Quantitative Cost-Schedule Risk Analysis in the 2015 LFM

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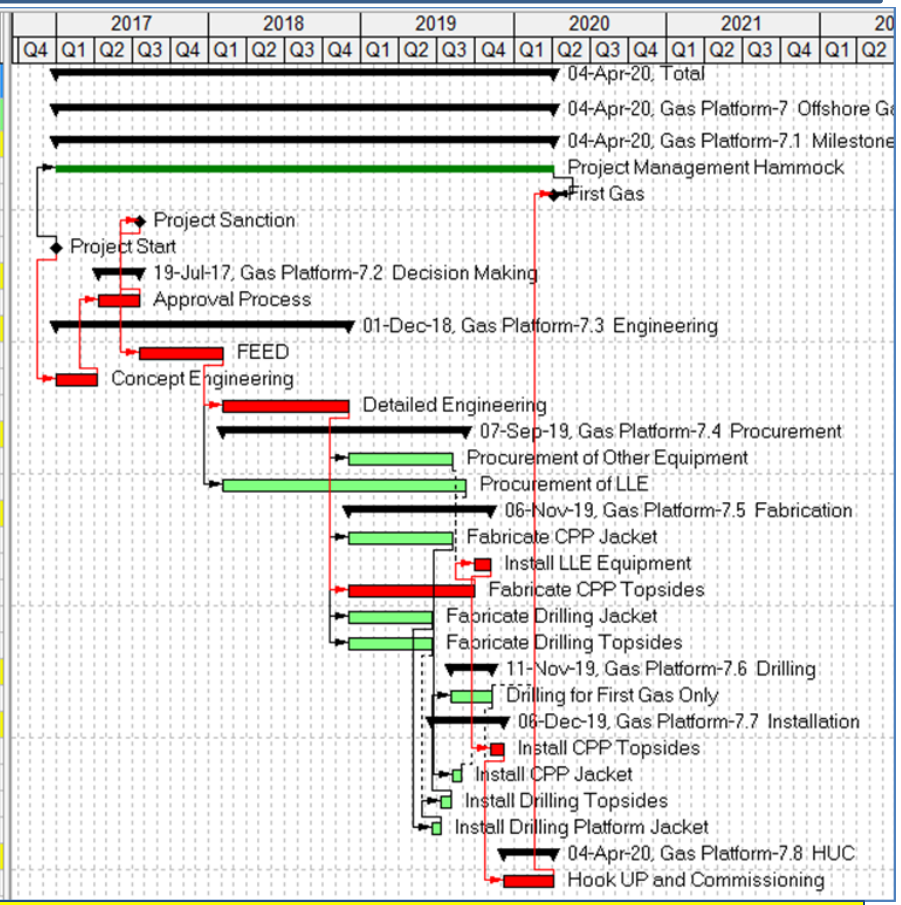
Example Schedule: Offshore Gas Production Platform Project

Activity ID	Activity Name	Original Duration	Start	Finish
Total		1190d	01-Jan-17	04-Apr-20
Gas Platform-7 Offshore Gas Pr		1190d	01-Jan-17	04-Apr-20
Gas Platform-7.1 Milestones and Ham		1190d	01-Jan-17	04-Apr-20
A1030	Project Management Hammock	1190d	01-Jan-17	04-Apr-20
A1020	First Gas	0d		04-Apr-20
A1010	Project Sanction	0d		19-Jul-17
A1000	Project Start	0d	01-Jan-17*	
Gas Platform-7.2 Decision Making		100d	11-Apr-17	19-Jul-17
B1000	Approval Process	100d	11-Apr-17	19-Jul-17
Gas Platform-7.3 Engineering		700d	01-Jan-17	01-Dec-18
C950	FEED	200d	20-Jul-17	04-Feb-18
C900	Concept Engineering	100d	01-Jan-17	10-Apr-17
C1010	Detailed Engineering	300d	05-Feb-18	01-Dec-18
Gas Platform-7.4 Procurement		580d	05-Feb-18	07-Sep-19
D1010	Procurement of Other Equipment	250d	02-Dec-18	08-Aug-19
D1000	Procurement of LLE	580d	05-Feb-18	07-Sep-19
Gas Platform-7.5 Fabrication		340d	02-Dec-18	06-Nov-19
E1030	Fabricate CPP Jacket	250d	02-Dec-18	08-Aug-19
E1025	Install LLE Equipment	40d	28-Sep-19	06-Nov-19
E1020	Fabricate CPP Topsides	300d	02-Dec-18	27-Sep-19
E1010	Fabricate Drilling Jacket	200d	02-Dec-18	19-Jun-19
E1000	Fabricate Drilling Topsides	200d	02-Dec-18	19-Jun-19
Gas Platform-7.6 Drilling		100d	04-Aug-19	11-Nov-19
F1000	Drilling for First Gas Only	100d	04-Aug-19	11-Nov-19
Gas Platform-7.7 Installation		170d	20-Jun-19	06-Dec-19
G1030	Install CPP Topsides	30d	07-Nov-19	06-Dec-19
G1020	Install CPP Jacket	20d	09-Aug-19	28-Aug-19
G1010	Install Drilling Topsides	25d	10-Jul-19	03-Aug-19
G1000	Install Drilling Platform Jacket	20d	20-Jun-19	09-Jul-19
Gas Platform-7.8 HUC		120d	07-Dec-19	04-Apr-20
H1000	Hook UP and Commissioning	120d	07-Dec-19	04-Apr-20



This is not the model I used for the LFM. That one is lost to the computer gremlins.

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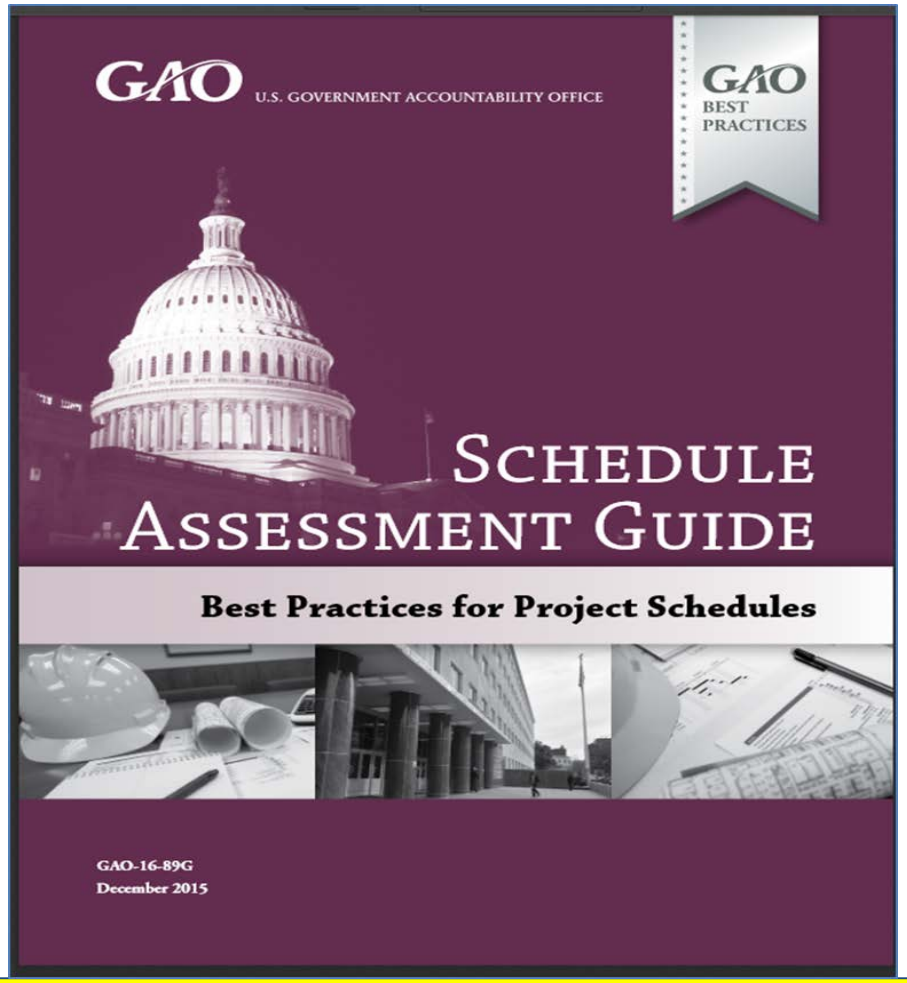
Test the Schedule against GAO 10-point Scheduling Best Practices



