The NCCA S-Curve Tool

DON Service Session

Department of Defense Cost Analysis Symposium 2011

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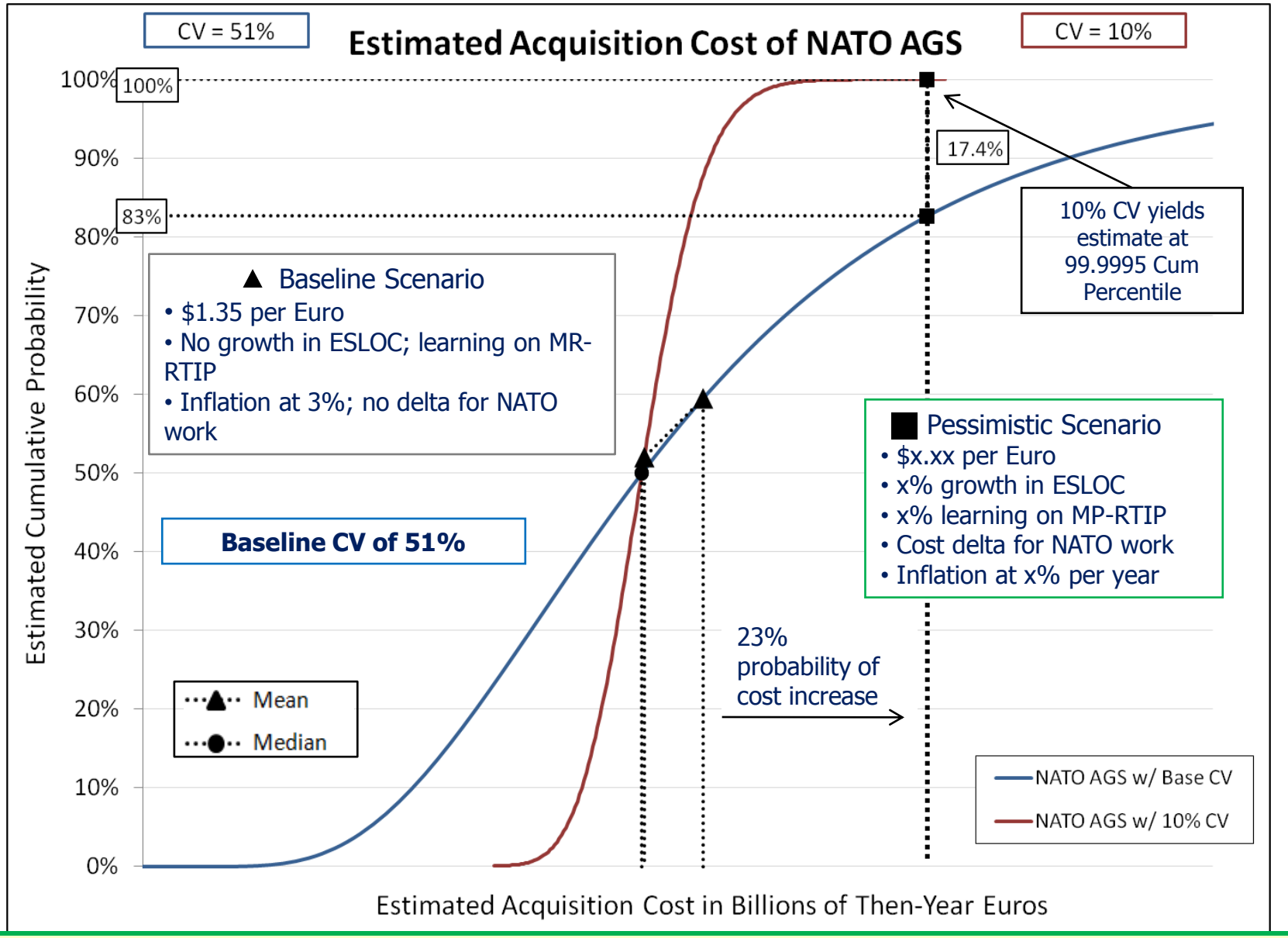
NCCA S-Curve Tool Outline

- S-Curve Tool overview
  - Recap of what you've already heard from Dr. Flynn
- Industry Risk Implementation Case Study
  - Read at your leisure, ask us about our scars later…
  - Focus on implementation of Lessons Learned in S-Curve Tool
- Motivation for S-Curve Tool
- Evolution of S-Curve Tool
- Guided Tour of S-Curve Tool
  - Screen shots
- Demonstration of S-Curve Tool
  - NATO AGS, OEM examples

Come see us afterward, or at SCEA/ISPA in June in Albuquerque!

<u>Warning</u>: There is a lot of ground to cover, so please forgive us if we put the spur to the horse (including ourselves)!

NATO AGS Example



Previous case study graphic – We'll demo its generation in the S-Curve Tool shortly

Objective of S-Curve Tool

- Leverage Dr. Flynn's historical analysis of SARs for DoN programs to develop a tool that will allow practitioners to easily and clearly:
  - Compare their estimate (S-curve!) to history in coefficient of variation (CV) and cost growth factor (CGF) [Benchmarking]
  - Compare two different estimates [Reconciliation]
  - Generate graphics for decision briefs
- Compatible with both:
  - Empirical methods such as Monte Carlo risk analyses
  - Parametric methods such as enhanced Scenario-Based Method (eSBM)
- The development team leveraged its experience in CV analysis at their last job in industry

S-Curve Tool Status

- Beta version 1.0 has been released
  - Macro-less Excel 2007 file (.xlsx)
  - Based on thorough vetting of breadboard / brassboard model
  - Being piloted on ICEs and Assessments within NCCA
  - Initial documentation and training developed
- Contains historical adjustment factors (CV and CGF) for [MS B & C], Acq, [w & w/o Qty and Inflation] for:
  - All DoN
  - Ships and Submarines
  - Aircraft
  - Missiles
  - Electronics / Other
- Beta version 2.0 slated for general release April 2011

S-Curve Tool Access

- "How do I learn more?"
  - Discuss with one or more of the tool POCs:
    - Mr. Richard Lee, RLee@technomics.net, lead developer
    - Mr. Peter Braxton, PBraxton@technomics.net, algorithm development
    - Dr. Brian Flynn, Brian.Flynn@navy.mil, sponsor, historical data analysis
- "How do I get access to the tool?"
  - Contact one of the tool POCs
    - Beta v2.0 will be first publicly-released version
  - Visit the NCCA website http://www.ncca.navy.mil
    - Tool and eSBM paper will be posted soon
    - Target date: 01 Apr 2011 (no fooling!)

Evolution of Risk at an Original Equipment Manufacturer (OEM)
A Case Study

"Progress, far from consisting in change, depends on retentiveness. When change is absolute there remains no being to improve and no direction is set for possible improvement: and when experience is not retained, as among savages, infancy is perpetual. **Those who cannot remember the past are condemned to repeat it.**"

