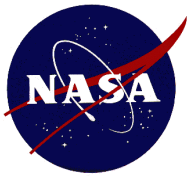


The Psychology of Cost Estimating

Andy Prince

NASA/Marshall Space Flight Center

Engineering Cost Office

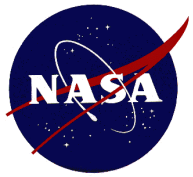


Outline



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- **The Problem**
- **The Cause(s)**
- **The Psychology**
- **The Solution(s)**



The Challenge of Prediction



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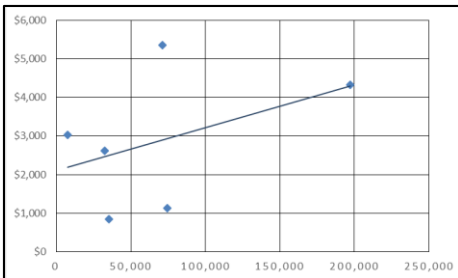
- **The Technical Environment**

- Technically Challenging
- Small, Specialized Industrial Base
- Fuzzy Requirements



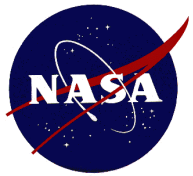
- **The Corporate Environment**

- Driven by Politics & Budget
- Bureaucratic (Government & Industry)
- Programmatic Consensus vs. Healthy Conflict



- **The Estimating Environment**

- Data Sets are Small and Noisy
- Models are Mysterious or Inadequately Validated
- Few Physics/Industrial Based Models



Prediction is Important

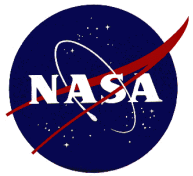


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“Prediction is important because it connects subjective and objective reality.”
- Nate Silver, The Signal and the Noise

Notes to Audience:

- **A Cost Estimate is a Prediction**
- **Anything Subjective is Open to Debate**

