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Cost Engineering in a Market-based Acquisition Process

Raytheon – Space & Airborne Systems

Darin Hoffman, PhD
WLE – West Affordability & Cost Engineering
Cell: 310-357-4794
Email: Darin.Hoffman@raytheon.com
El Segundo, CA 90245 USA

How much does this cost ?

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Estimation Methodologies

- Engineering Judgment
  - The engineering build-up method develops the cost estimate at the lowest level of the WBS, one piece at a time, and the sum of the pieces becomes the estimate.
- Analogy
  - An analogy uses the cost of a similar program to estimate the new program and adjusts for differences
- Parametric: basic CERS ($/lb.) to Complex Models (multi-variant)
  - A cost estimating methodology using statistical relationships between historical costs and other program variables such as system physical aspects
- Others
  - Actual Costs
  - Expert Opinion
  - Extrapolation
  - Learning Curves
  - …

Purpose of Program Affordability

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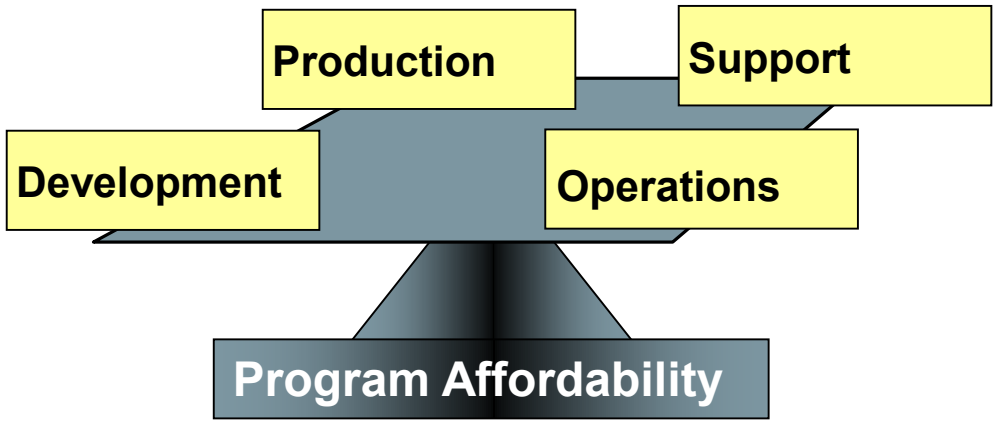
- Minimize Total Life Cycle Costs to the Customer, While Meeting all Requirements

M1126 Stryker™ ICV

M1A2 SEP Abrams™ Tusk



- ➢ To Track Cost As a Technical Performance Measure (TPM) of the Deliverables
- ➢ Assist the Program in Achieving a Proper Balance Among Technical Performance, Affordability (Development, Production, Operating and Support), and Producibility.

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Affordability Goal Setting

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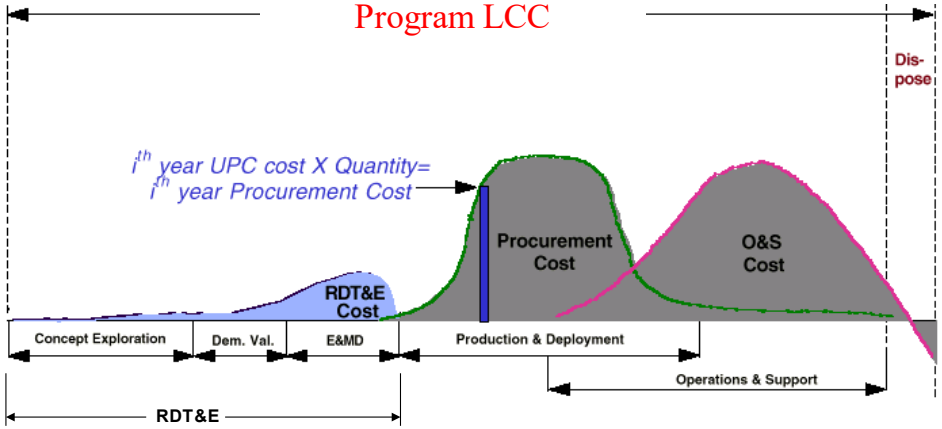
Customer Mandate

- Program affordability targets shall be treated by the program manager as a Key Performance Parameter (KPP).
- Affordability targets:
  - Total Development Cost
  - Average Unit Acquisition Cost
  - Average Annual Operating and Support cost per unit.

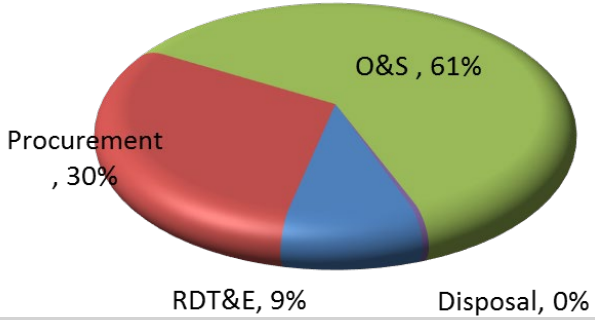


Includes all contractor and identified customer costs

Raytheon Guideline

- Cost Technical Performance Measure (TPM) is an Affordability Metric
- Gate Reviews: Program Reviews the Affordability / DTC
- Program Performance Reviews
  - Issues / Accomplishments
  - System DTC Variance
  - Cost Reduction Roadmaps
  - Future Plans (Short to Long Term)

Ex. Fixed Wing Aircraft - Fighters



Program Affordability spans the entire life cycle of every program

Architecting for Affordability

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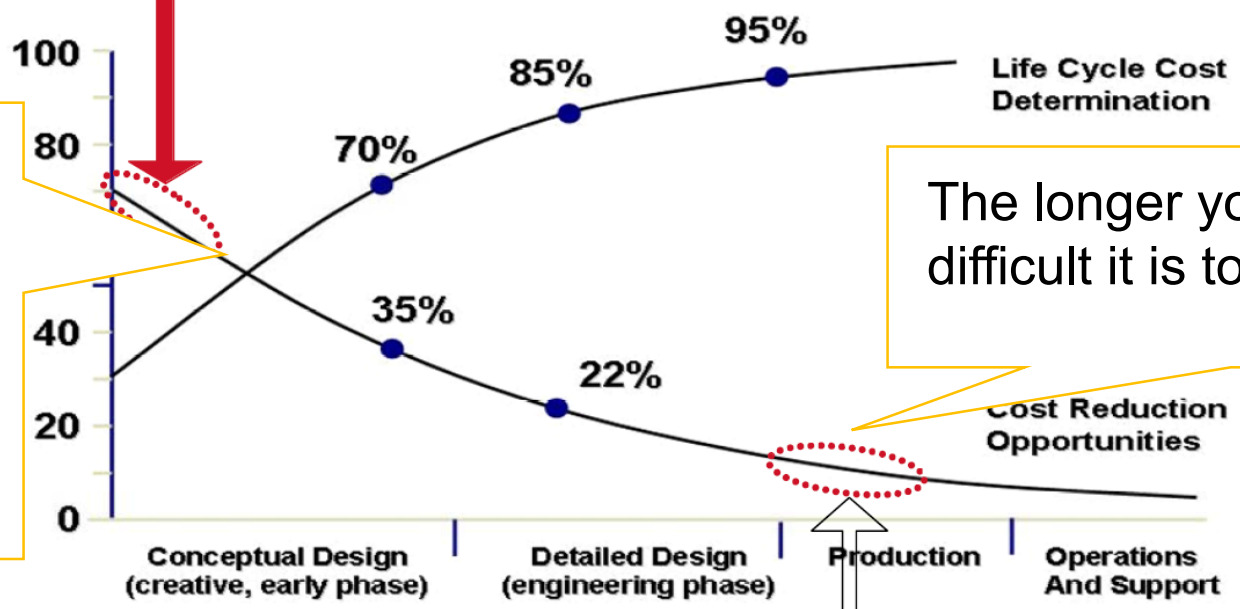
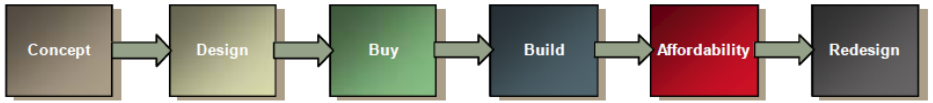
New Model

The concept phase is when the trades between alternatives that affect affordability can be made and maximum cost savings achieved.



The longer you wait, the more difficult it is to optimize cost.

Source: DARPA Rapid Design Exploration and Optimization Project



Current Model

Program Affordability spans the entire life cycle of every program

Traditional Cost Management

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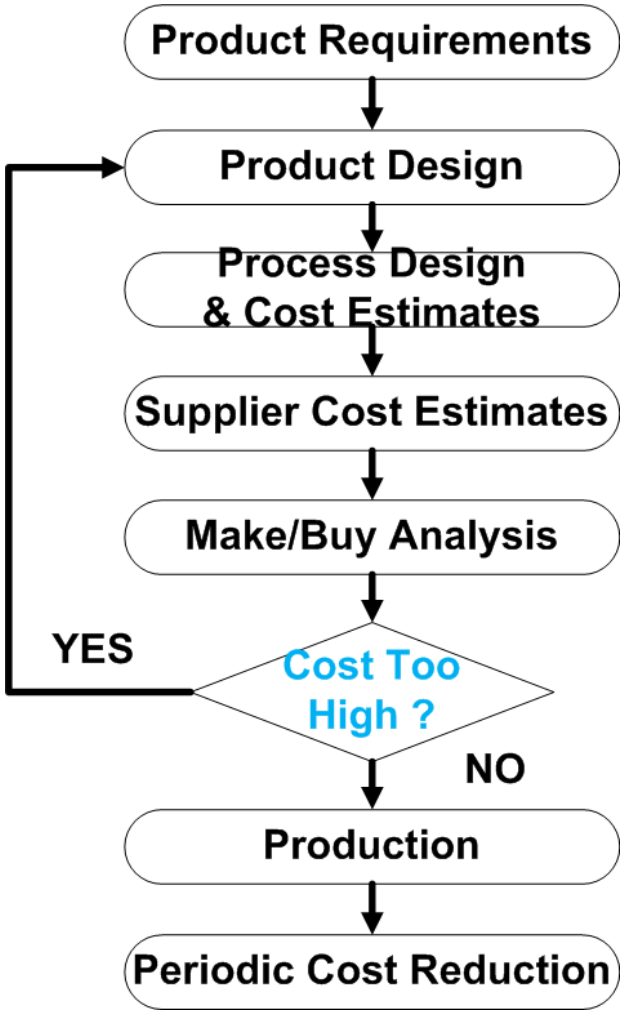
- Focus on meeting customer's requirements.
  - Cost is seen as a **Dependent** variable
  - Cost is a result of functionality, features, and performance.



Cost is considered late in process, causing cost to be higher than desired.

Dealing with Uncertainty

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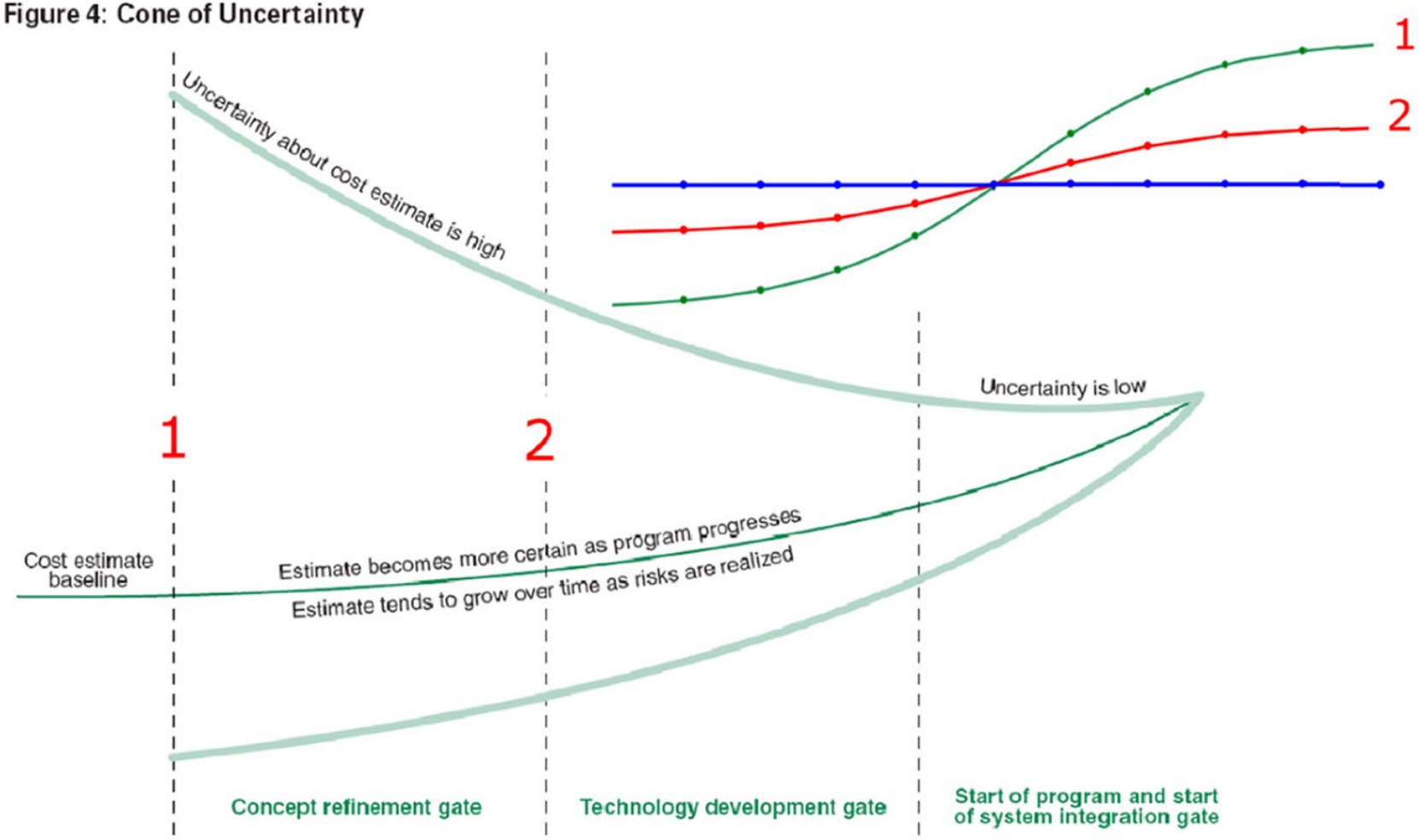
Figure 4: Cone of Uncertainty



Source: GAO.

