

# Assuring Credibility in the Cost Estimate; Part II

- ICEAA Workshop, May 2020; Processes & Best Practices Track [not presented]
- ICEAA Distance Learning Series, Aug 2020



Henry Apgar  
MCR Solutions LLC  
McLean, VA  
hapgar@mcricri.com

# Introduction

## ABSTRACT

This presentation updates the original, presented at the 2016 ICEAA International Workshop (Bristol), which traced the maturation of cost estimating attributes and focused on **cost estimate credibility**. Evidence is provided in the words of government and industry executives, estimating and engineering handbooks, professional journals, and government auditing manuals. This update incorporates the credibility of contemporary cost drivers such as system maturity and cost growth. This presentation concludes with guidance for the estimating professional.

## BIO

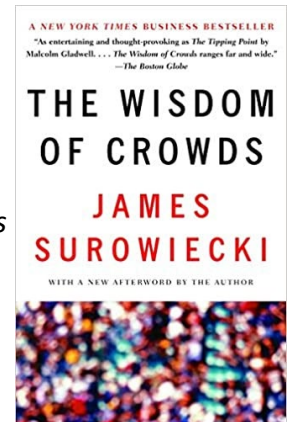
**Henry Apgar** is an ICEAA lifetime member and Certified Cost Estimator/Analyst (CCEA). He is co-founder of ISPA and has earned its Lifetime Achievement (Freiman) Award. Hank is a Cost Analyst for MCR where he develops parametric cost estimating models and prepares independent cost estimates for international clients. He has a BS degree in electrical engineering and an MBA. Hank authored the Cost Estimating Chapter for the Space Mission Engineering Handbook and he was elected an AIAA Associate Fellow.

# So, What is *Cost Estimate Credibility*?

- Is it enough to use good models based on verified data?
- Are there rational synonyms for **credibility**, such as confidence level, realism, accuracy, or reasonableness?
- Should 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 my program manager or my customer that my estimate is a **credible prediction** of a future event?

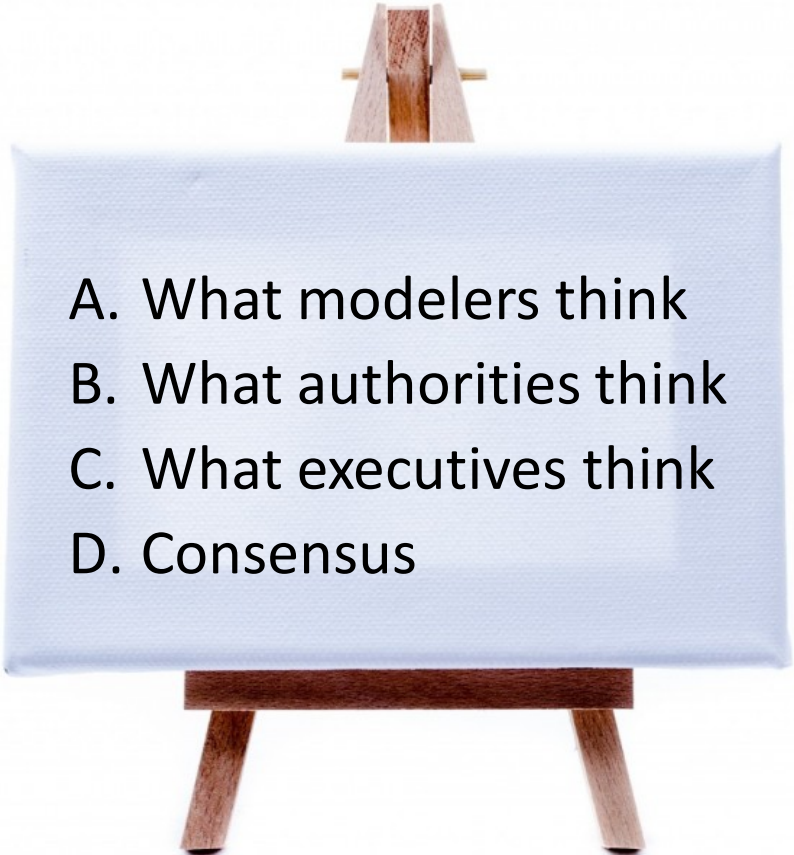
Let's ask our peers .....

