A Simple, Universal Approach to Cost Risk Analysis: Integrating Simulations and Sensitivities

By Eric Hawkes and Eric Druker

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Objectives

1. We want to introduce to the cost estimating community a methodology titled, Enhanced Sensitivity Analysis (ESA)

2. Show that this methodology, when combined with current approaches, creates a universal approach for cost risk analysis (you can decide if it is simple)

3. Introduce the concept of integrating sensitivity analysis with probabilistic techniques

Agenda

- Background
- A Critique of Current Approaches
- Enhanced Sensitivity Analysis
- Case Study
- General Approach

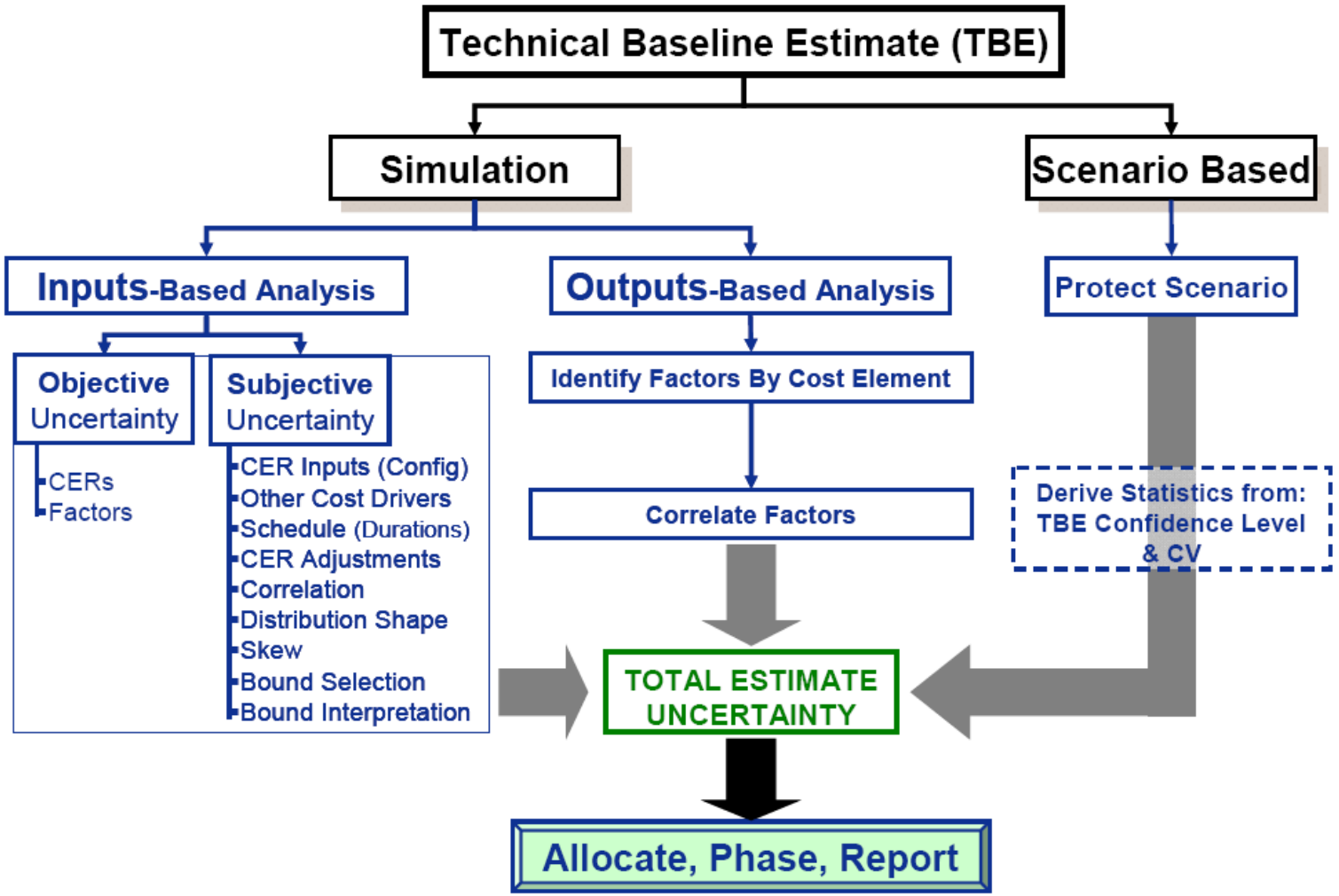
Background

- Given the history of cost overruns and since "Point estimates alone are insufficient for good decisions"[1], we must provide decision-makers with Cost Risk Analysis
- Cost Risk Analysis attempts to:
  - Put bounds on the estimate (we're 80% sure it's below this number)
  - Guard against optimism (plan for success)
- United States Air Force Cost Risk and Uncertainty Analysis Handbook presents three methods for accomplishing this:
  - Inputs-based simulation (recommeded[2])
  - Outputs-based simulation
  - Scenario-based method
- GAO's Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs presents the inputs-based simulation method and a single-variable sensitivity analysis

1: GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs, pg 138

2: United States Air Force Cost Risk and Uncertainty Analysis Handbook, pg 41 "A sound rationale is required if diverting from Inputs-based simulation"

