NORTHROP GRUMMAN

Risk-Based Return On Sales (ROS) for Proposals with Mitigating Terms and Conditions

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The Problem

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- "Tell me the 20th, 50th, and 80th percentile of Cost, and the ROS at the 80th."
- Risk tool provides these numbers without real insight into the *distribution* of ROS
- On a complex FPI contract with mitigating terms and conditions (Ts & Cs), the one-to-one correspondence of ("on-the-shareline") cost and ROS was destroyed
  - "Eureka!" graph on next slide
  - It became evident that what we really wanted was the 20th percentile of ROS
  - Explaining this to decision-makers was a challenge
  - Developing a "scenario" that produced both the 20th percentile ROS *and* the 80th percentile cost was a challenge
  - Oh, and the situation was complicated by split buy and at-cost vs. equitable adjustments!
- The solution: Develop analytical and empirical tools for determining the distribution of ROS

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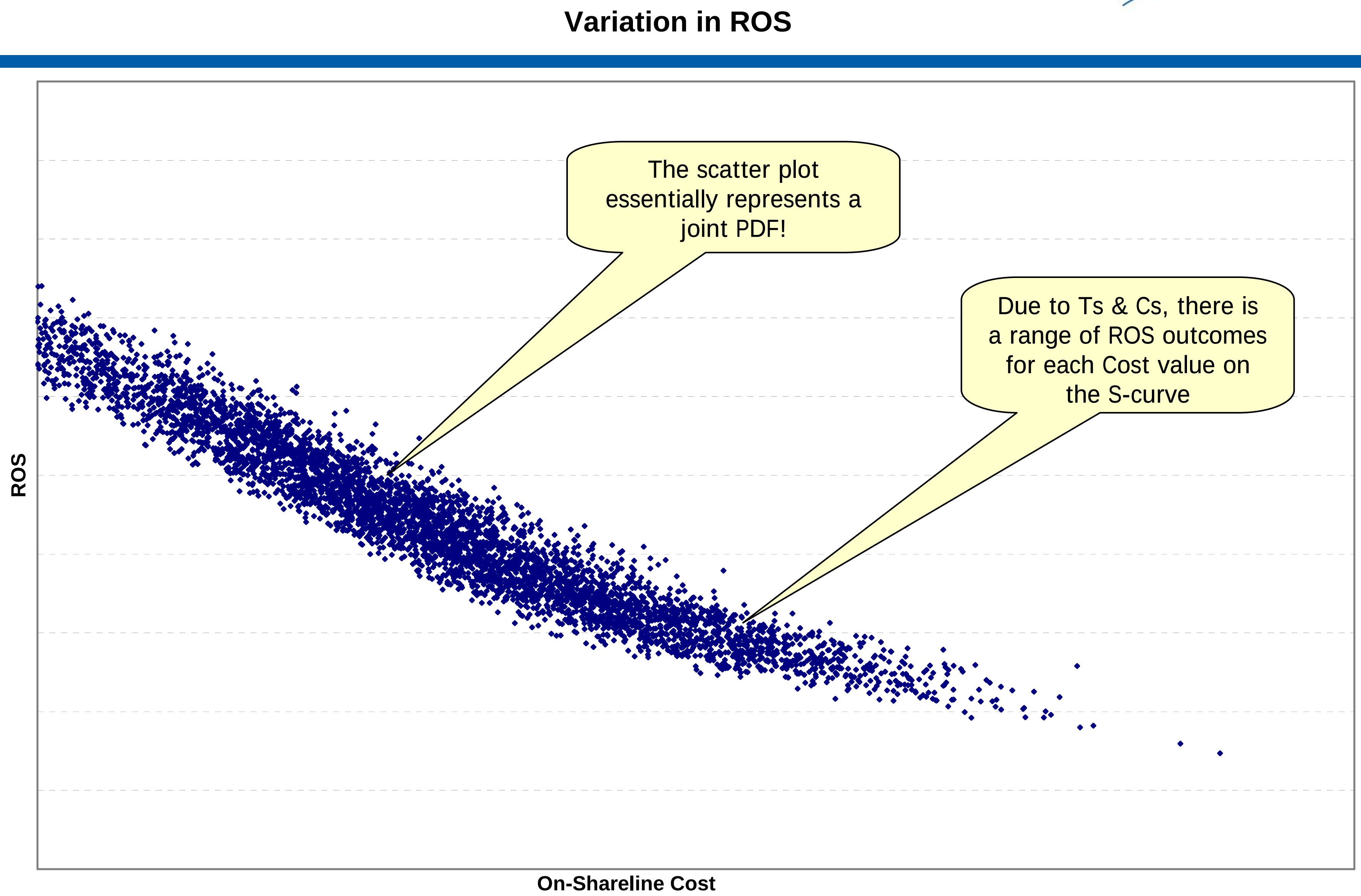
Cost vs. ROS



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Outline

- Contract Types Overview
  - Contract Types are just functions that map Cost to Profit, Price, and ROS
  - Reviewing the conventional wisdom on contract types and risk
- Contract Types and Risk
  - Looking at your range of possible outcomes across the shareline
- Risk-Based ROS
  - Percentiles vs. Mean and the distribution of ROS
- Distribution of ROS (analytical, without Ts & Cs)
  - Transformation of random variables
- Distribution of ROS (empirical, without Ts & Cs)
  - Monte Carlo cross-check
- Distribution of ROS with Ts & Cs
- Closing Thoughts

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Contract Types Overview

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ROS could be negative!

- Fixed-Price
  - Firm-Fixed-Price (FFP) [FAR 16.202]
  - Fixed-Price Incentive (FPI) [FAR 16.204]

Incentive contracts [FAR 16.4]

ROS strictly positive

- Cost-Reimbursement [FAR 16.3]
  - Cost-Plus-Incentive-Fee (CPIF) [FAR 16.304]
  - Cost-Plus-Award-Fee (CPAF) [FAR 16.305]
  - Cost-Plus-Fixed-Fee (CPFF) [FAR 16.306]
- Contract Types vary according to
  - Degree and timing of the responsibility assumed by the contractor for the costs
  - ***Amount and nature of the profit incentive*** offered to the contractor for achieving or exceeding specified standards or goals
- We'll omit CPAF because it is by definition subjective

Cost Estimating Body of Knowledge (CEBoK), Module 14 Contract Pricing, SCEA, 2009.

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Contract Types Conventional Wisdom

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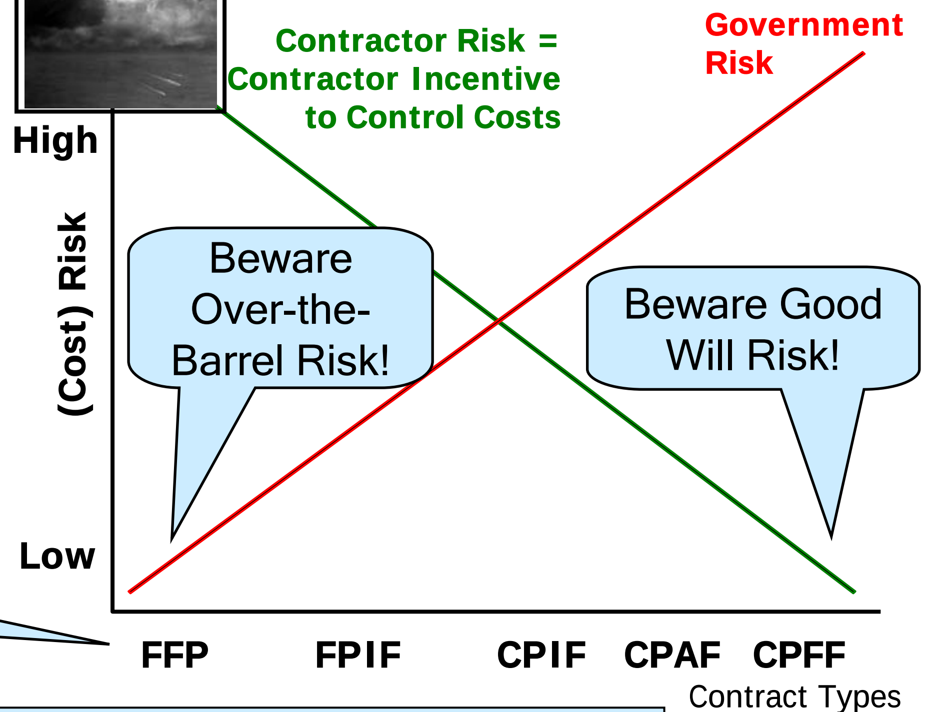
- Cost-Reimbursement contracts are high risk to the government
  - But what about Good Will Risk?! (LPD 17)

- Fixed-Price contracts are high risk to the contractor
  - But what about Over-the-Barrel Risk?!
    - Manifests as Default or Cancellation (A-12)
  - But what about Economic Price Adjustment (EPA)?!
    - We'll come back to that...
  - But also high opportunity!

- FFP is cheaper for the government
  - But the contractor will price in risk!

Typical continuum



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Fee, Profit, and Margin

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- Fee = Profit = Return On Cost (ROC): Amount of money earned by contractor over and above Cost, *expressed as a percentage of Cost*
  - Fee technical only applies to Cost-type contracts
  - We will used Fee and Profit interchangeably
    - In particular, TF = Target Fee/Profit, to distinguish from TP = Target Price

- Margin = Return On Sales (ROS): Profit *expressed as a percentage of Revenue* (= Cost + Profit = Price)

Tip: This is a "percent-centric" slide; these three quantities can also be reported in dollars ($).

Warning: The error is in denominator!

Fee = Profit = \$1M / \$10M = 10.0%

Margin = \$1M / \$11M = 9.1%

Margin = Fee / (1+Fee)

Fee = Margin / (1–Margin)

Remember this formula!

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Contract Types with Andy Rooney

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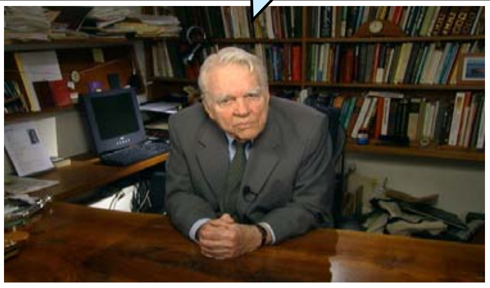
"You know what really bugs me…?!"



- Contracts people are English majors, Cost people are Math majors
  - FAR = blah, blah, blah – just give me a piecewise linear function!
  - Contract Data Elements specify outputs (Min Fee, Max Fee, Ceiling Price), we want inputs (RIE endpoints, PTA)
- Contract Types are just functions that map Cost to Profit, Price, and ROS...
  - ...as you depart from Target Cost
  - If you come in at Target Cost, contract type is immaterial
    - Of course, you *never* come it an Target Cost (no estimate is ever right)
- Incentive contracts is a misnomer [FAR 16.4]
  - *All* contracts provide an ROS incentive, just a matter of degree
  - Only contract type that would incentivize overruns is cost plus fixed *percent* fee, which is specifically prohibited [FAR 16.102(c)]
  - If you don't think contractors are motivated by ROS, you're crazy!
- Fixed Price Incentive (FPI) ain't fixed! [FAR 16.403]
  - What part of "price adjustment formula" did you not understand?!
  - Contractors are given extreme risk (past PTA), but not commensurate extreme opportunity

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Toy Problem

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- Typical Set of Inputs
  - Target Cost (TC) = $10.0M
    Target Profit (Fee) (TF) = $1.0M
    Target Price (TP) = $11.0M [all]
  - 10% Profit (ROC)
    9.1% Margin (ROS) [all]
  - 70/30 Over-Target Shareline
    40/60 Under-Target Shareline [CPIF/FPI]
  - Min Fee (mF) = 3%, Max Fee (MF) = 20% [CPIF]
  - Ceiling Price (CP) = 130% [FPI]

$$RIE_{low} = TC - \frac{(MF - TF)}{CS_{under}}$$

$$RIE_{high} = TC + \frac{(TF - mF)}{CS_{over}}$$

$$PTA = TC + \frac{(CP - TP)}{GS_{over}}$$

Target Cost	$ 10.0		
Target Profit	$ 1.0	10.0%	Profit Percent
Target Price	$ 11.0	9.1%	Margin Percent
Min Fee	$ 0.3	3.0%	Min Fee Percent
Max Fee	$ 2.0	20.0%	Max Fee Percent
Under Gov Share	40%		
Under Cont Share	60%		
Over Gov Share	70%		
Over Cont Share	30%		
PTA	$ 12.9		
Ceiling Price	$ 13.0	130.0%	Ceiling Price Percent
RIE Low	$ 8.3		
RIE High	$ 12.3		

yellow fill = input
blue fill = calculated

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Firm-Fixed-Price (FFP)

Contract Data Elements:
TP = FFP

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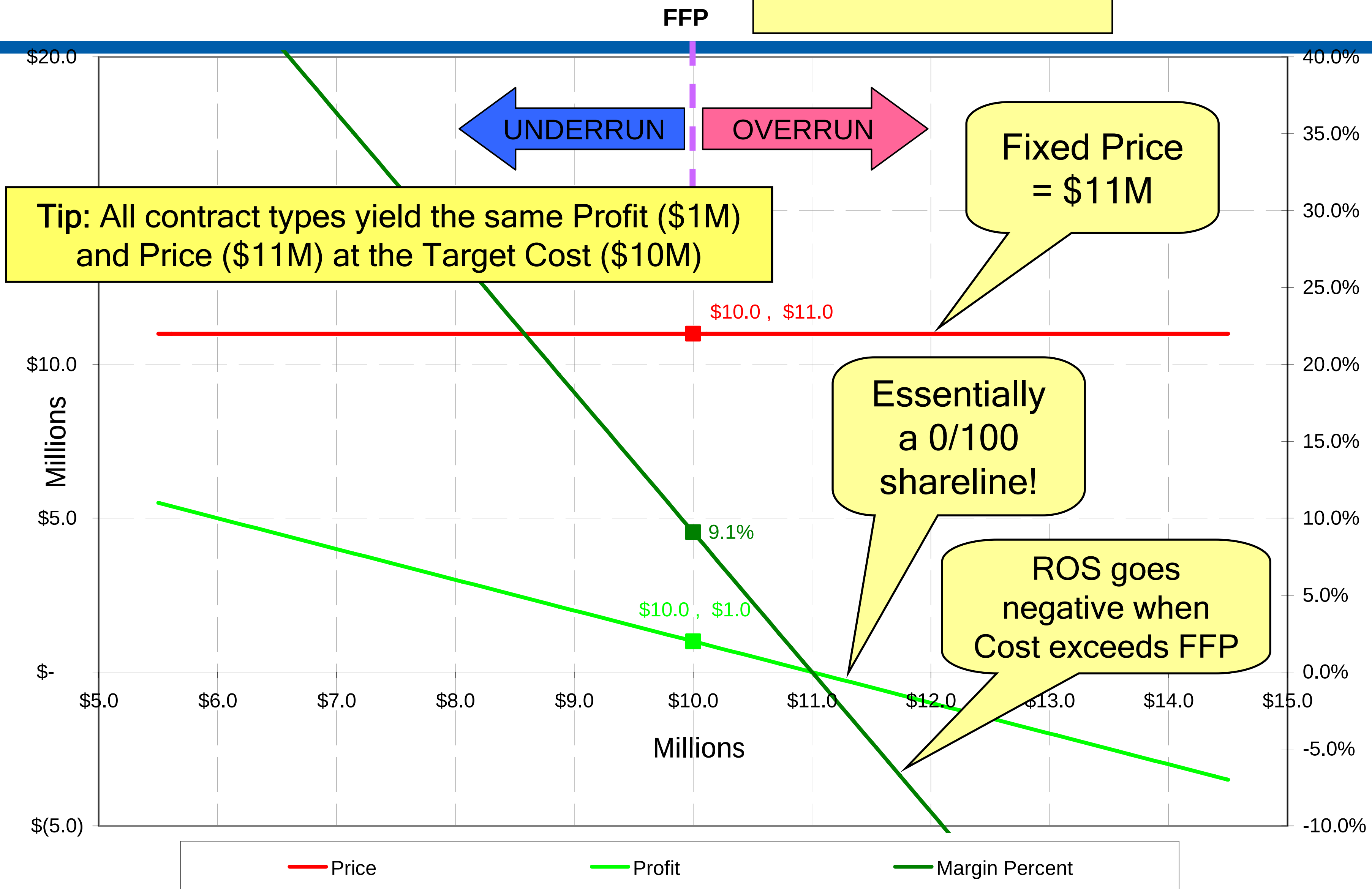

