Deciphering JCL

How to use the JCL scatterplot and isocurves

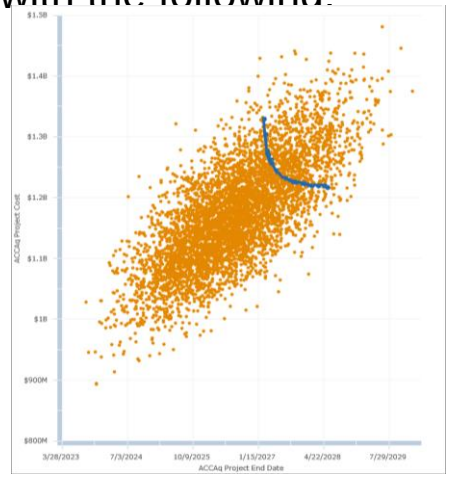
Eric Druker

2013 NASA Cost Analysis Symposium

Integrated Cost and Schedule Risk Analysis (ICSRA) is quickly growing in popularity in both the public and private sectors

- Programs have recognized that, while traditionally treated separately, cost, schedule, and risk are inherently linked and need to be analyzed in an integrated manner
- NASA has even gone so far as to formalize ICSRA through their agency-wide Joint Confidence Level (JCL) policy
- NPR 7120 requires base programs and projects involved in space flight and information technology:
  - Be baselined or rebaselined and budgeted based on a *joint cost and schedule probabilistic analysis* developed by the program or project in accordance with the following:

Programs are to be baselined or rebaselined and budgeted at a confidence level of 70 percent or the level approved by the decision authority of the responsible Agency-level management council. *For a 70 percent confidence level, this is the point on the joint cost and schedule probability distribution where there is a 70 percent probability that the project will be completed at or lower than the estimated amount and at or before the projected schedule*. The basis for a confidence level less than 70 percent is to be formally documented



Source: NPD 1000.5A

Policies such as NASA's have lead to programmatic decisions being made based on results captured as bivariate distributions

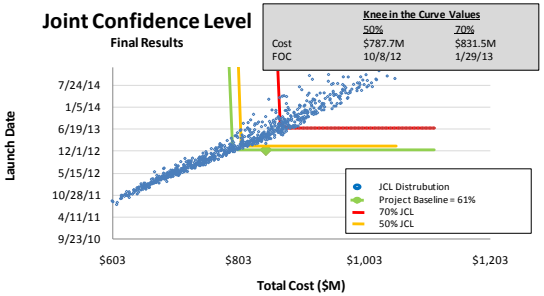
- JCLs are captured as results from a bivariate distribution
- Bivariate distributions are an order of magnitude more complicated to understand than the S-Curves cost estimators, and the decision makers we serve, are used to seeing
- This has lead to common misinterpretation/misrepresentation of JCL results
- This presentation will focus not on the ICSRA methodologies themselves but rather their associated scatterplot and isocurve outputs, the meanings behind these outputs, and how to interpret (and not interpret) them
  - A brief introduction to ICSRA will be provided for the indoctrinated
- Specific topics to be discussed include:
  - The JCL Scatterplot – Where does it come from and how do we calculate a JCL isocurve?
  - The JCL ISO Curve – What does it tell us (and not tell us) ? How can we best use it?
- The presentation will conclude with recommendations for analysts and policy makers using JCL isocurves to set program budgets and plans

Several methodologies are available for performing ICSRAs with their use depending on program phase and available artifacts

Joint Risk Analysis:

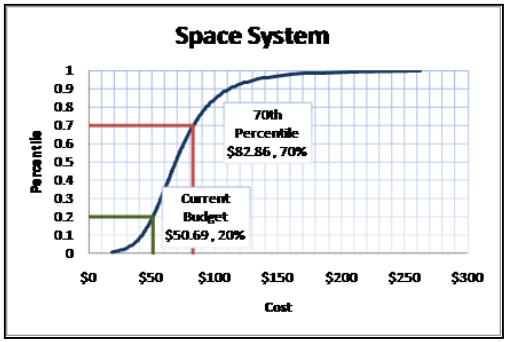
- Cost Loaded Schedule-Based Simulation (NASA Policy)
- Multivariate Regression

Joint Risk Analysis methods estimate cost and schedule simultaneously; JCL scatter plot produced directly from analysis



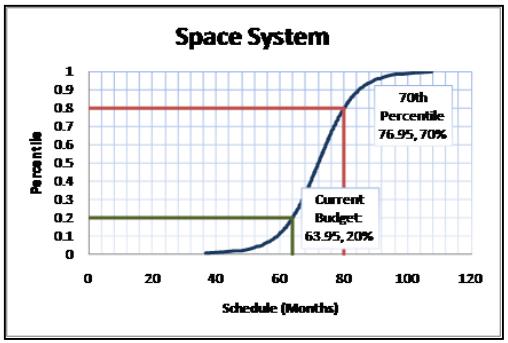
Cost Risk Analysis:

- Inputs-Based Simulation
- Outputs-Based Simulation
- Scenario Based
- Parametric Analysis



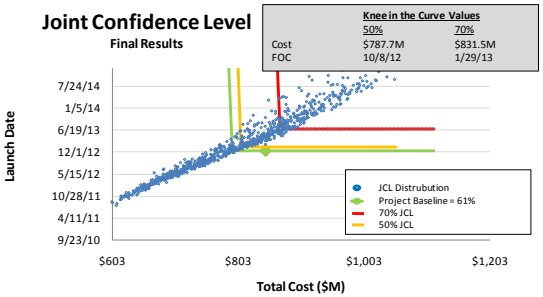
Schedule Risk Analysis:

- Parametric Analysis
- Schedule-Based Simulation



When Joint Risk Analysis methods are not used, cost and schedule risk analyses must be combined using a Monte Carlo simulation

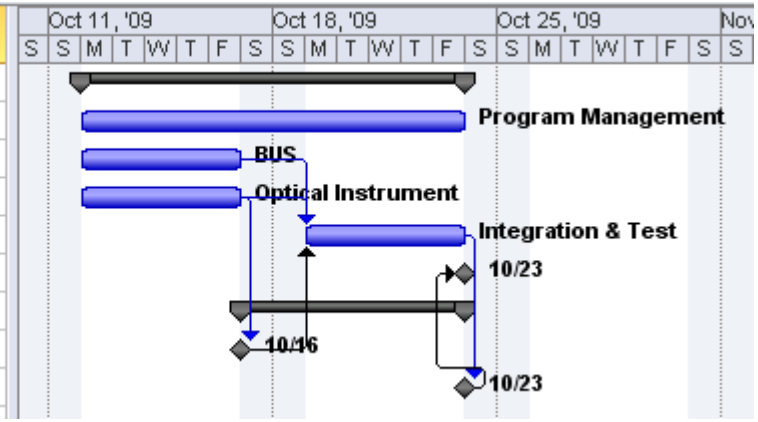
Monte Carlo Simulation



When risk analyses are combined, care must be taken to ensure results are compatible

The fundamental theory of ICSRA is that cost and schedule growth are intrinsically linked

	Task Name	Duration	Start	Finish	Cost	Fixed Cost	Resource Names
1	**Firesat Program**	**10 days**	**Mon 10/12/09**	**Fri 10/23/09**	**$23,400.00**	**$0.00**	
2	Program Management	10 days	Mon 10/12/09	Fri 10/23/09	$8,000.00	$0.00	Program Management
3	BUS	5 days	Mon 10/12/09	Fri 10/16/09	$4,600.00	$1,000.00	BUS
4	Optical Instrument	5 days	Mon 10/12/09	Fri 10/16/09	$5,000.00	$1,000.00	Optical Instrument
5	Integration & Test	5 days	Mon 10/19/09	Fri 10/23/09	$5,800.00	$1,000.00	Integration & Test
6	Launch	0 days	Fri 10/23/09	Fri 10/23/09	$0.00	$0.00	
7	**Risks**	**5 days**	**Fri 10/16/09**	**Fri 10/23/09**	**$0.00**	**$0.00**	
8	Late Delivery of FPA	0 days	Fri 10/16/09	Fri 10/16/09	$0.00	$0.00	Optical Instrument
9	Additional Therm Testing	0 days	Fri 10/23/09	Fri 10/23/09	$0.00	$0.00	Integration & Test

