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More Trouble With Estimating at the 80th Percentile

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Presented by

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Previously On "80"…

- "The Trouble With Budgeting to the 80th Percentile"
  - A presentation by T.P. Anderson to the Military Operations Research Society (MORS) in 2004
    - Discussed the consequences of budgeting each program in a portfolio of programs to the 80th percentile
    - Found that if individual programs were budgeted at the 80th percentile, then the portfolio of programs was budgeted at a much higher percentile – 95th percentile or more!
    - Suggested that budgeting individual programs at a lower percentile – 55th to 65th – would result in portfolios being budgeted to near the 80th percentile
  - The benefit would be portfolio budgets with a high degree of confidence while enabling decision makers to budget individual programs at a lower level

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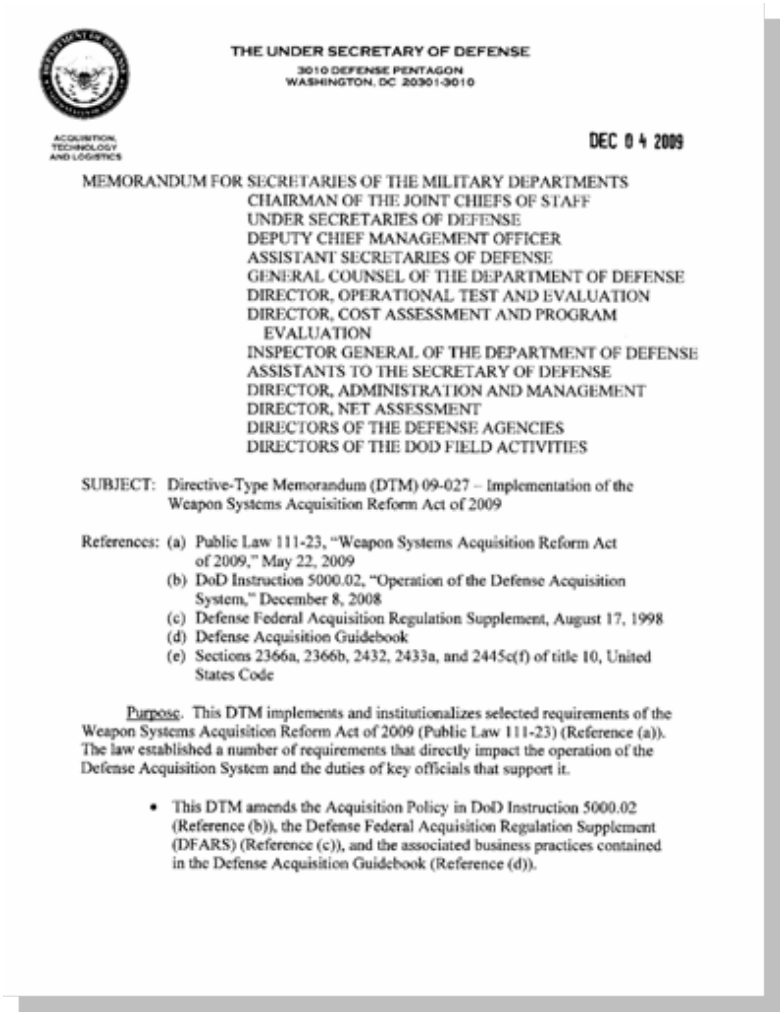
In This Week's Episode…

- New guidance from Congress and USD(AT&L)
  - Implementation of "*Weapon Systems Acquisition Reform Act (WSARA) of 2009*" – Public Law 111-23
  - Among other issues, ***suggests*** establishing the cost estimate at no less than the 80 percent confidence level

"…state the confidence level used in establishing the cost estimate…the rationale…and, if the confidence level is less than 80 percent, the justification for selecting the lower confidence level."



THE UNDER SECRETARY OF DEFENSE
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WASHINGTON, DC 20301-3010

ACQUISITION, TECHNOLOGY AND LOGISTICS

DEC 04 2009

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
DEPUTY CHIEF MANAGEMENT OFFICER
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
DIRECTOR, COST ASSESSMENT AND PROGRAM EVALUATION
INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE
ASSISTANTS TO THE SECRETARY OF DEFENSE
DIRECTOR, ADMINISTRATION AND MANAGEMENT
DIRECTOR, NET ASSESSMENT
DIRECTORS OF THE DEFENSE AGENCIES
DIRECTORS OF THE DOD FIELD ACTIVITIES