http://www.gao.gov/products/GAO-16-89G

Third-Party Software Can Help in Testing the Quality of the Schedule

ORACLE
PRIMAVERA RISK ANALYSIS

Schedule Check Report

Plan Summary

Title	Offshore Gas Production Platform		
File name	C:\Users\David\Documents\Architect of the Capitol\Chiller Project\Schedule Review\Offshore Gas Production Platform.plan		
Plan finish date	04/04/2019	Tasks with no progress	30
Plan remaining duration	1920	In progress tasks	0
Normal tasks	17	Completed tasks	0
Summary tasks	9	Total tasks	30
Milestone tasks	3	Resource assignments	17
Hammock tasks	1	Budget cost	$1,317,200
Monitor tasks	0	Remaining cost	$1,317,200
Calendars	5	Actual cost	$0
Links	27	Total cost	$1,317,200
Resources	14		

Report Summary

Task view	All tasks
Constraints	1
Open-ended tasks (Does not include ignored links)	2
Out of sequence updates ("broken logic")	0
Lags longer than 0 units	0
Negative lags ("leads")	0
Positive lags on Finish-to-Start links	0
Start-to-Finish links	0
Lags between tasks with different calendars	0
Links to / from summary tasks	0
Duration uncertainty distribution shape 2	Not checked
Total number of items found	3

Oracle Primavera Risk Analysis Schedule Check Report

Ribbon Analyzer

Missing Predecessors	Missing Successors	Open Start	Open Finish	Lags	Leads	Hard Constraints	Soft Constraints	Score
1 (5%)	1 (5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5%)	0 (0%)	90%

Deltek Acumen FUSE

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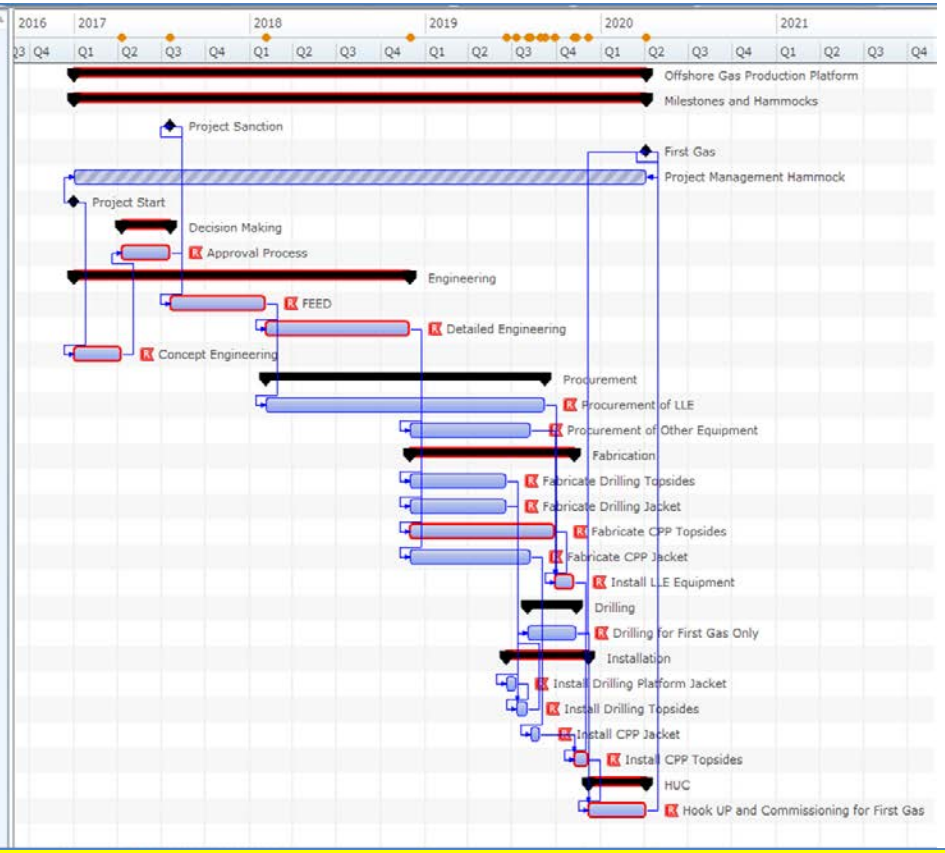
Import to Integrated Cost-Schedule Risk Analysis Software

UID	Task	Start Date	End Date	Duration	Cost
Gas Pla	▼ Offshore Gas Production Platfor	01/01/2017	04/04/2020	1,190	$1.697M
Gas Pla	▼ Milestones and Hammocks	01/01/2017	04/04/2020	1,190	$80,000
A1010	Project Sanction		07/19/2017	0	$0
A1020	First Gas		04/04/2020	0	$0
A1030	Project Management Ham	01/01/2017	04/04/2020	1,190	$80,000
A1000	Project Start	01/01/2017		0	$0
Gas Pla	▼ Decision Making	04/11/2017	07/19/2017	100	$8,000
B1000	Approval Process	04/11/2017	07/19/2017	100	$8,000
Gas Pla	▼ Engineering	01/01/2017	12/01/2018	700	$256,000
C950	FEED	07/20/2017	02/04/2018	200	$80,000
C1010	Detailed Engineering	02/05/2018	12/01/2018	300	$160,000
C900	Concept Engineering	01/01/2017	04/10/2017	100	$16,000
Gas Pla	▼ Procurement	02/05/2018	09/07/2019	580	$350,000
D1000	Procurement of LLE	02/05/2018	09/07/2019	580	$250,000
D1010	Procurement of Other Equ	12/02/2018	08/08/2019	250	$100,000
Gas Pla	▼ Fabrication	12/02/2018	11/06/2019	340	$836,000
E1000	Fabricate Drilling Topsides	12/02/2018	06/19/2019	200	$180,000
E1010	Fabricate Drilling Jacket	12/02/2018	06/19/2019	200	$140,000
E1020	Fabricate CPP Topsides	12/02/2018	09/27/2019	300	$320,000
E1030	Fabricate CPP Jacket	12/02/2018	08/08/2019	250	$164,000
E1025	Install LLE Equipment	09/28/2019	11/06/2019	40	$32,000
Gas Pla	▼ Drilling	08/04/2019	11/11/2019	100	$80,000
F1000	Drilling for First Gas Only	08/04/2019	11/11/2019	100	$80,000
Gas Pla	▼ Installation	06/20/2019	12/06/2019	170	$47,200
G1000	Install Drilling Platform Ja	06/20/2019	07/09/2019	20	$8,000
G1010	Install Drilling Topsides	07/10/2019	08/03/2019	25	$13,600
G1020	Install CPP Jacket	08/09/2019	08/28/2019	20	$9,600
G1030	Install CPP Topsides	11/07/2019	12/06/2019	30	$16,000
Gas Pla	▼ HUC	12/07/2019	04/04/2020	120	$40,000
H1000	Hook UP and Commission	12/07/2019	04/04/2020	120	$40,000



39-month
$1.7 billion
Project

Using Booz Allen Hamilton Polaris©
http://www.boozallen.com/consulting/products/polaris