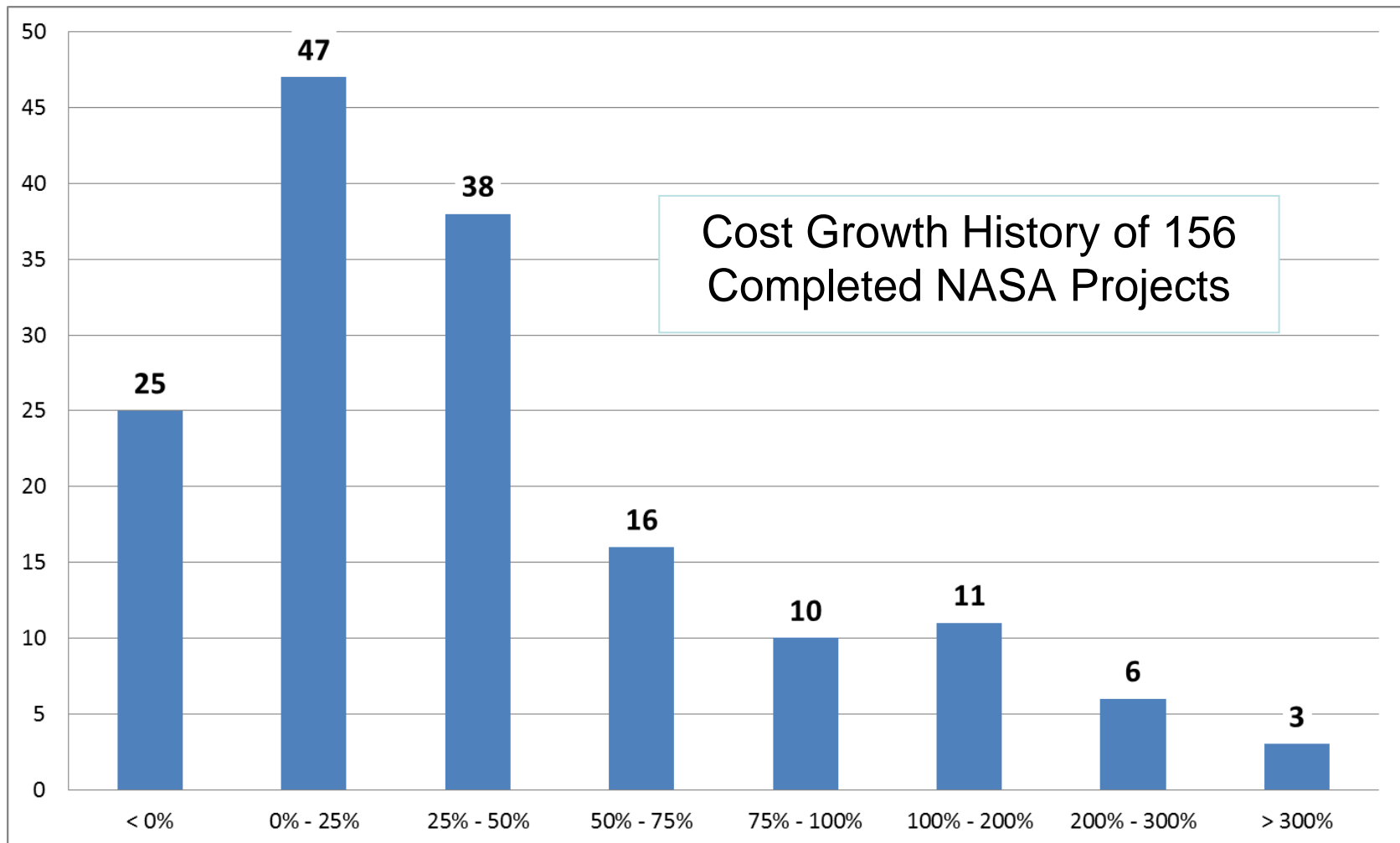


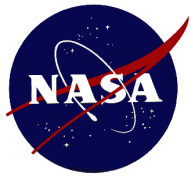
The Problem



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Cost Overruns have become Institutionalized within the Federal Government



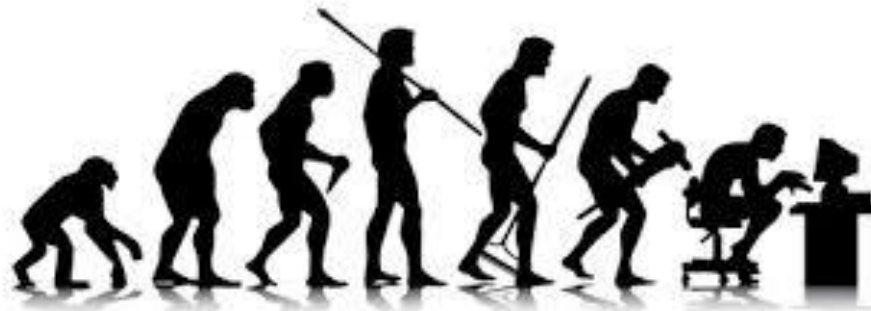


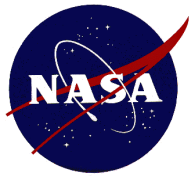
Causes of Cost Overruns



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- **Bad Models, Inadequate Data, Poor Cost Estimators**
- **Undefined Technical Requirements, Overestimated TRL's, Funding Shortfalls, Bad Managers, etc.**
- **Customers Unwilling to Accept the Truth**
- **A Broken Corporate Governance Process**
 - The Right People are not getting the Right Information at the Right Time
- **The Fact that Everyone Involved in Developing and Using Cost Estimates are Human**



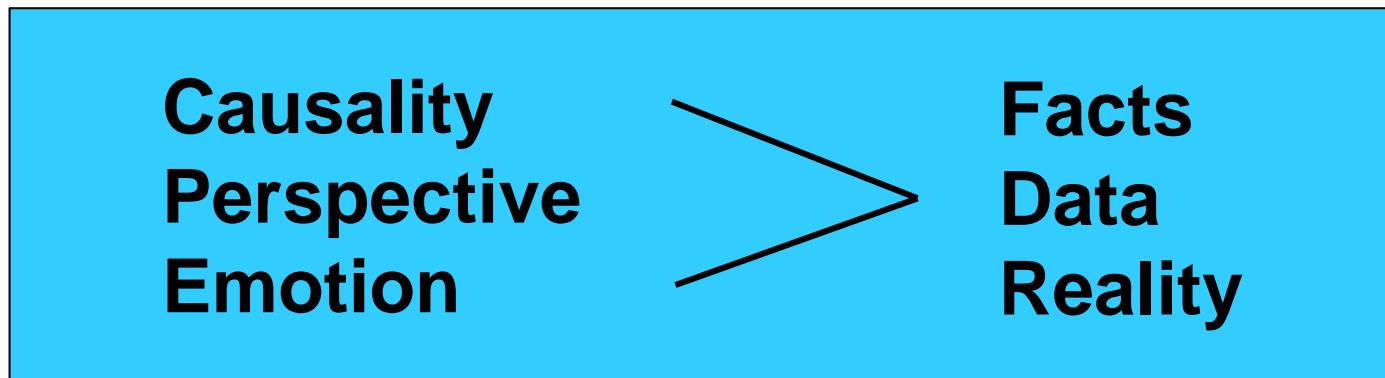


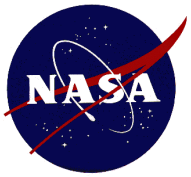
The Human Factor



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- Over the last 70+ years, psychological research has uncovered many surprising attributes of human cognition
 - We are **overconfident**
 - Our thinking is often **shallow**
 - We **prefer stories and anecdotes** over facts and data
 - We don't trust statistics because **statistics are non-intuitive**
 - We **fear loss** more than we value gains
 - **Personal experience and knowledge** trumps everything