SUBJECT: Directive-Type Memorandum (DTM) 09-027 – Implementation of the Weapon Systems Acquisition Reform Act of 2009

References: (a) Public Law 111-23, "Weapon Systems Acquisition Reform Act of 2009," May 22, 2009
(b) DoD Instruction 5000.02, "Operation of the Defense Acquisition System," December 8, 2008
(c) Defense Federal Acquisition Regulation Supplement, August 17, 1998
(d) Defense Acquisition Guidebook
(e) Sections 2366a, 2366b, 2432, 2433a, and 2445c(f) of title 10, United States Code

Purpose. This DTM implements and institutionalizes selected requirements of the Weapon Systems Acquisition Reform Act of 2009 (Public Law 111-23) (Reference (a)). The law established a number of requirements that directly impact the operation of the Defense Acquisition System and the duties of key officials that support it.

- This DTM amends the Acquisition Policy in DoD Instruction 5000.02 (Reference (b)), the Defense Federal Acquisition Regulation Supplement (DFARS) (Reference (c)), and the associated business practices contained in the Defense Acquisition Guidebook (Reference (d)).

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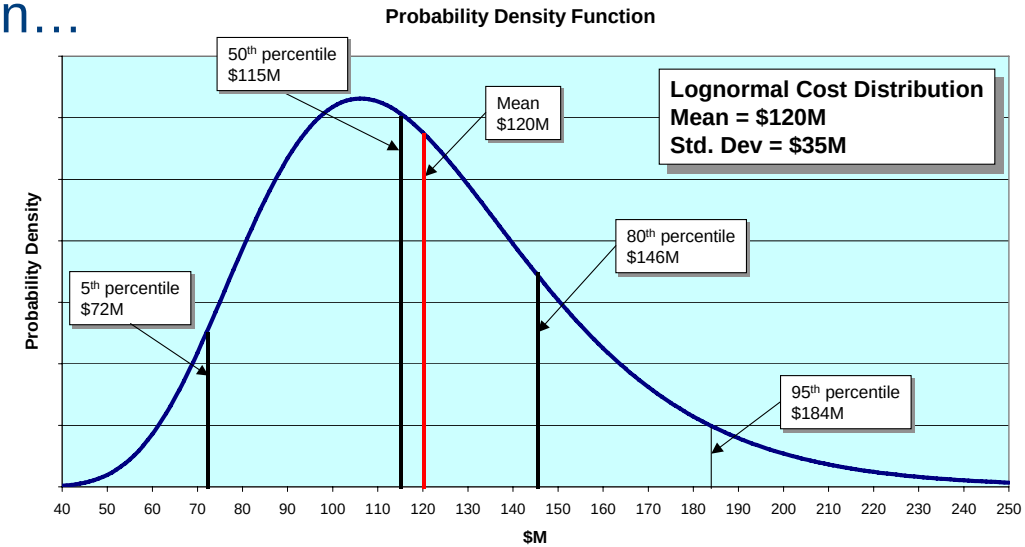
The Cost Probability Distribution

- So, you've established a cost estimate with a cost probability distribution…



- Now you have to decide what to report as "the estimate"
- *Weapon Systems Acquisition Reform Act of 2009* suggests reporting the 80th percentile of the cost distribution as "the estimate"
- Will this reduce the likelihood of a future cost overrun?

Probably Not!