Market Driven Cost Management

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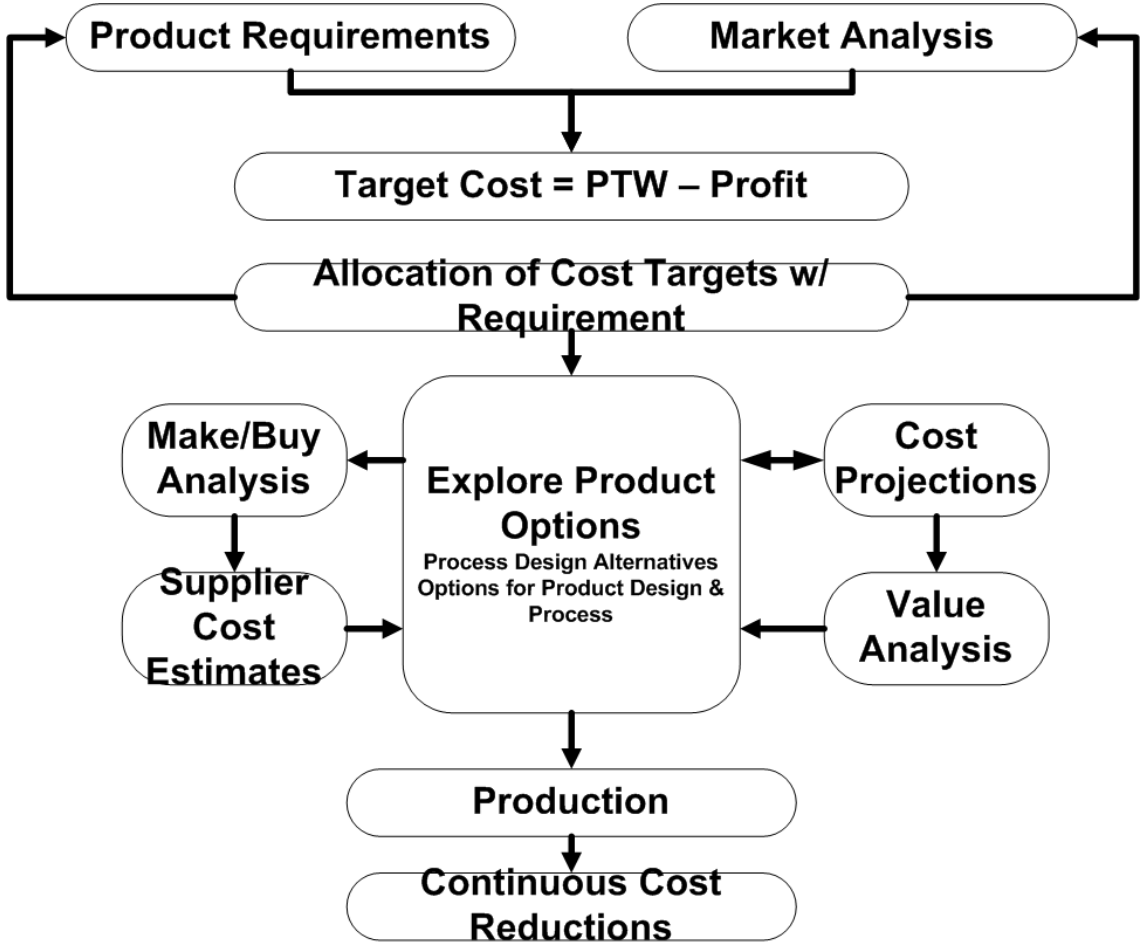
1. Market Driven Pricing
   - Product oriented to customers needs and affordability
2. Cost is an Independent variable
   - Cost is treated early and driver when defining hardware/software requirements
3. Proactive
   - Cost is actively worked on during the product and process development



When done early, there is alignment between the cost and the technical solution maximizing the win probability

Cost as a Requirement

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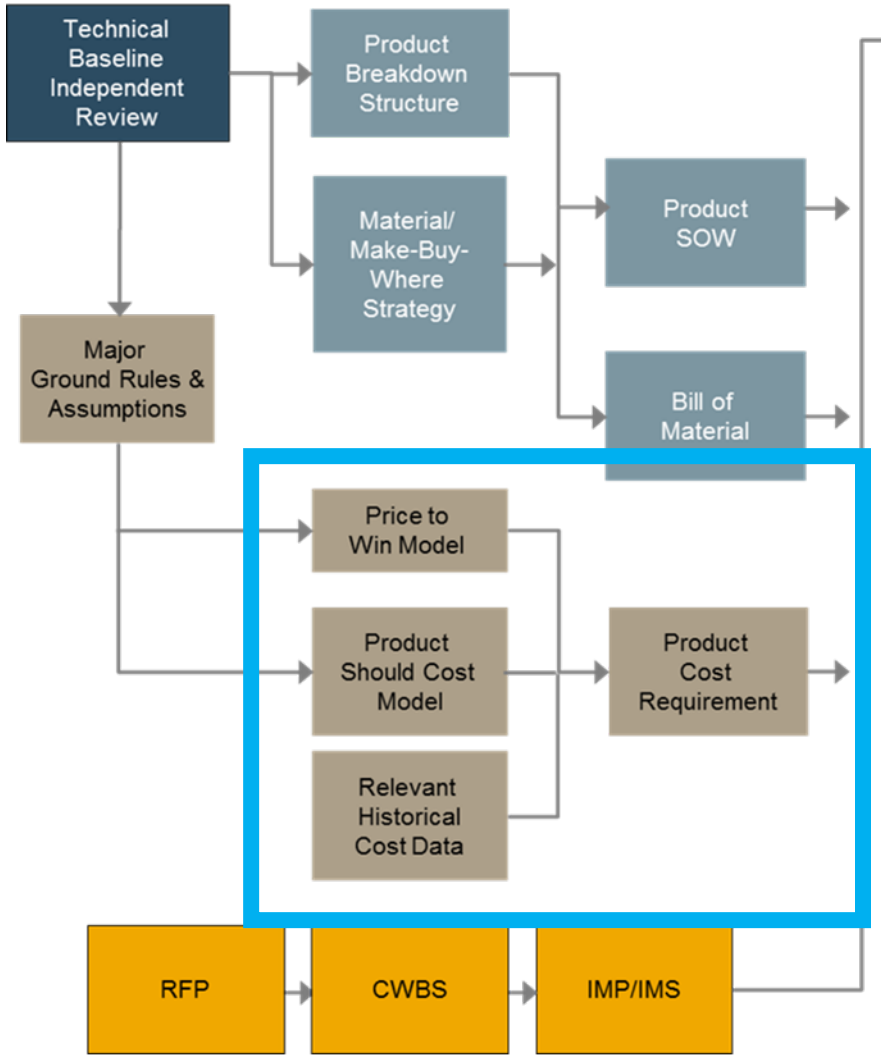
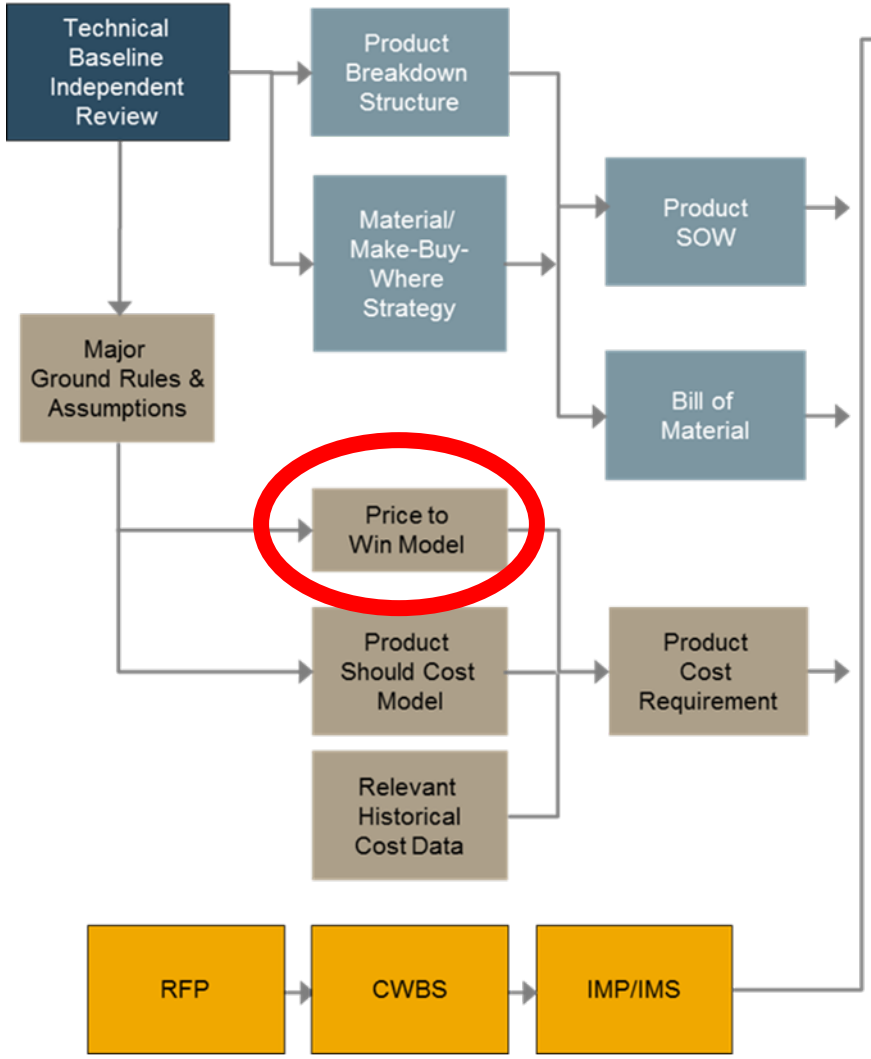


Formal
Proposal Development
Engine

Development:
Technical Offering Trade
Assessment of
Financial Cost Volume

Product-based bidding: Top Down ➔ Lower Cost, Higher Quality



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Price to Win Overview

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What is Price to Win?	*Price to Win (PTW) is the recommended bid price at which the customer will select the our solution instead of competitors' solutions in a competitive procurement process.*

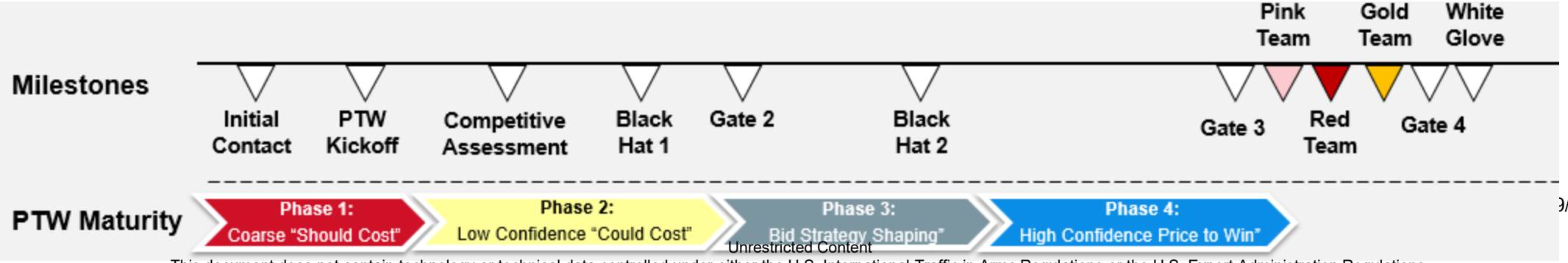
THE GOAL OF PTW ANALYSIS

- **Develop a market-based price for a competitive pursuit based on a deep understanding of both the *customer* and the competitors**
  - **what customers want and what they are willing to pay**
  - **what is the competitor's solution, and what will they bid**
- **The PTW recommendation provides a pivotal data point from which to develop the pricing strategy for our solution**

