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Joint Confidence Level: Integrating Cost & Schedule Uncertainty

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- **Abstract:** This presentation will discuss the ongoing work toward completing a Joint Confidence Level of cost and schedule uncertainty with emphasis on annual phasing, and the impact of annual resource availability on a JCL. The author(s) will show how a schedule network with uncertainty can be replicated in ACEIT, and how the cost estimate with uncertainty can be linked with the schedule. The presentation will illustrate how the schedule and uncertainty can impact both the total cost and the cost phasing of the cost estimate. The presentation will also demonstrate how the new reports in ACEIT 7.2 can be used to visualize the JCL annual results.
- **Presentation Purpose:** Provide background on Joint Confidence Level analysis. Discuss JCL methodologies and implementation in cost and schedule applications. Show examples of JCL analysis and reports – both cumulative and annual.



- **Joint Confidence Level (JCL) Introduction**
 - Background & Overview

- **JCL Details**
 - Cost & Schedule Methodology Overview
 - Project JCL Goals & Solution
 - Reliance on Project Data

- **Annual View of Cost Uncertainty**

- **JCL Methodology Overview**
 - Schedule Replication in Cost Model
 - ACE Implementation
 - Standard Visualizations

- **Conclusion**



Joint Confidence Level

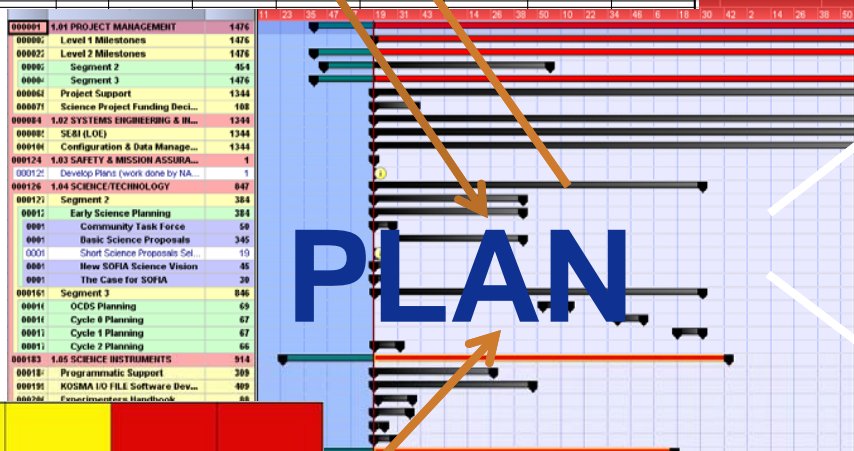
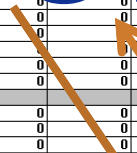
- **A view of cost and schedule confidence level, together**
- **Probability that a given program's cost will be equal or less than the targeted cost AND schedule will be equal or less than the targeted schedule date**
- **Analysis that provides insight to decision makers regarding the probability of success for a given program plan**
- **It is NOT a tool, product, or specific application**
- **It is a "Systematic process" of integrating cost, schedule, and risk into a cohesive picture of the program's ability to achieve cost and schedule goals**



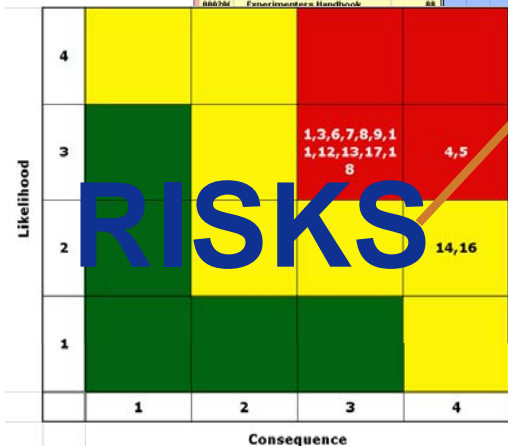
Source Data & Results Visualization

SOFIA Program Total (Dollars in K)								
Description	Tech WBS	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Program/Project Mgmt	1	0	0	0	0	0	0	0
Systems Engineering & Integration	2	0	0	0	0	0	0	0
Safety & Mission Assurance	3	0	0	0	0	0	0	0
Science / Technology	4	0	0	0	0	0	0	0
Science Instruments	5	0	0	0	0	0	0	0
Aircraft / Spacecraft	1.06	0	0	0	0	0	0	0
Mission Operations	1.07	0	0	0	0	0	0	0
Launch Vehicles & Services	1.08	0	0	0	0	0	0	0
Ground Systems	1.09	0	0	0	0	0	0	0
Systems Integration & Testing	1.10	0	0	0	0	0	0	0
Education and Public Outreach	1.11	0	0	0	0	0	0	0
Total Plan		0	0	0	0	0	0	0
Program Reserves		0	0	0	0	0	0	0
Total Program Budget w/Reserves		0	0	0	0	0	0	0

