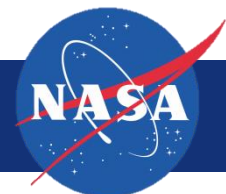


# Bridging the Gap

## Linking Parametric Estimating to Program Management (LPEPM) Task

ICEAA Presentation  
June 2014

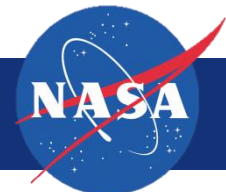
Ted Mills	NASA Cost Analysis Division
Mike Smith	Booz Allen Hamilton
John Swaren	PRICE Systems



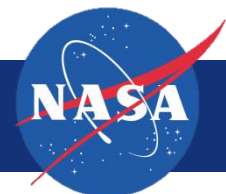
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  - Thought Experiment: JCLs and narrow CVs



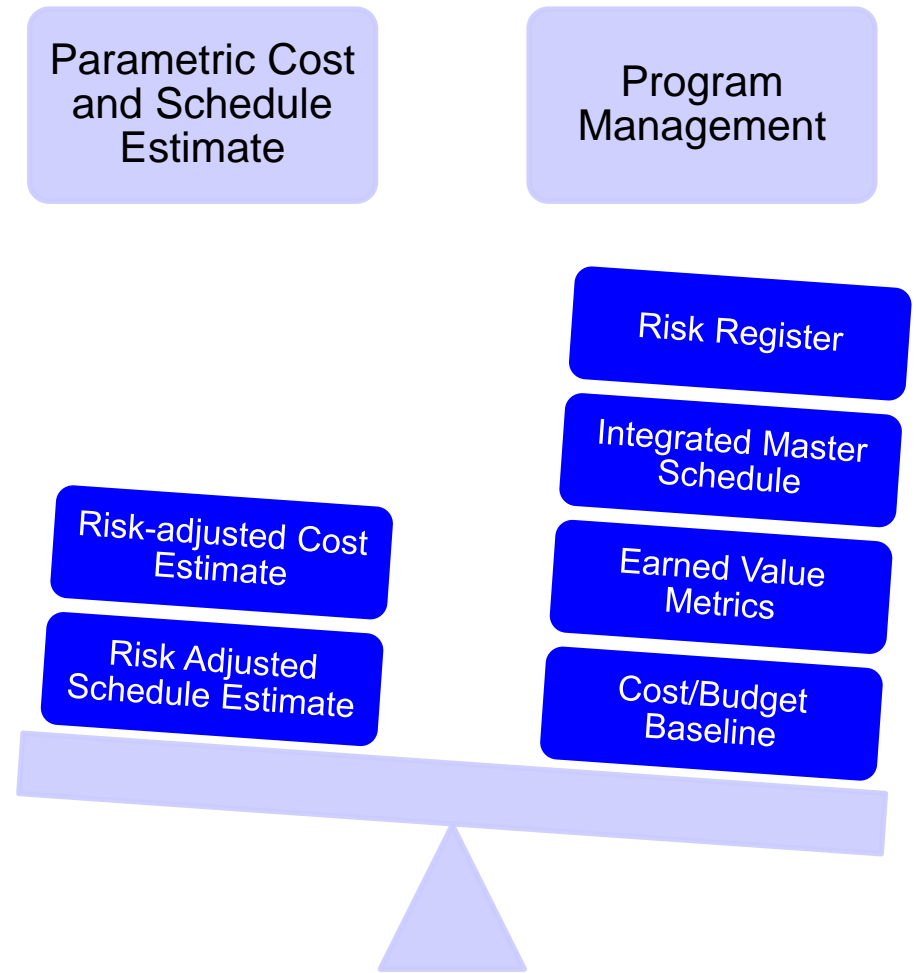
# INTRODUCTION & BACKGROUND



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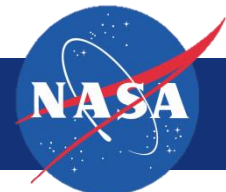
# Using today's methodologies, parametric and programmatic analyses are incompatible

- ▶ Program analyses on the IMS and cost baseline are typically performed at a low level and rely on SME uncertainty parameters; potentially calling into question the validity of the results
  - JCL analyses conducted at NASA have been observed to render unrealistically small CoVs compared to historical data
- ▶ Parametric analyses, while based on historic data and justifiable, do not tie to the program artifacts
  - Similarly, programmatic performance data is rarely incorporated into parametric analyses
  - This limits their usefulness as it is difficult for PMO staff to make sense of the results
- ▶ These challenges have resulted in a pervasive culture where parametricians are put at odds against the program management community
  - Parametric cost and schedule estimates are used for budget formulation. Once they have been used to establish the initial baseline, the linkage between them and the programmatic artifacts (budget, IMS, risk register) is typically broken

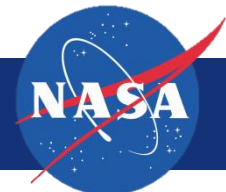


# LPEPM Defined

- ▶ **LPEPM has become a pronoun... One that bears definition so that we share a common understanding**
  - LPEPM = “Linking Parametric Estimates to Program Management [Artifacts]”
  - The core hypothesis is that we can make parametric estimates more meaningful to PMs, and maintain or restore the relevance and value provided by parametricians throughout the project life cycle, by taking elementary steps early on in our own process to align parametric cost estimates to programmatic artifacts.
- ▶ **LPEPM is NOT**
  - A cost model
  - An estimating tool
  - A dashboard
- ▶ **LPEPM is**
  - A philosophy – a call to the cost community to help our own cause by considering our PM brethren when generating estimates
  - An approach – a modest addition to the means we already employ to generate parametric estimates
  - A process – a research based, repeatable, step-by-step methodology for linking parametrics to programatics



# THE RESEARCH SPRINT

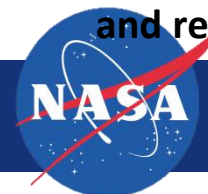


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# **This research endeavored to bridge the gap between parametrics and programmatics using a real-world case study**

- ▶ **Select a Test Case upon which both a JCL and parametric estimate have been performed**
  - LPEPM team selected a [major component of an ongoing developmental space flight hardware] as its test project
  - [The Program in question] had recently performed its JCL analysis using the Polaris tool
  - Cost Estimators from the local NASA Center had recently performed a parametric estimate on [the same component] using the TruePlanning tool
  
- ▶ **Convene a multi-disciplinary team for a week to explore models, methods, and processes**
  - LPEPM “Research Sprint” invited parametricians, model builders, SW developers, coders, mathematicians, cost estimators, schedule analysts, risk experts, JCL practitioners
  - Research Sprint was held November 4-8 at Booz Allen Hamilton offices in Herndon, VA
  
- ▶ **Structure the effort; Define the outcomes**
  - The workshop was defined around answering a specific, finite set of research questions
  - The team would physically map the parametric estimate to the JCL to compare each “apples-to-apples”
  - The team was charged with articulating a defined process for linking parametric estimates to Program Management artifacts, and to propose and prototype any tools needed to enable the effort

**This presentation provides a hi-level description of the process used for the case study, with observations and recommendations, followed by a step-by-step process for linking parametrics to programmatics**



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# Three Research Questions, Two Distinct Vernaculars

Project Managers (PM) and Cost Estimators (CE)

## 1. Question 1: How can parametrics reflect the impact of changes to requirements or technical baseline?

- **PM:** How can we use parametrics to estimate the additional time and resources required, and risks created, when changes are made to a project's requirements and/or technical baseline
- **CE** How can updated parametric cost and schedule estimates be overlaid on top of programmatic artifacts such as the IMS, risk register, and budget to show the additional time and resources required, and risks created, when changes are made to cost and schedule drivers

## 2. Question 2: How can parametric estimates be applied to strengthen and reinforce JCL?

- **PM:** How can JCL inputs be reinforced using parametric estimates based on cost and scheduled data from completed NASA projects
- **CE:** How can JCL inputs be reinforced using cost and schedule data from completed NASA projects and statistics from CERs and SERs

## 3. Question 3: How can parametrics be used to crosscheck JCL results?

- **PM:** How can JCL results be sanity checked for reasonableness using parametric estimates based on cost and schedule data from completed NASA projects
- **CE:** How can metrics from JCL results (CV of cost and schedule, correlation between cost and scheduled, etc.) be crosschecked against cost and schedule data from completed NASA projects and statistics from CERs and SERs



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# LPEPM Research Sprint Team

The Research Sprint brought together leading industry experts in cost estimating, scheduling, and risk management to tackle the three research questions.

## ► PRICE Systems SMEs

- Arlene Minkiewicz
- Bruce Fad
- Melissa Winter
- Bob Koury
- John Swaren

## Special Thanks to NASA staff for their support:

- J.C. Atayde
- Melek Ferrara
- Wes Archiable
- Charles Hunt
- Ted Mills

## ► Booz Allen SMEs

- Eric Druker
- Tom Dauber
- Graham Gilmer
- Ken Odom
- Mike Cole
- Wes Archiable
- Mike Smith
- Brandon Herzog
- Nisha D’Amico
- Marina Dombrovskaya