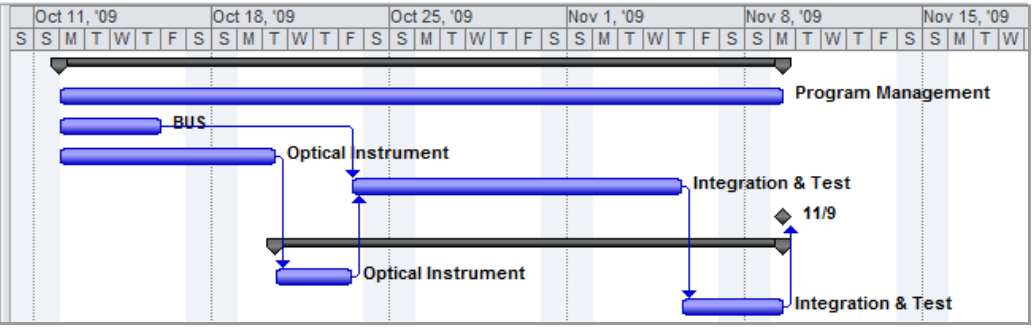


Cost Uncertainty

Risks

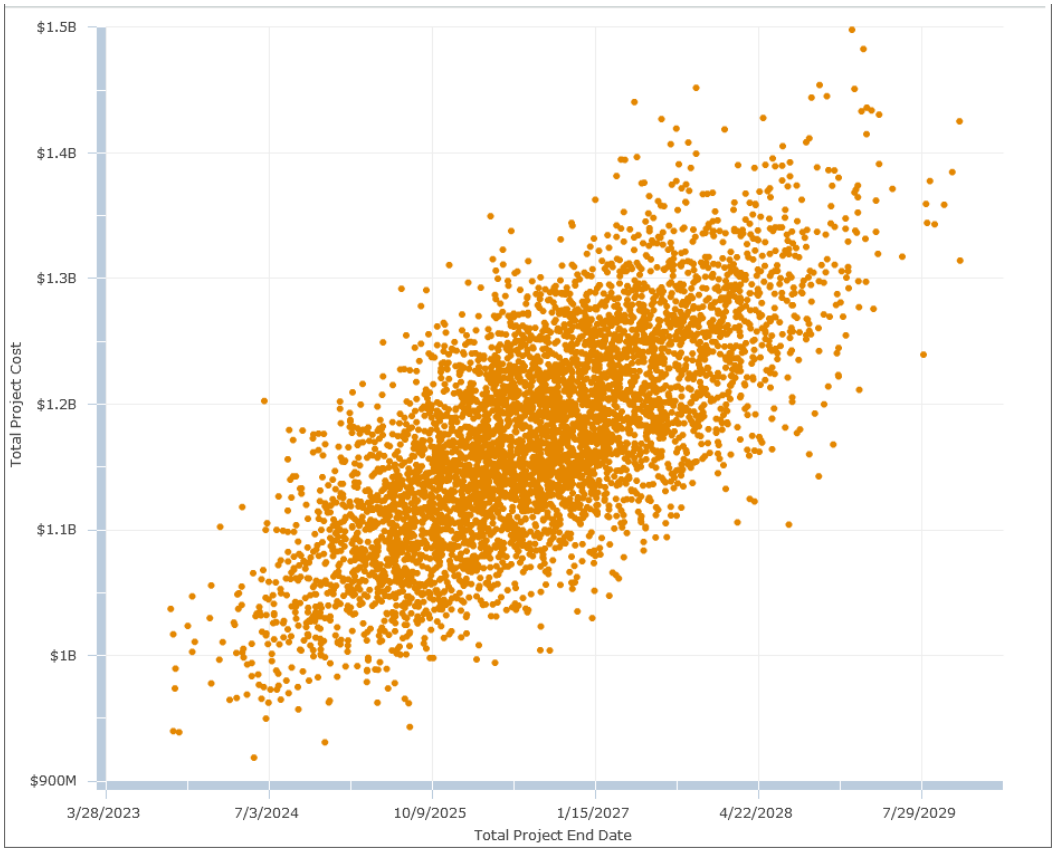
Schedule Duration Uncertainty

	Task Name	Duration	Start	Finish	Cost	Fixed Cost	Resource Names
1	**Firesat Program**	**20.5 days**	**Mon 10/12/09**	**Mon 11/9/09**	**$42,040.00**	**$0.00**	
2	Program Management	20.5 days	Mon 10/12/09	Mon 11/9/09	$16,400.00	$0.00	Program Management
3	BUS	4 days	Mon 10/12/09	Thu 10/15/09	$3,580.00	$700.00	BUS
4	Optical Instrument	6.5 days	Mon 10/12/09	Tue 10/20/09	$6,000.00	$800.00	Optical Instrument
5	Integration & Test	9 days	Fri 10/23/09	Thu 11/5/09	$9,740.00	$1,100.00	Integration & Test
6	Launch	0 days	Mon 11/9/09	Mon 11/9/09	$0.00	$0.00	
7	**Risks**	**14 days**	**Tue 10/20/09**	**Mon 11/9/09**	**$6,320.00**	**$0.00**	
8	Late Delivery of FPA	3 days	Tue 10/20/09	Fri 10/23/09	$4,400.00	$2,000.00	Optical Instrument
9	Addditional Therm Testi	2 days	Thu 11/5/09	Mon 11/9/09	$1,920.00	$0.00	Integration & Test



The JCL scatterplot represents points sampled from the bivariate distribution of cost and schedule

- For parametric analyses the scatterplot only exists where Monte Carlo simulations have not been run
- For non-parametric analyses, or parametric analyses where marginal distributions have been combined through a simulation, each point on the scatterplot represents a single iteration of the simulation
  - Each point represents one potential outcome for the program's final cost and schedule
- Oftentimes this scatterplot is available at all levels where costs have been mapped to the schedule



The JCL isocurve is a collection of cost and schedule pairs where there is a 70% probability that both are achieved

- Meeting a 70% (or any %) JCL can be achieved in many ways
  - 80% Confidence Level (CL) for both cost and schedule[1]
  - 100% CL for cost, 70% CL for schedule
  - 70% CL for cost, 100% CL for schedule
- To meet NASAs (or any) JCL requirement a program can be budgeted/planned at any point along this isocurve

[1]This is just an example set of marginal CL solutions. Marginal CLs satisfying a JCL are program specific and are dependent on many factors including the correlation between cost and schedule

JCL isocurves have been presented and marketed as giving programs insights that they simply do not provide

- Over the past few years, I have heard, or seen in writing, the following incorrect statements:
  1. JCL isocurves allow a program the ability to trade-off cost and schedule
  2. JCL isocurves allow a program the ability to see the cost impact of constraining a schedule
  3. Any point on the JCL isocurve is valid way to budget/plan a program

- Sometimes, these statements are corrected with the caveat of *while maintaining an X% joint confidence level*
  - Unfortunately most analysts and decision makers are missing the subtle, but important, distinction captured in this caveat

- Over the next several slides I will attempt to:
  1. Explain the JCL metric using a concise analogy
  2. Demonstrate how developing budgets/plans based on the JCL isocurve can lead to cost and schedule growth when not accounting for conditional distributions
  3. Make recommendations for how ICSRA and the associated JCL isocurve can be more accurately used for programmatic decisions

