RE01: *Joint Cost Schedule Model(JCSM) - Recent AFCAA Efforts to Assess Integrated Cost and Schedule Analysis*

Presented at the 2011 ISPA/SCEA Joint Annual Conference and Training Workshop - www.iceaaonline.com

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Abstract: The Space Division of Air Force Cost Analysis Agency (AFCAA) supports Air Force (AF) and Department of Defense (DoD) Major Space Acquisition programs by providing thorough, effective, independent cost estimates (ICEs) and conducting special studies for decision makers. Recently AFCAA has initiated a research task to assess the potential for developing a joint cost-schedule model and the usability of the model.

This presentation will provide insight and share preliminary findings and observations of the research effort to discover a joint cost and schedule modeling methodology for parametric and analogy based space system cost and schedule estimates. The preliminary results will address the total spacecraft level. The focus of the presentation is on parametrics and a process that complements current AFCAA estimating techniques. The presentation will discuss prior concepts identified by the industry and provide insight into the key enabling parameters for joining cost and schedule distributions. Furthermore, there will be a discussion on how the integrated cost/schedule analysis can be used by decision makers to make informed decisions about funding levels that are consistent with realistic program schedules.

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Joint Cost Schedule Model (JCSM)

Recent AFCAA Efforts to Assess Integrated Cost and Schedule Analysis

ISPA/SCEA Conference – June 2011

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Outline

- **Background**
- **JCSM in Action**
  - **Establishing a budget from our Independent Cost and Schedule Predictions**
  - **Analyzing impact of schedule acceleration**
  - **Quantifying potential cost impact of a schedule slip**
- **Summary**

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Two Big Questions

How do we establish a budget from our independent cost and schedule predictions?

How much schedule can we accelerate and maintain a target confidence level? How much does this cost?

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AFCAA Study Findings – Validation of Prior Studies

- **Cost and Schedule are Related**
  - Verified through analysis of USAF and NASA space programs
- **Independent Cost and Schedule Distributions can be Joined**
  - Several techniques
  - All use marginal distributions with correlation as the enabler
- **Joint Confidence Level (JCL) Provides Useful Metric**
  - Generated from combination of cost and schedule uncertainty analysis
  - Identifies cost-schedule range to meet combined objectives
  - Used to determine JCL Frontiers (e.g., cost and schedule values for 70% JCL)

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AFCAA Study Findings – NEW

- **Joint Cost Schedule Models can be Generated from Parametric Results**
  - Created via correlation of marginal cost and schedule distributions
  - Analysis indicates correlation range is between 40-80% for Space
- **Cost Growth as a Function of Schedule Growth Typical Follows a Power Form**
  - Property of joining right skewed distributions
  - Cost is conditional to schedule
  - Cost growth accelerates as schedule slips past the mean
- **Joint Confidence Statistics are Sensitive to Correlation Value**
  - Conditional cost probabilities and JCL value dependent on correlation
  - Mean of marginal cost and schedule distributions not impacted by correlation

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AFCAA Study Findings – NEW

- **JCSM Results Provide Valuable Insight**
  - Identifies minimum cost for a specific schedule, and vice versa
  - Allows calculation of JCL metric and resultant **JCL Frontier Curve**
  - Supports calculation of conditional costs through regression analysis of cost/schedule scatter plot data, underlying cost/schedule inertia

- **Cost Penalties for Schedule Changes can be Calculated from JCSM Results**
  - JCL Frontier Curve identifies impact of schedule compression
  - Regression of scatter data generates a **Cost/Schedule Inertia Path** which can be used to identify impact of schedule slip
  - Cost penalties are dependent on location

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Establishing a Budget from our Independent Cost and Schedule Predictions

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How does Estimating Community do It?

- **Cost set at a target confidence level and phased over a target schedule date**
  - *"Budgeting to at least the mean of the distribution or higher is necessary to guard against potential risk."* - GAO Cost Estimating and Assessment Guide, March 2009
- **Mean cost phased over mean schedule**
- **Cost and schedule obtained from a target Joint Confidence Level, and phased accordingly**
- **Top-down budget**

Study: Define Method that Complements ICE Process

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Case Study

- **FireSat Example -**
  - Hypothetical Unmanned Space Mission
  - Defined in SMAD and used in AFCAA Cost Risk and Uncertainty Handbook
- **Cost and Schedule Point Estimates**
  - System Cost: $229,635 (BY2011$K) ~ 21% Cost Confidence Level
  - Launch Date: 3/31/2018 ~ 40% Schedule Confidence Level
    - SDD to Launch Duration: 78 Months
- **Risk Analysis Results**

	Point Estimate	Confidence Level	Mean	Std. Deviation	Coefficient of Variation (CV)
System Cost (BY2011$K)	$ 229,635	21%	$302,050	$ 92,230	0.3053
SDD to Launch Duration (months)	78	40%	82	11	0.1360
Launch Date	3/31/2018	40%	7/19/2018		

	Cumulative Density Functions										
	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%
Cost Uncertainty Results - BY2011$K	$185,764	$205,141	$227,010	$248,146	$ 265,436	$285,392	$307,221	$ 334,113	$368,178	$416,615	$469,858
Schedule Uncertainty Results - Months	65	68	72	75	78	81	83	87	90	96	101
Schedule Uncertainty Results - Finish Date	3/3/2017	6/6/2017	10/4/2017	1/7/2018	3/31/2018	6/21/2018	9/15/2018	12/18/2018	4/15/2019	10/6/2019	3/7/2020

Question: How to Budget to the Mean?