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.*” ***This revision is based on feedback from my peers.***



**Credibility...the quality of being convincing or believable**

# Presentation Outline

- 
- A wooden easel with a white sign attached to it. The sign contains the presentation outline.
- A. What modelers think
  - B. What authorities think
  - C. What executives think
  - D. Consensus

## A. What cost modelers think regarding:

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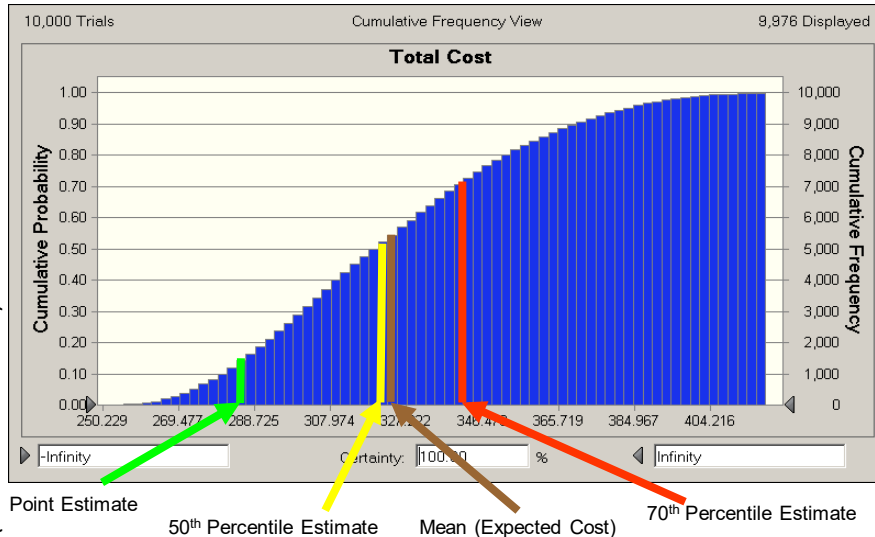
- Uncertainty/JCL
- SRL/TRL
- Growth (cost, mass, power)
- Concept of Operations



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# Estimate Uncertainty (Confidence Level)

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

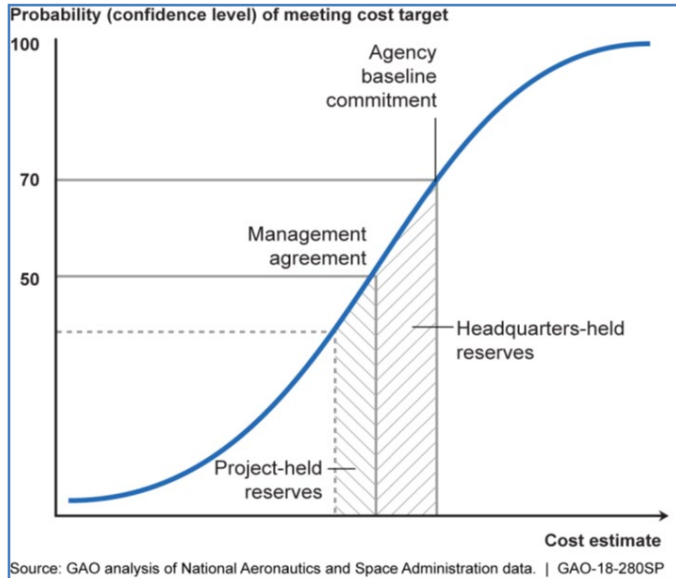


Graphic courtesy of **Steve Book**, mentor to many of us.