-George Santayana, *The Life of Reason*

http://en.wikiquote.org/wiki/Santayana#Vol._I.2C_Reason_in_Common_Sense

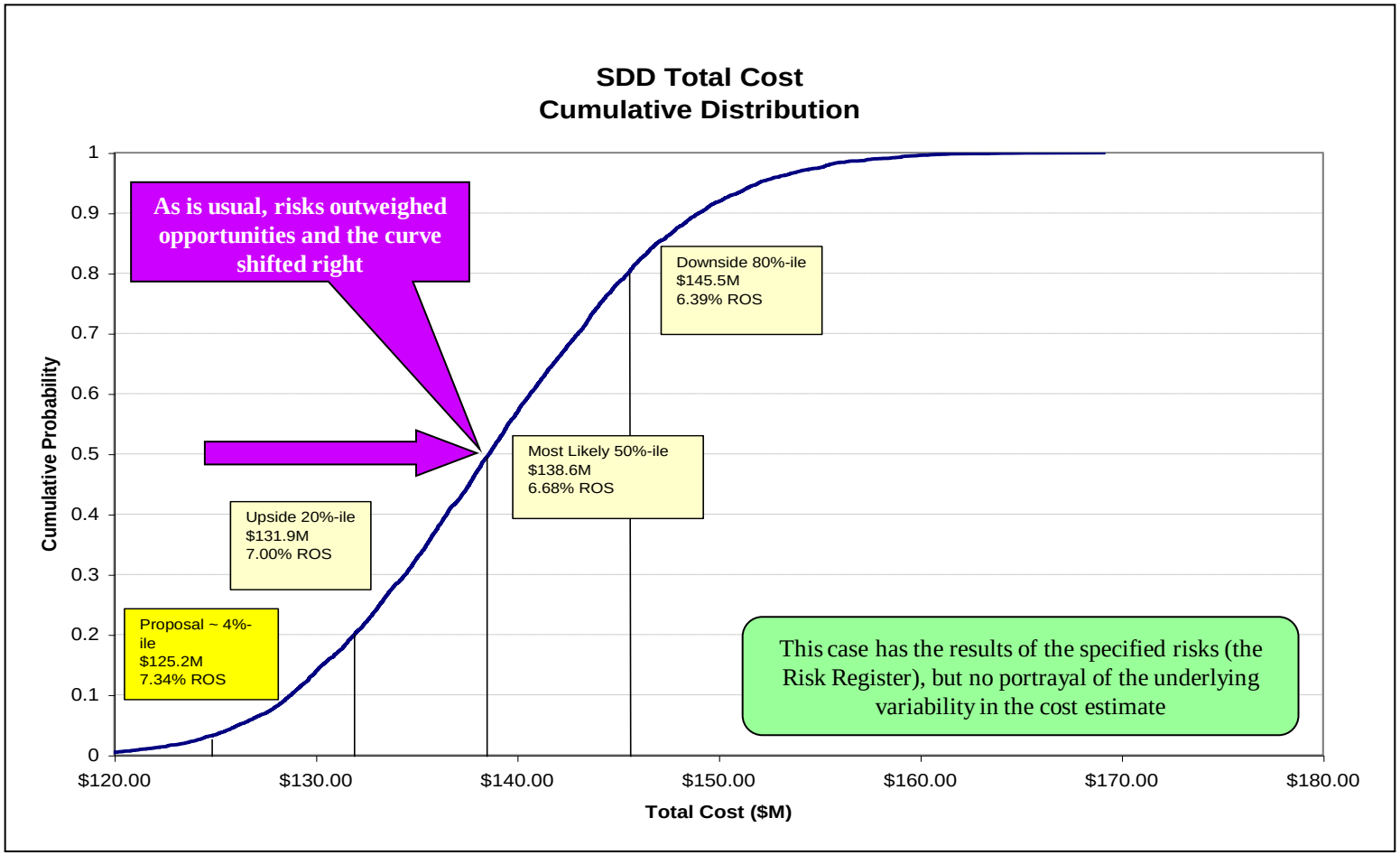
Insufficient CV

An ICE with and without Cost Estimating Variance
(a.k.a. Cost Estimating Uncertainty or Cost Estimating Risk)

SDD (Risks & Opportunities Only)

± 4.9%

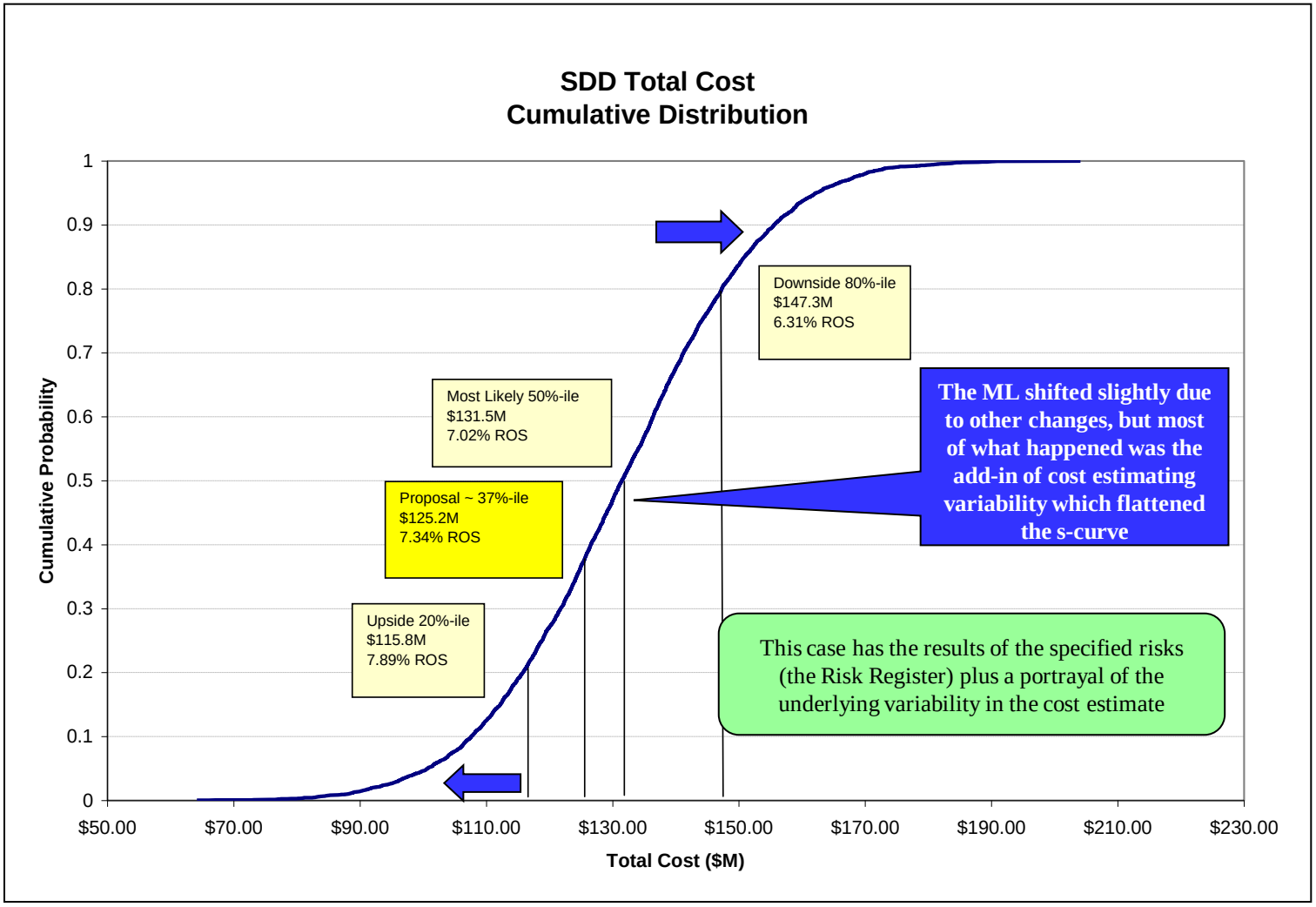
	Proposal	Upside	Most Likely	Downside
Cost	$ 125,219,843	$ 131,924,597	$ 138,603,127	$ 145,505,394
Fee	$ 9,924,967	$ 9,924,967	$ 9,924,967	$ 9,924,967
Price	$ 135,144,810	$ 141,849,565	$ 148,528,094	$ 155,430,362
ROS	**7.34%**	**7.00%**	**6.68%**	**6.39%**
		CPFF Contracts		



SDD (Cost Estimating Variance Added)