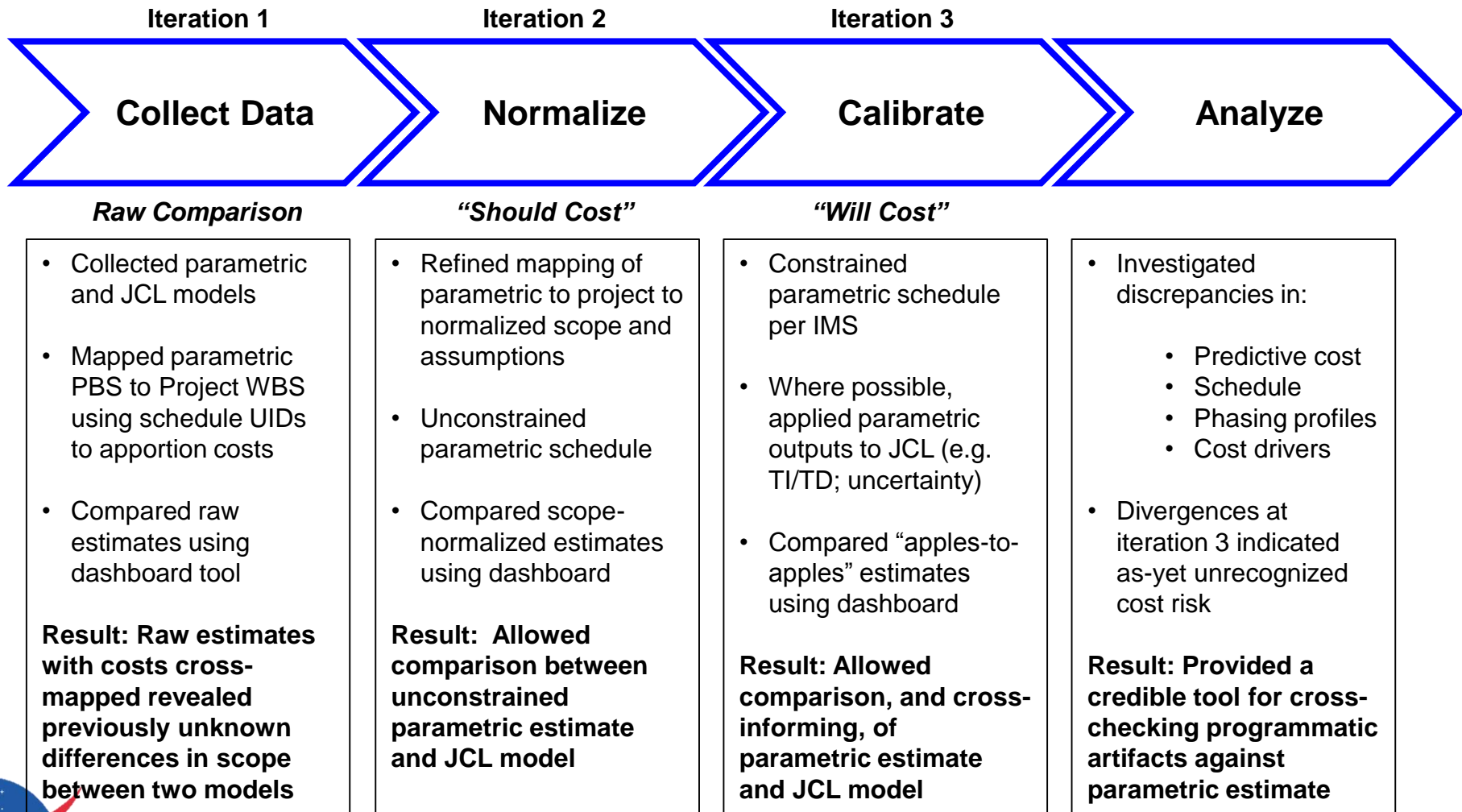
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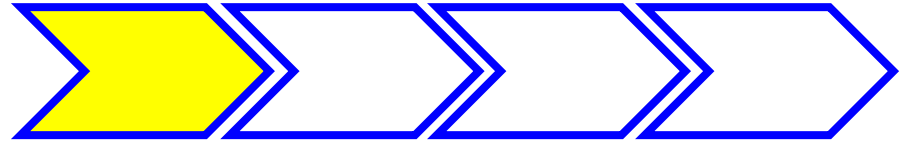
# LPEPM STEP-BY-STEP



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# Research team attempted to link the COST OFFICE parametric estimate to the Program's own JCL model



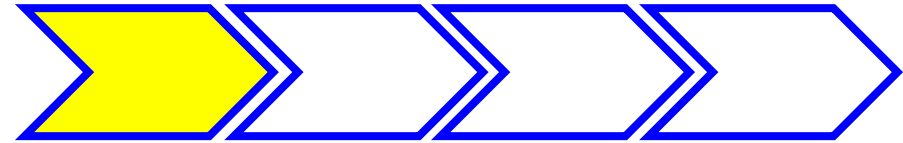


## Step 1: Collect Data

The first step the LPEPM Team took was to capture, juxtapose the Project estimates to the raw parametric estimate for direct comparison

- ▶ **We collected the Parametric Estimate & Outputs** from the Center Cost Team (TruePlanning), and exported to the Data Template
  - Predictive cost estimate / S-curve data points
  - Schedule output generated in TruePlanning (deterministic; but would have taken probabilistic if it existed)
  - Cost/Budget phasing data by year
  - Cost Driver data points (to produce or replicate any Tornado Chart outputs)
- ▶ **Collected [Program's] JCL inputs and outputs** from the [Program Team] (Polaris), and exported corresponding four data sets
  - If no JCL had existed, the Team would have used [Program's] existing probabilistic cost estimate, IMS, phasing plan, and risk list in lieu of JCL tool outputs
- ▶ **Mapped costs between the parametric and programmatic models** using IMS/JCL UIDs and mapping them to corresponding parametric model cost objects and activities until all costs are apportioned
- ▶ **Imported the templates into the Dashboard Tool to produce Iteration 1**

# Collect Data

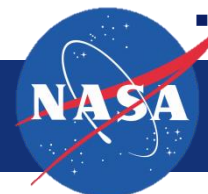


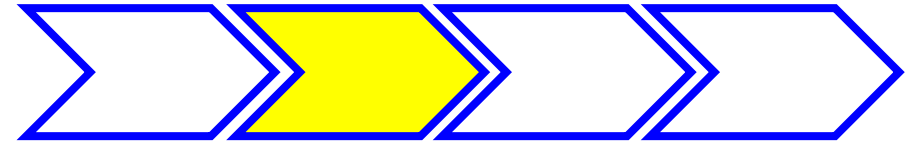
## ► PURPOSE

- Step 1 was designed to capture and juxtapose programmatic and parametric outputs **as they exist in their rawest form**, regardless of commonality of scope or degree of calibration, and to lay those outputs alongside one another in a common format for accessible, side-by-side comparison
- It serves as the starting point for initiating subsequent conversations about scope mapping and calibration
- Harvesting data for import into Data Templates will initiate the estimator to the process and complexities associated with finding and exporting proper, relevant data sets
- Dashboard Iteration 1 provides a visual reference against which to compare successive dashboard iterations

## ► OBSERVATIONS

- Most JCL tools currently available readily export outputs to Excel or XML. Even if a JCL has not been performed, it could expedite the process to attempt importing programmatic artifacts into a JCL tool
- Parametric models may rely on 3<sup>rd</sup> party intermediary applications (Crystal Ball, @Risk) to produce probabilistic outputs.
- For iteration 1, incorporate schedule data from the parametric tool as-is. If the initial parametric schedule is constrained, leave the constraints in place. If it is unconstrained, make no changes
- If the Project's programmatic artifacts are not sufficiently mature to integrate in a JCL tool, populating the template for the programmatic side could be considerably more labor intensive
- Do not worry if the parametric schedule is deterministic. It will show as a vertical line on the schedule Dashboard





## Step 2: Normalize

A common PM complaint about parametric estimates is that *“It doesn’t reflect my Project.”*

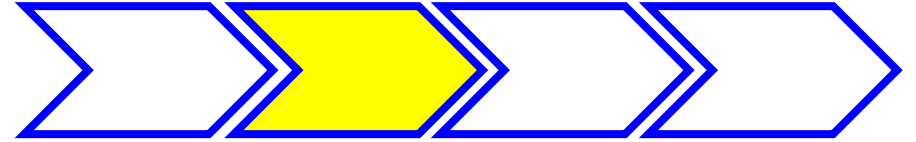
This step sought to normalize content scope and assumptions so that the parametric estimate covered the same content as addressed in programmatic documents (IMS & estimates).

- ▶ We revisited the Step 1 mapping of PBS to WBS, *this time to ensure scope aligned one-to-one*
- ▶ This revealed holes, overlaps and conflicts of scope and adjudicated with JCL analysts. ***Our intent was to get the parametric model to reflect scope as the Project captured it***
- ▶ **Removed schedule constraints in parametric schedule** to generate a “should cost” estimate

Cost Mapping		True Planning Mapping						
System Cost Object	Activity	JCL Start Dates	Project Initiation and Planning for Development	Project Management and Control for Development	Quality Assurance Management for Development	Configuration Management for Development	Documentation for Development	Project Initiation and Planning for Production
6008	Management	9/1/2011	100%	100%	0%	100%	0%	100%
6083	Safety and Mission Assurance		0%	0%	0%	0%	0%	0%
6016	Project - Design	9/1/2011	0%	0%	0%	0%	100%	0%
6084	Test & Evaluation	9/1/2011	0%	0%	0%	0%	0%	0%
2494	Project - SE&IT	9/1/2011	0%	0%	0%	0%	0%	0%
2728	Project - Manufacturing and Assembly	9/1/2011	0%	0%	0%	0%	0%	0%
2729	Avionics	9/1/2011	0%	0%	0%	0%	0%	0%
4811	Propulsion		0%	0%	0%	0%	0%	0%
Assembly Cost Object			Requirements Definition and Analysis	System Design	Development Engineering	Development Manufacturing	Development Tooling and Test	Production Engineering
6008	Management	9/1/2011	0%	0%	0%	0%	0%	0%
6083	Safety and Mission Assurance		0%	0%	0%	0%	0%	0%
6016	Project - Design	9/1/2011	100%	100%	100%	0%	0%	TBD
6084	Test & Evaluation	9/1/2011	0%	0%	0%	0%	0%	0%
2494	Project - SE&IT	9/1/2011	0%	0%	0%	100%	100%	TBD
2728	Project - Manufacturing and Assembly	9/1/2011	0%	0%	0%	0%	0%	0%
2729	Avionics	9/1/2011	0%	0%	0%	0%	0%	0%
4811	Propulsion		0%	0%	0%	0%	0%	0%
Hardware Cost Object			Development Engineering	Development Manufacturing	Development Tooling and Test	Production Engineering	Production Manufacturing	Production Tooling and Test
6008	Management	9/1/2011	0%	0%	0%	0%	0%	0%
6083	Safety and Mission Assurance		0%	0%	0%	0%	0%	0%
6016	Project - Design	9/1/2011	0%	0%	0%	0%	0%	0%
6084	Test & Evaluation	9/1/2011	0%	0%	0%	0%	0%	0%
2494	Project - SE&IT	9/1/2011	0%	0%	0%	0%	0%	0%
2728	Project - Manufacturing and Assembly	9/1/2011	0%	100%	100%	TBD	TBD	TBD
2729	Avionics	9/1/2011	0%	0%	0%	0%	0%	0%
4811	Propulsion		0%	0%	0%	0%	0%	0%