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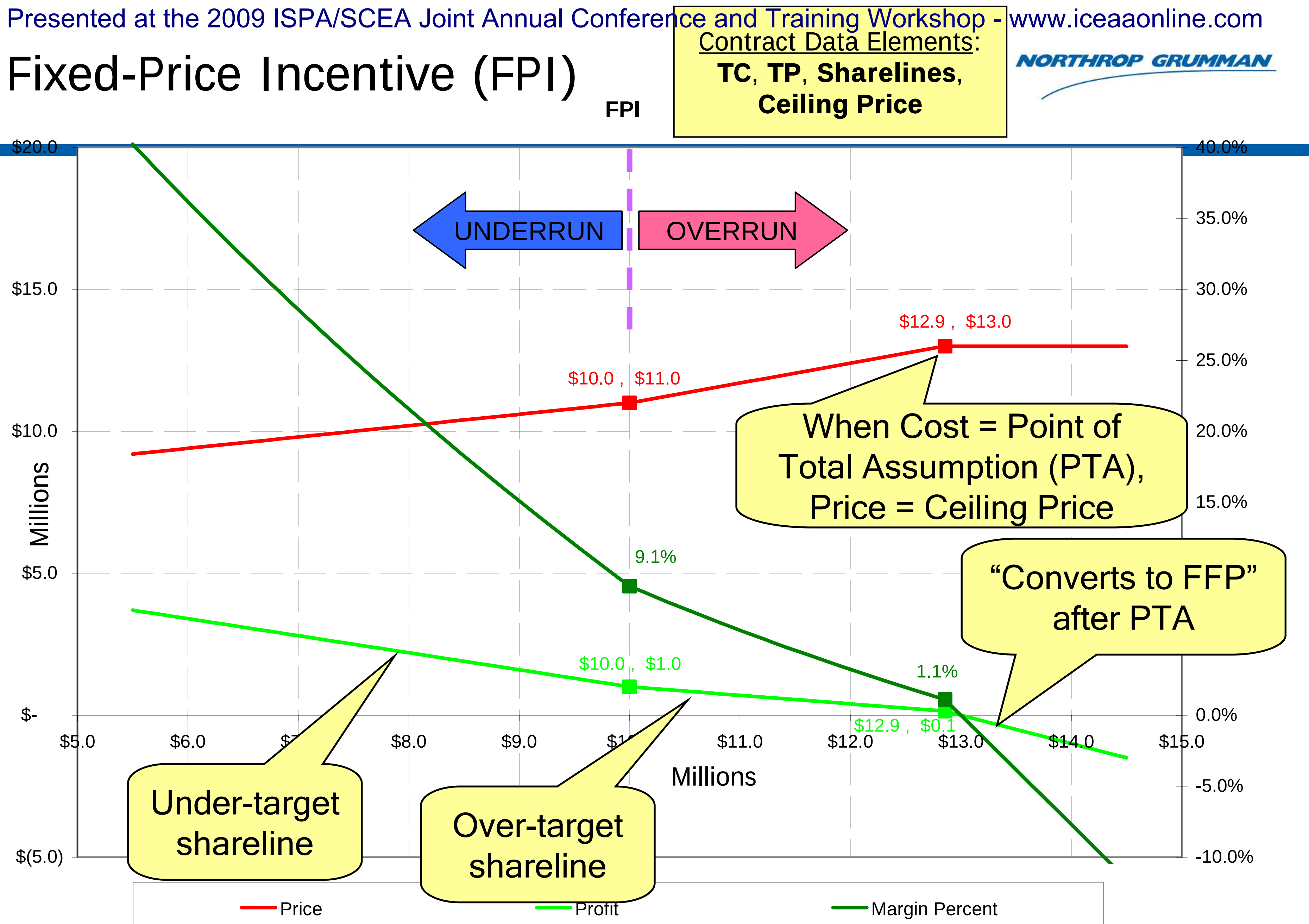
Fixed-Price Incentive (FPI)



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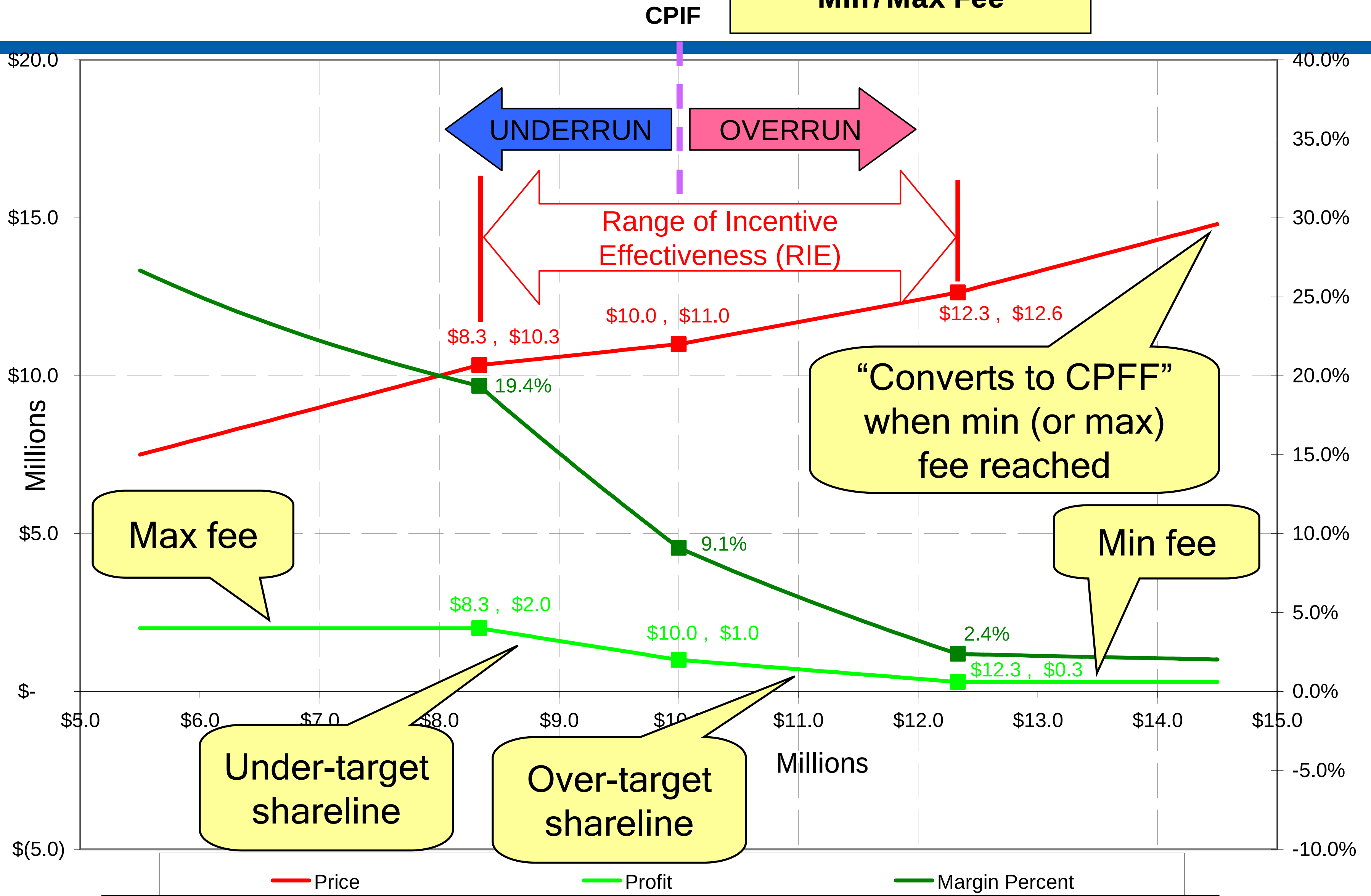
Cost-Plus-Incentive Fee (CPIF)

Contract Data Elements:
TC, TF, Sharelines, Min/Max Fee



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Cost-Plus-Fixed-Fee (CPFF)

Contract Data Elements:
TC, FF = TF

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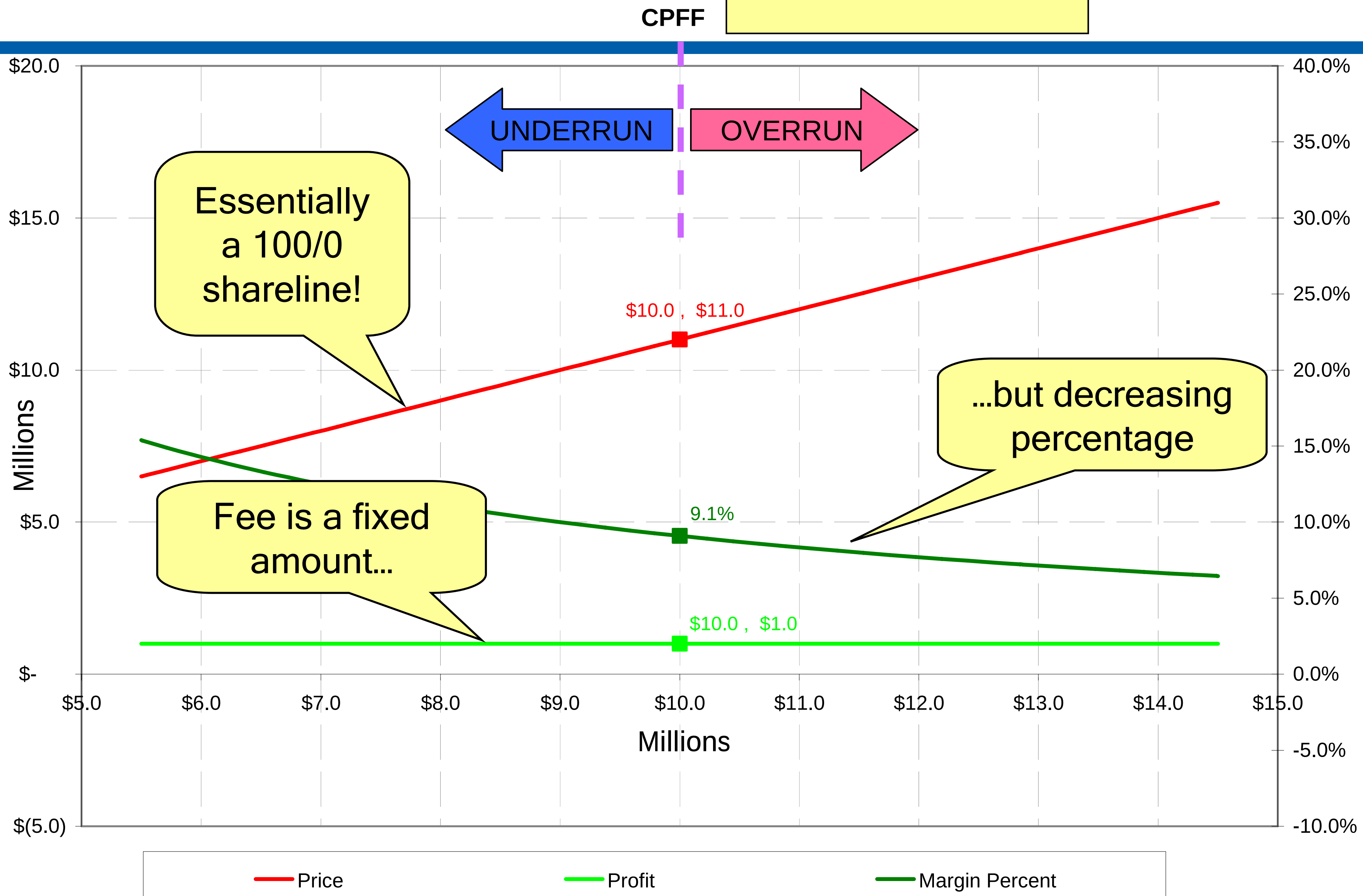

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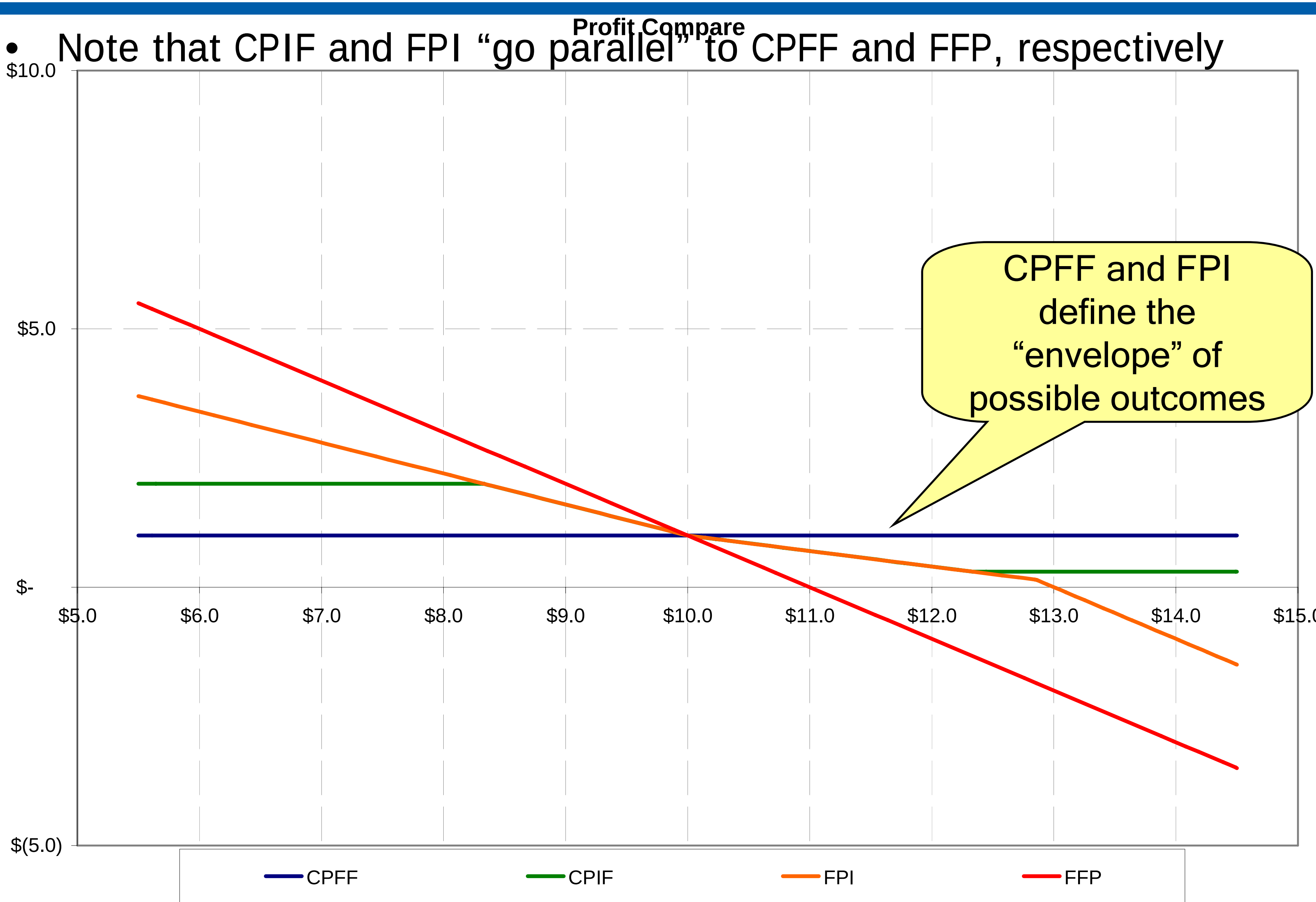
Contract Types Comparison – Profit (Y)