± 12.0%

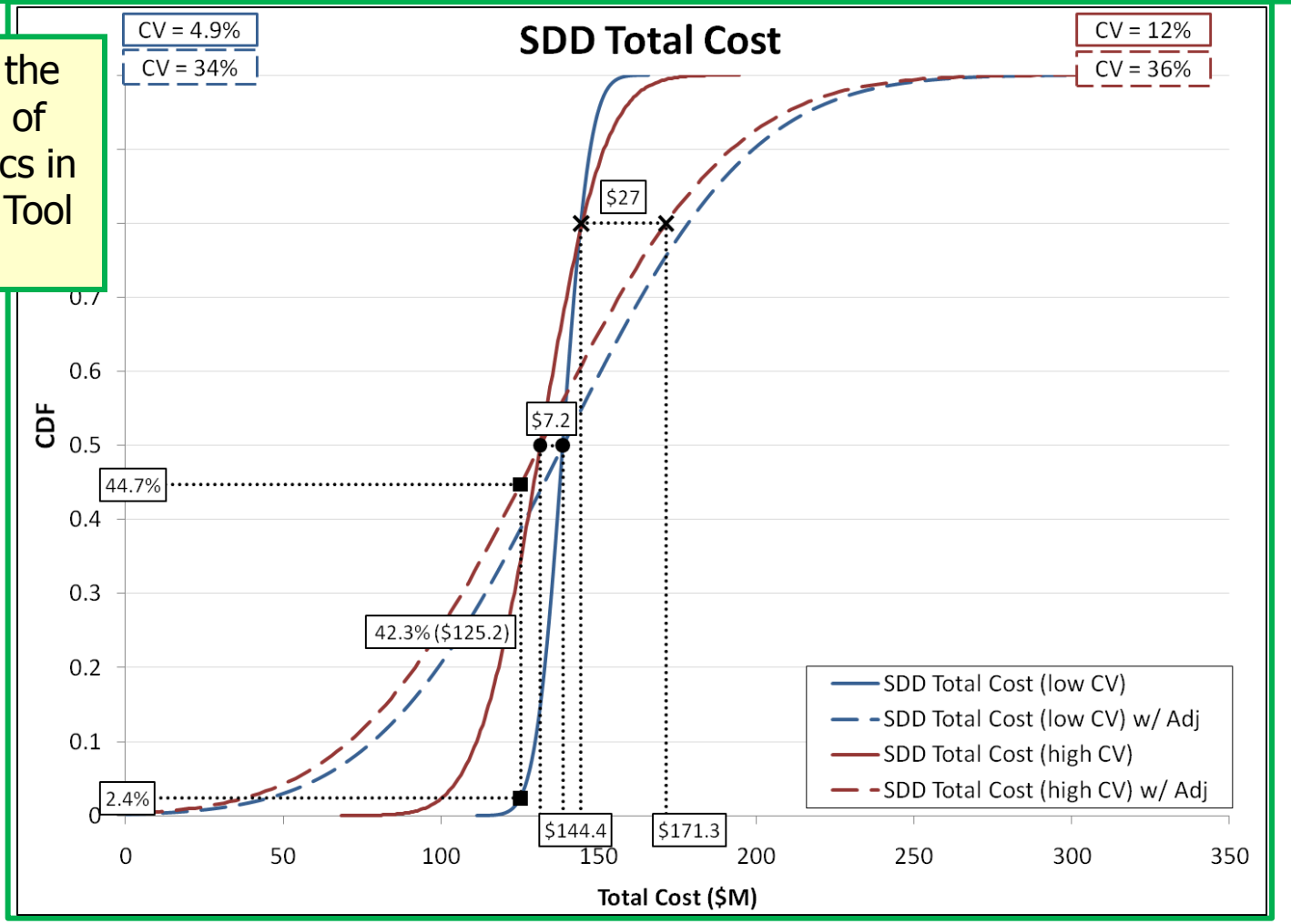
	Proposal	Upside	Most Likely	Downside
Cost	$ 125,219,843	$ 115,792,733	$ 131,455,455	$ 147,279,388
Fee	$ 9,924,967	$ 9,924,967	$ 9,924,967	$ 9,924,967
Price	$ 135,144,810	$ 125,717,700	$ 141,380,422	$ 157,204,355
ROS	**7.34%**	**7.89%**	**7.02%**	**6.31%**
		CPFF Contracts		



The Graphic Nobody Saw (or Wanted to See!)

ESTIMATE 1		ESTIMATE 2 (Historical Adjustment)	
ESTIMATE 1 TITLE	SDD Total Cost (low CV)	ESTIMATE 2 TITLE	SDD Total Cost (high CV)
Mean	$138.7	Mean	$131.5
20th Percentile	$132.95,20%	20th Percentile	$118.22,20%
80th Percentile	$144.39,80%	80th Percentile	$144.78,80%
Proposal Estimate	$125.2,2%	Proposal Estimate	$125.2,34%

We'll demo the generation of these graphics in the S-Curve Tool shortly



The Seductive S-Curve

- **Smoothness**:
  - Empirical CDFs are **smooth**, even for 100 trials of a Monte Carlo, conveying a false sense of precision
  - Corresponding empirical PDFs show noise and thus convey our uncertainty
- **Scale and Steepness**:
  - Because the y-axis of an S-curve is always 0 to 1 (cumulative probability) and the x-axis usually auto-scales in Excel, it's hard to get a sense of the **scale** and corresponding **steepness** of an S-curve
  - A practiced reviewer will look at the x-axis and do some quick mental math, but S-curves should always be labeled with their CV to easily convey scale and steepness and to lift the burden of caution from the reviewer
- **Similarity**: Because of the previous two bullets, S-curves tend to look the **same**, which means we need to be cautious in viewing them
- **Comparisons (Serial vs. Side-by-Side)**:
  - Meaningful comparisons between S-curves need to be done on the same graph; it is too hard to detect differences flipping from one chart to the next, especially given the previous three bullets
  - By contrast, if a *change in a series, or variability* is being illustrated, then serial display[1] is fine
- **Basis**: Along with the above concerns, there is the question of the underpinnings of risk analysis that the S-curve conveys: the S-curve is the **sausage**, and the risk analysis is the sausage factory; we cannot be confident in the former without fully delving into the latter

1. Serial displays, called "small multiples", are strongly advocated by Edward Tufte, an expert in the presentation of informational graphics

Comparison of Metrics for Variability

Metric/Requirement	Shows Asymmetry?	Good for Comparisons?	Difficulty of Computation	Utility for Percentiles
Standard Deviation (SD)	N	N	L	L
CV (SD/mean)	N	Y	L	L
20th /50th /80th Percentiles	Y	N	M	M
Three-Point Estimate (L/ML/H)	Y	N	L	L
PDF	Y	N	H	M
S-curve (CDF)	Y/N	N	H	H