THE PTW PROCESS IS…

- **…an analytical method of estimating the price a competitor will bid using multiple approaches**
- **…grounded in a foundation of solid Competitive Intelligence (CI) collected throughout the pursuit**
- **…started very early in the capture process, and is updated continually through the Final Proposal Revision (FPR) phase, as useful CI improves the fidelity of the PTW estimate**

Timeline



“Pricing is the moment of Truth”:

E.R. Corey (Harvard Business School) - 1962

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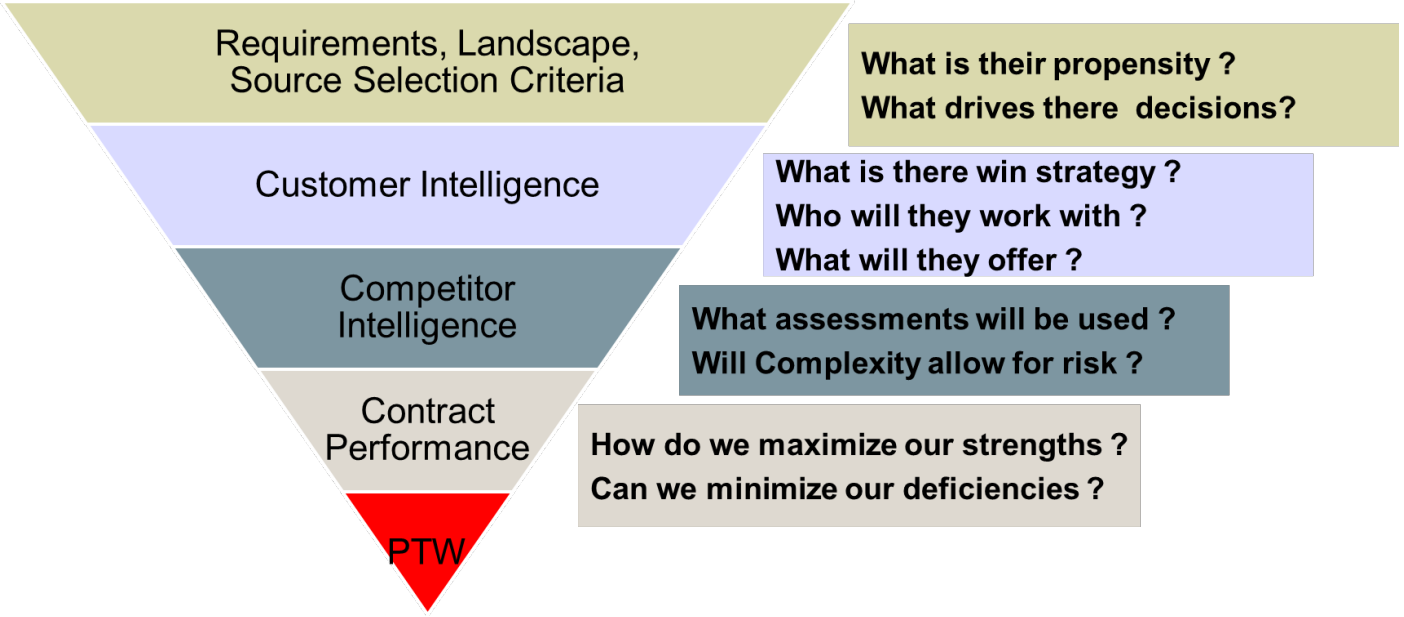
- A PTW always should always begin with plan to research the customer, the competition, and the proposed solution
- A good PTW should be independent from the capture team, so that it will provide an alternative approach (one developed from the competitor’s viewpoint), thereby challenging the capture team to develop the best win strategy.



PTW Methodology – The Nine

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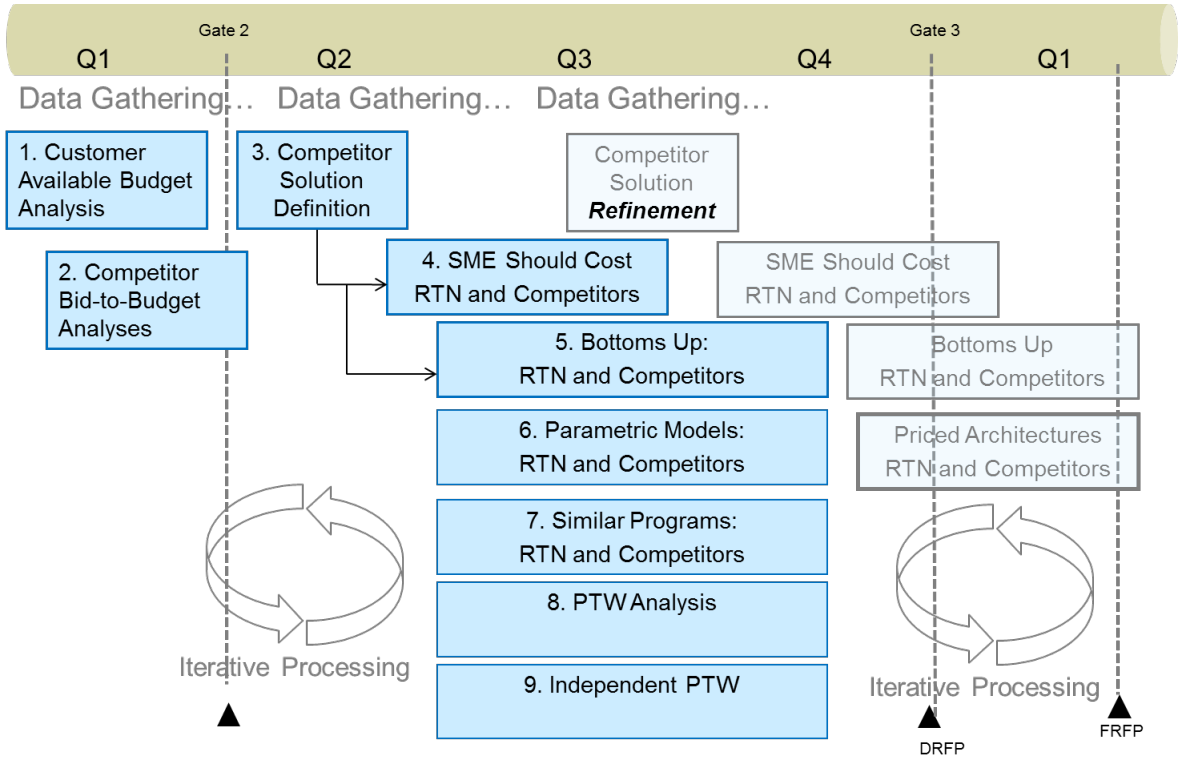
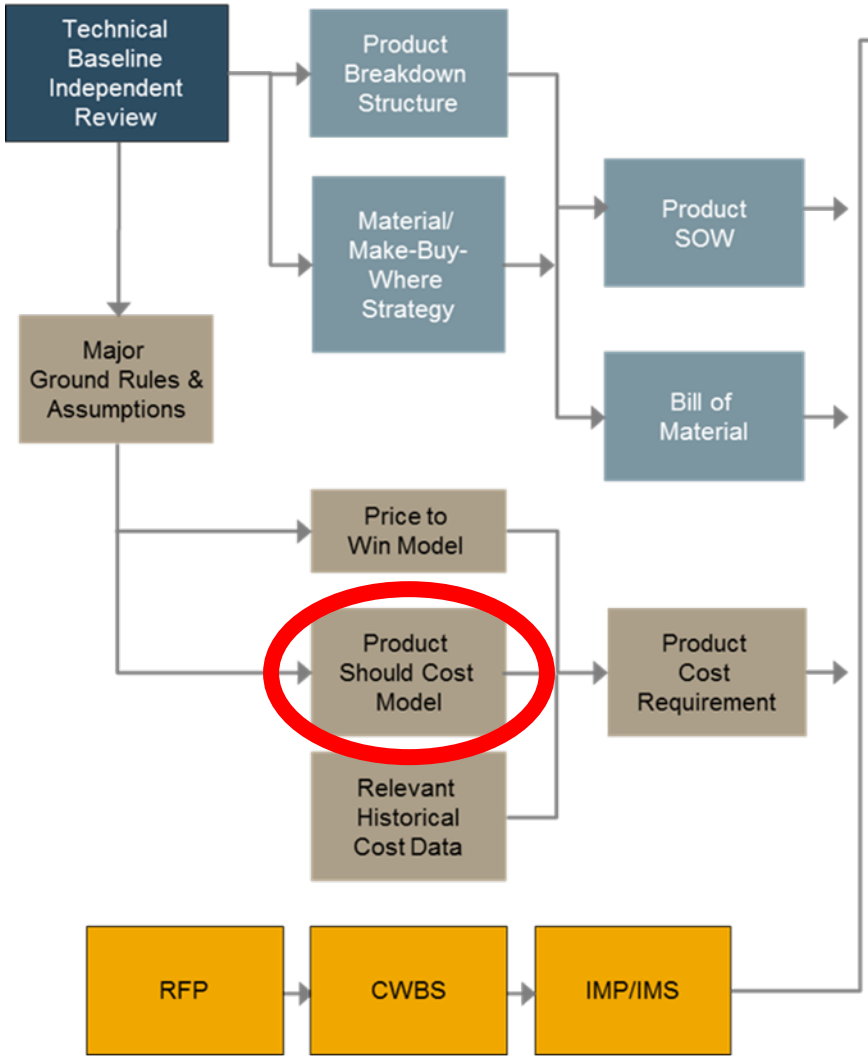


Analysis	Who	Description
1. Customer Available Budget	BD	An analysis to determine the amount of money from the customer available to a program.
2. Bid-to-Budget	BD	A comparison of past competitor bids relative to the customer's available budgets for similar programs.
3. Solution Definition	SME	A technical definition of the competitor's architecture. The should cost and bottoms up will be based on this architecture. It will likely be refined over time.
4. Should Cost	SME	A gross, rough order of magnitude cost estimate for a system by major WBS element. Based primarily on engineering judgment from SMEs who are knowledgeable about that system. Purpose is to get a quick estimate of system cost. Also called "Delphi" or "Component Substitution."
5. Bottoms Up	PTW	A detailed cost estimate of the architecture using specific geographic locations of work, escalation over time, BOEs, a BOM, vendor quotes, types of labor, teaming arrangements, etc. It is to be an accurate representation of the cost of the system.
6. Parametric Model	PM	A metric by which one can compare similar systems. Example: Cost per pound, cost per kilowatt, etc.
7. Similar Programs	PM	A cost comparison of similar past or existing programs to the one defined in item 3. Validates or contrasts to provide additional perspective. May also be called "similar to" analysis.
8. PTW Analysis	PTW	A gathering of data into a cohesive story for each competitor's likely prices and a price target range for RTN to bid in order to win.
9. Independent PTW	TBD	A PTW performed by a group that are outside the Capture.



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Affordability Model Attributes

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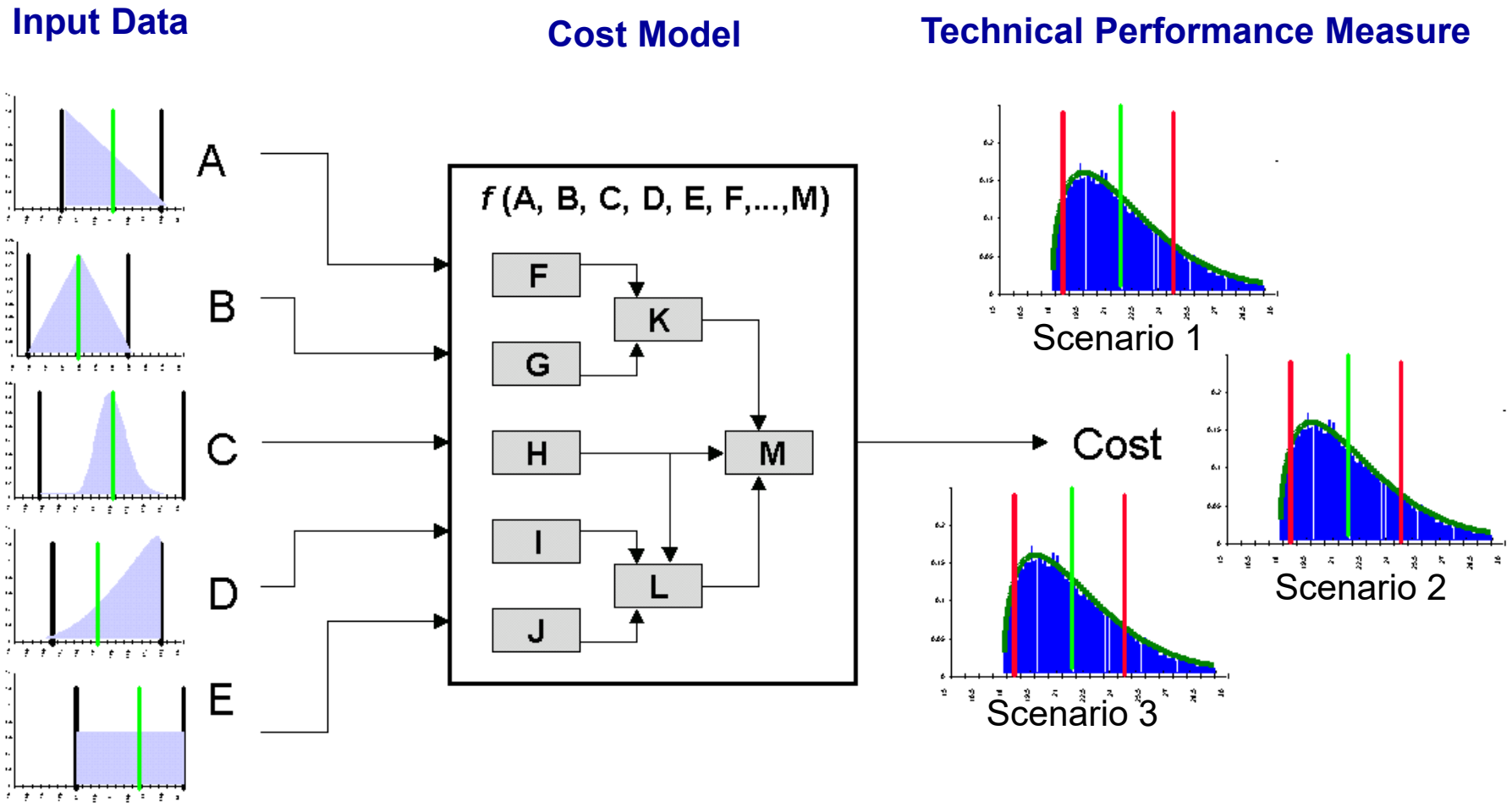
– Cost Modeling will allow IPTs to compare cost projections against cost targets under a variety of scenarios



