ACE Joint Probability Utility

Joint Cost & Schedule Risk Analysis

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Abstract

This presentation demonstrates the upcoming Joint Probability Utility and its application. It will show an example of how to use the tool to conduct a Joint Cost & Schedule Risk Analysis, construct visualizations, and report calculated results. Lastly, it will expand on the example by discussing other possible applications such as joint analysis of development and production costs.

Outline

- **What do I mean by Joint Probability?**
  - Conducting the Cost Risk Analysis
  - Conducting the Schedule Risk Analysis
  - Key Factors, End Result, and Definitions
- **Using the simulation results**
  - Process in Joint Probability Utility (JPU)
- **Visualization Outputs**
  - Scatter Plot
  - Joint Probability Contour Plot
  - Cumulative Probability Contour Plot
- **More than just Cost & Schedule**
  - Examples using ACE Tutorial File
- **Conclusion**

What is Joint Probability?

- **What do I mean by Joint Probability?**
  - The probability of two random variables, each with their own distribution (uncertainty) occurring a particular point
  - Cumulative Joint Probability (or Joint Confidence Level) is the total cumulative probability of both variables being at or lower than the target variable
  - For only two variables, such as cost & schedule, the result is a bivariate distribution.
  - Analyzing the resulting distribution can provide
    - Joint Probability
    - Cumulative Probability
    - Joint Confidence Level

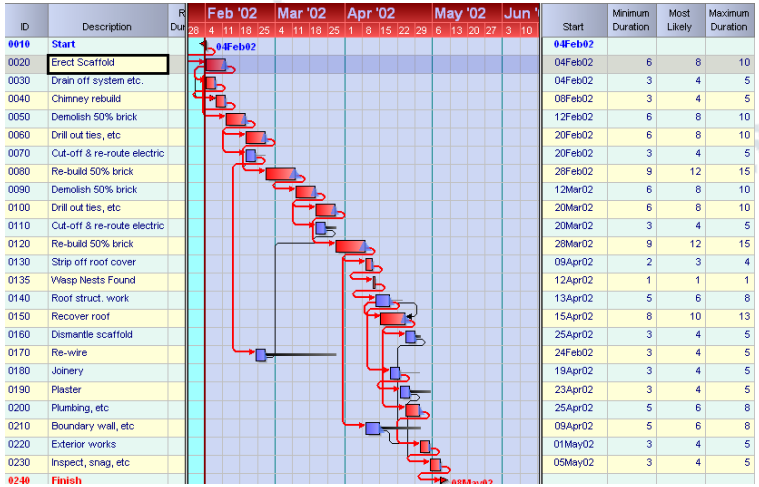
  - Example: Rolling 2 regular dice (6-sided), what is the probability that a Die one will equal 1 and the other will equal 6? (Joint Probability!)

Cost Risk Analysis

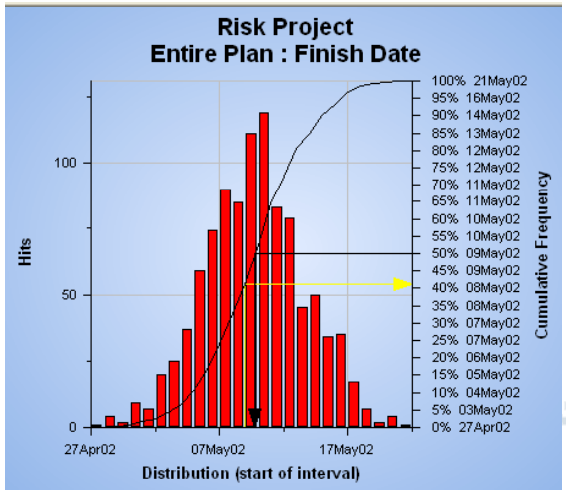
- **To complete JCL on cost & schedule, uncertainty/risk analysis needs to be completed**
  - Detailed How To? See the AFCAA Cost Risk Uncertainty Handbook
- **Methods available to include uncertainty as well as discrete risks**
- **Challenge: Need to understand behavior of costs**
  - JCL…schedule…how is cost affected by schedule changes?
  - Fixed cost increase due to schedule growth, etc
- **Challenge: Common WBS**
  - JCL…schedule…how to load all costs against schedule?
  - Schedule WBS by Activity VS. Cost WBS by Product
- **Flexibility in re-summarizing source detail estimate (ACE!)**
- **Ability to specify uncertainty at varying levels (ACE!)**