← Estimated Cost

- Is it good (convincing) enough to just cite a *range of estimates* or do we need a *point estimate with a probability*?
- Does consideration of **estimate confidence enhance estimate credibility?**

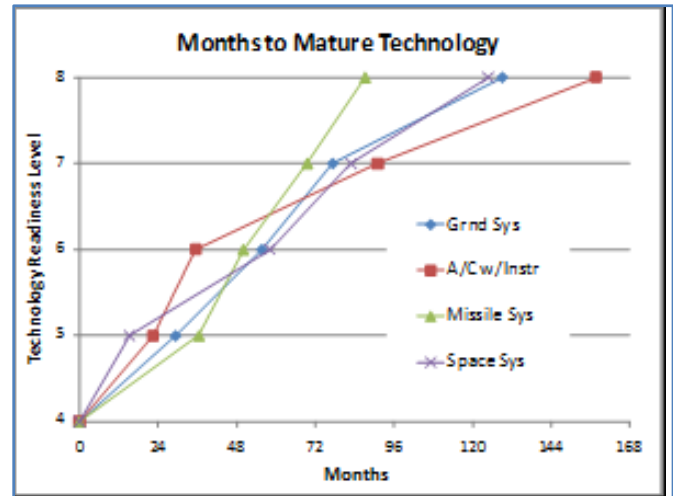
# Then, What about Joint Confidence Level (JCL)?



- GAO promotes 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).
- Or, is this a case of confidence in the program plan rather than in the program estimate? [maybe, that is our intent]

# Technical/System Readiness Levels (TRL/SRL)

- Extends analysis beyond weight and complexity cost drivers.
- Technology Readiness Assessment (TRA) assesses amount of “new design” required.
- TRL 8 vs TRL 6, for example
- System Readiness Level (SRL) assesses effort to achieve initial and full operational capabilities (IOC and FOC).
- Both factors enhance **credibility** of cost and schedule estimating.



Ref: Malone, P.; MCR; Applying System Readiness Levels to Cost Estimates; IEEE 2020.



# Predicting Cost Growth

- Rely on cost history of similar programs.
- Affects design maturity and redesign.
- Derive from predicted mass or power growth.

- May affect payload more than spacecraft.
- Consideration of cost growth enhances estimate credibility.

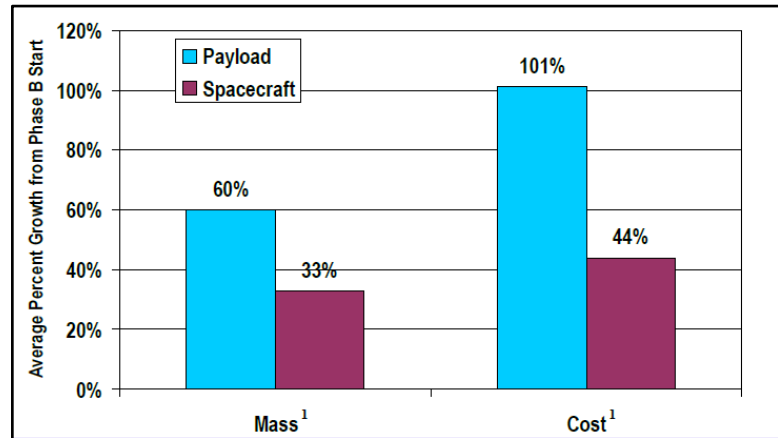
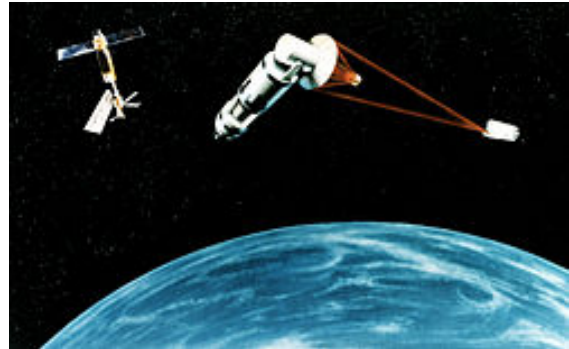


