2015 Abstract Collection

The CAD would like to welcome you to the 2015 NASA Cost Symposium. This document contains the names of the authors/presenters and abstracts for all the presentations that will be presented this year. In the Symposium Agenda you will notice that each presentation has an associated "ID". These IDs can be used to find the presentation abstract that you are interested in.

This year the NASA Cost Symposium is more packed than ever before! There are 43 presentations, 9 Special Sessions, and an awards banquet full of worthy nominations all packed in an eventful three days.

Contents

01_ Integrating Risk Mitigation into JCL Analysis

Authors: Justin Hornback, Kelly Moses, Jon Bell, James Taylor

Presenters: Justin Hornback, Kelly Moses, Jon Bell, James Taylor

Biography:

Abstract: The Joint Confidence Level (JCL) assessment process is intended to provide NASA stakeholders at the Agency level the ability to make risk-informed decisions for Programs/projects (P/p) with a lifecycle cost of $250M or greater. A JCL helps set the foundation to answer fundamental questions such as: does the project have enough funds, can the project meet the schedule, what are the areas of risk toward successful execution of the project, and what risk mitigation strategies provide the best project benefit?

As with any process/procedural requirement, there may be flaws or points of contention and the current JCL process is no exception. One of the main points of contention from P/p's is the JCL analysis does not take into account effort underway and/or planned to mitigate potential risks and uncertainties from happening. Push back from P/p's is focused on the JCL solely looking at worse case scenarios and "make things look worse" than what is going on. In some cases P/p's have incorporated minimal (in some cases zero) uncertainty and risk impacts on the grounds that mitigation activities eliminate the probability of a risk/uncertainty from occurring.

While there is some validity to these concerns, minimizing and/or omitting risk and uncertainty from the analysis, it is not completely valid. In several cases when a P/p has taken this approach, they forget to incorporate a key part of taking credit for risk mitigation. Often times cost and/or schedule activities associated with risk mitigation efforts are not captured within the P/p's baseline budget and/or IMS, let alone captured within JCL models. This whitepaper

will discuss how and why mitigation activities must be incorporated into the analysis, as well as how this can be useful for completing the analysis of mitigation effectiveness.

The intent of this paper is to provide insight for methodologies pertaining to capturing risk mitigation cost and schedule activities within NASA's JCL analysis process. These methodologies are not solely limited to NASA's JCL process and should be incorporated in Programmatic and risk assessments, probabilistic risk analysis and developing cost/schedule range estimates. These methodologies are intended to assess and compare effectiveness mitigation strategies for effective resource allocation.

02_ Using Earned Value Data to Forecast the Duration of Department of Defense (DoD) Space Acquisition Programs

Authors: Shedrick Bridgeforth, Jonathan D. Ritschel, Edward D. White, Grant Keaton

Presenters: Shedrick Bridgeforth, Jonathan D. Ritschel, Edward D. White, Grant Keaton

Biography:

Captain Shedrick Bridgeforth, USAF, works as a space system cost analyst for the Air Force Cost Analysis Agency at Joint Base Andrews, Maryland. He is a recent graduate of the master's degree program at the Air Force Institute of Technology (AFIT), where he earned an MS in Cost Analysis. Capt Bridgeforth holds the Professional Cost Estimator/Analyst certification from the International Cost Estimating and Analysis Association.

Lieutenant Colonel Jonathan D. Ritschel, USAF, is an assistant professor and director, Cost Analysis Program, in the Department of Systems Engineering and Management at the AFIT. He received his BBA in Accountancy from the University of Notre Dame, his MS in Cost Analysis from AFIT, and his PhD in Economics from George Mason University. Lt Col Ritschel's research interests include public choice, the effects of acquisition reforms on cost growth in DoD weapon systems, research and development cost estimation, and economic institutional analysis.

Captain C. Grant Keaton, USAF, is the director of financial management at Osan Air Base, Korea. He earned a B.S. in Economics and a minor in Russian from the United States Air Force Academy and an M.S. in Cost Analysis from the Air Force Institute of Technology. His current research focuses on time series analysis and quantitative content analysis

Dr. Edward "Tony" White is a professor of Statistics at the AFIT. His research interests include design of experiments, biostatistics, growth curves, linear and nonlinear regression, categorical data analysis, log-linear models, statistical simulation, and response surface modeling. Dr. White received his PhD in Statistics from Texas A&M University in 1998.

Abstract: The accuracy of cost estimates is vital during this era of budget constraints. A key component of this accuracy is regularly updating the cost estimate at completion (EAC). A 2014 study by the Air Force Cost Analysis Agency (AFCAA) improved the accuracy of the cost estimate at completion (EAC) for space system contracts. The study found schedule duration to be a cost driver, but assumed the underlying duration estimate was accurate. This research attempts to improve the accuracy of

the duration estimate from the AFCAA study; accuracy is evaluated with the Mean Absolute Percent Error (MAPE). The methods researched here are more accurate, timely, and reliable than the status quo method. The original objective, to improve the accuracy of the duration estimates for the cost estimating model, was achieved. The accuracy gains ranged from 2.0% to 13.4% for single contracts, 3.2% to 5.1% for OTB contracts, and 2.9% to 5.2% for all contracts combined. The accuracy improvement is more pronounced from 0% to 70% completion, with a 4.0% to 7.6% increase in accuracy. The accuracy improvement for the EAC was 6.5% (24.4% vs. 17.9%).

09_ Growth Estimation Relationships (GER)

Authors: Eric Plumer, Vincent Larouche, & Rey Carpio

Presenters: Eric Plumer, Vincent Larouche

Biography:

Rey Carpio: Several years of experience in systems acquisition for Department of Defense programs and National Aeronautics & Space Administration (NASA) programs, with particular emphasis on cost analyses, cost estimating, and financial management. Background includes experience in independent cost estimating and analyses, earned value management, procurement, and leadership. Presently with Tecolote Research, Hampton Roads Office—providing technical support to NASA at Langley Research Center, Goddard Flight Research Center, NASA Hq, and Johnson Space Center. Prior to Tecolote, Rey was with NASA, a member of Senior Executive Service (SES), evaluated agency mission-related programs and projects to ensure cost effectiveness, quality, performance, and strategic alignment; provided independent cost estimates in support of these evaluations. And prior to NASA, Rey spent 20 years in the Air Force with several assignments across the globe.

Vincent Larouche: Vincent Larouche is an Analyst with Tecolote Research Inc., Los Angeles Office. Vincent is one of lead analysts performing NASA CADRe development, completing over ten CADRe's. He is also responsible for collecting data, developing cost estimates, and maintaining project schedules for various NASA projects. Vincent has supported NASA by sharing improvements for CADRe and ONCE, progressing schedule and cost estimation. Prior to NASA, Vincent researched the economic impact of commercial fire interventions in the city of Long Beach. He has a BA in economics from California State University, Long Beach.

Abstract: The motivation of the this study is to share the project management's interest in identifying parameters to serve as leading indicators of the project's ability to achieve cost, schedule, and mass targets—and avoid schedule slips, cost growth, and mass growth late in the development process. This presentation is anchored on the understanding that project's ability to accommodate cost, schedule, and mass growth relative to the size of the contingency/reserve margins has historically affected the cost, schedule, and mass growth in subsequent project phases.

The method and database employed to conduct this study were carefully studied. CADRe data was analyzed extensively and relevant results were developed from the database. As a result of the analysis, a new relationship was

developed—the Growth Estimating Relationship (GER). Three sets of GERs were developed for cost, schedule, and mass. Preliminary results show promising usage.

12_ONCE[1]

Authors: James Johnson, Eric Plumer, Julie McAfee, Mike Blandford

Presenters: James Johnson

Biography:

Abstract: Presentation will provide an overview of the One NASA Cost Engineering (ONCE) database as well as cover several of the new features and enhancements that have been incorporated in the last year.

14_NICM[2]

Authors: Joe Mronzinski, Hamid Habib-Agahi

Presenters: Joe Mrozinski

Biography:

Joe Mrozinski is a systems engineer in JPL's Systems Analysis and Modeling group. Joe is the NICM Task Co-Manager. His other successes at JPL include Principal Investigator for various mission concept studies, technology portfolio assessment, human-robotic task allocation for lunar/Martian/NEO applications, trade-tool software development for JPL's Team X design center and A Team, and several trade studies and mission/architectural optimizations. Joe's other professional experience includes five years of leadership positions in the field of residence education, supporting both the University of Michigan and the California Institute of Technology. Before joining JPL in 2004, Joe received his Masters in Space Systems Engineering at the University of Michigan, where he also earned a B.S. in Aerospace Engineering and a B.A. in Philosophy, with a focus on Ethics and Artificial Intelligence.