- Note that CPIF and FPI “go parallel” to CPFF and FFP, respectively



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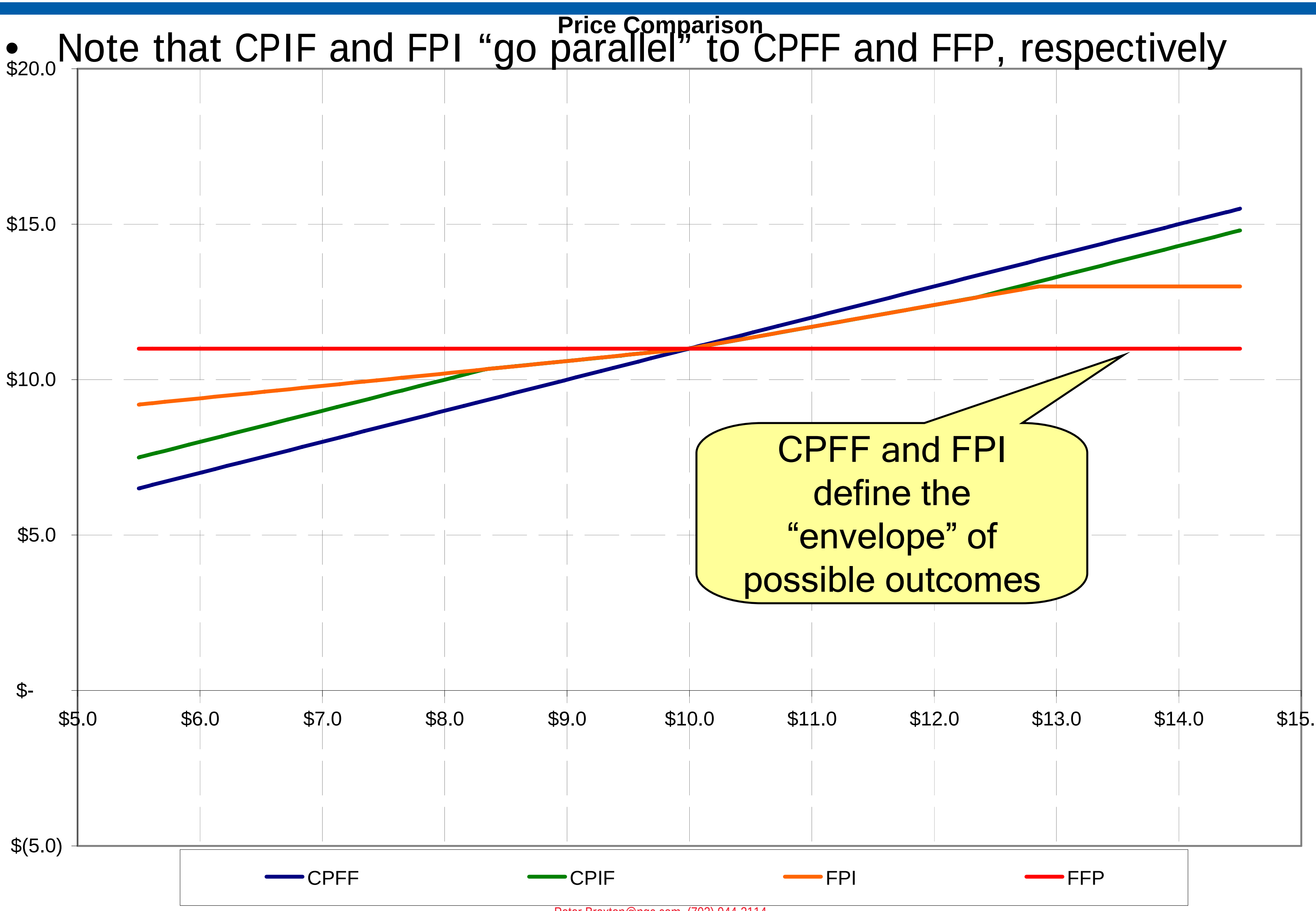
Contract Types Comparison – Price (X+Y)

- Note that CPIF and FPI “go parallel” to CPFF and FFP, respectively



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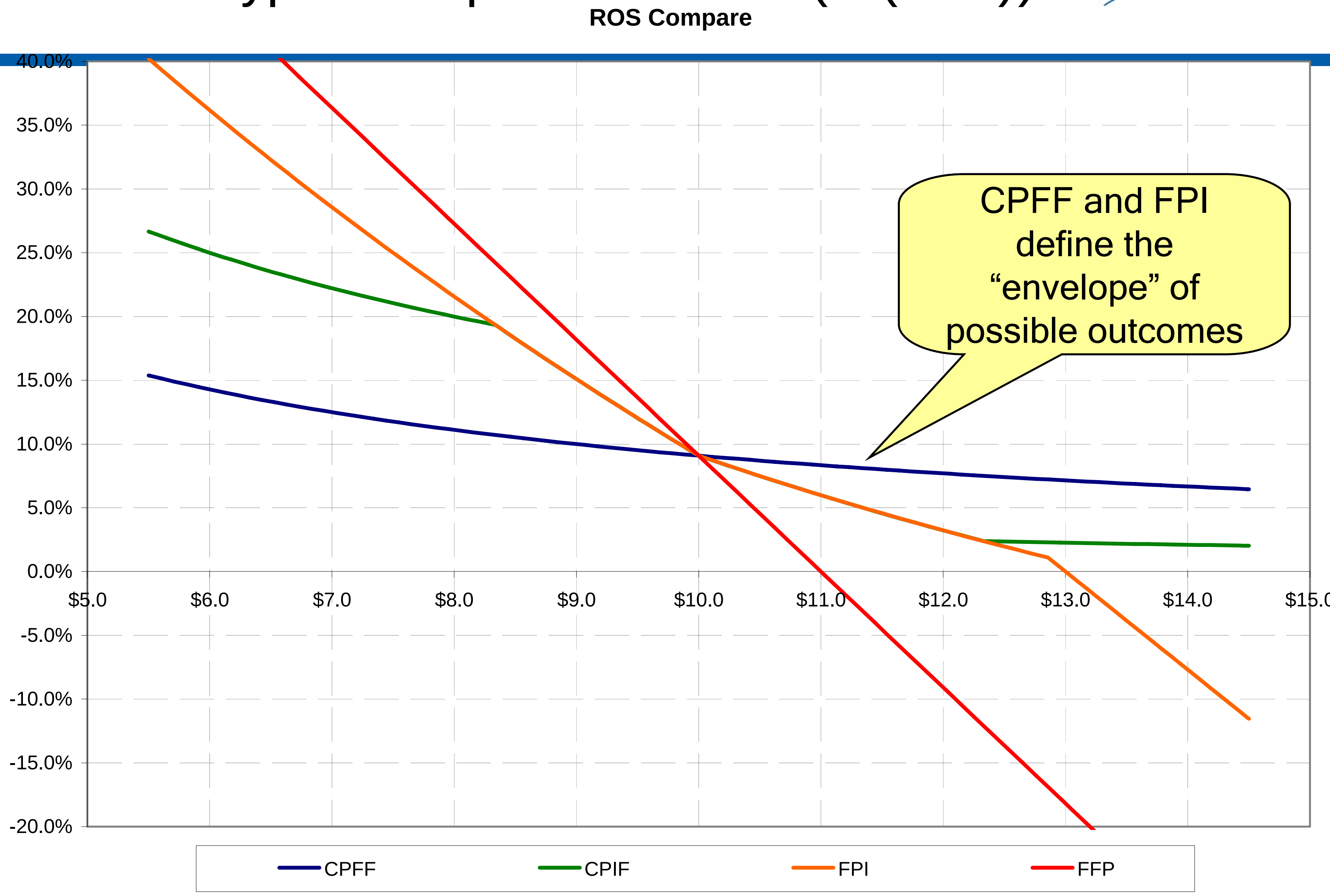
Contract Types Comparison – ROS (Y/(X+Y))



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Contract Types and Risk

- We wish to examine the interplay of risk and uncertainty with contract geometry for the various contract types
  - In view of conventional wisdom
  - Looking at "range of possible outcomes across the shareline"
- Imagine a bell curve and/or S-curve of cost (assume normal) superimposed on the ROS function
  - If you, like the author, have no imagination, we'll show it to you shortly!
- What happens when...
  - Estimate is aggressive?
    - Competitive (full-and-open) or negotiation (sole-source) pressure on Target Cost
    - Compensate by adding one standard deviation to Target Cost as risk
  - Estimate is padded?
    - Does this still happen?
    - Compensate by subtracting one standard deviation from Target Cost as opportunity
  - Variation is understated?
    - Cost Estimating Variability or risks/opportunities omitted
    - Compensate by doubling coefficient of variation (CV)
- We would like to observe the effect on the mean and key percentiles (20/50/80) of ROS
  - To do this, we need a method to determine the distribution of ROS (the main event)
  - In fact, we have two!

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S-Curves – The Shaping Forces

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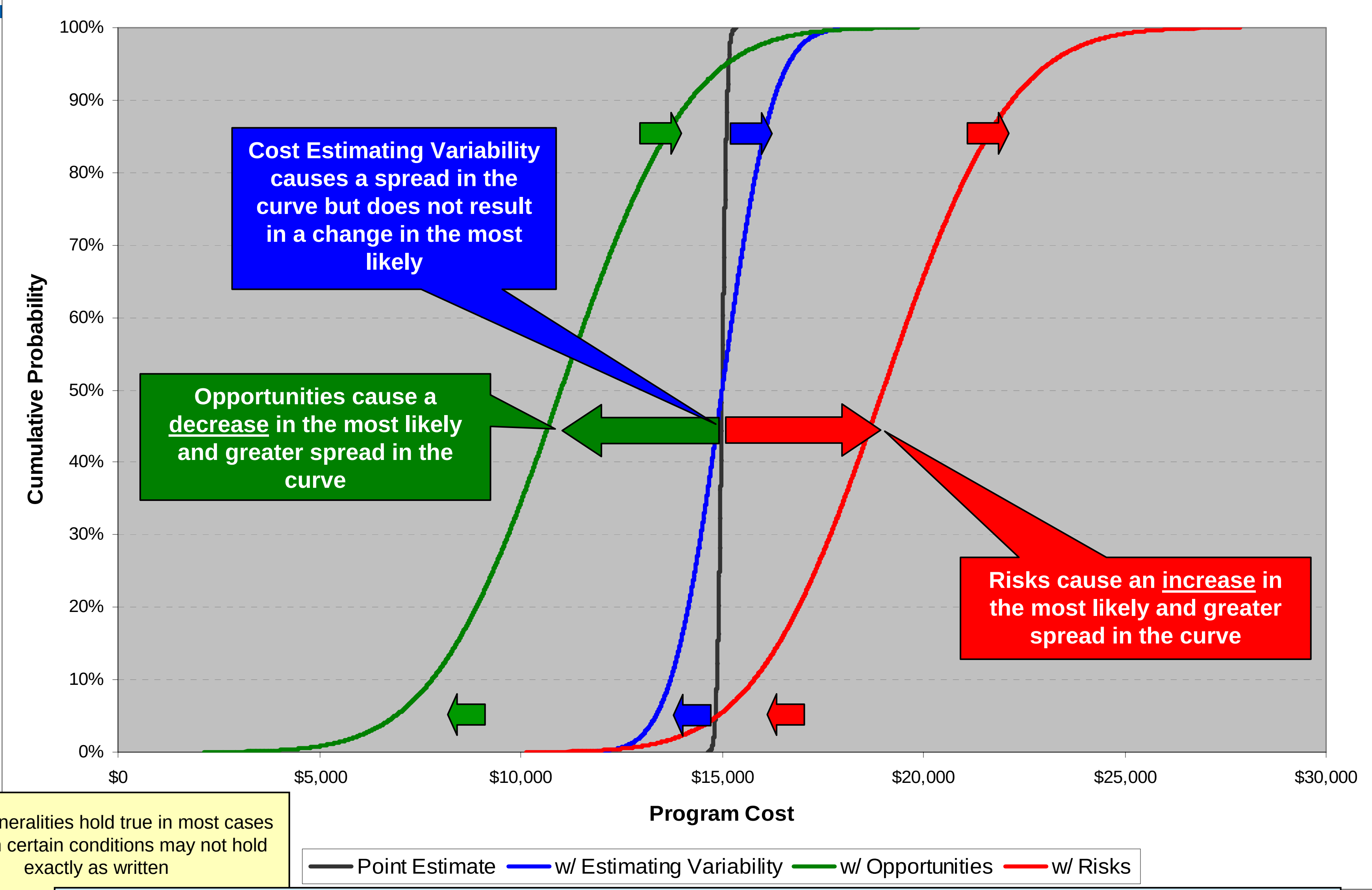

These generalities hold true in most cases but given certain conditions may not hold exactly as written

"S-Curves and Risk," Northrop Grumman Contracts, Pricing, and Supply Chain Conference, 2008.