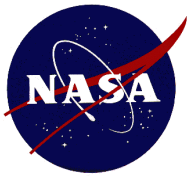


The Irrational Human



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- Behavioral Economists & Psychologists have found that *even when making financial decisions*, our behavior is “Predictably Irrational”
- “...we are really far less rational than the standard economic theory assumes. Moreover, these irrational behaviors of ours are neither random nor senseless. They are systematic, and since we repeat them again and again, predictable.”
 - Dan Ariely, Predictably Irrational, p. xx
- “It’s no revelation that the human mind is not a purely rational calculating machine. It is a complex system that seems to comprehend and adapt to its environment with an array of simplifying rules. Nearly all of these rules prefer simplicity over rationality. Those that are not quite rational but perhaps not a bad rule of thumb are called “heuristics.” Those that fly in the face of reason are called “fallacies.””
 - Douglas W. Hubbard, How to Measure Anything, p. 221

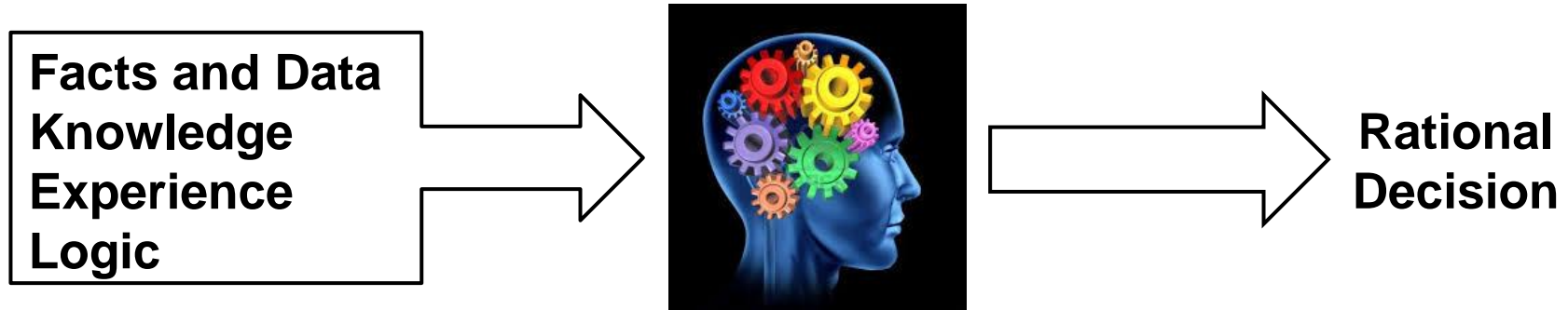


Thinking

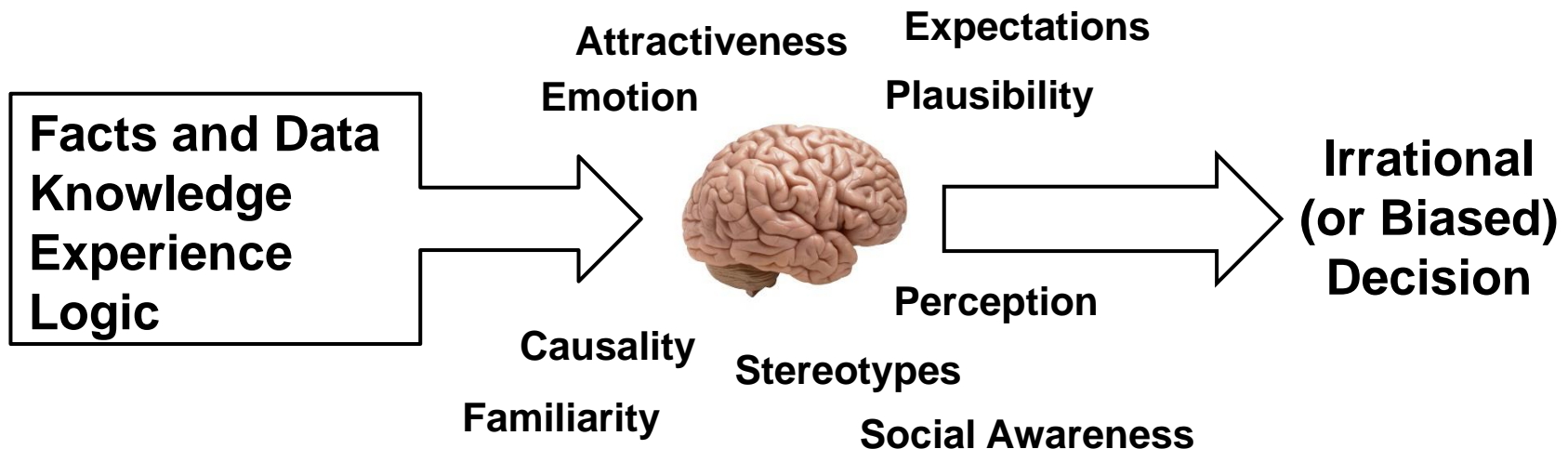


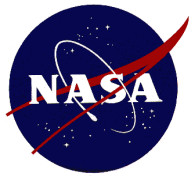
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How We Think We Think