Hamid Habib-Agahi has a Bachelor Degree in Electrical Engineering and a Doctorate in Mathematical Economics from Purdue University. He has been on the faculty of the University of Waterloo and the University of Pennsylvania and has published numerous articles in leading economics, statistics and management science journals and has coauthored two books. He is currently a principal systems engineer, the manager of the Systems Analysis & Model Development Group at JPL and the manager of NASA Instrument Cost Model (NICM) development. He has been working for over 30 years in the area of risk analysis, probabilistic cost model development, systems analysis, and resource optimization in support of NASA flight missions as well as NASA's Deep Space Network ground system.

Abstract: Presentation will provide an overview of the NASA Instrument Cost Model (NICM) as well as cover several of the new features and enhancements that have been incorporated in the last year.

15_ An Assessment of Risk Lists and Categorization at Major Milestones Across the Lifecycle of NASA Missions

Authors: Bob Bitten, John Goble

Presenters: Bob Bitten, John Goble

[1] There will also be a Special Sessions demo for ONCE – check your agenda
[2] There will also be a Special Sessions demo for NICM – check your agenda

Biography:

Abstract: Project-generated cost and schedule risks are a key driver in the process of budgeting missions at a specific cost and schedule consequence level, commonly referred to as a Joint Confidence Level (JCL). The development, management, and presentation of cost and schedule risk lists at mission milestones is thus a crucial task in project planning. This briefing discusses the available risk lists at PDR, CDR, and SRR across a set of 11 NASA missions. Risks are categorized by system and subsystem to support further analysis and assist in creating a checklist for developing risk lists for future analyses. The effort indicates that risk lists vary substantially from milestone to milestone and across missions, with formal presentations typically reporting only a subset of the actual risk list. Furthermore, the analysis indicates that project risks typically focus on the element of primary responsibility of the mission's Center. Key recommendations include requiring a full, clearly named, project-level risk list at each milestone with consistent risk IDs that can be traced across the risk to threat to lien to encumbrance cycle. In addition, it is also recommended that all risks with cost/schedule impact be recorded as threats. It is also expected that the risk lists gathered during the study serve as an initial data set for use in a NASA-wide database of risks.

16_ Portfolio Optimization

Authors: Fred Kou

Presenters: Fred Kou

Biography:

Abstract: Technology is continually changing our society and, more than ever, is also providing impetus in advancing the sophistication and creativeness of the project management professionals. In the field of cost and schedule analysis we have seen a proliferation of analysis tools and methods in advancing the understanding and quantification of the impacts of risks. Most of these tools can serve as a powerful analytical platform to bring intelligence and insight to the decision making process. Mathematical programming is a technique that has been widely applied to many management science problems such as logistics, queuing and resource planning. In this paper, the author introduces the concept of mathematical programming and portfolio optimization, and its potential application in the cost and schedule risk analysis.

The general mathematical programming formulation can be expressed as:

Optimize:f(x)

Subjected to:

$g(x) \le b$,

$h(x)= b_{eq}$,

$l \le x \le u$

Where f(x) is an objective function to be optimized, x is the decision variable. g(x) is a vector function of inequality constraints and h(x) is a vector function of equality constraints, and l and u are the upper and lower bounds of x. In a simple example, we can let x be the duration of each tasks, and f(x) can be constructed as total project duration, and b the total available resource, then the optimization problem becomes to minimize total project duration given the resource b. The flexibility of

this approach allows f(x) to be a wide range of objective functions. In this paper the author will examine a few potential applications, with examples, in the cost and schedule analysis area.

17_ A "Common Risk Factor" Method to Estimate Correlations between Distributions

Authors: The Marc Greenberg

Presenters: The Marc Greenberg

Biography: The Marc Greenberg has been working for NASA's Cost Analysis Division (CAD) since October 2012. At NASA, he is helping the Space Technology Mission Directorate (STMD) improve its cost estimating methods, facilitates the NASA Cost IPT and provides decision-support to NASA leadership.

Marc previously worked in the field of cost analysis for the Department of Homeland Security, Naval Center for Cost Analysis, Defense Acquisition University and Naval Sea Systems Command. He received his BS in Ceramic Science and Engineering (Pennsylvania State University) in 1987 and an MS in Engineering Management (George Washington University) in 1998. He is professionally certified as a Cost Estimator/Analyst, Level III certified in Business - Cost Estimating, and is a member of Omega Rho International Honor Society.

Abstract: Whenever historical data is unavailable, a cost analyst may decide to depict uncertainty of an activity or cost element using expert judgment. A practical means for collecting such uncertain data is to ask a subject matter expert (SME) for the lowest, most likely and highest value which, consequently, produces a triangular distribution. Although the cost analyst would possess the requisite properties of this distribution, she would typically have difficulty (a) describing the risk factors that contribute to the distribution's dispersion and/or (b) providing a measure of how much the identified risk factors contribute to the distribution's dispersion.

This paper starts off by using a notional Driving Time Triangular Distribution derived from expert opinion (Reference: "Expert Elicitation of a Maximum Duration Using Risk Scenarios", Greenberg 2014). This given distribution not only includes the three-point parameters of the triangular distribution but also includes relative contributions of risk factors to its overall uncertainty. For example, the elicitation procedure on driving time revealed that departure time contributed 11% to overall Driving Time Uncertainty while weather conditions contribute contributed 22% to overall Driving Time Uncertainty.

For this paper, we assume this elicitation process was repeated for a second transportation mode (for another commuter) that is typical of a morning commute: Taking the Bus and Metrorail. Given elicited percent contributions of risk factors to uncertainties of each of these two activities (Driving Time Uncertainty and Taking the Bus and Metrorail), a methodology is then used to estimate a correlation coefficient among this pair of activities. The premise of the methodology is to estimate mutual information associated with risk factors that underlie each triangular distribution. The technique used to approximate such mutual information leverages the unique properties of a joint probability

distribution of a unit square – where the risk factors (underlying uncertainties for their respective commute-time activities) are assumed to be uniformly distributed random variables. The geometric output associated with each random variable on the unit square is compared to that of the 'possibility space' of its respective larger random variable, leading to an estimated 'intersection' of this pair of common risk factors. This intersection is then assumed to be a proxy of correlation.

The methodology presented in this paper can provide several benefits over current methods SMEs specify correlation. For example, it is common practice that when a pair of activities are seen as "moderately" correlated, the SME will refer to a reference table to get the associated correlation coefficient. From reference table X, "moderate" correlation equals 0.4 (on a scale from 0 to 1). Reference table Y shows "moderate" correlation to be equal to 0.5. This inconsistency can lead to debates, disagreements, etc. Nevertheless, after a correlation value is agreed upon it is still very difficult for the SME to provide a reasonable basis for this subjective measure of correlation.

The "common risk factor" methodology, on the other hand, uses SME-provided risk factors to estimate correlation. Therefore, the SME and cost analyst are able to provide a basis for the correlation because sufficient rationale (and traceability) already exists for the risk factors used to estimate the correlation.

The paper closes with a second example on how the "common risk factor" method can be applied to estimate correlation between two spacecraft cost elements: Structures & Mechanisms and Thermal Control Systems.

18_Using Stochastic Optimization to Improve Program Planning and Risk Analysis

Authors: Graham Gilmer, Eric Druker

Presenters: Graham Gilmer, Eric Druker

Biography:

Abstract: Minimizing the cost of complex programs is critical for government agencies trying to meet their missions in today's fiscal environment. Identifying cost-saving measures is currently a manual procedure where an analyst must make an educated guess as to what actions will have the greatest effect in reducing cost and schedule growth, and then test their hypothesis by running the new plan through a risk analysis model. This process is manual, slow, and must be iterated many times in order to arrive at a solution – which may or may not be the optimal case. This presentation outlines a methodology, piloted on real-life programs, for using the emerging field of stochastic optimization to automate the identification of cost-saving measures on complex programs. With this operations research-based methodology, users can define their fiscal and resource constraints. The stochastic optimization model prioritizes risks to the program, quantifying their impacts and enabling the users to pursue an optimal mitigation strategy for meeting budget and schedule goals.