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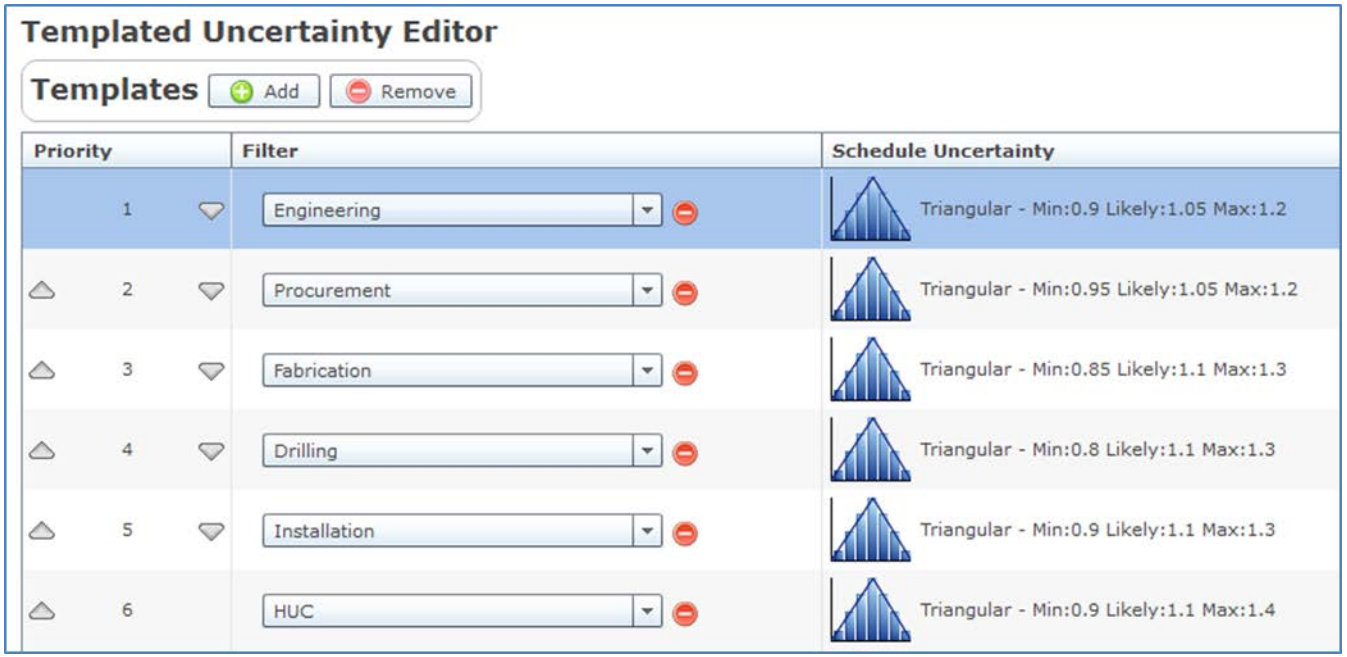
Adding Uncertainty to Activity Durations and Resource Quantities by Reference Ranges

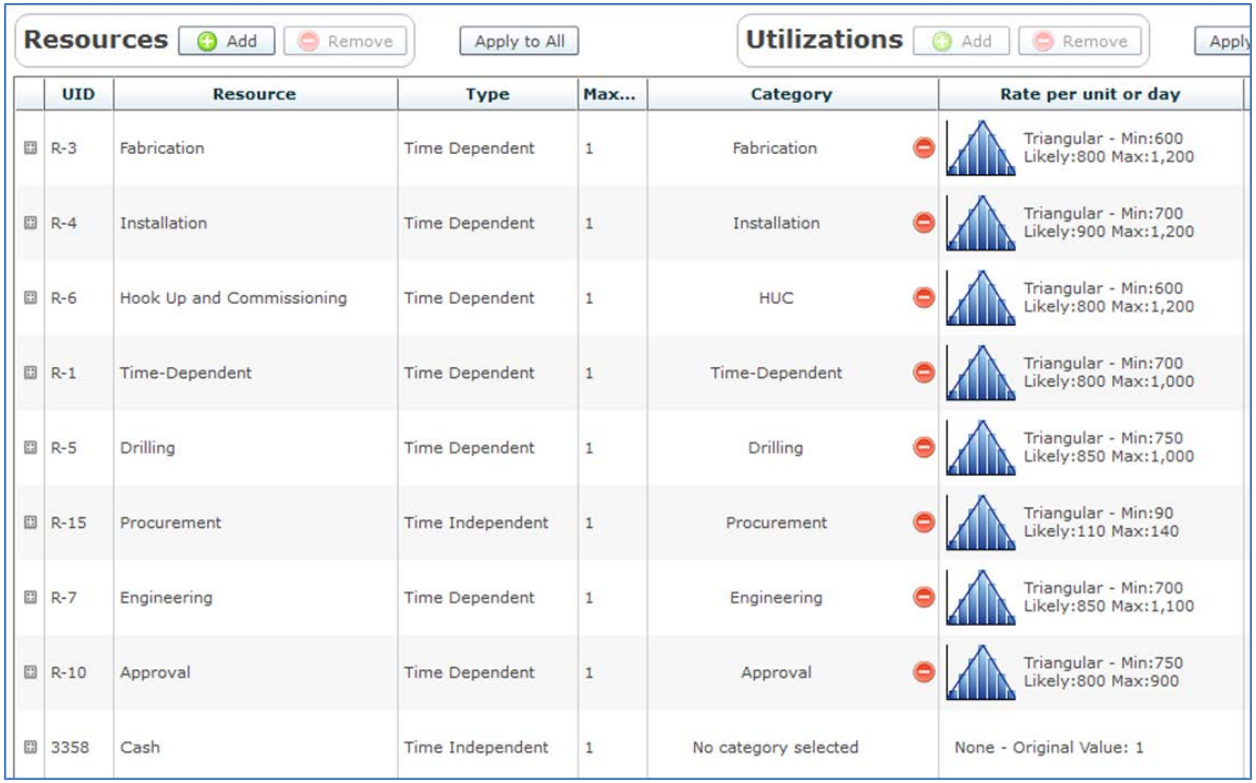
- Uncertainty in schedule duration is similar to "common cause" variation related to six sigma process control concepts developed by Walter Shewhart and championed by Edwards Demming
- "Common cause variability is a source of variation caused by unknown factors that result in a steady but random distribution of output around the average of the data …. Common cause variation is also called random variation, noise, non-controllable variation … " (http://www.isixsigma.com/dictionary/common-cause-variation/)

Uncertainty to Activity Durations by Reference Ranges



These represent uncertainty parameters for the entire activity class (engineering, procurement, fabrication…). To achieve that while using the specified ranges on each activity within the class, these uncertainty values must be correlated 100%