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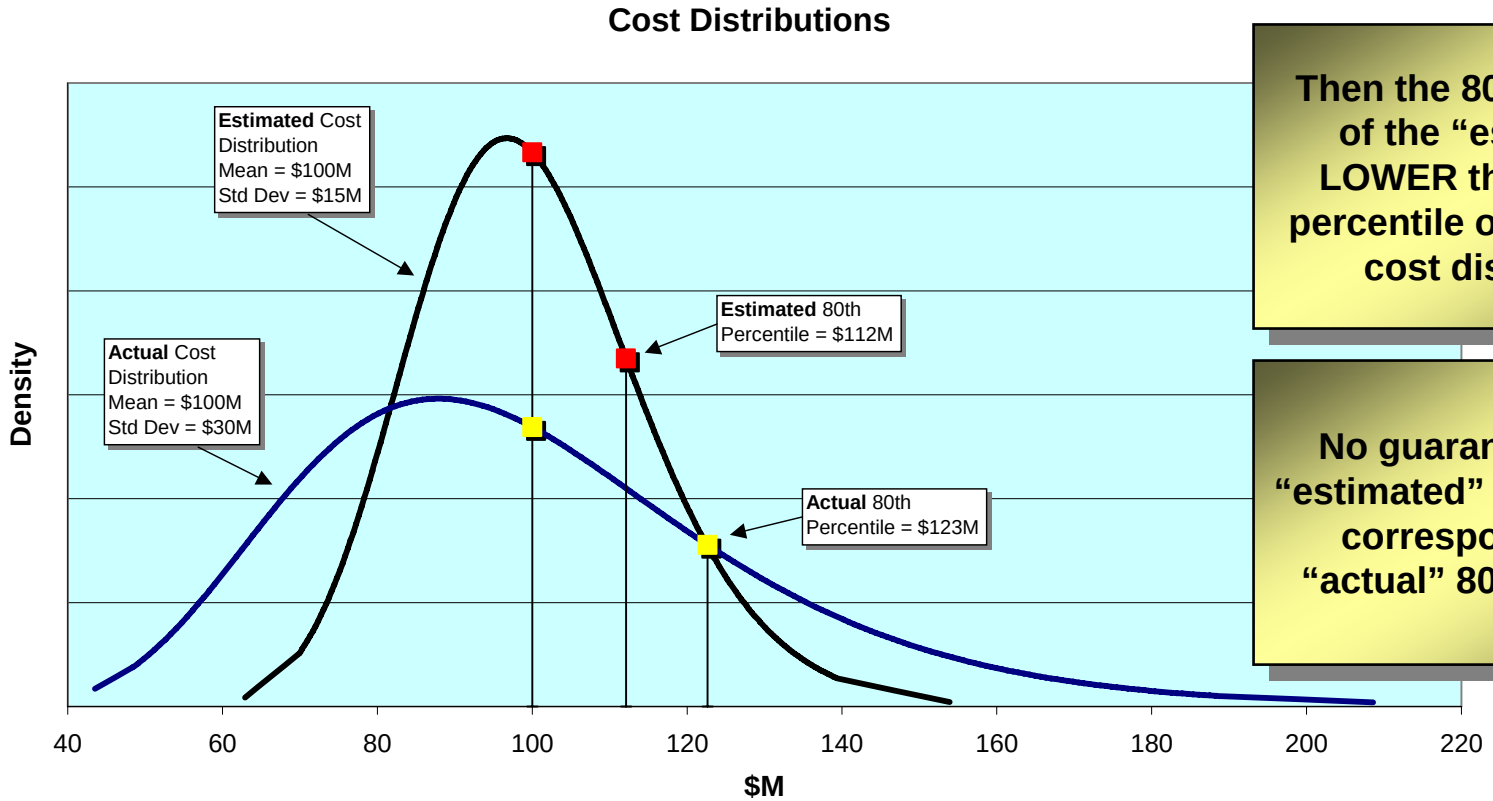
Why Not? There is a Problem

- At best, the cost distribution is an *educated guess* based on *limited information* about the range of possible cost for the system whose cost is being estimated
- Suppose the "actual" uncertainty is greater than what is estimated…



Then the 80th percentile of the "estimate" is LOWER than the 80th percentile of the "actual" cost distribution

No guarantee that the "estimated" 80th percentile corresponds to the "actual" 80th percentile!