Framework in Air Force Cost Risk and Uncertainty Analysis Handbook



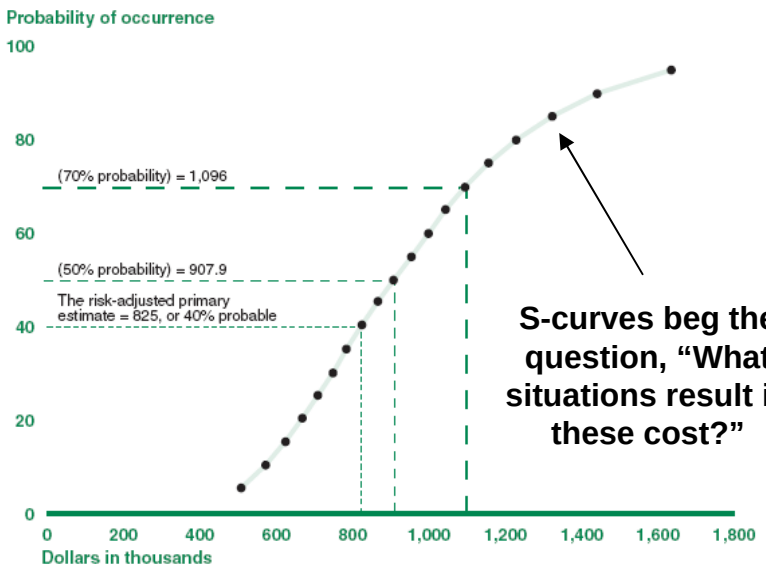
A Critique of Current Approaches – Inputs and Outputs-based Simulations

Inputs-based simulation

Pro	Con
Produces S-curves	Requires lower-level distributions
Able to quantify how much 'risk dollars' in estimate	Analysts prone to guess at distributions type/parameters
Tailors risk to program	Prone to results-based revision
Able to handle any number of unknowns	Does not show what drives the variability
	Need to know correlation matrix

Outputs-based simulations

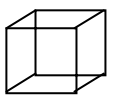
Pro	Con
Produces S-curves	Difficult to justify factors (e.g. are all aircraft acquisitions equal risk?)
Simple to execute	Not recommended by Air Force Cost handbook
Includes 'unknown-unknowns' risks	



Limitations of S-curves

- S-curves on their own lack traceability. The purpose is to show probable cost outcomes, not the situations that result in those costs
- Difficult to quickly detail assumptions and parameters behind results
- Assumes cost growth is purely stochastic and not influenced by decisions
  - PMs can always trade performance and schedule for cost
  - Largely ignores impact of a good (or bad) PM
- They don't tell the PM anything they don't already know ("Mr. PM, there is a chance it could be very expensive")
- If analysts compute S-curves in an academically correct way, the results would break budgets
- Assumes program is mature

Program maturity (proposed risk analysis method)

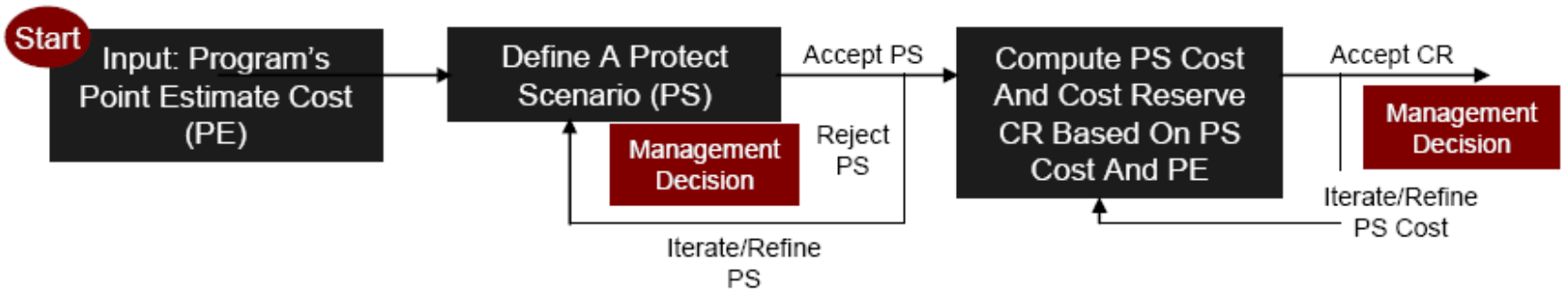
- ■ : Program still a concept: Change likely (SME guess)
- □ : Reasonable program definition: Cost drivers identified / functional relationships understood (Sensitivity analysis)
-  : Mature program: Distributions of cost drivers and correlations known (Probabilistic techniques)

A Critique of Current Approaches – Scenario-based Approach

Scenario-based Approach

Pro	Con
Process requires mgmt buy-in	Not continuous
Produces bounds that correspond to events	Does not capture unknown-unknowns
Tailors risk distribution to program	Requires mgmt. time and commitment
Provides traceability	Not recommended by Air Force handbook