**Unique IDs from the Program’s JCL mapped to parametric assembly and cost objects, then allocated across activities**

- ▶ We made no changes to Project (i.e. JCL) inputs at step 2. The aim was to get the parametric to mirror project docs before turning knobs
- ▶ Re-ran the Dashboard as Iteration #2



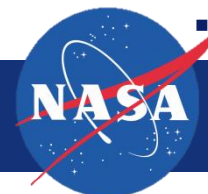
# Normalize

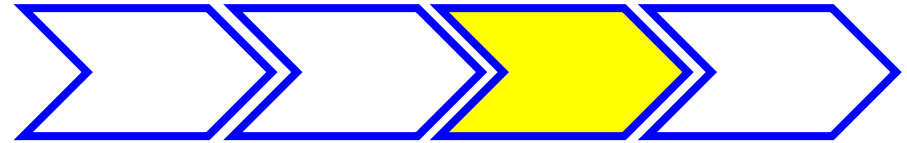
## ► PURPOSE

- Step 2 was intended to result in a scope-normalized “apples-to-apples” comparison of parametric to programmatic, in which the parametric model is adjusted to reflect content the way the Project does (builds credibility: starts to address the “that’s not my project” objection)
- Removal of schedule constraints in the parametric tool results in a cost-optimized schedule – based on generic logic contained in TruePlanning. While this is an abstraction, ***it provides a baseline against which to gauge the effect of compression or extension penalties incurred when project-based schedule constraints are applied in a subsequent step***
- The mapping activity provides a de-facto independent crosscheck of the Project IMS and technical scope coverage

## ► OBSERVATIONS

- The parametric tool we used is organized around a Product Breakdown Structure (PBS), while Project artifacts are based on a WBS, usually driven by the IMS. Mapping between the two in order to get the parametric model to reflect scope as the Project recognizes it is a critical step towards earning credibility with the PM
- Mapping was dense, tedious and time consuming. We had individuals from the parametric modeling side as well as from the Program’s JCL team cross-walking the two models. Some activities align 1-to-1 (management) but others are more obscure (e.g. design). Allow sufficient time for this and get the right people around the table
- Note that no change is made to any of the programmatic elements for Iteration 2. The goal is to bring the parametric into line with the programmatic
- Remove schedule constraints in the parametric tool, BUT retain a credible project start date so that phasing aligns



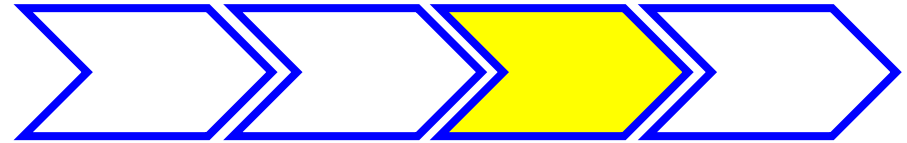


## Step 3: Calibrate

**The third step was intended to achieve two ends. (1) Inform the parametric model with enough Project-specific calibration to earn acceptance as a credible and valid crosscheck instrument. (2) To allow an opportunity for each model to inform the other**

- ▶ We constrained the parametric schedule with dates from the project's deterministic (not probabilistic) IMS
  - Captured and populated project start and end dates because the parametric model looks for Start/End dates of activity phases like design, manufacturing, I&T, etc
  - Lesson: Less is better. Err on the side of fewer schedule constraints than more. The intent of constraining the schedule is to trigger schedule compression/extension penalties contained within the model
- ▶ Adjusted key parametric inputs based on information available from the Project
  - Weight (mass) of structure vs. electronics (where available)
  - Organizational complexity, Functional Complexity, etc.
- ▶ Informed Project inputs/models based on Parametric inputs
  - Labor/Material assumptions in the parametric model were applied as overrides to JCL TD/TI assumptions
  - Team considered carrying over uncertainty from parametric to the JCL model





# Calibrate

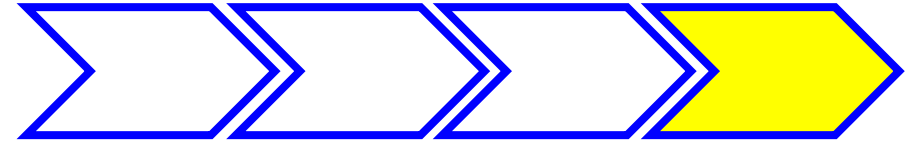
## ► PURPOSE

- Step 3 (and resulting Dashboard Iteration 3) is the first juxtaposition of parametric and programmatic estimates wherein the parametric model has been scope normalized and reasonably adjusted to reflect key realities of the Project, including schedule constraints informed by the Project's schedule.
- The opportunity to cross-calibrate is the means by which to allow the best elements of one model to be incorporated into the other. Iteration 3 provides an opportunity for the programmatic results to be re-run using inputs from the parametric model (if desired) to override existing inputs

## ► OBSERVATIONS

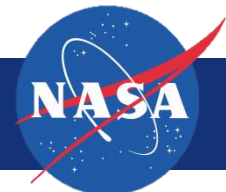
- Populating the Data Templates for each of the 3 iterations can be time consuming and should be factored into the analyst's production schedule. Our parametric tool uses a 3<sup>rd</sup> party application to run Monte Carlo simulations. Depending on the size of the models or the number of analysts with access to the tool, this can become a logjam
- When aligning the parametric schedule, a few key start/end dates work fine. Don't over-constrain
- Remember: the intent of this activity is to produce a credible independent crosscheck of Project artifacts as a means of (a) flagging potential blind spots (b) providing PMs and RMs with a different perspective on risk and cost drivers (c) providing a credible crosscheck of Project artifacts, findings, estimates and projections based on historical actuals captured in CERs. It is **not** the goal to have the two models arrive at the same estimate. Discrepancies between the two become potential areas for investigation
- The process is intentionally iterative, with the Dashboard specifically designed to capture each iteration for immediately accessible reference: All this is done as a means of buying credibility in the eyes of the PM for the parametric outputs as each iteration aligns the parametric more closely to something the PM recognizes

## Step 4: Analyze



- ▶ **With paired data sets presented visually alongside one another at three distinct iterations, the Dashboard enabled accessible observation and analysis. Divergences between the two models could be indicative of areas where potential cost risk resides or programmatic blind spots exist**
  - **Cost**
    - Do the JCL and parametric cost S-curves intersect? If they don't, the implication is that the Project's execution plan falls outside the historical record captured in parametric CERs (reality check). What discrepancies exist at the sub-element level and what accounts for them?
  - **Schedule**
    - In the parametric model, what is the effect on cost of constraining the schedule between Iterations 2 and 3? Is the model invoking compression or extension penalties? Is it doing so appropriately?
    - In Iteration 2, how close is the Project schedule to the unconstrained parametric schedule? Are there activities in the IMS whose duration diverges significantly from the "cost optimized" parametric schedule?
  - **Phasing**
    - Do the phasing curves look similar? Does each year fall within the expected budget for that year?
  - **Cost Drivers**
    - Parametric models offer a different take on cost drivers – from an input POV. It could interest a PM to observe the effect of weight or mission complexity or organizational maturity on the overall cost model

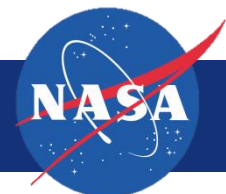
# OBSERVATIONS AND LESSONS LEARNED



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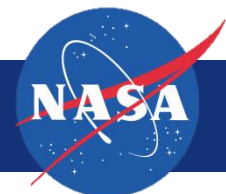
# Research team evaluated how compatible parametric outputs are with JCL model artifacts, inputs, and outputs

- ▶ JCL analyses currently lies at the edge of TruePlanning's capabilities – this study provides a roadmap on how it, and similar parametric tools, can develop capabilities to aid the JCL process
- ▶ **Compatibility was evaluated for three different JCL model components:**
  - JCL model artifacts: How can parametric estimates inform the cost estimate, schedule, and risk register
  - JCL inputs: How can parametric estimates inform the risk and uncertainty inputs in JCL models
  - JCL outputs: How can parametric estimates be used to cross-check JCL model outputs
- ▶ **Compatibility was measured on a low-medium-high scale**
  - High: JCL component can easily be directly informed by the parametric estimate
  - Medium:
    - JCL component can be informed by the parametric estimate however the necessary information is not readily available within the parametric tool **or**
    - Necessary information to inform the JCL component is readily available within the parametric tool but additional calculations are required to extract the data
  - Low: JCL component is not well informed by the parametric model
- **Goal is for parametricians and program analysts to work together to improve these metrics by applying methodology to more programs**



# Compatibility of parametric outputs with JCL components varies

JCL Component	Compatibility with Parametrics	Location in TruePlanning Model	LPEPM Reference Slide
<b>Model Artifacts</b>			
Schedule	Medium	Results Sheet – Schedule	Backup
Cost Estimate	High	Results Sheet – Cost Estimate	Backup
Risk Register	Medium	Input Sheet - Risk	Backup
<b>JCL Inputs</b>			
Schedule Uncertainty	Low	Available through COM API	Backup
Cost Uncertainty	Low	Available through COM API	Backup
TI/TD Breakout	High	Results Sheet – Cost Estimate	Backup
Correlation	Medium	Available through COM API	
Risks & Opportunities	Medium	Input Sheet - Risk	Backup
<b>JCL Outputs</b>			
Risk-Adjusted Schedule	Low	Available through COM API	Backup
Risk-Adjusted Cost Estimate	High	Results Sheet - Risk	Backup



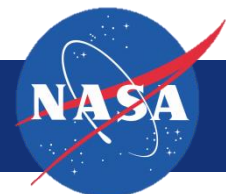
# The LPEPM team made several observations germane to both the parametric, JCL and PM communities

- 1. Linking parametric estimates to program management artifacts is possible and valuable**
  - Revealed inconsistencies in scope and assumptions between the two that could not have been uncovered otherwise
  - Provided a crosscheck for both estimates and, in limited cases, provided JCL model inputs
- 2. Parametric estimates and JCL models, more often than not, use different structures**
  - Parametric estimates often weight based, using structure from the Master Equipment List (MEL)
  - JCL models typically structured using the program's Work Breakdown Structure (WBS)
- 3. Structural misalignment between models, and their production by disparate groups, almost inevitably leads to estimates build using different assumptions**
  - Research team believed they had normalized estimates following initial mapping but a glance at the first dashboard revealed previously unknown inconsistencies between estimates
  - Truly normalizing the estimates was much harder than anticipated
  - Observations 1 and 2 raises question as to validity of parametric/programmatic comparisons where aforementioned process has not been performed



