Back to the Big Easy: Revisiting Hilbert's Problems for Cost Estimating

MG1-7

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International Cost Estimating and Analysis Association (ICEAA) Annual Conference

Tuesday, June 18th, 2013 – Friday, June 21st, 2013

Abstract

At the International Congress of Mathematicians at the Sorbonne in Paris in 1900, German mathematician David Hilbert boldly put forth a list of 23 theretofore unsolved problems in mathematics, which subsequently became quite influential in 20th-century research efforts. At the Joint SCEA/ISPA Conference in New Orleans in June, 2007, the authors audaciously emulated Hilbert with a list of 21 problems for cost estimating and risk analysis. Because cost is an inherently but not purely analytical field, some of the problems took the form of broader issues to be addressed, and because cost is an interdisciplinary field, there's always a chance some of the problems may have been solved elsewhere (such as in the realm of probability and statistics) but the solution not yet fully "imported" into the cost world. This paper is a progress report of sorts, summarizing much of the research that has occurred in the intervening six years, and adding in a few new problems we neglected to include the first time because our proverbial headlights did not shine far enough down the cost estimating highway.

The original problems were grouped into four categories. The first, Professional Identity, comprised the **body of knowledge**, **community of practice**, **analyst paradox**, and **integrity** of the profession. Developments here include the merger of ISPA and SCEA to form ICEAA; the rebirth of CostPROF as CEBoK, and designation of the Body of Knowledge (BoK) Chair distinct from Training; the publishing of the GAO Cost Estimating and Assessment Guide; the establishment of the OSD CAPE by WSARA, subsuming the erstwhile Cost Analysis Improvement Group (CAIG); and the continued reinvigoration of the profession by bright young analysts as the Baby Boomers draw ever nearer to retirement.

The second category, Analytical Techniques, comprised **double analogy**, **theoretical probabilistic underpinnings**, **standardization of CERs**, **thought experiments**, **grand unified theories**, or GUTs, of **learning curve** and **estimates at completion (EACs)**, **physics-based estimating**, and estimating **emerging technology**. Developments here include numerous papers on risk, general-error regression models (GERM), serious concerns with the traditional Cumulative Average (CUMAV) learning curve formulation, progress-based EACs, and new trends in software and automated information systems (AIS), including enterprise resource planning (ERP). Other technological advances likely remain buried in the black world.

The third category, Cost Estimating Implementation, comprised **meta-cost estimating**, **data rights management**, **epistemology of cost models**, and **blended cost models**. There has been perhaps the least progress here, though developments such as XML-based CPRs, IMS-based cost models, and conflation of multiple probabilistic estimates show some promise.

The fourth category, Integration with Related Disciplines, comprised "**self-fulfilling prophecy**," **skewness in risk**, **portfolio management**, **contract incentives**, and the **uncertain partnership with cost management**. Developments here include the infamous 80th percentile of WSARA and its retraction, research into heteroskedastic regression models for the size effect, extensions of risk-based return on sales (ROS), and the Better Buying Power initiatives. A combination of the debt crisis, pending

sequestration, and the end of the wars in Iraq and Afghanistan promises to spur renewed interest in portfolio management for the DoD.

While the original list of problems was surprisingly relevant and comprehensive, a few major areas were not anticipated. One is the emergence of joint cost and schedule risk analysis; the related interest of cost estimators in schedules, as evidenced by GAO's "sequel" Schedule Assessment Guide; and the coincident improvements in Monte Carlo simulation technology. Other key risk analysis areas include the enhanced scenario-based method (eSBM), the use of SME assessments, and data-based coefficients of variation (CVs) and correlations.

Background – Will the Real Hilbert's Problems Please Stand Up?

David Hilbert, Henri Poincaré, and the Turn of the Century

In 1900, German mathematician David Hilbert boldly put forth a list of 23 theretofore unsolved problems in mathematics (in the process anticipating Michael Jordan's uniform number by several decades!). On August 8th of that year, he famously discussed ten of the problems at the International Congress of Mathematicians, a party if there ever was one, held at the Sorbonne in Paris. Subsequently, these problems became quite influential in 20th-century research efforts in the field of mathematics. (There was even a red-headed stepchild of a 24th problem.) While these problems were not necessarily new, Hilbert distilled and focused attention on them. Some were clearly defined, others were more philosophical or open-ended.Though many were solved, some almost immediately, others remain unsolved to this day, most famously the Riemann Hypothesis (Problem #8).

Hilbert's Problems came at a time where the whole of known mathematics was quickly exceeding the ken of any one individual, however brilliant. Henri Poincaré, in the early 20th century, is said to be "the *last* person to understand fully all of mathematics."[1]

For more background on Hilbert's Problems, see http://en.wikipedia.org/wiki/Hilbert%27s_problems.

Characteristics of "Hilbert's Problems"

In drawing the analogy – hey, we're cost estimators! – to Hilbert's Problems, we use that as a general term for a set of problems and issues that are intended to focus the community and engage the brightest thinkers. It is a set of problems broader than any one individual can tackle, but by providing some structure to them, we hope to enable broad participation and an informal "division of labor" in addressing them. They also come at a critical juncture in the maturity of the profession.

Often the statement of the problem, or at least the initial stab at it, is a moral victory in and of itself. Some of Hilbert's original problems were sufficiently vague as to spur debate as to the precise formulation of the problem, to such an extent that there is no consensus whether some problems have been adequately solved or not. While we won't claim that Hilbert was purposefully imprecise, we imagine he felt it was more important to do his best to formulate an elusive problem than to leave it unstated altogether, and we have followed the same philosophy here.

There are a couple of key differences between our "Hilbert's Problems" and the originals. Because cost is an inherently but not purely analytical field, some of the problems take the form of broader issues to be addressed, as opposed to specific analytical problems to be solved. Also, because cost is an interdisciplinary field, some of the problems may have been solved elsewhere (such as in the realm of probability and statistics) but the solution not yet fully "imported" into the cost world.

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[1] Ian Stewart, *The Problems of Mathematics* (New York: Oxford, 1987), as cited in Jerry P. King, *The Art of Mathematics* (New York: Plenum Press, 1992).

Hilbert's Problems for Cost Estimating were initially put forward at the 2007 Joint ISPA/SCEA Conference in New Orleans, and what started as a whimsical paper idea was mentioned by then-President of SCEA Dan Nussbaum in his opening remarks. It was a momentous time, arguably the start of serious momentum toward the eventual SCEA/ISPA merger. 2006 was the last year of separate domestic conferences – coincidentally in Washington state (ISPA) and Washington, DC (SCEA) – and 2007 the first year of joint conference training. It is fitting, then, that the first-ever ICEAA conference be held again in New Orleans, and we chose this occasion to revisit the "Hilbert's Problems" laid out in our original presentation. The intervening six years have brought a wealth of new research, some of it by the authors, as well as additional experience, perspective, and awareness. While this still cannot be an entirely comprehensive survey – unlike the turn-of-the-century Poincaré, we don't have complete knowledge of cost estimating and risk analysis – it can still serve as a useful starting point for discussions in the community. Many of these problems could be entire papers – or groups of papers – in and of themselves, and we can only hope to scratch the surface here.