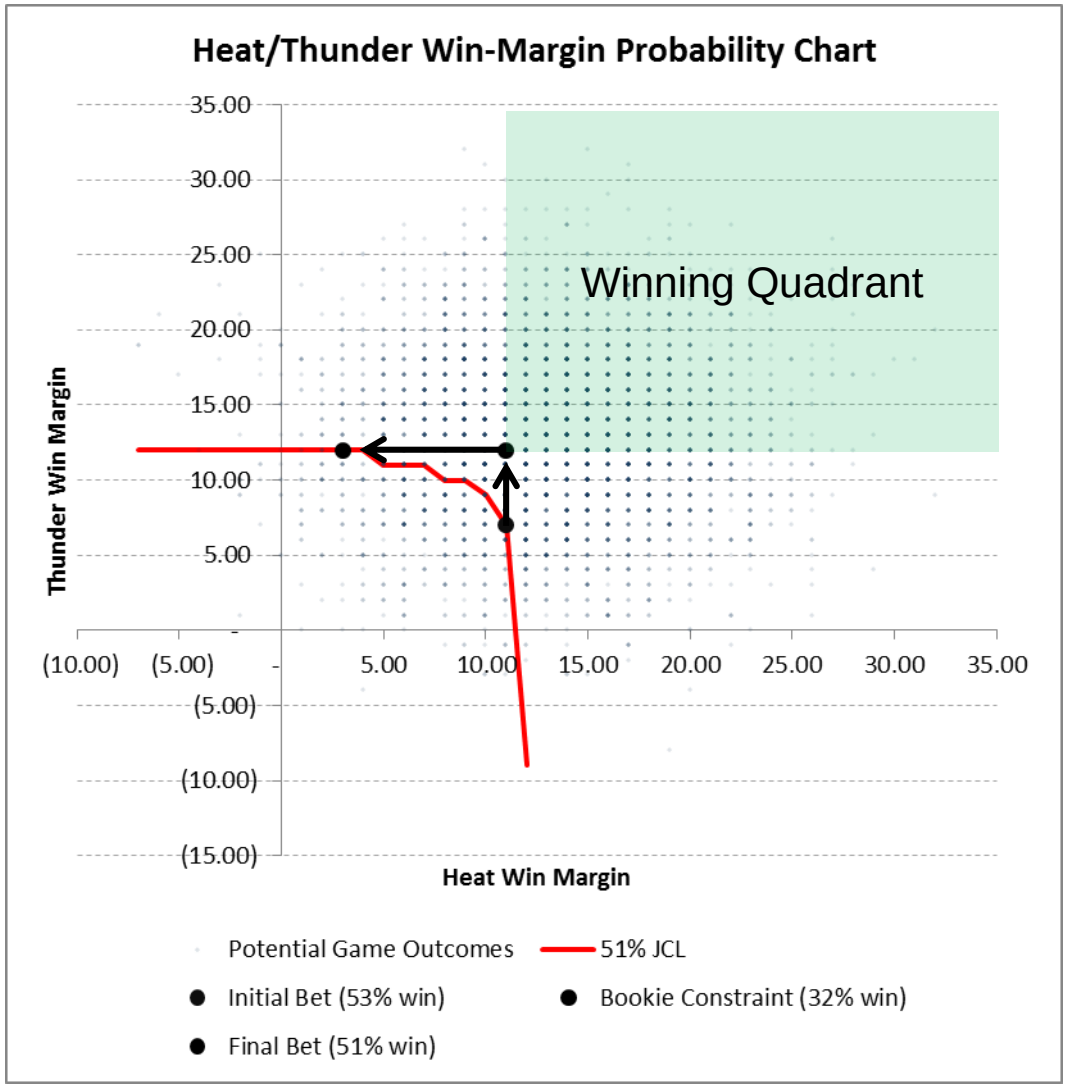
JCL isocurves can best be understood using an analogy to parlay bets[1]

- A parlay is a single bet linking together two or more individual wagers and is dependent on all of those wagers winning together[2]
  - Parlay bets are paid out at higher odds than single game bets due to the additional risk associated with them
- For example, let's say I place a two-team NBA parlay bet on the Heat (-11) over the Celtics and the Thunder (-7) over the Lakers
  - To win this bet, the Heat will need to win by 12 or more points and the Thunder by 8 or more points
  - Based on a detailed statistical analysis, I believe there is a 62% probability the Heat will cover and an 85% probability the Thunder will cover
- Assuming the outcomes of these games are uncorrelated[3] I can multiply their individual win probabilities to find that I have a 53% probability of winning the parlay – making it a good wager
  - This means my wager is essentially at the 53% JCL

[1]This analogy initially arose out of a conversation with Erik Burgess [2]Source: Wikipedia
[3]A potentially spurious assumption in today's NBA (See 2000 and 2002 Western Conference Finals)