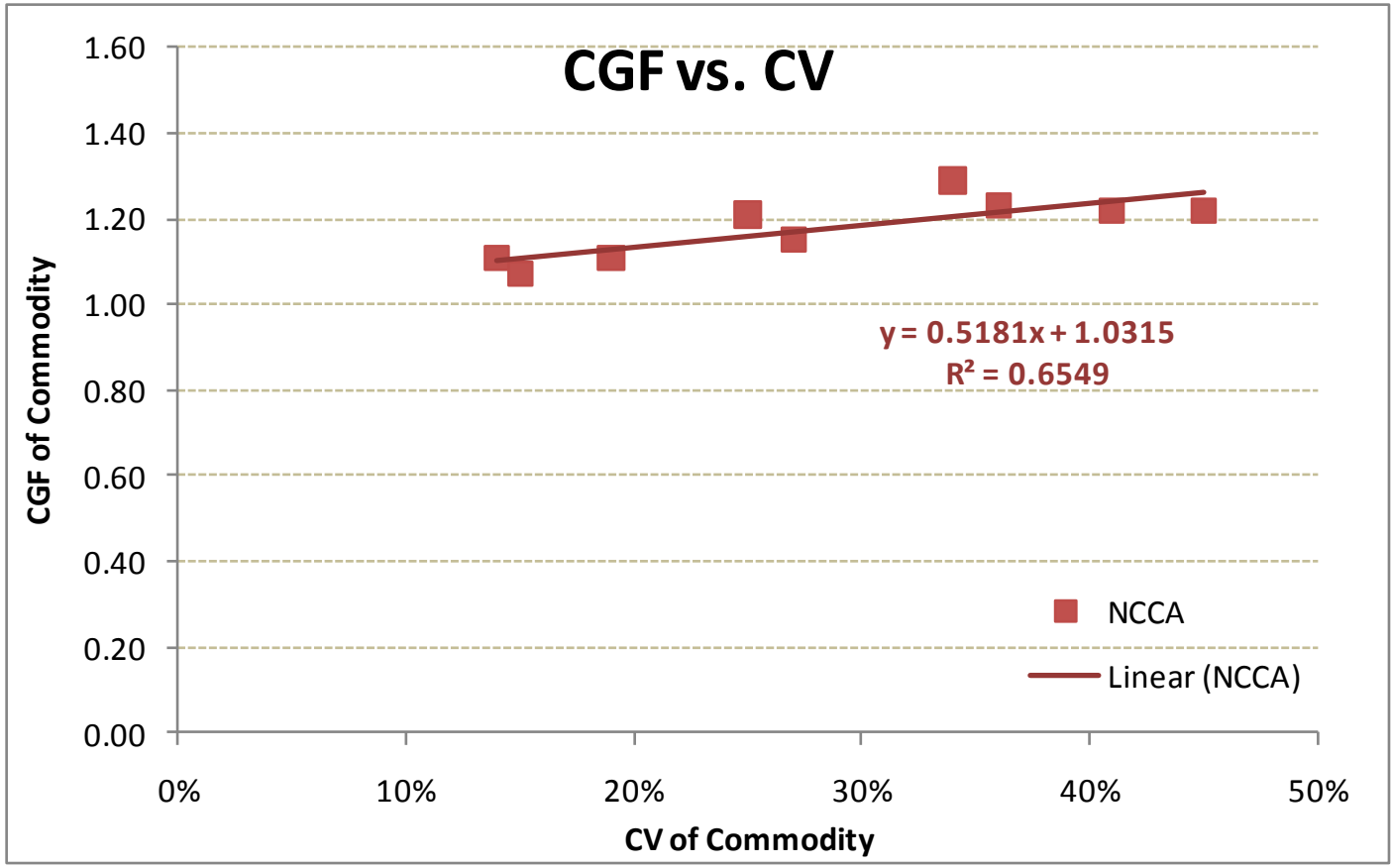
Y = Yes, N = No | H = High, M = Medium, L = Low

green = good, yellow = OK, red = poor

- No single metric does everything
- Minimum requirements can be met with the S-curve and the CV
  - With the PDF superimposed, all requirements are met

More Motivation!

- Overly tight CVs indicate overstatement of our certainty, that's a given
- Even more compelling is that the <u>understatement of CV is tied to understatement of cost growth</u>
  - Caveat: this is growth by commodity, and may not relate to cohorted estimate pairs
- This relationship is almost preordained since risks cause growth in CGF <u>and</u> CV
- The graph enables computation of an implied rise in the mean when we raise the CV
- <u>Note</u>: This thought process not yet coded in tool



CV Growth Implies CGF Growth			
CV	**Value**	**Implied CGF**	**CGF Increase**
CV_1	20.0%	1.135	
CV_2	35.0%	1.213	0.078

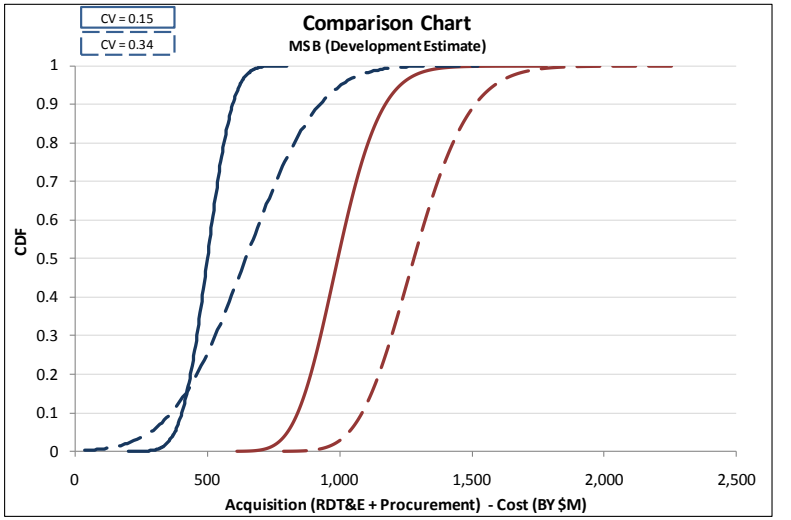
Evolution of Requirements

Tasking	Orig.	New
CV	x	
CGF		x
Single Estimate vs. Historical [Benchmarking Mode]	x	
Parametric (e.g., Normal with Mean and CV)	x	
Empirical (i.e., Risk Monte Carlo output of up to10,000 trials)		x
Point Estimate (i.e., risk analysis not yet done)		x
1st est. vs. 2nd est. (or 2 phases) and Historical [Reconciliation mode]		x

- Modest but useful additions to the tool were suggested by
  - Industry experience (Empirical and Reconciliation)
  - Consideration of NCCA's future uses (Reconciliation)
  - Reviewers (Point Estimate input)

S-Curve Tool Design Considerations

- Tradeoffs Addressed
  - Capability vs. Complexity
    - Minimizing the cost of complexity
  - Permissive vs. Restrictive Controls
    - “Pistol in the playroom” vs. “the Soup Nazi”
- Effective Design
  - Color / geography / brevity
- Organization and clarity
  - Make the flow intuitive
  - Be consistent and mnemonic
- Clear Structure (sideline the side issues)
  - Computations and data
- Error anticipation *and* detection



S-Curve Tool Development Epiphanies

Legend:
Blue font signals broader application

- Probability distributions
  - Lognormal: Better understanding of the lognormal and related normal
    - CV rules of thumb for shift from median to mean or mode
    - "Pivoting" on the median vs. "pivoting" on the mean
  - Alternate specification: Normal and Lognormal
    - Any two of:
      - Mean, median, or mode
      - CV
      - Any percentile
    - Lognormal two solutions
      - Mean and percentile, or mode and percentile

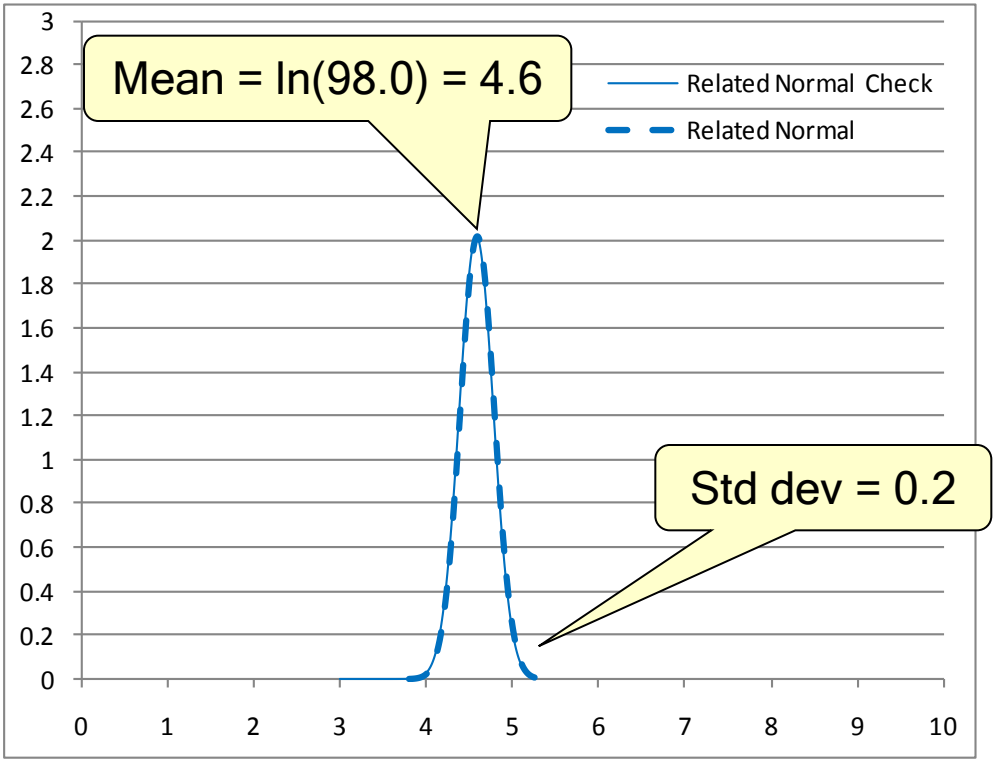
We learned that the lognormal is even harder than we'd guessed, it sometimes has two solutions