These problems come at a time when many of our most valuable (Baby Boomer) analysts are nearing retirement. In fact, since the last writing, one of the co-authors received the SCEA Lifetime Achievement Award, successfully nominated the inimitable Steve Book for the same, and retired from full-time cost analysis. Steve himself passed away, sadly, but he was remembered in a touching tribute by Neil Albert at the Department of Defense Cost Analysis Symposium (DoDCAS) in February, 2012, and his accomplishments and spirit loom large over the community, spurring us to address challenges such as those outlined herein.

It is hoped that these problems will help engage the "next generation" of analysts as the torch is passed to them, to keep this a vital profession. See also the Analyst Paradox below.

Hilbert's Problems for Cost Estimating – Revising the List

In revisiting and revising our list of Hilbert's Problems, we want to explore whether any have been solved sufficiently so as to be closed; whether new problems need to be added; and whether the open problems should be regrouped in any way.

Closed Problems

Unlike the immediate response to the original Hilbert's Problems, resulting in the solution of a few, none of our problems merits closure at this time. The closest are the first two to be discussed under Hilbert's Problems Metadata

As we present each problem within the five board groups that follow, we will use the same basic structure. First we state the Problem itself, as pithily as possible, usually in a sentence or two. In a few cases, we are coining a phrases (e.g., the "analyst paradox") and may need a little bit more explanation of what we have in mind. Next we describe the Previous Situation, which roughly equates to the state of the world as we observed it back in 2007, or whenever the problem was formulated. In many cases, a considerable amount of work had been done, purposefully or by chance, to address an issue before we decided to canonize it in our list. We summarize that work, and subsequent progress over the ensuing

six years, under the Progress Made heading. Often, we will cite one or more papers in this section, though our bibliography is admittedly not as thorough as we would like.In some instances, we even cite papers from this conference (ICEAA 2013) based on the preliminary listing, though we can only guess at their contents from the titles and our knowledge of the lead author. Finally, we make suggestions for Future Research, and we look forward to dialogue with colleagues in the community to better define the road ahead.

Group #1 – Professional Identitybelow. This is not to say that our original presentation fell on deaf ears, though as statisticians we will not venture to specify the nature of the correlation and the direction of causation, if any. (Did people work on problems because they heard our presentation and were inspired, or did we simply anticipate what they were going to be working on anyway?) We attribute the lack of definitive progress primarily to the fact that ours is an applied field, and very few if any of us have the luxury of devoting all or even a significant portion of our time to research.

New and Unanticipated Problems

There were some problems that either we did not anticipate or we were unaware of at the time. Now that our headlights are shining six years farther down the cost estimating highway, there are a few that we can add. In the spirit of Rumsfeld's unknown unknowns (or perhaps more appropriately, Umberto Eco's antilibrary, as described by Nassim Nicholas Taleb in *The Black Swan*), there are certainly others that we have inadvertently omitted this time around as well.

The new problems discussed below are the use of subject matter experts (SMEs) in Problem

Cost estimating and analysis relies on historical data but is constantly being asked to estimate "state of the art" systems. Examples include the transition from wired to wireless networks, and from manned to unmanned aircraft (and other vehicles); use of advanced materials; and miniaturization, including nanotechnology.

Previous Situation

Often we find ourselves estimating in a "data-poor" environment and trying to make subjective adjustments to account for new technology and/or NWODB.

Progress Made

There has been some success in time-driven parametric trends based on or similar to Moore's Law and Kryder's Law. This includes the work of Blackburn, Cormier, Converse, et al., on RAID storage. Estimating using this approach assumes these trends will continue for some length of time into the future without fretting over which specific technological advances will allow them to continue.

Another approach is capabilities-based costing, which either explicitly or implicitly makes use of technological trends.

In the IT/software world, new architectures such as SOA, and new development processes such as Agile, have presented challenges and opportunities. In hardware, unmanned systems such as UAVs have become increasingly prevalent.Cost of services, such as the Help Desk associated with AIS and business process re-engineering (BPR) associated with ERP implementation, are also of keen interest.

Future Research

The aforementioned double analogy and parametric trend techniques hold promise.

If estimators can be "embedded" with engineers on new technologies, this will help accelerate the pace of data collection and methods development. Commodity-focused professional organizations such as

the Association for Unmanned Vehicle Systems International (AUVSI) (http://www.auvsi.org/) and Help Desk Institute (HDI) (http://www.thinkhdi.com/) can help.

Ironically, the further one is trying to estimate into the future, the further one has to go into the past for supporting data (mirror image!).This idea was more fully developed with the Pierre Pfimlin Bridge illustration at the beginning of Module 2 Cost Estimating Techniques in CEBoK®.

Group #3 – Cost Estimating Implementation; joint cost and schedule risk, data-based CVs and correlations, and top-level vs. detailed risk, all in Problem

There is no systematic process for eliciting assessment from subject matter experts (SMEs) and quantifying the risk and uncertainty inherent in those assessments.

Previous Situation

Expert Opinion method of last resort, but frequently used, especially in risk analysis.

Progress Made

Marc Greenberg paper. "Teaching Pigs to Sing"

"The Correct Use of Subject Matter Experts in Cost Risk Analysis," Richard L. Coleman, Peter J. Braxton, Bethia L. Cullis, NPS ARS 2010, DOE 2010 CFO Conference/Cost Analysis & Training Symposium

Future Research

Developing SME track records.

Group #4 – Cost and Schedule Risk Analysis [New]; and a broader discussion of sister disciplines in Problem

Analysts are often unable to explain to the satisfaction of decision-makers the results of the Monte Carlo simulation for risk analysis conducted on a complex LCCE. The community is divided between top-level methods like eSBM and improving detailed methods that require Monte Carlo.

Previous Situation

Off-the-shelf Monte Carlo simulation tools such as Oracle (formerly Decisioneering) Crystal Ball, @Risk, and ACE RI$K make it all too easy to "turn the crank" and generate a risk-based cost estimate without understanding the process and its inputs and outputs. If inputs are not based on defensible data, and if the process is not implemented correctly, then the outputs are suspect. One school of thought is that we need to focus on improving the inputs and process for Monte Carlo risk analysis. The other, championed by the likes of Paul Garvey, is that a more intuitive top-level risk analysis is preferable.

Progress Made

eSBM can use historically based CVs and even percentiles.

Air Force Cost Risk Uncertainty Analysis Handbook (CRUAH), Air Force Cost Analysis Agency (AFCAA)

"Enhanced Scenario-Based Method for Cost Risk Analysis: Theory, Application, and Implementation" Paul R. Garvey, Peter Braxton, Brian Flynn, Richard Lee, SCEA/ISPA 2012 Best Paper in Risk, *Journal of Cost Analysis and Parametrics*

Future Research

Going forward, both approaches are important.As an acid test for too-steep S-curves, Jim Barattaof NCCA has suggested plotting a nominal Nunn-McCurdy breach, which is not all that uncommon. If it falls at an unreasonably high percentile (above the 99th, say), that is a clear indication that the CV of the estimate is too low.

Group #5 – Integration with Related Disciplines.

Regrouping…Literally!

The previous paper grouped the problems into four areas: Professional Identify; Analytical Techniques; Cost Estimating Implementation; and Integration with Related Disciplines. Ironically, in view of the fact that cost estimating and risk analysis have become more integrated over the years, we choose to split the erstwhile group of Analytical Techniques into Cost Estimating Techniques, and Cost and Schedule Risk Analysis. This is not to say the problems in the former should be divorced from risk considerations, but rather that risk analysis considerations have become so important that they merit a separate group.