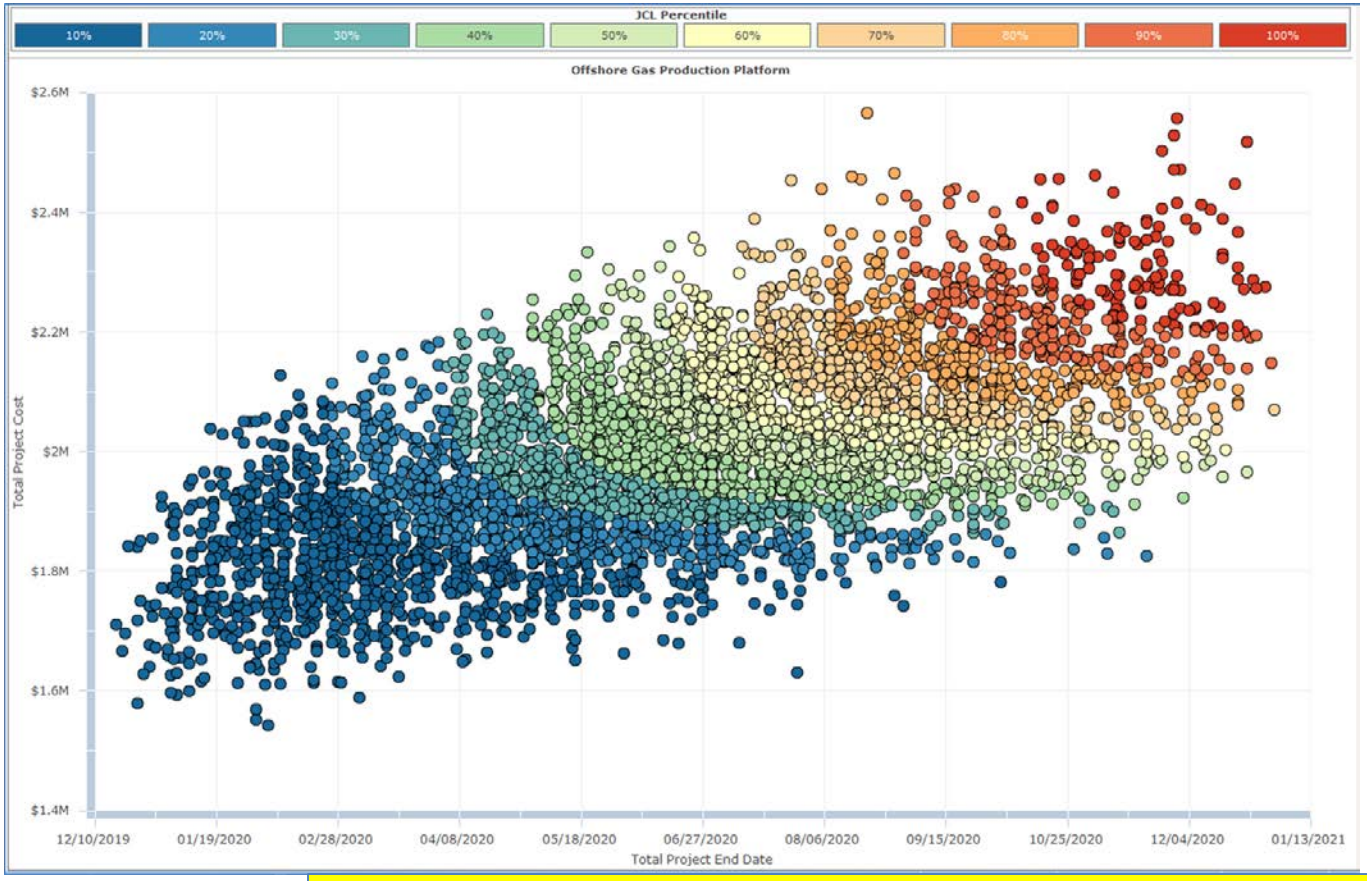
Resource usage Uncertainty Ranges



Resources Add Remove Apply to All Utilizations Add Remove Apply

UID	Resource	Type	Max...	Category	Rate per unit or day
R-3	Fabrication	Time Dependent	1	Fabrication	Triangular - Min:600 Likely:800 Max:1,200
R-4	Installation	Time Dependent	1	Installation	Triangular - Min:700 Likely:900 Max:1,200
R-6	Hook Up and Commissioning	Time Dependent	1	HUC	Triangular - Min:600 Likely:800 Max:1,200
R-1	Time-Dependent	Time Dependent	1	Time-Dependent	Triangular - Min:700 Likely:800 Max:1,000
R-5	Drilling	Time Dependent	1	Drilling	Triangular - Min:750 Likely:850 Max:1,000
R-15	Procurement	Time Independent	1	Procurement	Triangular - Min:90 Likely:110 Max:140
R-7	Engineering	Time Dependent	1	Engineering	Triangular - Min:700 Likely:850 Max:1,100
R-10	Approval	Time Dependent	1	Approval	Triangular - Min:750 Likely:800 Max:900
3358	Cash	Time Independent	1	No category selected	None - Original Value: 1

Scatterplot: Effect of Uncertainty on Durations and Resources



Correlation Finish Date – Cost calculated at 62%. Upward slope reflects effect of uncertain durations on cost

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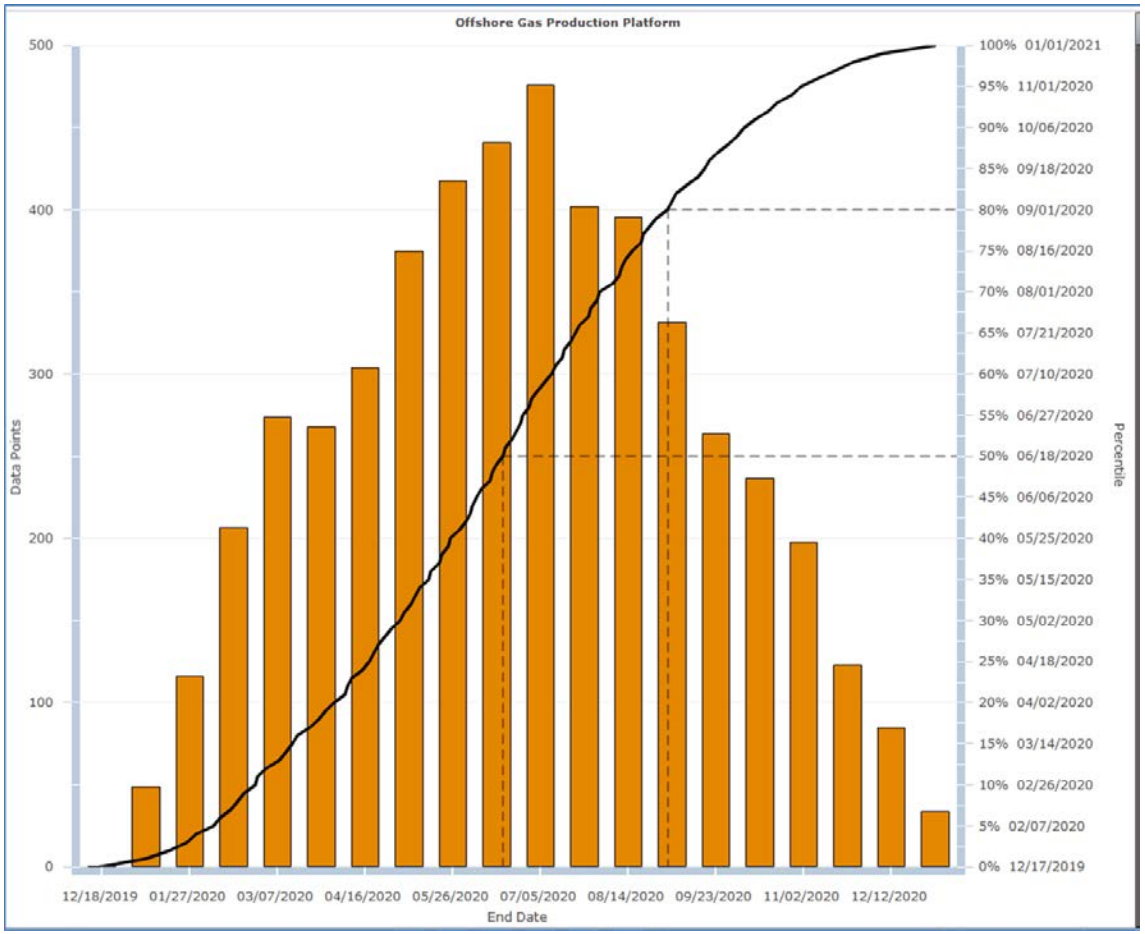
Effect of Uncertainty on Finish Date