19_Development of the Small Satellite Cost Model 2014 (SSCM14)

Authors: Eric Mahr, Anh Tu, Anil Gupta

Presenters: Eric Mahr

Biography:

Eric Mahr is a Senior Engineering Specialist in the Space Architecture Department at The Aerospace Corporation. His expertise is in spacecraft and architecture development. He has worked on a number of architecture and mission developments, studies and evaluations for NASA, the Air Force, and commercial organizations. He has a B.S. in Aerospace Engineering from the University of Arizona and a M.S. in Aerospace Engineering from the University of Colorado.

Anh Tu is a Senior Engineering Specialist in the Economic and Market Analysis Center at The Aerospace Corporation. Accomplishments include 1) formulation of models to optimize rocket propulsion test facility for NASA, 2) technology infusion model development involving performance prediction, obsolescence, cost implications and the optimization of product replacement, 3) problem formulation and analysis lead for a multi-billion program involving hardware and software cost estimation effort using a parametric cost simulations tool and 4) leading cost research methodology development efforts for integrating cost and risk. She has a B.S. in Industrial Engineering from California Polytechnic State University and a M.S. in Operations Research from the University of Southern California.

Anil Gupta is a Senior Project Leader in the Economic and Market Analysis Center at The Aerospace Corporation. He has developed business models for various Government agencies in the areas of life cycle cost analysis, cost-risk analysis, financial planning, delay and disruption, resource allocation and acquisition analysis. He has a Ph.D. in Business Administration from the University of Southern California, Los Angeles; an M.S. in Industrial Engineering and Operations Research from Kansas State University and a Bachelor of Technology degree in Mechanical Engineering from Indian Institute of Technology, New Delhi, India.

Abstract: Prompted by the rise in the use of small satellites throughout the space industry in the late 1980's, The Aerospace Corporation began to study small satellites to better understand the design principles that were being employed in their implementation. These studies highlighted the fact that cost models developed for traditional large satellites were not applicable to small satellites. This led to the development of the Small Satellite Cost Model (SSCM) in the mid 1990's. This model estimates subsystem- and system-level costs for satellites weighing less than 1000 kg using cost estimating relationships (CERs) derived from actual costs and technical parameters. Over the years, SSCM has evolved to account for the increasing number of small satellites that have been launched, refine the CERs and increase the scope of the model. This paper will discuss the development of the current version of SSCM. The topics covered will include the history of SSCM, the CER generation process, updates from the previous version of SSCM, the application of the model and future efforts to enhance the model.

20_Mission Operations Cost Estimation Tool (MOCET)

Authors: Marc Hayhurst, Shirin Eftekharzadeh, Brian Wood, Vishnu Jyothindran, Bob Kellogg, Cindy Daniels, Washito Sasamoto, Lissa Jordin

Presenters: Marc Hayhurst, Shirin Eftekharzadeh, Brian Wood, Vishnu Jyothindran, Bob Kellogg, Cindy Daniels, Washito Sasamoto, Lissa Jordin

Biography:

Abstract: The Mission Operations Cost Estimation Tool (MOCET) is a model developed by the Aerospace Corporation in partnership with NASA's Science Office for Mission Assessment (SOMA). MOCET provides a new capability to generate cost estimates for the operational, or Phase E, portion of NASA science missions. Motivation behind MOCET stems from a recent study indicating that the operations portion of NASA missions can experience cost growth as great as 40% from their initial baseline, highlighting the need for stronger estimation capabilities that can be utilized early in formulation. The development approach for the model used actual historical monthly data segregated into phases consistent with various operational activities. An additional goal of development was to minimize the number of subjective inputs required from the user to foster more consistent estimates in less time. The model is comprised of Cost Estimating Relationships (CERs) that were derived from historical data for Planetary, Earth Science, and Explorer Missions. The derived CERs and accompanying documentation have been implemented as a standalone Excel based tool that is intended to be used throughout the NASA costing community.

21_ Interactive Applications for Modeling and Analysis with Shiny

Authors: Nicole Bishop

Presenters: Cindy Fryer, Paul Guill, Nicole Bishop

Biography:

Abstract: R is a widely used programming language for data analysis and statistical computing. It is free, open-source and is supported by a vast community of users, making it a powerful and flexible tool for analysis. RStudio is an integrated development environment for R and it facilitates the use of R to carry out statistical analysis. One of the many capabilities available in RStudio is a package called Shiny. Shiny is a framework for building browser-based applications and easily turning R code into interactive and dynamic displays. The applications can be displayed in a web-browser and have a user-friendly interface that anyone can use, while still providing all of the computational power of R in the background.

These tools are ideal for conducting cost model development and analysis. They make it possible to efficiently share models, create documents and reproduce results. Also, the interactive user interface makes it easier and quicker for others to conduct analysis.

This presentation will illustrate how Shiny is being used at Goddard's Resource Analysis Office (RAO) to turn models into user-friendly applications. A model developed with NICM data from NASA's ONCE database will be used to demonstrate how Shiny can be applied to the cost estimating process. We will start with a brief overview of building and deploying an application, followed by a demonstration of the application in use.

22_ What's the Point?: Discussion of How CER Point Estimates Should Be Interpreted in Probability Distributions

Authors: Betsy Turnbull, Tom Parkey

Presenters: Betsy Turnbull, Tom Parkey

Biography:

Abstract: The location on a distribution one chooses to represent with the CER point estimate is very important. This paper is an examination of current guidance on how CER point estimates should be interpreted within uncertainty distributions for Monte Carlo simulations. Included is an exploration of the benefits and drawbacks of various distribution types for application in cost estimation, and the effects that decisions regarding shape and point estimate location have on final estimates (underestimating, allowing for negative costs, etc.). Subsequently, there will be a discussion of the guidance for how the results of CERs should be represented in uncertainty analysis and an argument for a method outside the current direction; employing the CER result as the mode of a lognormal distribution. This paper is intended to spur a general discussion on the subject within the cost community.

24_ This Is Not Your Father's Old Spacecraft: An Examination Into Using Modern Data To Inform Manned Spacecraft Cost Estimates

Authors: Susan Bertsch

Presenters: Susan Bertsch

Biography:

Abstract: NASA's Cost Analysis Division (CAD) has made great strides in using its CADRe initiative to gather mission cost and technical data and to disseminate this information via the ONCE database. This data has been used throughout the cost estimating community to improve the Agency's cost modeling efforts, including updates to the CAD-sponsored Project Cost Estimating Capability (PCEC).

Unfortunately, this wealth of new data has been entirely on the unmanned scientific, planetary, and robotic missions, leaving those working on manned spacecraft estimates to wonder what's in this for them. As manned Mars exploration initiatives and commercial crew activities pick up, it is imperative that we use this wealth of new data to better inform our cost estimates and not continue to drive around on our father's old spacecraft data.

This paper will examine techniques for credibly incorporating this new data within our cost estimation frameworks to better estimate costs for manned space and commercial developments. Topics that will be examined include

- The cost of estimating a manned space vehicle, how that cost is calculated within our core tools, and revisiting our “rules of thumb” in light of new concepts for ensuring reliability
- Estimating the cost of spacecraft being developed in the commercial sector
- Research initiatives underway at JSC to capture manned space data from our ISS Program, the Orion EFT-1 mission, the Engineering Directorate, the ExtraVehicular Activity Office, and other human spaceflight projects

26_ Improving the NICM Software CER

Authors: Dr. Jairus Hihn, Leora Justeri, Mike DiNicola

Presenters: Dr. Jairus Hihn, Leora Justeri, Mike DiNicola

Biography: ***Jairus Hihn*** (Ph.D, U. Maryland) is a Principal Member of the Engineering staff at NASA’s Jet Propulsion Laboratory and is currently the lead for the NASA Software Cost Improvement Task, the JPL software metrics activities, where he is trying to establish a laboratory wide software metrics and estimation program. He has over 60 publications including recent articles IEEE Transactions in Software Engineering. Jairus received ISPA’s Parametrician of the Year Award and the USC Software and Systems Engineering Lifetime Achievement Award.

Michael DiNicola is a Member of the Engineering staff at NASA’s Jet Propulsion Laboratory. He has been working as a cost analyst and cost model developer for over eight years.