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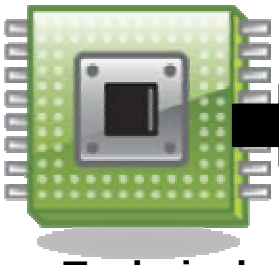
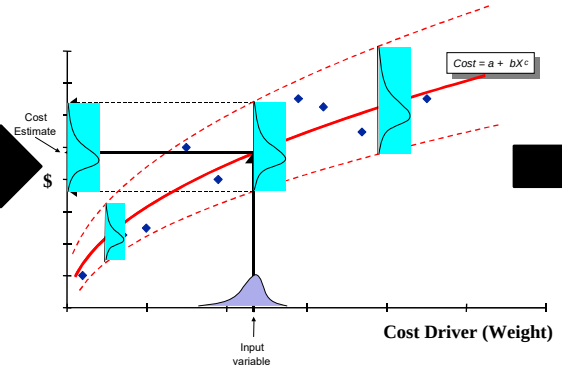
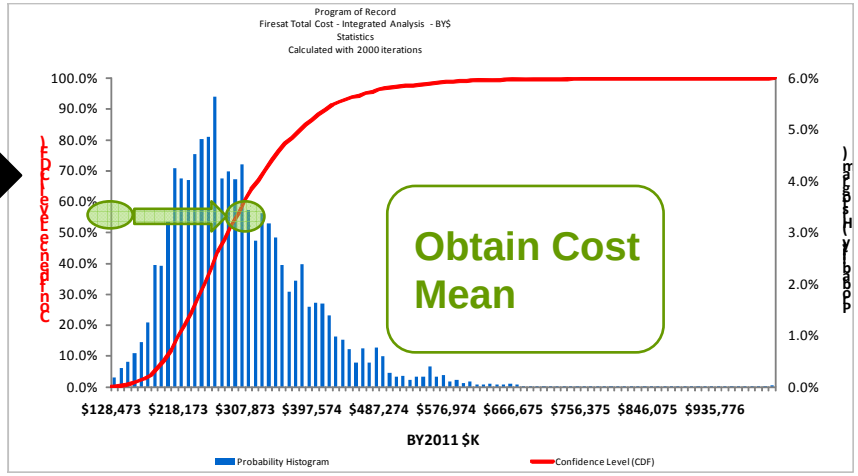
ICE Cost and Schedule Approach