Schedule Risk Analysis

- **An integrated master schedule is ideal, but a high level representation can behave similarly…**
- **Logically linked network of schedule activities**
- **Uncertainty specified on the activity duration**
- **Ability to incorporate discrete events (probabilistic branching)**
- **Challenge: Schedule must be compatible with cost estimate**
  - JCL…cost…is the schedule from the same plan as the cost
  - Need to ensure the finish date is the same for both plans
- **Ability to specify correlation between schedule activities**



ID	Description	Start	Minimum Duration	Most Likely	Maximum Duration
0010	Start	04Feb02			
0020	Erect Scaffold	04Feb02	6	8	10
0030	Drain off system etc.	04Feb02	3	4	5
0040	Chimney rebuild	08Feb02	3	4	5
0050	Demolish 50% brick	12Feb02	6	8	10
0060	Drill out ties, etc	20Feb02	6	8	10
0070	Cut-off & re-route electric	20Feb02	3	4	5
0080	Re-build 50% brick	28Feb02	9	12	15
0090	Demolish 50% brick	12Mar02	6	8	10
0100	Drill out ties, etc	20Mar02	6	8	10
0110	Cut-off & re-route electric	20Mar02	3	4	5
0120	Re-build 50% brick	28Mar02	9	12	15
0130	Strip off roof cover	09Apr02	2	3	4
0135	Wasp Nests Found	12Apr02	1	1	1
0140	Roof struct. work	13Apr02	5	6	8
0150	Recover roof	15Apr02	8	10	13
0160	Dismantle scaffold	25Apr02	3	4	5
0170	Re-wire	24Feb02	3	4	5
0180	Joinery	19Apr02	3	4	5
0190	Plaster	23Apr02	3	4	5
0200	Plumbing, etc	25Apr02	5	6	8
0210	Boundary wall, etc	09Apr02	5	6	8
0220	Exterior works	01May02	3	4	5
0230	Inspect, snag, etc	05May02	3	4	5
0240	Finish				