JCL isocurves can best be understood using an analogy to parlay bets

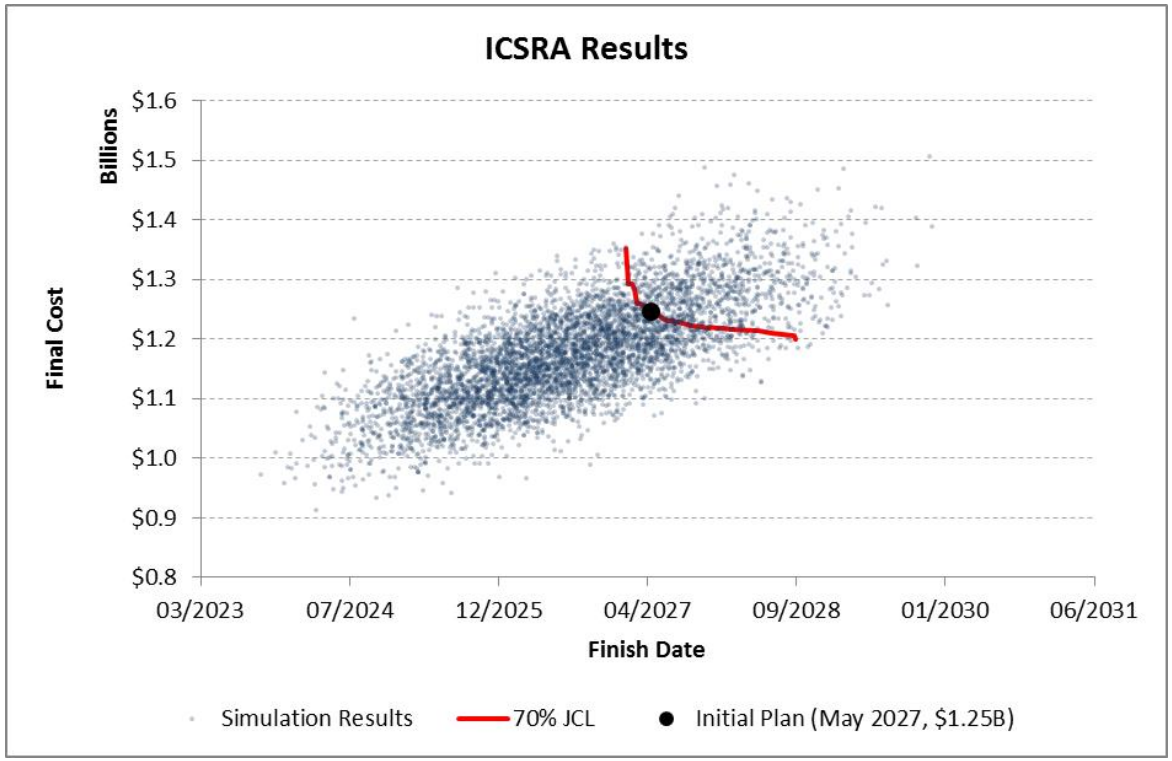
- Let's suppose that my bookie comes back to me and said he could only accept a parlay bet where the Thunder line is (-12)
  - This reduces my probability of winning the Thunder half of the bet to 53% and the probability of winning the parlay to 32%
- In order to maintain a >50% probability of winning my bet I need to convince my bookie to lower the line on the Heat from (-11) to (-3)
  - This increases my probability of winning the Heat half of the bet to 95%
  - This results in a 51% probability of winning the parlay bet
- This analogy is how some programs are currently using ICSRA
  - Cost and schedule are traded off up and down an isocurve to meet a JCL



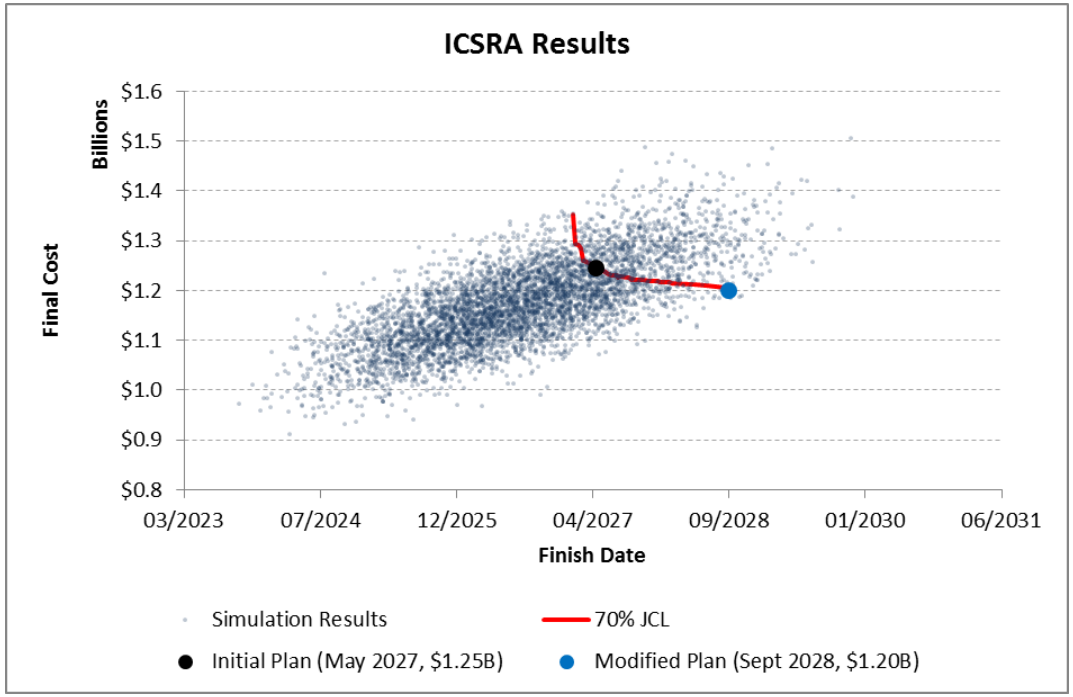
JCL isocurves have been presented and marketing as providing programs the ability to trade-off cost and schedule

- In ICSRA there is a causal relationship between cost and schedule inhibiting the extension of the parlay bet trade-off example to program management

- To explore this further, let us examine a program as it works to achieve a 70% JCL under two scenarios
  1. A constrained budget
  2. A constrained schedule



In the first scenario, the program has a budget constraint of $1.2B, $50M below their initial plan