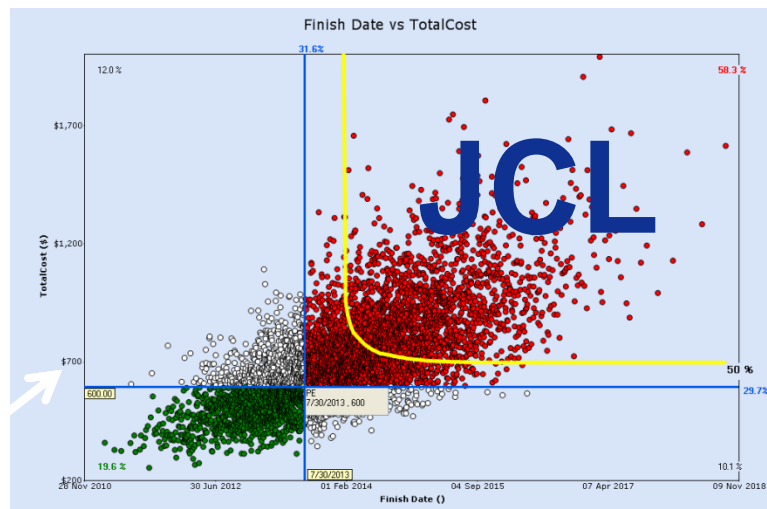
COST



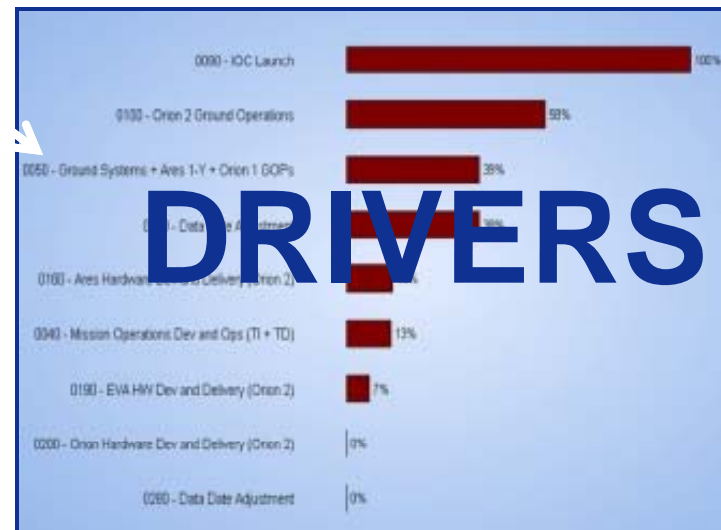
PLAN



RISKS



JCL

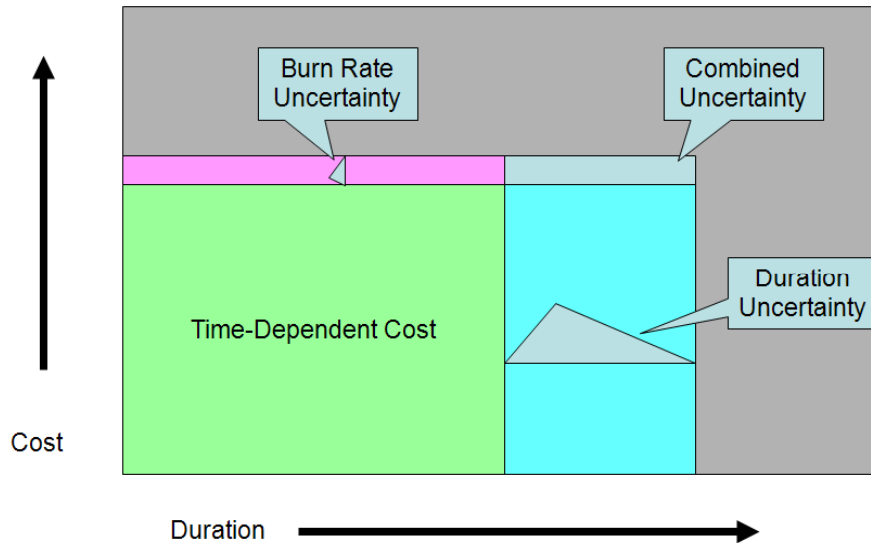


DRIVERS

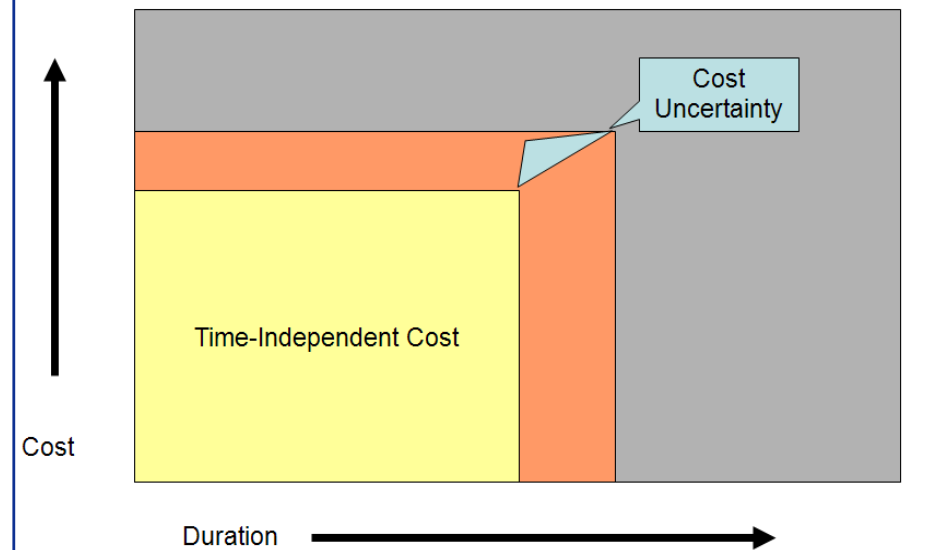


Identification of Two Separate Cost Behaviors

- ◆ Time-dependent cost is a function of the burn rate and task duration
- ◆ Total Cost = Burn Rate * Duration

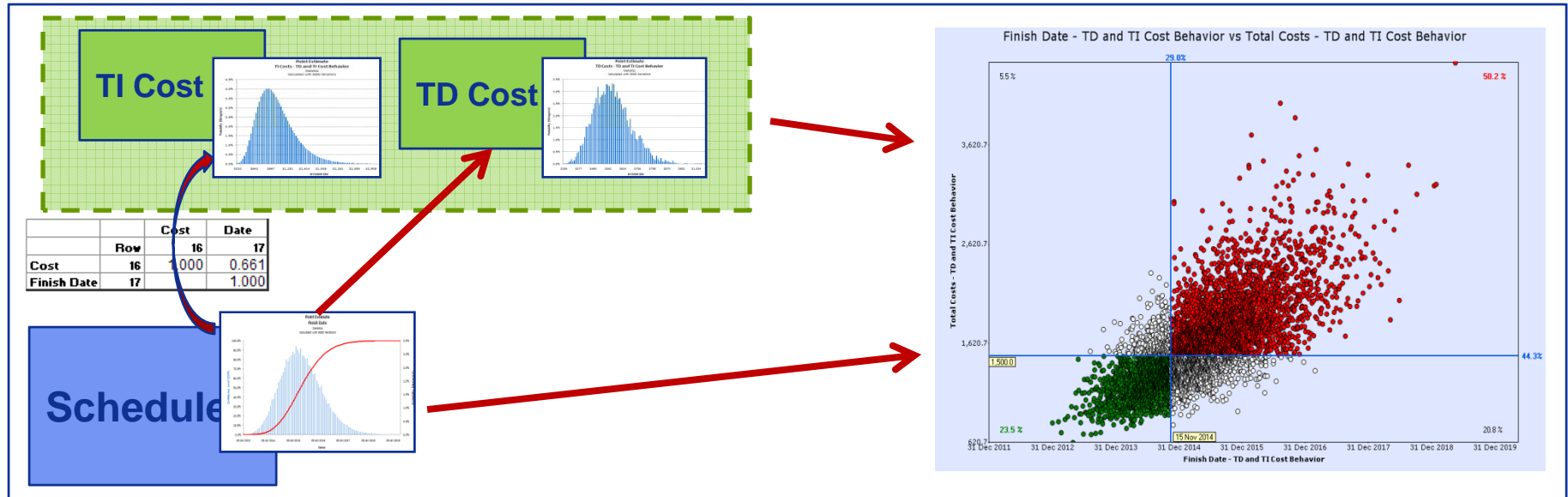


- ◆ If the Duration of the task changes, cost may be rephased over the new Duration, but Total Cost remains the same
- ◆ $Burn\ Rate_2 = Total\ Cost / Duration_2$ ($BR_2 = TC/D_2$)





JCL Models Cost as a Function of Schedule



■ Requires Multiple Items

- Costs Broken into TD and TI Cost Behavior
- TD Cost Modeled as a Function of Schedule (Duration * Burn Rate)
- TD Burn Rate Uncertainty
- Schedule Uncertainty
- TI Cost Uncertainty
- Correlation between Schedule and TI-derived costs

WBS/CES Description	Approp	Unique ID	Point Estimate	Phasing Method	Equation / Throughput	Fiscal Year	Units	Start Date	Finish Date	Distribution Form	
** Modeled as TD and TI Costs											
Total Costs - TD and TI Cost Behavior			\$ 1,500.000 (42%) *								
TI Costs - TD and TI Cost Behavior	3600		\$ 1,000.000 (50%) *	BE		1000	2009	\$M	JLC3_SD	JLC3_FD	LogNormal
TD Costs - TD and TI Cost Behavior	3600		\$ 500.000 (29%) *	TS	JLC3_BurnRate * JLC3_Duration	2009	\$M	JLC3_SD	JLC3_FD		
TD Burn Rate	3600	JLC3_BurnRate	\$ 8.333 (44%) *	C	500 / 60					Beta	
Finish Date - TD and TI Cost Behavior		JLC3_FD	15NOV2014 (29%) *	C	DateAdd(JLC3_SD, 0,JLC3_Duration)						
Duration (Months)		JLC3_Duration	60.000 (29%) *	C	60					LogNormal	
Start Date		JLC3_SD	15NOV2009 *	C	15Nov2009						