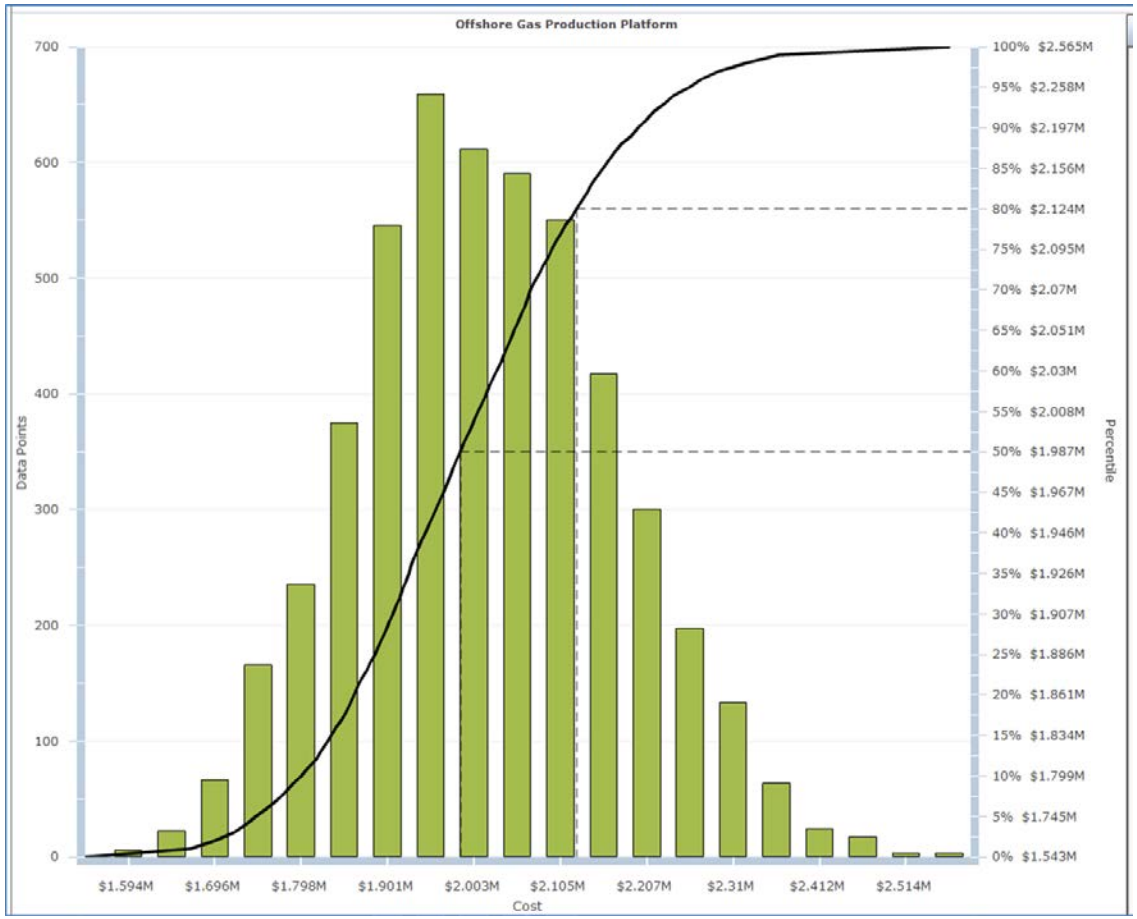


Deterministic Finish Date 4/4/20

P-80 Finish Date 9/1/20

Effect = + 5 months

Effect of Uncertainty on Project Cost



Baseline = $1.69 billion

P-80 cost = $2.12 billion

Over cost = $427 million or 25%

Add Project-Specific Risks

- Risk is similar to “special causes” in six sigma
- “… special cause variation is caused by known factors that result in a non-random distribution of output…Special cause variation is a shift in output caused by a specific factor such as environmental conditions or process input parameters. It can be accounted for directly and potentially removed...” (http://www.isixsigma.com/dictionary/variation-special-cause/)
- Hence, pre-mitigated risks are the subject of risk mitigation workshops

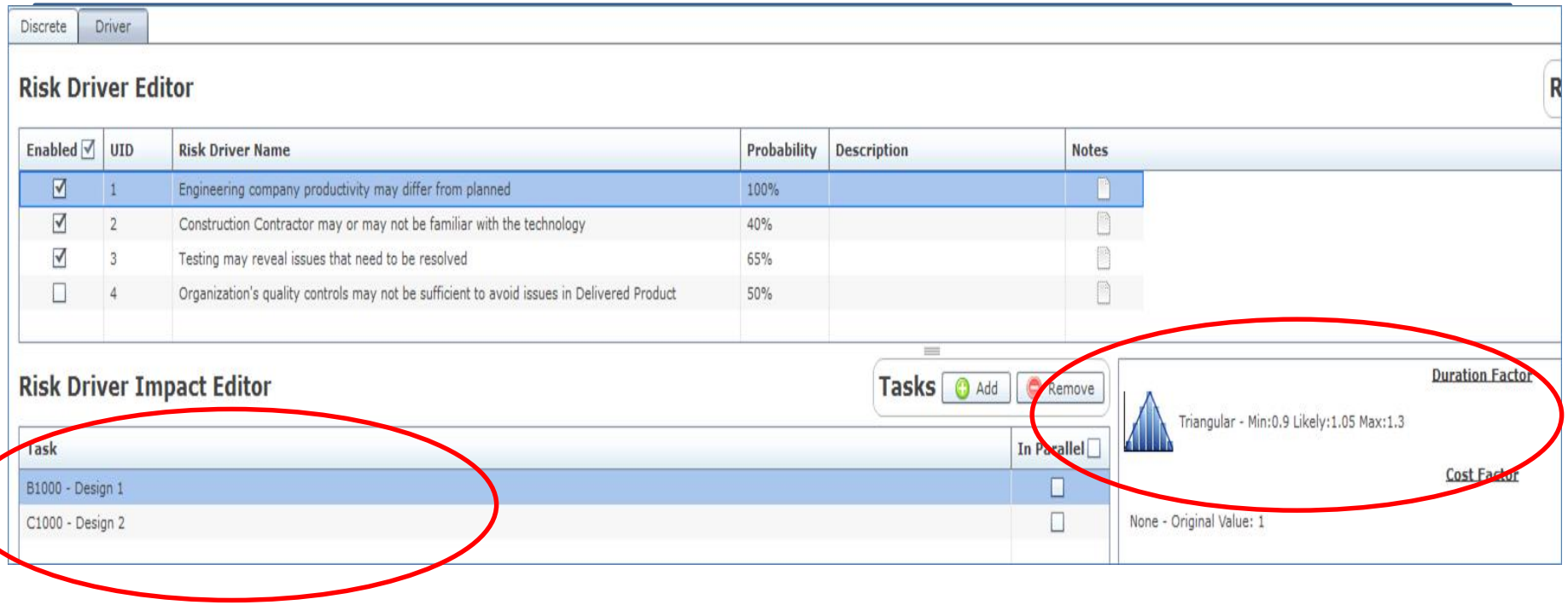
Risk Drivers (1)

- Each identified risk has a probability that it will occur with some effect on time or cost
- If the risk occurs it affects activities' durations and costs
  - If time-dependent resources (labor, rented equipment) it will vary the daily burn rate
  - If time-independent resources (equipment to be installed, material) it will affect the entire cost directly

Risk Drivers (2)