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S-Curves – The Shaping Forces

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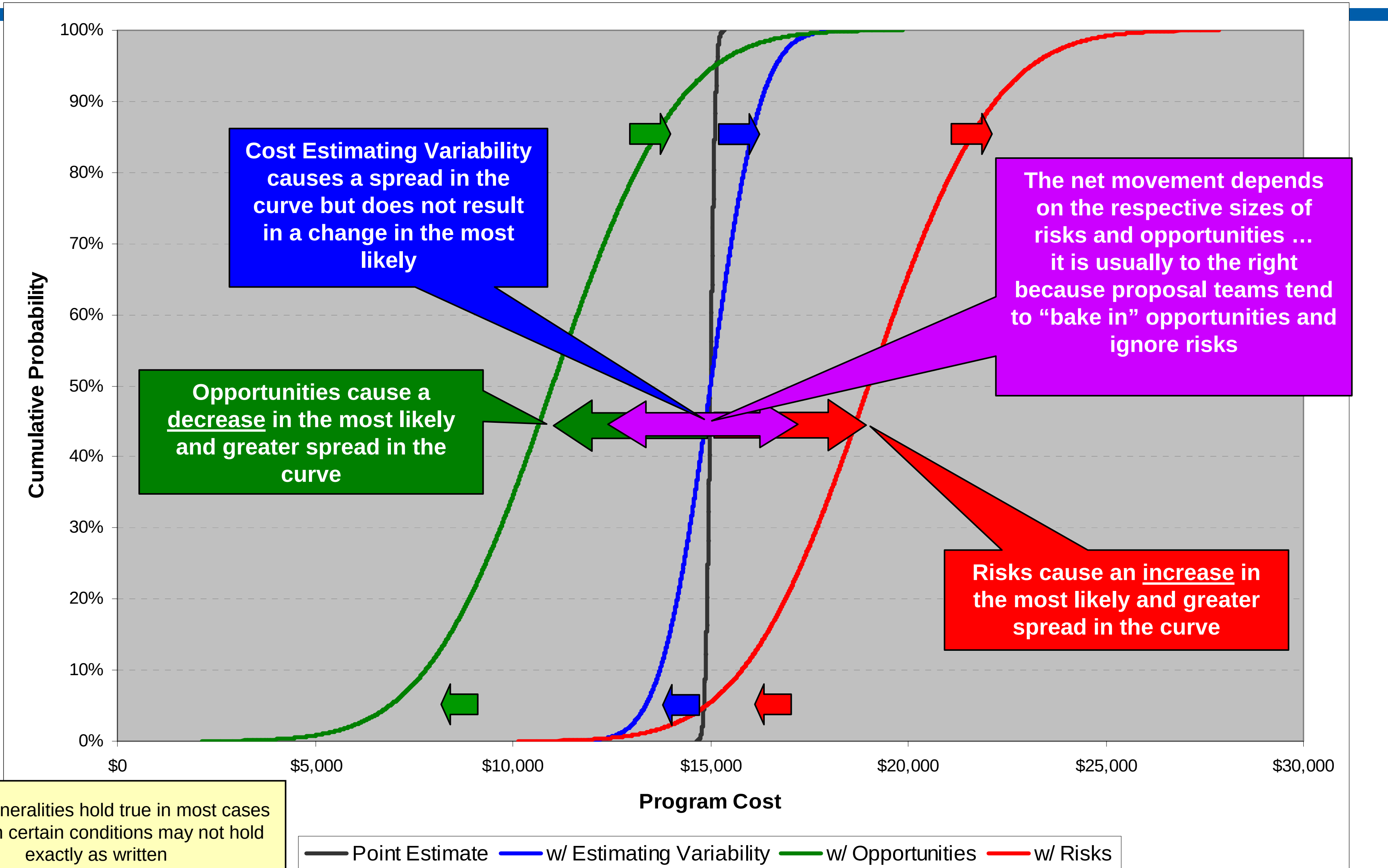

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Distribution of Cost and Functions of Cost

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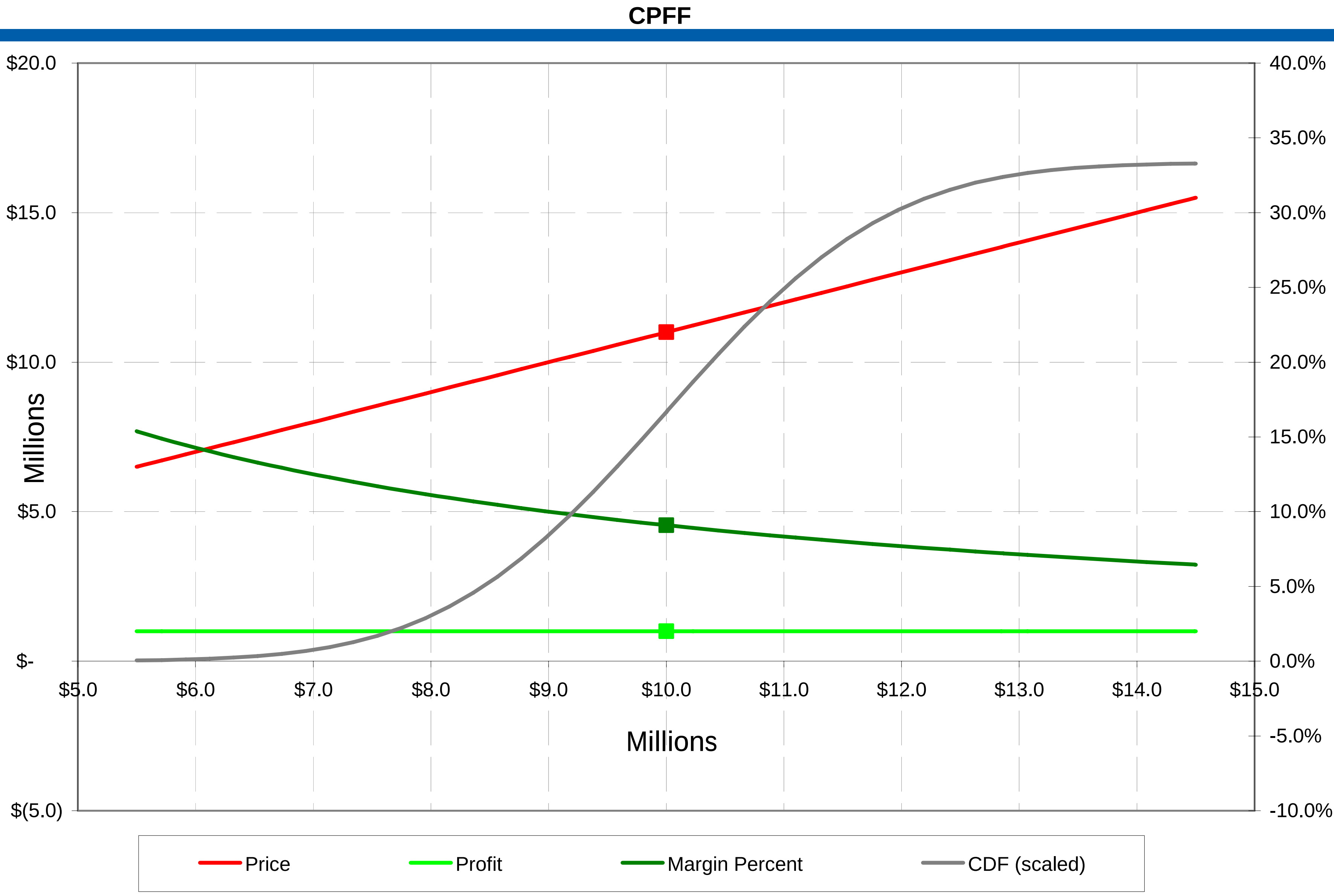

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Risk-Based ROS

- It’s the ROS, stupid!
  - Return On Sales (ROS) is single biggest motivating metric for contractors
- Bid ROS is a meaningless number
  - Like To-complete Cost Performance Index (TCPI) in EVM
- Percentiles (20/50/80) of ROS helpful for decision-making
  - Especially 80th for risk averse
- Mean ROS is best single metric for portfolio expectations
  - Ideally should be considered in conjunction with Cost for proper dollar-weighting
- We really want *distribution* of ROS
  - Enables us to calculate percentiles, means, and other statistics
  - Requires additional computational steps, but…
- The good news is:
  - No additional cost risk analysis is required
  - “Monte’s never busy”

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Warning: Math Ahead!

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- Why do the analytical method at all, when we can just Monte Carlo?
- Analytical method gives insight into "what is really going on"
  - Improved understanding by the analyst will help ensure proper use of automated tools
- Analytical method enables faster what-if analysis
  - Don't have to re-run the Monte Carlo every time you change parameters
- Analytical method is valuable cross-check for Monte Carlo
  - Caught input errors on two out of four Monte Carlo runs
    - Inadvertent reversal of Government/Contractor Share
    - Confusion between % and $ for Min and Max Fee
- It's like the joke about the dog...
  - Because we can!

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Distribution of ROS (Analytical)

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- Without Ts and Cs
- Transformation of random variables!
  - We math nerds always get excited about real-world applications of something we learned in school and thought we'd never use again!
- Define random variables:
  - X = Cost
  - Y = Profit (Fee) = f(X), where f is determined by contract type
    - Bright green line from earlier contract type graphs
    - Piecewise linear function for all major contract types (FFP/FPI/CPIF/CPFF)
    - Monotonically <u>non-increasing</u> function of Cost
      - In fact, monotonically decreasing except for CPFF
  - X+Y = Price
    - Monotonically <u>non-decreasing</u> function of Cost
      - In fact, monotonically increasing except for FFP
  - Z = ROS = Y/(X+Y) = 1 - X/(X+Y)
    - Monotonically <u>decreasing</u> function of Cost (for *all* contract types)

Distributions of Profit, Price, and ROS are continuous but not smooth at "break points"

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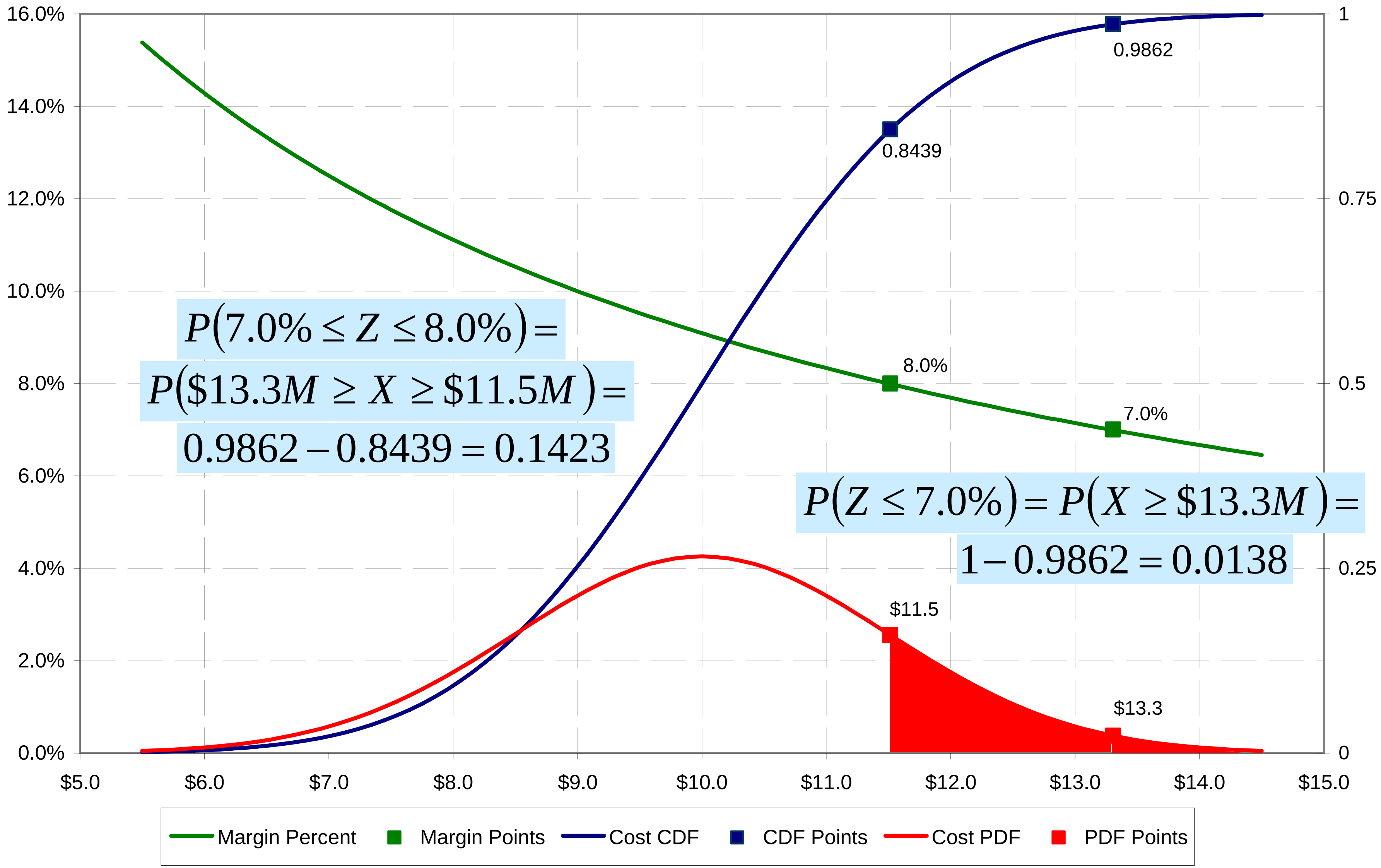
Distribution of ROS – Geometric Interpretation

CPFF



$$P(7.0\% \le Z \le 8.0\%) = P(\$13.3M \ge X \ge \$11.5M) = 0.9862 - 0.8439 = 0.1423$$

$$P(Z \le 7.0\%) = P(X \ge \$13.3M) = 1 - 0.9862 = 0.0138$$

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Distribution of ROS – The "Easy Way"

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- Using the Cumulative Distribution Function (CDF) and logic (outlined on the Eggspectation kiddie placemat in crayon!)

$$F_Z(z) = P(Z \le z) = P\left(\frac{Y}{X+Y} \le z\right) = P\left(1 - \frac{X}{X+f(x)} \le z\right) =$$

$$P\left(1 - z \le \frac{X}{X+f(X)}\right) = P\left(X + f(X) \le \frac{X}{1-z}\right) = \boxed{P\left(f(X) \le X\frac{z}{1-z}\right)} =$$

$$P(X \ge g(z)) = 1 - P(X \le g(z)) = 1 - F_X(g(z))$$

- The formula for g(z) depends on f(X) and hence contract type
  - Since f(X) is piecewise linear, there's always a simple solution
  - We'll enumerate the solutions for the four basic contract types
- The outlined step has interesting conceptual and geometric interpretations
  - Probability that Profit is less than profit percentage times cost! [slap forehead]
  - As z goes from 0 to 1, the line y = (z/(1-z))x traces out 90 degrees, starting from the x-axis and rotating counterclockwise to the y-axis
  - Intersects the decreasing Profit function further and further to the left
  - Hence captures a bigger and bigger chunk of the right part of the PDF of cost!