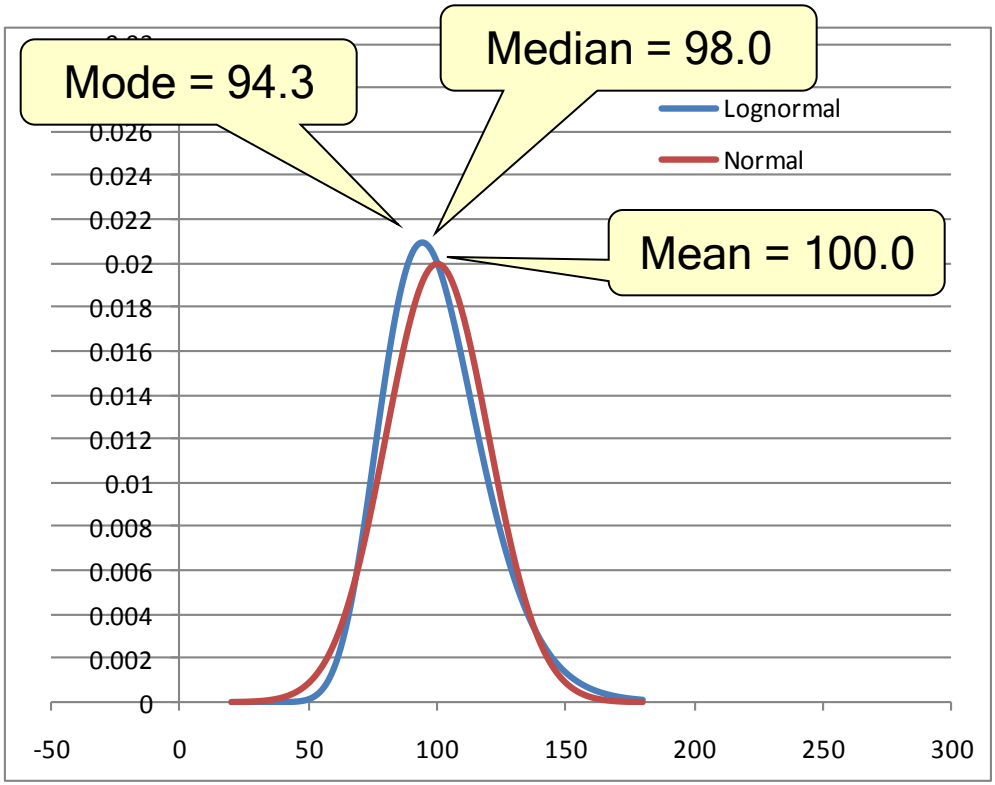
- Data analysis
  - Standard deviation vs. CV vs. pseudo-CV (s.d. divided by *median*) for historical CGFs
- Model
  - CGF-only historical adjustment: not just a translation, because we determined to believe the CV *not* to believe the standard deviation
  - Graphical sampling
    - Developed to solve noisy PDF problem (got worse, not better, with more trials)
    - Reduces size, increases speed of model
    - Order of operations: transformation of stats quicker than stats on transformed data

Related Normal Example

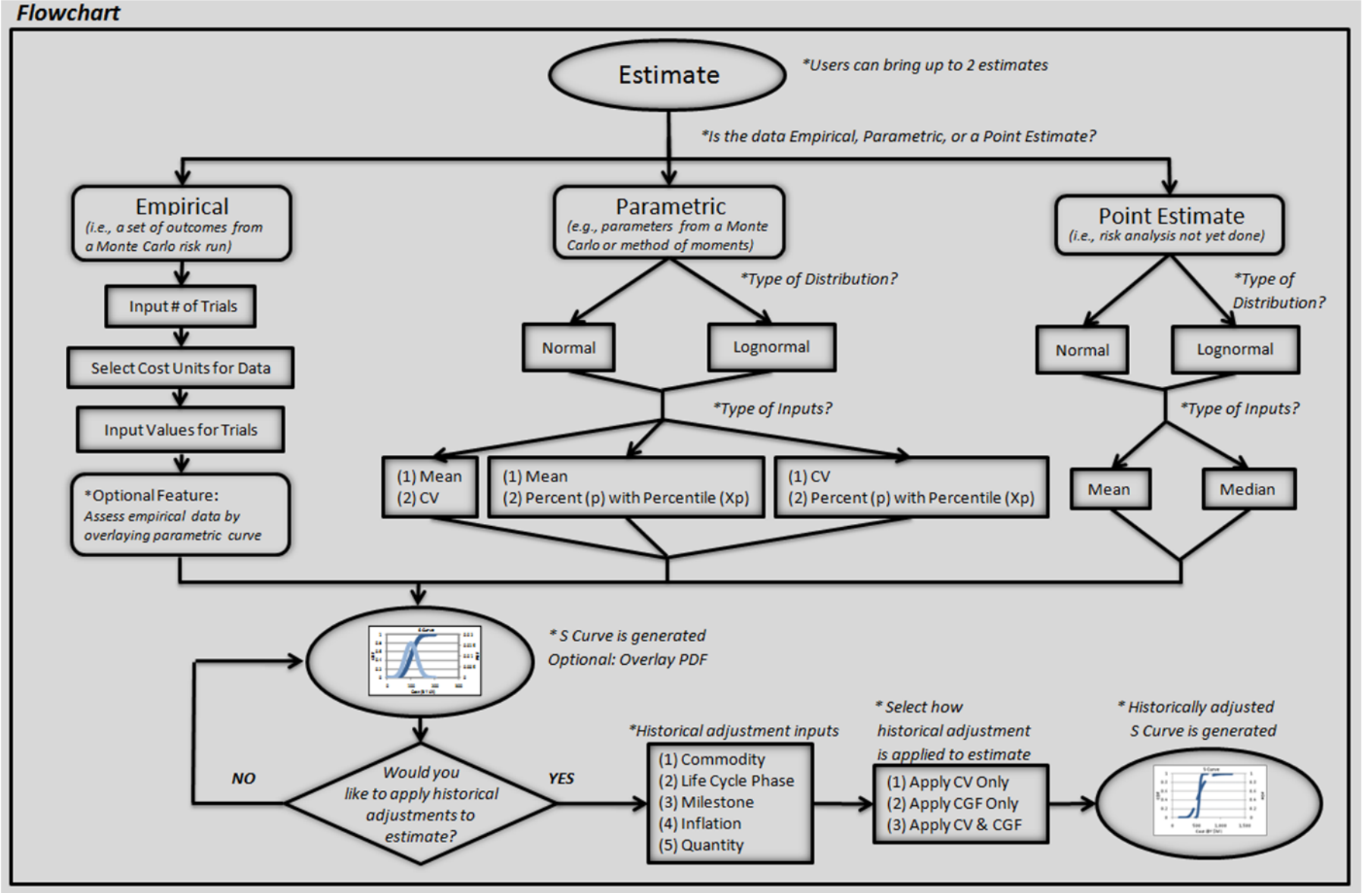
- Mean = 100, CV = 20%
  - Mode shift = -3.8% (wrt median)
  - Mean shift = +2.0% (wrt median)