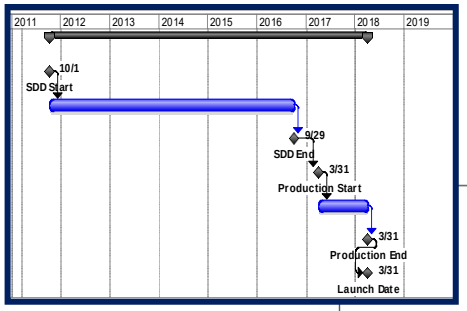
Technical Parameters

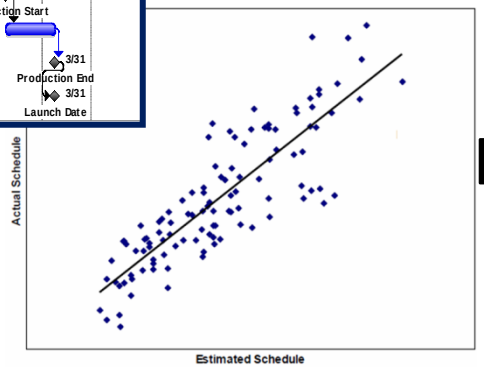


CERs / Cost Model

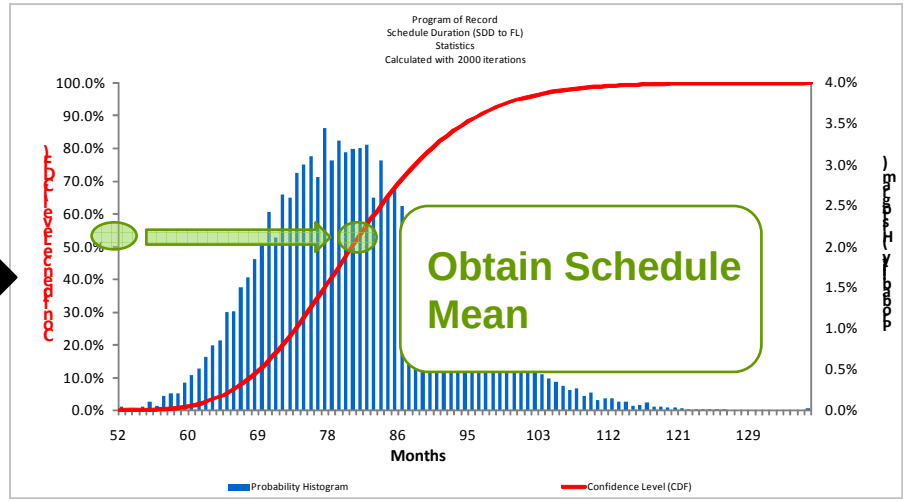


Cost Uncertainty Analysis





SER/ Schedule Risk Analysis



Schedule Uncertainty Analysis

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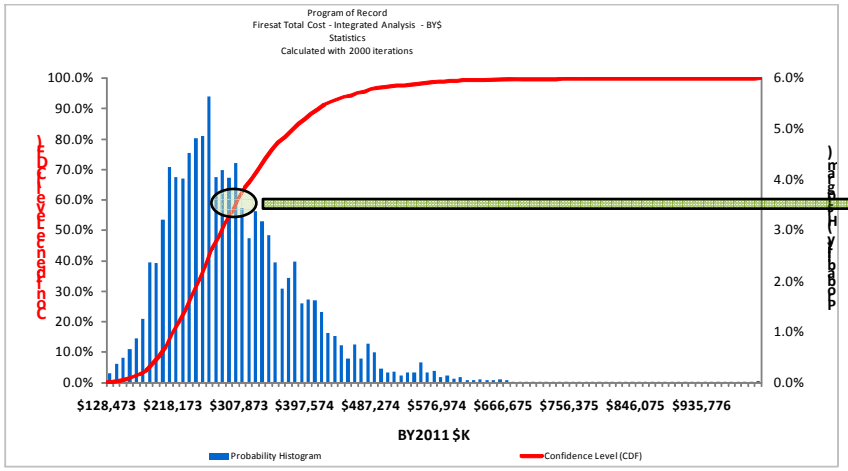
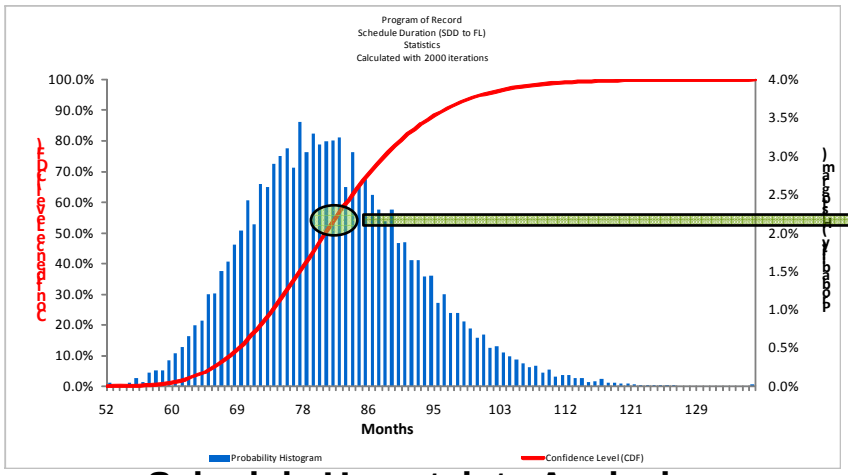
Setting the Mean Budget

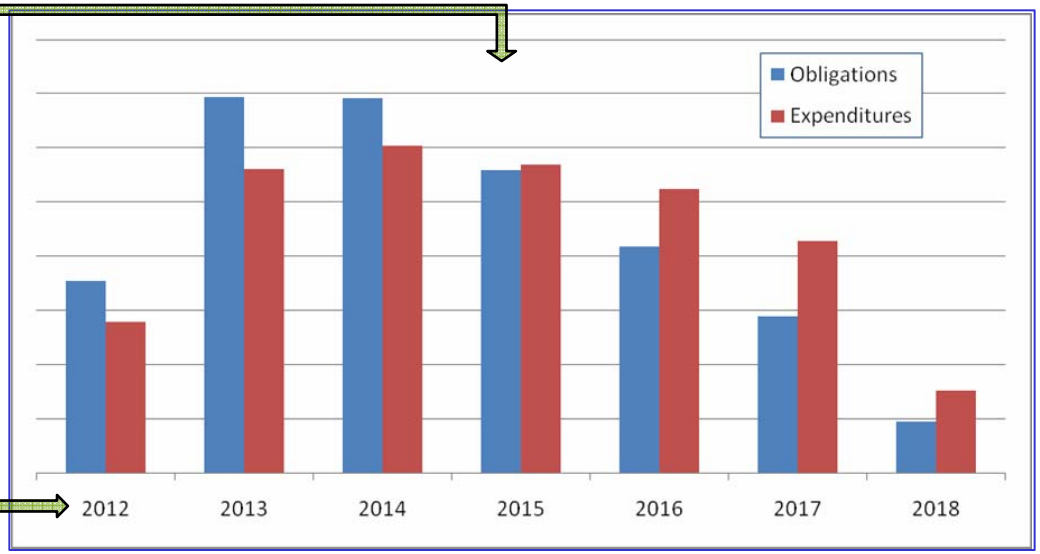
Cost Uncertainty Analysis





Schedule Uncertainty Analysis

1. Find Mean Cost and Schedule
2. Determine Expenditure Profile
3. Phase Expenditure over Schedule
4. Convert to Budget Profile