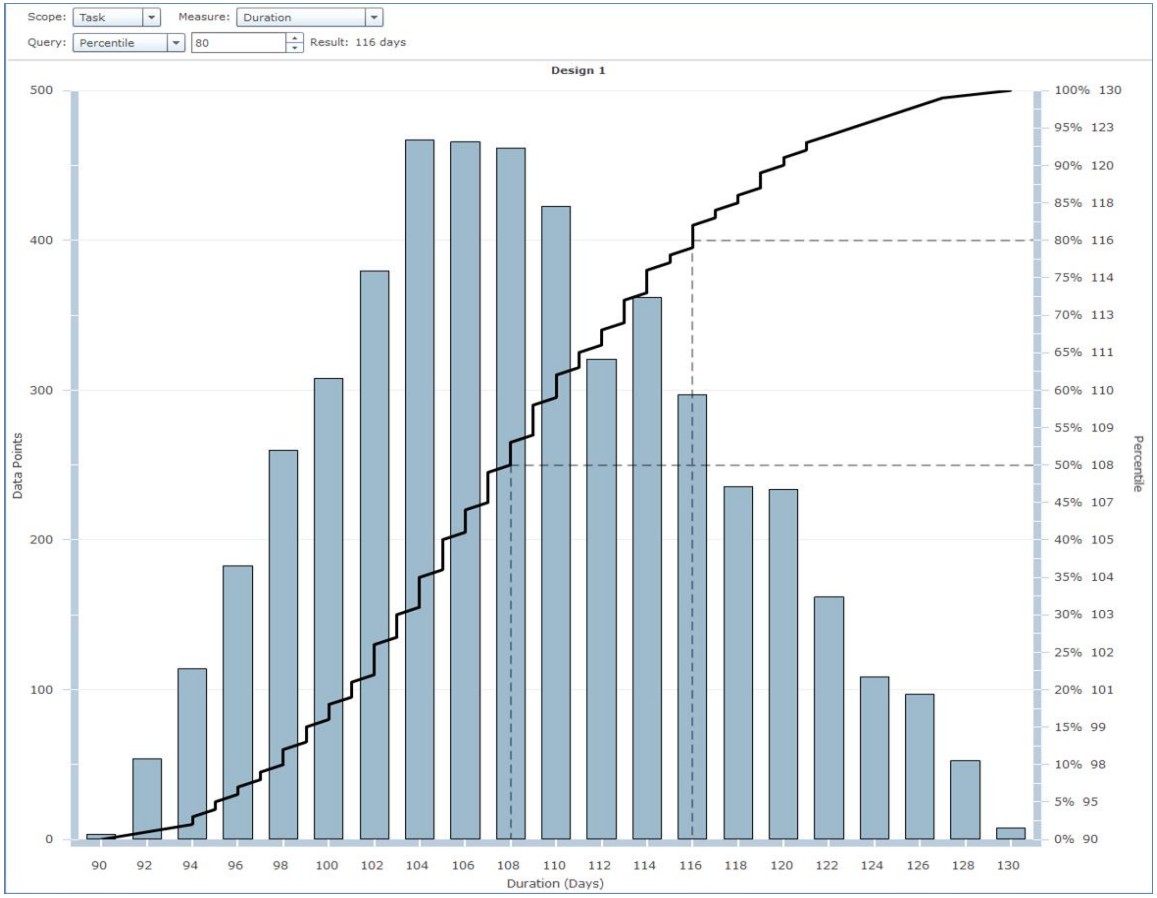
- A risk may affect multiple activities
- Activities may be affected by multiple risks
- If a risk driver occurs it has a multiplicative effect on the durations of the activities it affects
  - Multiplier < 1.0 ➔ shorter duration, opportunity
  - Multiplier > 1.0 ➔ longer duration, threat
- Multiplier is chosen at random from input distribution (usually 3-point estimate, triangle)

Introducing Risk Drivers that Cause Additional Variation in the Simulation



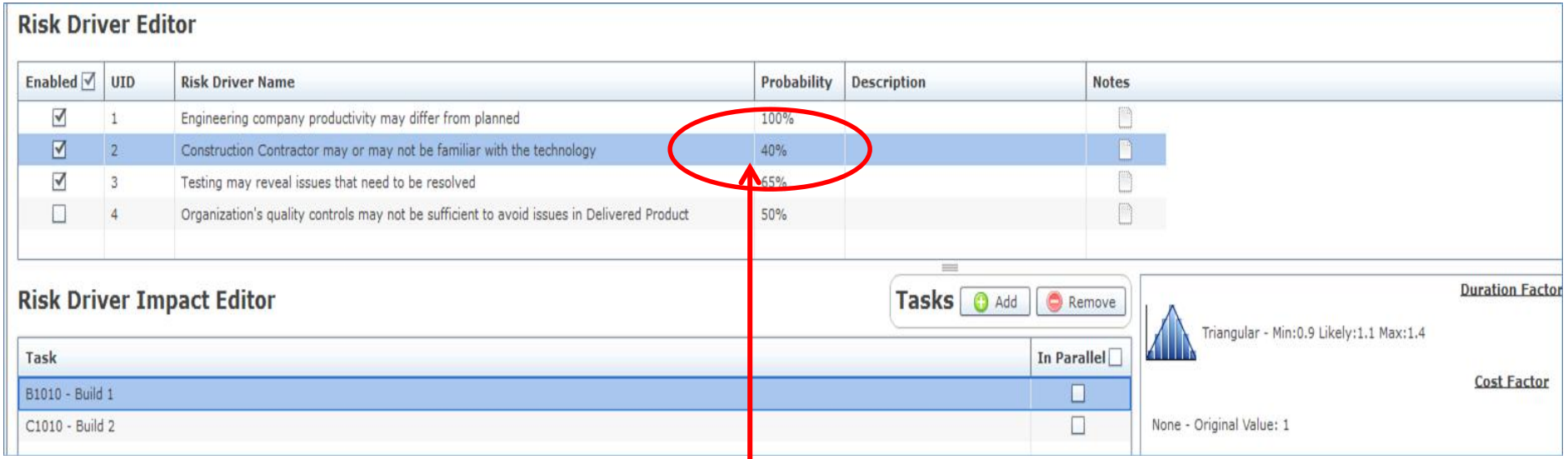
Four risk drivers are specified. The first is a general risk about engineering productivity, which may be under- or over-estimated, with 100% probability. It is applied to the two Design activities

100% Likely Risk Driver's Effect on Design Duration



With a 100% likely risk the probability distribution of the activity's duration looks like a triangle. Not any different from placing a triangle directly on the activity

Risk Driver with Risk at < 100% likelihood



With this risk, the Construction Contractor may or may not be familiar with the technology, the probability is 40% and the risk impact if it happens is .9, 1.1 and 1.4. It is applied to the two Build activities

With a 40% Likelihood, the "Spike" in the Distribution Contains 60% of the Probability

Here is where the Risk Driver method gets interesting. It can create distributions that reflect:

- Probability of occurring
- Impact if it does occur

Cannot represent these two factors with simple triangular distributions applied to the durations directly