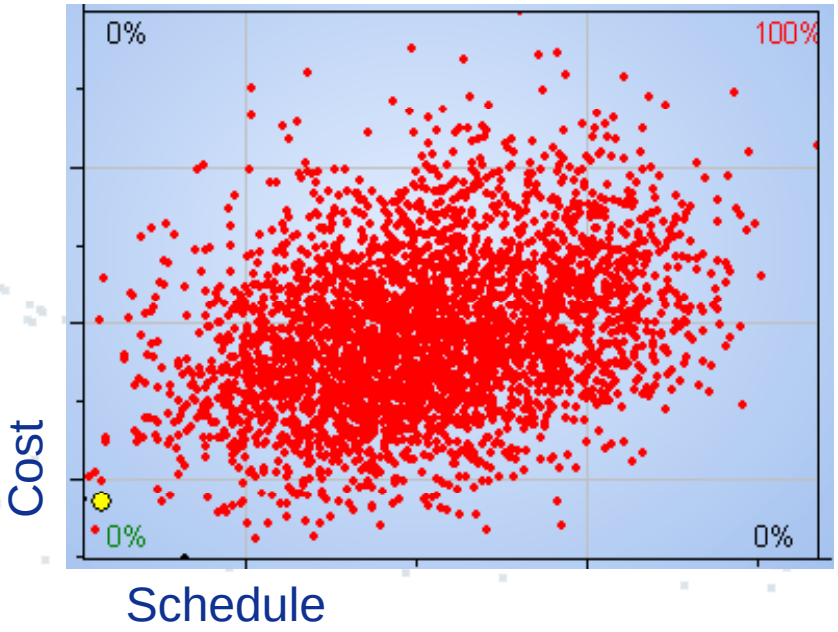
Key Factors for JCL Cost & Schedule

- Cost & Schedule risk analysis complete
- Cost risk analysis should not include uncertainty due to schedule!
- IMS contains network of logically linked activities
- Behavior of cost established to allow the total cost to calculate as a function of the schedule duration
- Ability to cost-load the network of schedule activities
- Ability to schedule-load the cost estimate (!!)

The End Result

- A distribution of cost & schedule pairs
- For every finish date, a total cost value reflective of the total schedule duration
- Number of pairs depends on number of iterations completed

	B	C	D	E
54				
55		Iterations	IOC Total Cost	IOC Launch Date
56		1	$17,876	11 Sep 2016
57		2	$15,113	14 Feb 2016
58		3	$21,661	07 Apr 2018
59		4	$21,948	06 Dec 2016
60		5	$16,929	26 May 2017
61		6	$16,014	22 Mar 2018
62		7	$15,156	06 Dec 2016
63		8	$14,743	23 Aug 2016
64		9	$13,974	15 Jul 2017
65		10	$15,000	05 Feb 2017
66		11	$17,756	14 Nov 2016
67		12	$15,303	13 Jan 2015
68		13	$18,612	10 Sep 2012

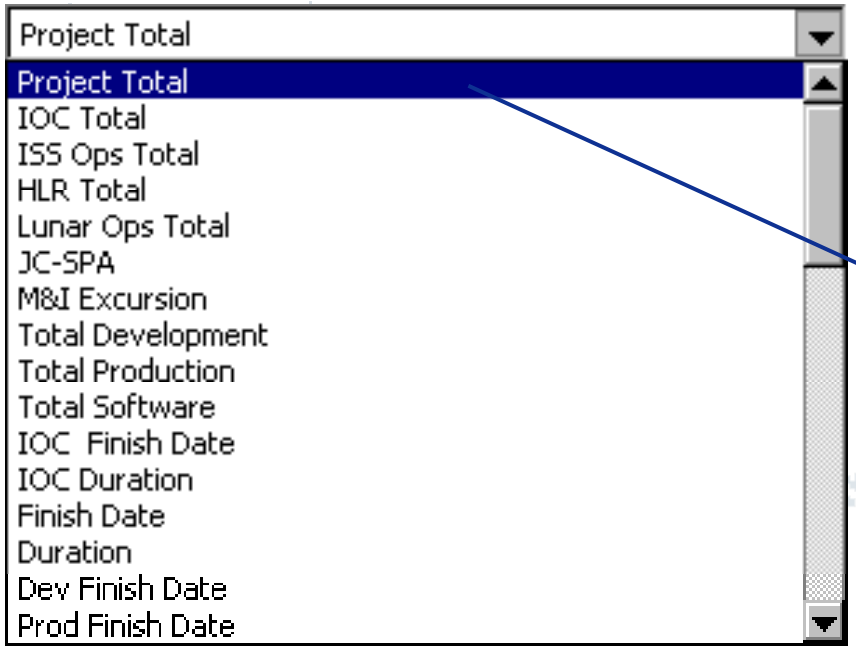


Definitions

- **Joint Probability – the probability of a single pair of random variables (X, Y) occurring given the total distribution of pairs.**
  - Example: The joint probability of the pair value, finish date = 01 Jan 2013 and total cost = $25B, is 1% in this distribution of 5k iterations. (meaning 50 of the iteration draws was the 01Jan2013, $25B pair)
  - The sum of all joint probabilities is 100%