Affordability Modeling

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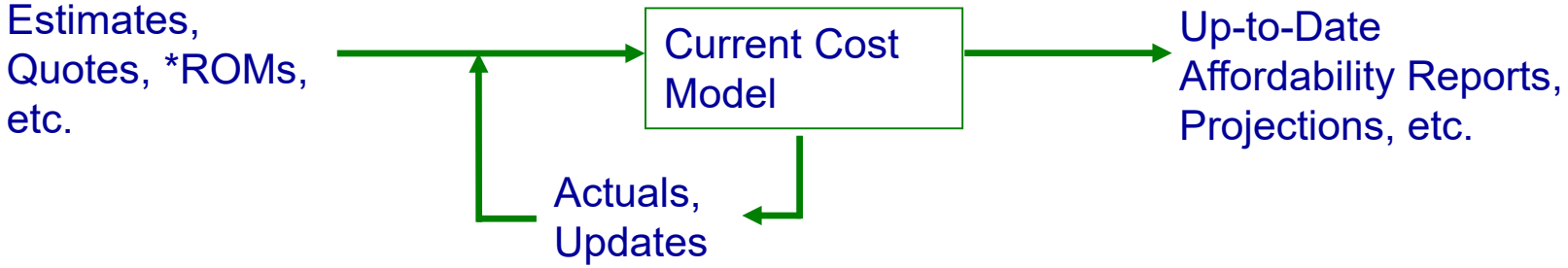
Input Data: Use Est. Values (Historical, Predicted, etc.) to populate initial Cost Models.

– As the program matures, Model is continually updated



– To Improve cost projection accuracy, the Cost Model should consider the following inputs:

- **Detailed Indentured Parts Lists**
- **Part Quantities**
- **Price Estimates**
- **Supplier Price Quotes**
- **Price Actuals**
- **Labor Hours, Standards & Realization Factors**
- **Requirements and IPT Summary**
- **Rates and Factors**
- **Support Pools and Burdens**
- **Six Sigma Worksheets**
- **Assembly Process Flow (Including Engineering Troubleshooting and Assistance)**
- **Assembly and Test Yields**
- **Rework, Attrition and Scrap**
- **Batch Sizes and Amortized Set-up Costs**
- **Material Allowances**
- **Negotiation Allowances**

Industry Parametric Modeling: SEER®

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- SEER® software uses:
  - Parametric algorithms
  - Built-in Knowledge Bases
  - User Defined Unique Knowledge Bases
    - Which Capitalize on existing Data
    - Calibration tools are built in so it can be customized to user defined experience and expertise
- **"Top Down"** Parametric approach:
  - Employs cost estimating relationships (CERs) or equations
  - Built-in CER Mapping Database
    - Employs cost estimating relationships or equations
  - Allows estimation based on measurement of key parameters that drive time and effort
    - Technical or physical characteristics of the product, personnel, and development environment
  - Once relationships are known, parameter values can be changed and the effects evaluated

What is SEER – H® (Hardware) ?

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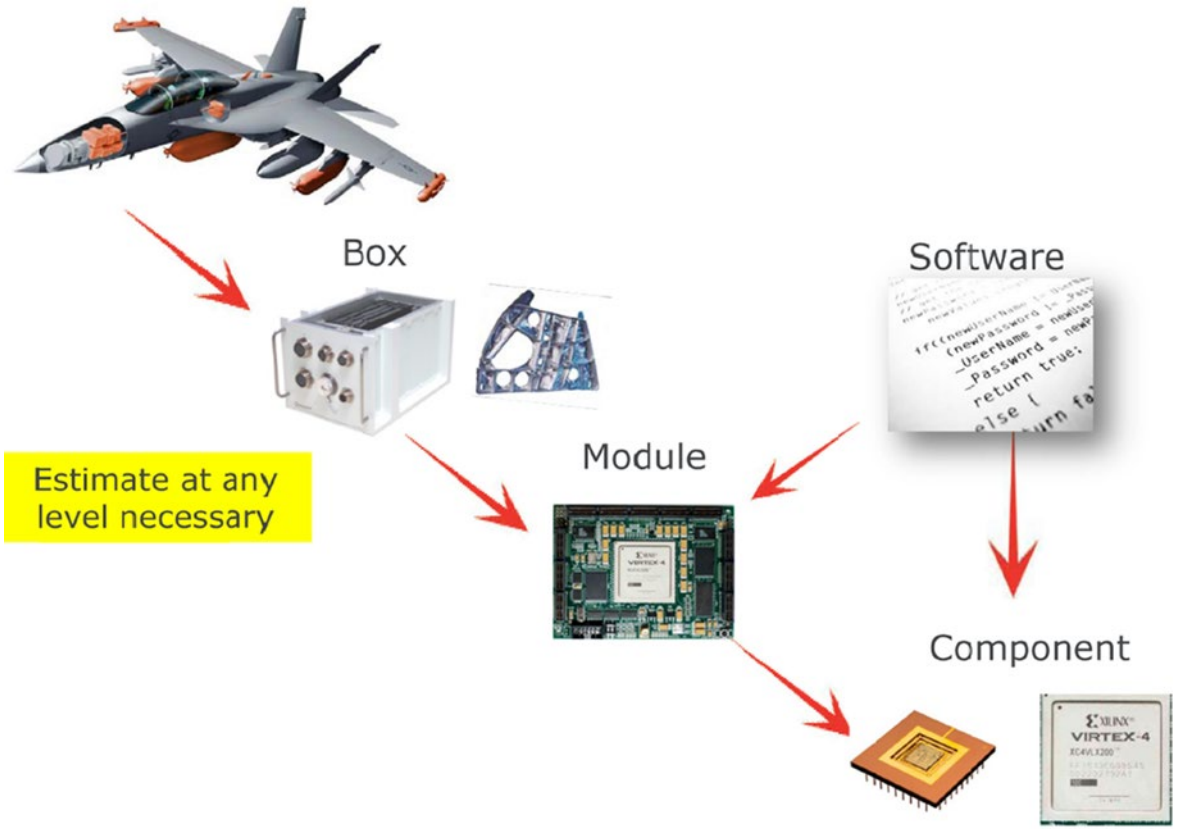
- SEER-H® is a parametric hardware estimation model
- Estimates development, production, operations and support cost as well as reliability of the hardware
- Utilizes:
  - Mapping Database
  - Knowledge Bases
  - Estimating Equations
- Bases estimates on a variety of cost driving parameters
  - Product description: **What is Being Built ?**
  - Mission description: **How it Must Perform ?**
  - Program description: **How it Will Be Built ?**
  - Maintenance description: **Who/Where/How will be done ?**
- Reports cost and reliability estimates in a variety of formats



SEER Integrated Tool Suite

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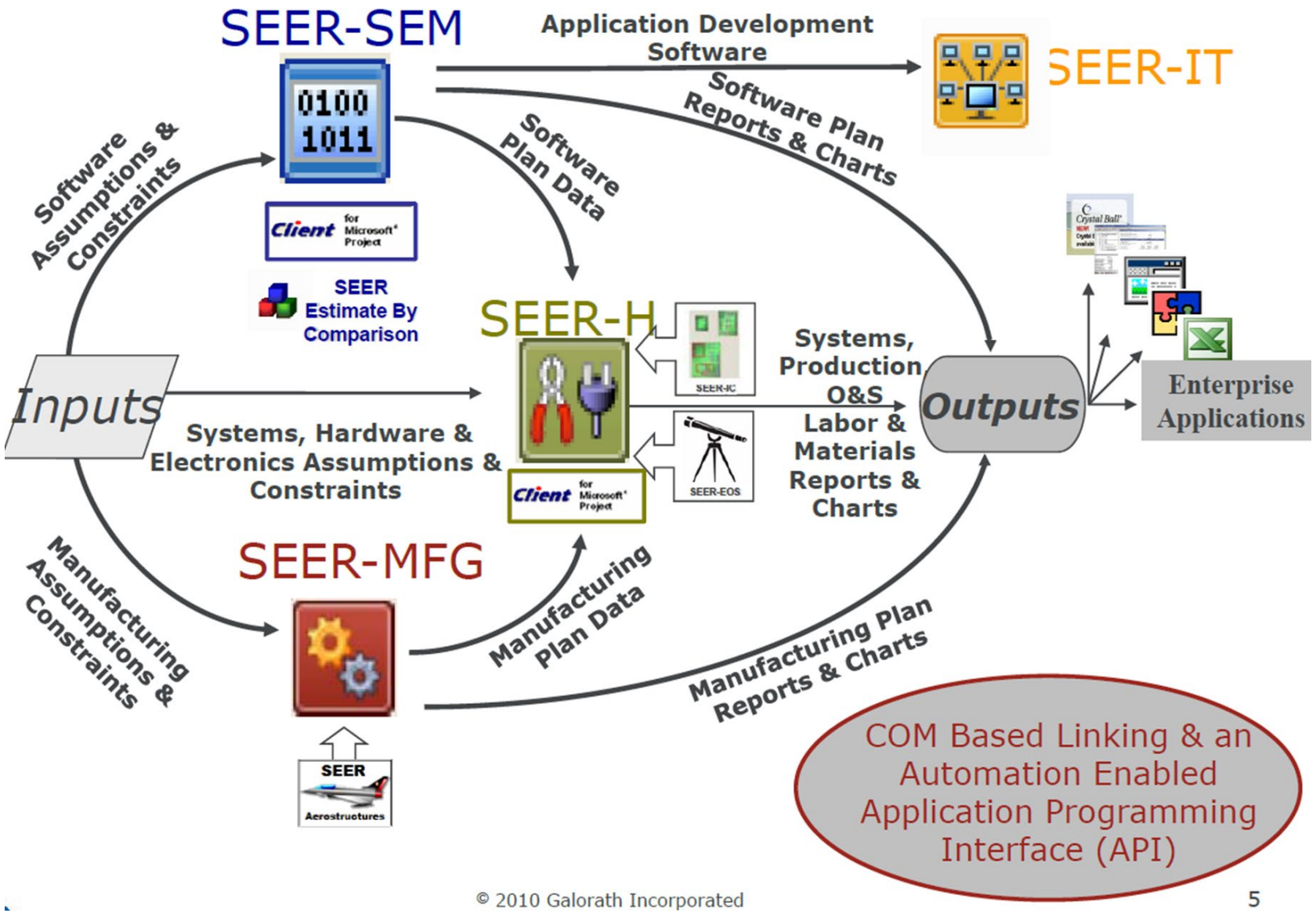