Figure ref: Hayhurst, et al; Aerospace Corp; Historical Mass, Power, Schedule & Cost Growth for NASA Instruments & Spacecraft; NASA 2016 Cost Symposium

# Concept of Operations (ConOps)

- ConOps is stakeholder's description of what the system should do and how it supports his operations.
- Certainly for life cycle estimate but also impacts development and production estimate; technology and operational assumptions are interdependent.
- Evidence of trade between design and logistics [between component reliability and MTBF] enhances estimate credibility.



*So, that's what modelers think*

Reference: Mordecai, N. et al; Towards a Model-Based Concept-of-Operations; IEEE 2020 Conference

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Presented for the International Cost Estimating & Analysis Association - [www.iceaaonline.com](http://www.iceaaonline.com)

## B. What the authorities\* think at:

- NASA
- MDA
- GAO
- QinetiQ
- Microcosm
- RAND

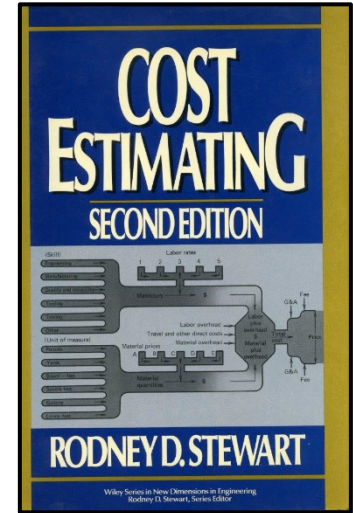
\*Authorities = authors of textbooks, journals, handbooks, etc.





# Cost Estimating (text)

- Early definitions: **Rod Stewart's\*** textbook on “Cost Estimating” advises 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 complete and detailed Work Breakdown Structure (WBS) with Dictionary\**.”



\*Defines the estimate

\***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).

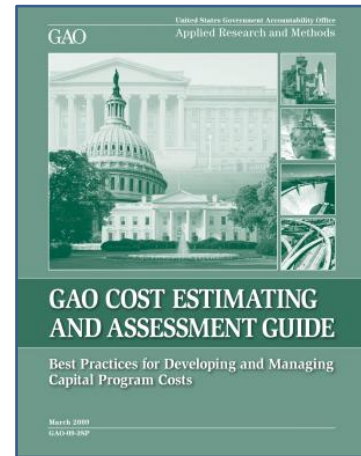
# GAO Cost Estimating and Assessment Guide

## Best Practices for Developing and Managing Capital Program Costs

First edition Nov 2009, General Accountability Office



- Incorporating “Theory and Practice of Cost Estimating for Major Acquisitions,” in subsequent editions [1972]
- Link cost estimating and EVM (performance-based program management) based on differences between estimated and actual costs.
- Integrate cost estimating, system development oversight, and risk management.
- Guide for Government Auditing Standards for federal audit community.
- After major industry survey (2006), including NASA and other case studies, GAO developed a process for developing **credible cost estimates**.



# MDA Cost Estimating & Analysis Handbook

- In 2012, **Dr. Christian Smart**, then **Chief of Cost Estimating, Missile Defense Agency (MDA)** published his Cost Estimating and Analysis Handbook, based partly on the revised 1972 GAO definition\* of what is required for a **credible cost estimate**:
  - Clear descriptions (system/subsystem tasks, estimating ground rules, technical characteristics).
  - Standard estimate structure (**WBS**)
  - Broad participation - include all stakeholders
  - Ensure data validity
  - Provision for program uncertainties (allow for unknowns)
  - Independent review

\* "Theory and Practice of Cost Estimating for Major Acquisitions" GAO



# NASA Cost Estimating Handbook

planned for update in 2020

- “...**Documentation** should include a reasonable description of each line item, along with **risk confidence levels** .... The level of detail varies ... but ... should be enough for another estimator to reconstruct the estimate.”
- “...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 ...different models and techniques.”
- *The handbook was a partial response to the 2006 GAO survey of NASA cost estimating credibility.*
- “...A **peer review** is another important part of completing an estimate...Before the estimate is presented to decision makers, ... get an outside review. This “sanity check” can provide an outside perspective and a fresh view of the estimate ... before presentation.”



