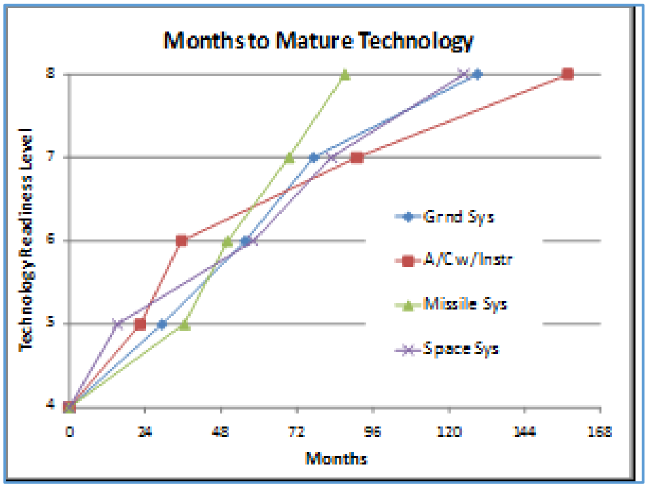


Figure 3. Evidence from program historic cost data confirms that the time (months) to mature takes longer to achieve a higher technology level (TRL). Reference Malone, P.; MCR; Applying System Readiness Levels to Cost Estimates; IEEE 2020.

For decades, we relied on the traditional (for hardware) cost drivers of weight, complexity, and time for predicting total program cost and schedule duration, especially for the acquisition phase. Lately, we see expansion of our candidate cost drivers list for life cycle cost estimates to include technical readiness levels (TRL) and system readiness levels (SRL) because these parameters consider the cost and schedule impact of the state of development at the beginning of the development period vs the desired technical end state, such as initial operational capability (IOC) and final operational capability (FOC). This approach works well with existing cost estimating models since the impact of TRL can be included as a factor on the original estimate (as shown in Figure 3).

The TRL and SRL parameters rank high on the candidate list of attributes which certify credibility, especially if quantified with a Technology Readiness Assessment (TRA).

A cost estimate without regard for potential cost and schedule **growth** is incomplete. Since the CARD is an unlikely source for this guidance, we must refer to previous project cost history for similar programs. In the absence of relevant cost growth history, we may rely on mass, power, or schedule growth history. Derived cost estimate adjustment factors can then provide the basis for cost growth prediction included in an estimate. This adjustment is sensitive to SRL and TRL factors, discussed above.

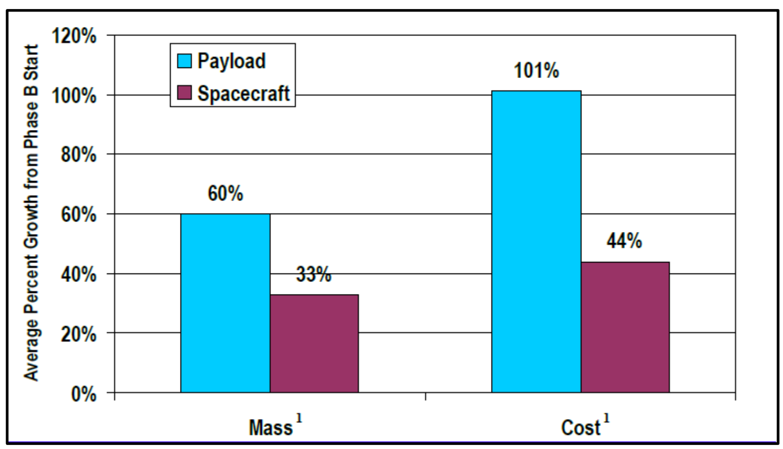


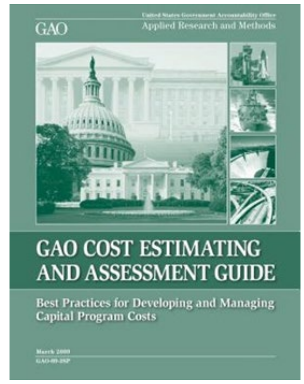
Figure 4. Historical NASA mass and cost growth (Phase B to delivery) for payload and mass. Reference Hayhurst, M.; Aerospace Corp; Historical Mass, Power, Schedule, & Cost Growth; NASA Cost Symposium, 2016.