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SEER® Cost Modeling Inputs

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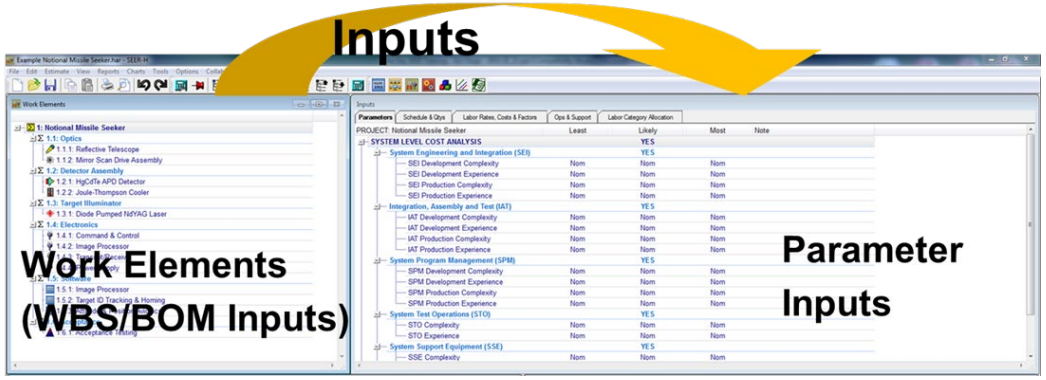
- Program Schedule:
  - Development = 1/6/2014
  - Production = 1/4/2016
  - Base Year = 2014
- Quantity
  - Development
    - Demo Systems
    - Types of Demonstration and EMD Units
  - Production
    - QTY
    - Build Plan number per year (or Month)
- Product Breakdown Structure
  - This is how the system will be put together
  - Prior to starting it is important to have a plan of how the team wants to group costs (across the Should Cost, PTW and RTN Cost)
  - Where items are being built (which facility will be responsible for which item)
  - The overall build and test plan
  - Useful Inputs SWAP and BOMs
- What find of Contract? CP or FF

- The Major Questions:
  - **Application**: overall hardware function (CPU, structure...) Separate sets for mechanical and electronic elements
  - **Platform:** operating platform (space, ground...)
  - **Acquisition:** development and production scenario (make, buy, outsource, shared development, CFE ...)
  - **Standards:** specifications and standards used in product development and production
  - **Reuse:** Percentage of design effort required to complete development and design effort.
  - **Product Description:**
    - Mechanical: Weight, Size, Material Type
    - Electrical: # of PCB, Board Size, Composition (if unknown size of box and % electronics)
    - Optical: Size, number, type
    - Software: Number of CSCIs, SLOC count for NEW, Modified Reused, including Purchased



SEER® Cost Modeling Outputs

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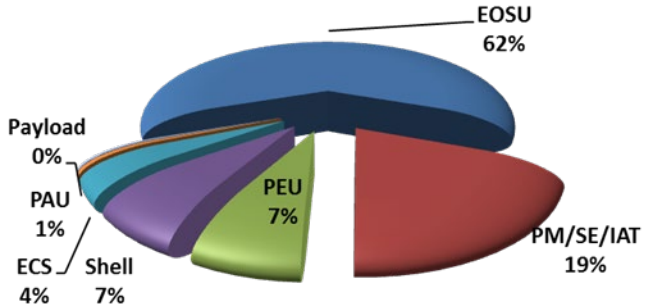
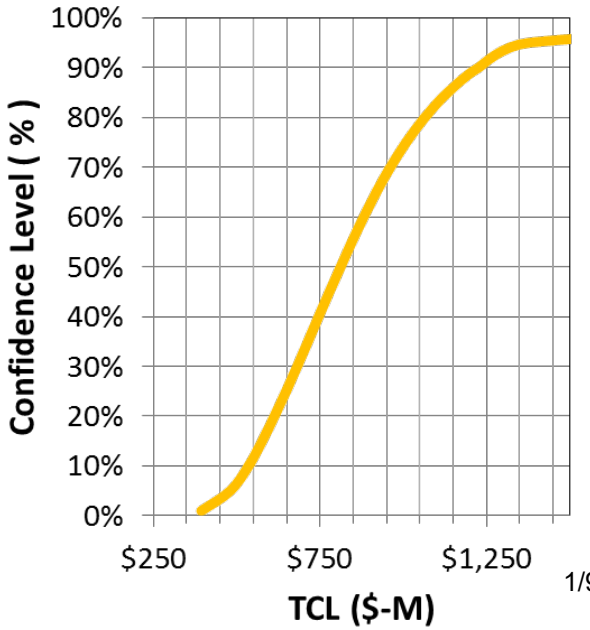
- With Good Inputs the model can reflect the program and the data can be analyzed:
  - Development vs Production.
  - Cost Drivers
  - System Level Costs: PM, SE, IAT
  - Confidence on the data
  - …



Outline Number	0	1	2	3	4	5	6
1	F-15 IRST - Production 100						
1.1		Development & Production Program					
1.1.1			Pod Hardware				
1.1.1.1				ECS - Cooling System			
1.1.1.2				PAU - Pod Adaptor Unit			
1.1.1.3				Pod Shell			
1.1.1.4				EOSU			
1.1.1.4.1					Final Integration & Acceptance Testing		
1.1.1.4.2					Shroud		
1.1.1.4.3					Scanning Afocal - (Azimuth Scanner)		
1.1.1.4.4					Inner Optical Bench		
1.1.1.4.5					Roll Base Drive		
1.1.1.5				Pod Electronics			
1.1.1.5.1					PEU Chassis		
1.1.1.5.2					PDU - Power Distribution Unit		
1.1.1.5.3					RM Processor		
1.1.1.5.4					IRST Processor		
1.1.1.5.5					Payload Processor		
1.1.1.6				Payload			
1.1.2			Pod Software - Instrumentation				
1.2		Flight Test / STE					
1.2.1			Flight Testing				
1.2.2			Special Test Equipment				

Base Year: 2014

	Hours	Material Cost
DEVELOPMENT TOTAL		
Subsystem		
Design		
Prototype Hardware		
Engineering Test		
Integration and Test		
Systems Engineering		
Program Management (Dev)		
Engineering Data		
Management Data		
Support Data		
Peculiar Support Equipment		
Tooling		
System		
System Engineering and Integration (SEI)		
Integration, Assembly and Test (IAT)		
System Program Management (SPM)		
System Test Operations (STO)		
System Support Equipment (SSE)		



This is not a Magic 8-Ball!

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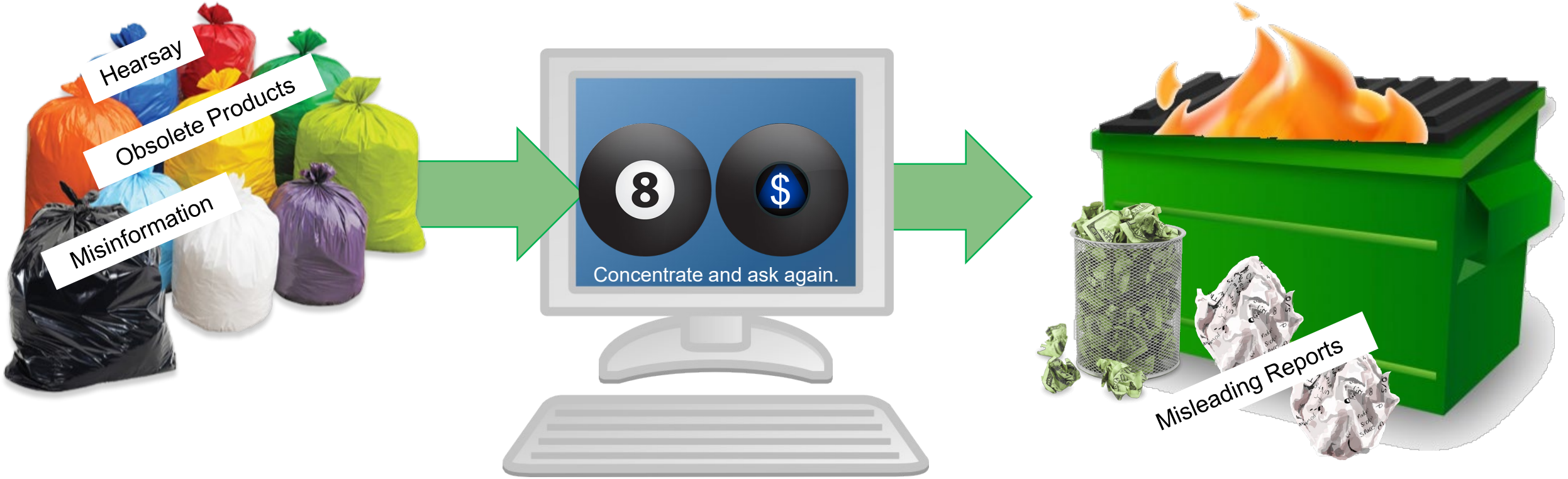

Garbage In is Garbage Out !

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https://www.seekpng.com/png/full/253-2536004_keyboard-png-images.png
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https://www.seekpng.com/ipng/u2q8u2y3i1q8w7y3_trash-can-full-of-crumpled-dollars-trash-can/
https://www.seekpng.com/png/full/25-259317_paper-png.png
https://www.seekpng.com/ipng/u2w7o0w7i1ratqbyo_magic-8-ball-image-8-ball-empty/

Deterministic vs. Monte Carlo Model

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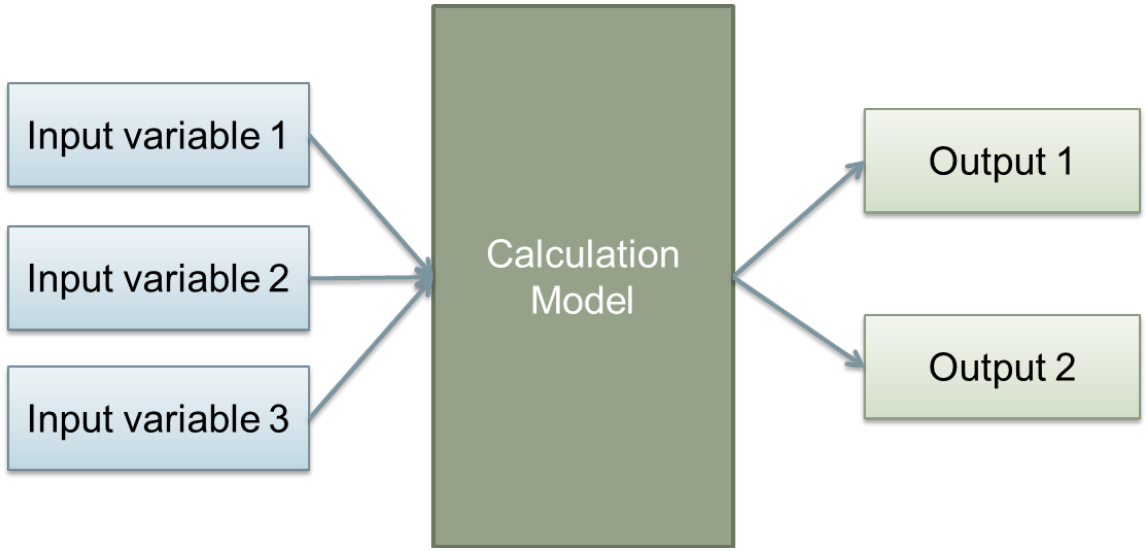
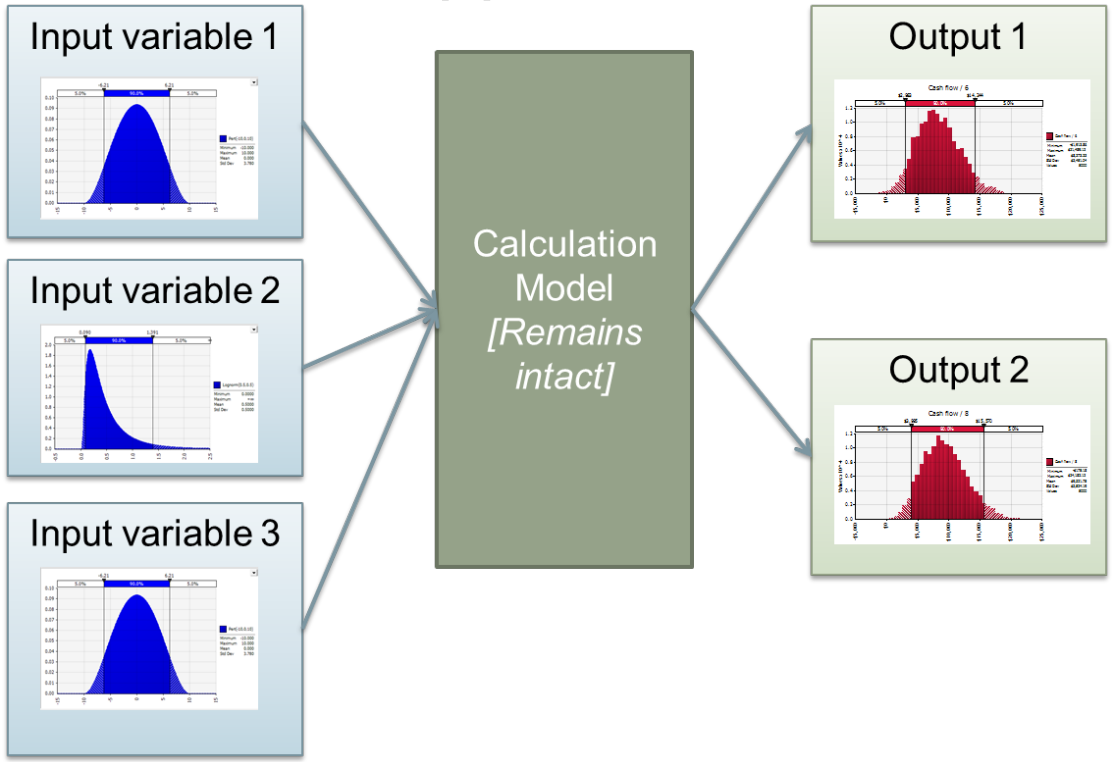
- Point Estimate