Leora Justeri is a graduate student in computer science at the California State University of Los Angles and an Intern at the Jet Propulsion Laboratory.

Abstract: The NICM software CER has not been updated in over six years when it was first developed. Since that time the available data has doubled. So it is clearly time for an updated CER. This work is a joint activity by the NASA Software Cost Modeling Task and the NICM team. In this talk we will describe:

- The new CER
- How it is a significant improvement over the existing CER
- Future directions
- Our model development, evaluation and validation approach which uses Magnitude of Relative Error (MRE) statistics and bootstrap cross-validation
    - Demonstrate MRE is an important supplemental metric to the traditional regression statistics

27_The NASA Spacecraft Software Cost Model: An Analogy Based Estimation Methodology

Authors: Dr. Jairus Hihn. Dr. Tim Menzies, George Mathews, James Johnson

Presenters: Dr. Jairus

Biography: ***Jairus Hihn*** (Ph.D, U. Maryland) is a Principal Member of the Engineering staff at

NASA's Jet Propulsion Laboratory and is currently the lead for the NASA Software Cost Improvement Task, the JPL software metrics activities, where he is trying to establish a laboratory wide software metrics and estimation program. He has over 60 publications including recent articles IEEE Transactions in Software Engineering. Jairus received ISPA's Parametrician of the Year Award and the USC Software and Systems Engineering Lifetime Achievement Award.

Tim Menzies (Ph.D, UNSW) is a full Professor in Computer Science at North Carolina State University; and the author of 200+ referred papers. He is an associate editor of IEEE TSE and the journals of Empirical Software Engineering journal, and Automated Software Engineering. He also co-founded the PROMISE conference on reproducible experiments in Software Engineering (see http://promisedata.googlecode.com). Website http://menzies.us; vita: http://goo.gl/8eNhY.

George Mathew is a graduate student in computer science at the North Carolina State University.

James Johnson is responsible for providing Cost Estimates and Assessments, Schedule Estimates and Assessments, Risk Analyses, and Joint Cost Schedule Risk Analysis for the Cost Analysis Division (CAD) at NASA Headquarters. His work for NASA HQ includes supporting high level Agency studies, providing support and consultation to projects, and developing policy and guidance for the Agency. While supporting NASA, James has received multiple individual and team awards recognizing his contributions and performance as an analyst.

Abstract: While there has been extensive work on improving parametric methods there is very little focus on the use of models based on analogy and clustering algorithms. At the 2014 NASA Cost Symposium we presented the results of a pilot study that investigated whether clustering algorithms using spectral analysis using only system level descriptors such as mission type and number of instruments were able to predict software effort as well as a parametric model such as the COCOMO II cost model[3]. In this paper we will describe the final methodology being used in the development of a NASA Software Cost Model using data mining clustering algorithms and evaluate its performance by comparing it to estimates from COCOMO II, a calibrated COCOMO II, linear regression, and K-nearest neighbor models. The characteristics of the clusters will be described and as well as an example application of the model. We will also show why it is important to use MRE statistics in addition to the standard statistics we typically use when developing parametric cost models. These results are based on the analysis of NASA robotic spacecraft flight software data obtained from the CADRe and other data sources. This presentation will provide the background for understanding the model that has been developed and is available on ONCE.

28_The Psychology of Cost Estimating

Authors: Andy Prince

Presenters: Andy Prince

Biography:

[3] J. Hihn, et. al., A Next Generation Software Cost Model, Proceedings of the 2014 International Cost Estimation and Analysis Association Professional Development & Training Workshop, Denver, Co, June 2014.

Abstract: The ultimate purpose of parametric cost estimates is to enable decision makers to make informed decisions concerning the allocation of resources. Yet despite decades of investment in cost estimating data, tools, and practices, large aerospace programs continue to experience significant cost overruns. Better cost estimators, tools, models, and techniques can help, but; addressing the root cause of this problem will require using human psychology to bridge the gap between the estimator and the decision maker.

The last 50 years of research into human psychology have yielded amazing findings into how we process information and how we use information to make decisions. The field of behavioral economics has made tremendous advances in applying these finding to describing how we humans make economic decisions. What these scientists have uncovered is surprising: humans are often irrational and illogical beings, making decisions based on emotion and perception, rather than facts and data.

29_ Crewed and Space Transportation Systems Cost Model (CASTS)

Authors: Richard Webb

Presenters: Richard Webb

Biography:

Abstract: As part of the MSFC Engineering Cost Office's strategy for upgrading cost estimating tools and capabilities, we are developing the Crewed and Space Transportation Systems Cost Model (CASTS). The CASTS model is a new, unique cost model for use in estimating space transportation systems, including crewed systems, and earth-to-orbit and in-space transportation systems. The first release of CASTS is included as part of PCEC version 2.0. This paper will provide an overview of the capabilities, estimating approach, historical database, and key features of CASTS as is currently available in PCEC 2.0 as well as plans for future improvements. Particular emphasis will be placed on providing a summary of the historical launch vehicle and crew systems database that provides the basis for CASTS CER's. We will discuss our primary findings and observations relative to efforts undertaken to upgrade and expand the historical database. Finally we will outline planned next steps for CASST development, including the Functional Breakdown Structure, updates and upgrades to the historical cost database documentation, CER updates as new data points and additional analyses are incorporated, and expansion to provide full integrated life cycle cost estimating capabilities.

31_PCEC v2.0 Overview[4]

Authors: Brian Alford, Mark Pedigo

Presenters: Peter Frederic

Biography:

Abstract: Version 2.0 of the Project Cost Estimating Capability has been under development since the release of v1.1.1 following last year's NASA Cost Symposium. This version, recently released in Beta form (full release expected prior to the 2015 Symposium), represents an evolution of the tool beyond its initial introduction last year. PCEC v2.0 begins the journey towards estimating to the full NASA Standard WBS and expands on the modularity and flexibility goals established at its inception.

[4] There will also be a Special Sessions demo for PCEC – check your agenda

32_ Spacecraft and Support Function Cost Models for NASA PCEC

Authors: Mark Jacobs, Shawn Hayes

Presenters: Mark Jacobs, Shawn Hayes

Biography:

Abstract: A new set of Cost Estimating Relationships (CERs) have been developed for NASA's Project Cost Estimating Capability (PCEC) covering development costs for robotic Earth and space science missions. Multiple estimating approaches have been explored during the creation of these CERs including standard regression analyses, constructive modelling with subject matter expert input, Principle Component Analysis (PCA), and tailored mixes of multiple approaches. Significant progress applying these approaches to various NASA WBS elements, including spacecraft, has been achieved.

33_Citizens' Perceptions of Cost, Schedule and Risk: A Participatory Technology Assessment of NASA's Asteroid Initiative

Authors: Zachary Pirtle, NASA Headquarters; Brian Rutkowski, NASA Kennedy Space Center; Pierre Bertrand, Massachusetts Institute of Technology; David Tomblin, University of Maryland/ECAST; Mahmud Farooque, Arizona State University/ECAST

Presenters: Zachary Pirtle, Brian Rutkowski,

Biography:

Abstract: NASA managers and engineers try to develop systems and perform missions that will have value for the public at an affordable cost. However, sometimes it is difficult to understand what society values, with little ability to engage in participatory input. Participatory technology assessment (PTA) is a methodology that seeks to gain public perspective in a way such that it can inform government decision-making. The goal to get informed input from the public is supported by past studies that show the significant ability of the public to process complex information (Sclove 2010). For engineering activities that are in the early stages of preliminary design, or in upstream engineering, PTA can be particularly useful in informing technical decision-making.

We will discuss an experiment that used PTA to see how members of the public reason about issues of cost, schedule and risk. Our focus will rely on cost and schedule deliberations that occurred during a deliberation on NASA's Journey to Mars[5]. The method to do this assessment relied on a unique research environment. In partnership with NASA, the Expert and Citizen Assessment of Science and Technology (ECAST) network conducted a PTA-based forum of NASA's Asteroid Initiative. ECAST organized two forums in Phoenix, Arizona and Boston, Massachusetts respectively on November 8th and 15th, 2014. 183 citizens attended in total. ECAST led the selection process for who attended and helped ensure that demographics were roughly comparable to local populations. ECAST worked to minimize self-selection biases on the part of space

[5] Other topics included Asteroid Detection, Planetary Defense and the downselect of the Asteroid Redirect Mission. The forum was focused on the Asteroid Initiative, where ARM is part of the broader Journey to Mars.

advocates among the participant pool. ECAST also developed informational content for citizens drawing upon NASA input. Those attending the one day forum spent the day learning about NASA's asteroid initiative, having experts on hand to answer basic questions.