CV (lognorm)	mode shift factor	mean shift factor	percentile of mean
10%	0.990	1.005	52.0%
20%	0.962	1.020	53.9%
30%	0.917	1.044	55.8%
40%	0.862	1.077	57.6%
50%	0.800	1.118	59.3%





S-Curve Tool Flowchart



S-Curve Tool Inputs tab

1. Define Estimate

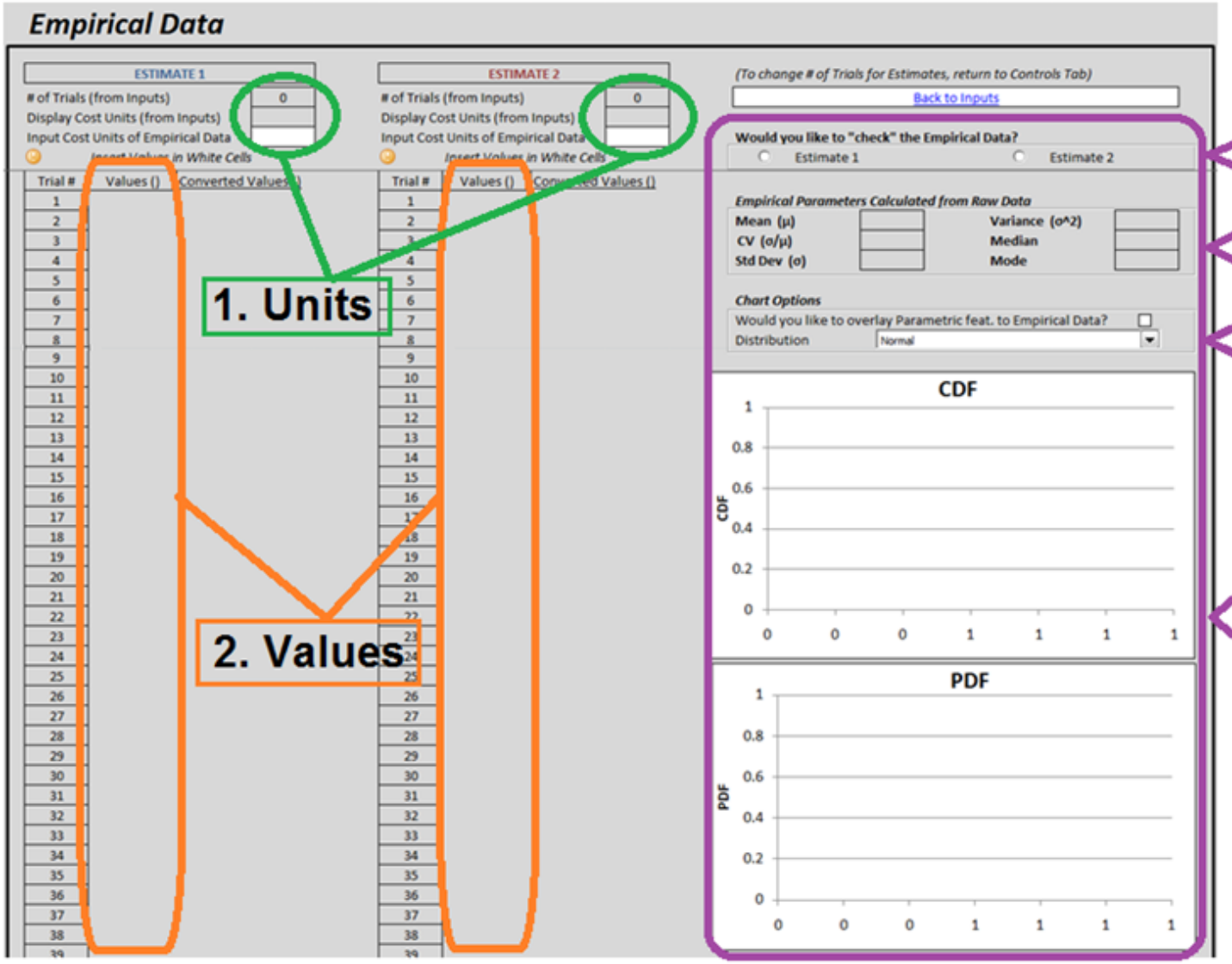
2. Choose Estimate Type & Input Parameters