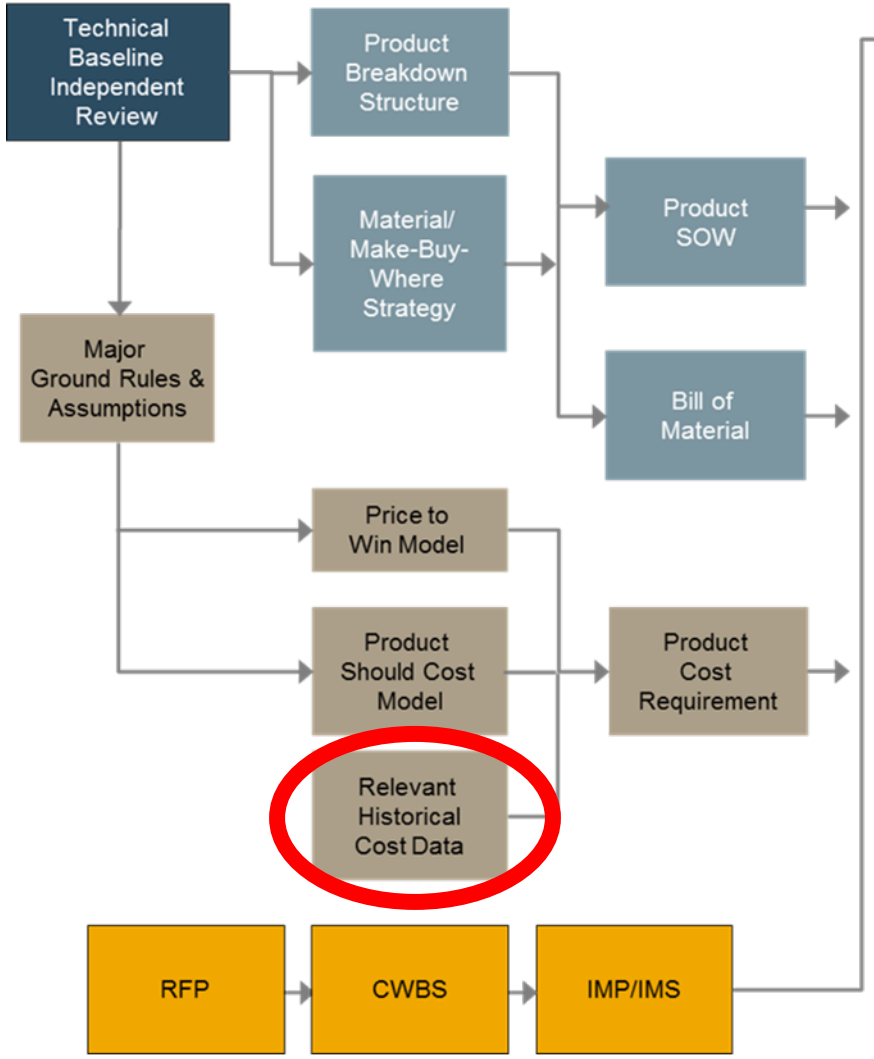


- Every Input variable is known.
- Output Variables are the combination of those inputs.

- Stochastic Approach



- Each input variable has a probability distribution.
- Output variables have new distribution based upon thousands of recalculations of the input variables variation



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WBS Mapping Initiative Objectives

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- Develop a program cost catalog for Space programs inclusive of program bio, cost collection assumptions, major milestone dates
- Utilize the MIL-STD-881 Space Systems WBS to map program actuals and to use in bidding process
- Provide a consistent cost collection system for robust comparative analysis across Space programs
  - All functions looking at the same source data
  - Currently going thru data validation with functional stakeholders to get buy in
- Reduce proposal/ROM cycle time by having the data available at all times
  - Avoid pulling the same data for each proposal
- Collaborate the CIPT on data collection

Align Cost Collection to the MIL-STD-881 for Space

Payload in MIL-STD-881D

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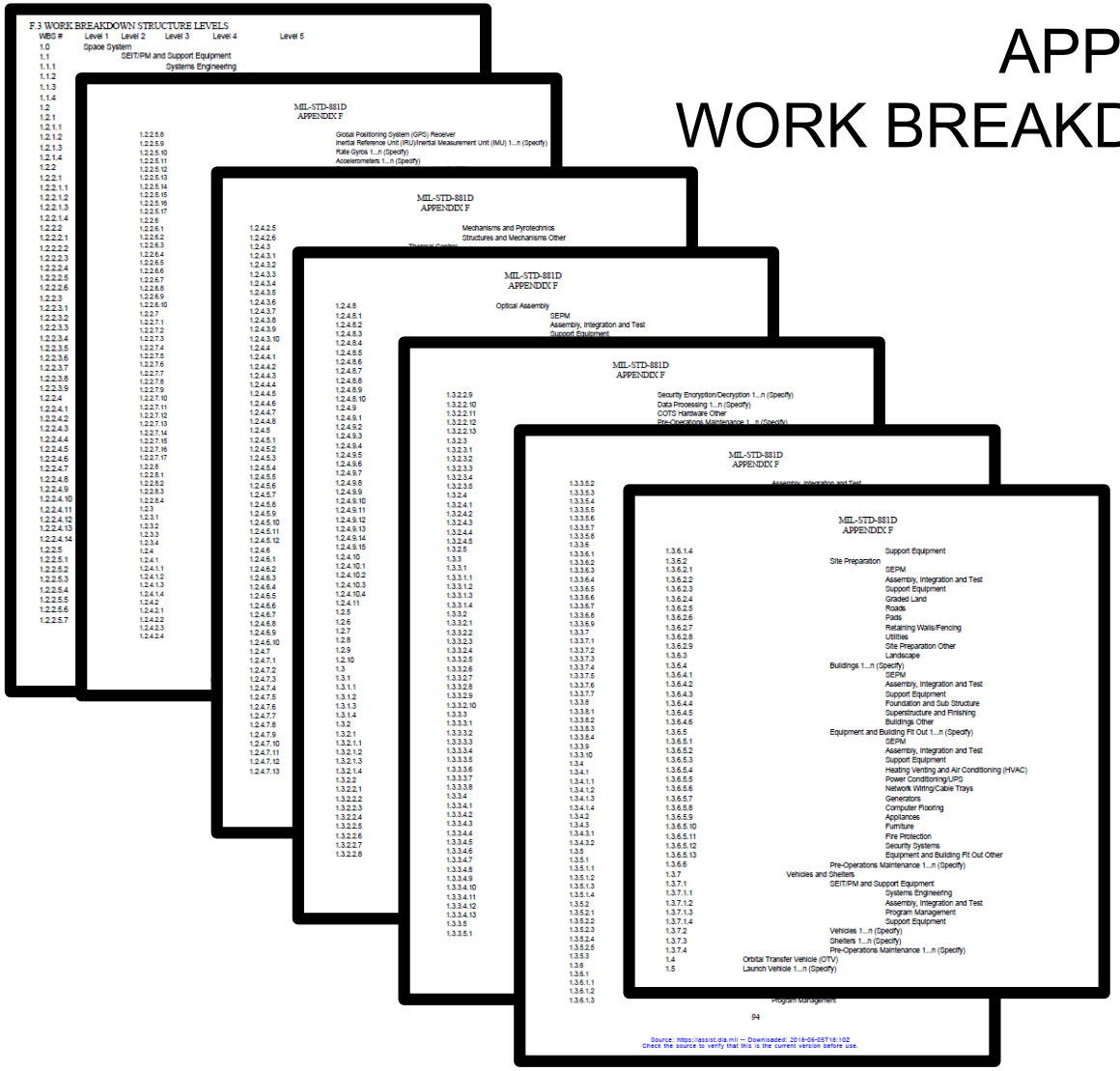
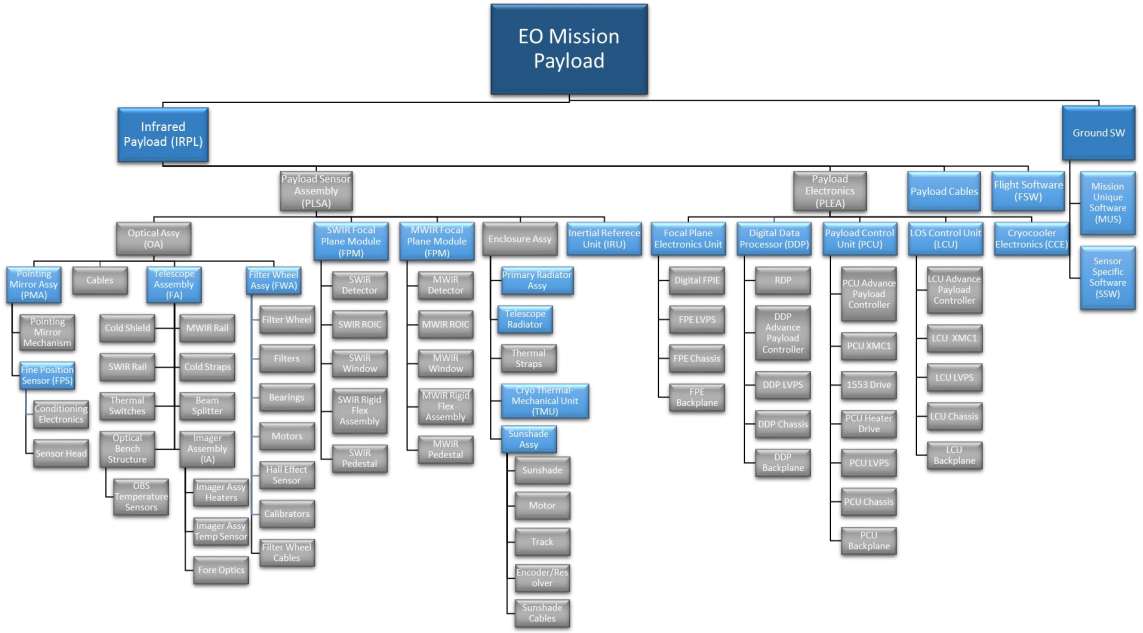


APPENDIX F: SPACE SYSTEMS
WORK BREAKDOWN STRUCTURE AND DEFINITIONS



How Does SEER® Help?

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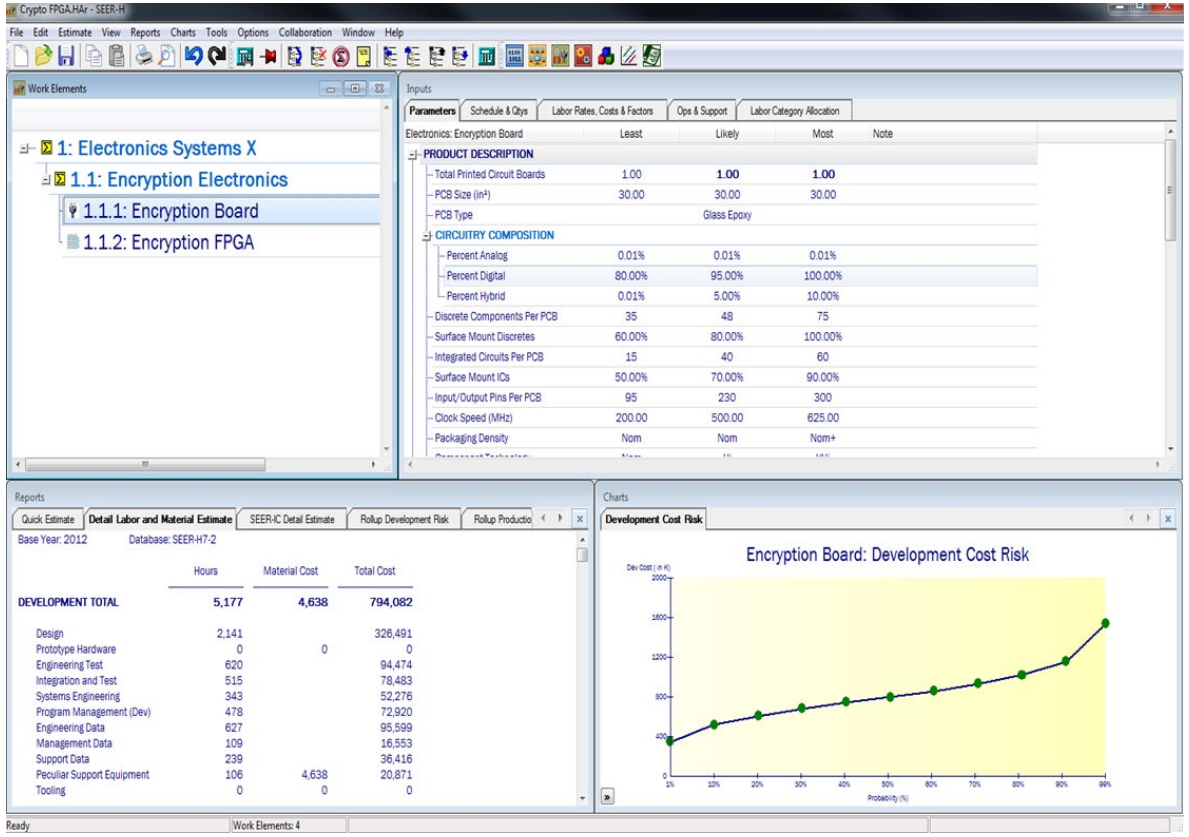
SEER® can answer the following questions

- Does X system cost $10M or $100M?
  - This is the question often asked to make early business decisions
  - Architectural solution usually very rough
- Does X System cost $10M or $20M?
  - High level architectural studies
  - Internal ROMs
  - ICE
- Does X System cost $10M or $12M?
  - Requires highly experienced tool users
  - Requires historical validation
  - Requires minimum "***guesstimation***"



Validation Run-Rules

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- Validation Project Description
  - Use SEER-H and SEER-SYS tools to model labor hours for a variety of space and airborne products and systems
    - Goal to understand the model prediction vs actuals
  - Establish a Validation Team
    - Ensure independence between SEER Tool users and senior cost estimator and financial analyst responsible for correlating EAC and Actuals to common WBS
  - Create SEER Tool User Guidelines
    - Model Inputs are based on design and requirements
      - Weight, component count, material type, quantity
    - Nominal Kbase setting will be used for all subjective inputs i.e. skill level and experience

Independence between SEER Model Implementation and Actual/EAC correlation is key to validity of validation effort.