Typical Project JCL Goals

- **Timely:** Complete the JCL analysis for the milestone event in the given timeframe
- **Transparency:** Utilize the current cost, schedule, and threat information to allow for thorough review during senior level review
- **Defendable:** Support all analysis with relevant project data to ensure successful project advocacy
- **Traceable:** Perform comparisons to prior analysis cycles and ensure that current results continue to show the evolution of the project position
- ***Annual:*** Provide insight into the annual cost/schedule requirements of the project and the adequacy of the current funds and timeline

Focus on Quality and Adherence to NASA HQ JCL Quality Standards



A Solution for Meeting All Goals

1. Use Existing Tools:

- Use a schedule application to build the Schedule and perform the Schedule Risk Analysis
- Use ACEIT model to house cost estimate and JCL-A implementation

2. Identify Schedule Activities and Obtain Statistics:

- Identify the summary schedule activities that are linked to the cost model (those activities that would otherwise be cost loaded in the schedule tool)
- Extract risk statistics for identified schedule activities
- Analyze resulting correlation
- Import schedule activities risk statistics into cost model

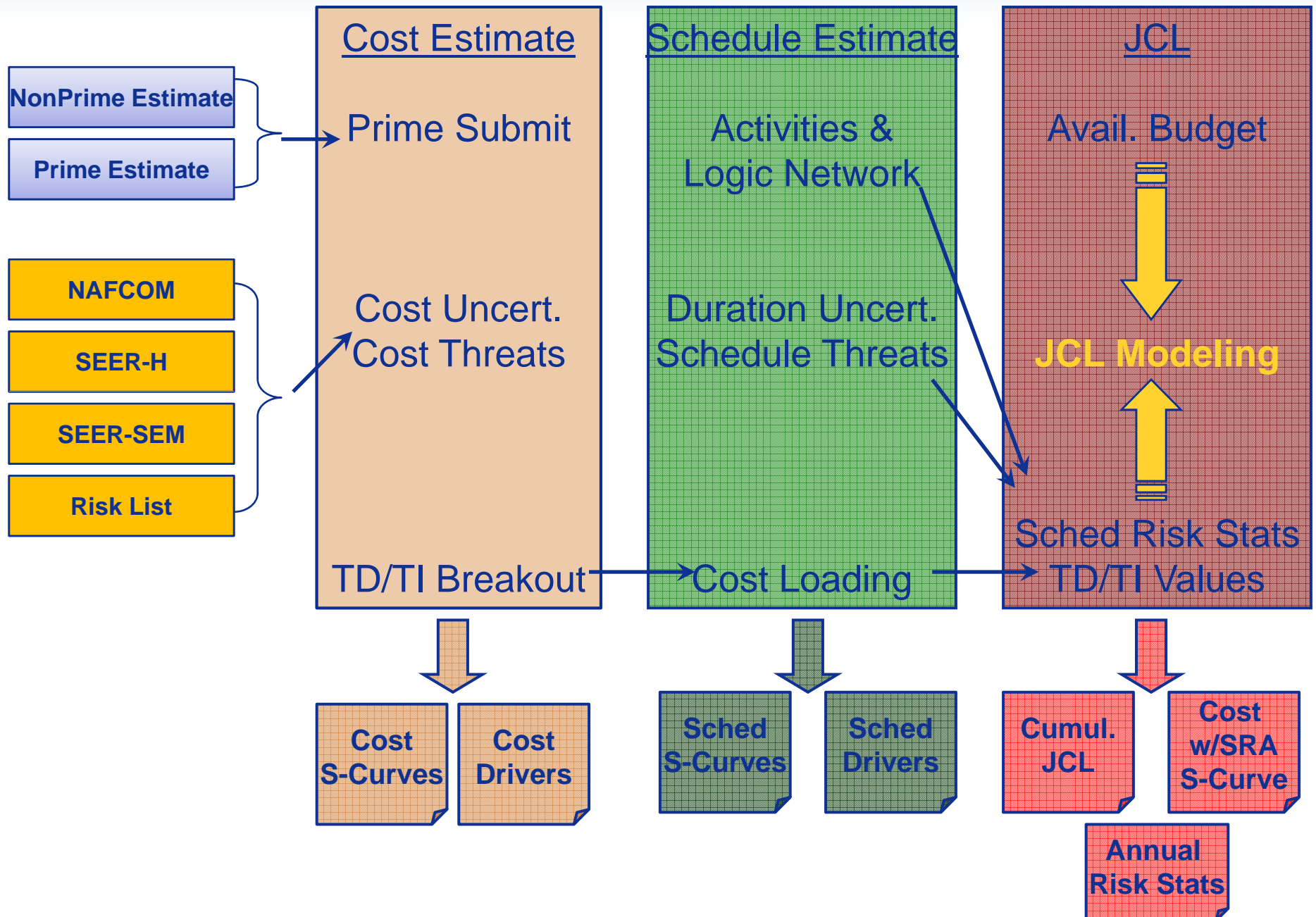
3. Create JCL-Annual Model in ACE

- Make cost model phasing and calculation sensitive to schedule duration
- Run risk simulation to calculate results for dates, duration, costs, and