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Distribution of ROS – The "Hard Way"

- Using the Probability Density Function (PDF) and Jacobeans (!)
- Agrees with PDF derived from CDF from the "Easy Way"
  - Applying Chain Rule from calculus!

$$p_Z(z) = \frac{d}{dz} F_Z(z) = -F_X'(g(z)) \cdot g'(z) = -p_X(g(z)) \cdot g'(z)$$

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Distribution of Cost

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- Top-level cost distribution is usually modeled as Normal or Lognormal
  - Assume Normal with mean mu and standard deviation sigma
  - Use p(x) for PDF and F(x) for CDF
    - X subscript to distinguish from Z subscript later for ROS distribution

$$X \sim N(\mu, \sigma)$$

$$F_X(x) = \int_{-\infty}^{x} p_X(t)\,dt = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{(t-\mu)}{2\sigma^2}}\,dt = \Phi\left(\frac{x-\mu}{\sigma}\right)$$

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Distribution of ROS – CPFF (The "Easy" Case)

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- Fixed Fee amount = TF
  - Linear (constant) function

$$Y = f(x) = TF$$

$$Z = \frac{TF}{TF + X}$$

$$P\left(TF \leq \left(\frac{z}{1-z} \right) X \right) = P\left(X \geq \left(\frac{1-z}{z} \right) TF \right) = 1 - P\left(X \leq \left(\frac{1-z}{z} \right) TF \right)$$

$$F_Z(z) = 1 - F_X\left(\left(\frac{1-z}{z} \right) TF \right)$$

Take derivative, apply chain rule

$$p_Z(z) = \frac{TF}{z^2} p_X\left(\left(\frac{1-z}{z} \right) TF \right)$$

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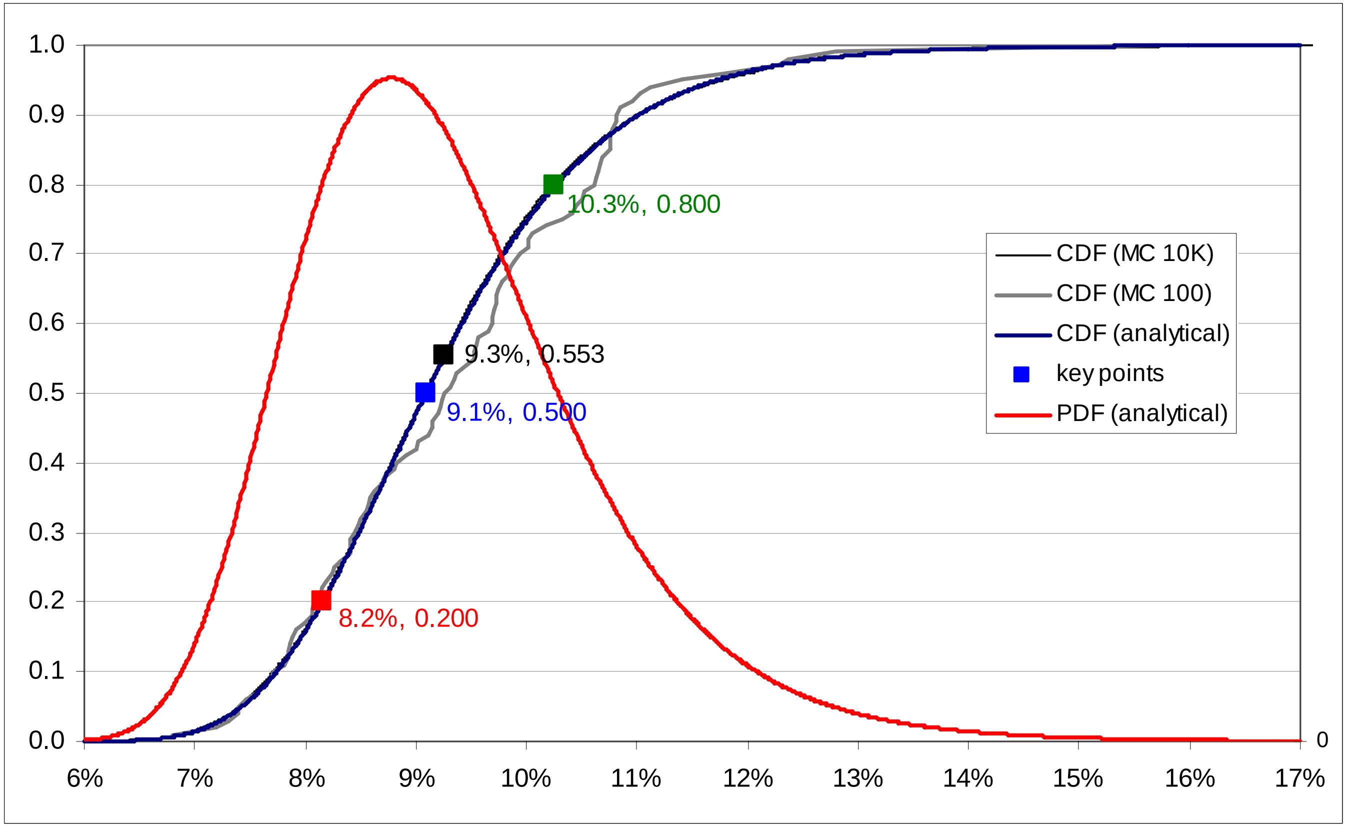
Distribution of ROS – CPFF (Toy Problem)

- Percentiles (20/50/80) and mean are shown on graph
  - Skew right: Mode < Median < Mean



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Distribution of ROS – FFP (Even Easier!)

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- FFP = Target Price = Target Cost + Target Profit
- Profit = FFP – Cost
- Linear function (slope of -1)

$$Y = f(x) = TP - X$$

$$Z = \frac{TP - X}{TP}$$

$$P\left(TP - X \leq X\frac{z}{1-z}\right) = P\left(X \geq TP(1-z)\right) = 1 - P\left(X \leq TP(1-z)\right)$$

Linear Combinations property: X is Normal implies Z is Normal

$$F_Z(z) = 1 - F_X\left(TP(1-z)\right)$$

Take derivative, apply chain rule

$$p_Z(z) = TP \cdot p_X\left(TP(1-z)\right)$$

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Distribution of ROS – FFP (Toy Problem)

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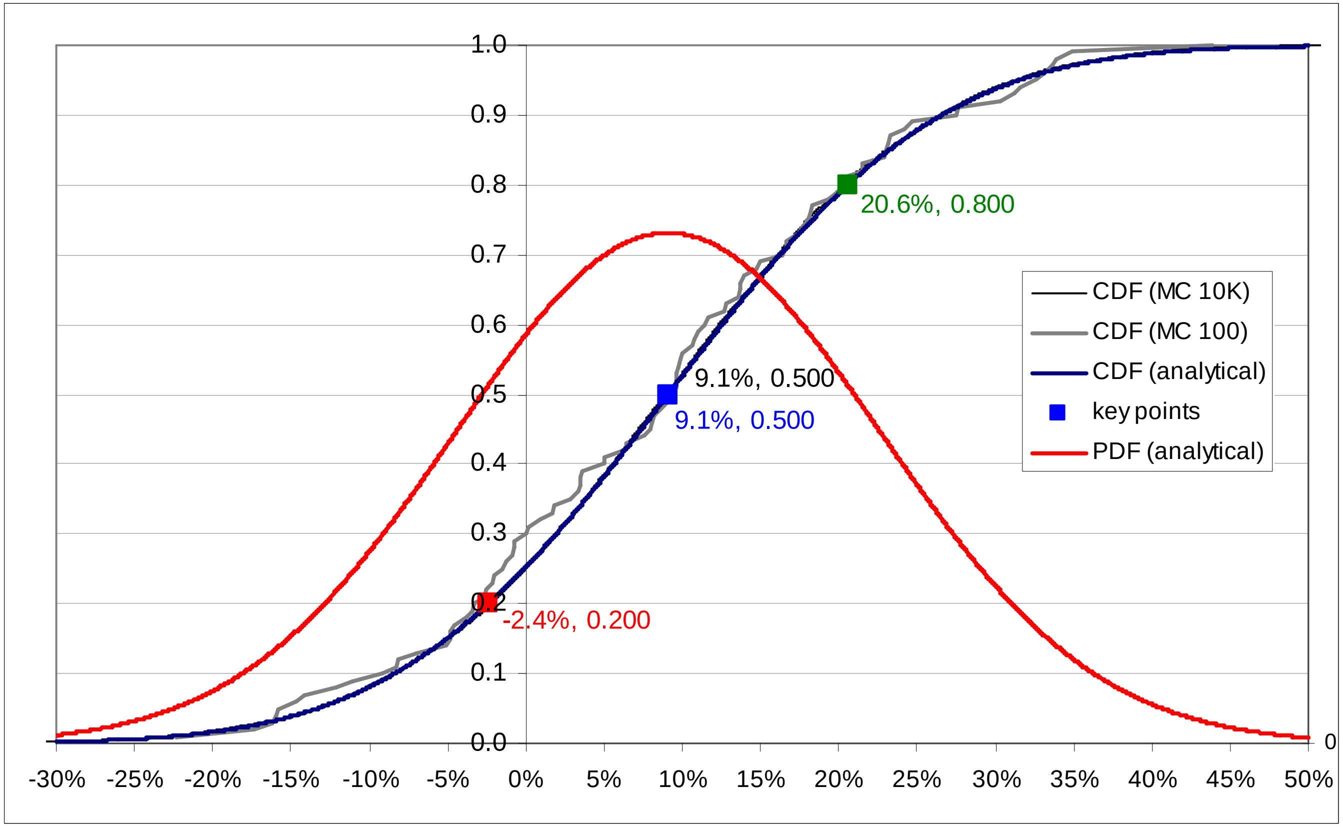
- Percentiles (20/50/80) and mean are shown on graph
  - Symmetric: Mode = Median = Mean



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Incentive Formula – FPI

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- Over-Target Shareline Adjustment until Point of Total Assumption (PTA)
  - Converts to FFP
- Under-Target Shareline Adjustment
- Piecewise linear function (three regimes)

$$Y = f(X) = \begin{cases} TF + CS_{under}(TC - X) & X \le TC \\ TF - CS_{over}(X - TC) & TC < X \le PTA \\ CP - X & X > PTA \end{cases}$$

$$X = TC \Leftrightarrow Z = \frac{TF}{TP}$$

$$X = PTA \Leftrightarrow Z = \frac{CP - PTA}{CP}$$

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Distribution of ROS – FPI

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$$P\left(\left(TF + CS_{under}\left(TC - X\right)\right) \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \frac{\left(TF + CS_{under}TC\right)\left(1-z\right)}{CS_{under} + GS_{under}z}\right)$$

$$P\left(\left(TF - CS_{over}\left(X - TC\right)\right) \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \frac{\left(TF + CS_{over}TC\right)\left(1-z\right)}{CS_{over} + GS_{over}z}\right)$$

$$P\left(CP - X \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \left(1-z\right)CP\right)$$

$$F_Z(z) = \begin{cases} 1 - F_X\left(\dfrac{\left(TF + CS_{under}TC\right)\left(1-z\right)}{CS_{under} + GS_{under}z}\right) & z \ge \dfrac{TF}{TP} \\ 1 - F_X\left(\dfrac{\left(TF + CS_{over}TC\right)\left(1-z\right)}{CS_{over} + GS_{over}z}\right) & \dfrac{CP - PTA}{CP} \le z < \dfrac{TF}{TP} \\ 1 - F_X\left(\left(1-z\right)CP\right) & z < \dfrac{CP - PTA}{CP} \end{cases}$$

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Distribution of ROS – FPI

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Take derivative, apply chain rule

$$p_Z(z)=\begin{cases}\left(\dfrac{TF+CS_{under}TC}{\left(CS_{under}+GS_{under}z\right)^2}\right)p_X\left(\dfrac{\left(TF+CS_{under}TC\right)\left(1-z\right)}{CS_{under}+GS_{under}z}\right) & z\geq\dfrac{TF}{TP}\\ \left(\dfrac{TF+CS_{over}TC}{\left(CS_{over}+GS_{over}z\right)^2}\right)p_X\left(\dfrac{\left(TF+CS_{over}TC\right)\left(1-z\right)}{CS_{over}+GS_{over}z}\right) & \dfrac{CP-PTA}{CP}\leq z<\dfrac{TF}{TP}\\ CP\cdot p_X\left(\left(1-z\right)CP\right) & z<\dfrac{CP-PTA}{CP}\end{cases}$$

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Distribution of ROS – FPI (Toy Problem)

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- Percentiles (20/50/80) and mean are shown on graph
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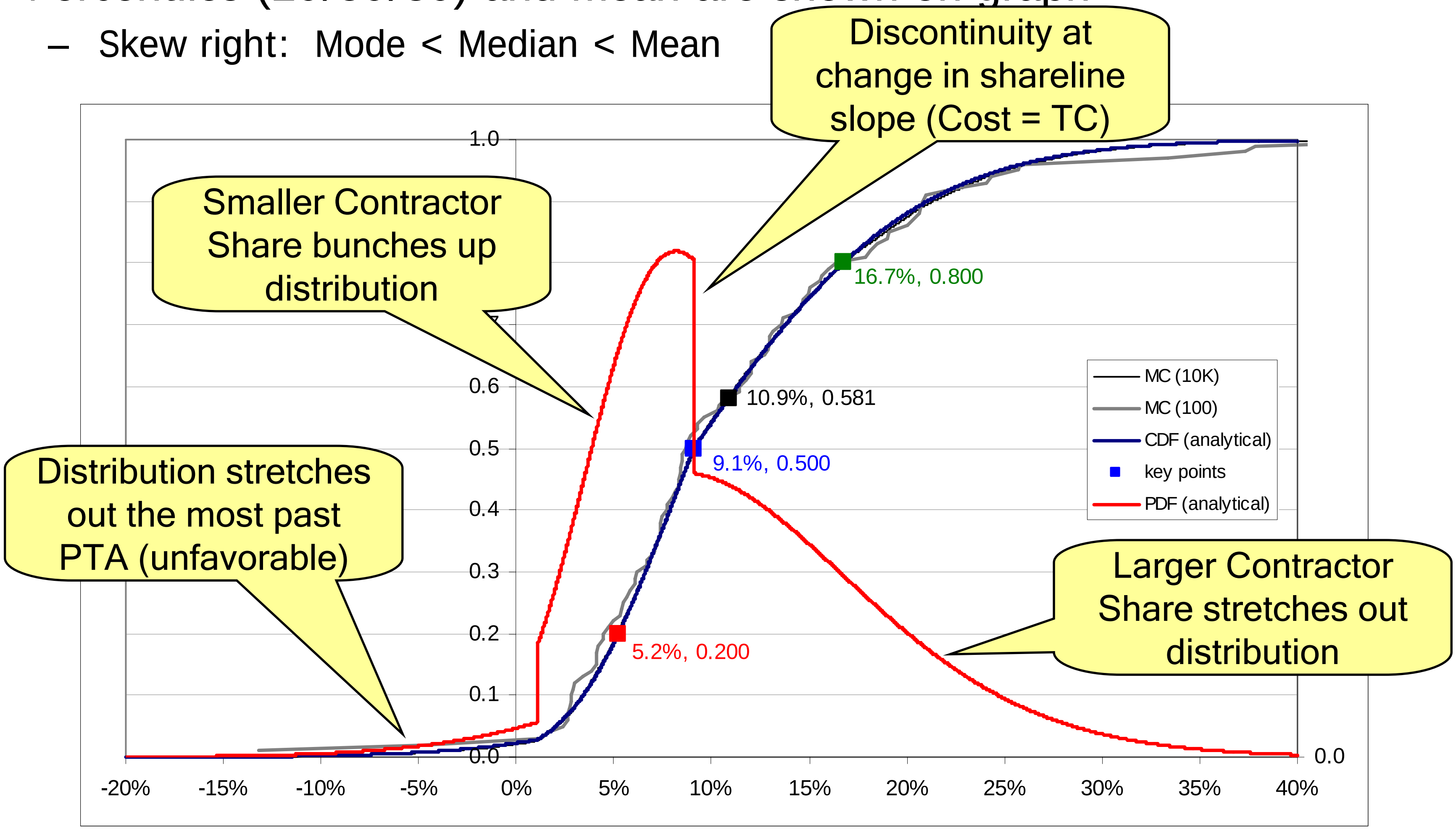