Airborne SEER-H® EAC Update

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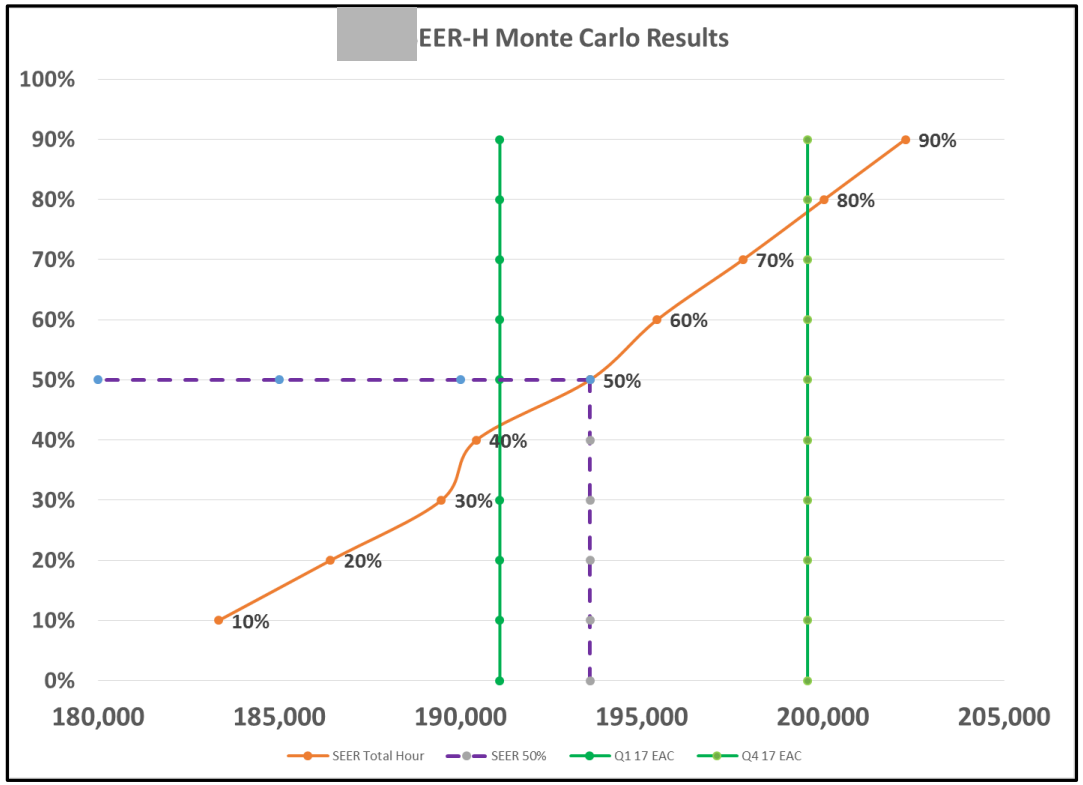
- Status updated on XXXX SEER-H® Prediction
  - Compare SEER-H prediction from 1Q-17 EAC and 4Q-17 EAC
  - 4Q Net increase of 6000 hours from previous EAC
    - Test Issues
    - Changes to text fixture design
    - Unanticipated change request from suppliers
    - Firmware development productivity lower than planned
  - SEER-H® confidence curve and risk
    - Estimate now aligns with a probability typically used to capture bids with low risk or higher confidence
    - Model has not utilized the Least/Likely/Most for design element parameters to capture risk
      - Potential model improvement would be to include



WBS Item	1Q17 EAC CEU Labor Hours	4Q17 EAC CEU Labor Hours	SEER® Labor Hours (50% Confidence)	% Difference
HW Element EMD Contract Subtotals	191082	199572	193565	3 %

SEER-H® aligns well with actual program cost and program execution

Space Payload SEER-H® Validation Model

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- Integrated Support Electronics (ISE)
  - Validation effort performed for both the Phase A and Phase B portion of the program through first article sell-off
  - SEER Inputs
    - Level 3: Unit, ISE
      - Platform: Space-unmanned, Standard: Military Full
    - Level 4: Modules
      - Platform: Space-unmanned, Standard: Military Full
    - Level 5: Components
      - Applications: Varied, Platform: Space-Unmanned, Standard: Military Full, Acquisition Category: Varied (Design Maturity)

WBS Item	1Q17 EAC CEU Labor Hours	SEER® Labor Hours (50% Confidence)	% Difference
ISE (Includes System Engineering Hours)	313939	319263	2%

Results obtained with only changing quantitative values on component counts and Development quantities.

Cost as a Requirement

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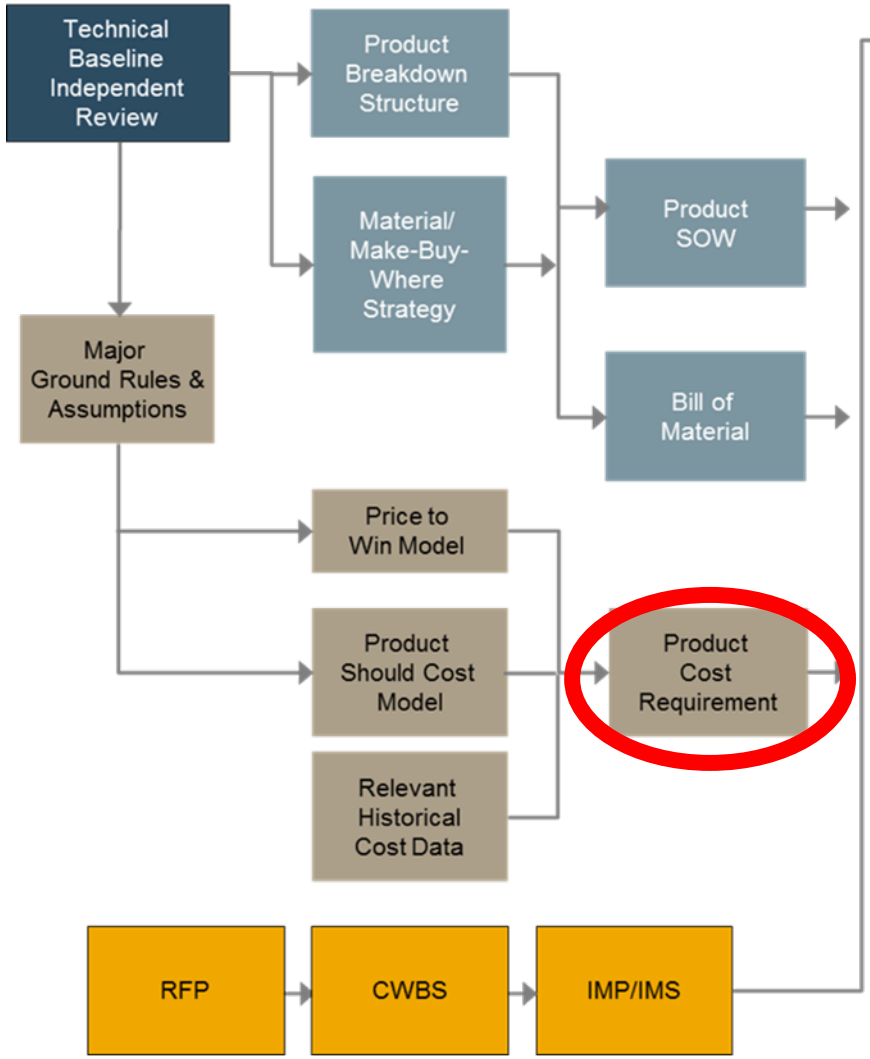

Formal
Proposal Development
Engine

Development:
Technical Offering Trade
Assessment of
Financial Cost Volume

Product-based bidding: Top Down ➔ Lower Cost, Higher Quality

Setting Cost Requirements

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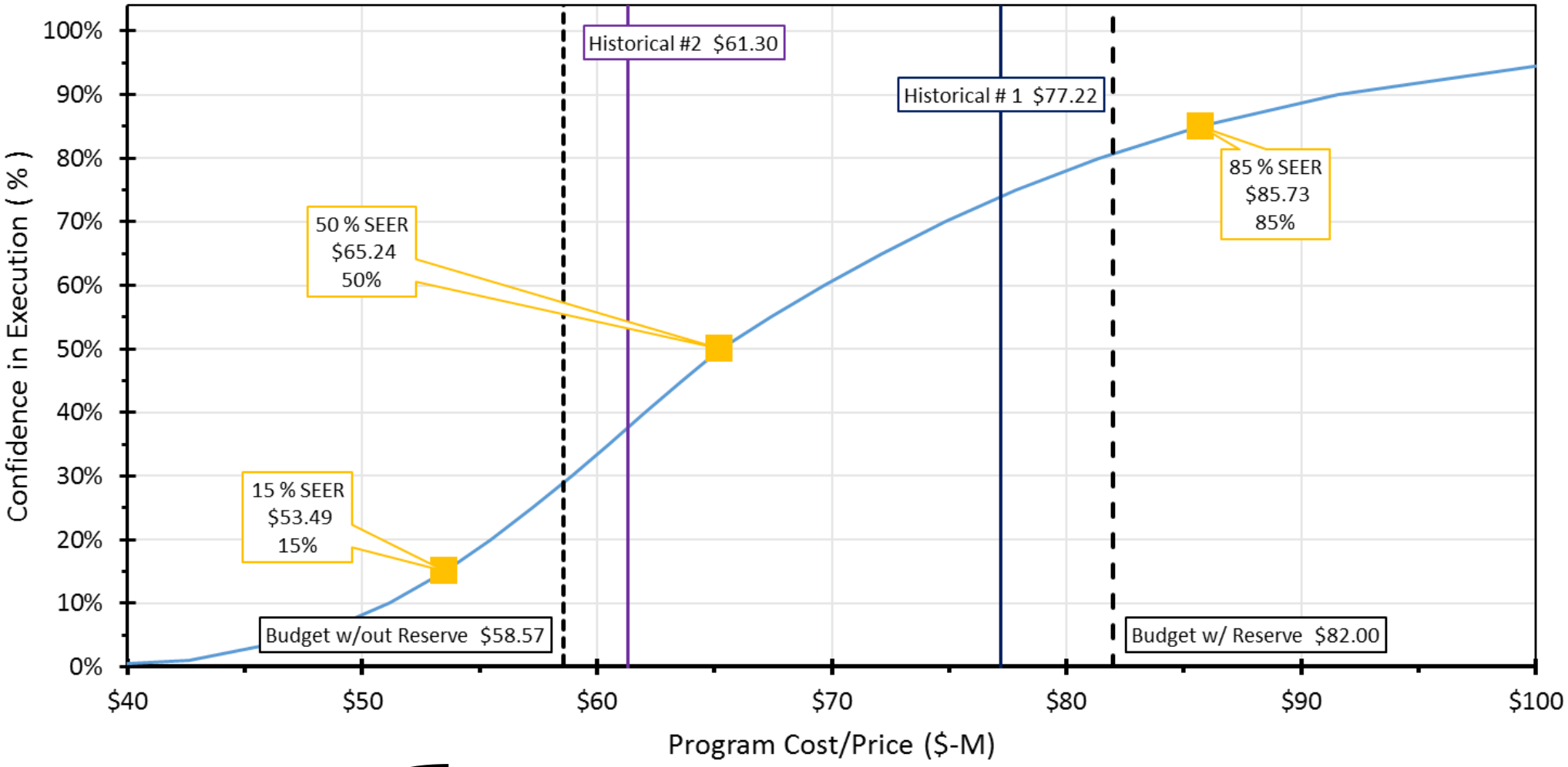

Choosing a cost Depends TPMs, Schedule, Contract Type, & Risk Tolerance

Parametric Range

Budget

Historical

SWAP - C

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Cost Threshold
Upper Affordability Limit