Total Cost is a Function of Duration and Costs are Phased Annually



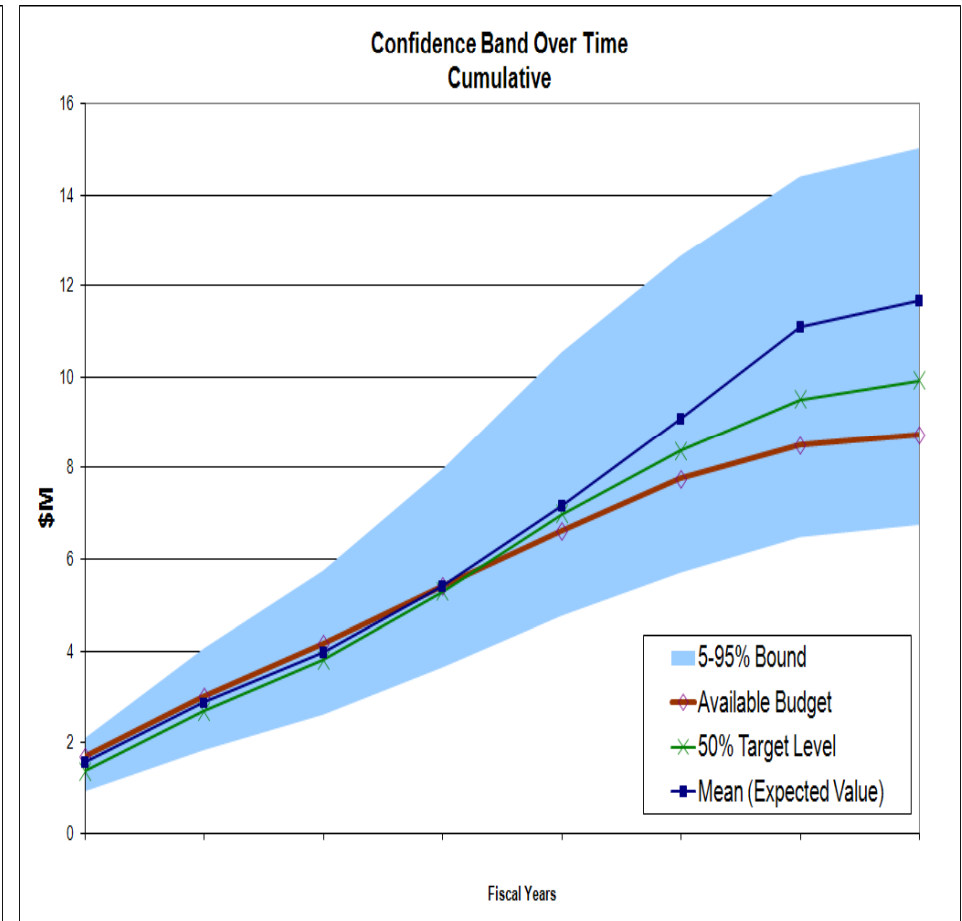
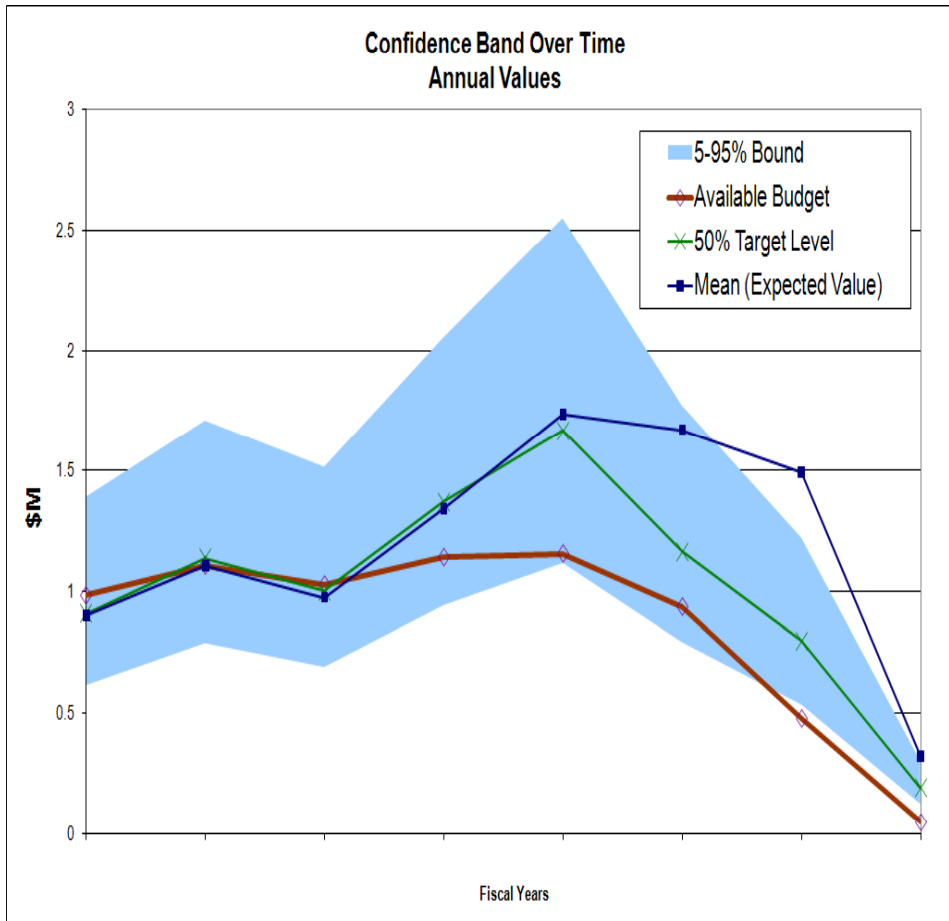
JCL Relies on Project Data





JCL with Insight into Annual Values

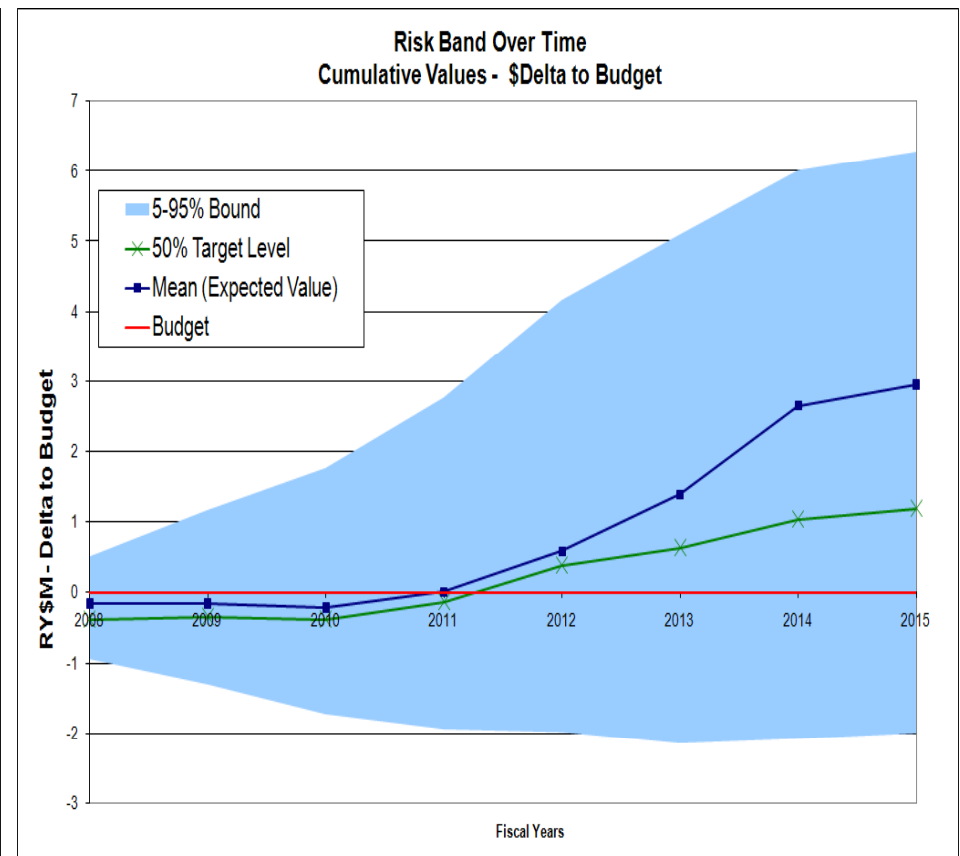
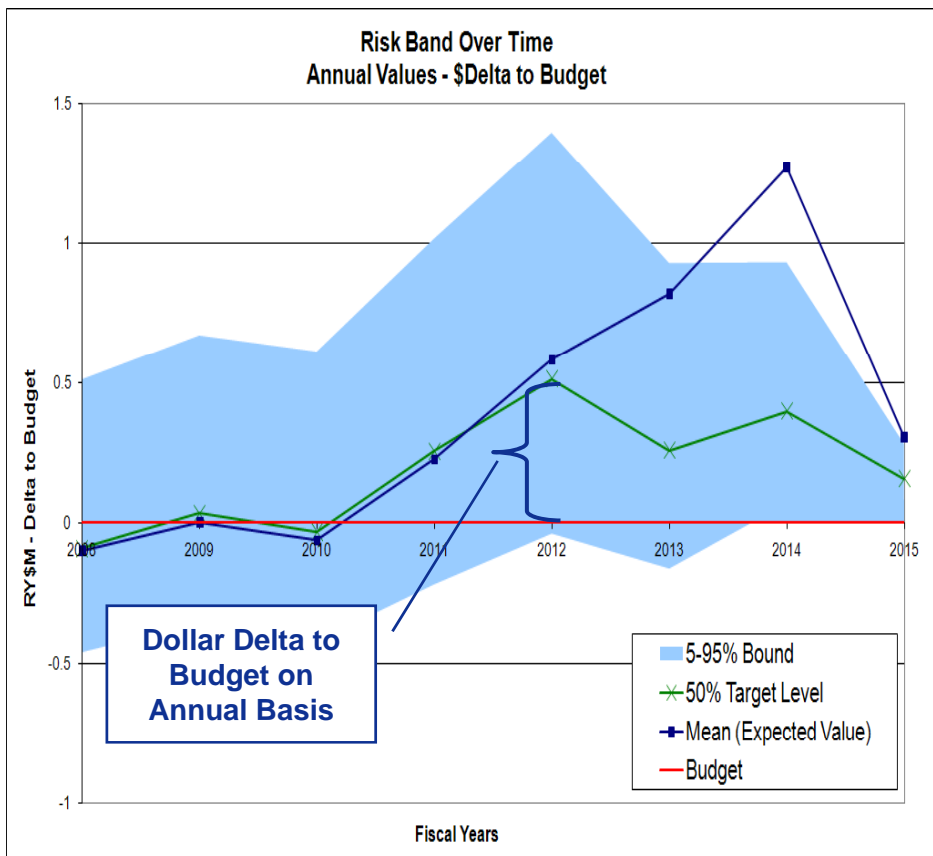
- **Annual View of Cost Risk Statistics with Schedule Uncertainty**
- Ability to compare Time-Phased Risk against Annual Budget
- Ability to display impact in out-years of rephased cost and schedule
- Available Visualizations Include: Cumulative & Annual
 - Able to display delta value between requirements and confidence level target