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Incentive Formula – CPIF

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- Over-Target Shareline Adjustment down to Min Fee
  - Converts to CPFF
- Under-Target Shareline Adjustment up to Max Fee
  - Converts to CPFF
- Piecewise linear function (four regimes)

$$Y = f(X) = \begin{cases} MF & X \le RIE_{low} \\ TF + CS_{under}(TC - X) & RIE_{low} < X \le TC \\ TF - CS_{over}(X - TC) & TC < X \le RIE_{high} \\ mF & X > RIE_{high} \end{cases}$$

$$X = RIE_{low} \Leftrightarrow Z = \frac{MF}{RIE_{low} + MF}$$

$$X = TC \Leftrightarrow Z = \frac{TF}{TP}$$

$$X = RIE_{high} \Leftrightarrow Z = \frac{mF}{RIE_{high} + mF}$$

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Distribution of ROS – CPIF

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$$P\left(MF \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \left(\frac{1-z}{z}\right)MF\right)$$

$$P\left(mF \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \left(\frac{1-z}{z}\right)mF\right)$$

$$P\left(\left(TF + CS_{under}(TC - X)\right) \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \frac{(TF + CS_{under}TC)(1-z)}{CS_{under} + GS_{under}z}\right)$$

$$P\left(\left(TF - CS_{over}(X - TC)\right) \le \left(\frac{z}{1-z}\right)X\right) = 1 - P\left(X \le \frac{(TF + CS_{over}TC)(1-z)}{CS_{over} + GS_{over}z}\right)$$

$$F_Z(z) = \begin{cases} 1 - F_X\left(\left(\frac{1-z}{z}\right)MF\right) & z \ge \frac{MF}{RIE_{low} + MF} \\ 1 - F_X\left(\frac{(TF + CS_{under}TC)(1-z)}{CS_{under} + GS_{under}z}\right) & \frac{TF}{TP} \le z < \frac{MF}{RIE_{low} + MF} \\ 1 - F_X\left(\frac{(TF + CS_{over}TC)(1-z)}{CS_{over} + GS_{over}z}\right) & \frac{mF}{RIE_{high} + mF} \le z < \frac{TF}{TP} \\ 1 - F_X\left(\left(\frac{1-z}{z}\right)mF\right) & z < \frac{mF}{RIE_{high} + mF} \end{cases}$$

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Distribution of ROS – CPIF

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Take derivative, apply chain rule

$$p_Z(z)=\begin{cases}\dfrac{MF}{z^2}\,p_X\left(\left(\dfrac{1-z}{z}\right)MF\right) & z\geq\dfrac{MF}{RIE_{low}+MF}\\ \left(\dfrac{TF+CS_{under}TC}{\left(CS_{under}+GS_{under}z\right)^2}\right)p_X\left(\dfrac{\left(TF+CS_{under}TC\right)(1-z)}{CS_{under}+GS_{under}z}\right) & \dfrac{TF}{TP}\leq z<\dfrac{MF}{RIE_{low}+MF}\\ \left(\dfrac{TF+CS_{over}TC}{\left(CS_{over}+GS_{over}z\right)^2}\right)p_X\left(\dfrac{\left(TF+CS_{over}TC\right)(1-z)}{CS_{over}+GS_{over}z}\right) & \dfrac{mF}{RIE_{high}+mF}\leq z<\dfrac{TF}{TP}\\ \dfrac{mF}{z^2}\,p_X\left(\left(\dfrac{1-z}{z}\right)mF\right) & z<\dfrac{mF}{RIE_{high}+mF}\end{cases}$$

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Distribution of ROS – CPIF (Toy Problem)

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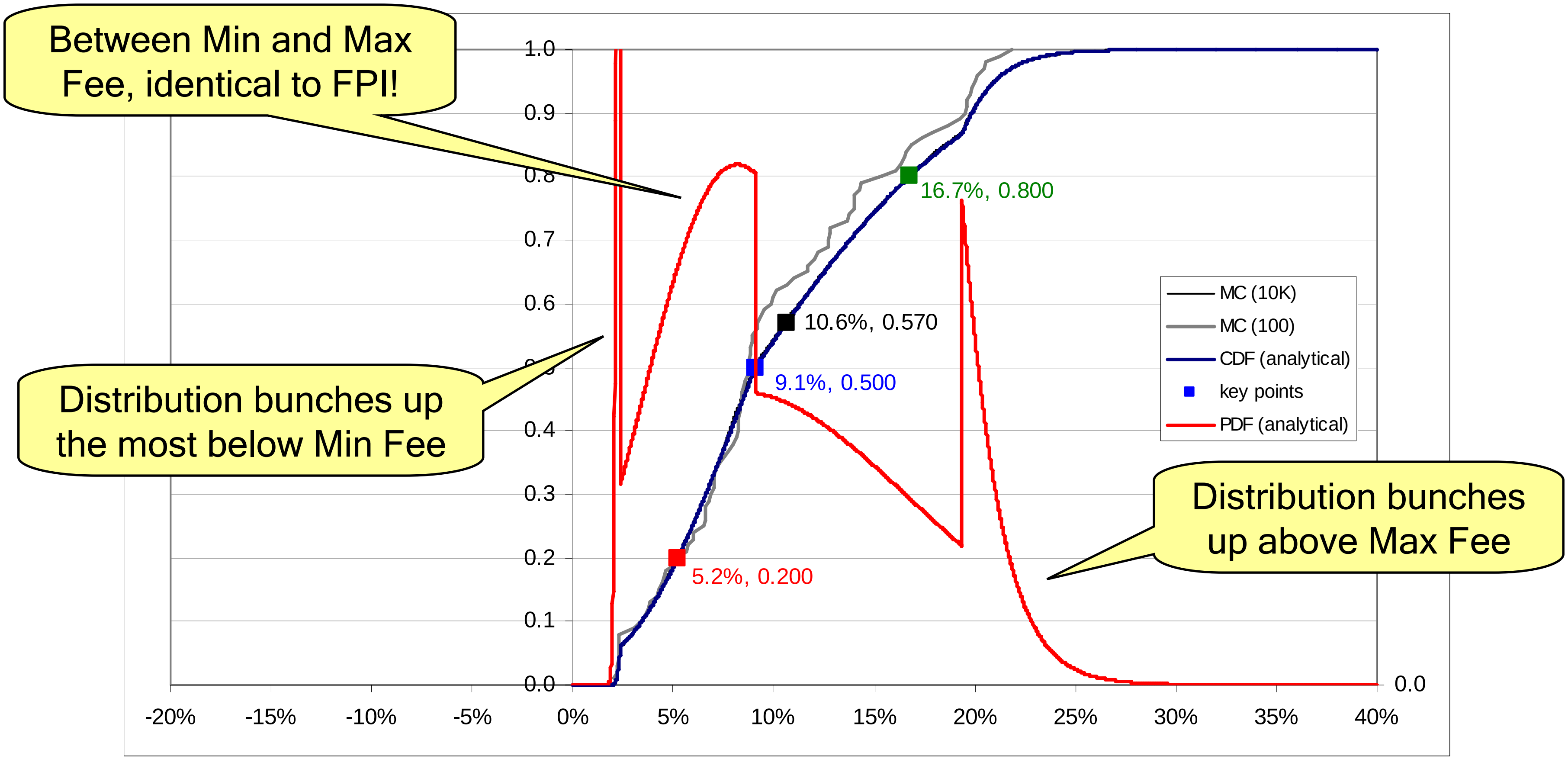
- Percentiles (20/50/80) and mean are shown on graph
  - Skew right: Mode < Median < Mean



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Distribution of ROS (Empirical)

- Without Ts & Cs
- Monte Carlo simulation results agree with analytical results!
  - Even at 100 trials (gray squiggle on graphs), close alignment with true ROS distribution
  - At 10,000 trials (thin black curve), agreement is much more precise
  - May be slight discrepancies in means due to extreme values
    - Limitation of spreadsheet calculations for analytical case

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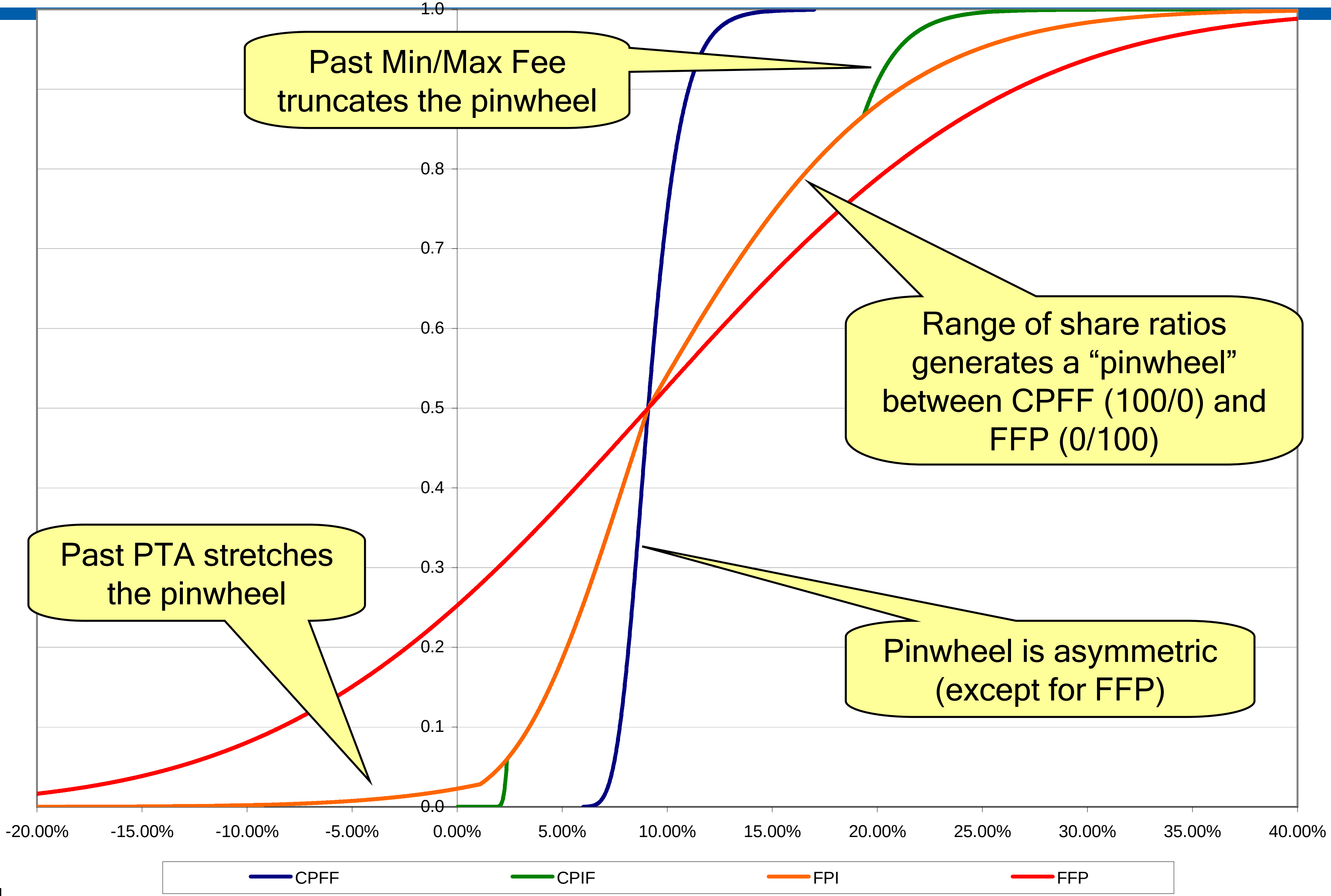
Distribution of ROS –Toy Problem Comparison



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Distribution of ROS – Pathological Cases

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- Comparison graphs for cases:
  - Base case: As previously shown
  - Aggressive cost: True base cost is $11.5M instead of $10.0M
  - Padded cost: True base cost is $8.5M instead of $10.0M
  - Understated variability: True standard deviation is $3.0M instead of $1.5M
- Summary table across all contract types:

MONTE CARLO	Base case ($10M)				Padded cost ($8.5M)				Aggressive cost ($11.5M)				Understated variability			
	FFP	FPI	CPIF	CPFF	FFP	FPI	CPIF	CPFF	FFP	FPI	CPIF	CPFF	FFP	FPI	CPIF	CPFF
20th percentile	-2.2%	5.1%	5.2%	8.1%	11.4%	10.5%	10.3%	9.3%	-16.0%	1.3%	2.3%	7.3%	-13.6%	2.0%	2.4%	7.4%
median (50th percentile)	8.9%	9.1%	9.0%	9.1%	22.9%	18.2%	18.2%	10.5%	-4.6%	4.6%	4.6%	8.0%	9.4%	9.1%	9.6%	9.1%
mean	9.0%	11.0%	10.6%	9.3%	22.8%	19.1%	16.6%	10.8%	-4.5%	4.4%	5.8%	8.1%	9.3%	12.5%	12.5%	7.5%
80th percentile	20.3%	16.8%	16.7%	10.2%	34.2%	26.9%	21.6%	12.1%	6.9%	8.4%	8.3%	8.9%	32.0%	25.4%	21.2%	11.9%

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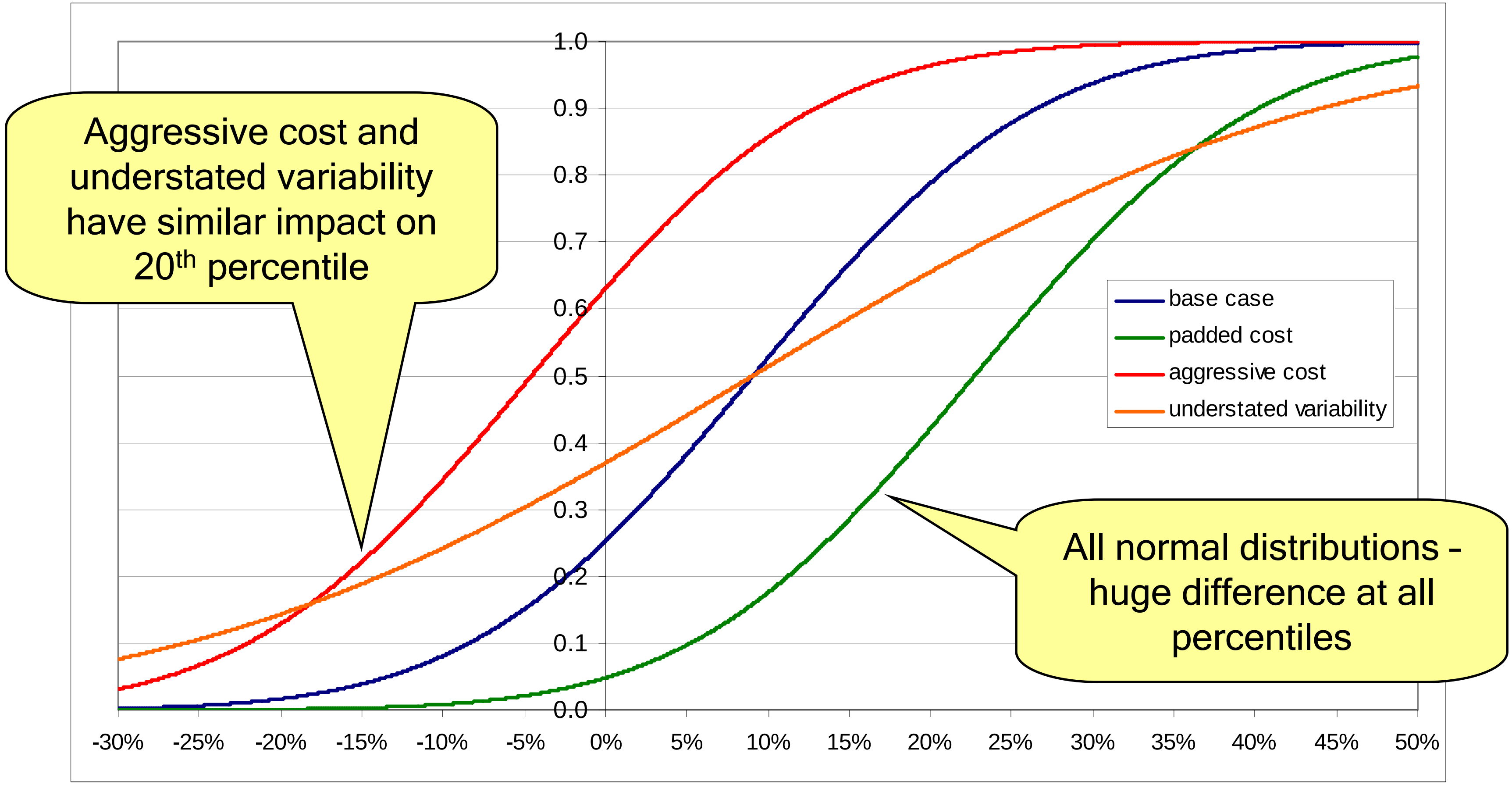
FFP – Pathological Cases