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Building the Joint Cost Schedule Model (JCSM)

- **Estimated Effort (Cost) and Duration (Schedule) are Modeled with Respective Uncertainties**
- **Correlation Implemented between Cost and Schedule Distributions**
- **Simulation Analysis Conducted to Obtain Cost/Schedule Pairs**
- **Joint Confidence Level (JCL) Obtained from Resulting Scatter**
  - Cost and Schedule confidence level calculated from data and identification of cost/schedule target pair
  - JCL is the percent of iterations that are less than and equal to both the cost and schedule target pair

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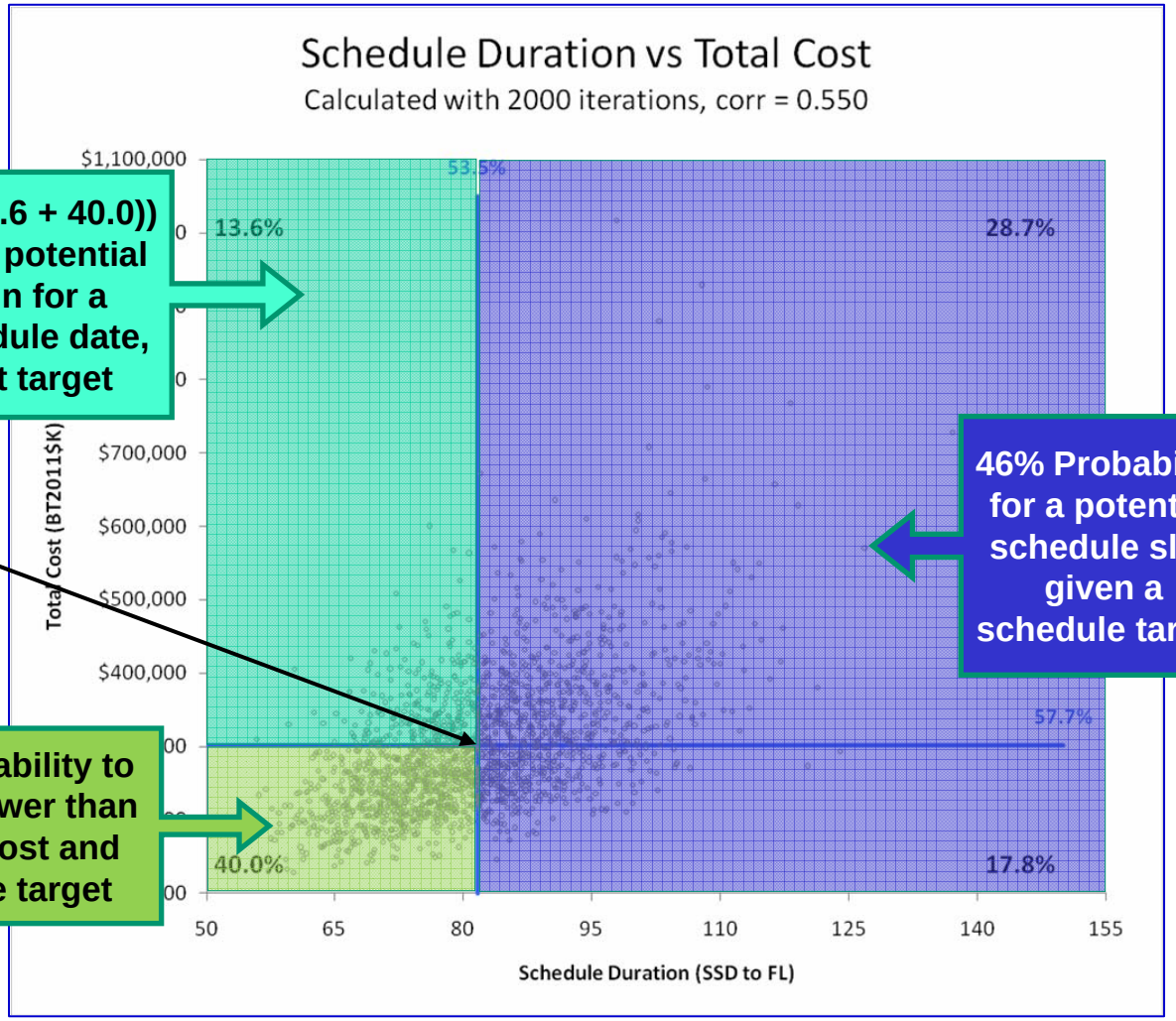
What is the JCL Metric?



25% (13.6 / (13.6 + 40.0)) Probability of potential cost overrun for a specific schedule date, given a cost target

Mean schedule, mean cost value

Marginal view… is at 54% schedule confidence, 58% cost confidence, and 40% joint confidence

40% Probability to be at or lower than a given cost and schedule target

46% Probability for a potential schedule slip, given a schedule target

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How Much Schedule can I Possibly Accelerate to Maintain a 40% JCL and What is the Dollar Impact?