Additional Benefits from Annual Values

- Provide insight into sizing of reserve levels required by year
- Indicates years (periods of time) of low and high funding relative to the underlying effort
- Data can be normalized as % delta to current funds
- Delta can be shown as Annual values or Cumulative total





Key Enablers for JCL-A

Uncertainty (Cost and Schedule): Uncertainty must be applied to cost and schedule parameters

Correlation: Must be able to correlate uncertainties

Discrete Risk Modeling: Allow for impact of discrete threats on cost and schedule

Cost Re-Phasing: Cost must be rephased according to new schedule dates from simulation (e.g. time-independent)

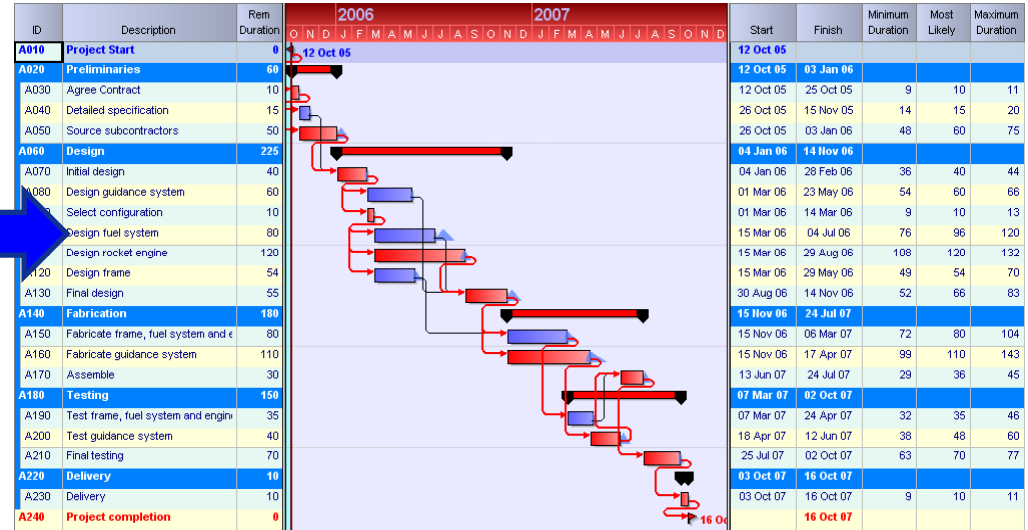
Cost ReCalculation: Cost must be recalculated and spread over new schedule duration from simulation (e.g. time-dependent)

Result: Must have capability to extract both cumulative and annual risk statistics



■ Key to JCL is to have Cost linked to Schedule

WBS/CES Description	Unique ID	Point Estimate	Equation / Throughput	RISK Specification
55 Total	Total\$	\$ 784,517,224 (37%)*		
56 RDT&E	RDT&E\$	\$ 93,154,198 (24%)*		
57 Concept Refinement		\$ 1,147,824*		
58 Contractor A		\$ 576,302*	[Cost Throughput]	
59 Contractor B		\$ 571,522*	[Cost Throughput]	
60 Technology Development		\$ 4,312,388*		
61 Contractor A		\$ 2,156,194*	2.0	
62 Contractor B		\$ 2,156,194*	2.0	
63 System Development and Demonstration		\$ 67,693,986 (24%)*		
64 Development Engineering		\$ 41,483,525 (36%)*		
65 Air Vehicle	AV\$	\$ 10,992,617 (20%)*		
66 Basic Structure		\$ 5,102,296 (52%)*	Struc_T1\$ * NRT1Ratio	
67 Navigation/Guidance		\$ 1,404,380 (41%)*	425.555-25.555*PCDWT	Form=Normal, PE=Mean,
68 Propulsion		\$ 2,399,545 (41%)*	6000 * NREC_Prop_Cptr%	Form=Normal, PE=Mean,
69 Software	AVSW\$	\$ 2,086,806 (5%)*	SMLab\$ * AVSWHrs	
70 Ground Station	G\$	\$ 25,079,814 (45%)*		
71 Procure OTS Parts		\$ 1,028,376 (17%)*	GSUC\$ * NGndStat	
72 Design New Parts		\$ 6,427,353 (40%)*	4500 * Complex	Form=Normal, PE=Mode,
73 Software		\$ 17,624,085 (47%)*	SMLab\$ * GSSWHrs	
74 Int & Assy		\$ 5,410,895 (39%)*	.15 * (AV\$FYTot + G\$FYTot)	Form=Normal, PE=Mode, Spread=Medium, GrpID=IA&T,
75 Prototype Manufacturing		\$ 3,691,594 (45%)*		
76 Air Vehicle		\$ 3,309,167 (50%)*	1.5 * AV_T1\$	Form=Normal, PE=Mean, CV=0.25, Seed=822408
77 Mobile Ground Station		\$ 382,427 (28%)*	1.75 * TGS_T1\$	Form=Normal, PE=Mean,
78 SEFM		\$ 31,713 (14%)*		