How We Really Think



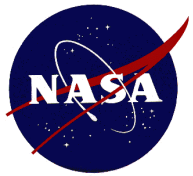


An Example of How Bias Affects Predictions



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- A cost estimate is a prediction
- Customers and professional estimators make predictions
- Most predictions fail to address *regression to the mean*
- **Daniel Kahneman (Thinking, Fast and Slow; p. 188):**
“...the prediction of the future is not distinguished from an evaluation of the current evidence – prediction matches evaluation. This is perhaps the best evidence we have for the role of substitution. People are asked for a prediction but they substitute an evaluation of the evidence, without noticing that the question they answer is not the one they were asked. This process is guaranteed to generate predictions that are systematically biased; they completely ignore regression to the mean.” (emphasis added)

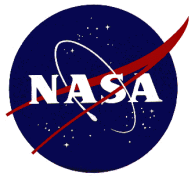


Translation



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Our biases cause us to make decisions that lead to unsupported deviations from the trends identified by the historical record.

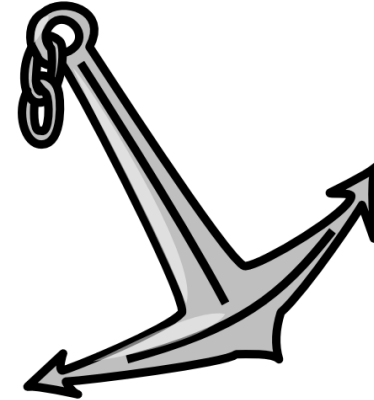


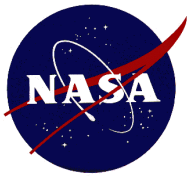
A List of Common Biases



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- Optimism/Overconfidence
- Anchoring (Relativity)
- Availability
- Kahneman: What You See Is All There Is (WYSIATI)
- Halo/Horns Effect (Confirmation Bias)
- Plausibility Effect
- Bandwagon Bias
- Attractiveness (Appearances)
- *Interactions between Biases*





Antidotes

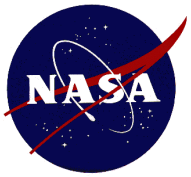


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- **Have a Good Process**
- **Inject a Healthy Dose of Reality**
- **Validate Your Results**
- **Embrace Uncertainty**
- **Be the Expert**

**Build Your
Own Story**

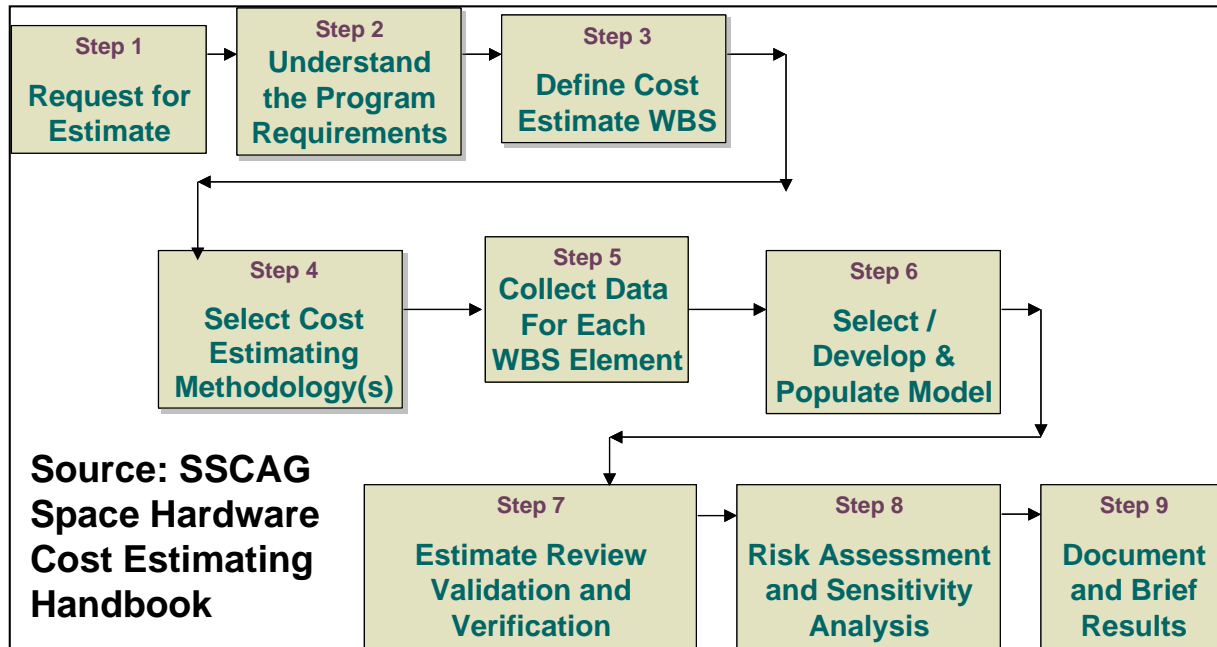
Kahneman: “At work here is that powerful WYSIATI rule. You cannot help dealing with the limited information you have as if it were all there is to know. You build the best possible story from the information available to you, and if it is a good story, you believe it. Paradoxically, it is easier to construct a coherent story when you know little, when there are fewer pieces to fit into the puzzle. Our comforting conviction that the world makes sense rests on a secure foundation: our almost unlimited ability to ignore our ignorance.” (emphasis added)