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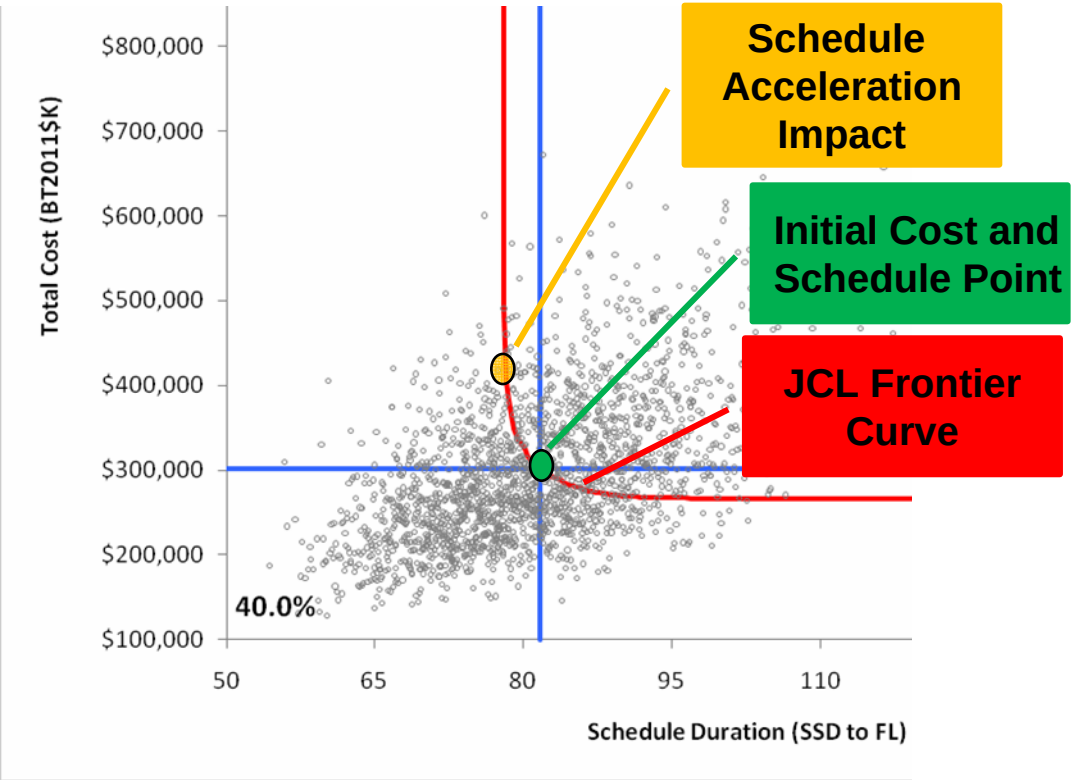
JCSM in Action – Schedule Acceleration

1. **Generate Scatter Plot from Marginal Distributions for Cost and Schedule and Relevant Correlation Value**

2. **Plot Project Plan's Cost and Schedule Value (Mean / Mean)**

3. **Create 40% Frontier Line**

4. **Identify Cost Impact**
   - Max = 3 mo. (4% reduction)
   - Cost increase = $99M (33% increase)



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If I Want to Target a 70 Month Duration What is the Dollar Impact to Maintain a 40% JCL

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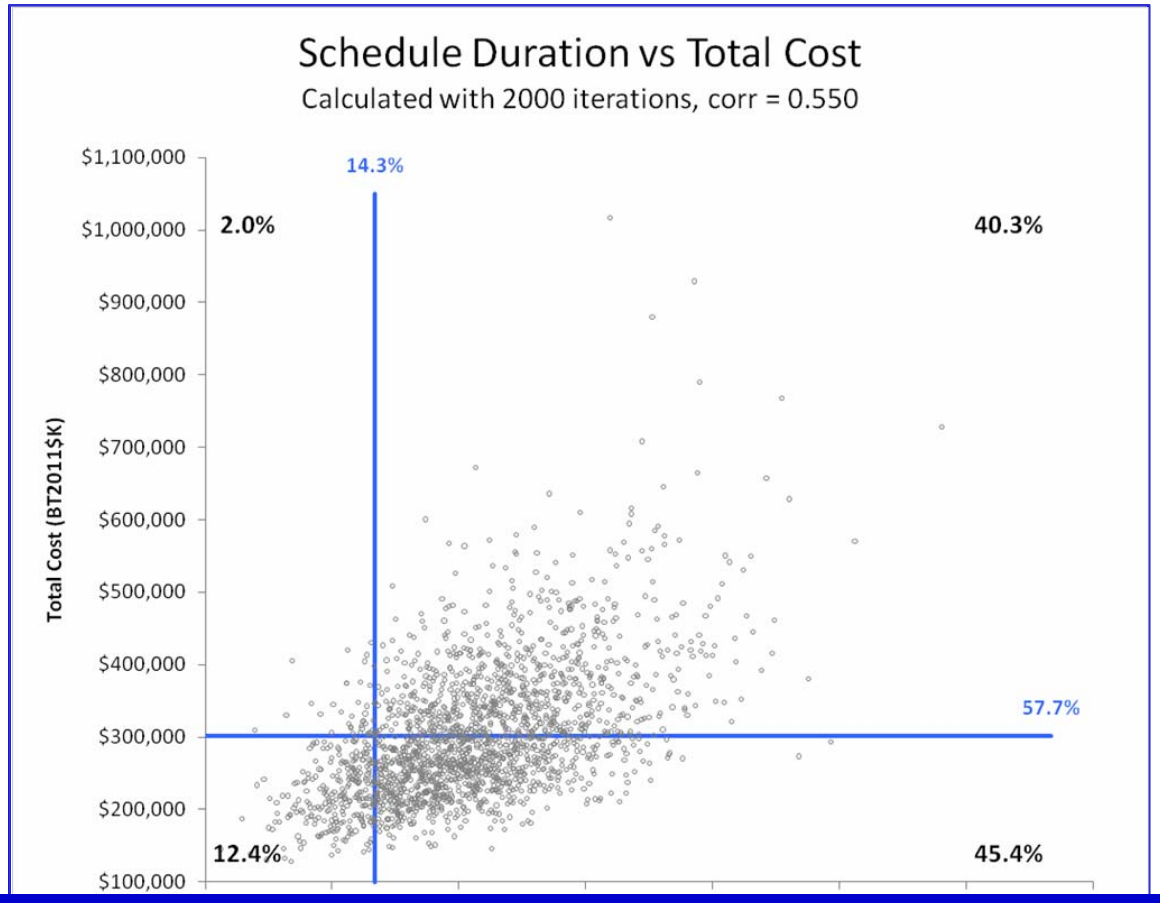
Targeting a 70 Month Duration