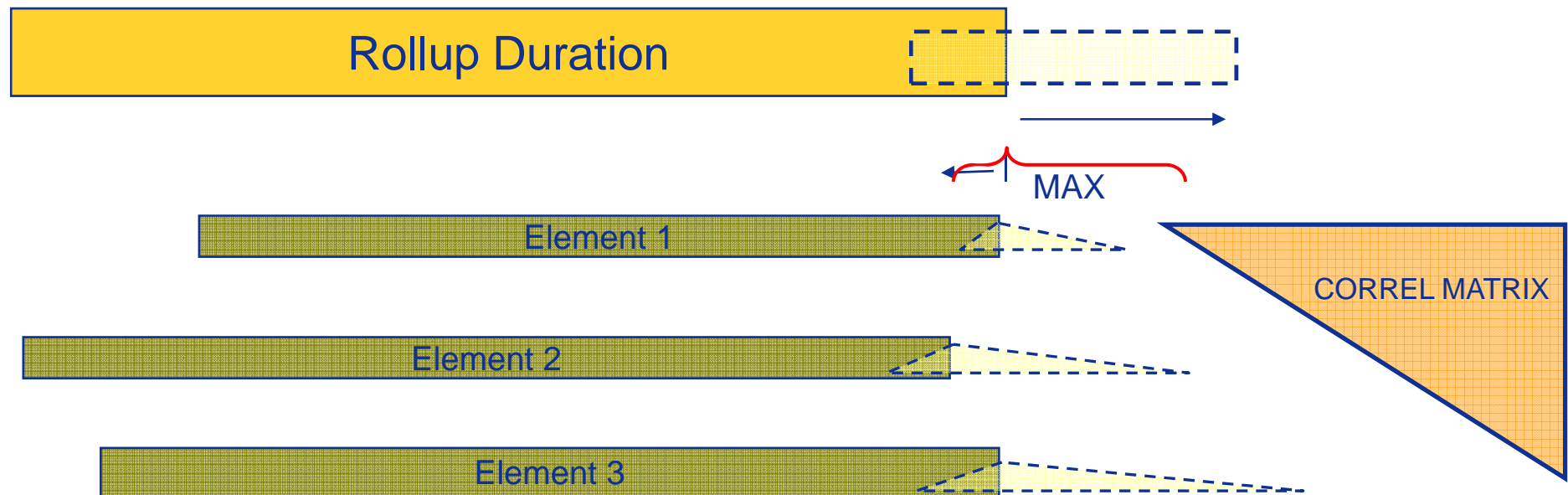
● Schedule sensitizing a cost model means :

- Cost Linked Schedule activities are captured in cost model with associated dates and uncertainty
- TD (LOE) costs are functionally related to schedule duration
- Cost is phased over the schedule duration



Schedule Logic in ACE

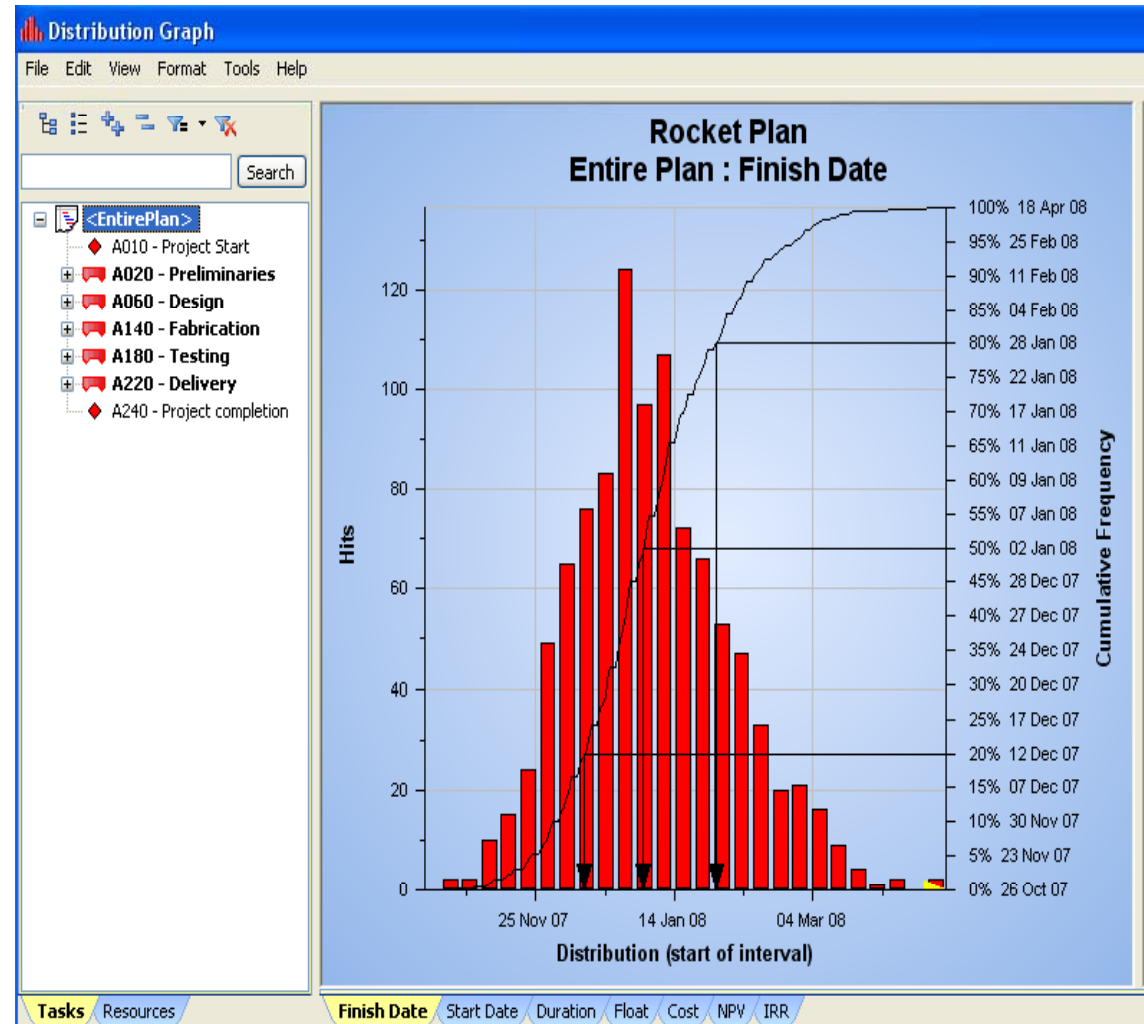
- **Replication of Schedule is Key**
- **Rollup Schedules are calculated based on Min/Max of lower level elements, not summation**
- **Methodology Applies the Mathematical Technique That a Rollup Schedule is Determined by the Max of Lower Level Schedule Activities.**
 - Each activity FD is modeled as a separate distribution using CDF generated from schedule risk tool
 - Rollup FD in cost model is calculated based on the max of the lower level activities
 - Resultant Correlation from the schedule risk tool is used to correlate the lower level schedule items





Steps to Replicate Schedule

- Identify activities in schedule for which costs will be linked
- Conduct Schedule Risk Assessment in schedule tool, including incorporation of Risk items
- Extract statistics for all activities at same level of cost-linked activities
- Extract resulting correlation between these elements (use JCL schedule extraction utility)
- Import into cost model





- **ACE contains functionality to enable JCL calculations using Schedule Uncertainty Data**
- **Schedule Calculation Methods**
 - Duration/Finish Date Calculations
 - Schedule Uncertainty Statistic Incorporation
 - Summary Schedule Calculations (Start Date, Finish Date, Correlation)
- **Duration Sensitive Cost Estimation Methods**
 - Burn Rate Calculations
 - Cost as Function of Duration Calculations
 - Cost Re-phasing
- **JCL Results**
 - S-Curves and Risk Statistics Reports (Cost / Schedule)
 - Cost vs Schedule Scatter Plot
 - Annual Cost Risk Results Over Time