The Process

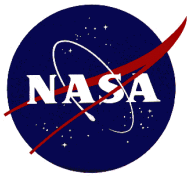


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The Process Provides:

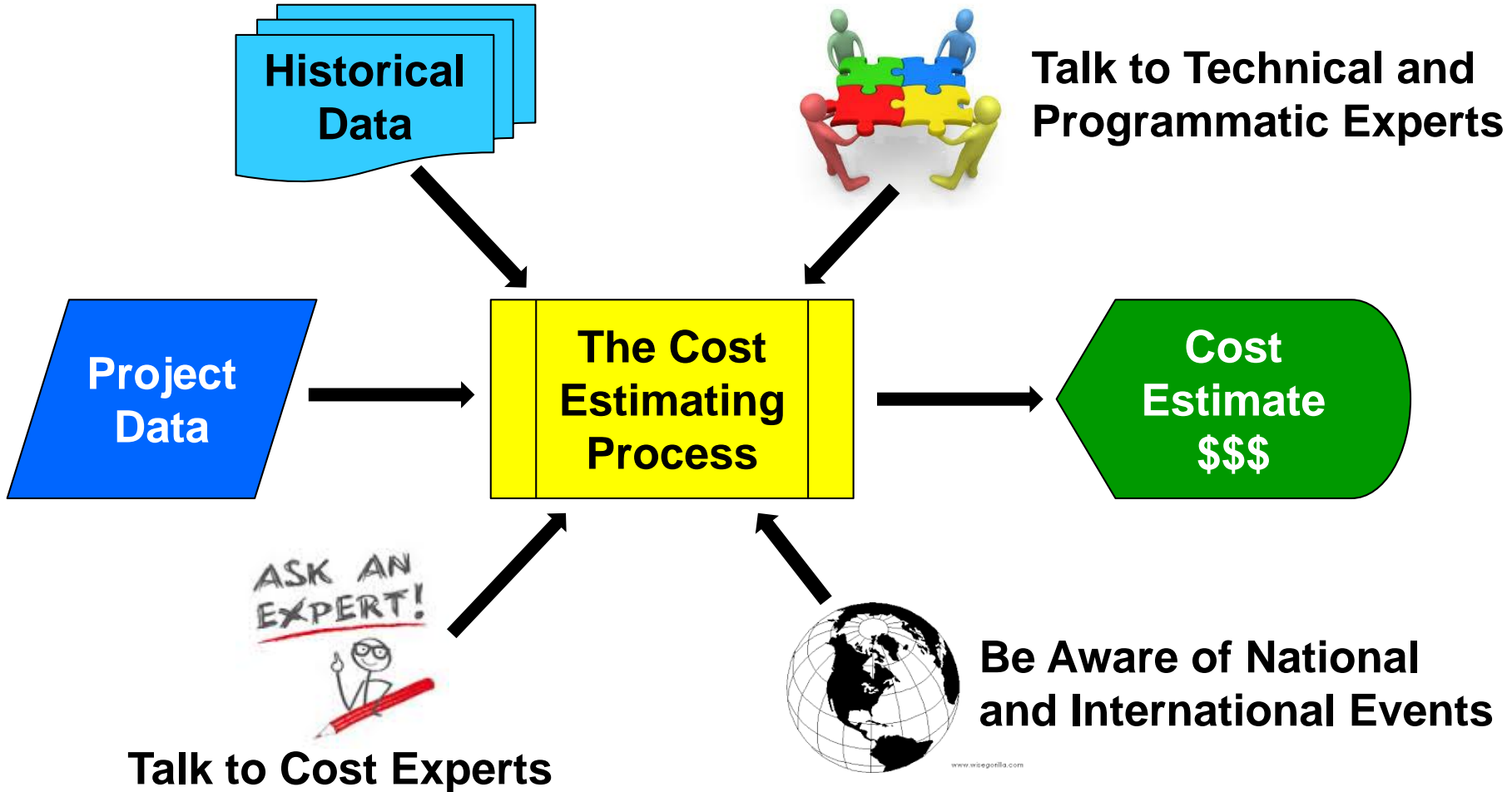
- Traceability
- Repeatability
- Best Practices
- Analytical Mindset
- **Steps to Mitigate the Effect of Biases**
- **Forms the Basis of Your Story!**



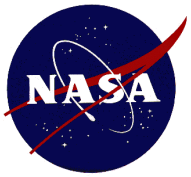
Injecting Reality



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Be Open Minded and Humble about what You Learn



A Note on History

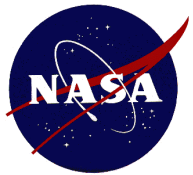


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Opinion: The Cost Community's Greatest Asset is Our Historical Data and Perspective