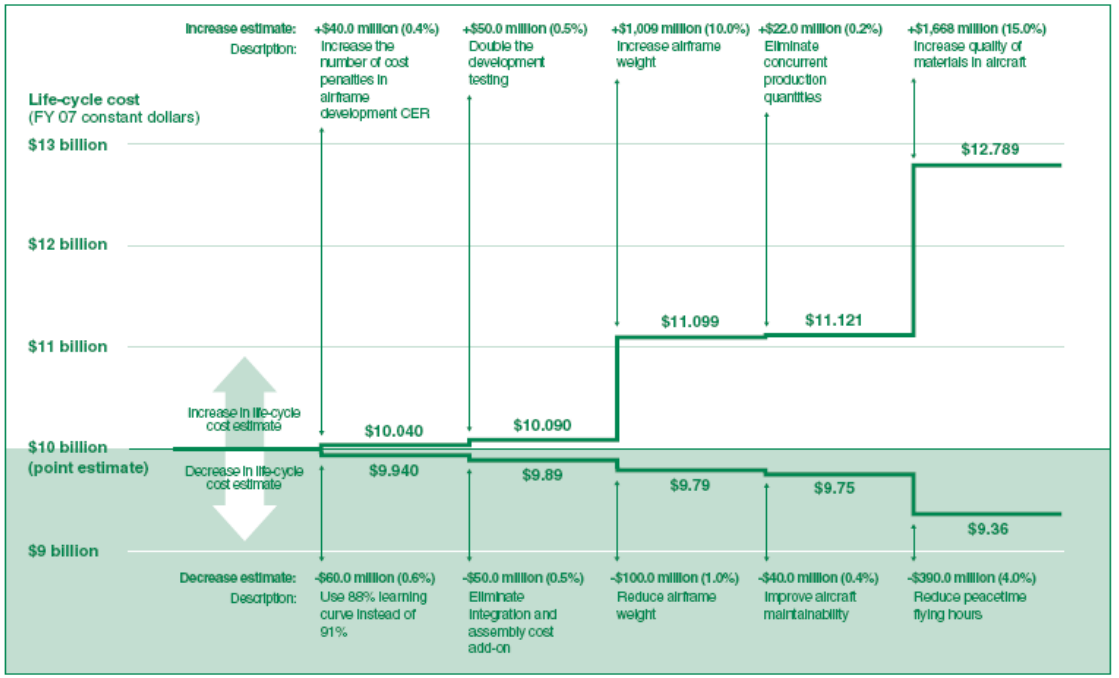
Non-statistical SBM



A Critique of Current Approaches – Sensitivity Analysis

Sensitivity Approach

Pro	Con
Produces bounds	Everything is discrete
Simple to execute	Does not communicate probability of events
Easily understood by Decision-maker	



Enhanced Sensitivity Analysis (ESA) – Description and Methodology

- ESA is a **methodology** that maps the 'response-surface' of the cost model using Design of Experiments techniques
- Developed by Booz Allen during a client engagement[1]
- ESA's goal is to focus attention on the parameters in the cost model, not S-curves

The Three-Step Methodology

1. Build cost model as usual with goal of parameterizing everything. Ensure that those parameters are schedule or technical driven. For CERs, have the estimating error as its own parameter.
2. Perform a screening experiment. Assign a high / low value to each parameter. Determine which parameters are driving the most variation.
3. Perform pair-wise sensitivities by varying two parameters at a time. Record the chart. Repeat until the response-surface is sufficiently mapped. Present results smartly.

1: Although independently developed, others have proposed similar approaches. Most notably, Kenny Horan proposed 'Cost Response Curves' in a 1996 ADoDCAS brief

Enhanced Sensitivity Analysis – A Case Study[1]

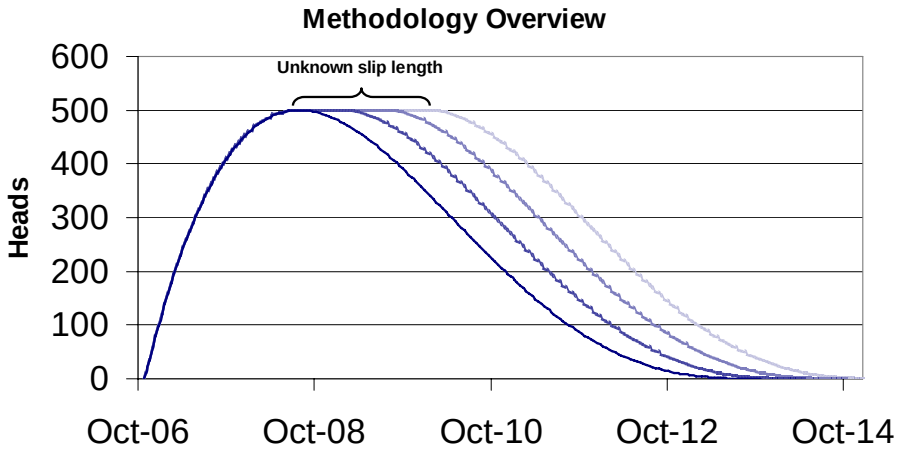
- Background: Air Force is considering developing a more fuel efficient engine and wants to perform a Business Case Analysis and a Life-Cycle Cost Estimate on the budding program.
- The program is Pre-Milestone A and uses radically new technology that is yet to be proven
- The engineers hope to get the fuel burn rate down to 1,000 lb/hr versus current rate of 9,000 lb/hr

Results from screening experiment

Phase	Methodology	Key Parameters
Development	Heads over time	Peak head count and Slip length
Production	T1 and Learning	T1 and Learning rate
O&S	Cost of Fuel * Fuel consumed	Fuel burn rate, Fuel inflation rate and today's cost of fuel