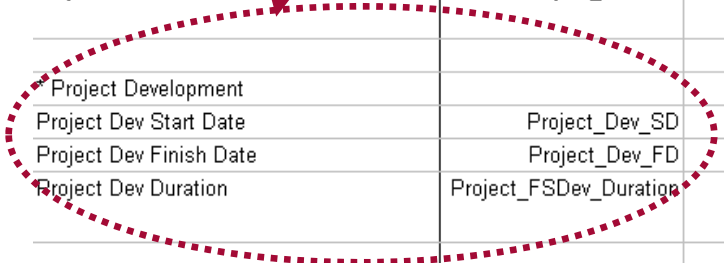
Duration Calculations

- Importing Start Date and Calculating Duration from Finish Date with Schedule Risk
- Including Duration from PertMaster in Import allows for comparison during validation

Schedule Activities imported have a Plan Start Date, Finish Date from the Schedule Risk Simulation, and Calculated Duration

Schedule Activities contain the Calculated Duration from PertMaster as well as the Calculated Duration using Custom CDFs – compare for Validation

WBS/CES Description	Unique ID	Phasing Method	Equation / Throughput	PlanDate (Date) Baseline Plan Date	PlanDuration (!) Plan Duration
** Schedule Information					
*** Cost Loaded Schedules					
* Project					
Project Start Date	Project_SD	C	PlanDate	DDMMYYYYY [Enter Plan	
Project Finish Date	Project_FD	C	ProjectIOC_FD	ProjectIOC_FD.PlanDate	
Project Finish Date - From PertMaster		C	ProjectIOC_PM_FD		
Project Duration	Project_Duration	C	DateDayDiff(Project_SD, Project_FD)+1		DateDayDiff(Project_SD.PlanDate, Project_FD.PlanDate)+1
* Project Development		C			
Project Dev Start Date	Project_Dev_SD	C	PlanDate	DDMMYYYYY [Enter Plan	
Project Dev Finish Date	Project_Dev_FD	C	Dev_Hamcock	Dev_Hamcock.PlanDate	
Project Dev Duration	Project_FSDev_Duration	C	DateDayDiff(Project_Dev_SD, Project_Dev_FD)+1		DateDayDiff(Project_Dev_SD.PlanDate, Project_Dev_FD.PlanDate)+1
* T&V (Flight Tests)					
T&V Start Date	T&V_SD	C	PlanDate	DDMMYYYYY [Enter Plan	
T&V Finish Date	T&V_FD	C	FltTests_FD	FltTests_FD.PlanDate	
T&V Duration	T&V_Duration	C	DateDayDiff(T&V_SD, T&V_FD)+1		DateDayDiff(T&V_SD.PlanDate, T&V_FD.PlanDate)+1





Incorporating Schedule Statistics

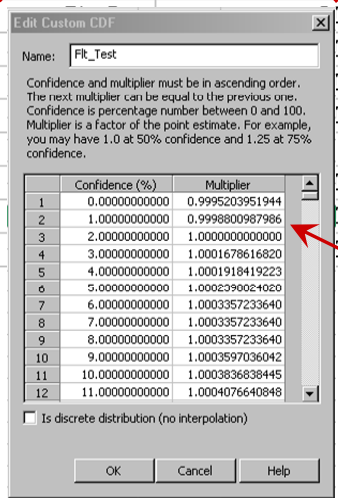
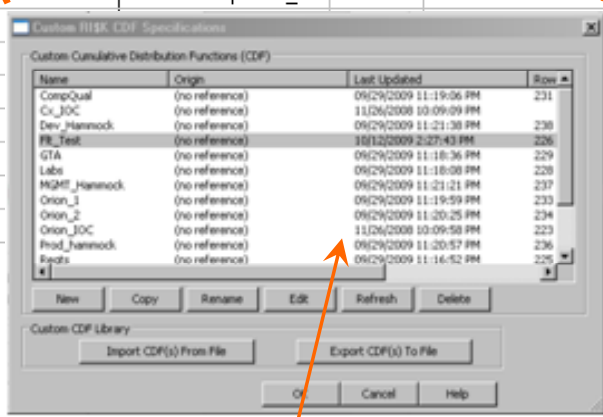
■ Importing Schedule Risks from PertMaster captures results from Schedule risk simulation as multipliers to a Plan Baseline Finish Date (Custom CDFs)

WBS/CES Description	Unique ID	Phasing Method	Equation / Throughput	PlanDate (Date) Baseline Plan Date	Distribution Form	CDF Keyword
* Schedules with Uncertainty						
Project IOC - calculated	ProjectIOC_FD		Max(Reqts_FD, FltTests_FD, SW_FD, Labs_FD, GTA_FD, STA_FD, CompQual_FD, SysQual_FD, Project1_FD, Project2_FD)	Max(Reqts_FD, FltTests_FD, SW_FD, Labs_FD, GTA_FD, STA_FD, CompQual_FD, SysQual_FD, Project1_FD, Project2_FD)		
Project IOC- S-Curve	ProjectIOC_PM_FD			PlanDate	DDMMYYYY [Enter Plan Date]	Project_IOC
Reqts	Reqts_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	Reqts
Flight Tests	FltTests_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	Flt_Test
Software	SW_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	SW
Labs	Labs_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	Labs
GTA	GTA_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	GTA
STA	STA_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	
Comp Qual	CompQual_FD	C		PlanDate	DDMMYYYY [Enter Plan Date]	
Sys Qual				PlanDate	DDMMYYYY [Enter Plan Date]	
Project 1				PlanDate	DDMMYYYY [Enter Plan Date]	
Project 2				PlanDate	DDMMYYYY [Enter Plan Date]	Project_2
Prod Hammock				PlanDate	DDMMYYYY [Enter Plan Date]	Prod_hammock
M&I Hammock				PlanDate	DDMMYYYY [Enter Plan Date]	MGMT_Hammock
Dev Hammock				PlanDate	DDMMYYYY [Enter Plan Date]	Dev_Hammock

Schedule Activities are Imported with Plan Finish Date and Custom CDF with Unique Keyword Name