The Journey to Mars deliberation at the ECAST forum was a deliberate effort to see how the public made trade-offs on cost, schedule and risk. What sorts of timeframes do citizens want exploration to occur in, and to what extent are they willing to trade schedule and cost for risk? To what extent do they want a full plan to go to Mars laid out now? Citizens had been given an overview of the capability driven framework and the challenges involved in going to Mars. The debate over these options was based on contrasting three possible approaches to Mars exploration, described below:

- Robotic and Orbital/Moon Missions: This scenario involves crewed missions being sent to orbit Mars and possibly to Phobos and Deimos. There were also a much larger array of robotic explorers being sent to Mars than NASA currently has.
- Viking Strategy: This scenario involves a small-scale crewed exploration mission that would set down on the surface of Mars and operate for several months before the crew would return to Earth.
- Pioneer Strategy This scenario involves a permanent settlement on the surface of Mars. These robots would also begin preparations for constructing permanent habitats. An initial large crew of human explorers would be refreshed every few months both in terms of supplies and personnel.

Background material expanded on these options, with citizens being told that each successive option required a massive increase in cost, schedule and risk required to perform it. Information on cost was kept to a qualitative level for two reasons: rigorous, public cost estimates of the above scenarios do not exist, and NASA managers are often confronted with qualitative differences between space architectures, where they make decisions without cost estimates. Thus, citizens debating on scenarios based upon qualitative differences can simulate decisions that managers must make. Citizens were asked which of the options should be the primary strategy for NASA after it has developed its initial exploration capabilities, with the implication that the more ambitious goals would take longer and require more money to complete.

We will show citizen votes for the three options as well as overview the debates they had in person and the written rationales they gave for their decisions. Citizen responses typically justified their choices based on a mix of values about cost, schedule, safety and other political and social values. Citizens also wrote out the time horizon that they want various Mars mission milestones to occur on, as well as tolerance for risk issues. The,transcripts and written responses for the forum reflect how a diverse group of the public reflected on cost and schedule in space mission planning—indeed, it shows that many actively made trade-offs on cost and risk. When asked to discuss and vote on whether to embrace the capability driven framework and proving ground approach to exploration, citizens actively discussed whether incremental approaches to exploration were valuable or not. There is some evidence that a large part of the public, after being informed about NASA's constraints, would be accepting of an incremental approach to exploration.

The above conclusions may be relevant to NASA managers considering programmatic decisions, but the methodology used here may also be of value. Participatory technology assessment represents a potential way for future research and analysis to provide managers with an independent perspective on programmatic issues. Public participation could potentially be part of the background decision making process of NASA as it develops its exploration and other strategic plans.

Citations:

Sclove, Richard. 2010. "Reinventing Technology Assessment: A 21st Century Model." Published by the Woodrow Wilson International Center for Scholars: Science and Technology Innovation Program. Washington, DC. Available at: [http://www.loka.org/documents/reinventingtechnologyassessment1.pdf]

35_ SEER Validation Study Results for NASA Space Science Missions

Authors: Sam Sanchez, Kathy Kha

Presenters: Sam Sanchez

Biography:

Abstract: The authors and their colleagues have modelled hundreds of space science instruments and missions and have performed multiple NASA sponsored cost validation studies. This talk will discuss a recent effort of validating the SEER suite against NASA space science missions through the use of CADRe data. Missions in this study included Explorer, Discovery, Mars Scout, and New Frontiers class missions. This presentation will summarize the results and conclusions from the study, including SEER model validation error bars, tailored guidance for model usage on space missions and instruments, and the creation of new "Space Catalogue" standard setting knowledge bases. The authors will also discuss lessons learned from this study and a new SEER space applications training course being developed based on these experiences.

36_ Early Formulation Probabilistic Cost Modeling: Balancing NASA's Vast Engineering Knowledge Base with Hard Data

Authors: Michael DiNicola

Presenters: Michael DiNicola

Biography:

Michael DiNicola[6] – Michael DiNicola works for the Jet Propulsion Laboratory in the Systems Modeling, Analysis & Architectures Group and has over eleven years of experience as a cost risk analyst and model developer. Over this time, Michael has developed several simulation-based cost risk models and has led cost development efforts for multiple JPL proposals and concept feasibility studies. He now leads the NICM statistical development as part of the NICM Team and collaborates with others in JPL's Engineering & Science Directorate to model and assess cost risk and concept feasibility. Michael attained his B.S. in

[6] Note: "DiNicola" is pronounced "Dee-ni-cola"; rhymes with "Pepsi-Cola".

Mathematics from UCLA and M.A. in Mathematics from UCSD.

Abstract: Assessing cost and feasibility of NASA space mission concepts at early design phases requires not only relevant flown mission data, but also strong engineering, scientific and financial expertise to guide the concept into what is many times new territory. Presented here is a Bayesian method for developing Cost Estimating Relationships that leverages both of these critical sources of information (i.e. expertise and data). This is done within a flexible modeling framework, allowing for real-time probabilistic cost assessments. We discuss how this method treats different kinds of information available and how to interpret results. Practical application of this method is also discussed, within the context of assessing mission feasibility, before commitments are made, proposals submitted and projects implemented.

37_A New Approach to Building a "Grassroots" S-Curve: Utilizing Expertise and Historical Performance Data to Produce a More Meaningful Cost Risk Assessment

Authors: Michael DiNicola, Kelli McCoy

Presenters: Michael DiNicola, Kelli McCoy

Biography:

Michael DiNicola[7] – Michael DiNicola works for the Jet Propulsion Laboratory in the Systems Modeling, Analysis & Architectures Group and has over eleven years of experience as a cost risk analyst and model developer. Over this time, Michael has developed several simulation-based cost risk models and has led cost development efforts for multiple JPL proposals and concept feasibility studies. He now leads the NICM statistical development as part of the NICM Team and collaborates with others in JPL's Engineering & Science Directorate to model and assess cost risk and concept feasibility. Michael attained his B.S. in Mathematics from UCLA and M.A. in Mathematics from UCSD.

Kelli McCoy – Kelli McCoy began her NASA career at KSC in 2004 as an industrial engineer in the Launch Services Program Business Office, following her graduation from Georgia Tech with an M.S in Industrial and Systems Engineering. She also holds a M.S. in Applied Math and Statistics from Georgetown University, as well as a B.S. in Industrial Engineering from Tennessee Tech University. After spending several years in the HQ Cost Analysis Division and as a Resource Manager in HEO, Kelli currently works in JPL's Engineering Systems Modeling, Analysis & Architectures Group as the Formulation Cost Risk Lead.

Abstract: Developing an S-Curve as a tool to assist cost risk evaluation of engineering build-up (a.k.a. "grassroots") cost estimates is now common practice. However, there remains much room for exploration and improvement. While engineering expertise is an indispensable tool used in this process, this should be

[7] Note: "DiNicola" is pronounced "Dee-ni-cola"; rhymes with "Pepsi-Cola".

balanced with historical performance data on similar programs as an indicator for how an organization will manage cost risk. Moreover, the S-Curve should have meaning anchored in reality and provide context to facilitate decision-making. Presented here is a Bayesian method for developing a "grassroots" S-curve that uniquely combines the technical engineering evaluation of cost risk with historical data and program performance (utilizing the NASA-funded Explanation of Change Cost Growth Study). We show how a more meaningful S-curve can be developed – where percentiles have a "real" context – with the intent of evaluating the cost risk posture of a grassroots estimate and informing management/stakeholder decisions.