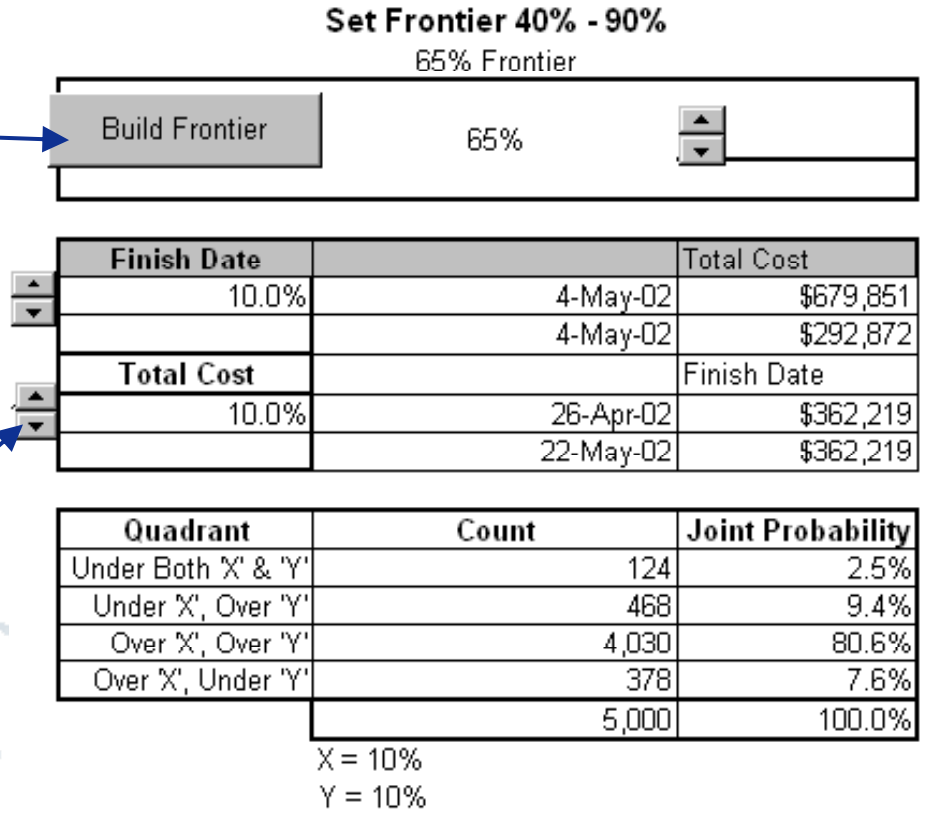
- **Cumulative Probability – the sum of the total probability up to a certain pair value (cost = x, schedule = y). This includes the sum of all probabilities for pair values <=x and y.**
  - Example: The cumulative probability of finishing before 01 Jan 2013, for a total cost less than $25B, is 10%.
  - S-Curves and Scatter plot quadrant
  - Joint Confidence Level

- **Demonstration - Input the simulation results**
- **Select from drop-down allows for easier storage of many simulation results**



Project Total	IOC Total	ISS Ops Total	HLR Total	Lunar Ops Total
$17,876	$12,348	$4,314	$832	$383
$15,113	$10,214	$3,938	$616	$345
$21,661	$13,263	$6,449	$1,338	$611
$21,948	$14,982	$5,364	$1,116	$486
$16,929	$11,598	$4,238	$704	$389
$16,014	$10,535	$4,371	$706	$401
$15,156	$10,346	$3,732	$756	$321
$14,743	$9,455	$3,976	$964	$348
$13,974	$9,495	$3,451	$714	$314
$15,000	$10,008	$3,917	$716	$358
$17,756	$12,270	$4,348	$764	$374

- **Scatter Plot**
  - Quadrants form Horizontal and Vertical lines
- **Frontier Line**
  - Specify % to draw line
- **User Controls**
  - Move the Horizontal and Vertical lines