## Observations (continued)

4. **Today's parametric estimating tools lag in ability to estimate schedule – particularly schedule risk**
  - Capturing schedule risk from parametric models was possible, but difficult
5. **Validity of JCL analysis has been under question due to narrow Coefficients of Variation, as compared to parametrics, in results – research team believes this criticism is unfounded**
  - CERs likely have artificially large CVs since the data used to produce them come from multiple populations representing various way of executing a program
  - Since JCL models eliminate uncertainty around program execution they necessarily must have lower CVs than parametric estimates
  - Topic further explored in Druker Paper: “Moving Beyond Technical Parameters in our CERs”



# LPEPM RECOMMENDATIONS





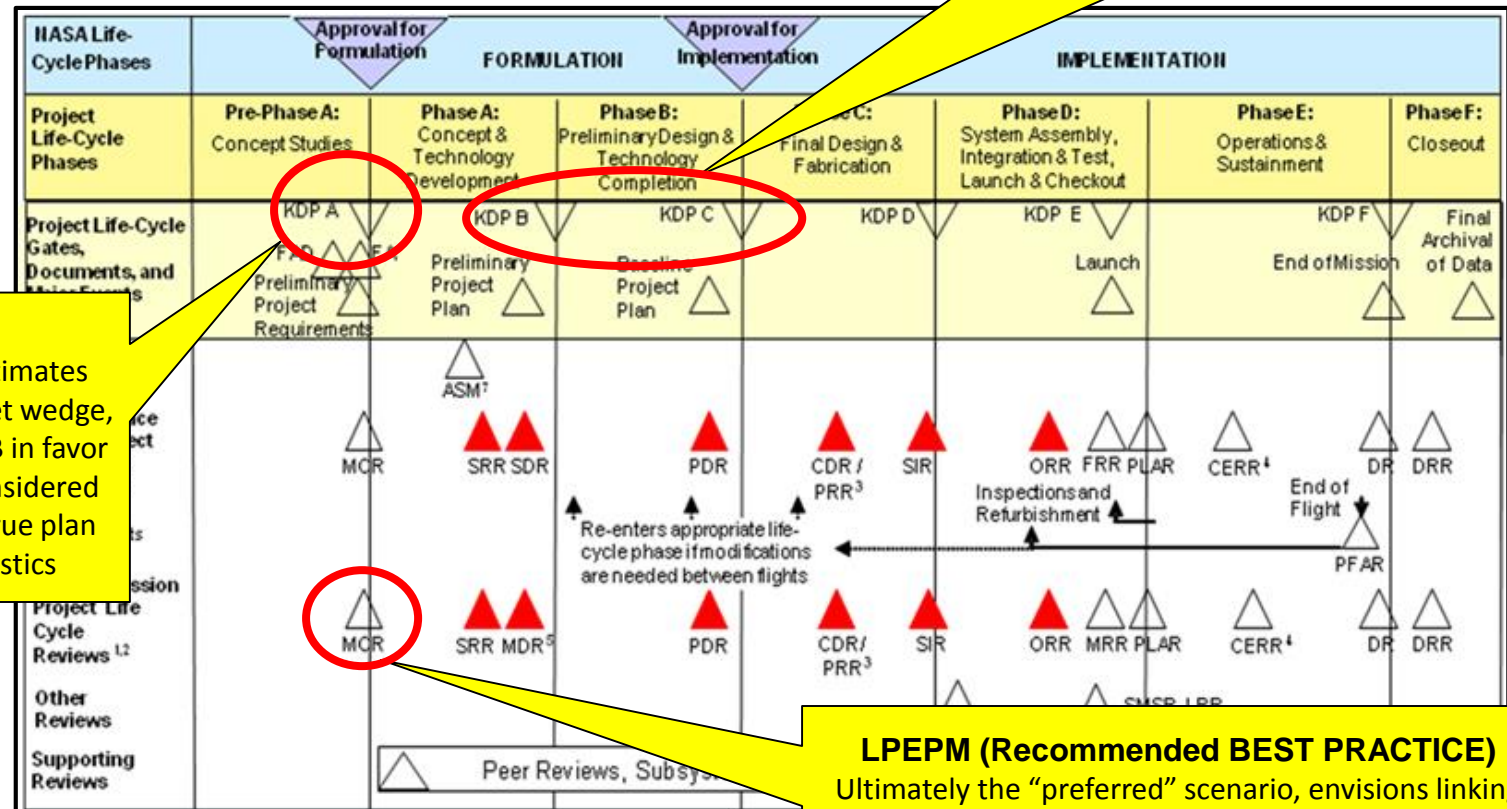
# LPEPM within the NASA Project Life Cycle

## LPEPM (Research Sprint)

Envisions a project with mature cost-schedule-risk artifacts, wherein an independently developed parametric model would have to align to the programmatic artifacts in order to earn credibility

## HISTORICALLY

Projects generate Parametric estimates around KDP-A to establish a budget wedge, but often abandon them by KDP-B in favor of the Project's own artifacts, considered more reflective of the Project's true plan and unique mission characteristics



NASA Project Lifecycle, from NPR 7120.5E

## LPEPM (Recommended BEST PRACTICE)

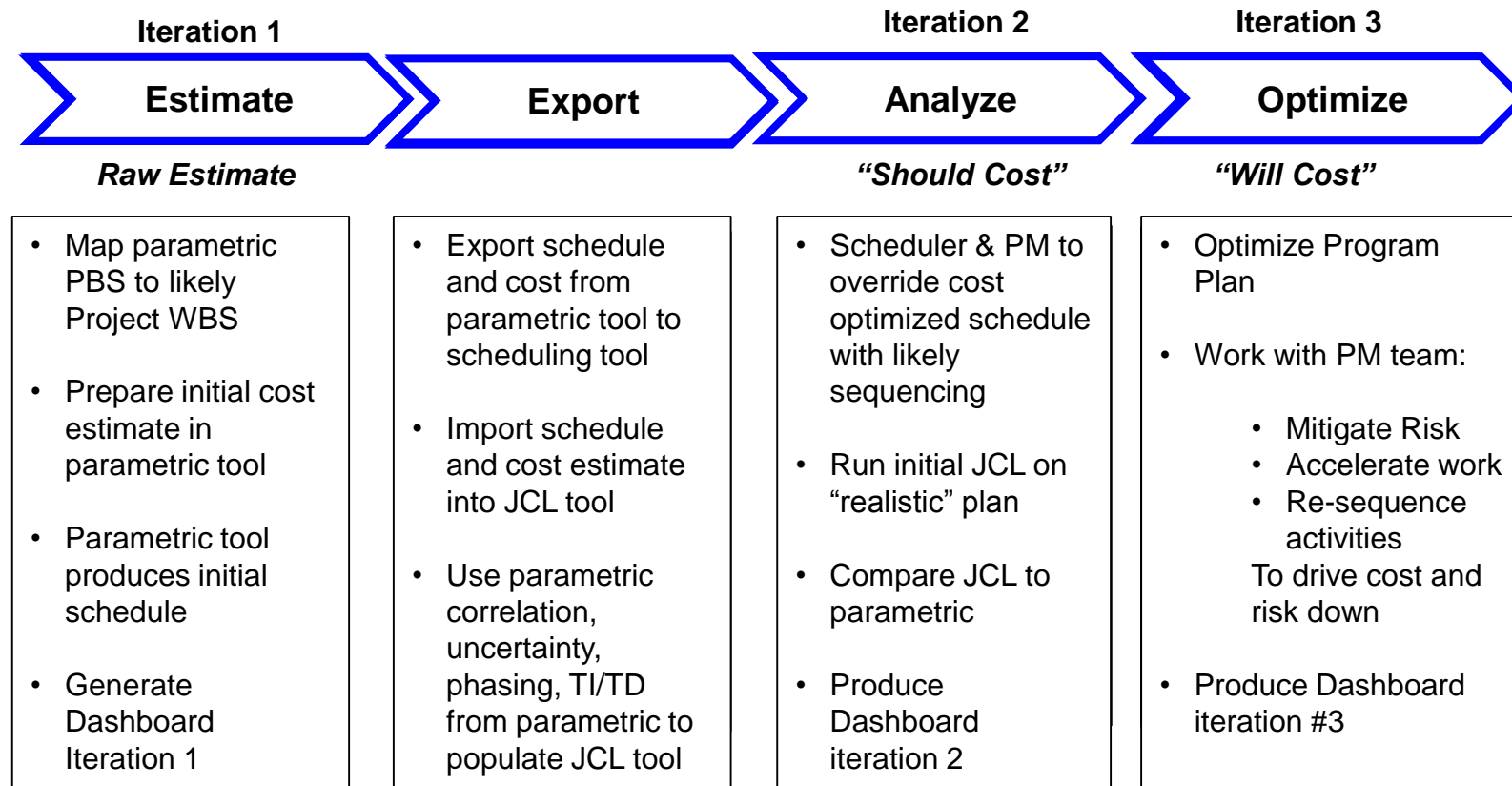
Ultimately the "preferred" scenario, envisions linking parametric estimates to programmatic artifacts from the beginning, such that each informs the other from the inception of the Project

# The ideal LPEPM approach is to implement parametric and programmatic approaches concurrently from Project inception

- ▶ **Traditionally, parametric estimates follow a product-focused structure based on the MEL**
  - Unfortunately, the MEL may not include programmatic considerations (such as who will be performing the work, when they will perform it, and where they will be located) that define the structure of the project management artifacts
- ▶ **Parametricians need to meet with the project management team, including the resource and scheduling teams, to understand how the plan is structured**
  - The estimate should then be built in this format by ensuring a mapping of the MEL to the project WBS
- ▶ **Research revealed benefits of increased focus on programmatic attributes during estimating process**
  - Consideration of schedule constraints and how they affect the cost estimate
  - Consideration of contract structures and how they may impact the project structure
  - Consideration of how programmatic attributes may impact cost drivers such as the manufacturing process index, organizational productivity, project complexity factor
- ▶ **Aligning our estimates to the project WBS and placing a stronger focus on the programmatic attributes will help to mitigate two frequent criticisms of parametric estimates**
  - It will allow for a much easier apples to apples comparison between the estimate and budget
  - It will allow project manager decisions to impact the estimate