Hilbert's Problems Metadata

As we present each problem within the five board groups that follow, we will use the same basic structure. First we state the Problem itself, as pithily as possible, usually in a sentence or two. In a few cases, we are coining a phrases (e.g., the "analyst paradox") and may need a little bit more explanation of what we have in mind. Next we describe the Previous Situation, which roughly equates to the state of the world as we observed it back in 2007, or whenever the problem was formulated. In many cases, a considerable amount of work had been done, purposefully or by chance, to address an issue before we decided to canonize it in our list. We summarize that work, and subsequent progress over the ensuing six years, under the Progress Made heading. Often, we will cite one or more papers in this section, though our bibliography is admittedly not as thorough as we would like.In some instances, we even cite papers from this conference (ICEAA 2013) based on the preliminary listing, though we can only guess at their contents from the titles and our knowledge of the lead author. Finally, we make suggestions for Future Research, and we look forward to dialogue with colleagues in the community to better define the road ahead.

Group #1 – Professional Identity

The four problems in the first group relate to our professional identity. As previously noted, the first two are arguably closest to being "solved." They are: defining the **body of knowledge**; aligning professional societies with the **community of practice**; solving the **analyst paradox**, in which there are not enough trained analysts, and not enough intellectually-stimulating work to sustain the current pool of analysts; and affirming the central role of **integrity** in cost estimating, especially vis-à-vis independence, risk, and cost realism.

Body of Knowledge

Problem

Cost estimating and analysis lacks a single unified definition of the body of knowledge.

Previous Situation

Aspects of the body of knowledge have long been captured by various books, papers, and courses, as well as implicitly by experienced analysts. The Cost Programmed Review Of Fundamentals (CostPROF) (2002) training syllabus was a good first attempt at encapsulating the body of knowledge.

Progress Made

At the time of the previous paper, the "CostPROF Update" was underway, which resulted in the release of a brand-new product by SCEA, the Cost Estimating Body of Knowledge (CEBoK®). It was purposefully renamed to emphasize the fact that it was no longer just a training curriculum, but also a desktop reference and codification of the body of knowledge. Features such as the Glossary, Bibliography, and Solutions Key to the Student Exercises made it more robust as SCEA's flagship product. Regular updates have produced new versions in October 2010 (v1.1) and May 2013 (v1.2), focused on expanding and enhancing the content; adding new topics, including the latest research; and better explicating existing ones. The authors have served as managing editor and senior reviewer, respectively for CEBoK® throughout its life cycle.

In parallel with CEBoK® development, Peter Andrejev and Kate Hiebert led the overhaul of SCEA's certification program, resulting in a two-level certification, with Professional Cost Estimator/Analyst (PCEA) requiring a minimum of two years' experience and encouraging new analysts to "stick with it"; and Certified Cost Estimator/Analyst (CCEA) still requiring five years' experience. A new, more robust two-part certification examination added a case study and achieved a more consistent and broad coverage of the body of knowledge. There has been significant interest in certification across the community, and large numbers of analysts have been certified at a desirable passing rate.

At about the same time, ISPA released the fourth and final edition of the Parametric Estimating Handbook (PEH), its flagship product.

Future Research

Two significant enhancements are planned for CEBoK® in the near term: the incorporation of the PEH, so that the new merged society has a single "merged" body of knowledge; and an overhaul and expansion of the cost and schedule risk analysis content. In addition, various possibilities are being considered for "Son of CEBoK®," including web distribution of training materials; online, on-demand training (think Khan Academy); an online bibliography, with direct access to research papers; and a Wiki to support a continually-updated (but not crowd-sourced – there ain't no crowd!) body of knowledge.

Community of Practice

Problem

Professional societies are not optimally aligned to support the cost estimating community of practice as a whole and are not taking full advantage of widely-available knowledge management and "social software" tools.

Previous Situation

Cost community interaction was primarily limited to conferences and small groups, such as ISPA/SCEA, DoDCAS, SSCAG, and the like. Professional organizations had chapters; government cost groups sponsored events, such as the NRO and Aviation CIPTs; corporations formed internal communities of practice (CoPs); and DAU and AFIT met training needs, primarily for government analysts required to pursue DAWIA certifications. Even when organizations are quite large, the cost component is relatively small. At best, this balkanization is inefficient; at worst, it could undermine the entire community.

Exacerbating the situation, the community was not very "electronic." There were maybe one or two email discussions each year.

Progress Made

It has taken the intervening six years for the ISPA/SCEA merger to come to fruition, and the first duly-elected board will take office on 01 July 2013, shortly after this conference. While that step has achieved significant efficiencies for the erstwhile ISPA and SCEA constituencies, there is still a broader cost community, both those active in the defense community who are not involved in ICEAA, and those in other industries (civil, oil and gas, etc.) more aligned with other societies like AACE International. Efficiencies have been achieved in the areas of the International Business Office; governance; conferences; publications; training; and body of knowledge, to name but a few.

Thanks to the tireless efforts of Don Clarke and others, the ICEAA website is greatly improved and database-driven, with features such as electronic access to publications and meeting minutes, and member lookup. ICEAA entered into a new publishing relationship with Taylor and Francis for the *Journal of Cost Analysis and Parametrics*, making it available online as well. Outside of ICEAA, DAU's Acquisition Community Connection (ACC) is available as a forum for policy and guidance, but it remains seldom-used, and its underlying software is clunky at best when compared with modern web standards.

Under the leadership of Dan Nussbaum and others, the Master's in Cost Estimating and Analysis (MCEA) distance learning program was jointly established by the Naval Postgraduate School (NPS) and Air Force

Institute of Technology (AFIT), helping meet the need for an advanced degree program for cost estimating professionals working full time.

A vision with two components was laid out in the previous paper. The first – "Ideal end state seems single society with Parametric SIG" – has largely come true, though the Parametric Special Interest Group (SIG) is still forming and storming under the leadership of Greg Kiviat. The promise of the second – "Centralized online community to enhance interaction and collaboration" – has yet to be realized, but baby steps have been taken on LinkedIn (where the SCEA group devolved into Del Rice's personal chat room) and Twitter, and more importantly with chapter-sponsored webinars.

Future Research

Rick Collins, Daniel Mask, and Eric Nardi are leading a Strategic Planning activity for ICEAA, including analysis of strengths, weaknesses, threats, and opportunities (SWOT). It will continue to develop Parametric SIG, and possibly others. With the expansion of ICEAA into UK, continental Europe, Australia, and Japan, it will need to go through some growing pains to become a truly international organization, exploring potential partnerships with SCAF, DACE, and others.

Analyst Paradox

Problem

The pool of trained analysts insufficient to support current market demand, yet there is not enough "cool" work to go around.

Previous Situation

Much of the cost estimating field has evolved into a de facto caste system, with a few graybeards and their acolytes, and an army of "worker bees." This is exacerbated by "Peter Principle," as many top analysts get promoted to management positions. When not doing hard-core math day in and day out, one's analytical skills tend to atrophy (or they may have gone undeveloped in the first place). The right "hump" of bimodal workforce (Baby Boomers) is nearing retirement.