Set Frontier 40% - 90%

65% Frontier

Build Frontier | 65%

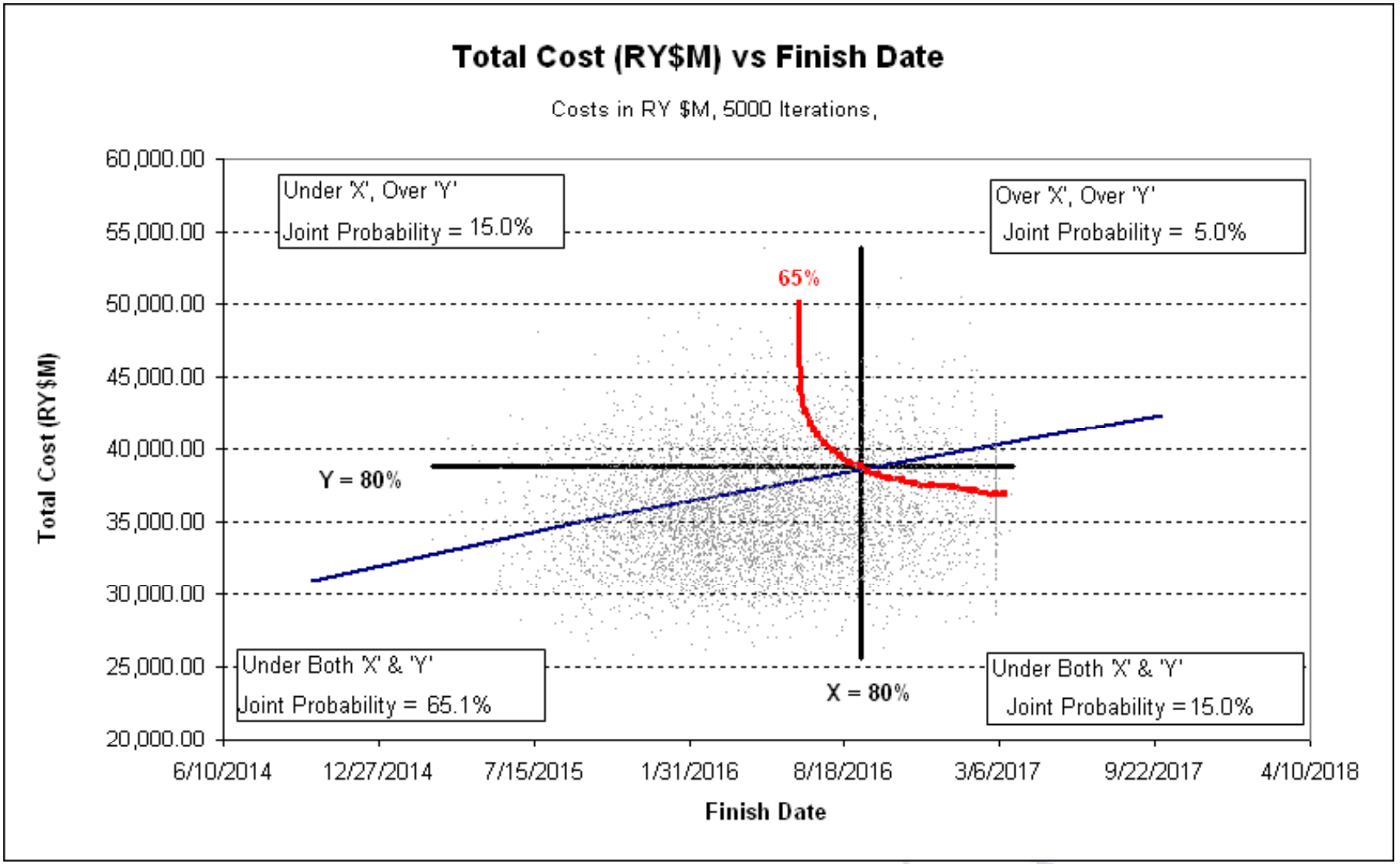
Finish Date		Total Cost
10.0%	4-May-02	$679,851
	4-May-02	$292,872
Total Cost		Finish Date
10.0%	26-Apr-02	$362,219
	22-May-02	$362,219