- **Provides General Context**
 - How Projects are Managed and Systems are Developed
 - What are Typical Problems and Issues
 - How have Challenges been Addressed and Overcome
- **Provides a Dose of Reality**
 - Specific Technical and Programmatic Analogies
 - Real Data for Establishing Base Rates
 - Boundary Conditions for Evaluating Sensitivities and Uncertainties
 - Data for Supporting Ground Rules and Assumptions

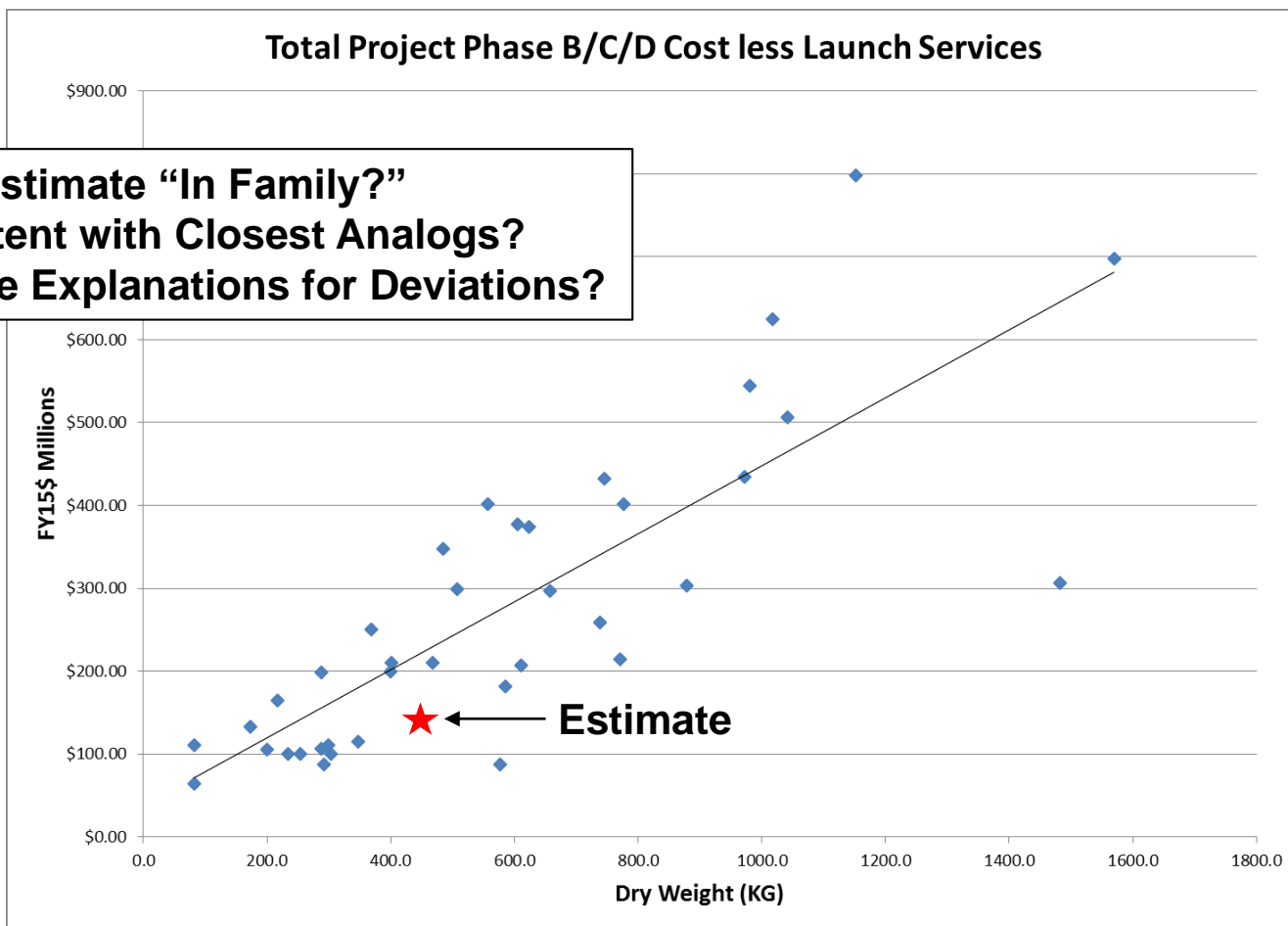
Look for Ways to Use the Historical Information to Provide Value Beyond the Cost Estimate!

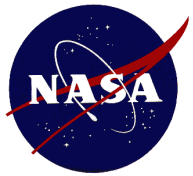


Validation



Is Your Estimate Consistent with Historical Experience?