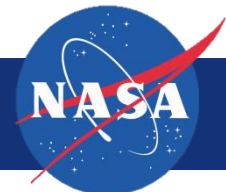


# This process depicts how the LPEPM Team believes parametrics should be integrated with programmatics IF the team starts with a mapped WBS



# The LPEPM research team makes the following recommendations for the cost community

1. When a parametric estimate is used as a cross-check tool, the parametrician's methodology should include steps to link to existing programmatic artifacts
  - Linking the two increases a PM's confidence in the numbers, reduces inconsistencies in scope and assumptions, and can reduce the reliance on SME judgment inputs in JCL models
2. Parametric estimates should use the same structure as the program management artifacts
  - Deliberately aligning structures from the beginning will allow for more meaningful cross-checks and will reduce inconsistencies in scope and assumptions as described above
3. The cost community needs to focus research not just on Cost Estimating Relationships (CERs) but also Schedule Estimating Relationships (SERs)
  - Cost and schedule are inextricably linked. Schedulers are working to incorporate cost in their analyses through ICSRA - we parametricians must follow or be left behind
4. CER and SER research should look closer at programmatic characteristics as independent values
  - Decision makers want and need to know how programmatic decisions affect cost and schedule – our current equations lag in this capability



# CONCLUSIONS & FORWARD WORK



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# Research study has proven that linking parametrics to programmatic is possible and provides value

- ▶ **Linking parametrics to programmatic fills several long-standing shortcomings in both analyses and is something both communities should strive to implement on their programs**
  - Allows an apples-to-apples comparison between the program and parametric estimates by ensuring consistent structure, technical scope, and program execution assumptions
  - Allows project manager decisions to inform the parametric model through the use of project-centric independent variables and the calculation of extension/compression penalties
  - In some cases allows parametric estimates to directly inform JCL components
  - Informs DoD's should-cost/will-cost analysis
  - Extends the value of parametric estimates into the project execution phases
- ▶ **Future areas of research and investment will continue to strengthen the link between these disciplines**
  - Identifying additional programmatic attributes in our CERs and SERs
  - Finding ways to include schedule uncertainty in our compression/extension penalties
  - Developing parametric estimating tools to better interface with programmatic artifacts

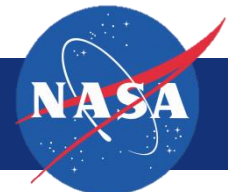


# BACKUP SLIDES



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# PARAMETRIC-TO-JCL COMPATIBILITY



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# JCL Model Artifacts: Schedule

Medium

- ▶ TruePlanning calculates an estimated duration for each cost object in the parametric model allowing for schedule to be calculated when a start-date is added
  - Estimated durations are further broken down into anticipated activities
- ▶ The TruePlanning developed schedule is not logically linked and is unlikely to be in a form useable in lieu of the IMS
- ▶ Nonetheless, significant value lies in the TruePlanning schedule
- ▶ Recommended practice is to cross-check IMS durations against the TruePlanning estimate
  - Potentially represents a method for developing the elusive “schedule BOE”
  - TruePlanning schedule could also be linked and ordered by a scheduler to help develop the IMS

Results				
Cost Objects   Input Sheet   Results   Chart				
STRUCTURES & MECHS/EXTERNAL ES Schedule				
Cost:	\$846,498,544	0.05%	Labor Requirement:	2,850.85 hours
Project Cost:	\$846,498,544		Project Labor Requirement:	6,029,156.67 hours
Schedule Data : STRUCTURES / Duration in months	Lag	Duration	Calculated Start Date	Calculated End Date
1 STRUCTURES & MECHS/E...		11.97	11/5/2011	11/3/2012
2 Development Engineering	0%	11.97	11/5/2011	11/3/2012
3 Development First Article Milestone	-1.98	0.00	9/4/2012	9/4/2012
4 Development Manufacturing	-5.20	7.17	3/29/2012	11/3/2012
5 Development Tooling and Test	0%	7.17	3/29/2012	11/3/2012
6 Production First Article Milestone	0.00	0.00	11/3/2012	11/3/2012
7 Production Engineering	0.00	0.00	11/3/2012	11/3/2012
8 Production Manufacturing	0.00	0.00	11/3/2012	11/3/2012
9 Production Tooling and Test	0%	0.00	11/3/2012	11/3/2012
10 Support Equipment Procurement	0%	0.00	11/3/2012	11/3/2012
11 Support Equipment Maintenance	0%	0.00	11/3/2012	11/3/2012
12 Initial Spares Procurement	0%	0.00	11/3/2012	11/3/2012
13 Replenishment Spares Procurement	0%	0.00	11/3/2012	11/3/2012
14 Contractor Support	0%	0.00	11/3/2012	11/3/2012
15 Shipping	0%	0.00	11/3/2012	11/3/2012
16 Operation	0%	0.00	11/3/2012	11/3/2012
17 Unit Level Maintenance	0%	0.00	11/3/2012	11/3/2012
18 Intermediate Maintenance	0%	0.00	11/3/2012	11/3/2012



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# JCL Model Artifacts & Inputs: Cost Estimate & TI-TD Breakout

High

- ▶ TruePlanning calculates a by-year cost estimate for the project broken down into phases and, if desired, resources required
  - This includes a TI-TD cost breakout
- ▶ Recommended practice is to use the parametric estimate in one of the two following ways:
  1. To directly cost-load the JCL schedule
  2. To cross-check against the cost-loaded JCL schedule
- ▶ Recommended practice is to use the percentage split between labor and material costs in TruePlanning as the percentage split for TI-TD costs in the JCL model

Results

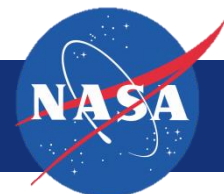
Cost Objects | Input Sheet | Results | Chart

PRICE RESEARCH- Resource costs by year

Cost: \$846,498,544 100.00% Labor Requirement: 6,029,156.67 hours

Project Cost: \$846,498,544 Project Labor Requirement: 6,029,156.67 hours

Costs : PRICE RESEARCH- Currency in USD (\$) (as spent)	Total	2011	2012	2013
1 Amount for Hardware	0	0		
2 Amount for Initial Supply Administra...	0	0	0	0
3 Amount for Software	0	0		
4 Amount for Support Supply Adminis...	0	0	0	0
5 Assembler	18,539,113	887	9,499	8,979,021
6 Business Analyst	8,207,360	333,069	2,535,782	3,234,820
7 Configuration Manager	96,856,938	5,405,621	58,639,287	28,432,219
8 Contractor Services	0	0	0	0
9 Design Engineering	173,570,876	11,499	129,669,118	24,556,838
10 Fabricator	0	0	0	0
11 Manufacturing Engineering	0	0	0	0
12 Material	103,262,956	611,534	53,742,440	47,589,256
13 Milestone Resource	0	0	0	0
14 Operator	0	0	0	0
15 Other Direct Costs	3,811,006	213,270	2,308,286	1,117,512
16 Programmer	241,382	6,796	228,769	5,961
17 Project Manager	56,768,016	2,877,052	33,873,348	17,262,755
18 Project Stakeholder	37,051,624	123,359	1,189,669	2,237,104



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# JCL Model Artifacts & Inputs: Risk

Medium

- ▶ TruePlanning does not identify discrete risks for the project however its risk inputs sheet can be used to ensure completeness of the project risk register
- ▶ For example, if there is a risk that a certain electronic component will not be reusable, that should be reflected with a pessimistic value in the Percent of New Electronics field
- ▶ Similarly, if there is weight growth projected this should be included somewhere in the risk register
- ▶ Recommended practice is to map risks to identify gaps from two directions:
  - Identify top cost drivers from TruePlanning model and identify corresponding risk register risks
  - Identify where risk register risks are held in TruePlanning model

Input Sheet: COMMAND\_TELEMETRY CONTROLLER

Cost Objects | Input Sheet | Results | Chart

**COMMAND & TELEMETRY CONTROLLER** Risk

Cost: \$1,198,273 0.14% Labor Requirement: 672,868.57 hours  
 Project Cost: \$846,498,544 Project Labor Requirement: 6,029,156.67 hours