38_X-1 to X-Wings ~ Developing a Parametric Cost Modeling

Authors: Steve A. Sterk, Aaron M. McAtee, Peter Frederic,

Presenters: Steve A. Sterk

Biography:

Abstract: In today's cost-constrained environment, NASA needs an X-Plane database and parametric cost and schedule model that can quickly provide rough order of magnitude predictions of cost and schedule from initial concept to first flight of potential X-Plane aircraft. This paper takes a look at the steps taken in developing such a model and reports the results. The challenges encountered in the collection of historical data and recommendations for future database management are dis-cussed. Then a step-by-step discussion of the development of Cost Estimating Relationships (CERs) and Schedule Estimating Relationships (SERs) is covered. This includes a statistical look at the relationship between potential cost/schedule drivers and cost/schedule, the correlation be-tween separate cost/schedule drivers, the selection of key parameters used in the model, and sensitivity analysis of the model parameters. An emphasis was placed on weight-based and complexity-factors based CERs/SERs. Finally, the model was used to calculate cost/schedule estimates for some conceptual designs.

39_Cost Confidence Interval Estimation: Sensitivity Analysis of Selected Input Distribution Types

Authors: Jeffrey H. Smith, Milana Wood, Fred Doumani

Presenters: Jeffrey H. Smith, Milana Wood, Fred Doumani

Biography:

Abstract: NASA Procedural Requirements necessitate the development of a range of probabilistic cost estimates at the key decision point, KDP 0/B, with confidence levels identified for the low and high values of the cost range. The assessment involves determining a range for project cost based on point estimates from each element of the project work breakdown structure (WBS). The point estimates are "current best estimates" (CBE's) and do not explicitly reflect the variety of risks and uncertainties associated with large scale projects. Some of these uncertainties are in part, quantified in the project's estimates of margins, risk-list items, and schedule risks.

The challenge for cost estimation is to extract the actual and potential risks and uncertainties from the project's plan and transform the costs and potential risks into a form that conveys the total cost uncertainty for the project. This paper describes the approach used at JPL to develop a cumulative probability distribution for total cost or "S-curve" used to compute confidence levels around the estimate and to provide a range of cost estimates for KDP 0/B decision making.

The goal of this paper is to evaluate in an empirical fashion, the differences obtained by varying the assumed input distributions for the triangular, normal, beta, and uniform probability distributions. To do this, cost estimates from four JPL projects were compared using each of the distributions: 1) the Surface Water Ocean Topography (SWOT) mission; 2) the Gravity Recovery and Climate Experiment Follow-On Project (GRACE); 3) the NASA-ISRO Synthetic Aperture Radar (NISAR); and the Mars 2020 mission (M2020).

Comparisons were based on seven metrics: the 50th, 70th, and 85th percentile estimates, the mean and standard deviation of the estimate, and the upper and lower bounds of the 95% confidence interval on the mean. The resulting percentage differences from the baseline (triangular distributions) were compiled and analyzed for each case. The results, observations, and conclusions of the comparisons are described.

40_ Orion Spacecraft Crew and Service Modules Life-Cycle Cost Estimate

Authors: Joel Castaneda, Stuart Mcclung, April-lyn Sturgeon McDaniel

Presenters: Joel Castaneda, Stu Mcclung

Biography:

Abstract: This paper will present how the KDP-C Life-Cycle Cost Estimate (LCCE) was determined for the Orion Spacecraft Crew and Service Modules (CSM). There were many challenges in developing a LCCE for the CSM—including data and methodology selection. It will focus on the methodology employed to estimate the Development (engineering design, drawing release, and test/verification) and Production of the Mechanism and Structure components of the CSM as well as describe the cross-checks used to corroborate the results.

41_ A Project Perspective on Schedule Risk Analysis

Authors: Lauren Bonine

Presenters: Lauren Bonine

Biography:

Abstract: The purpose of this presentation is to provide the NASA Cost Symposium audience insight into the schedule risk analysis process used by the Stratospheric Aerosol and Gas Experiment III on the International Space Station (SAGE III on ISS) Project. The presentation will focus on the schedule risk analysis process highlighting the methods for identification of risk inputs, the inclusion of generic risks identified outside the traditional continuous risk management process, and the development of tailored analysis products used to improve risk informed decision making.

SAGE III on ISS is an earth-observing instrument project managed and led by NASA Langley Research Center (LaRC) and planned for launch on SpaceX to the ISS in early 2016. The project

included refurbishment and testing of a heritage instrument, procurement and testing of payload monitoring equipment, and design, development and testing of a flight computer and payload mounting bracket. The project has also partnered with the ISS Program for an instrument pointing system that was developed under the European Space Agency (ESA) by Thales Alenia Space Italia (TASI).

SAGE III utilized schedule risk analyses in preparation for each Key Decision Point or major lifecycle review starting at Key Decision Point B (KDP-B) through KDP-D. The analyses supported each KDP and the analyses products were key to evaluating the Project's schedule reserve posture and the driving risks. The iterative nature of the analysis resulted in an evolved approach to risk modeling and the development of a methodology to actively manage schedule reserve at critical phases of project implementation.

As the Project's risk management process evolved, the management team identified a set of generic risks, common to the development of any spaceflight project. These generic risks describe events that pose a real threat to the project schedule but are not typically captured in the risk management process because they are outside of the projects' control or cannot be reasonably mitigated. Examples of such risks include test anomalies with no specific pre-indicators and center closure due to significant weather events.

As the Project approached the Assembly, Integration & Test and Launch Operations phase, methods were developed to create a risk informed schedule reserve burn down that estimated the amount of reserve needed for specific project activities. The risk informed reserve burn down has been used as a management tool to track reserve posture over time at a confidence level estimated reserve requirement, and inform decisions regarding the development of testing descope plans, adjustment of shift staffing, and use of reserve.

The project-led schedule risk analysis has lent itself to not only providing forward looking predictions of meeting project schedule requirements, but also to supporting management decisions to increase project success. The analysis was tightly coupled with pre-existing programmatic activities such as schedule and risk management. The SAGE III timeline and schedule risk analysis process, the identification and application of generic risks and the methodology, and the challenges and benefits of risk informed reserve burn down will all be described in greater detail to the NASA Cost Symposium audience.

42_ Joint Cost and Schedule Risk Analysis: Uncertainty versus Risk Input Distribution Types

Authors: Erica Beam and Fred Doumani

Presenters: Erica Beam and Fred Doumani

Biography:

Abstract: This presentation is an overview of how the JPL Joint Confidence Level (JCL) Process applies risk and uncertainty distributions to model the Project's JCL at KDP C.

NASA 7120.5E requires that all programs and projects develop a resource-loaded schedule and perform a risk-informed probabilistic analysis that produces a JCL at KDP C. The process involves generating the resource-loaded analysis schedule based on the Project's

Integrated Master Schedule (IMS) and Cost Plan. Applying uncertainty in the form of uniform distributions to all cost resources and schedule deliveries to I&T based on JPL's Flight Project Practices recommendations for funded schedule margin. Applying risk based on the Project's risk list with mitigation plans, cost and schedule consequences and likelihood identified by the Project.

The JPL Process has been using Uniform Distributions for uncertainty and a combination of Uniform and Triangular Distributions for Risk. Different distributions types have been recommended and the purpose of this presentation was to evaluate the differences between the triangular, trigen, and uniform probability distributions. To do this, JCL models from previous JPL projects were compared using each of the distributions.

43_QuickCost 6.0

Authors: Joe Hamaker and Ron Larson

Presenters: Joe Hamaker and Ron Larson

Biography:

Dr. Hamaker has 40 years of experience in the cost estimating profession. Skills include cost estimating and analysis, cost risk analysis, design to cost, engineering economics and related disciplines for all types of space projects including scientific spacecraft, spacecraft instruments, launch vehicles and human space programs.

In the energy sector, Dr. Hamaker has been involved in several cooperative endeavors in which NASA technology was applied to energy projects—specifically Dr. Hamaker developed a parametric cost model for coal gasification plants (for TVA), a parametric cost model for terrestrial solar heating and cooling (for DOE) and a parametric cost model for the Space Satellite Power System (again for DOE). All these models included an extensive design to cost and economic analysis components.

Dr. Hamaker has initialized and managed several cost estimating organizations including the NASA Marshall Space Flight Center Engineering Cost Office, the NASA Headquarters Cost Analysis Division and the cost department of The Millennium Group International and others. In these instances he was responsible for the initial recruitment and hiring of the professional staff, the drafting of policy and procedures and day to day management.