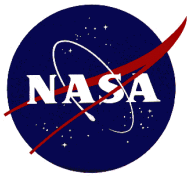
Validation w/Limited or No Data



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- **Study** the Data You have
- **Look for Parallels and Similarities**
 - i.e. The Systems Engineering Processes should Generally be the same for all Large R&D Programs
- **Use Bayesian Approaches (Smart, 2014)**
 - *Know Your Base Rates!*
- **Calibrate and Evaluate**
 - Take an Existing Estimate
 - Reproduce using a Known Cost Model
 - *Evaluate the Model Settings*
- **Disaggregate Estimate into Functional Elements**
 - *Review Functional Cost with Experts*

Less Ground Truth, Greater the Opportunity for Bias



Risk and Uncertainty



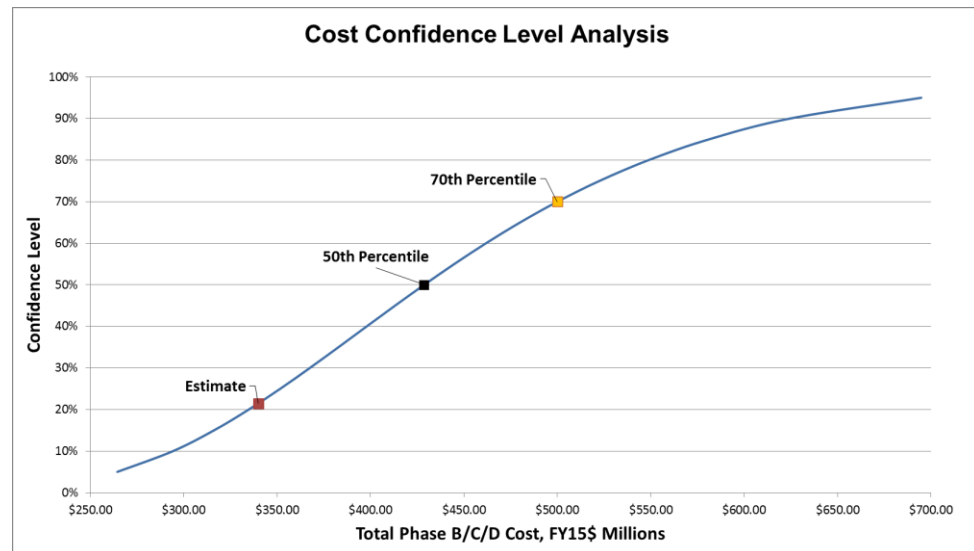
- Risk: Chance of Loss, Chance Something could go Wrong
- Uncertainty: Indefiniteness about the Outcome
- Quantifying risk and uncertainty can lead to a **focus on the inputs**, rather than the outputs
 - NASA JCL Experience

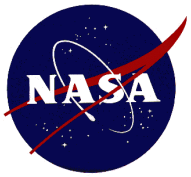
• Quantifying risk and uncertainty explores the impact of changes in the **subjective** assessment

- Quantifying Uncertainty

- Sensitivity Analysis
- Confidence Level Analysis

- **My Opinion:** Point estimates create a false sense of certainty and deprive decision makers of useful information





Be the Expert



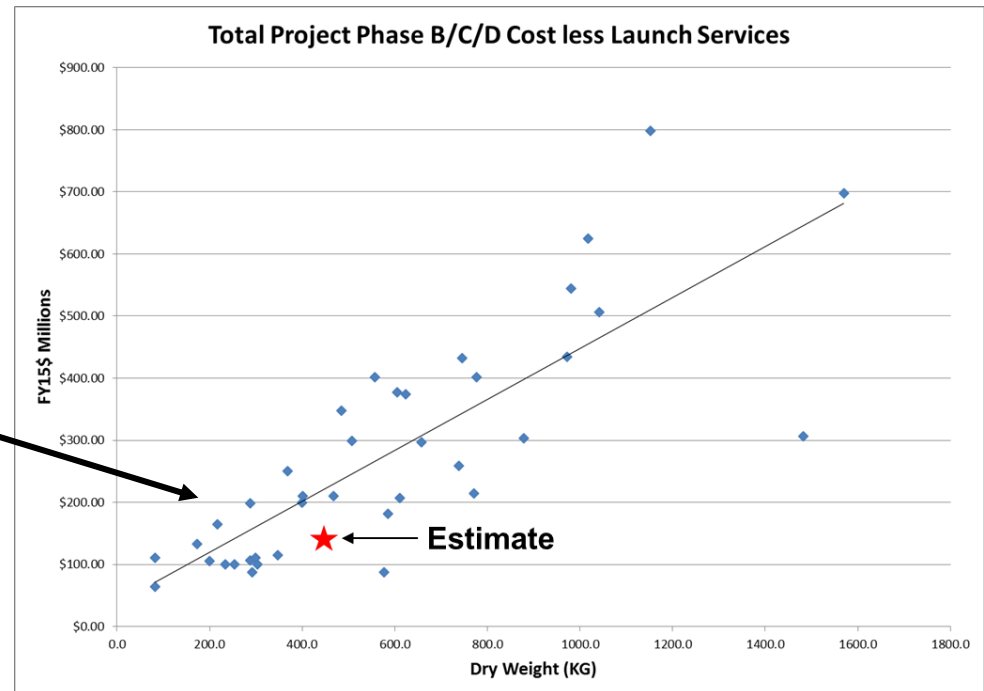
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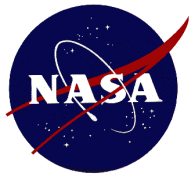
- Daniel Kahneman, Nate Silver, Malcolm Gladwell, and Douglas Hubbard all agree that **combining mathematical models with expert human judgment improves the accuracy of predictions**
- **Joe Hamaker:** “But my point is that many of us close to the practice do have some innate and intuitive ability, honed by years of being associated with the cost estimating game, that is usually pretty reliable when it comes to judging the quality of a cost estimate.” – What are Quality Cost Estimates or the 260 Hz Cost Estimate

- **Humans can ask the “Why” question**

- **Example: “Why is this estimate is below the trend line?”**

- Heritage?
- High TRL rating?
- Significant uncosted contribution?
- Others?