# NASA/Marshall Space Flight Center (Paper/Journal)

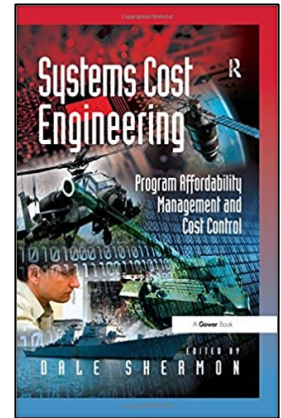
- **Andy Prince**, Cost Estimating Director, NASA/MSFC, “The Credibility of NASA Cost Estimates” (2011) Paper, argues that:
  - Credibility is a **quality metric**, based on :
    - Degrees of independence of the estimator,
    - Sound technical and program baseline,
    - Risk analysis and cross-checks,
    - Auditable historical data
    - Linkage to schedule
  - Management culture with desire to know the truth
- Andy’s predecessor, **Dr. Joe Hamaker**, then Director Hq NASA Cost Analysis Division, ISPA Journal (2007) advises “... **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**).”





# Systems Cost Engineering (Text)

- Dale Shermon (UK, QinetiQ) also endorses the metric “**accuracy**” for a parametric cost **model**; accuracy can be improved by **calibration** of
  - **product** (complexity, technology) and/or
  - **organization** (accounting structure, productivity)e.g., running the model in reverse and then estimate at lower WBS levels, e.g., PRICE Systems “ECIRP”.
- Dale recommends a **quality assurance program** to maintain discipline in cost model application through multiple estimating methods/models and historic trend analysis.

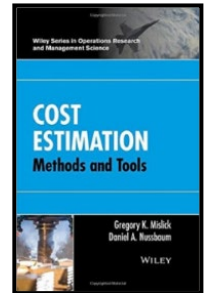


2009, Gower

# Cost Estimation, Methods And Tools (Text)

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

\*In post-publication interview, Greg expanded on what makes a good estimate: *"...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 ...how you came to these conclusions."*



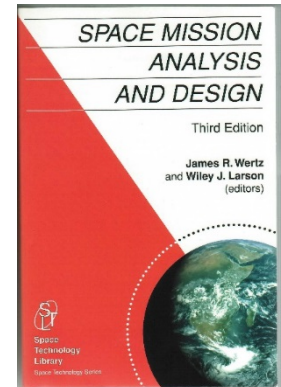
Wiley 2015



2016 ICEAA Educators of the Year

# Space Mission Engineering (Handbook)

- **Jim Wertz**, David Everett, 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, former ISPA Pres) defines cost realism as the perception of the estimate, i.e., how likely is the estimate to closely predict the future event - conveys inherent quality of the prediction:
  - Applied accepted estimating procedures
  - Proven (and calibrated) estimating tools
  - Demonstrates estimating cross-checks and second opinions



Earlier version of SMAD

# RAND (Reports)



- **Bernie Fox**, et al, RAND (2008), “Guidelines and Metrics for Assessing Space System Cost Estimates” [available at <http://www.rand.org/pubs>]
- How to **assure** your estimate is **credible** [it’s 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).
  - Recommend a Cost Analysis Requirements Description (**CARD**)
    - System description, operating scenario, acquisition schedule,
    - Risk assessment