Progress Made

Many government and contractor organizations have established successful "farm team" programs for interns and new college hires, though they are sometime difficult to sustain for long periods of time. Intensive training and certification programs, many relying on CEBoK® and CCEA, have helped.

Future Research

We need to strive for improvement in bringing the breadth and diversity of workforce to bear on analytical problems,while making best use of talents. We should "share the wealth" for both methods development and research, and applied estimating, as a healthy balance of the two leads to well-rounded analysts, and the precise balance can vary quite a bit from individual to individual.

Integrity

Problem

There is no formal acknowledgment of the particular importance of integrity in the pursuit of cost estimating and risk analysis.

Previous Situation

Integrity is the foundation for independence, intellectual honesty, and other characteristics vital to the profession. The inherent uncertainty in estimating makes integrity more, not less, important. To date, there has been no explicit community-wide commitment to integrity, and it is too important to take for granted. Natural pressures often threaten to compromise independence and objectivity.

Progress Made

Many government agencies and corporations have ethics and compliance programs, and these are necessary but not sufficient, as they may have a limited focus (e.g., timecard reporting). Sadly, there have been unfortunate incidents in recent years, such as the misuse, intentional or incidental, of competitor data. There have also been shining individual examples of a commitment to integrity, wherein analysts have suffered personally as a "reward" for doing the right thing.

"Two Timely Topics: Independence and Cost Realism," R. L. Coleman, J. R. Summerville, S. S. Gupta, ASC/Industry Cost/Schedule Workshop, Oct 04, SCEA/ISPA 2005

"A Case Study in EAC Growth," R. L. Coleman, SCEA 2010

Future Research

It is recommended that the new merged ICEAA incorporate integrity in membership, training, and certification. This can serve as a discriminator in comparison with other professional societies. Estimators must be beholden to the truth, first and foremost.

Group #2 – Cost Estimating Techniques

The seven problems in the second group relate to specific cost estimating techniques: defining the **double analogy** estimating technique; the **standardization of CERs**, developing "open" standards together with documentation requirements, and addressing both factors (including the role of the y-intercept) and analogies (including the adjustment) under the umbrella of the parametric approach; using **thought experiments** in conjunction with systematic data analysis to test theoretical constructs, developing better mental models without overindulging the need to explain; development of a **"grand unified theory" of learning curves**; development of a **"grand unified theory" of estimates at completion (EACs)**; addressing **physics-based estimating**, modeling and simulation, and chaos; and development of techniques for estimating **emerging technology**.

An eighth problem, **theoretical probabilistic underpinnings**, was moved to the new risk analysis group (#4).

Double Analogy

Problem

(Single) analogies are often poorly applied in estimating. One driving problem is the need to account for "paradigm shifts" or new ways of doing business (NWODB) not inherent in the traditional historical analogy data.

Previous Situation

Attempts to account for NWODB stretch the credibility of a single analogy. A departure from historical data results in estimates with weak or no basis.

Progress Made

The "Adjusting Analogies" paper laid groundwork for more systematic and rigorous treatment of analogy estimates. "To b or Not to b" explored the role of a non-zero y-intercept, not present in a traditional scaled analogy but encourage in an adjusted analogy.

"Independent Cost Estimation," Patti Tisone, Richard L. Coleman, ISPA/SCEA 2007

"Analogies: Techniques for Adjusting Them," R. L. Coleman, J. R. Summerville, S. S. Gupta, So. MD SCEA Chapter, Feb 2004, ASC/Industry Cost/Schedule Workshop, Apr 04, SCEA 2004, MORS 2004

"'To b or Not to b': The y-intercept in Cost Estimation," R. L. Coleman, J. R. Summerville, P. J. Braxton, B. L. Cullis, E. R. Druker, ISPA/SCEA 2007

Future Research

Describe a standard approach for the double-analogy technique. Compound traditional analogy adjustment (e.g., weight based) with a second paradigm-shift adjustment from a *second historical program*. That's the key difference from a traditional analogy, which may have multiple adjustment

factors, but they are all based on ratios from the same pair of programs: the historical data point and the system to be estimated. We should also examine the implications for risk analysis.

This is cost estimating according to Ecclesiastes: "There's nothing new under the sun." We're always doing something different, so while we may not have done the particular new thing before, we can find an analogous historical case where we've done something similarly different!

Standardization of CERs

Problem

While the use of CERs as cost-predicting equations seems quite straightforward, *universal "open" standards for CERs and supporting data and documentation are lacking*. A Type 1 solution to this problem would be to develop guidance for the owner of the data so that CER results can be viewed with confidence by the consumer of the estimate. A Type 2 solution – broader and preferred, but more difficult to obtain – would be standards which allow others who do not own the data to use the CERs themselves with the proper reflection of risk and uncertainty.

Previous Situation

Models, estimates, and organizations all have idiosyncratic standards, and there is a lack of consensus in the community. Some regression results state little else than the coefficients, while other provide a slew of statistics, many of which few analysts understand.

Progress Made

CEBoK Module 8 (Regression Analysis) sets forth basic criteria for evaluating CERs, but the focus is admittedly on single-variable OLS. F- and t-statistics are universally acknowledged for judging statistical significance, but there is some disagreement over appropriate significance levels. The default is alpha = 0.05, but some argue for a slightly more lax standard (say alpha = 0.10) for small data sets, which are common in cost estimating.

Equally important is quantification of uncertainty. Too often, only the standard error of the estimate (SEE) is provided, but this only accounts for the "fuzz" and "noise" about the regression line. For very large data sets, this suffices, since we know the true regression line with great precision, but for the aforementioned typical small datasets there is considerable uncertainty in both the y-intercept ("bounce") and slope ("wiggle"), the latter of which is magnified as we move away from the center of the data. For single variable OLS, it turns out it's sufficient to provide the standard error of the slope coefficient, and of course the mean of x. For multivariate relationships, this may be more complicated, as matrix algebra is involved.

Proponents of IRLS, MUPE, ZMPE, GERM, etc., have written papers detailing application of those approaches. "To b or not to b…" (Coleman, et al.)continues to bridges the gap between analogies, factors, and CERs.

"The Use of Analysis of Variance in CER Development," M. E. Dameron, R. L. Coleman, J. R. Summerville, 36th ADoDCAS and SCEA 2003

"'To b or Not to b': The y-intercept in Cost Estimation," R. L. Coleman, J. R. Summerville, P. J. Braxton, B. L. Cullis, E. R. Druker, ISPA/SCEA 2007

Future Research

Develop comprehensive CER standards. More broadly, these could be estimating standards that addressing analogy and build-up estimates as well, and establish standard red/yellow/green/blue color ratings for estimate quality as are often applied in proposal evaluation (see CEBoK® Module 14 Contract Pricing for an example). Standards would distinguish proper and improper application from matters of taste or preference. They would enable (auditable) evaluation of CERs and models even when the data behind them are proprietary.

It would seem that ICEAA would be the appropriate organization to champion standards, at least initial, but a standards organization such as ISO or ANSI could also be considered.

Thought Experiments

Problem

While cost estimating must always rest on analysis of historical data, too often this analysis proceeds without a mental model.

Previous Situation

Analytical techniques tend to be applied by rote, and even when undertaken creatively, analysis can seem willy-nilly or unguided.