- To meet their 70% JCL requirement, the program plans to budget at a point on the tail of their JCL isocurve
  - By extending the schedule to September 2028 the program can budget at $1.2B and still meet their 70% JCL requirement
- While technically meeting their JCL requirement, let's look at what would happen if the program actually slipped to their new date

To determine the likely cost outcomes for any end date the conditional distribution must be calculated

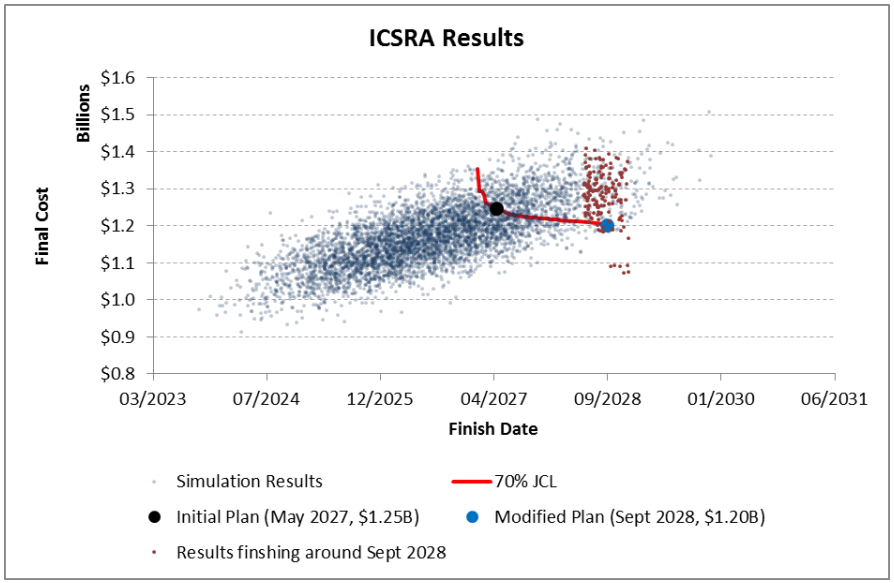
- To continue the analysis, a method for calculating conditional distributions from a JCL scatterplot needed to be developed

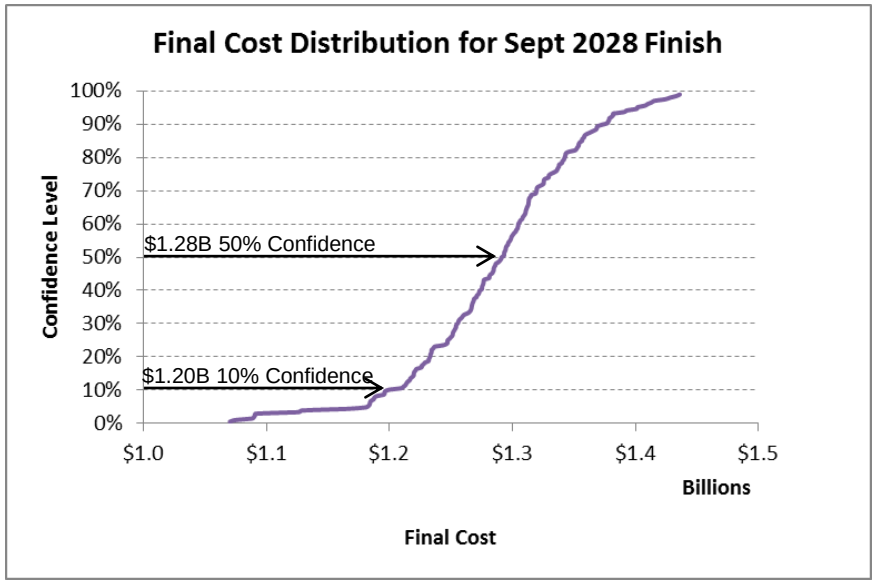
- The following methodology is proposed for calculating conditional distributions of cost on a particular finish date
  - Calculate the absolute value of the difference between the finish date for each point on the JCL scatterplot and the finish date in question
  - Capture the finish date and final cost for the closest 200 trials (4% if the simulation involved 5,000 iterations)
  - Sort these 200 trials in ascending order and convert them into a cumulative distribution – these points represent the conditional distribution

- The author recognizes that there may be a more robust mathematical solution to this problem and leaves it to further research

- This methodology was selected because it is straightforward enough to be applied by most analysts without requiring an advanced degree in statistics
  - On a side note, developing this methodology for calculating conditional distributions took longer than writing the entire rest of the paper

If the schedule slips 16 months to September of 2028 the program is likely to grow in cost to $1.28B