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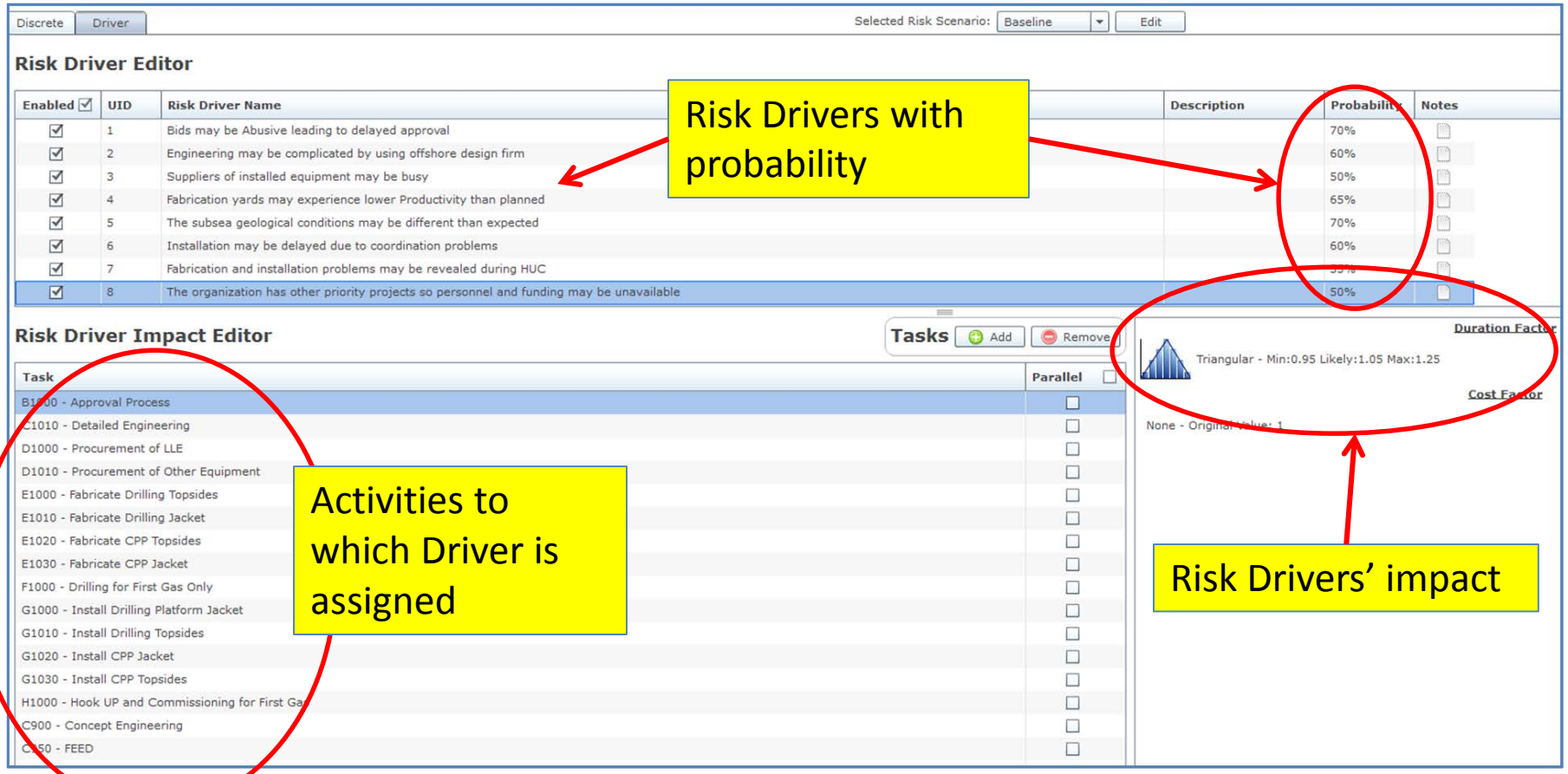
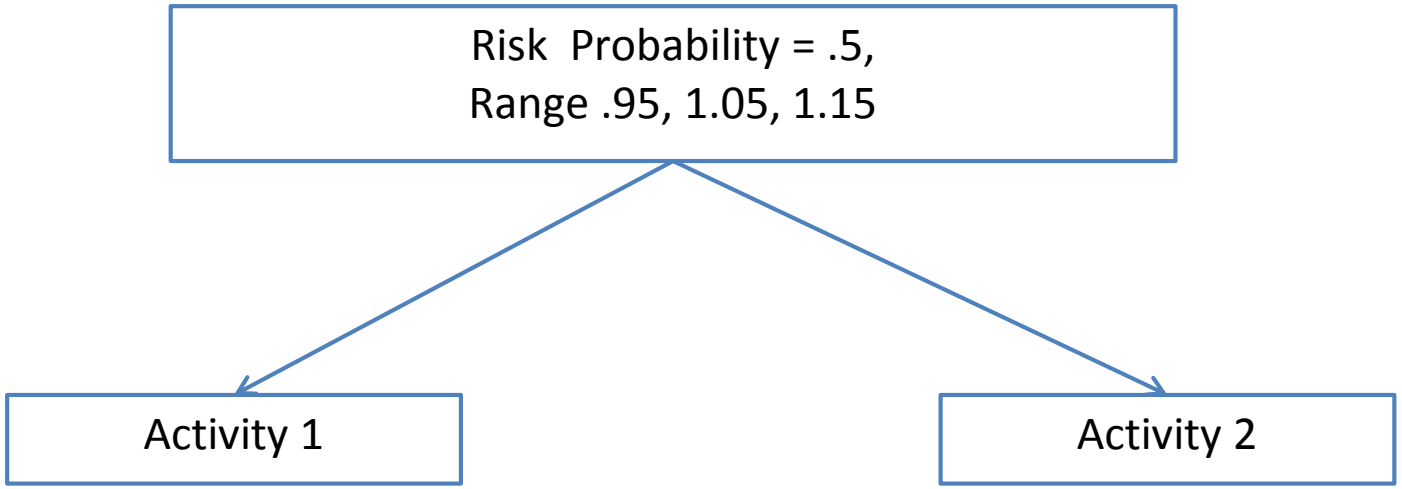
Using Risk Drivers Method



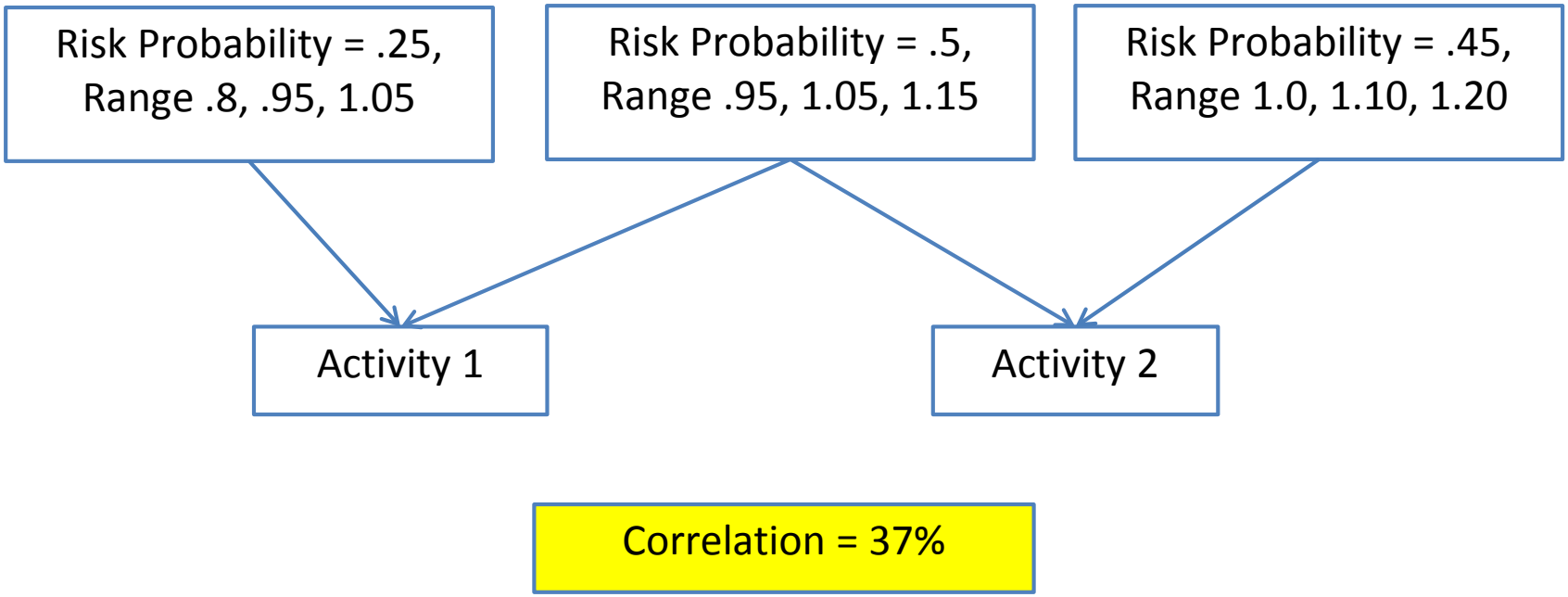
Risk Factors Model How Correlation Occurs Coefficients are Calculated (1)



Correlation = 100%

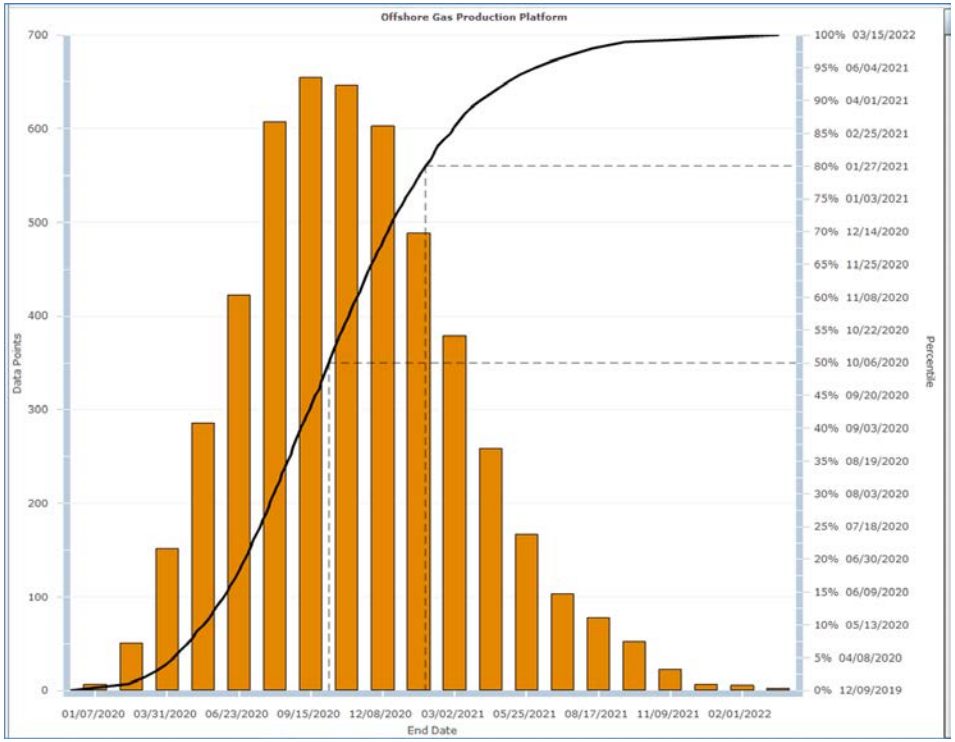
We are very bad at estimating correlation coefficients directly