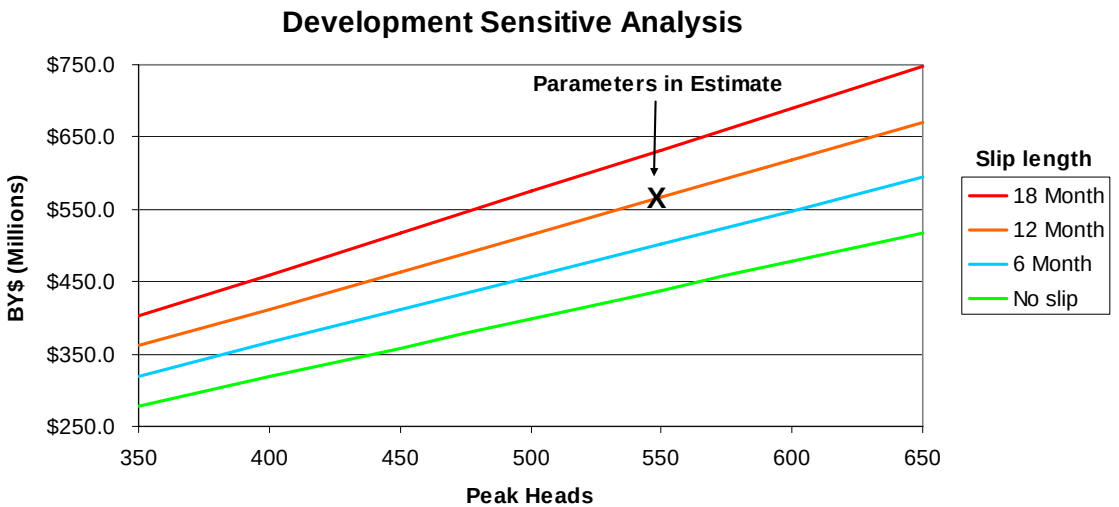
1: The scenario was used with permission, but all numbers are notional and the methodologies have been simplified

Enhanced Sensitivity Analysis – Development Estimate



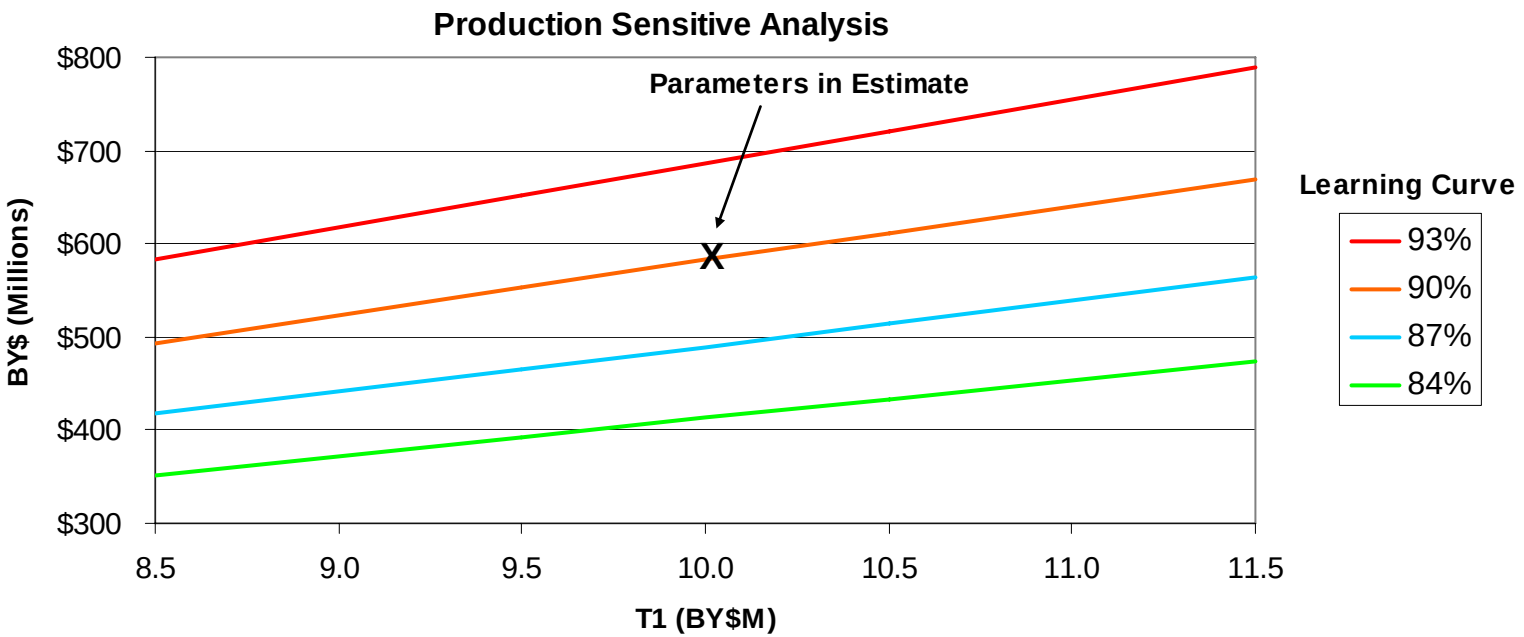
- Analyst not required to make such statements such as, “I’m 80% sure the development cost will be less than $650M”
- Not required to define distributions

- This approach forces discussion around why analyst choose certain key parameters (excellent place for historical examples)
- Approach able to handle two or three unknown variables