Cannot Accelerate Schedule and Maintain Overall Confidence Level Without Adding More Funds

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What is the Cost Impact if my Schedule Slips?

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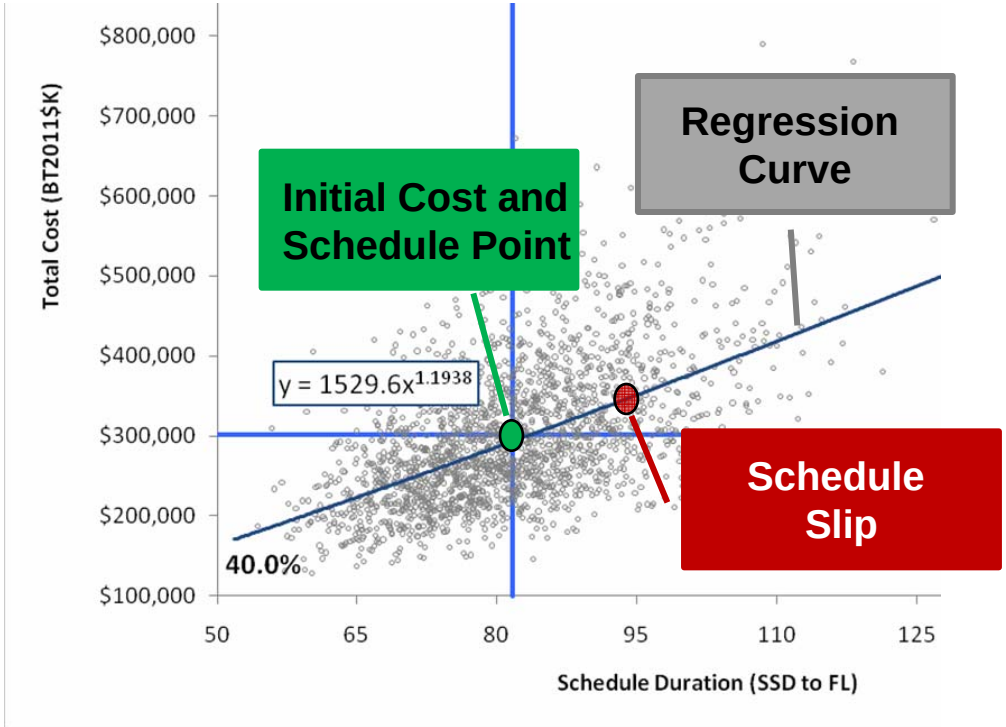
JCSM in Action – Schedule Slip

1. **Generate Scatter Plot from Marginal Distributions for Cost and Schedule and Relevant Correlation Value and plot Project Plan's Cost and Schedule Value**

2. **Run Regression on Scatter (Cost = a + b*Duration^c)**

3. **Translate regression to project cost and schedule**

4. **Determine cost of schedule slip**
   - 12 month slip = $43M (14% cost increase)



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If I Want to Target a 60% JCL What is the Cost and Schedule Target