Mr. Larson is a Senior Analyst with Galorath Federal, Inc. Prior to his retirement from civil service in 2015, he was assigned to NASA's Independent Program Assessment Office (IPAO) at NASA Headquarters where he was responsible for providing independent cost/schedule estimates and analyses for NASA program/project reviews. Prior to joining the IPAO in 2004, Mr. Larson was a senior cost analyst at the NASA HQ Cost Analysis Division. Before joining NASA in 2003, Mr. Larson was an employee of The Aerospace Corporation where he provided support to the Intelligence Community (IC) Cost Analysis Improvement Group (CAIG) from its inception in 1999, performing ICEs, ICAs and cost research tasks for a broad spectrum of IC projects. While an employee of both Management Consulting and Research (MCR) and The MITRE Corporation, Ron provided cost support to the National Reconnaissance Office (NRO) Cost Group (NCG). He also worked for Daimler-Chrysler Space Division as a Project Control Manager and served as a lead parametric cost analyst. Ron spent nearly ten years working for Lockheed

Missiles & Space Company on mission planning and operations for classified space programs. He also worked as a Systems Design Engineer for Chrysler Corporation's Space Division (Michaud) on the Saturn/Apollo program. While on active military duty with the US Air Force, Ron served as an Atlas-F ICBM launch officer in the Strategic Air Command.

Ron has served several terms on the Board of Directors of the International Society of Parametric Analysts (ISPA, now ICEAA) and he received their Service Award in 1997. He is also a member of the Space Systems Cost Analysis Group (SSCAG) and a Senior Member of the American Institute of Aeronautics and Astronautics (AIAA).

Mr. Larson holds a Bachelor of Science degree in Chemical Engineering (Management Option) from the Illinois Institute of Technology. Ron is an FAA-Certified Flight Instructor (Instrument) and holds a Commercial Pilot's Certificate.

Abstract: QuickCost is a parametric Cost model developed over the 2001 to 2011 time period with application to a variety of space missions. The original versions of QuickCost were developed by Dr. Joseph Hamaker while working for NASA Headquarters. Dr. Hamaker while employed by SAIC and then at TMGI accomplished intermediate updates of the model. The last update was in March 2011 with the release of QuickCost 5.0. This paper will describe the work being done to issue QuickCost 6.0.

44_ Utilizing PRICE TruePlanning at JPL

Authors: Milana Wood, Bryan Kobie, Melissa Winter, and Fred Doumani

Presenters: Milana Wood

Biography:

Abstract: This presentation will discuss how JPL is building upon its existing calibration efforts with PRICE-H in an effort to calibrate TruePlanning to support internal cost estimation activities, including the support of design/cost trades, cost validations, and independent cost estimates.

The PRICE TruePlanning tool is a cost estimation framework that allows the cost estimator to develop, analyze and report their project estimate based on an organization's specific needs. The Hardware Component Manufacturing Complexity for Structure/Electronics parameter is essential to characterizing an organization's past performance and developing future estimates. It is recommended by PRICE Systems that the process of calibration be used to derive the value of the Manufacturing Complexity for Structure/Electronics from historical projects, while establishing relationships between the complexity value and a missions technical parameters. These relationships can then be used as a basis for design/cost trades in forward estimates. The purpose of this presentation is to discuss the process and results of JPL's calibration effort of TruePlanning and provide recommendations on how to use the results as well as lessons learned. This presentation will focus on the five tasks of the calibration effort: 1) Data Collection 2) Data Analysis 3) Model Calibration 4) Analysis of the Results and 5) Findings/Recommendations.

45_ Quantitative Risk Assessment: An overview of risk analysis concepts at

NASA with an International Space Station Program (ISSP) Viewpoint

Authors: Kendrick Glenn, Michael Jansen, Oscar Gutierrez

Presenters: Kendrick Glenn, Michael Jansen, Oscar Gutierrez

Biography:

Abstract: This two-phase paper will provide a unique perspective on life-cycle affordability based on experience with NASA's International Space Station (ISS) Program. The paper will emphasize the importance of affordability as key to risk-informed decision processes, and in turn to sustainability. The first phase will define quantitative risk analyses as applied in the ISS Program, which must consider the interests of non-profit US-international partnerships and profit-oriented commercial partnerships in the calculation and mitigation of cost and schedule risks over the life-cycle. The second phase will provide a behind-the-scenes look at a Monte Carlo simulation based on an ISS case scenario.

A game show depiction of Monte Carlo will be used to demonstrate a behind the scenes look at the simulation strategy. A cradle to grave view of the process from when an ISS project manager conceptualizes a potential negative consequence to the program to how the Assessments, Cost Estimating, and Schedules office project likelihood and magnitude of the risk will be revealed.

The ACES QRAs are used in various reporting venues such as Early Warning System, Program Risk Advisory Board, Cost Containment, Program Planning Budgeting and Execution exercises, and ISS Monthly Program Review reports to name a few. The QRA allows program management to protect for potential cost growth and prioritize work in the coming government fiscal years.

46_Schedule Execution Analysis

Authors: Antonio Rippe, Darren Elliott, James Reilly

Presenters: Antonio Rippe

Biography:

Abstract: Schedule execution analysis enables rapid insight into the location and magnitude of changes to assess if there are potential impacts lurking that may affect overall program performance. Schedule execution analysis is currently being used for basic project control by delivering qualitative and quantitative schedule analysis information for all levels of management decision making for the Ground Systems Development & Operations (GSDO) Independent Assessment Team (IAT) on a monthly basis.

This paper will focus on the areas of insight provided by the schedule execution analysis:

1. Overall schedule topology
2. Identifying Work Shifting
3. Identifying Date drifting
4. Durations changes
5. Critical Path change
6. Critical Path activity slips
7. Critical Path duration changes

47_ODNI Research

Authors: Brian Wells and Carrie Gamble

Presenters: Brian Wells and Carrie Gamble

Biography:

Abstract: The Office of the Director of National Intelligence will address current general cost and schedule research projects. Particular areas of emphasis will include cost estimating methodologies, tracking projects across their lifecycles, and retrospectives. The brief will detail our processes and cost estimating methodologies used to consolidate data, perform analyses, and construct cost estimating relationships (CERs). We will address how the ODNI tracks cost estimates and uses results to drive areas of focus for future research projects. In addition, retrospectives are a new capability to perform more detailed analyses of completed projects and better understand positive and negative characteristics that resulted in final cost or schedule deltas compared to lifecycle estimates.

48_ Validation of PRICE True Planning Space Missions Cost Model

Authors: Arlene Minkiewicz, John Swaren

Presenters: Arlene Minkiewicz, Dom Costa

Biography:

Mr. Swaren is PRICE Systems' lead Solutions Architect for NASA related customers. He has over 25 years of experience in requirements analysis, estimation, risk, software sizing, parametric model development and pricing/ valuation. His consulting engagements have supported NASA, DoD, DHS, Boeing, Sikorsky, and Pratt & Whitney.

He has earned graduate degrees in Engineering, Statistics, Computer Science, Marketing and Finance, with an undergraduate degree in Mathematics. He has also had PMP, Six-Sigma and Agile-Scrum training. He contributes to PRICE as a consultant, researcher, trainer and mentor. He is a frequent contributor of web blogs, newsletters articles, training materials and webinars.

Arlene F. Minkiewicz is the Chief Scientist at PRICE Systems, LLC with over 30 years of experience at PRICE building cost models. She leads the cost research activity for TruePlanning, the suite of cost estimating products that PRICE provides. She is a software measurement expert dedicated to finding creative solutions focused on helping make software development professionals successful. She is widely published and speaks frequently on software related topics.

Abstract: Cost estimate validation test results are presented for a set of missions representing each NASA science organization (Planetary, Earth Sciences, Heliophysics, and Astrophysics) using a recently released cost model for NASA robotic science missions, PRICE Systems TruePlanning for Space Missions (TPSM). Model estimates use "as-launched" input data and results are compared to actuals. The highly tailored TPSM approach enables detailed assessments integrating technical and programmatic (schedule) requirements and mimics a grass-roots bottoms-up methodology with a substantially reduced cost estimate development effort.