Progress Made

Journal articles on predicting learning curve slope for aircraft and missiles, and EACs, have been rife with regressions but little thought or explanation given to why they work. By contrast, great explanatory power can be achieved by analysis that "deconstructs" the data using appropriate, testable, and well-accepted mental models (e.g., Markov chains).

"An Enterprise Model of Rising Ship Costs: Loss of Learning Due to Time between Ships and Labor Force Instability," R. L. Coleman, J. R. Summerville, B. L. Cullis, E. R. Druker, G. B. Rutledge, P. J. Braxton, ISPA/SCEA 2007, 4th Annual Acquisition Research Symposium, 2007, DoNCAS 2008

Future Research

We recommend a balanced approach to data analysis and use of theoretical constructs. Thought experiments can quickly produce "perfect-world" results from hypothesis, which can then be tested using real data. Dirac's belief in "beautiful equations" can co-exist with messy data!

Be mindful of Ockham and Ptolemy. Don't introduce epicycles into models to justify your geocentric world view when the data indicate otherwise. Seek simple (but not simplistic) models, and don't cling to models when statistical evidence accrues against them.

Learning Curve GUT

Problem

Learning curve can often be the single biggest driver in acquisition cost, yet projected learning curves are often assumed with little basis.

Previous Situation

Curves based on superficial analysis or industry standards are often applied. At this very conference, there is a paper that attempts to remedy this situation for satellites.

With lower quantities, it takes longer to establish the true curve of the current program, and the "shelf life" of such curves is short, without understanding disruptive effects.

Cumulative average (CUMAV) theory is still prevalent in many circles. Despite its historical significance, there is increasing evidence that it is not appropriate for estimating, and unit theory should be used instead.

Progress Made

The Advanced Learning Model (ALM) presented in the ships study below systematically accounts for change orders and green labor, and produces a statistically-significant model for loss of learning based on interval (percent overlap).

Hu and Smith have proposed the CUMAV-Iterative alternative to CUMAV-Direct, and while it effectively highlights the shortcomings of the latter, it seems to offer no advantage over unit theory.

"An Enterprise Model of Rising Ship Costs: Loss of Learning Due to Time between Ships and Labor Force Instability," R. L. Coleman, J. R. Summerville, B. L. Cullis, E. R. Druker, G. B. Rutledge, P. J. Braxton, ISPA/SCEA 2007, 4th Annual Acquisition Research Symposium, 2007, DoNCAS 2008

"Cum Ave or Unit? Is the Choice Between Cum Average vs. Unit Theory a Fair Fight?" Bethia L. Cullis, Richard L. Coleman, Peter J. Braxton, ISPA/SCEA 2008

Future Research

Percent overlap approach offers promise for reliable learning curve predictions. The overall modeling approach has potential application to other commodities, such as UAVs and satellites, with the greatest similarity for complex systems with longer build spans. If percent overlap as a driver of learning curve slope proves to be universal, there could even be the potential for application *across* commodities.

It would instructive to rerun the thought experiment in the "Fair Fight" paper using the fair comparisons laid out in Hu and Smith to compare Unit and CUMAV-Iterative.

Estimate At Completion (EAC) GUT

Problem

The so-called "statistical" formulae from the EVM Gold Card are not, and are notoriously prone to "tail chase." That is, at any point, the formulaic EAC is more of a lower bound than a true expectation

(mean). We wish to develop a consistent statistically-significant method for arriving at estimates at complete (EACs).

Previous Situation

In-stride EACs rely on intuitive EVM formulae driven by performance indices, but these formulae seem to consistently underestimate, producing the so-called EAC "tail chase." It is straightforward to devise a thought experiment illustrating how systematic underestimation, "hold back" MR, and optimistic progress reporting shows could produce the tailchase.

Performance indices are quotients, and quotients are not generally statistically well behaved.

Progress Made

Christensen, et al., have systematically examined various formulae and established thumb rules, but this may just be making the best use out of improper tools.

"Do Not Sum…" (Book) proposed a risk-based roll-up of lower-level EACs. This has become a generally accepted practice, but it doesn't address the application of flawed EAC formulae at the lower levels.

Roy Smoker has written some recent papers that try to estimate EAC without getting tripped up by BAC growth, but the most promising are the last two listed below.

"Predicting Final CPI," R. L. Coleman, M. E. Dameron, J. R. Summerville, H. F. Chelson, Steve L. Van Drew, SCEA 2003, ASC/Industry 2003 Cost and Schedule Workshop

"Software Estimation Through the Use of Earned Value Data," Jeff R. Jaekle, Justin W. Greene, Eugene P. Cullen, Eric R. Druker, and Richard L. Coleman, ISPA/SCEA 2007

"Ending the EAC Tailchase," E. R. Druker, R. L. Coleman, J. Jaekle, E. Boyadjis, ISPA/SCEA 2007

"Performing Statistical Analysis on Earned Value Data," E. R. Druker, D. Demangos, R. L. Coleman, Awarded ISPA/SCEA Best Paper on EVM, SCEA/ISPA 2009, DoNCAS 2009, ISPM 2009

Future Research

The essential progress-based EAC approach relies on a family of regressions at various percent complete values. Applied to shipbuilding, this method had its greatest success when an independent measure of physical progress was available outside the EVMS, but traditional earned value percent complete (BCWP/BAC) could also be tried. Early returns show that this approach is unbiased and has a low standard error.

Physics-Based Estimating

Problem

To develop physics-based cost estimates and understand implications for uncertainty in modeling and simulation (M&S) designed for deterministic inputs.

Previous Situation

CERs are often driven by physical measures (e.g., weight), but these are usually understood to be proxies for "content" and/or "complexity"

True physics-based CERs are often attempted in O&S, incorporating reliability theory and other techniques.

Progress Made

In O&S, factors that drive physical wear and tear such as age (Grinnell, et al.) and OPTEMPO (Cincotta, et al.) are potential drivers. For acquisition, a deep understanding of physics relationships and design principles can help with the sizing, and hence costing, of a certain commodity type, as in John Horak's work with radar, and thePerformance-Based Cost Model (PBCM) for ships developed by Mike Jeffers, Bob Jones, Bob Nehring, and others.

Navy's OSCAM attempts to use "systems dynamics" M&S for O&S cost modeling, but does not account for chaotic behavior that may occur due to CER uncertainty.

"How Age Affects Operations and Support Costs Differently Across Platforms," S. E. Grinnell, J. R. Summerville, R. L. Coleman, SCEA 2006

"Incremental Weight and Cost Model," B. A. Brophy, R. L. Coleman, J. R. Summerville, P. J. Braxton, SCEA/ISPA 2005

Future Research

Look for opportunities to expand and solidify physics-based estimating. Understand how chaotic behavior may be introduced in M&S where driving equations (e.g., CERs) have significant uncertainty. Consider interactions with the problems of theoretical probabilistic underpinnings and thought experiments.

Emerging Technology

Problem

Cost estimating and analysis relies on historical data but is constantly being asked to estimate "state of the art" systems. Examples include the transition from wired to wireless networks, and from manned to unmanned aircraft (and other vehicles); use of advanced materials; and miniaturization, including nanotechnology.

Previous Situation

Often we find ourselves estimating in a "data-poor" environment and trying to make subjective adjustments to account for new technology and/or NWODB.