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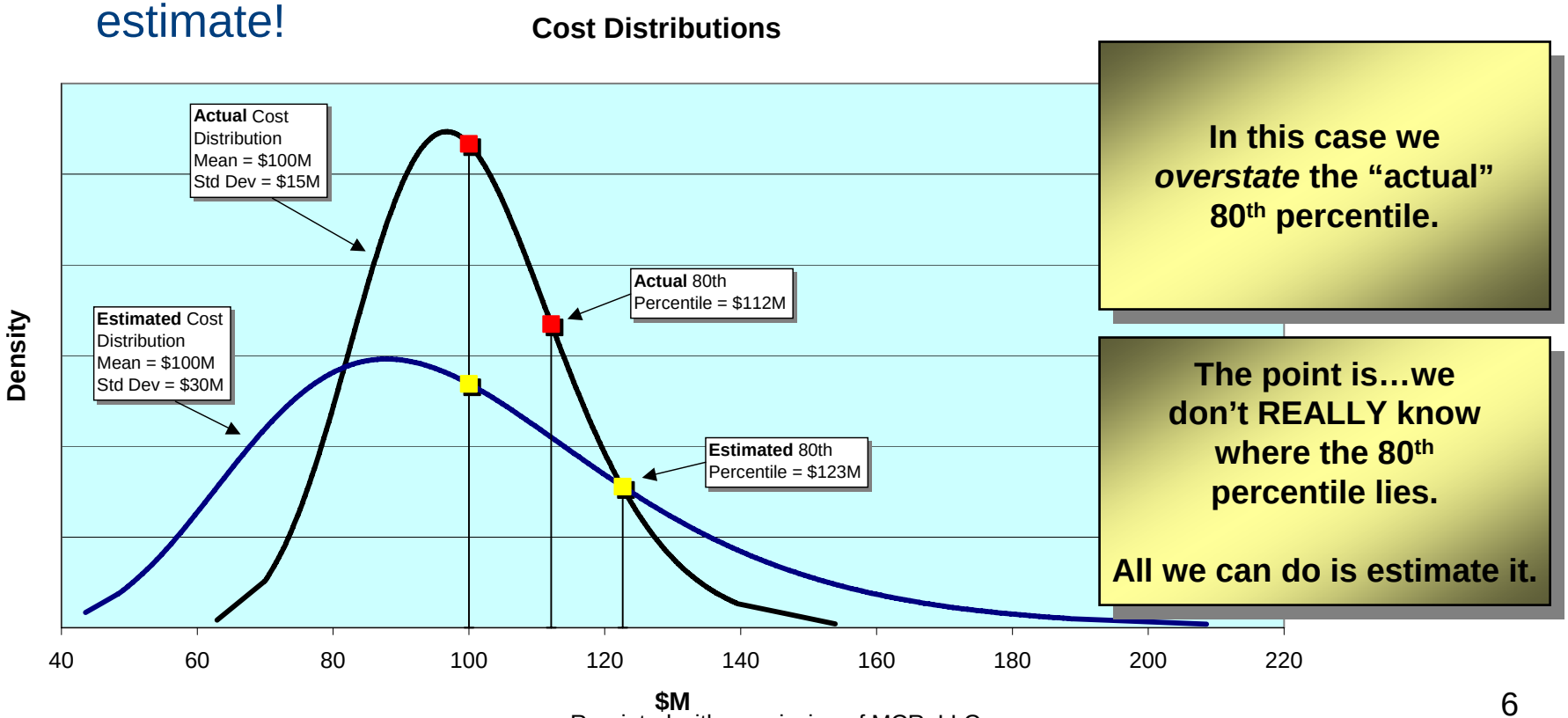
Conversely

- Similarly, the "actual" uncertainty may be LESS than the "estimated" uncertainty
- In this case, we might achieve a favorable result by calling out the 80th percentile, but it would be accidental…not because of our cost estimate!



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But…There is a *Bigger* Problem

- Suppose we COULD determine the TRUE location of the "actual" 80th percentile
  - Would that keep us out of trouble?
  - Unfortunately not
- The primary cause of cost growth is due to CHANGES that occur over the acquisition life cycle
- The problem is that we estimate the cost of a system as it is defined TODAY
  - But, we all know that the program will CHANGE as time progresses!
- This means that the entire cost distribution (usually) marches to the right over time
  - So, an 80th percentile measured TODAY, might become the 20th percentile of TOMORROW

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Here is What Usually Happens

- One way to look at the acquisition life cycle:
  - (1) Cost is estimated for TODAY's "technical baseline"
  - (2) Requirements changes and/or schedule slips and/or funding perturbations occur
    - Cost distribution shifts to the right
  - (3) Problems are identified that require engineering changes to resolve
    - Cost distribution narrows, but shifts further to the right
  - (4) Repeat steps (2) and (3) numerous times…
- By the time the program nears completion, the cost distribution has moved so far to the right that almost every point on it exceeds the 80th percentile of the baseline (initial) cost estimate!