Mass and cost growth data for space programs typically show more growth for the payloads than for the spacecraft (as shown in figure 4.). In any case, cost growth is a solid candidate for assuring your cost estimate credibility.

A life cycle cost estimate relying on generic history-based operating factors may be a starting point, but the credible life cycle estimate will require development of an operations model which will consider deployment, maintenance, and attrition. Including cost growth in one's estimate can foster an attribute of estimate credibility. Accordingly, consideration of the intended Concept of Operations (ConOps) is vital to assuring estimate credibility.

What the Experts Think

The **General Accountability Office** (GAO) led the crusade, as early as 1972, in its publication, “Theory and Practice of Cost Estimating for Major Acquisitions,” by establishing the following minimum requirements for a **credible** cost estimate in the world of capital programs.



- 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

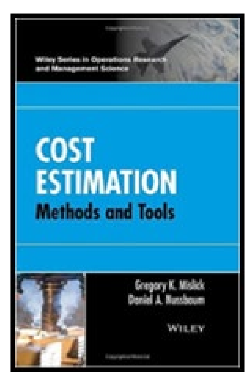
GAO followed in 2009 with its first Cost Estimating and Assessment Guide for use in conjunction with Government Auditing Standards. The guide establishes a consistent methodology for developing capital program cost estimates and presents its actual survey results of federal agency practice on cost estimating.

The **Missile Defense Agency** (MDA) adapted these same GAO estimate credibility requirements to develop its Cost Estimating and Analysis Handbook in 2012. The MDA Chief of Cost Estimating, **Christian Smart**, included in his 2012 Cost Estimating Handbook the following attributes of a credible cost estimate:

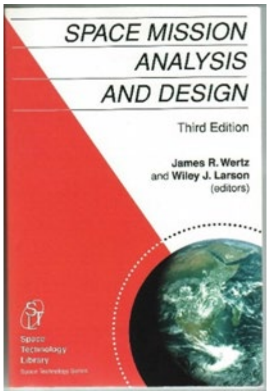
- Using a standard estimate structure (work breakdown structure),
- Clearly identifying all estimating inputs (system description, ground rules, technical characteristics),
- Making available valid and relevant historical data,
- Identifying program uncertainties, and
- Conducting an independent review

The **NASA** Cost Estimating Handbook (updated in 2014) suggests that estimates be documented with reasonable description for each line item, along with **risk confidence levels,** such that another estimator could reconstruct the estimate. Their handbook is clear that “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.” One stimulus to developing the NASA handbook was the NASA case history in the earlier GAO survey. NASA now relies on peer reviews and sanity checks to verify the reasonableness and **credibility** for its estimates.

Andy Prince, Chief Estimator at Marshall Space Flight Center, in his 2011 ICEAA paper, “The Credibility of NASA Cost Estimators.” argues that cost estimate **credibility** is a quality metric (not an accuracy metric) which is dependent upon a sound program baseline, reliable and auditable historical cost data, and a management culture with desire to know the truth. Andy supports his predecessor, **Dr. Joe Hamaker**, then Director of Hq NASA Cost Analysis Division, who wrote in the ISPA Journal (2007) that “… accuracy is important; but we can’t know the accuracy until the project is complete…”



Dan Nussbaum, former Director of the Naval Center for Cost Analysis (NCCA) and current Professor at the Naval Post Graduate School (NPS), argues in his 2015 book “Cost Estimation, Methods, and Tools,” that a good estimate depends on completeness, reasonableness, and defensibility. His co-author and NPS Cost Analysis Chair, Greg Mislick, expanded on what makes a good estimate in a post-publication review as "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."