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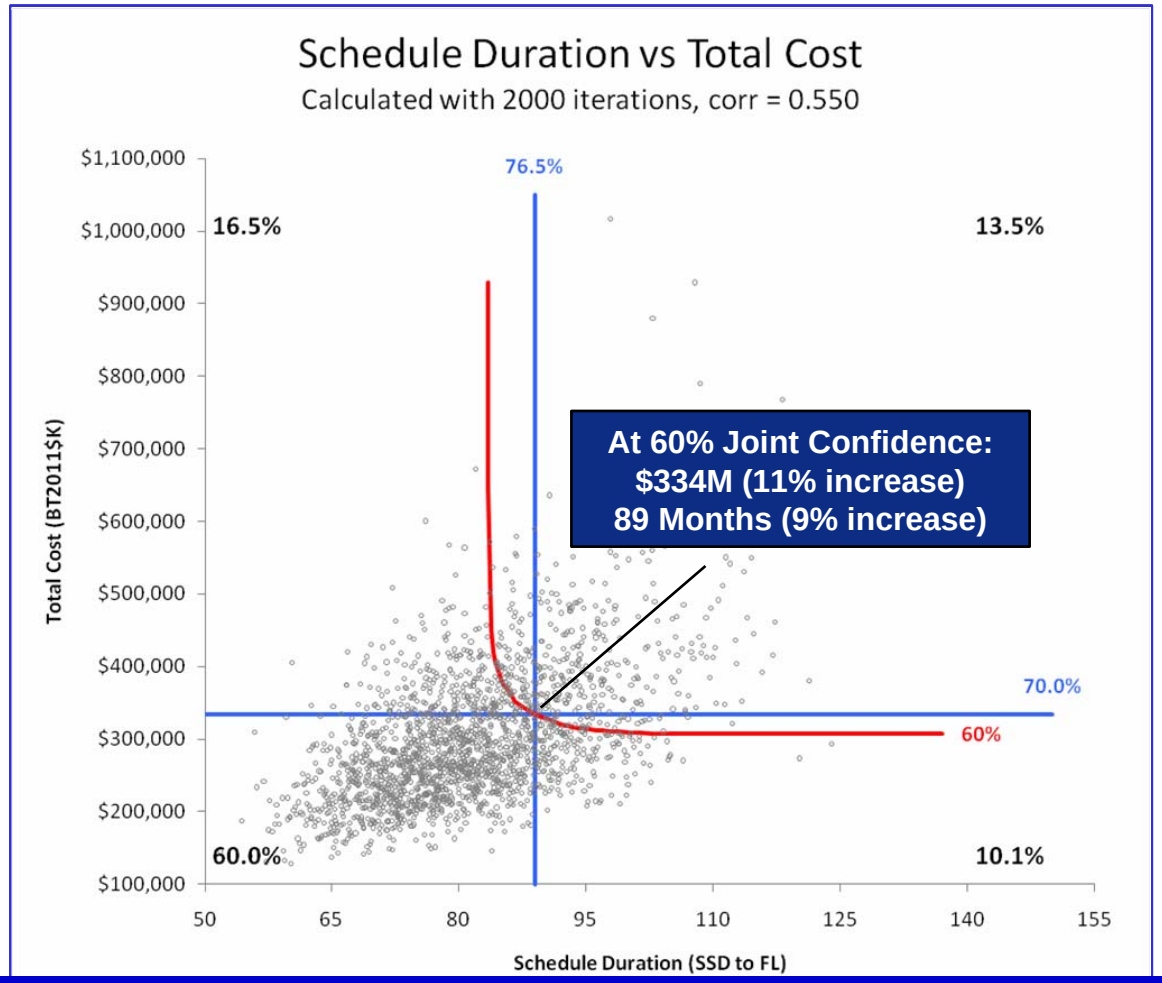
Targeting a 60% Joint Confidence



Cost increases as schedule increases, and so does JCL…

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Summary

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AFCAA Study Findings - Summary

Project Formulation

- Cost and Schedule are Related
- Cost and Schedule Distributions can be Joined
- Cost Growth vs Schedule Growth Follows a Power Form
- Cost is Conditional to Schedule
- Cost Mean – Schedule Mean are not affected by Correlation

Project Execution

- Joint Cost Schedule Models Enhance Understanding of a Project's Cost/Schedule Behavior
- Cost Penalties for Schedule Changes can be Calculated from JCL Frontier Curves and Project Cost/Schedule Inertia Paths
- Impacts of Funding Changes can be Derived from JCSM Results
  - Change in CCL and JCL values
  - Modeling of Effort Rollover