Requirements

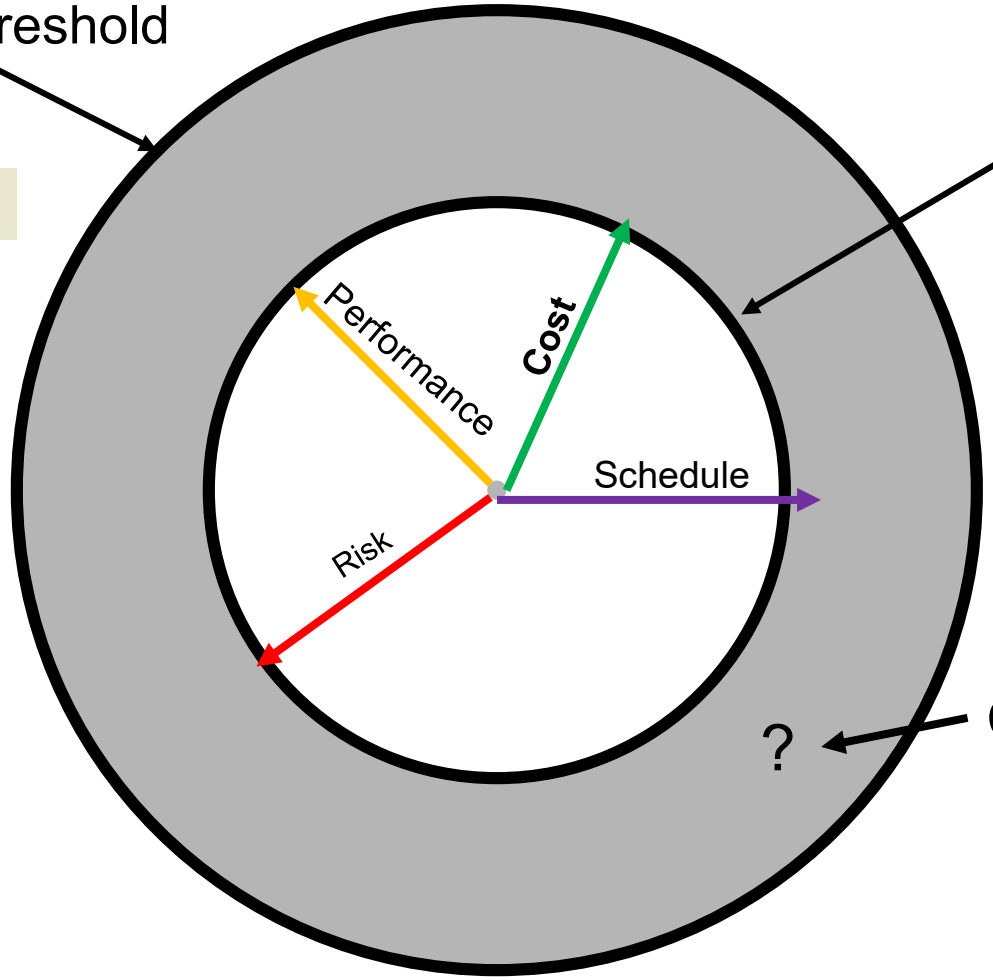
LCC

Mission Needs

ILS

Customer

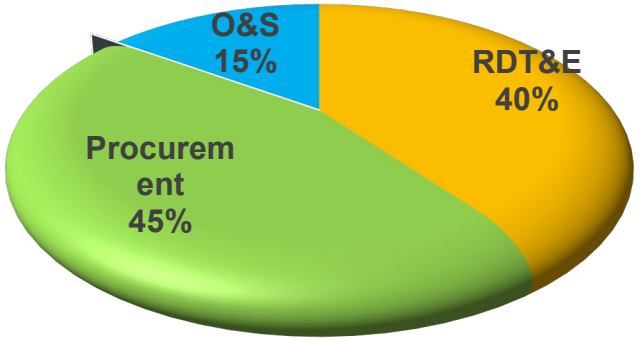
Schedule



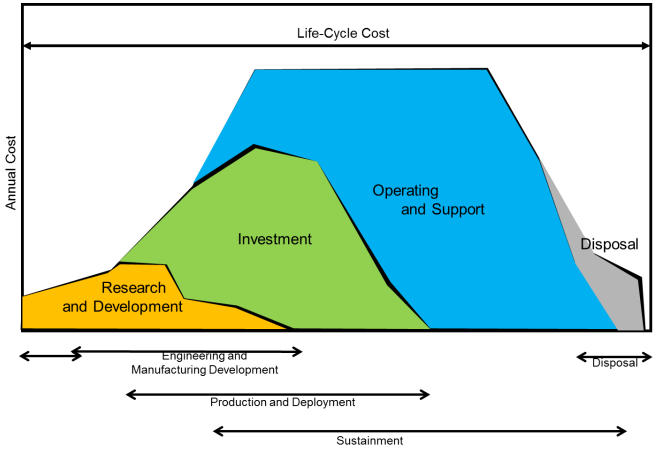
Cost Goal
Desired Cost

Cost Target
- Optimal Solution
- Best Value
- Meets Schedule
- Lowest Risk
- ….

% of Program Life-Cycle Cost Average – Space Systems



*OSD Cost Assessment & Program Evaluation, 3/14



Cost Engineering's Mission is balance the customer's needs with what they can afford!

A Successful Effort

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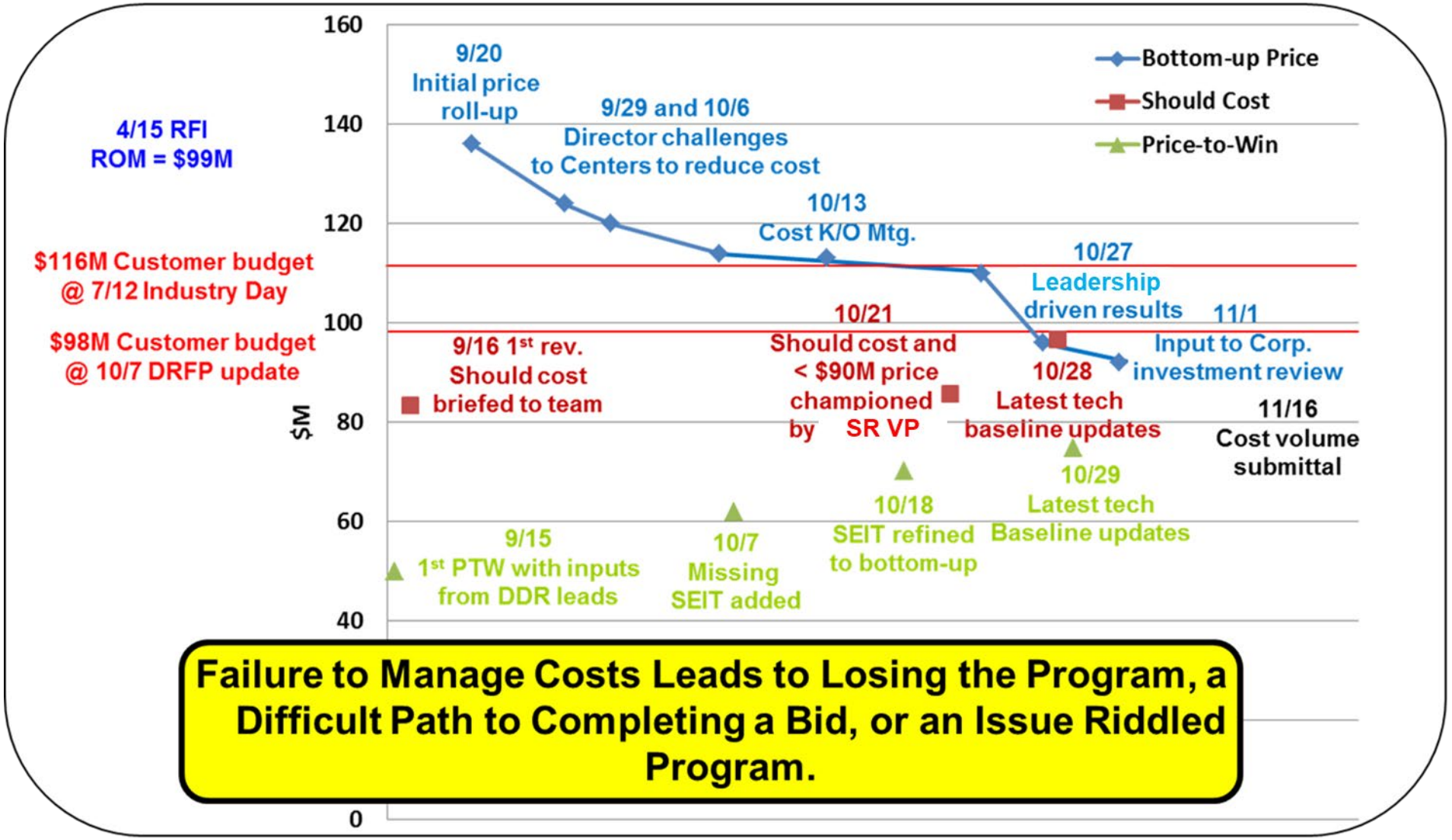

Failure to Manage Costs Leads to Losing the Program, a Difficult Path to Completing a Bid, or an Issue Riddled Program.

Lessons Learned

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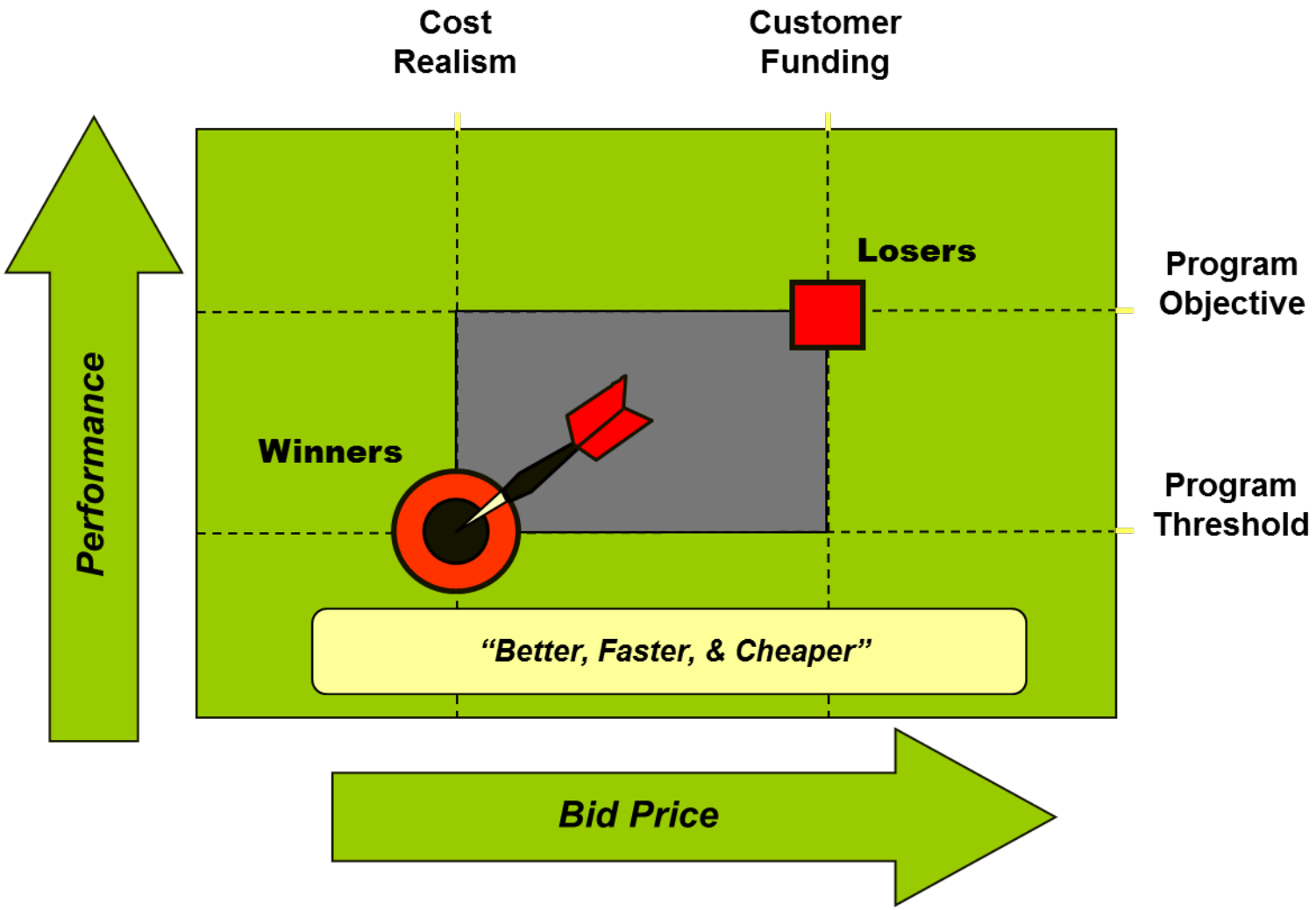

Winners Understand & Anticipate Customer's "Best" Value