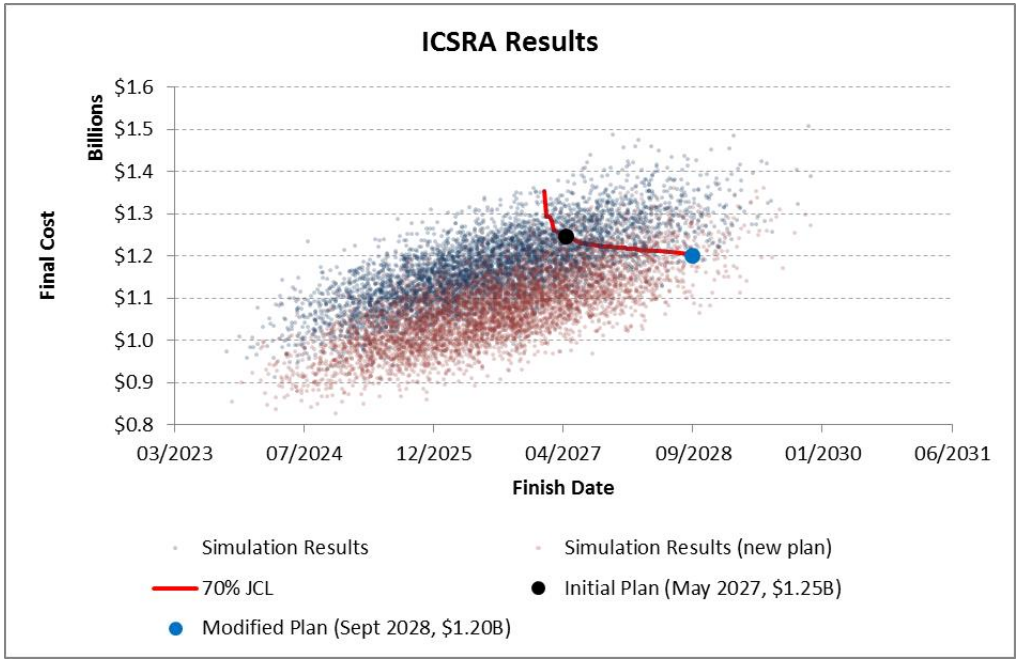


- The scatterplot on the left shows the closest 200 trials to the September 2028 planned finish date
  - It is visually apparent that the budgeted cost is on the low end of the potential final cost outcomes associated with finish date

- Using the methodology from the previous slide provides two further insights:
  - If the planned schedule of September 2028 is achieved, the planned budget of $1.2B is at the 10% confidence level
  - The most likely cost estimate associated with this plan is $1.28B - $80M over the constrained plan and $30M over the initial plan

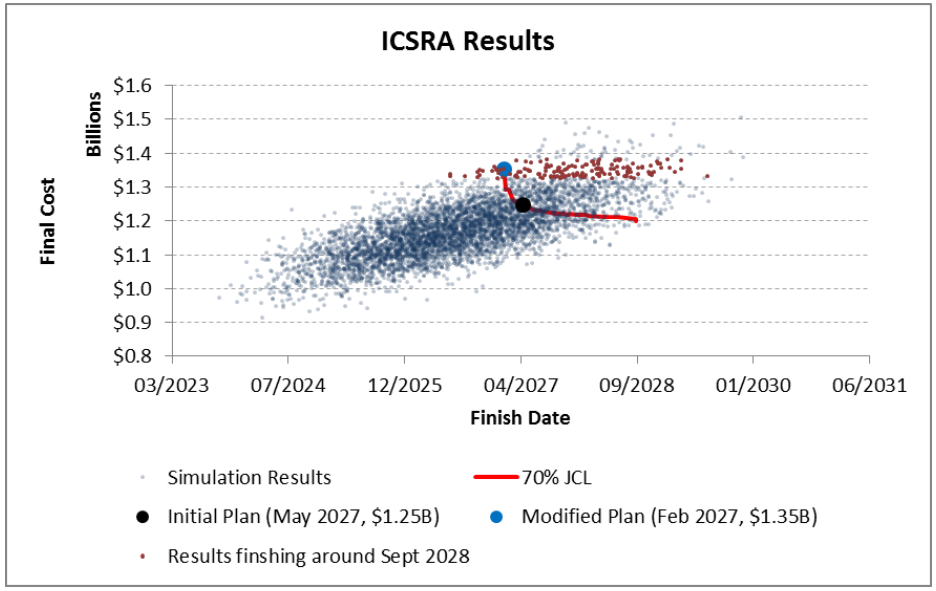
Planning to this JCL will almost certainly ensure the program grows in cost above even its unconstrained plan

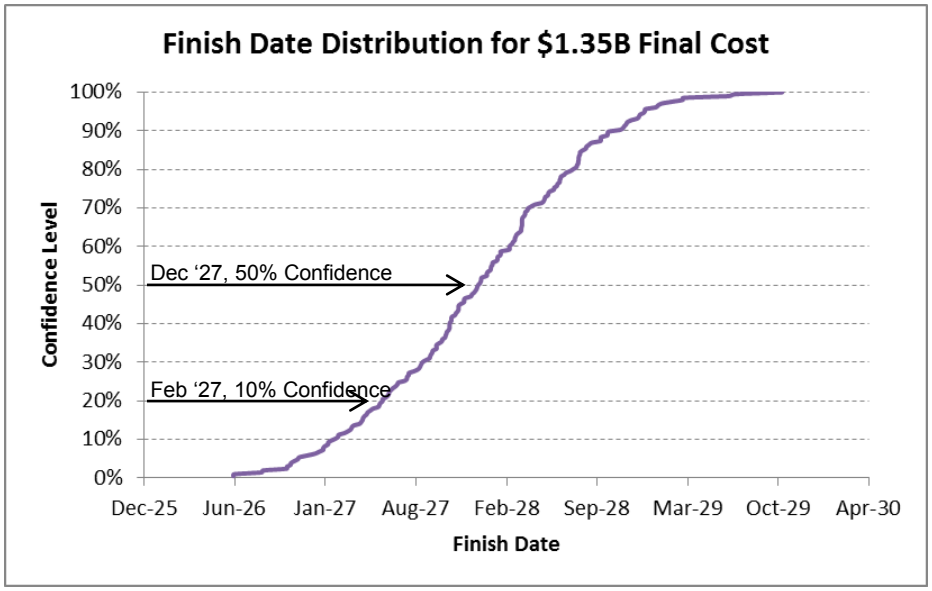
- Programs will tend to use all of their available schedule resulting in a higher final cost than the plan from the JCL curve
- This is an example of how misrepresenting or misinterpreting JCL isocurves can cause a program to grow in cost
- Rather than relying on JCL isocurves, programs should modify the program to reduce overall cost and schedule
- Modification could include the following
  - Removing scope
  - Re-planning activities
  - Mitigating risks
- As these actions are proposed, the ICSRA should be re-run so that their impact on the program can be predicted