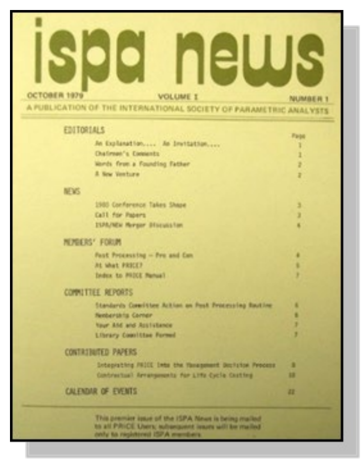
In the Cost Estimating chapter of the 2011 book, "Space Mission Engineering (the new SMAD)," I suggest that cost realism (not accuracy or precision) depends on the <u>perception</u> of the estimate to predict future costs if the estimator used acceptable estimating procedures, calibrated his estimating tools, and scheduled cross-checks.

The 2008 **RAND report** "Guidelines and Metrics for Assessing Space Cost Estimates," suggest that estimate **credibility** depends on completeness (all program elements included), consistency (within the directed program), and reasonableness (using appropriate methods and assumptions). RAND recommends creation of a Cost Analysis Requirements Description (CARD) to document the system architecture, operating scenario, and risk assessment to assure **credibility** of the ultimate estimate.

Defense Contract Audit agency (DCAA) Director **Chuck Starrett**, in his article for issue #1 (October 1979) of the ISPA News (forerunner to the ISPA Journal of Parametrics), identified his five attributes for judging a cost estimating <u>model</u> to be **credible** are:

1. Logical parametric relationships,
2. Verifiable cost and technical data,
3. Significant statistical relationships (high r^2),
4. Reasonably accurate predictions (requires keeping track), and
5. Continuous monitoring and recalibration of the CERs.

These same criteria were later introduced into the DCAA Auditing Manual.



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The next DCAA Director, **Bill Reed**, in his keynote address to the 1993 ISPA Conference in San Francisco, stressed that **credible** cost <u>estimates</u> need to:

1. Be based on actual cost history,
2. Be stable over time,
3. Result from open communications between estimators and their managers,
4. Be consistent with a company's written policies and procedures, and
5. Be made or reviewed by the person ultimately responsible for performing the work.

In 2006, the Journal of Parametrics initiated a series of five articles on assuring quality in cost estimates. In the first article, **Rich Hartley**, then Deputy Assistant Director of the Air Force for Cost and Economics, identified several areas "to watch out for," some of which are:

- Lack of transparency associated with data sources and estimating methods,
- Unrealistic risk analysis, failure to define risk assumptions, or not linking risks to cost impacts, and
- Excessively detailed briefings to decision makers or dependence on extraneous information.

The second of five articles, this one by **Dr. Joe Hamaker**, then Director of the Hq NASA Cost Analysis Division, offered the following attributes of quality in cost estimates 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, and
- A management culture that desires good estimating.

The third of five articles, by **Dick Janda**, Lockheed Martin Vice President of Program Assessment and Evaluation, offered the following check list for a quality estimate:

- Is the estimate based on objective data, not cherry-picked data?
- Is the estimate honest?
- Are the data and analysis relevant?
- Is the basis of the cost estimate logical?

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. He established the Army Cost Review Board (CRB) to combine multiple cost estimates (program office, independent estimate) into a single Army Cost Position (ACP) with several initiatives, since as linking capability with cost.

The final article, by **Herve Joumier,** Chief of Cost Estimating for the European Space Agency (ESA), defined estimate qualities from his perspective as:

- To forget the magic number concept,
- Recognize the dangers of the "initial poor or naïve cost estimate" paradigm, and
- Recognize the value of accountability [who prepared the estimate].

The 2015 ICEAA Conference Overall Best Paper by **Andy Prince** suggested the following estimating "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), and
- Falling in love with a subjective assessment.

Consensus

But where is the consensus of this peer wisdom? My conclusion is that a **credible cost estimate**, can be assured by these following five elements:

1. A state-of-the-art, transparent, and clearly defined estimating structure and process;
2. Correct use of calibrated cost models (or statistically qualified CERs) based on relevant and verified data;
3. A defined baseline, sound assumptions, and a full set of relevant cost drivers;
4. Peer reviews, sensitivity analyses, and crosschecks; and
5. Enhanced by cost and schedule predictions with joint confidence assessment.

And, that's how I see **credibility** as our most significant estimate attribute.