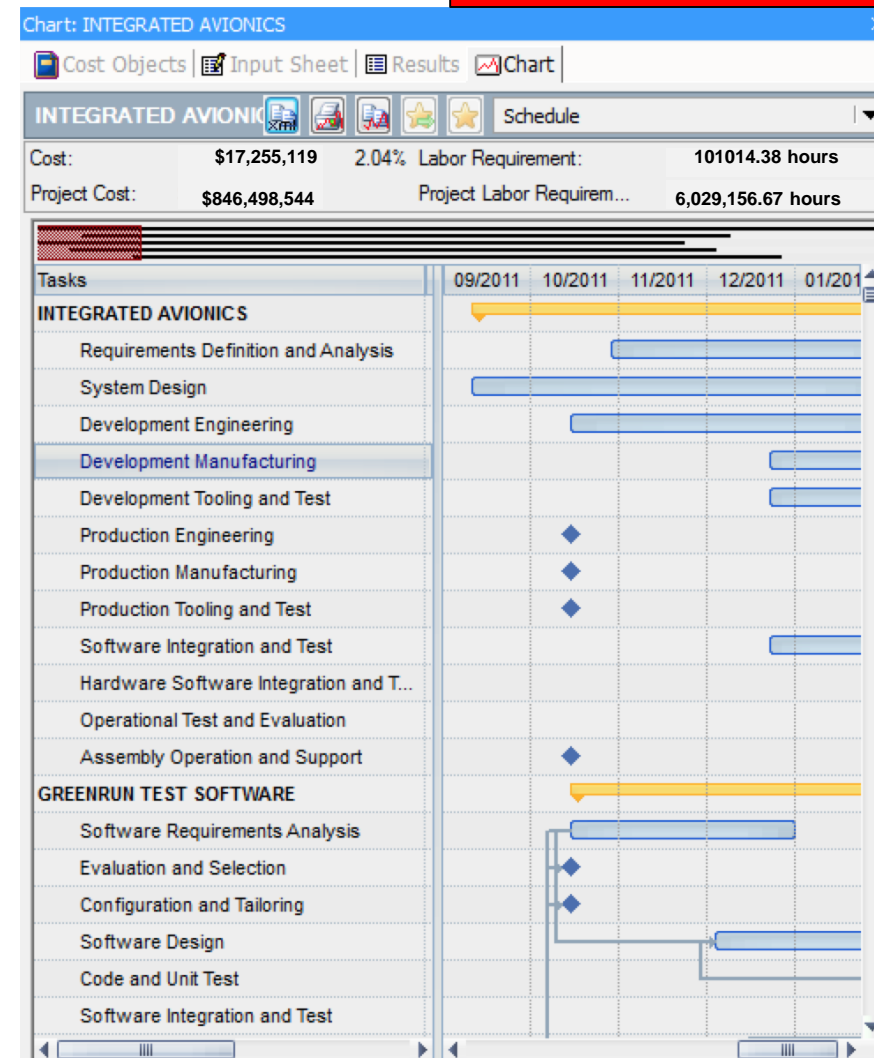
Worksheet Set: <Inherited>

		Value	Pessimistic	Optimistic	Notes
1	Quantity Per Next Higher Level	2.00			
2	<b>Additional Units</b>				
3	Number of Additional Production Units	0.00			
4	Number of Additional Prototypes	1.00			
5	<b>Cost Sharing Units</b>				
6	Total Number of Production Units Produced	0			
7	Total Number of Prototypes Produced	5.00			
8	<b>Technical Description</b>				
9	Operating Specification	2.50			
10	Weight of Structure	0.000			
11	Weight of Electronics	44.000	61.600	35.200	
12	Volume	1.000			
13	Manufacturing Complexity for Structure	6.000			
14	Percent of New Structure	100%			
15	Percent of Design Repeat for Structure	0%			
16	Manufacturing Complexity for Electronics	8.576			
17	Percent of New Electronics	50%			
18	Percent of Design Repeat for Electronics	80%			

# JCL Model Inputs & Outputs: Schedule Uncertainty and Risk-Adjusted Schedule

Low

- ▶ TruePlanning does not have an inherent schedule uncertainty result but it can be ferretted out through use of the Crystal Ball API
  - Schedule uncertainty is represented by effort uncertainty
  
- ▶ Necessarily, to include schedule uncertainty TruePlanning's schedule compression/extension feature cannot be used
  - One of TruePlanning's features is the ability to calculate the cost impact of a constrained or extended schedule
  - If the schedule is constrained or extended then we cannot quantify the uncertainty around it
  - Doing both would require data surrounding how compression and extension impact schedule uncertainty – this is beyond the reach of the estimating and project management community today
  
- ▶ Recommended practice is to only use schedule uncertainty from TruePlanning if the schedule is not compressed or extended
  - This situation is rare as it negates one of the most powerful and useful features of TruePlanning

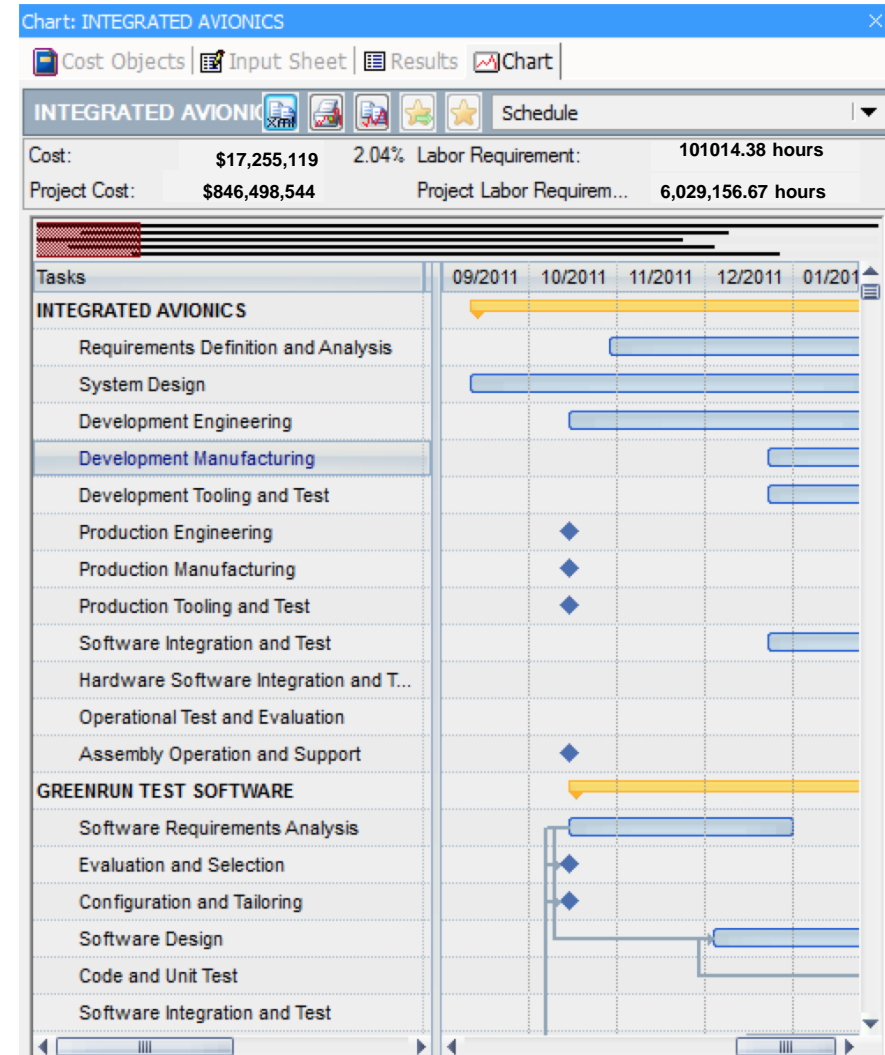


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# JCL Model Inputs: Cost Uncertainty

- ▶ In a JCL model, cost uncertainty is represented in several dimensions
  - Uncertainty around burn rates for TD costs
  - Uncertainty around estimates for TI costs
  - Uncertainty around TD cost resource usage (for resource loaded schedules only)
  
- ▶ TruePlanning provides the risk adjusted cost estimate but in most cases it is difficult to divide this uncertainty into its cost/schedule components
  - In simpler terms, if a risk-adjusted TD cost estimate is  $\pm 10\%$ , how do we know whether the burn rate uncertainty is  $\pm 10\%$ , the schedule uncertainty is  $\pm 10\%$  or a blending of the two?
  - If extension/compression penalties are not in use then TruePlanning can provide schedule uncertainty allowing cost uncertainty to be separated out
  
- ▶ Recommended practice is to only use TruePlanning to inform cost uncertainty inputs if extension/compression penalties are not in use

Low

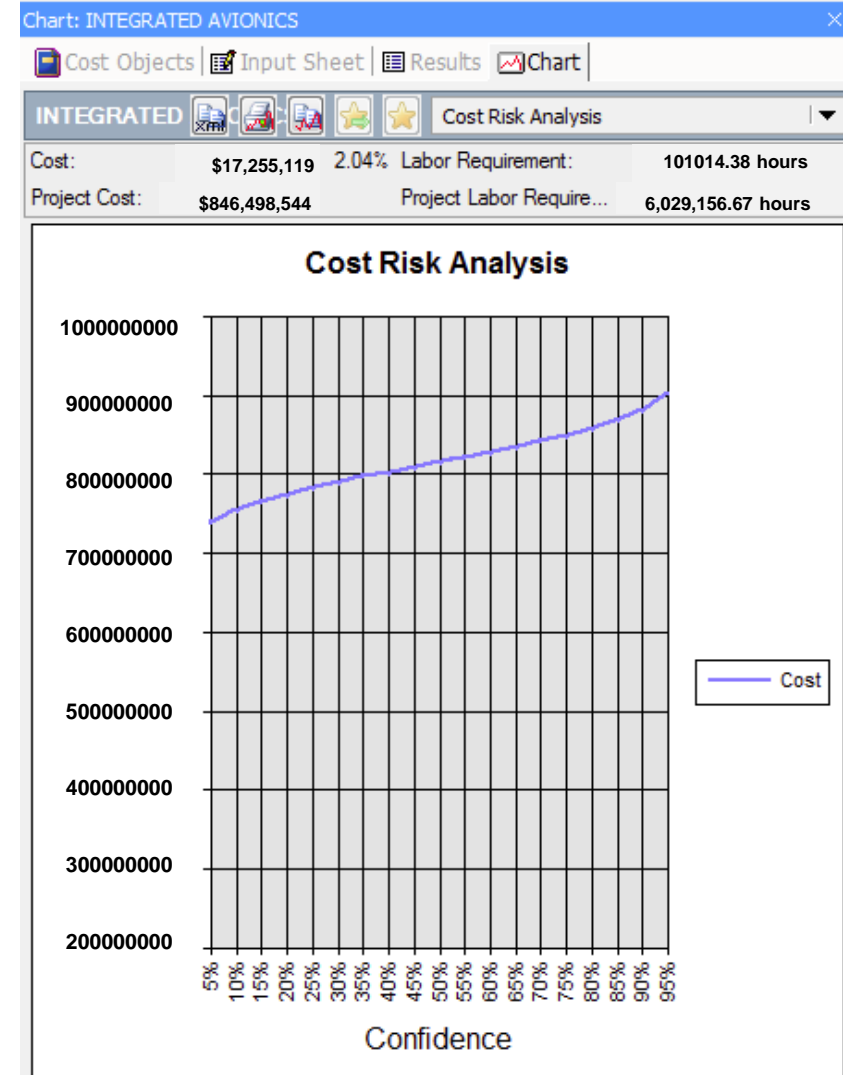




# JCL Model Outputs: Risk Adjusted Cost Estimate

High

- ▶ TruePlanning provides the risk adjusted cost estimate for each cost object within the model as well as for the project as a whole
  - This estimate is also parsed by years and project phase and divided into TI-TD costs
- ▶ Recommended practice is to compare the risk adjusted cost estimate from the parametric model against the risk adjusted cost estimate from the JCL
  - The JCL model is likely to have a smaller CV since it accounts for the specific way the project will be executed
  - Nonetheless, the JCL s-curve should fall somewhere on the parametric s-curve or the results can be considered “out of family”