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FPI – Pathological Cases

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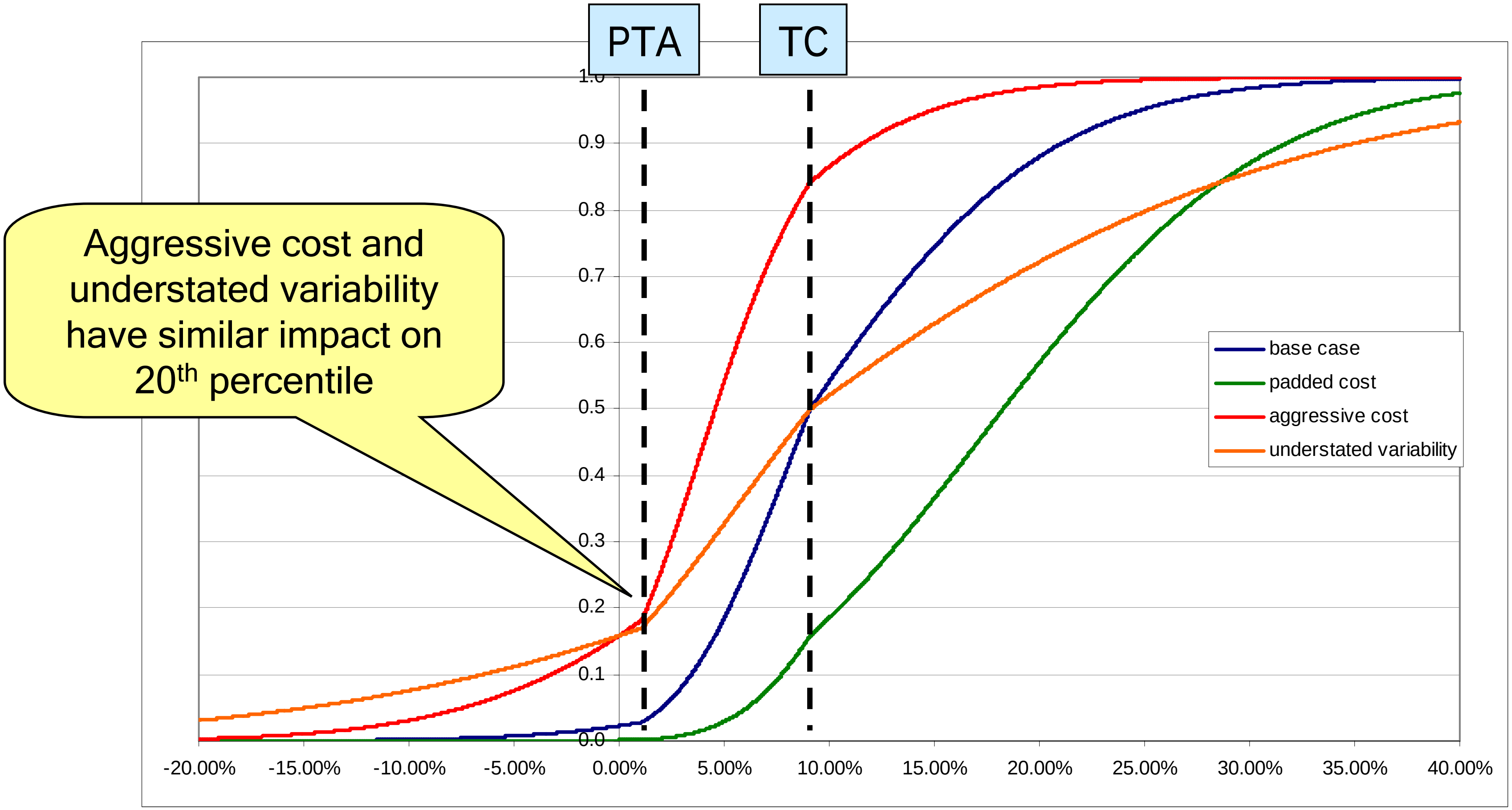

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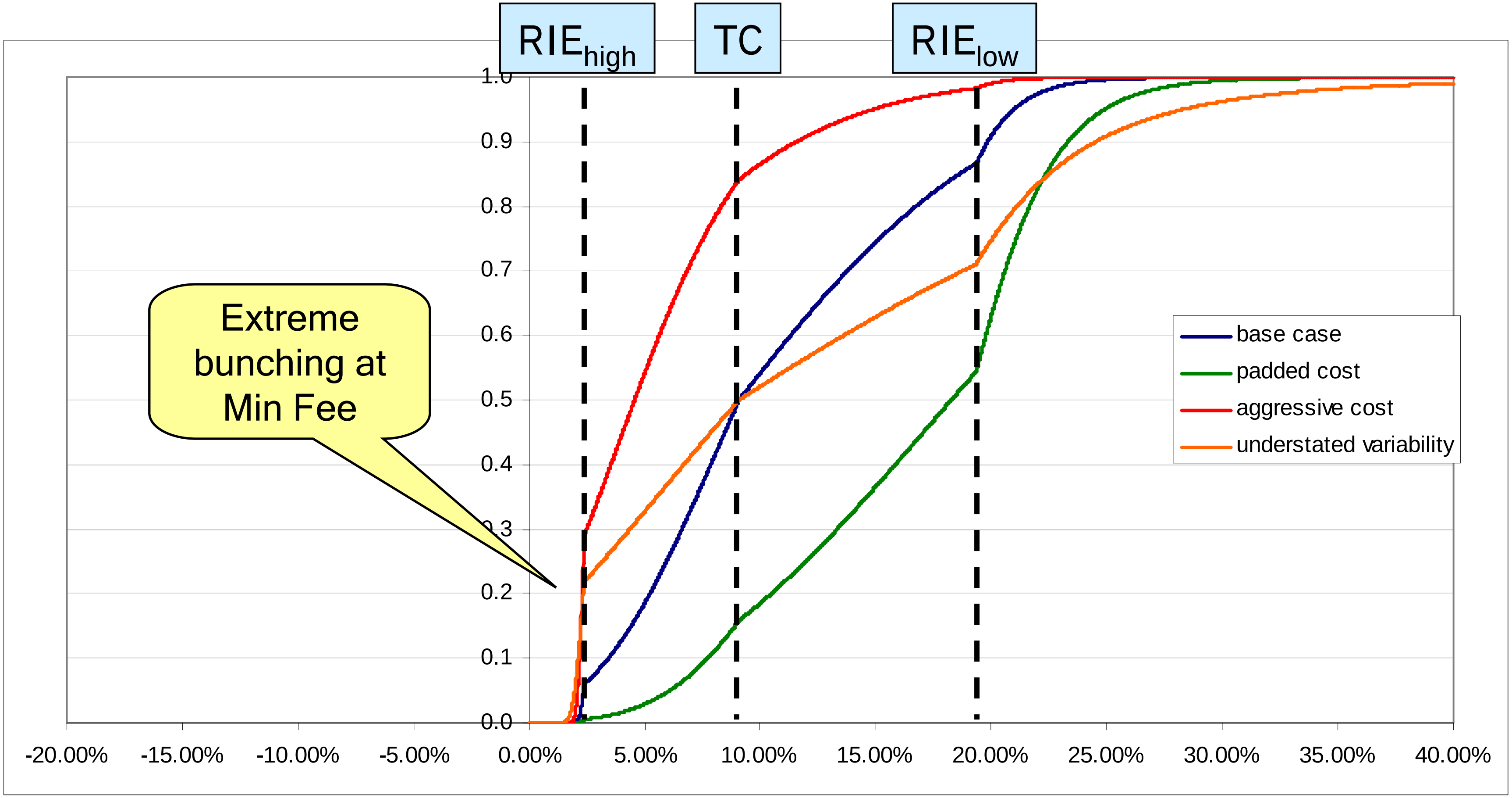
CPIF – Pathological Cases



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CPFF – Pathological Cases

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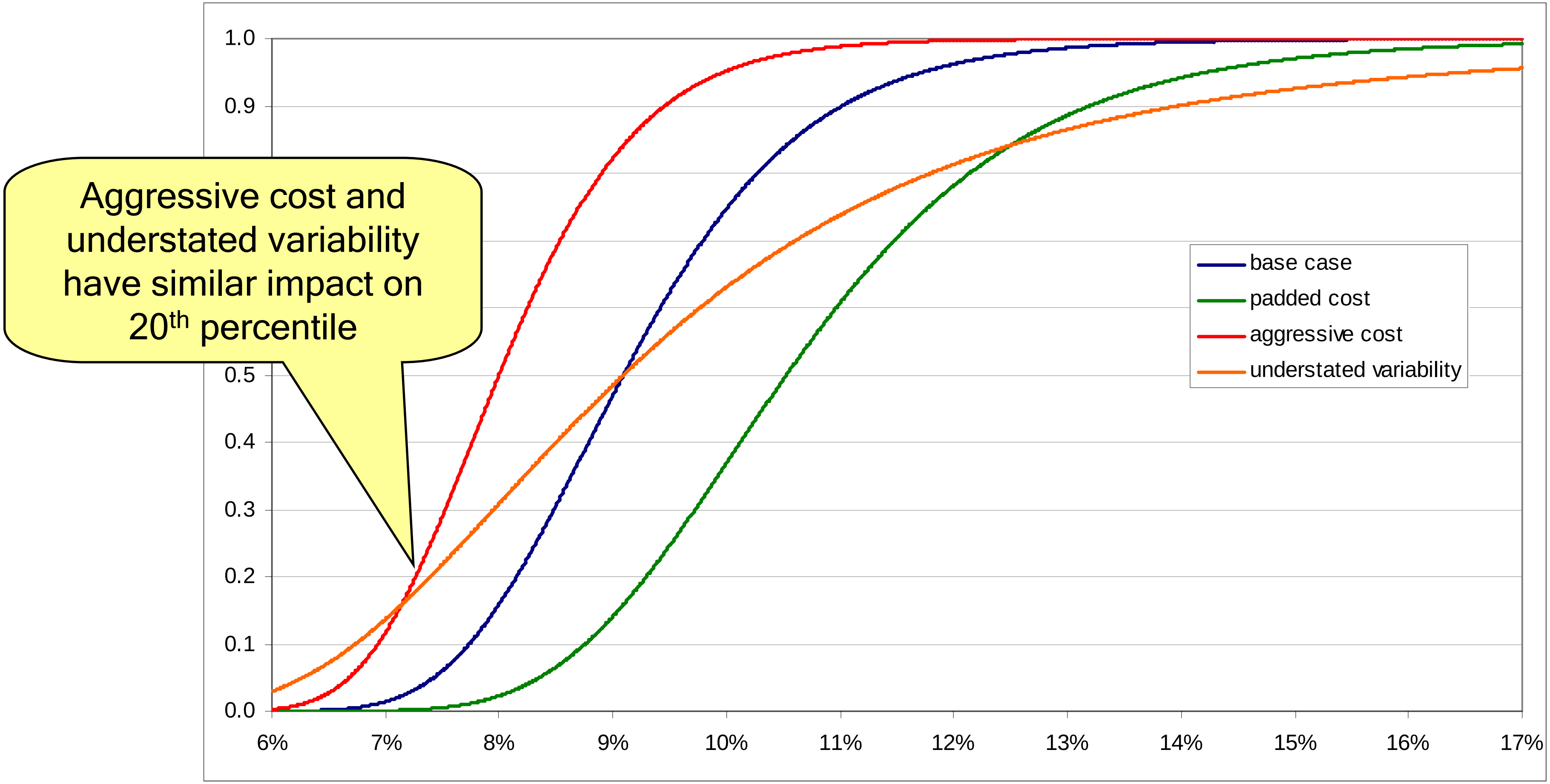

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Terms and Conditions (Ts & Cs)

- Oftentimes, expected cost growth is simply applied to the fee structure being proposed for the program
  - However, it is important to consider any terms and conditions (Ts & Cs) of the contract that may mitigate cost growth
- Although cost growth may be likely to occur, margin impacts may be mitigated through T&Cs
  - Cost Growth does not always equal Margin Loss
- Examples include:
  - Late delivery of GFE that causes cost and schedule growth
  - Catastrophic Escalation
  - Changes in threat or requirements
- It is sometimes possible to isolate uncertainty and cost growth attributable to these risks and model their margin impacts appropriately

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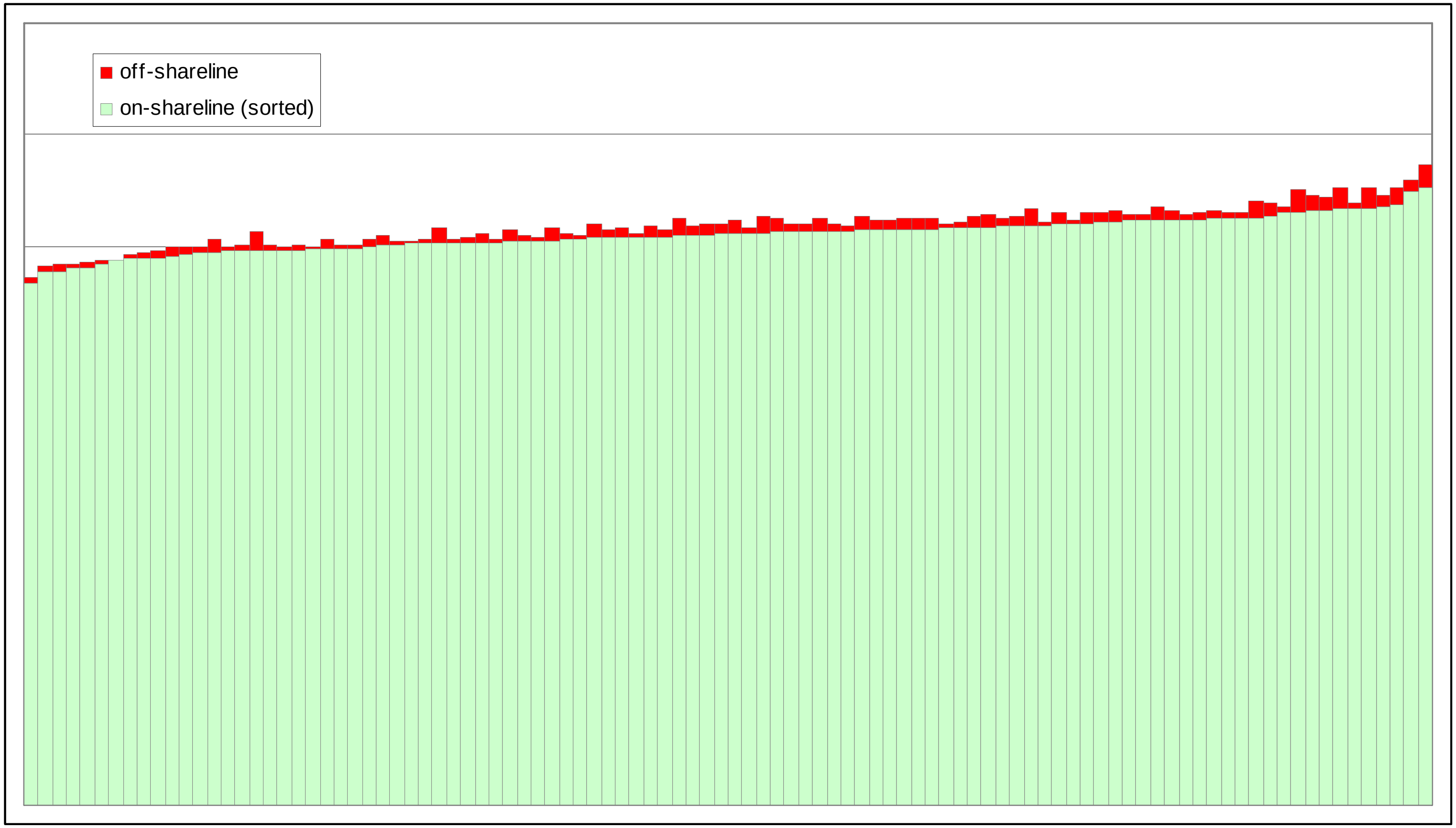
Ts and Cs Impact on the S-Curve