3. Derived Parameters from Inputs

4. "Check" Estimate w/ Chart Options

5. Historical Adjustment

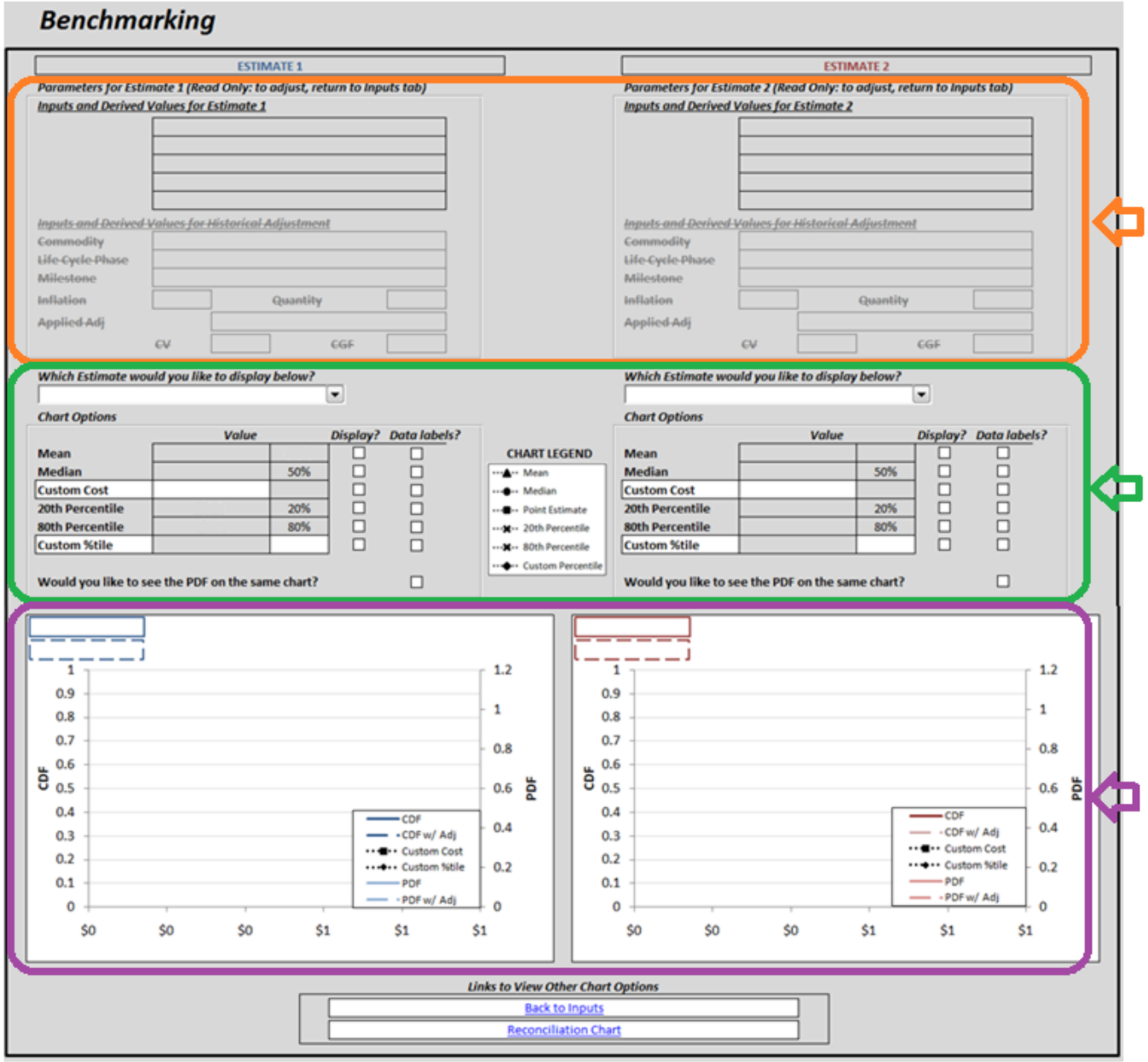
S-Curve Tool Empirical tab



***Optional: "check" Empirical data**

1. Choose between Estimate 1 or 2
2. Derived Parameters from Empirical Data
3. Chart Options
4. Chart of CDF & PDF

S-Curve Tool Benchmarking tab

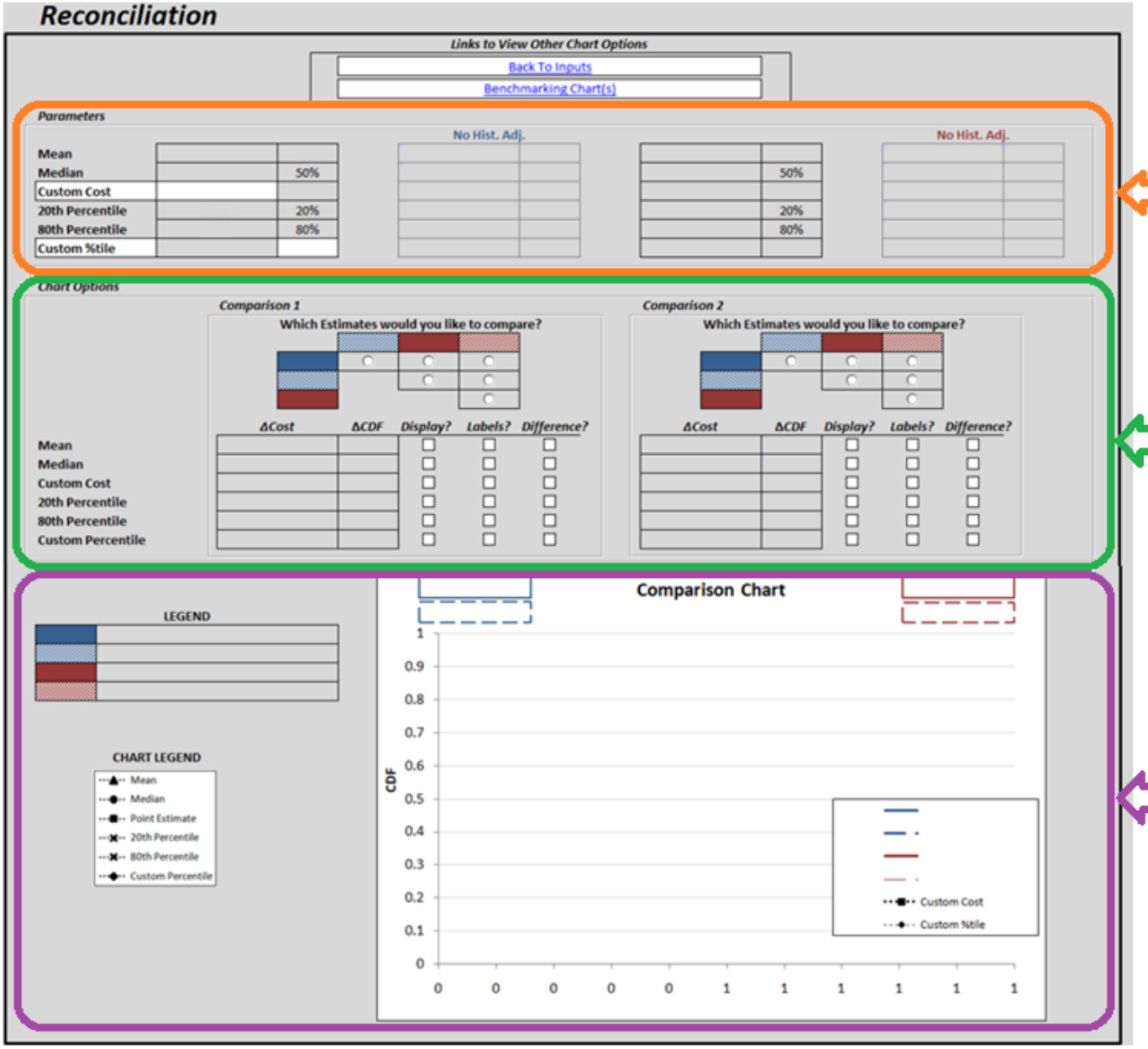


1. Parameters from "Input" Tab

2. Select estimate & apply chart options

3. View chart based on selections from chart options

S-Curve Tool Reconciliation tab



1. Derived Parameters from "Inputs" Tab

2. Select which estimates to compare & apply chart options

3. View chart based on selections from chart options

S-Curve Tool Demo

“Let’s go the Excel…!”

NCCA S-Curve Tool Backup

Alternate Specification of Normal

Given	Mean	Std Dev	CV
Mean, CV	μ	$CV \cdot \mu$	CV
Mean, Percentile (X_p, p)	μ	$\frac{\boxed{X_p} - \mu}{Z_p}$	$\frac{\left(\frac{\boxed{X_p}}{\mu} - 1\right)}{Z_p}$
CV, Percentile (X_p, p)	$\frac{\boxed{X_p}}{1 + Z_p \cdot CV}$	$\frac{\boxed{X_p} \cdot CV}{1 + Z_p \cdot CV}$	CV