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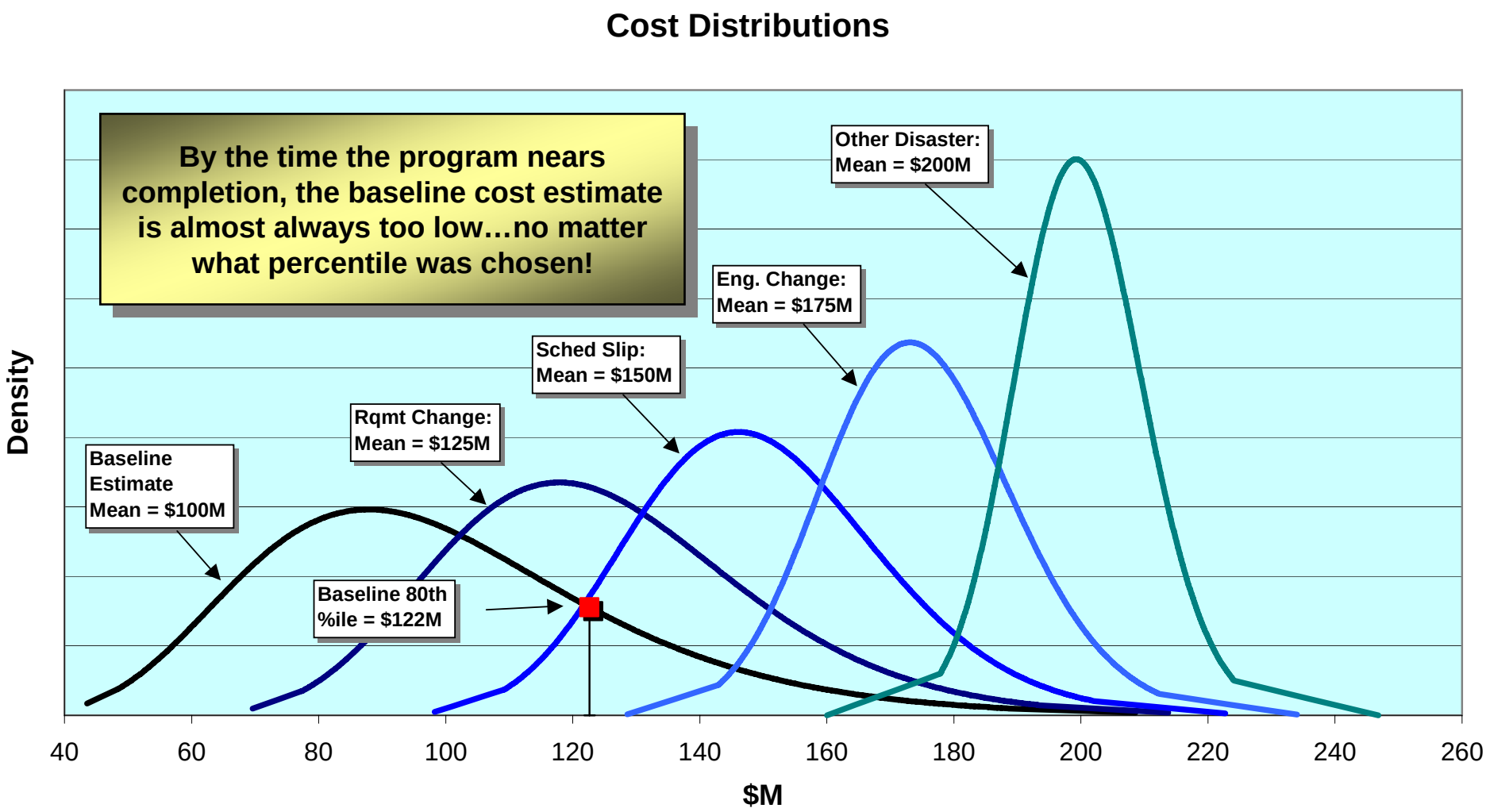
Graphically…



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Key Cost-Growth Drivers

- There are plenty of undesirable things that can happen to an acquisition program, for example:
  - Requirements changes
  - Programmatic changes
  - Schedule instability
  - Funding perturbations
  - Incomplete definition of initial requirements
  - Insufficient systems engineering
  - Optimistic technical and programmatic assumptions
  - Engineering changes
  - Beyond state-of-the-art technology
  - Other unforeseen events!
- Any of these events will generally lead to cost growth!

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So…What Can We Do About It?

- The only way to pin down the "real" cost estimate is to know, *a priori*, the specific changes that will occur over the life cycle
  - But this is almost impossible
  - Changes can be anticipated, but nobody wants to see them in their cost estimates
- One solution would be to collect libraries of data on program changes over time
  - Then we could develop predictive models to anticipate changes
  - This would enable cost estimators to model the cost of the "final" system rather than the "baseline" system
- Another option is to continuously update the cost estimate whenever a change occurs

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What if We Had a "Change" Database?

- If we collected "change" data, we might be able to quantify the historical cost impact of changes such as:
  - Requirements changes
  - Technical changes
  - Schedule changes
  - Etc…
- Then we could make statements like the following and use them in our cost estimates:
  - "Requirement changes cost an average of $X"
  - "Each technical change costs an average of $Y"
  - "On average, schedule changes will add Z% to an estimate"
  - Etc.