# C. What the Cost Executives think at:

after modelers and authorities

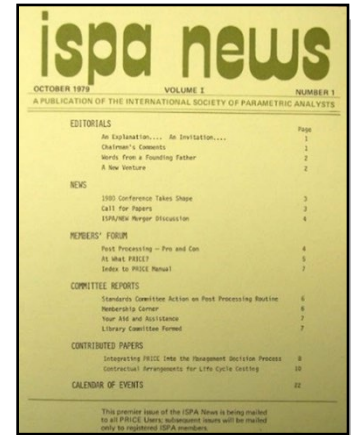
- 
- Defense Contract Audit Agency
  - Air Force CAIG - now Cost Analysis and Program Evaluation (CAPE)
  - Hq NASA
  - Lockheed Martin
  - European Space Agency (ESA)



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# DCAA Auditor's Perspective (Journal)

- August 1991 ISPA Journal reprinted **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**]
- Referred to a previous article in (October 1979 ISPA News) by **Chuck Starrett**, then **DCAA Director**, who identified current **cost model auditing criteria (still used)** before submitting estimate to government:
  1. Logical relationships,
  2. Verifiable data,
  3. Significant statistical relationships (high r-squared),
  4. Reasonably **accurate** predictions, and
  5. Proper systems monitoring [of data/models].



ispd news	
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This premier issue of the ISPA News is being mailed to all PRICE Users; subsequent issues will be mailed only to registered ISPA members.

# DCAA Director's Perspective

- The ISPA Journal of Parametrics reprinted the **1993 ISPA Conference Keynote Address** by **Bill Reed, DCAA Director**. Referring to 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 identified where contractor cost **estimates** were **failing credibility test**.
  - 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.
- Barrier to the founding of ISPA was perception that parametric estimates could not be audited; here was contrary evidence.



# Beginning series of Journal Articles:

## 1. Air Force CAIG [now CAPE]

- The Summer 2006 **ISPA** Journal featured first of a series of invited articles - **Rich Hartley** [Chief, Cost Analysis Improvement Group (CAIG)\* and Deputy Assistant Secretary of the Air Force for Cost and Economic entitled “What are **Quality Cost Estimates**?”
- Identifies following areas to ‘watch out for’:
  - Lack of transparency with data sources or methods; failure to establish clear track from actuals to estimates; “cherry-picking” of data.
  - Unrealistic risk-analysis results; not defining risk inputs 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 with the cost estimate.
  - Lack of, or improper, model calibration.
  - Overlooking WBS elements (i.e., systems-of-systems level, systems engineering, program management, etc.).



\* Now, Cost Analysis and Program Evaluation (CAPE)



# 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

- Fall 2008 issue of the **ICEAA** Journal of Cost Analysis and Parametrics (successor to the ISPA Journal of Parametrics): contractor perspective by **Richard Janda**, VP of **Program Assessment and Evaluation, Lockheed Martin**.
- Believes the following characteristics assure a **quality cost estimate**:
  - Is the estimate based on **objective** data?
  - Is the analysis **honest**? [the honest broker credential]
  - Are the data and analysis **relevant**?
  - Is the basis of the cost estimate **logical**?
  - How well is the estimate **communicated**?



# Continuing Journal Series:

## 4. Army CEAC

- 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)** describes Army process to ensure adequate cost estimates:
  - 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.
- Where possible, link capability to cost.



# Continuing Journal Series:

## 5. European Space Agency

- In 2011, the European Space Agency (ESA) submitted (ICEAA Journal 2011); **Herve Joumier, Chief of Cost Estimating, ESA, “Quality Cost Estimates ...”**
  - 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) by **constraints**:
    - 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**, in *The Psychology of Cost Estimating*, warns of an overtly-biased estimate from these “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 “not doing things the ‘old way; and
- Falling in love with subjective assessment.



# D. Consensus

*So, The wisdom of the crowd (our peers) advises that the **cost estimate credibility** can most likely be assured by four major attributes:*

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 pertinent and verified data;
3. A defined baseline, sound assumptions, and a full set of relevant cost drivers;
4. Peer reviews, sensitivity analyses, independent reconciliations, and crosschecks; enhanced by joint cost and schedule confidence assessment.