Quadrant	Count	Joint Probability
Under Both 'X' & 'Y'	124	2.5%
Under 'X', Over 'Y'	468	9.4%
Over 'X', Over 'Y'	4,030	80.6%
Over 'X', Under 'Y'	378	7.6%
	5,000	100.0%

X = 10%

Y = 10%

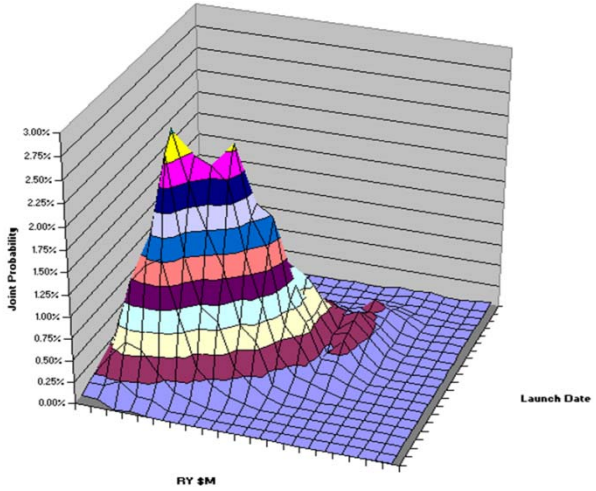
Inside JPU - Screenshot

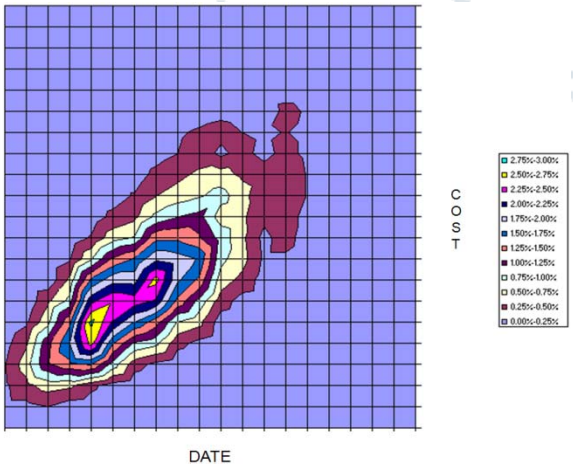


- **Notional Data for illustrative purposes only**

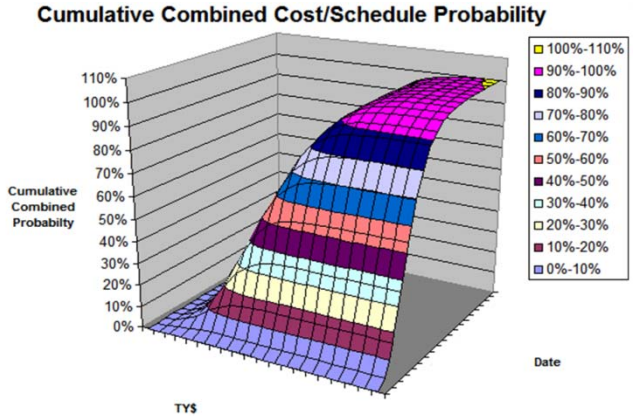
Inside JPU - Contour Plots

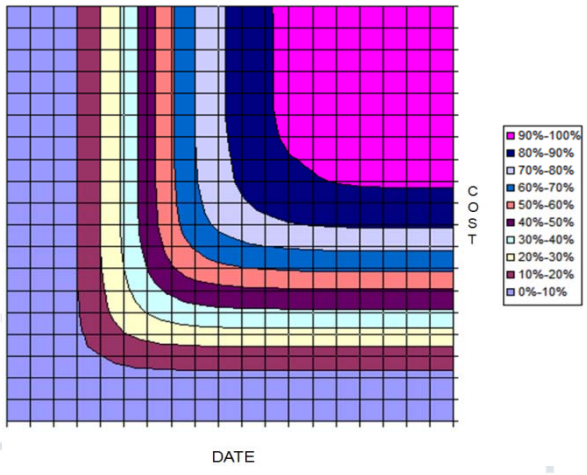
- **Joint Probability**





- **Cum Probability**



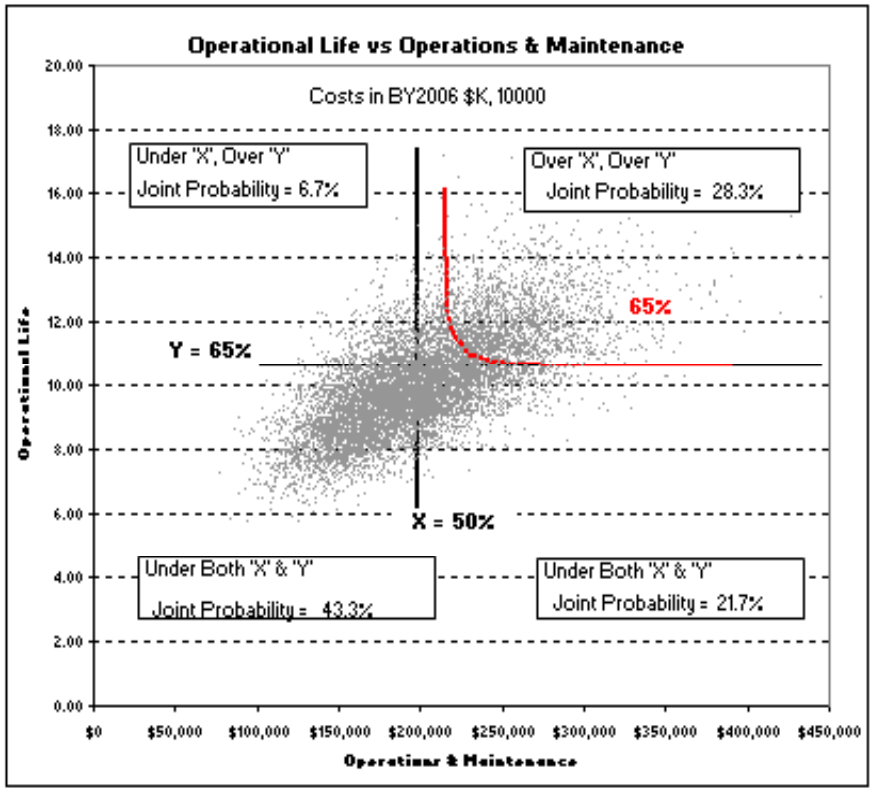


More than Cost & Schedule

- **ACE Example file demonstrations (06 – Advanced Risk.aceit)**
  - **Operational Life and Total O&M Cost**
    - How is total O&M cost a function of op life?
      - OpFieldedUnits = Fielding Schedule. Life is used to calculate how many units are operating in the field at any one time. Cost for O&S is largely based on the number of units operating in the field.
  - **RDTE Costs for Nav/Guid of Air Vehicle & Nav/Guid Weight (lbs)**
    - CER calculating Cost relies on Nav/Guid Weight
    - How does distribution of weights impact total cost?
  - **Analyze the joint probability of the technical parameter to a total cost**

OpLife and O&M Costs

Joint Probability Chart



Set Frontier 40% - 90%

65% Frontier

Buld Frontier	65%	0

Operations & Maintenance		Operational Life
50.0%	$198,232	17.42
	$198,232	5.78
Operational Life	Operations & Maintenance	
65.0%	$77,131	10.60
	$444,442	10.60