Progress Made

There has been some success in time-driven parametric trends based on or similar to Moore's Law and Kryder's Law. This includes the work of Blackburn, Cormier, Converse, et al., on RAID storage.

Estimating using this approach assumes these trends will continue for some length of time into the future without fretting over which specific technological advances will allow them to continue.

Another approach is capabilities-based costing, which either explicitly or implicitly makes use of technological trends.

In the IT/software world, new architectures such as SOA, and new development processes such as Agile, have presented challenges and opportunities. In hardware, unmanned systems such as UAVs have become increasingly prevalent.Cost of services, such as the Help Desk associated with AIS and business process re-engineering (BPR) associated with ERP implementation, are also of keen interest.

Future Research

The aforementioned double analogy and parametric trend techniques hold promise.

If estimators can be "embedded" with engineers on new technologies, this will help accelerate the pace of data collection and methods development. Commodity-focused professional organizations such as the Association for Unmanned Vehicle Systems International (AUVSI) (http://www.auvsi.org/) and Help Desk Institute (HDI) (http://www.thinkhdi.com/) can help.

Ironically, the further one is trying to estimate into the future, the further one has to go into the past for supporting data (mirror image!).This idea was more fully developed with the Pierre Pfimlin Bridge illustration at the beginning of Module 2 Cost Estimating Techniques in CEBoK®.

Group #3 – Cost Estimating Implementation

The five problems in this area are **meta-cost estimating**, or the application of sound cost estimating principles to the planning and execution of cost estimating itself; development of guidelines for **data rights management**; establishing the **epistemology of cost models**, or how the analyst knows the model is operating as desired to produce the "right" answer (akin to verification and validation); description of **blended cost models**; and a new problem, the use of **subject matter experts (SMEs)**.

Meta-Cost Estimating

Problem

Cost organizations have failed to proactively justify their level of effort (LOE) by equating scope (cost estimating effort) with cost using a basis of estimate (BOE).

The cobbler's children have no shoes!

Taking our own medicine in estimating the cost of cost estimating

Especially as related to the recurring vs. non-recurring effort of cost estimating and analysis

Estimates vs. research

Configuring vs. coding

Staff organizations, where LOE is determined by inertia; or

Program office organizations, where LOE is at the mercy of Program or Business Management

Sometimes cost isn't even in the BOEs!.

Previous Situation

Cost estimating organizations by and large fail to plan and manage the total scope of their effort in a systematic way

Number and scope of estimates

Investments needed in data, methods development, research.

Progress Made

Rule of thumb: NR = Recurring

Meta-cost estimating analogue of Indirect = Direct

Challenge to keep Recurring from producing burn-out, NR from stagnating.Jim Fiume rule of thumb.

Future Research

Greater discipline within cost estimating organizations

Clarify fine line between coding and configuring models

Better "salesmanship" in justifying traditionally unpopular estimating effort to external customers

Decision makers, acquisition, program management, contracts, design engineering, et al.

CAIV for cost estimating: "We could do [xxx] if you gave us [yyy]."

Hard to tie to quality of estimates. Better data collection (tasks/activities).

Data Rights Management

Problem

Adding organizational barriers to data access chokes off an already data-poor environment. Anti-Willie Sutton, go where the data aint!

Previous Situation

Organizations jealously guard their data

Somewhat understandable for industry

Consolidation has created even internal barriers to data!

"Proprietary" misused for "Private"

"Coopetition" necessitates NDAs and careful firewalls

Persistent within government as well

Unwillingness to share across multiple levels

Inability to share, even when government has paid for data.

Progress Made

Data needs addressed on an ad-hoc basis. DCARC, EVM Central Repository, JCARD, Contracts Database.

Future Research

Develop community-wide data rights management plan

Thorny legal, contractual, and financial issues

Approaches to pooling data anonymously or at a sufficiently high level to enable cross-cutting analysis

COTS software often uses this approach.

Epistemology of Cost Models

Problem

How do you know your model is giving the "right" answer?

Are your computations correct? (verification)

Coleman's Commandment: Commit no avoidable errors!

Are your methodologies correct? (validation).

Previous Situation

Presumably COTS and GOTS models undergo some sort of V&V

Widespread "homegrown" Excel models rarely undergo any formal testing

Small errors usually flushed out by an attentive team of sharp analysts

Can be perniciously elusive due to mode scope and complexity

Murder boards (internal) and reconciliation (external) help

Peer programming idea from Agile software development.

Progress Made

Comparison of COTS models looks at end results

Techniques like Conditional Formatting help identify errors.

Future Research

Develop process and guidelines for V&V of models

Address at "cost estimating functionality" level

Inflation, time phasing, learning curve, factors, risk, etc.

Track records cross-check risk analysis V&V

Cf. standarization of CERs.Role of ACEIT, e.g.

Blended Cost Models

Problem

We need a (better) way to incorporate multiple estimating techniques on a simultaneous and continuous basis.

Previous Situation

Cross-checks universally acclaimed but not as widely used

DAU technique transition through cost estimating life cycle generally accepted, but many estimators "stuck in a rut" with pet technique.

Progress Made

Estimates/model may evolve piecemeal throughout program life cycle

No up-front planning

No retention of earlier methods when supplanted by later (presumably more detailed) methods.

"Transitioning from Parametric to Buildup Estimates," A. E. Wiley, R. L. Coleman, M. E. Dameron, B. A. Brophy, SCEA 2004

Future Research

Develop capability in both "homegrown" Excel and COTS/GOTS models

Needs to incorporate simultaneous estimates at different WBS levels.

Use of Subject Matter Experts (SMEs) [New]

Problem

There is no systematic process for eliciting assessment from subject matter experts (SMEs) and quantifying the risk and uncertainty inherent in those assessments.

Previous Situation

Expert Opinion method of last resort, but frequently used, especially in risk analysis.

Progress Made

Marc Greenberg paper. "Teaching Pigs to Sing"

"The Correct Use of Subject Matter Experts in Cost Risk Analysis," Richard L. Coleman, Peter J. Braxton, Bethia L. Cullis, NPS ARS 2010, DOE 2010 CFO Conference/Cost Analysis & Training Symposium

Future Research

Developing SME track records.

Group #4 – Cost and Schedule Risk Analysis [New]

This is the new grouping of the six, comprising the following problems: developing the **theoretical probabilistic underpinnings** for risk analysis associated with cost estimating (previously listed under Group #2 Analytical Techniques), especially addressing the difficulties associated with the fact that our data come from "experiments" that are neither controlled nor repeatable; refuting the **"self-fulfilling prophecy"** of cost growth (previously listed under

Group #5 – Integration with Related DisciplinesAcquisition); the question of **skewness in risk**; the emergence of **joint cost and schedule risk**; establishment of **data-based coefficients of variation (CVs) and correlations**; and **top-level vs. detailed risk**.

Theoretical Probabilistic Underpinnings

Problem

Cost estimating relies on statistical analysis of data produced under "messy" real-world conditions. This is in contrast to the controlled, repeatable experiments typical of scientific data analysis. Another way of stating this problem is that we must always use *cross-program data* (one outcome each of many different experiments) to estimate *within-program uncertainty* (the range of possible future outcomes for one experiment).

Previous Situation

Application of traditional regression techniques to sparse, uncontrolled data sets

Even social science can rely on larger data sets and some manner of control.