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What Else Could We Do?

- Then we could take a step-by-step approach to establishing an estimate of the FINAL program cost and uncertainty
  - BASELINE
  - BASELINE + rqmts changes
  - BASELINE + rqmts changes + tech changes
  - BASELINE + rqmts changes + tech changes + sched changes
  - Etc…
- The end result would be an estimate of the cost of the FINAL program
  - Decision makers would be able to see the impacts of requirements changes, technical changes, schedule changes, etc., and plan accordingly
  - Select the 80th percentile of the FINAL program cost estimate

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Example

- Decision makers could see at a glance the impact of the changes that their programs may experience
  - And, may be able to make plans to mitigate the "changes"

80th Percentile Program XYZ	FY10$M NRE	REC	TOTAL	PCT Delta
BASELINE	**$ 225.0**	**$ 500.0**	**$ 725.0**	**0%**
+ Rqmts Changes	$ 56.3	$ 125.0	$ 181.3	25%
+ Tech Changes	$ 33.8	$ 75.0	$ 108.8	15%
+ Sched instability	$ 22.5	$ 50.0	$ 72.5	10%
+ Funding instability	$ 18.0	$ 40.0	$ 58.0	8%
+ ECPs	$ 67.5	$ 150.0	$ 217.5	30%
+ Other Unknowns	$ 22.5	$ 50.0	$ 72.5	10%
FINAL PROGRAM	**$ 445.5**	**$ 990.0**	**$1,435.5**	**198%**

NOTE: These numbers are for illustrative purposes only.

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This Has Been Discussed Before

- Steve Book of MCR considered the subject when researching metrics for NASA Cost Readiness Levels (CRLs) in 2005
  - "Performance of the Interquartile Range (IQR) as a Marker for the Cost Readiness Level (CRL) Quality Metric for NASA Cost Estimates"
  - *NASA Cost Analysis Symposium*, New Orleans, April 2005
  - Attempted to quantify the evolution of cost probability distributions of NASA programs across acquisition phases
- Angela Vu of MCR actually developed a "change database" for SMC programs in 2008
  - "USAF/SMC Cost Growth Study Using Contract ECOs"
  - Studied sources of cost growth in SMC programs by analyzing contract modifications and requirement changes with goal of improving cost estimating and risk analysis

So…it CAN be done, and the greater Cost Community should be doing it!

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Some Argue "It's Already In There"

- I disagree (mostly)
- Yes, our Cost Estimating Relationships (CERs) are based on real programs that had real problems, but…
  - Every data point is for a "completed" program
  - And, our CERs do not contain data for programs that failed or were cancelled due to issues of excessive cost
  - So, we use "completed" program data to estimate the cost of an "incomplete" program description
  - If we used our CERs to estimate the cost of the FINAL program, then we would be okay
  - But, instead we use our CERs to estimate the cost of the BASELINE program description – which has not yet experienced any problems!
  - So, our cost distributions for BASELINE program descriptions are too low relative to FINAL program descriptions
- What's "in there" impacts the uncertainty (variance), but the events we are interested in are those that shift the mean!

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Conclusions

- Acquisition leaders need to understand that BASELINE cost estimates are almost always too low – even at the 80th percentile
  - Establishing the 80th percentile for the BASELINE cost estimate will not necessarily protect us from cost growth due to program changes
- Cost growth can be mitigated only if we estimate the cost of the FINAL program rather than the BASELINE
  - Our CERs will not protect us either
- Strive to get the first moment right, and do your best on the second moment
  - Use the resulting distribution to make intelligent decisions, but don't pin your hopes on the 80th percentile – it is too elusive
- Development of a "change" database may help us predict cost growth in a defendable way
  - Could be used to make the leap from the BASELINE program estimate to the FINAL program estimate

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Acronym List

CER	Cost Estimating Relationship
CRL	Cost Readiness Level
ECO	Engineering Change Order
IQR	Interquartile Range
MORS	Military Operations Research Society
NASA	National Aeronautic and Space Administration
NRE	Non-recurring Engineering
PCT	Percent
REC	Recurring
SMC	Space and Missile Systems Command
USAF	United States Air Force
USD(AT&L)	Undersecretary of Defense for Acquisition, Technology and Logistics
WSARA	Weapon Systems Acquisition Reform Act (of 2009)

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QUESTIONS?