In the above example, scope has been removed and risks mitigated. This has resulted in a JCL scatterplot where the constrained budget is at a higher conditional confidence level

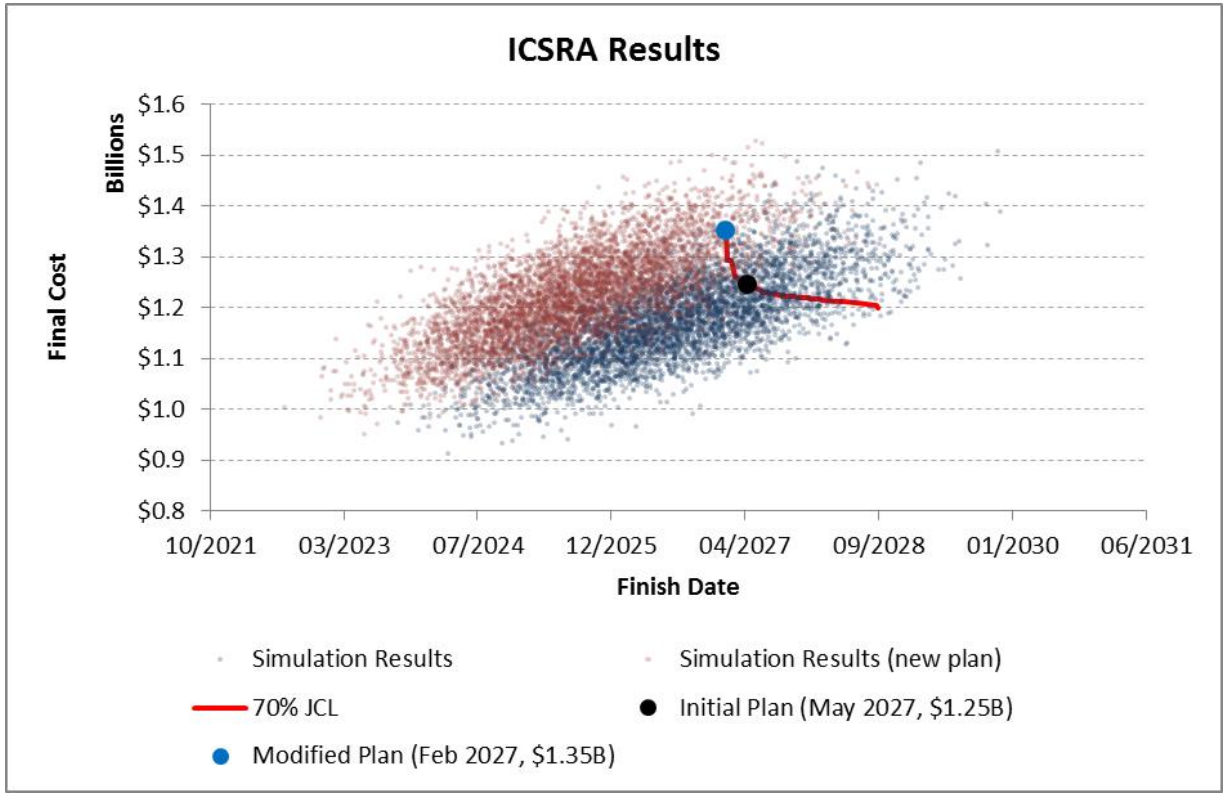
Looking at the previous example from the opposite direction, JCL isocurves do not show the cost impact of constraining a schedule





- If the program has a constrained finish date of February 2027 its budget can be raised to $1.35B in order to maintain its 70% JCL
- However, this schedule is at the 10% confidence level
- If costs rise to the budget of $1.35B, under the current plan the program is likely to grow 9 months to December of 2027
  - And what program manager doesn't use their available budget?

To meet a constrained schedule the program will need to change their plan and rerun the ICSRA model



In the above example, activities have been compressed causing costs and risk levels to rise. This has resulted in a JCL scatterplot where the constrained schedule is at a higher conditionall confidence level

JCL can be a useful metric for ICSRA but conditional distributions are even more important

- Policy makers should recognize the limitations of the JCL isocurve and create policies accounting for marginal distributions
  - Example: Programs should be budgeted and planned at the 70% Joint Confidence Level while assuring that the cost and schedule associated with that budget and plan are at least at the 50% confidence level
  - A methodology has been presented for calculating conditional probabilities

- Analysts should not ascribe more value to the JCL metric than it provides
  - Moving up and down the JCL isocurve **does not:**
    - Allow programs to trade-off cost and schedule
    - Allow programs to see the cost impact of accelerating schedule
  - Each of these requires that the ICSRA model be re-run with the alternate plan