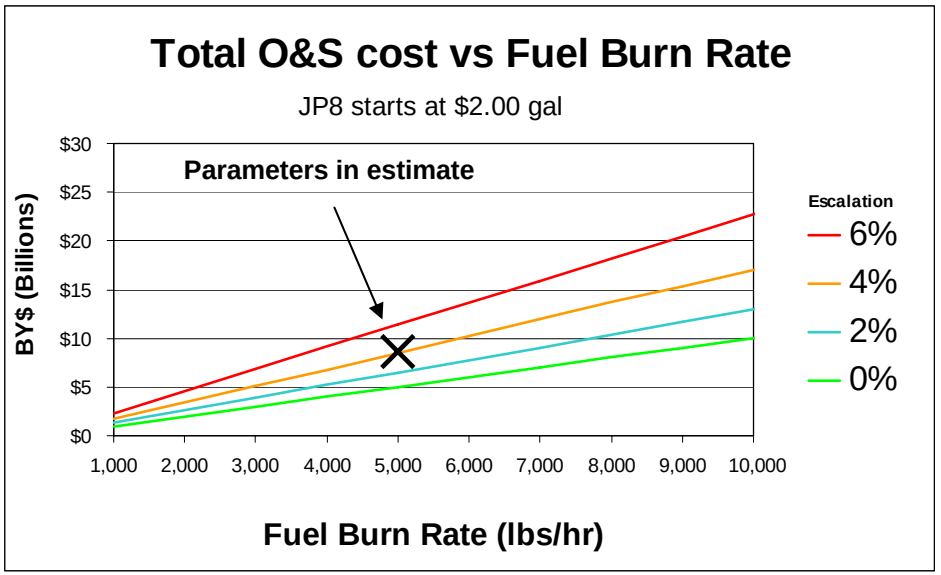
Enhanced Sensitivity Analysis – Production Estimate

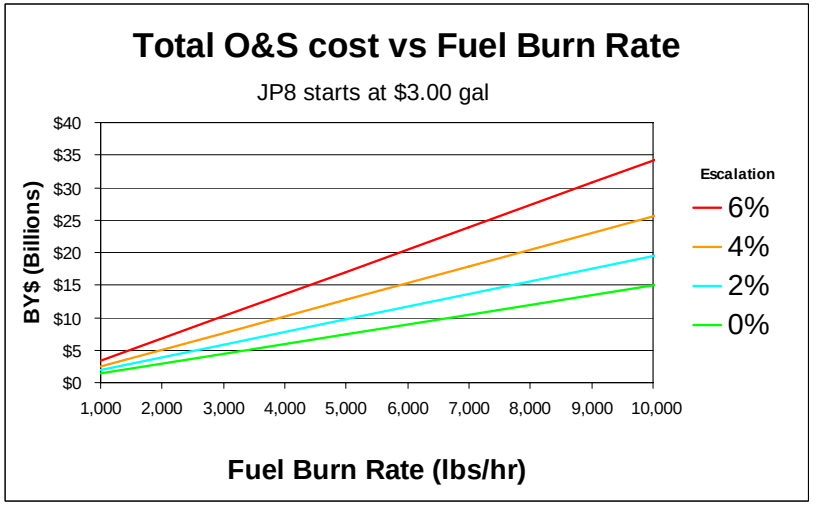
- In this example, we demonstrate how to implement ESA when using learning curves
- There is still no requirement to assign probabilities. Though if data is available, it is possible to develop 'confidence ellipses', discussed in-depth later.

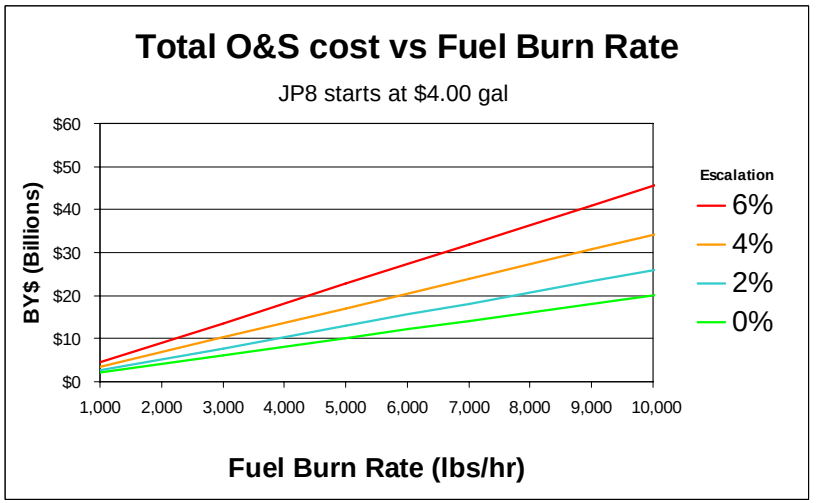


Enhanced Sensitivity Analysis – O&S Estimate

- In this example, we should how to portray three independent unknowns: fuel price, burn rate, and rate of fuel price escalation over inflation.
- This analysis also lays ground-work for future trades







A Comparison of Enhanced Sensitivity Analysis with Inputs-based simulation

Supporters of ESA claim:

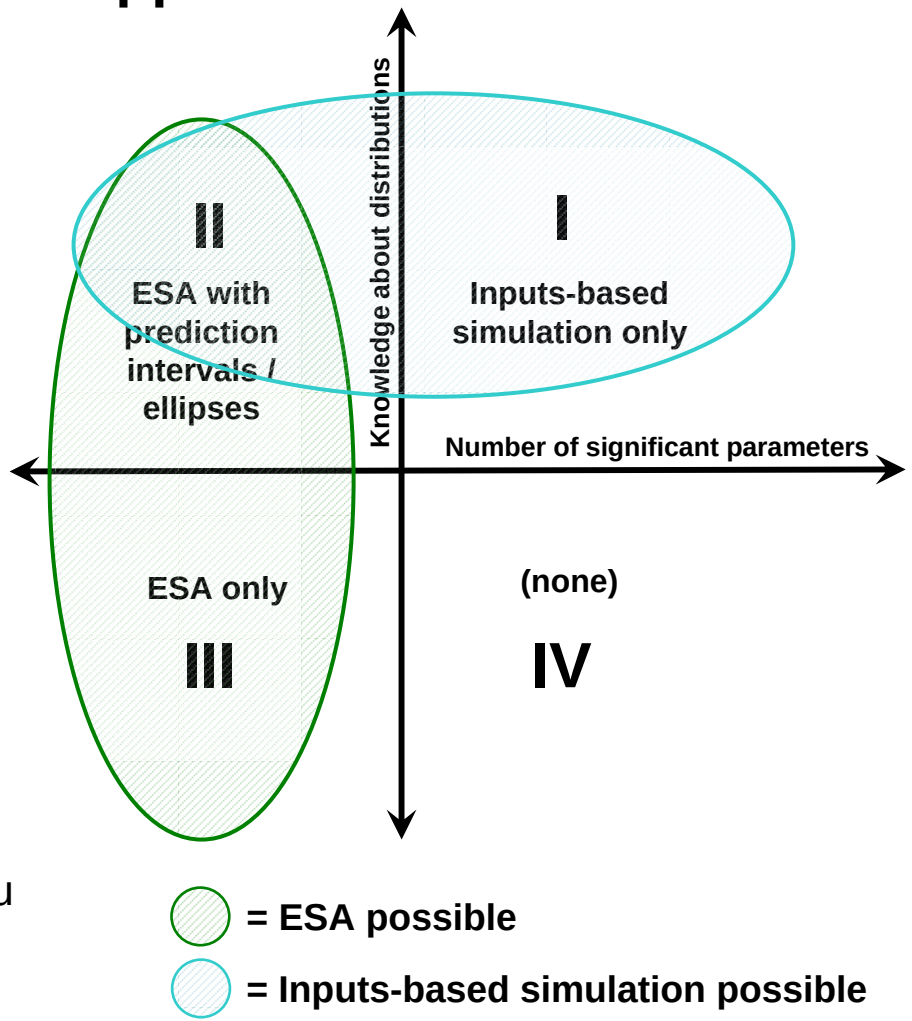
- Results are more insightful – provides traceability
- Better at fighting optimism because discussion is about parameters, not S-curves
- Requires no additional data
- Simple to execute – no requirement for advanced degree in statistics or simulation
- Visual results easy for decision-maker to understand
- Allows decision-makers to buy into parameters
- Reduced need for subjective "rules of thumb"
- More repeatable – able to be standardized
- Much easier to review

Supporters of Inputs-based simulation claim:

- Better at putting bounds on estimate
- Easier for analyst to communicate how much "risk-dollars" are in estimate
- Analysis able to be integrated into portfolio management
- Handles any number of unknown parameters simultaneously (ESA limited to two or three parameters)

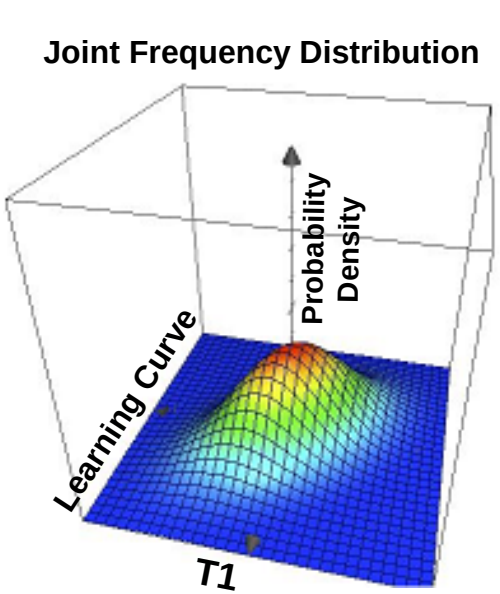
Why not combine them? A Universal Approach

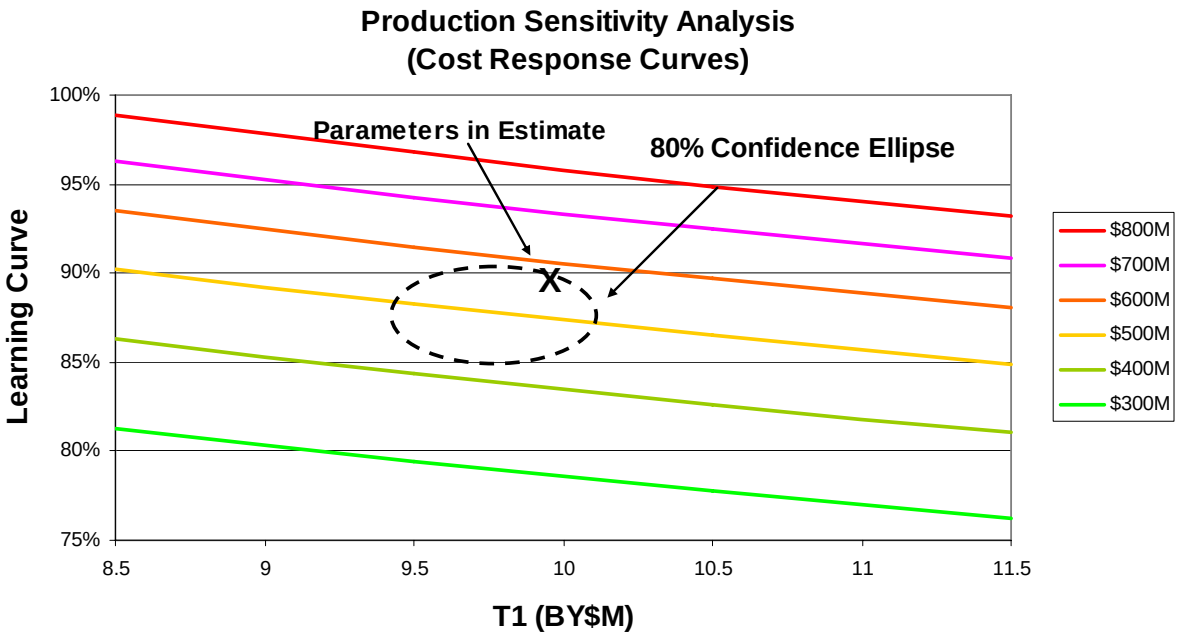
- The chart to the right informs the analyst which analysis method to use
  - If you have data to defend distributions, then use inputs-based simulations
  - If the number of unknown parameters is manageable, then use ESA
- The analyst must determine which quad he/she is in
- If in quad II, you have opportunity to develop confidence ellipses (next slide)
- If in quad IV, I recommend building a separate cost model, with just a few top-level parameters (a quad III solution) and then centering it on the point estimate from the primary cost model. This way, you get the best of both worlds: a high-fidelity estimate with only a few significant parameters