Progress Made

The Lady Tasting Tea gives an excellent perspective on the 20th-century statistical revolution in science

"Ship Enterprise Costs…" (Summerville, Coleman, et al.) embodies best-in-breed analysis independent of an underlying probability theory

"Bootstrap Bounds…" (Book, et al.)examines implications of particular assumption of multiplicative errors

"An Enterprise Model of Rising Ship Costs: Loss of Learning Due to Time between Ships and Labor Force Instability," R. L. Coleman, J. R. Summerville, B. L. Cullis, E. R. Druker, G. B. Rutledge, P. J. Braxton, ISPA/SCEA 2007, 4th Annual Acquisition Research Symposium, 2007, DoNCAS 2008

Future Research

Develop a testable probability theory underpinning the data sets and analysis typical of cost estimating

Address questions like: Are we estimating the instance or the mean?

This is a daunting problem – even Kolmogorov was unable to reinvent his probability axioms before his death.

"Self-Fulfilling Prophecy"

Problem

Proper accounting for risk and use of management reserve (MR) are often circumvented by the claim of "self-fulfilling prophecy." This sentiment of "If you budget it, they will spend it!" is often referred to by the acronym MAIMS (Money Allocated Is Money Spent).

Previous Situation

Sufficient risk "wedges" and MRs are rare

IPTs try to "game" system by initially padding estimates.

Progress Made

Thought experiment on spending to budgeted percentile (50th) – see next slides

"Do not budget to 80th percentile…".

"The 'Right' Way To Do Cost Target Allocations: A Confluence of Cost, Risk, and CAIV," P. J. Braxton, B. A. Brophy, R. L. Coleman, J. R. Summerville, SCEA 2004

Future Research

Develop data-based theory of budgets, MR, and cost growth

Work with PM, EVM communities

Apply adequate risk to estimates as long as historical evidence of cost growth persists

Management approach to budgeting to maximize probability of success while minimizing wasteful spending

Budgeting to a high percentile risks inducing self-fulfilling prophecy and failing to fund needed programs

Budgeting to a low percentile minimizes self-fulfilling prophecy but requires larger MRs and efficient process for frequent requests for additional funding.

Skewness in Risk

Problem

While cross-program risk has been demonstrated to be right-skew, it remains unclear whether within-program risk is typically symmetric (normal) or right-skew (lognormal).

Previous Situation

Many studies have asserted the CGF distribution across many DoD programs to be distributed log-normally, e.g., Arena and Younossi1

Especially complicated by the fact that our data come from "experiments" that are neither controlled nor repeatable, and even worse, are assailed for impurities of the SAR data base.

Lognormal often recommended.

Progress Made

A paper by Summerville and Coleman2 presented a risk approach that recommended applying a normal distribution with a mean and standard deviation based on a weighted-average risk score based on several objective measures

Could it be possible that the log-normal distribution described in the Arena and Younossi paper is due to the risk scores from the Summerville and Coleman paper being distributed log-normally?

This would give the illusion of an underlying log-normal distribution when the actual distribution is normal with a mean and standard deviation dependent on the technical score

We're not necessarily advocating dropping the umbrella log-normal assumption that is being used in many methods, especially when the technical score is unknown.

"Analysis and Implementation of Cost Estimating Risk in the Ballistic Missile Defense Organization (BMDO) Risk Model, A Study of Distribution," J. R. Summerville, H. F. Chelson, R. L. Coleman, D. M. Snead, ISPA/SCEA1999

"Risk in Cost Estimating," R. L. Coleman, J. R. Summerville, M. R. DuBois, 1999 Integrated Program Management Conference

"Risk in Cost Estimating General Introduction &The BMDO Approach," R. L. Coleman, J. R. Summerville, M. DuBois, B. Myers, 33rd DoDCAS 2000

"Taking a Second Look: The Potential Pitfalls of Popular Risk Methodologies," Druker, Coleman, Braxton, Leonetti, ISPA/SCEA 2007

Impossible Certainty: Cost Risk Analysis for Air Force Systems, Arena, Younossi, et. al.. Santa Monica: RAND Corporation, 2006

"Cost and Schedule Risk" (CE V), Coleman, Summerville and Dameron, TASC Inc., June 2002

"Normality of Work Breakdown Structures," M. E. Dameron, J. R. Summerville, R. L. Coleman, N.L. St. Louis, ISPA/SCEA 2001

"Distributions for Total Cost – Normals, Lognormals, Triangles and Mistaken Identity," J. R. Summerville, R. L. Coleman, M. E. Dameron, SCEA 2003

"Don't Let The Financial Crisis Happen To You: Why Estimates Using Power CERs Are Likely To Experience Cost Growth," E. R. Druker, R. L. Coleman, P. J. Braxton, SCEA 2009

Future Research

We present this as a thought experiment that could be expanded on at a later date.

Joint Cost and Schedule Risk [New]

Problem

Cost risk analysis and schedule risk analysis have traditionally been conducted in a vacuum from each other (if at all!).

Previous Situation

Cost risk analysis approaches are fairly robust in the community, but the schedule (IMS) has traditionally been the province of the EVM community.

Progress Made

Schedule analysis and schedule risk analysis taught for many years. GAO Schedule Assessment Guide. JCL NASA. Resource-loaded schedule approach, Hulett, Druker. Top-level parametric approach, Michael Ross (ISPA 2012 Best Paper).Advances in simulation (speed and correlation).

"The Relationship Between Cost Growth and Schedule Growth," R. L. Coleman, J. R. Summerville, 35th DoDCAS, SCEA 2002, Acquisition Review Quarterly, Spring 2003

Future Research

Data to support analyses.

Data-Based CVs and Correlations [New]

Problem

Coefficients of variation (CVs) observed in LCCEs are often implausibly low, and correlation is often omitted, not handled properly, or not based on historical data.

Previous Situation

S-curves not shown or not labeled, low CV issue not realized or swept under the rug.Steve Book's famous 0.2-0.3 injected correlation solution was proposed principally to solve low CV issues, not to solve correlation per se. This original proposal has been followed by a number of recommendations for minimum correlations, e.g., the GAO Cost Estimating and Assessment Guide.

Progress Made

NCCA S-Curve Tool, SAR study. AFCAA CRUAMM. GAO Cost Estimating and Assessment Guide.

Future Research

For realistic correlation, an analysis of actual correlations in a single system is urgently needed. CERs and their attendant correlation are almost always developed piecemeal, so that there is no single view the level of correlation. For a first step we would need a single weapon or system, such as a ground combat vehicle, or aircraft, with a fairly large quantity, with unit (not lot) data and a WBS at least one or two levels deep (the more the better.) The study should analyze pairwise correlations throughout and determine a reasonable thumb, whether components manufactured elsewhere and integrated in are correlated with the basic vehicle. Simultaneously, as a useful object lesson, the overall actual variability of costs of a group of units ought to be compared with the variability obtained by summing (assumed) independent elements at the next level(s) of WBS. This would presumably demonstrate what Dr. Steve Book's paper was aimed at, while the actual correlations would provide a data-based antidote to the problem he identified.

Top-Level vs. Detailed Risk [New]

Problem

Analysts are often unable to explain to the satisfaction of decision-makers the results of the Monte Carlo simulation for risk analysis conducted on a complex LCCE. The community is divided between top-level methods like eSBM and improving detailed methods that require Monte Carlo.