Schedule CDFs for each Activity available for use in JCL-A Model via Unique ID

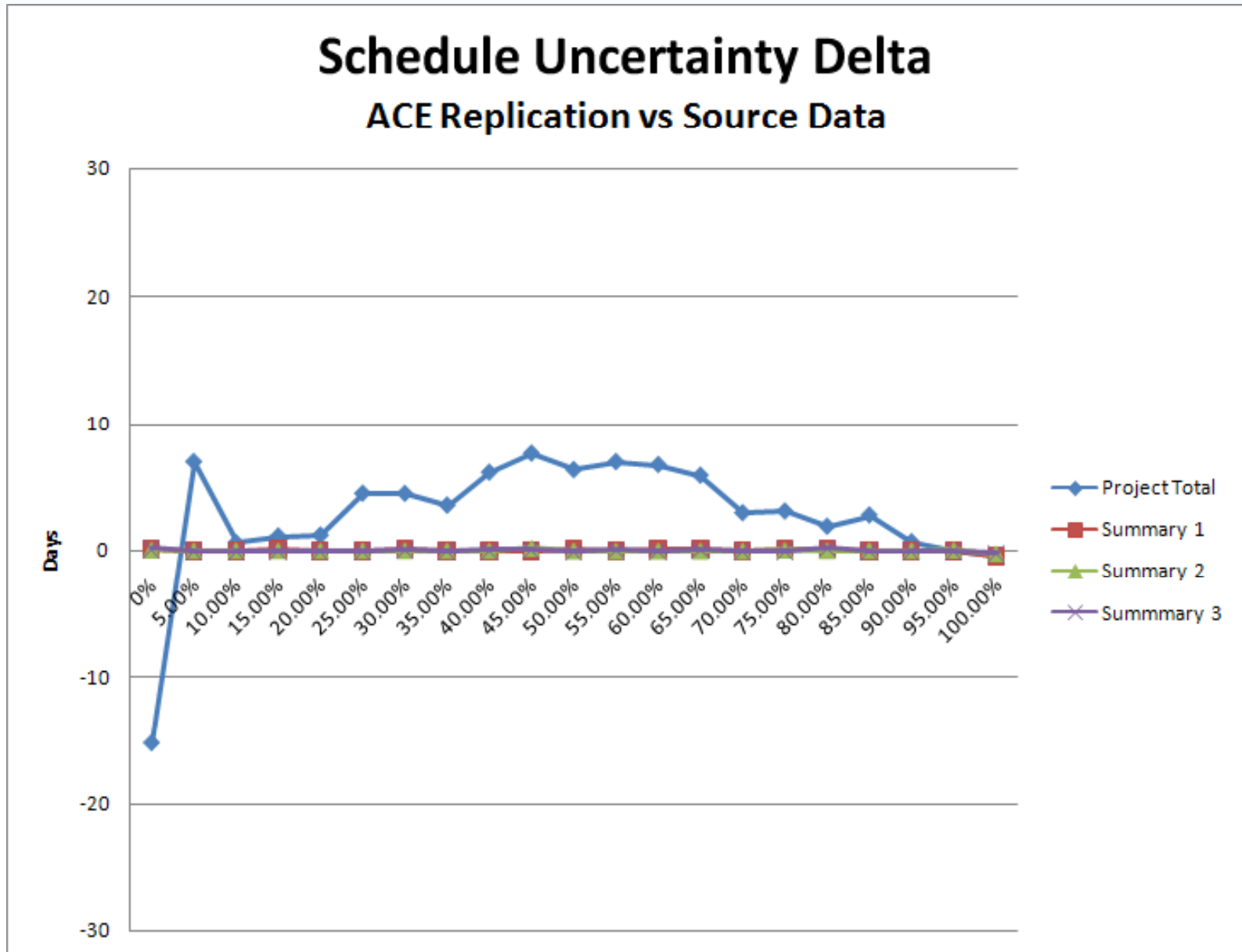
Custom CDFs replicate the results from PertMaster with Multipliers to a Plan Finish Date Confidence Intervals



Custom CDFs are stored in the model representing the results of the Schedule risk simulations in PertMaster



ACEIT vs Schedule Uncertainty Comparison



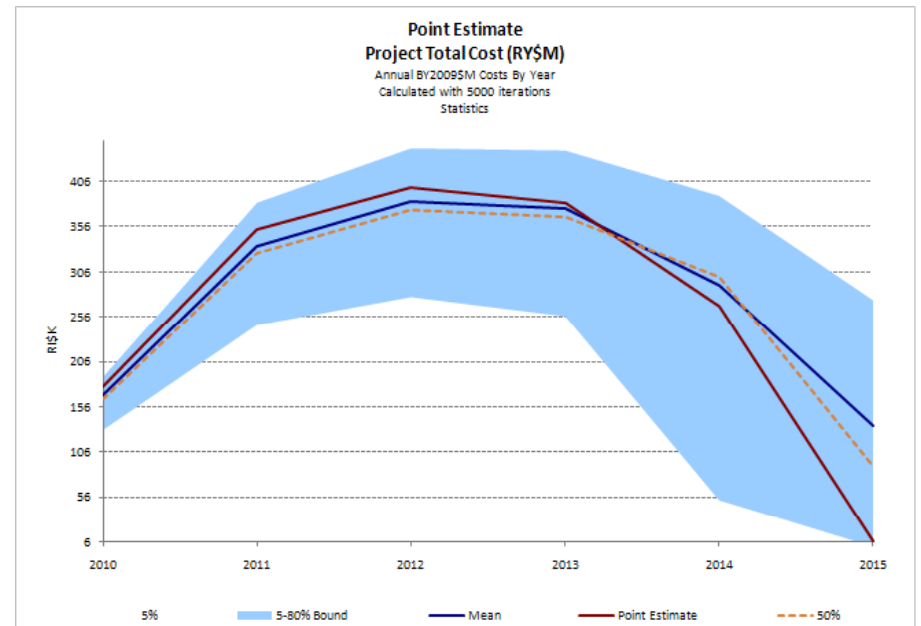
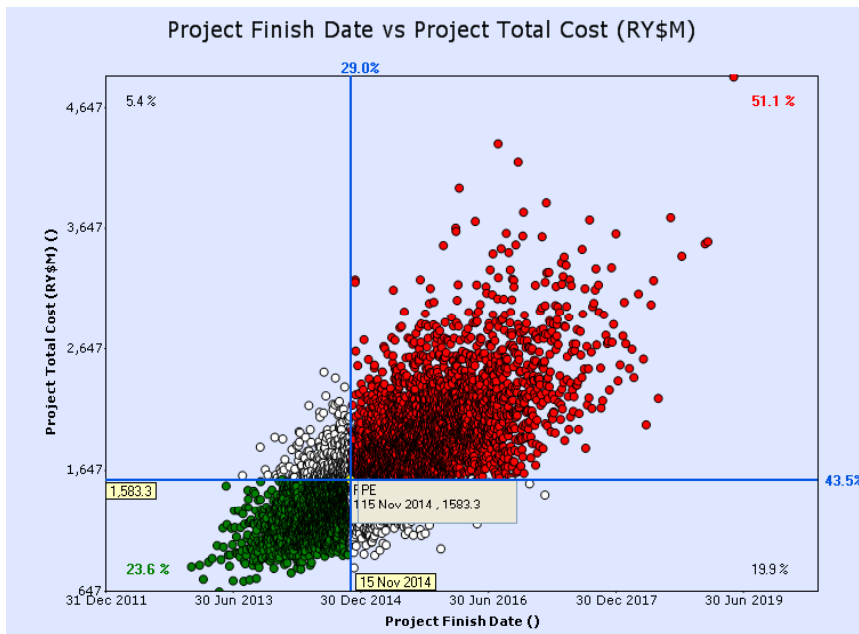


JCL-A provides Standard JCL Visualizations

- JCL-A model continues to provide Total Cost and Finish Date as a pair of values for plotting on an XY or Contour Graph
- Can use either C-SPOT or features in ACEIT 7.2

Total Cost and Finish Date results as simulation pair for JCL plotting

WBS/CES Description	Unique ID	Point Estimate	Phasing Method	Equation / Throughput
* JCL-A Results (Cost Schedule Pair) - TY\$M	*JCLA			
Project Total Cost (RY\$M)		1,583.318 (43%)	F	JCL3_TotalCost * BYtoTY(3600, FYBY, FYYR)
Project Finish Date		15NOV2014 (29%) *	C	JLC3_FD





■ Key Lessons Learned:

- Joint Confidence Level analysis provides integrated look at cost and schedule risk
- Cost and schedule tools can be used to calculate JCL
- Results can be viewed either cumulatively or annually
- Schedule sensitizing a cost model can provide the ability to calculate cost as a function of schedule duration
- It is possible to replicate a Summary Schedule, and Detail Schedules, with schedule risk stats and resulting correlation

■ Leveraging both Schedule & Cost platforms to complete JCL ensures the “*best of both worlds*”

- Schedule Platform completes a robust and thorough Schedule Risk Analysis
- Cost Platform completes an integrated Cost Risk Analysis
- Platforms are used for what they do *best*



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