- When you sort by on-the-shareline cost (green bars), off-the-shareline cost (red bars) and total cost are not in order
  - Unless there is perfect correlation
  - Different trials from the Monte Carlo produce the percentiles of interest for different quantities



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Distribution of ROS with Ts & Cs

- Monte Carlo simulation example with Ts & Cs
  - Base contract with symmetric cost uncertainty
  - Single risk mitigated off the shareline with no fee
  - Scenario 1 (easier): FFP base with normal risk
  - Scenario 2 (harder): FPI base with triangular risk
- Case 1: independent risks (e.g., escalation completely mitigated)
  - Thumbnail sketch of analytic approach, turns into a 2-variable integral!
  - Pairings of on-shareline and off-shareline costs that produce a given ROS
- Case 2: correlated risks (e.g., escalation partially mitigated)
  - Too hard, and Monte's never busy!
- How to put your point in the cross-hairs
  - Pull 80th percentile Cost and 20th percentile ROS from the Monte Carlo
  - Compute ROS at 80th percentile Cost
  - Add off-shareline cost needed to lower ROS to 20th percentile ROS

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Scenario 1: Two S-Curves for Cost

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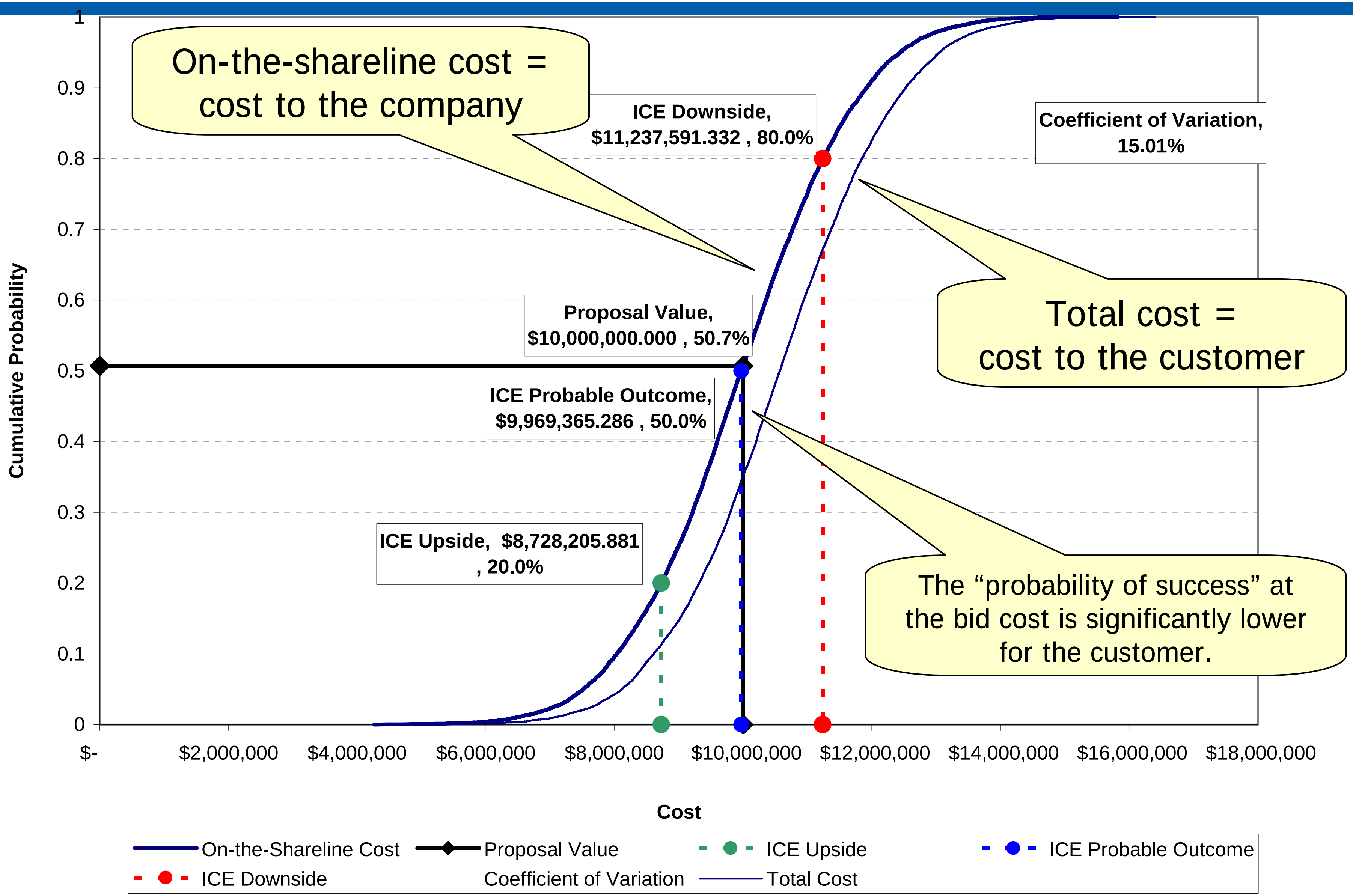

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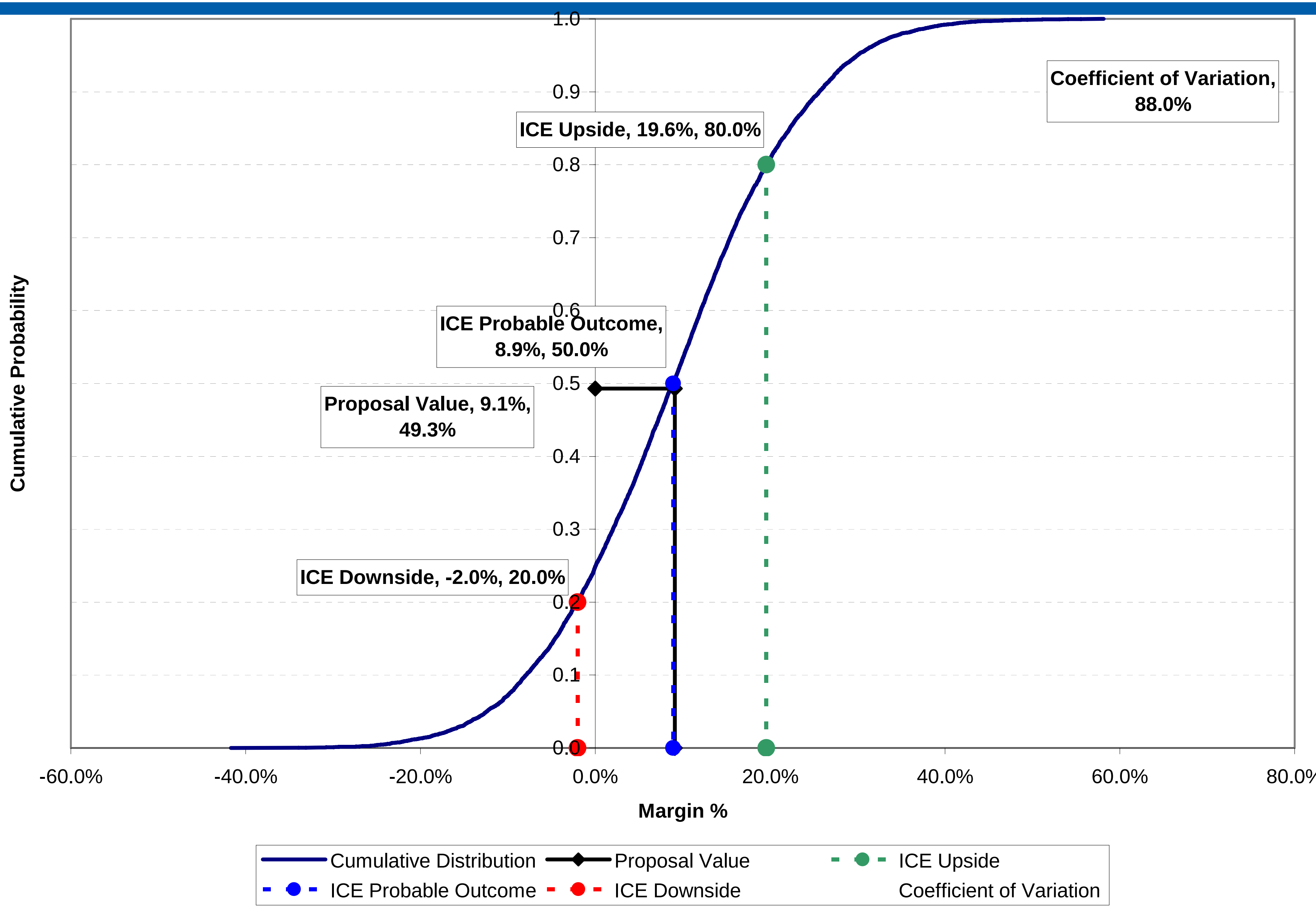
Scenario 1: S-Curve for ROS



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Scenario 1: ROS vs. (On-the-Shareline) Cost

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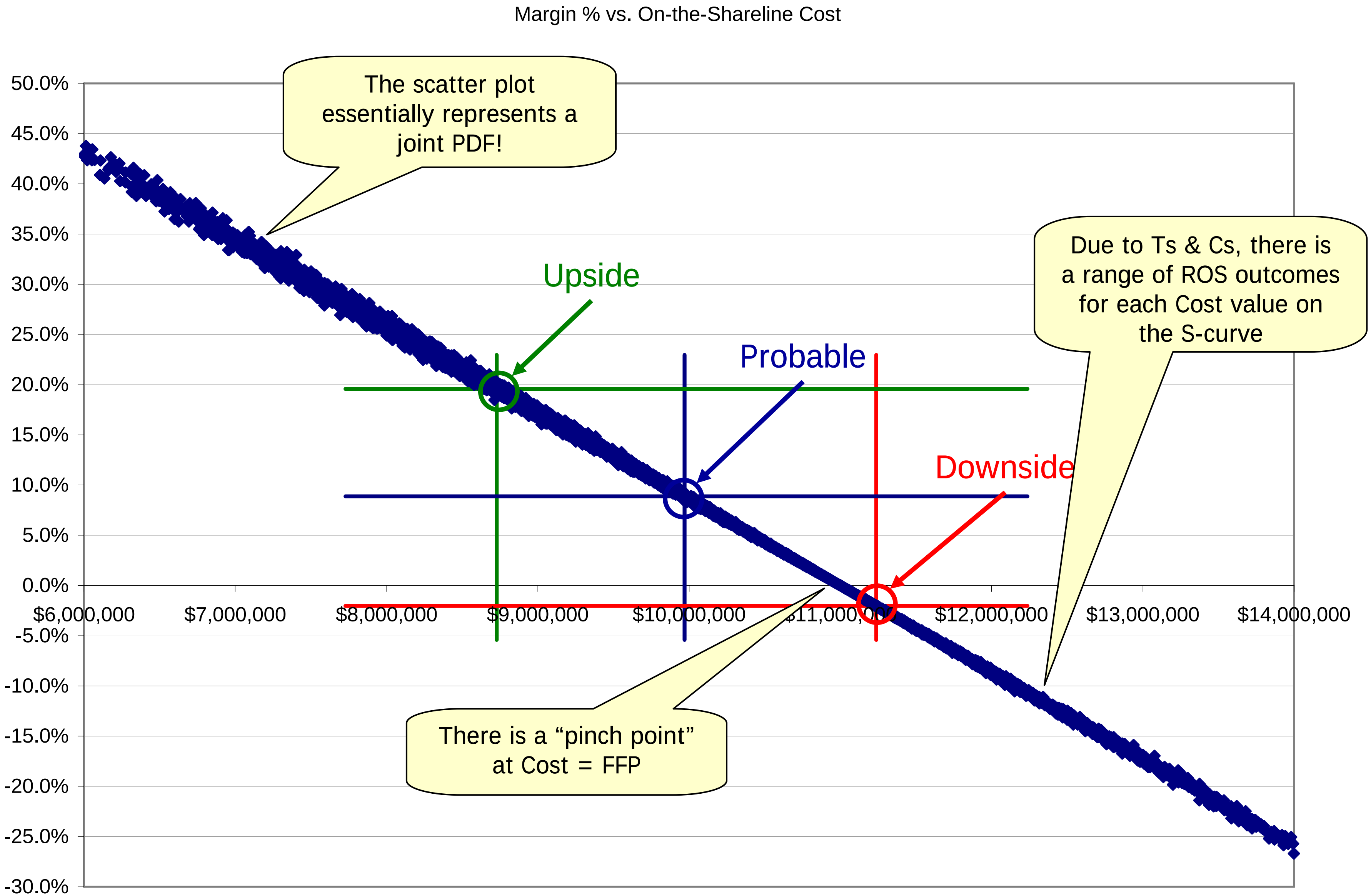

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Closing Thoughts

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- Presence of mitigating Ts & Cs destroys the one-to-one correspondence of cost and ROS
  - You want the 20th percentile ROS, not the ROS at the 80th percentile of cost!
- We recommend looking at the distribution of ROS
  - Monte Carlo should generally suffice
- As with Earned Value Management (EVM), Contracts would benefit from application of quantitative techniques and data analysis from Cost
  - More thoughtful and appropriate implementation of contact types to the mutual benefit of government and contractor
  - Too many *apparent* “levers” cloud the fact that there are very few *real* levers
- Next steps:
  - Risk-based modeling of Cost and ROS at a portfolio level
  - More thorough development of analytical cases (for “fun”)
  - Universal Contract Type! (see coda)

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Coda: Universal Contract Type

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- Minimal Specifications:
  - Target Cost and Target Profit (Fee) (which together determine Target Price)
  - Optimistic and Pessimistic Costs
  - Shareline in each of four regimes

$$FFP = \left(TC, TF, TC - \xi, TC + \xi, \frac{0}{100}, \frac{0}{100}, \frac{0}{100}, \frac{0}{100} \right)$$

$$FPI = \left(TC, TF, TC - \xi, PTA, \frac{GS_{under}}{CS_{under}}, \frac{GS_{under}}{CS_{under}}, \frac{GS_{over}}{CS_{over}}, \frac{0}{100} \right)$$

$$CPIF = \left(TC, TF, RIE_{low}, RIE_{high}, \frac{100}{0}, \frac{GS_{under}}{CS_{under}}, \frac{GS_{over}}{CS_{over}}, \frac{100}{0} \right)$$

$$CPFF = \left(TC, TF, TC - \xi, TC + \xi, \frac{100}{0}, \frac{100}{0}, \frac{100}{0}, \frac{100}{0} \right)$$

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Cadenza: The Proverbial Cocktail Napkin