Previous Situation

Off-the-shelf Monte Carlo simulation tools such as Oracle (formerly Decisioneering) Crystal Ball, @Risk, and ACE RI$K make it all too easy to "turn the crank" and generate a risk-based cost estimate without understanding the process and its inputs and outputs. If inputs are not based on defensible data, and if the process is not implemented correctly, then the outputs are suspect. One school of thought is that we need to focus on improving the inputs and process for Monte Carlo risk analysis. The other, championed by the likes of Paul Garvey, is that a more intuitive top-level risk analysis is preferable.

Progress Made

eSBM can use historically based CVs and even percentiles.

Air Force Cost Risk Uncertainty Analysis Handbook (CRUAH), Air Force Cost Analysis Agency (AFCAA)

"Enhanced Scenario-Based Method for Cost Risk Analysis: Theory, Application, and Implementation" Paul R. Garvey, Peter Braxton, Brian Flynn, Richard Lee, SCEA/ISPA 2012 Best Paper in Risk, *Journal of Cost Analysis and Parametrics*

Future Research

Going forward, both approaches are important.As an acid test for too-steep S-curves, Jim Barattaof NCCA has suggested plotting a nominal Nunn-McCurdy breach, which is not all that uncommon. If it falls at an unreasonably high percentile (above the 99^{th}, say), that is a clear indication that the CV of the estimate is too low.

Group #5 – Integration with Related Disciplines

This grouping of four problems comprises: transcending budgeting and establishing the role of cost estimating in **portfolio management** (Budgeting); determining statistically the **impact of incentives** on contract cost control, if any (Contracts), including possible application of game theory to government-contractor interactions; better defining the uncertain partnership with **cost management** (CAIV); and better defining interactions and synergies with the **sister disciplines** of EVM, Schedule Analysis, Risk Management, Project Management, Contract Management, and Systems Engineering.

Portfolio Management

Problem

The current politicized annual budget process, though intended to enhance fiduciary responsibility, makes no verifiable contribution thereto!

Previous Situation

Cost and risk do not contribute significantly enough to budgeting

Little "bang-for-the-buck" in constant "churn" of budget.

Progress Made

Navy and Air Force portfolio management approaches/models

Consortium for Advanced Manufacturing – International (CAM-I) Cost Management Systems (CMS) Beyond Budgeting round table.

Future Research

Encourage maximal use of cost and risk for responsible portfolio management within current system

Need both increased funding stability for flagship programs and increased agility for S&T / immediate-threat programs

Contract Incentives

Problem

Cost incentives in contracts have not been shown to reduce cost growth.

Previous Situation

Contract "geometries" have a number of "moving parts," the risk-based interaction amongst which is not well understood (especially by contracting officers!)

Target cost, fee pools, sharelines, etc.

Progress Made

Risk-based ROS analysis.Successful on CVN 78 negotation.

"Risk-Based Return on Sales (ROS) for Proposals with Mitigating Terms and Conditions," P. J. Braxton, R. L. Coleman, E. R. Druker, B. L. Cullis, C. M. Kanick, A. V. Bapat, SCEA 2009, DoDCAS 2010

"Risk-Based Return On Sales (ROS) As a Tool For Complex Contract Negotiations," P. J. Braxton, R. L. Coleman, SCEA 2010

Future Research

Historical contract analysis.

Uncertain Partnership with Cost Management

Problem

Cost estimating is needed to enable cost management but is often complicit in "cost fantasy".

Previous Situation

CAIV not properly applied.

Progress Made

Erstwhile Navy cost participation in CAM-I CMS Target Costing working group. Better Buying Power 2.0, Should Cost and Will Cost

"The Risk Cube Method – Probability of Failure and Consequence of Failure," R. L. Coleman, M. E. Dameron, J. R. Summerville, ASC/Industry Cost and Schedule Workshop, Apr 2003

"Monte Carlo Techniques for Determining Management Reserve," E. R. Druker, N. A. Shaw, Chuck Casserly, J. R. Summerville, R. L. Coleman, SCEA 2006

"Making Risk Management Tools More Credible - Calibrating the Risk Cube," J. R. Summerville, R. L. Coleman, M. E. Dameron, SCEA 2006, DoDCAS 2007, Awarded ISPA/SCEA Best paper on Risk

"The 'Right' Way To Do Cost Target Allocations: A Confluence of Cost, Risk, and CAIV," P. J. Braxton, B. A. Brophy, R. L. Coleman, J. R. Summerville, SCEA 2004

Future Research

Historical study of sources of cost reduction

Do less

Do things better

Do things differently.

PARCA for opportunities as well as risks.

Sister Disciplines: EVM, Schedule Analysis, Risk Management, Project Management, Contract Management, and Systems Engineering [New]

Problem

Too often cost estimating operates in a vacuum from (potentially) related disciplines, or works only at arm's length, where things are "thrown over the fence," or is at odds with them.

Previous Situation

Traditional IPT roles, competing interests.

Progress Made

Interaction at conferences, through working groups, and on programs.

"The Relationship Between Cost Growth and Schedule Growth," R. L. Coleman, J. R. Summerville, 35th DoDCAS, SCEA 2002, Acquisition Review Quarterly, Spring 2003

"Predicting Final CPI," R. L. Coleman, M. E. Dameron, J. R. Summerville, H. F. Chelson, Steve L. Van Drew, SCEA 2003, ASC/Industry 2003 Cost and Schedule Workshop

"Cost and Schedule Risk" – Cost Estimating Training Module V, R. L. Coleman, J. R. Summerville, M.E. Dameron, TASC, Inc., SCEA 2002

"The Risk Cube Method – Probability of Failure and Consequence of Failure," R. L. Coleman, M. E. Dameron, J. R. Summerville, ASC/Industry Cost and Schedule Workshop, Apr 2003

"A Survey of Cost Risk Methods for Project Management," R. L. Coleman, J. R. Summerville, PMI Risk SIG Project Risk Symposium 2004

11 Schedule Realism, F. K. Blackburn, H. F. Chelson, T.L. Eng, L. J. Guffey, R. L. Coleman and J. R. Summerville, MORSS 2005

12 Schedule Realism Model, R. W. Boulais, E. R. Druker, J. R. Summerville, R. L. Coleman, S. T. Cobb, N. A. Shaw, J. N. Davis, T. B. Goughnour, SCEA 2006

13 Monte Carlo Techniques for Determining Management Reserve, E. R. Druker, N. A. Shaw, Chuck Casserly, J. R. Summerville, R. L. Coleman, SCEA 2006

14 Making Risk Management Tools More Credible - Calibrating the Risk Cube, J. R. Summerville, R. L. Coleman, M. E. Dameron, SCEA 2006, DoDCAS 2007, Awarded ISPA/SCEA Best paper on Risk

15 Risk Management, E. W. Wojtan, R. L. Coleman, SCEA 2006

Future Research

Cf. Community of Practice.

Conclusions – Onward Into the 21st Century

We make no promises to revisit this list of problems every six years. It would be more useful as a living document. Certainly not all cost research has to fall under it, but we hope it will be helpful as an overall road map for the profession going forward.

For an updated version of this paper, please contact Peter J. Braxton at PBraxton@technomics.net or (703) 944-3114.