An example of a Quad II solution

- Plot cost on the contour lines, not on the y-axis (constant cost curves)[1]
- Analyst might have to show sensitivities around lower WBS element such as Recurring production versus total appropriation funding
- Calculate confidence ellipses either by hand or by simulation (preferred)





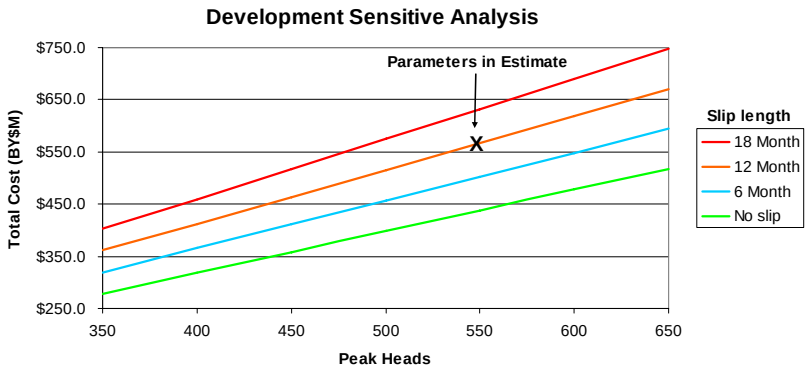
1: If modeled in Excel, I recommend using Goal Seek

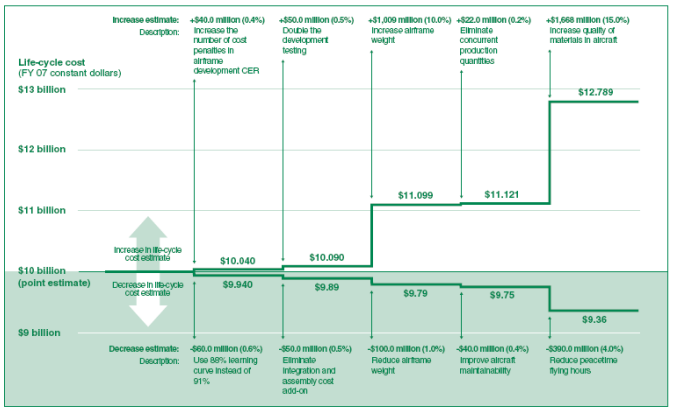
Comparing Results

ESA

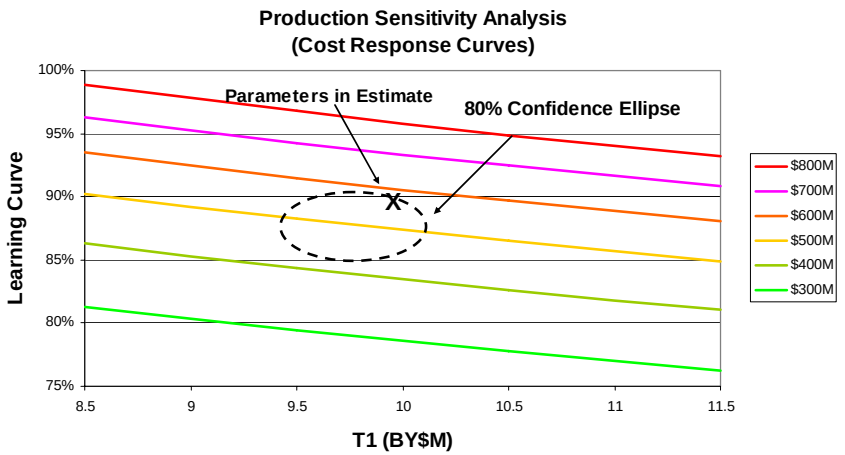
Current Techniques

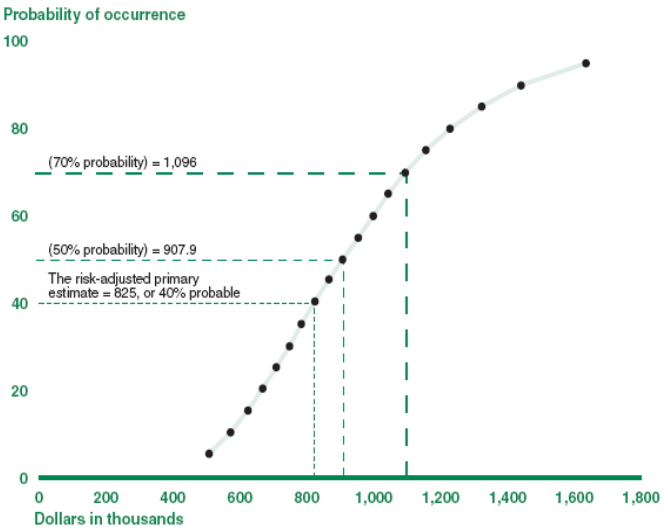
Sensitivity Analysis





Probabilistic Analysis





Some Concluding Quotes and Thoughts

"The true test of the utility of cost analysis is the ability to respond quickly to program turbulence…"[1]