TPSM implements a set of CERs that estimate robotic Earth and Space Science Missions' costs of Design, Fabrication, Assembly Integration and Test (AI&T), and Launch Operations, along with the support functions associated with these activities. The Space Component, the heart of the Space Missions models, represents a special implementation of the TruePlanning for Hardware – Hardware Component model. These models contain input parameter guidance specific to NASA robotic space missions. Similarly the Space Assembly model is a special implementation of the TruePlanning For Systems – Assembly model which has been adapted for space missions estimation. The Space Component and Space Assembly are used in the model to estimate costs for design and fabrication for both the spacecraft and any payload. The Space Subsystem and Space System models implement CERs for Launch Operations activity costs, Assembly Integration & Test Activity costs, and the costs for functions (Project Management, Systems Engineering etc.) that support the design, fabrication, AI&T, and Launch Operation Activities.

The methodology supporting TPSM has evolved over the 30+ years it has been in use supporting NASA cost analyses and attempts to capture as many relevant cost drivers for robotic space science missions as possible. TPSM validation results are described and the model captures all NASA Phase B-D WBS elements except the launch vehicle. Comparison details cover the overall project, spacecraft and subsystems, science instruments, and project support functions.

49_ Planning for the Next Generation of TDRS

Authors: Robert Giannini, Alesyn Lowry, Bob Menrad, Sabrena Yedo

Presenters: Robert Giannini, Sabrena Yedo

Biography:

Abstract: Constrained resources, competing priorities, and multiple developmental efforts occurring simultaneously has put the Human Exploration and Operations Mission Directorate (HEOMD) in a tight position with little flexibility available in its portfolio. This places extreme pressure on HEOMD to identify a path forward for the next generation of its Tracking and Data Relay Satellites (TDRS), also known as TDRS-4G.

The TDRS project was established in 1973. The prime design goal was to provide continuous, around the clock communications services to NASA's most critical low earth-orbiting missions, and improve the amount of data that could be received. The Space Network program, which was established in the early 1980s to replace NASA's worldwide network of ground tracking stations, is largely comprised of a constellation of geosynchronous TDRS spacecraft that provide telecommunications, tracking and clock calibration, testing and analysis, and ground elements. Currently, six TDRS spacecraft are in service; half are from the first generation and the other half are comprised from the second generation of TDRS. TDRS K and L, both from the third generation, are undergoing service testing in space. NASA will complete its work on TDRS M in 2016, thereby completing three generations of TDRS. Since the life expectancy of the aging fleet is uncertain, NASA must begin planning for the 4th Generation in order to maintain a desired

six-plus-one constellation of TDRS spacecraft. With multiple developmental efforts, as well as the extension of the International Space Station through 2024, HEOMD has not identified a funding source within its five year budget horizon to begin development of this next TDRS generation. With other government agencies utilizing TDRS, it is vital NASA maintain the TDRS constellation or grasp the implications of assuming more cost and schedule risk to the aging program.

Through investigation and analysis, the team will evaluate the likely cost of the 4th Generation of TDRS and the dates by which these satellites must be launched to provide near continuous information relay services, and/or alternative approaches to maintain these required services. The team will also determine feasible alternatives to fund this requirement within the current HEOMD portfolio. In order to provide this assessment, the team will evaluate assumptions of designed mission lifetimes, future capability demands, and architecture alternatives. The team will gather historical cost, schedule, and technical data from the previous three generations of TDRS through SID's TDRS data as well as Cost Analysis Division (CAD) compiled data and tools such as CADRe in order to better understand the likely requirements of 4th Generation TDRS. After gathering this information, the team will also utilize this data to model budgetary and scheduling "what-if" scenarios that incorporate risk and uncertainty.

The benefits of this study are two-fold. By pursuing this study, the Agency can examine viable paths forward for Next Generation TDRS which will assist in future agency planning and can be incorporated into the AMPM. Additionally, this study will put to use vast data and information collected via CAD data sources and illuminate to the cost estimating community how this data can aid agency-level discussions and decisions on strategy.

53_In-House Build Efficiencies: PM, SE, and MA

Authors: Meagan Hahn

Presenters: Meagan Hahn

Biography:

Abstract: Existing analysis demonstrates that while total mission hardware cost continues to be a reliable predictor of total PM, SE, and MA costs, other variables have statistically significant impact on these critical mission functions. Specifically, the external vs. internal spacecraft build is shown to be a cost driver in mission level PM, SE, and MA costs (Hahn, 2014). However, this analysis did not include additional (and non-trivial) wrap costs incurred by the spacecraft vendor for high reliability missions. Our analysis proves there is an inherent efficiency in total PM, SE, MA costs—both in absolute dollars and in percentage of flight system—with in-house spacecraft builds. An end-to-end mission capability facilitates management and engineering efficiency, thereby freeing resources for those elements that ultimately increase the success of the mission (e.g. payload and science return). The perceived cost savings of a procured bus may be offset by both the cost of oversight and the opportunity cost of instrument capabilities.

54_ Challenges of Validating Low Cost Missions: The Class D Conundrum

Authors: Meagan Hahn

Presenters: Meagan Hahn

Biography:

Abstract: In a budget constrained environment, there are more opportunities for low cost Class D science missions than for higher class missions (e.g. Discovery, New Frontiers, Flagship, etc.). However, NASA does not want to sacrifice cost credibility, cost realism, or requirements/product assurance with its low cost missions; we remain risk averse. Furthermore, we lack sufficient data points and clear understanding of how Class D translates to tailored mission requirements, resulting in an artificial mission impasse entirely constructed of an inability to validate costs for missions that, by definition, should be more accepting of cost, schedule, and technical risk. These missions should not face cost validation against a database primarily constructed of missions subject to Class A/B/C requirements, higher complexity, longer lifetimes, and larger payload suites. Not only are the existing CERs representative of higher mission cost class, the historically driven risk analyses overestimate cost growth. This paper will demonstrate the difference between realized and estimated cost for Class D balloon missions to quantify the bias against this mission class in the current cost evaluation processes. This will allow us to identify which variables need to be adjusted when estimating this mission class. It behooves the community to be cognizant of the limitations of the standard estimating tools in quantifying total Class D mission cost—there are credible adjustments that can (and should) be made to validate costs.

55_ Analysis of Recent NASA Flight Software Costs

Authors: Nicole Powers

Presenters: Nicole Powers

Biography:

Abstract: This paper begins the process of developing parametric Cost Estimating Relationships (CERs) for flight software costs. All data for the analysis was taken from CADRe. Several parameters were investigated through multiple linear regression analysis such as SLOC, schedule duration, mission class, institution, etc. The regression results were used to determine the best predictors of flight software costs. The following sections will detail the analysis of flight software parameters and the regression results.

56_ Development of AMES Cost Model (Ames Micro/Nano-satellitES Cost Model)

Authors: Michael Sok Chhong Saing, Leon Yueh-Liang Shen, Tommy Paine

Presenters: Michael Sok Chhong Saing, Leon Yueh-Liang Shen, Tommy Paine

Biography:

Abstract: The increase in nano- and microspace development and deployment since the late 1990s has created a new paradigm of

microspace research and exploration which calls for a cost model to generate an initial cost estimate based on actual historical project data. Since 2006, NASA Ames Research Center (ARC) has led and/or collaborated with private industry and universities on nano and microsatellite project missions and technology demonstrations. NASA ARC is focusing on its center-led nano and microspace missions for research, development, and cost relationships which will lead to the development of a nano- and microsatellite cost model focusing on cubesat form factors 1U - 6U and less than 14kg in mass. As NASA ARC continues to develop and deploy nano- and microsatellites, it is imperative for cost estimates to be as accurate as possible to meet design and cost constraints. The cost model will generate a rough order of magnitude (ROM) during the early planning phase to estimate 1) spacecraft bus hardware test, and assembly related activities cost; 2) project level work breakdown structure (WBS) aligned to NASA's WBS; 3) phasing cost plan; 4) cost risk probability distribution with selected Monte Carlo simulation tools. The cost model's capabilities will be able to provide an initial cost estimate from the input design and mission parameters.

The data is the driver for the cost model's initial cost estimate capabilities. Data mining for the spacecraft bus components and project level cost has been met with challenges due to lack of standardization. As data collection and research continues, the prime data that will layout the foundation work for this model includes, but is not limited to, the following: project wraps cost (such as Project Management, Project Systems Engineering, etc..), environmental testing activities, mission class, production quantities, procure versus in-house built hardware, operating orbit and environment type, type of missions (science, communication, and technology demonstration), and other related spacecraft bus and project level mission designs. Once sufficient data is categorized and normalized, the Cost Estimating Relationships (CERs) development will take place and provide the model's capabilities to generate initial cost estimates.