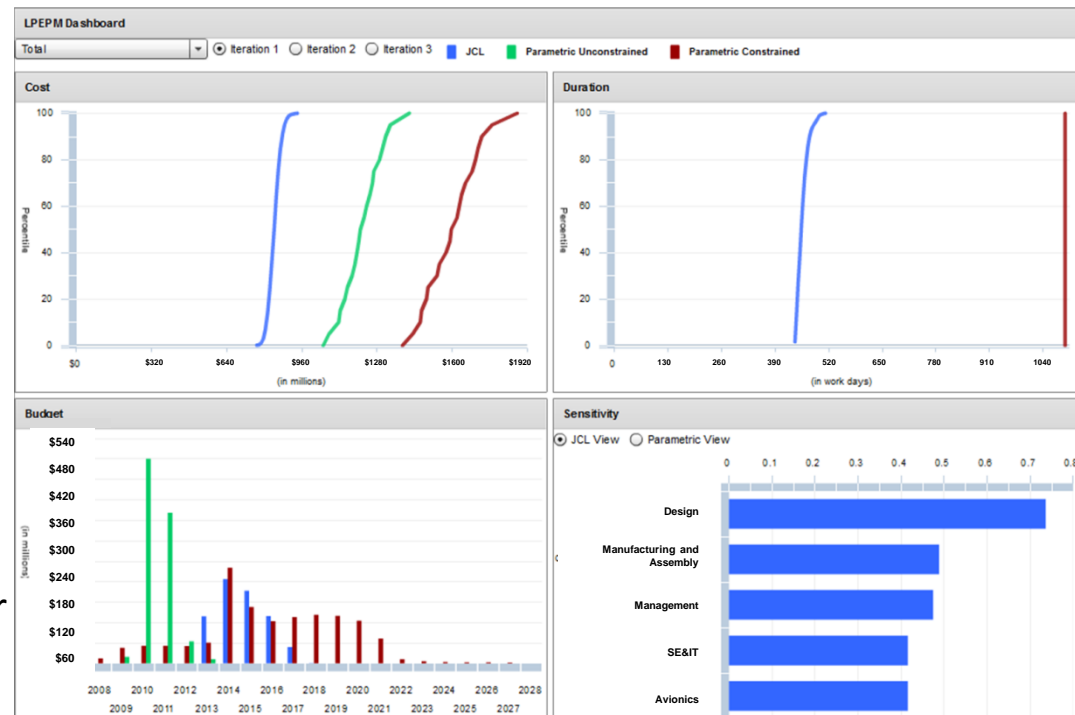
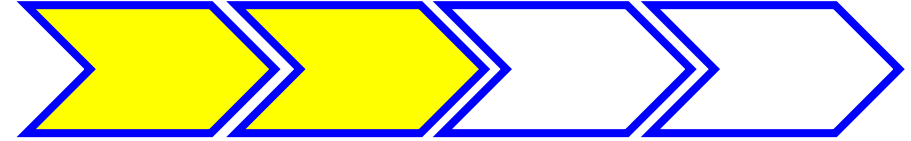


# LPEPM DASHBOARD VIEWS



# Steps one and two focus on building the parametric estimate and using it to inform parametrics wherever possible

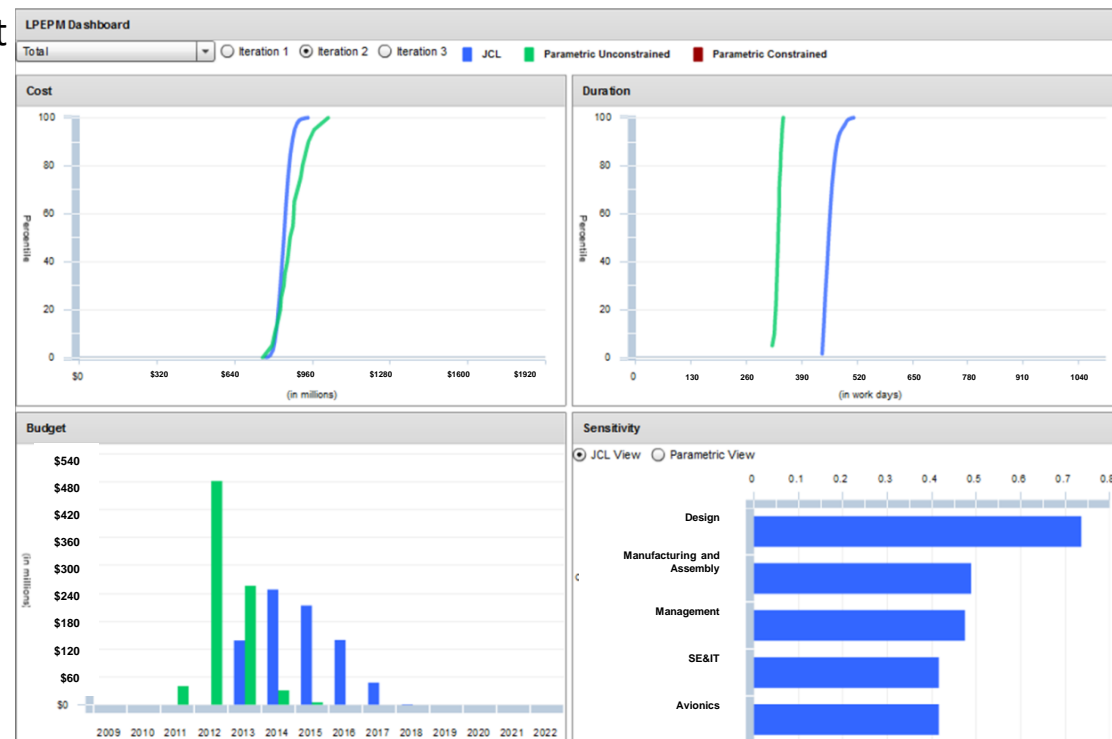
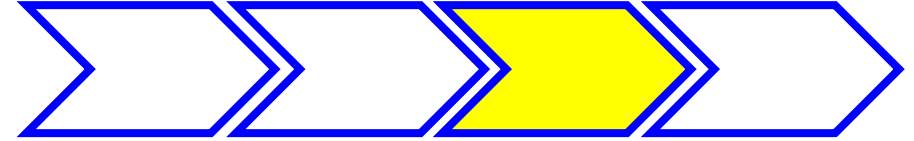
- ▶ Step one (Estimate) allows a raw, apples-to-apples comparison between the parametric and project cost and schedule estimates
  - This is akin to providing an independent estimate
- ▶ This comparison provides a point of reference but has several shortcomings limiting its value
  - Parametric estimate (both cost and phasing) represents an average of how the work has been performed on completed projects used to develop CERs
  - In reality, project managers can sequence work so that the project is executable within their budget envelope
- ▶ Step two incorporates components of the parametric estimate into the JCL model wherever possible
  - This enables the parametric estimate to be viewed in light of the program plan



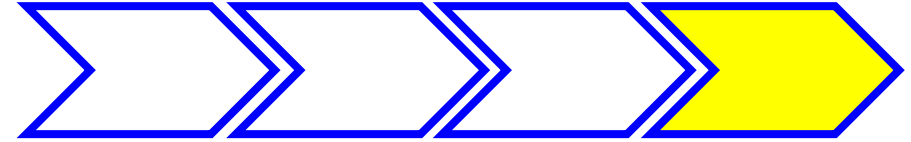


# Step three provides a should-cost estimate representing what the project will cost given the execution plan

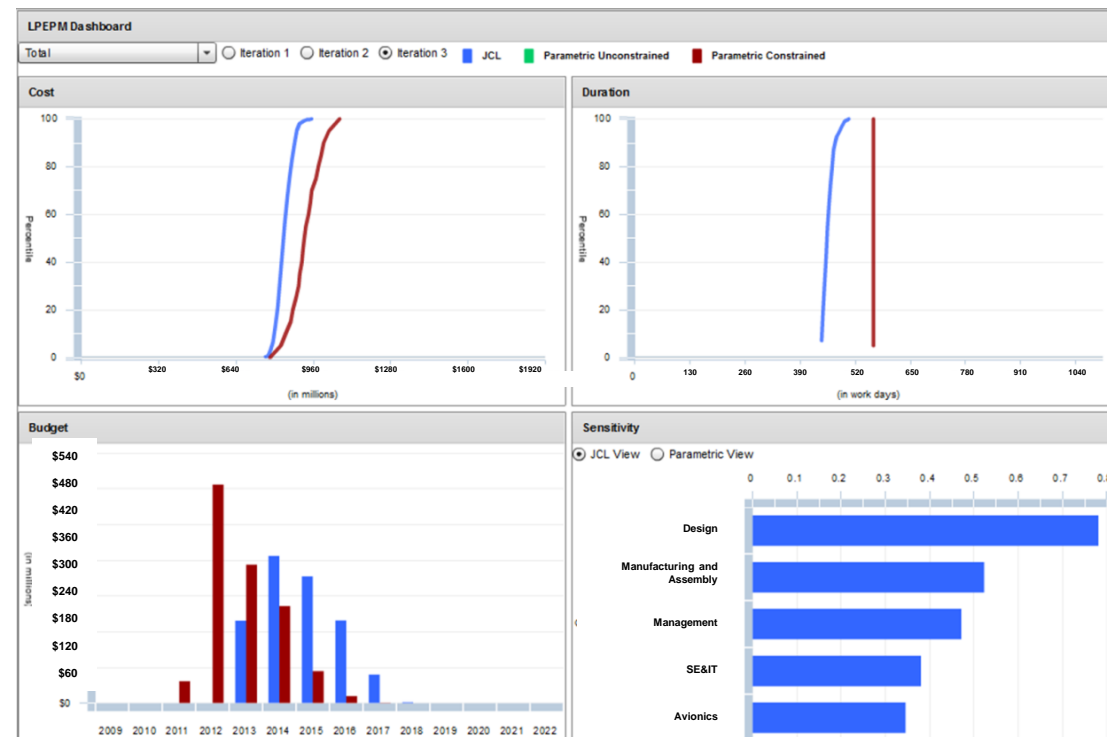
- ▶ Once the JCL model is loaded with parametric inputs the analyst has a JCL model representing the specifics from the parametric estimate
- ▶ Step three is to analyze this model, which best represents the programmatic attributes
- ▶ At this point, the risk adjusted (but unconstrained) schedule can be fed back into the parametric estimate to calculate compression and extension penalties
- ▶ This estimate represents a should cost – the parametric estimate fed through the project plan and informed by external constraints