"Cost analysis cannot … produce results that are more valid than input data" [1]

"Enough data will never be available to develop a known frequency distribution" [2]

- The above quotes support the case for sensitivity over probabilistic analysis
  - Sensitivity analysis lays groundwork for a program's invariable schedule/funding shifts
  - Sensitivity analysis does not require that the analysts know the distribution type or parameters
- Last SCEA conference's 'Best Paper' titled, "The Fractal Geometry of Cost Risk", proposed that cost growth does not follow the typical distributions but that it follows a power distribution. If true, then cost analysts have been:
  - Overstating our capabilities
  - Providing decision-makers with misinformation (80% confidence numbers that aren't really 80% numbers in reality)
- Policy should specify what needs to be done, but not how. The analyst should determine the analysis technique based on the situation.

1: Army Acquisition Procedures Pamphlet 70_3 dated Jan 08, pg 75 for both

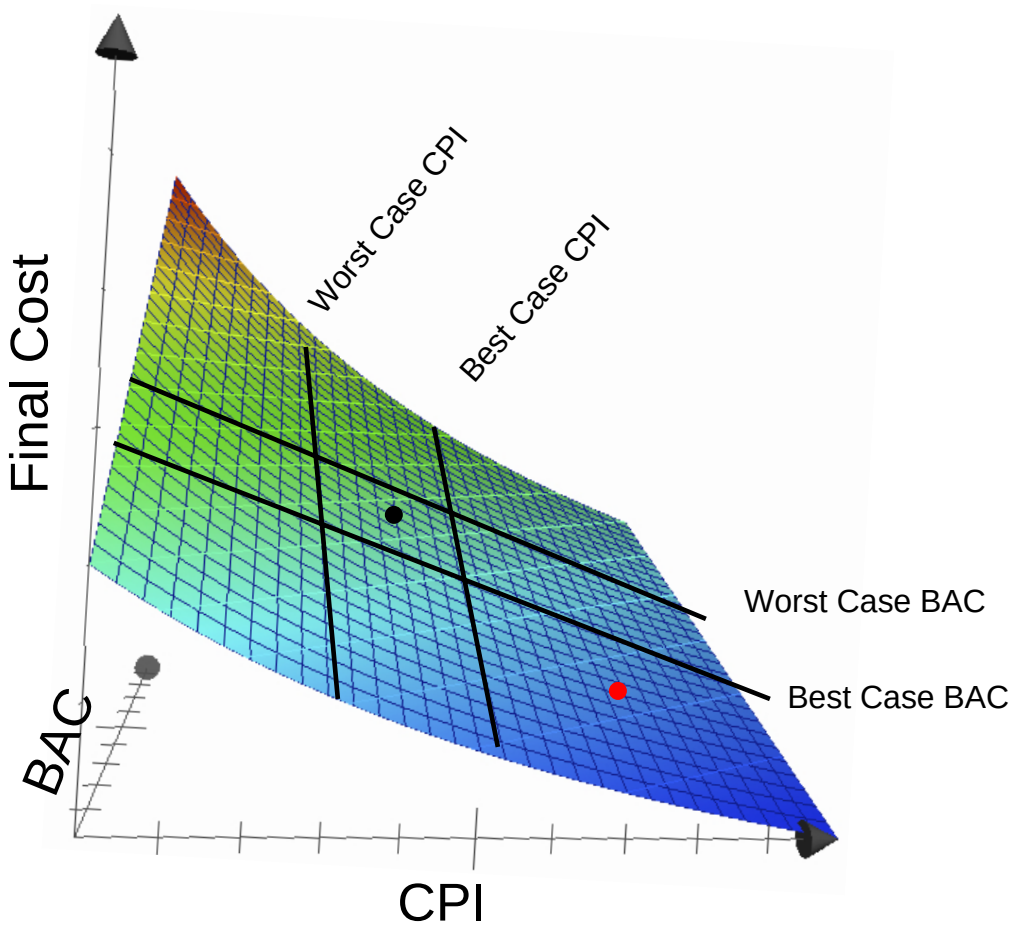
2: GAO: Assessment Guide "Best Practices for Estimating and Managing Program Estimate" pg 138

Bonus Slides

ESA Applied to EVM Analysis [1]

- ESA can also be applied to an EVM environment to communicate Cost Risk
- Analyst used historical EVM data to determine bounds on the final BAC and CPI using:

  Final Cost = (Final BAC)/(Final CPI)
- The calculated EAC represents the EAC using the current BAC and CPI
- The Most Likely EAC represents the EAC using the predicted final BAC and CPI
  - The lines on the graph visualize the bounds used in the statistical risk analysis



- Calculated EAC
- Most Likely EAC

1: Druker, E. Demangos, D. *Performing Statistical Analysis on Earned Value Data*, Society of Cost Estimating & Analysis Conference, St. Louis, MO. June 2009