$$Z_p = \Phi^{-1}(p)$$

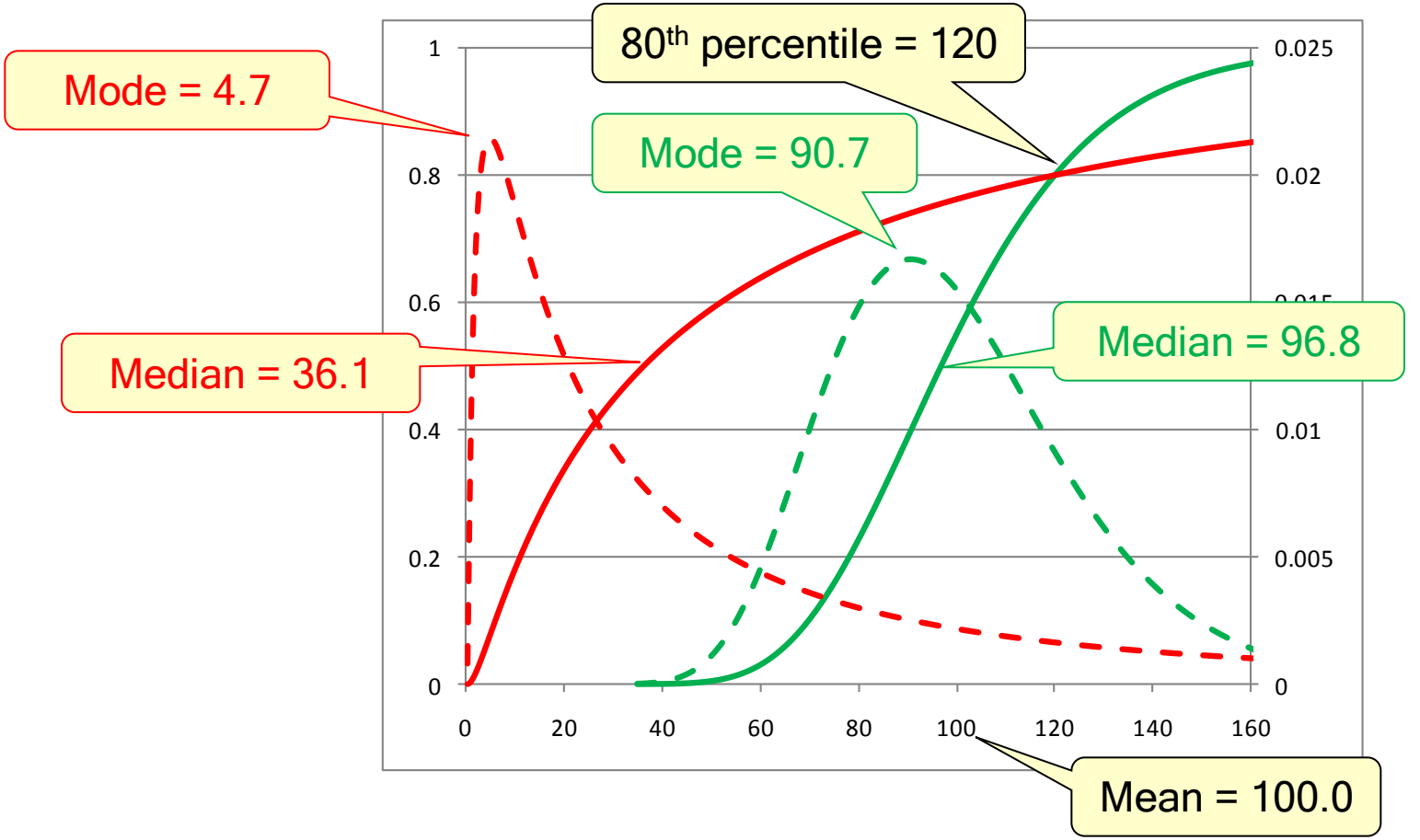
Alternate Specification of Lognormal

Given	Mean	Std Dev	CV	μ	σ
Mean, CV	$E(X)$	$CV \cdot E(X)$	CV	$\ln\left(\frac{E(X)}{\sqrt{1+CV^2}}\right)$	$\sqrt{\ln\left(1+CV^2\right)}$
Mean, Percentile (X_p, p)	$E(X)$	$CV \cdot E(X)$	$\sqrt{e^{\sigma^2}-1}$	$\ln\left(\frac{E(X)}{\sqrt{1+CV^2}}\right)$	$Z_p \pm \sqrt{Z_p^2 - 2\ln\left(\frac{X_p}{E(X)}\right)}$
CV, Percentile (X_p, p)	$e^{\mu+\frac{\sigma^2}{2}}$	$CV \cdot E(X)$	CV	$\ln X_p - Z_p\sqrt{\ln\left(1+CV^2\right)}$	$\sqrt{\ln\left(1+CV^2\right)}$

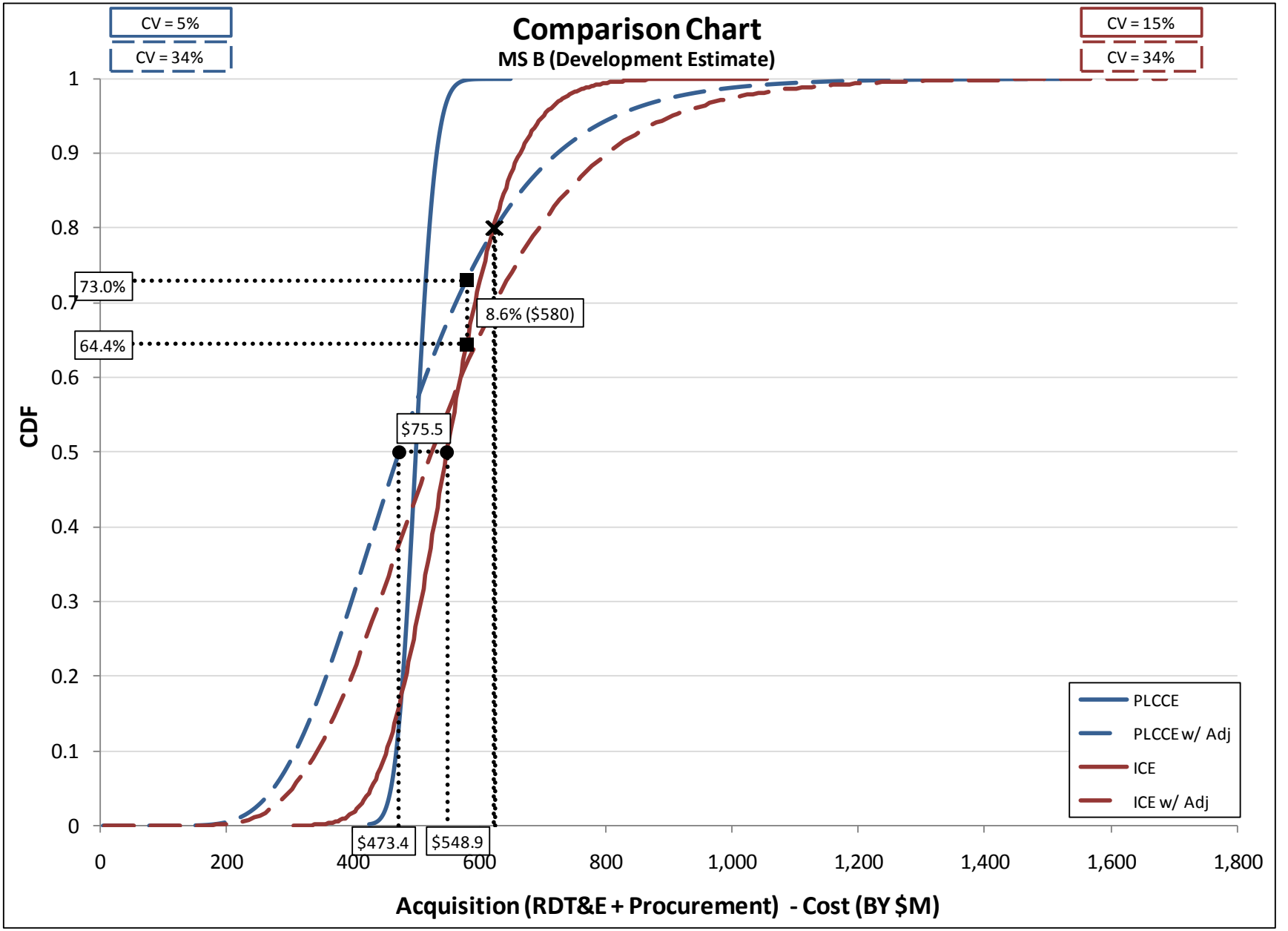
$Z_p = \Phi^{-1}(p)$

Two Lognormals Example

- Mean = 100, 80th percentile = 120
  - "Regular" solution with 26% CV
  - "Extreme" solution with 258% CV!



Reconciliation Mode of S-Curve Tool



Beliefs Drive Results

- Choices can trigger the law of unintended consequences
- The below tables show what our choices imply
- Results assume CV increases (top) and CGF > 1.0 (bottom)
  - If CV drops, or CGF < 1.0, reverse the cited effects

Pivot Point Choices	**Maintain $ of Median (Case 1)**	**Maintain $ of Mean (Case 2)**
Normal	No Effect	No Effect
LN	Median Constant Mean $ Rises, Mean % Rises	Median $ Drops Mean % Rises

CGF Choices	**Believe CV**	**Believe SD**
Normal/LN	SD Rises	CV Shrinks