# Step four provides the project management team an opportunity to identify and mitigate lead sources of cost and schedule growth



- ▶ At this point, the JCL model is informed by parametrics and reflect the realities the project is operating under
- ▶ Traditional JCL analysis methods can be used to identify lead sources of cost and schedule risk and mitigate them to help project fit within budget and schedule envelope
- ▶ Potential actions include
  - Ability to incorporate/assess changes to technical requirements
  - Extending or compressing tasks within the schedule
  - Re-sequencing work; mitigating risks
- ▶ Resulting estimate is most akin to a “will-cost” estimate where PM has taken specific actions to reduce cost and schedule risk



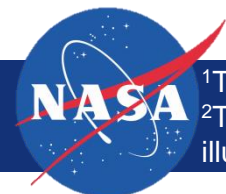
# THOUGHT EXPERIMENT



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# Research team conducted a thought experiment to examine why JCLs exhibit smaller CVs than those seen in historical data

- ▶ JCL analyses have been criticized as unrealistic since their results typically exhibit smaller Coefficients of Variation (CVs) than parametric analysis of historical data dictates
- ▶ To begin examining this issue, the research team first considered the validity of the parametric CVs to which JCL results are often compared
- ▶ To-date, parametric analyses have not sufficiently accounted for how programs are structured, sequenced, and executed
  - Some CERs include independent variables describing whether the program was budget constrained
  - No variables<sup>1</sup> include independent variables describing whether work was conducted in parallel or serial or whether the program was time constrained
- ▶ Research team theorizes that today's CERs are likely built from datasets containing multiple embedded populations – thus artificially increasing the CV of parametric estimates
  - A thought experiment<sup>2</sup> on the next slide will attempt to demonstrate this effect and show its implications

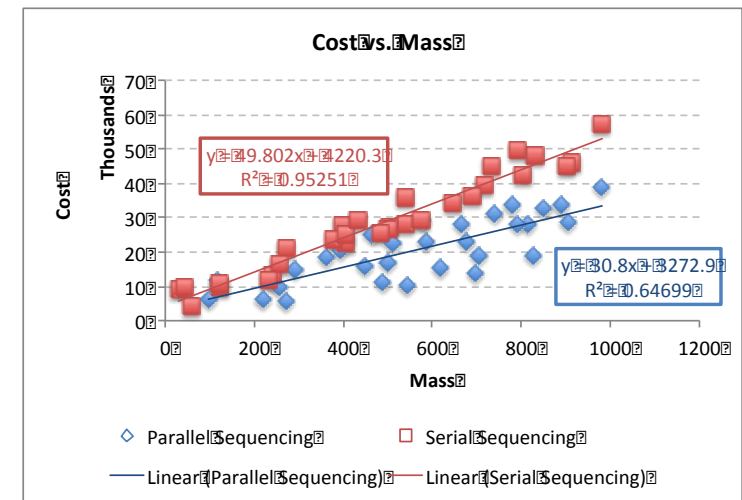
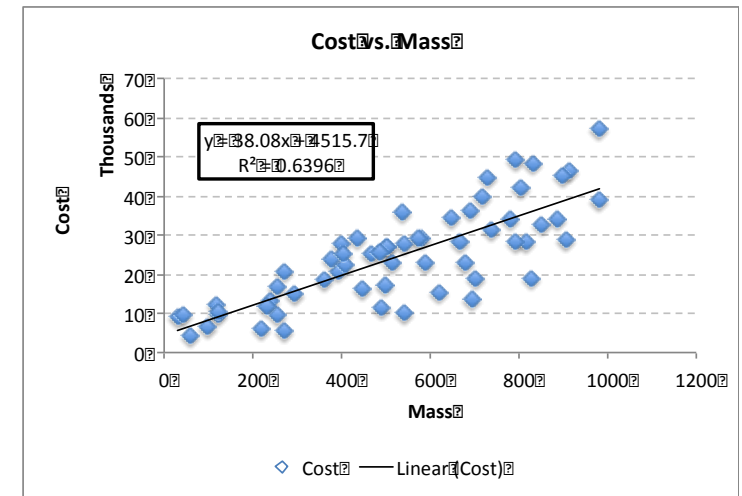


<sup>1</sup>To the knowledge of the research team

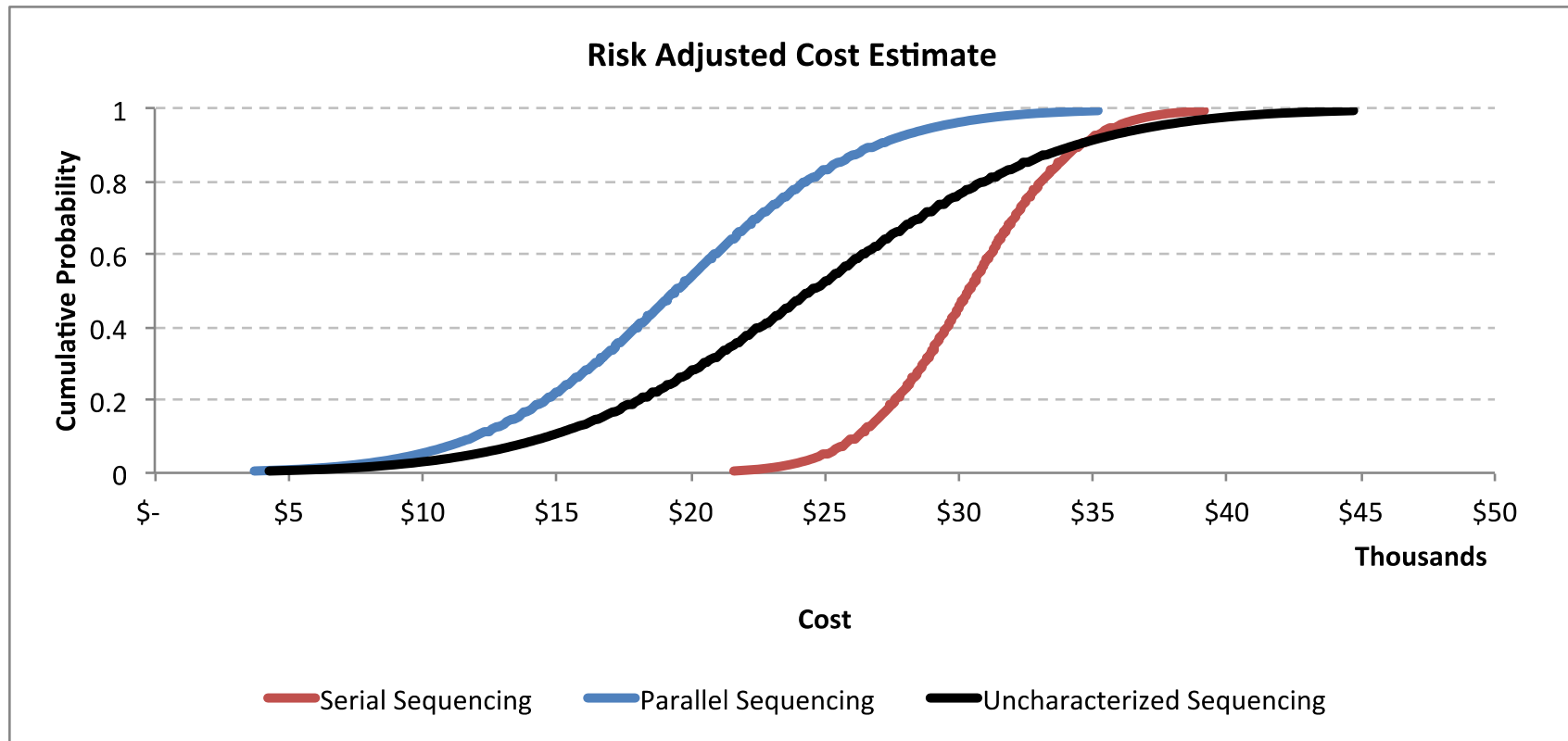
<sup>2</sup>This thought experiment uses a data set constructed by the authors to illustrate their hypothesis – it is not real data

# Sampling from multiple populations could result in CERs with higher Coefficients of Variation

- ▶ The top data-set represents a traditional CER
- ▶ The bottom data-set represents the same data but split into two CERs, one representing programs where work was largely done in parallel, the other where work was largely done in serial
- ▶ In this thought experiment, dividing the data set into two separate populations based on how the work was sequenced resulted in CERs capable of producing more precise estimates with tighter CVs
- ▶ Uncertainty distributions around a point estimate located approximately at the mean of both CERs are shown on the next slide



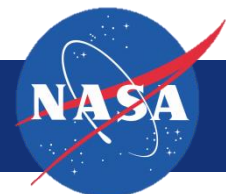
In this thought experiment, accounting for how work is sequenced results in more precise estimates



We hypothesize that CER error (and thus CVs) are artificially inflated since the CERs are based on data from separate and distinct populations

# Parametric research should pivot from developing new statistical approaches to incorporating new independent variables

- ▶ A great deal of time and energy is being expended developing new, and expanding on old, statistical analysis methodologies
  - While these certainly improve our estimates, there is no new analysis technique that is going to substantially increase the accuracy or precision of our estimates
- ▶ On the other hand, the inclusion of programmatic characteristics as independent variables in our parametric analyses has the potential to yield dramatic results while addressing the complaint from PMs that our estimates don't account for their specific plan
- ▶ To accomplish this, we are going to need to be creative in the characteristics we select and how we measure them
- ▶ Some characteristics are easy to quantify: # of contractors/subcontractors working on the program, # of states/country work is being performed in, # of requirements
- ▶ Others will be harder: schedule complexity, work sequencing, budgetary environment, schedule constraints, architecture complexity



## Results from JCL results are heavily influenced by programmatic characteristics – particularly the sequencing of work

- ▶ Admittedly, narrow CVs are still being driven by a number of shortcomings and errors that are commonplace in JCL models
  - E.g: Lack of, or insufficient, correlation; SME underestimation of uncertainty; bias/optimism
- ▶ Still, JCL models are capable of accounting for a variety of programmatic characteristics that today's parametrics largely ignore
  - Budgetary and scheduling constraints
  - Sequencing of work/activities
  - Cost, schedule, technical, and programmatic risks
- ▶ Since JCL models represent a specific execution plan, and parametrics include all of the execution plans ever executed, they should be expected to have a lower CV