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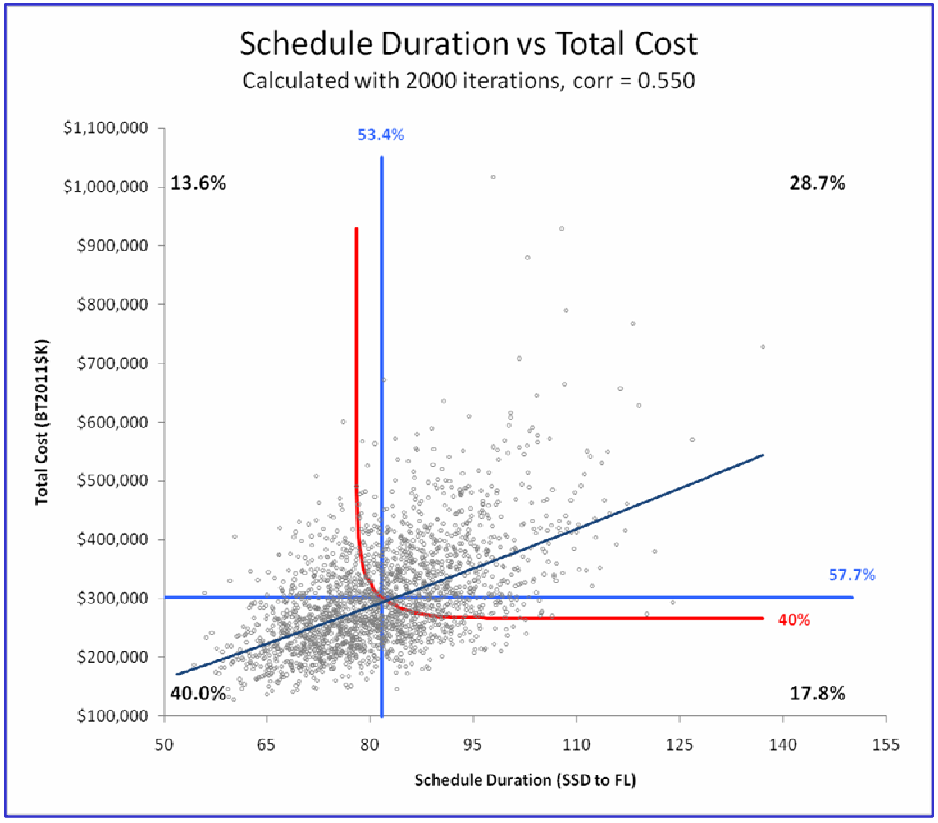
Five Key Tools

1. **Scatter Plot – Determine JCL Value**
2. **JCL Frontier Curve – Identify Cost Penalty for Schedule Acceleration**
3. **Project Intensity Curve – Cost / Schedule Inherent Behavior**



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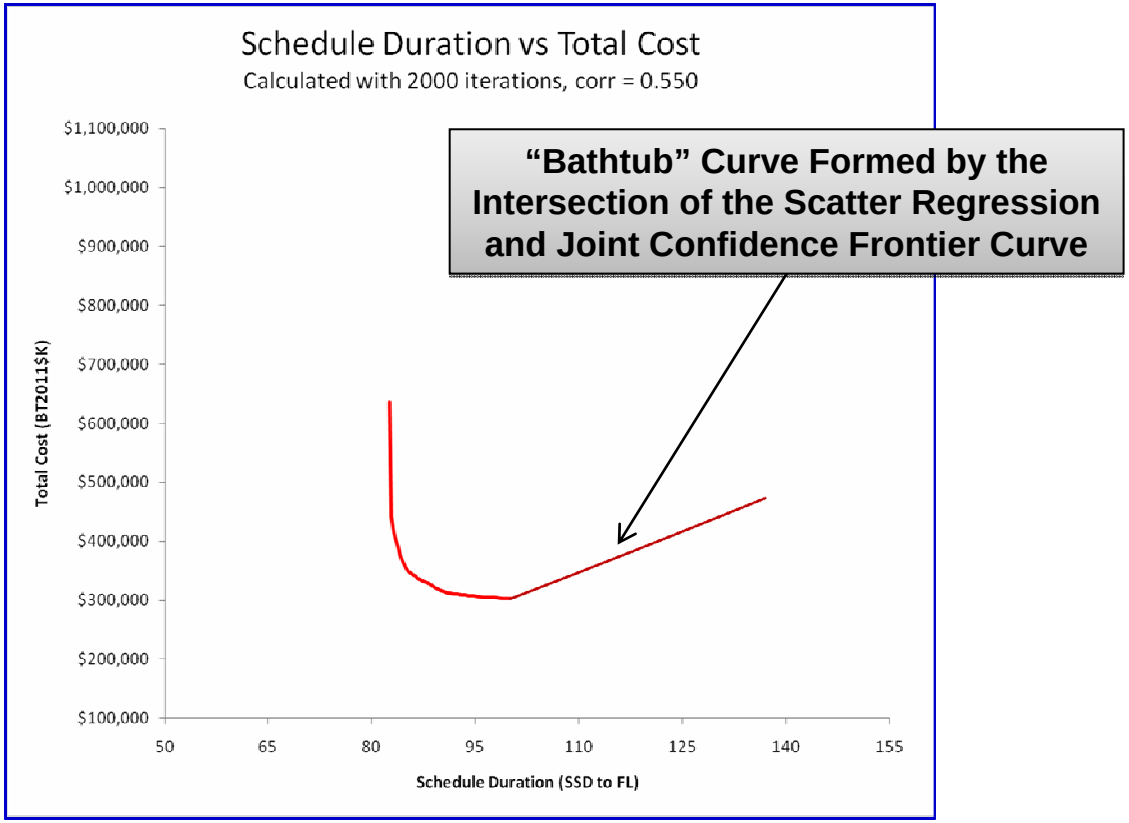
JCSM in Action - Cost Penalty Curves

- **Cost/Schedule Penalty curves can be generated from Frontier Curves and Regression Lines**



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