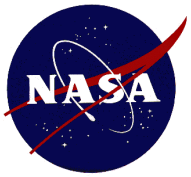


Become the Expert



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- **A trained mind** is a powerful tool – our subconscious is constantly processing a tremendous amount of data
- **Malcolm Gladwell**: “Just as we can teach ourselves to think logically and deliberately, we can also teach ourselves to make better snap judgments.” – Blink
- **Helps to have years of experience – use the experience you have**
- **Study the historical projects in your databases and libraries**
- **Learn and memorize base rates**
- **Engage with and learn from professionals from other disciplines**
- **Take classes, get more or advanced degrees**
- **Read widely, especially books about technological achievements, science, organizational behavior, human behavior, biographies and memoirs, etc. – let curiosity be your guide**
- **Attend professional society conferences, workshops, luncheons, etc. be open to new data, thoughts, and ideas**



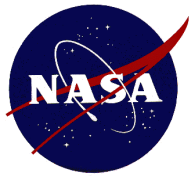
Telling Your Story



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- **People Relate to Stories that Explain things within the Context of their Worldview (**Know Your Customer!**)**
 - Psychological Research: Beliefs Trump Statistics
 - Effective Communications: Values Alignment
- **Start with the **Facts and Data****
 - “Everyone is entitled to his own opinion, but not his own facts.” – Sen. Daniel Patrick Moynihan
- **Show the **Relationship** between the Facts, Data, Base Rates, and Subjective Assessments, make it Transparent and **Keep it Simple****
- **Bound Uncertainty, Validate Results**
- **“Credible, Supportable, Defendable” – Richard Webb**

Goal is for Your Estimate to be a Logical Outcome of the Evidence



Things to Look Out For



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Discarding or ignoring applicable data



Placing **significant emphasis** on a single bit of data or expert opinion



Tenuous analogies or extrapolations



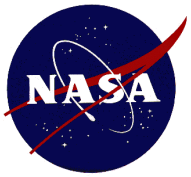
An estimate that **deviates significantly** from the historical trend and/or reasonable analogs



Any estimate that depends on **changes in historical business practices**



Falling in love with a subjective assessment



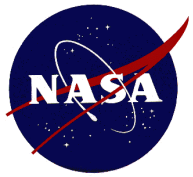
Key Takeaways



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- **We are all biased**, these biases affect how we develop our estimates and how our estimates are received
- You can **control your behavior** but you can only **influence others**
- The cost community's **greatest asset** is our **historical data and perspective**; use this to bound uncertainty, validate your estimates, and establish base rates

A **valuable cost analysis** is not one that gives the customer the answer they want, but **gives the customer answer they need**



Bibliography



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- Ariely, Dan, *Predictably Irrational*, Revised and Expanded Edition, New York: Harper Perennial, 2009
- Aschwanden, Christie, "Your Brain is Primed to Reach False Conclusions." *fivethirtyeight*. February 17, 2015.
<<http://fivethirtyeight.com/features/your-brain-is-primed-to-reach-false-conclusions/>>
- Gladwell, Malcolm, *Blink, The Power of Thinking Without Thinking*, New York: Little, Brown and Company, 2005
- Hamaker, Joseph W., "What Are Quality Cost Estimates? Or the 260 Hz Cost Estimate," *Journal of Parametrics* Vol. 25, Issue No. 1, 2007: 1 – 7
- Hubbard, Douglas W., *How to Measure Anything*, New Jersey: John Wiley & Sons, 2010
- Kahneman, Daniel, *Thinking, Fast and Slow*, New York: Farrar, Straus and Giroux, 2011
- Levitt, Steven D. and Dubner, Stephen J., *Freakonomics, a Rouge Economist Explores the Hidden Side of Everything*, New York: Harper Perennial, 2009
- Mlodinow, Leonard, *The Drunkards Walk: How Randomness Rules Our Lives*, New York: Pantheon Books, 2008
- Mooney, Chris, "The Science of Why We Don't Believe Science." *Mother Jones*. May/June 2011.
<<http://www.motherjones.com/politics/2011/03/denial-science-chris-mooney>>
- Silver, Nate *The Signal and the Noise: Why most Predictions Fail but some Don't*, New York: The Penguin Press, 2012
- Smart, Christian, "Bayesian Parametrics: How to Develop a CER with Limited Data and Even Without Data," *Proceedings of the 2014 International Cost Estimating and Analysis Association Professional Development and Training Workshop*, Colorado: June, 2014
- Surowiecki, James, *The Wisdom of Crowds*, New York: Anchor Books, 2005