Quadrant	Count	Joint Probability
Under Both 'X' & 'Y'	4,330	43.3%
Under 'X', Over 'Y'	672	6.7%
Over 'X', Over 'Y'	2,826	28.3%
Over 'X', Under 'Y'	2,172	21.7%
	10,000	100.0%

X = 50%
Y = 65%

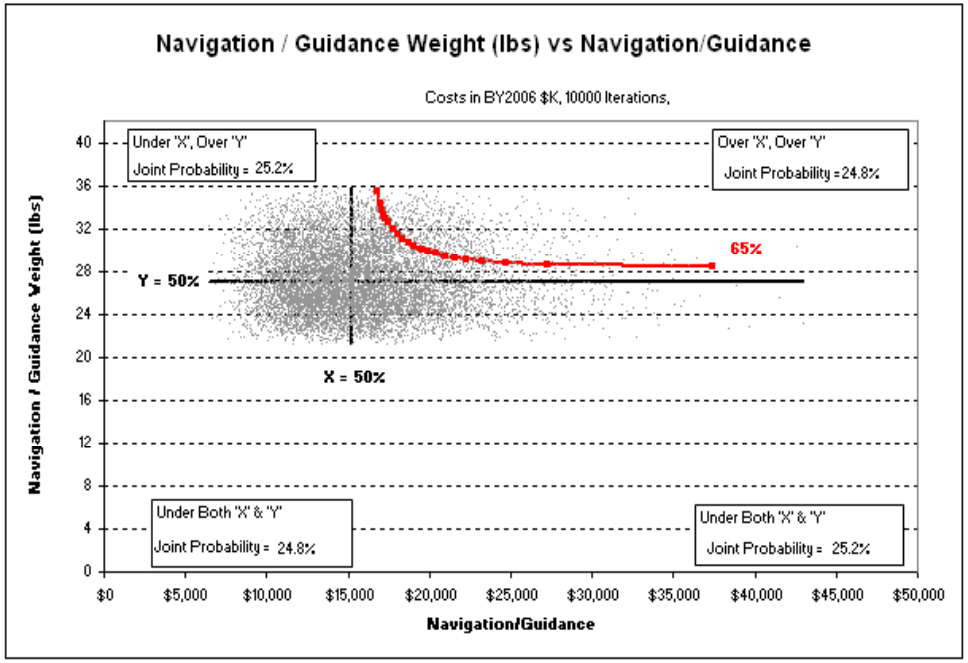
50% Cost Value

65% CL Tech Parameter

- **In this example OpLife can be partial years, an improvement to the model would force OpLife to integer only (RndUp)**

Nav Wgt (Lbs) & RDTE Costs

Joint Probability Chart



Set Frontier 40% - 90%

65% Frontier

Build Frontier 65%

Navigation/Guidance		Navigation / Guidance Weight (lbs)
50.0%	$15,238	35.81
	$15,238	21.22
Navigation / Guidance Weight (lbs)		Navigation/Guidance
50.0%	$6,443	26.93
	$42,988	26.93

Quadrant	Count	Joint Probability
Under Both 'X' & 'Y'	2,484	24.8%
Under 'X', Over 'Y'	2,518	25.2%
Over 'X', Over 'Y'	2,480	24.8%
Over 'X', Under 'Y'	2,518	25.2%
	10,000	100.0%

X = 50%
Y = 50%

50% Cost Value

50% CL Weight (lbs)

Conclusion

- JPU is projected to be delivered with ACEIT v7.2
- Intent is to make JPU Tool Independent; that is, the user can use simulation results from a variety of sources (ACE, CBall, @Risk, etc) to generate the reports
- Easily constructs JCL visualizations
- Easily conduct JCL on many variables, not just cost & schedule