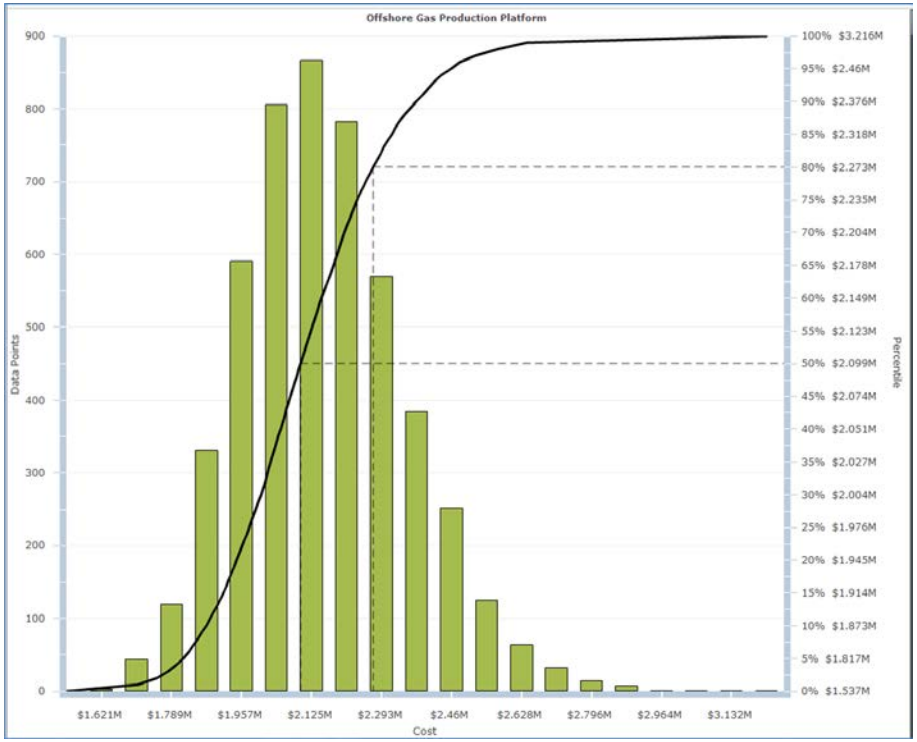
Risk Factors Model How Correlation Occurs Coefficients are Calculated (2)



- Correlation is modeled as it is caused in the project
- Correlation coefficients are generated, not guessed
- Correlation drives the results correctly
- By modeling correlation we never get an inconsistent correlation coefficient matrix

What End Date and Cost should be put forward?





P-80 finish date is 1/27/21, adding another 5 months to the project

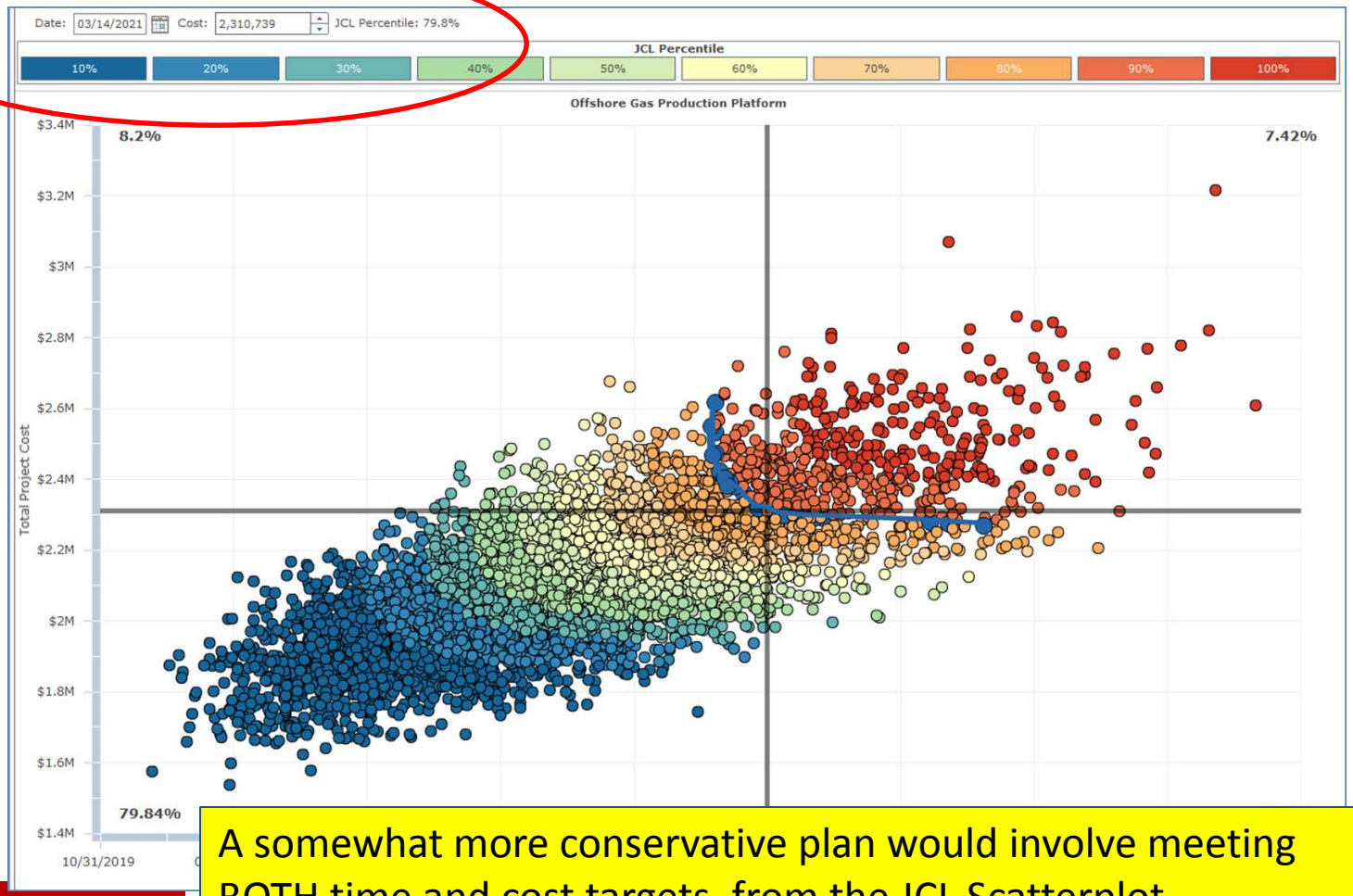
P-80 cost is $2.27 billion, adding another $150 million to the project from uncertainty

Is this enough?

Use the Time – Cost Scatterplot to Estimate Targets to meet BOTH Objectives

- The histograms / cumulative distribution functions estimate finish date and cost to meet each target individually
- To meet BOTH targets, use the scatterplot
- Meeting both targets requires a more conservative (later date, more cost) estimate
- How much more time and cost depends on their correlation

Plan to Meet BOTH Finish Date and Cost Targets from JCL Scatterplot



A somewhat more conservative plan would involve meeting BOTH time and cost targets, from the JCL Scatterplot

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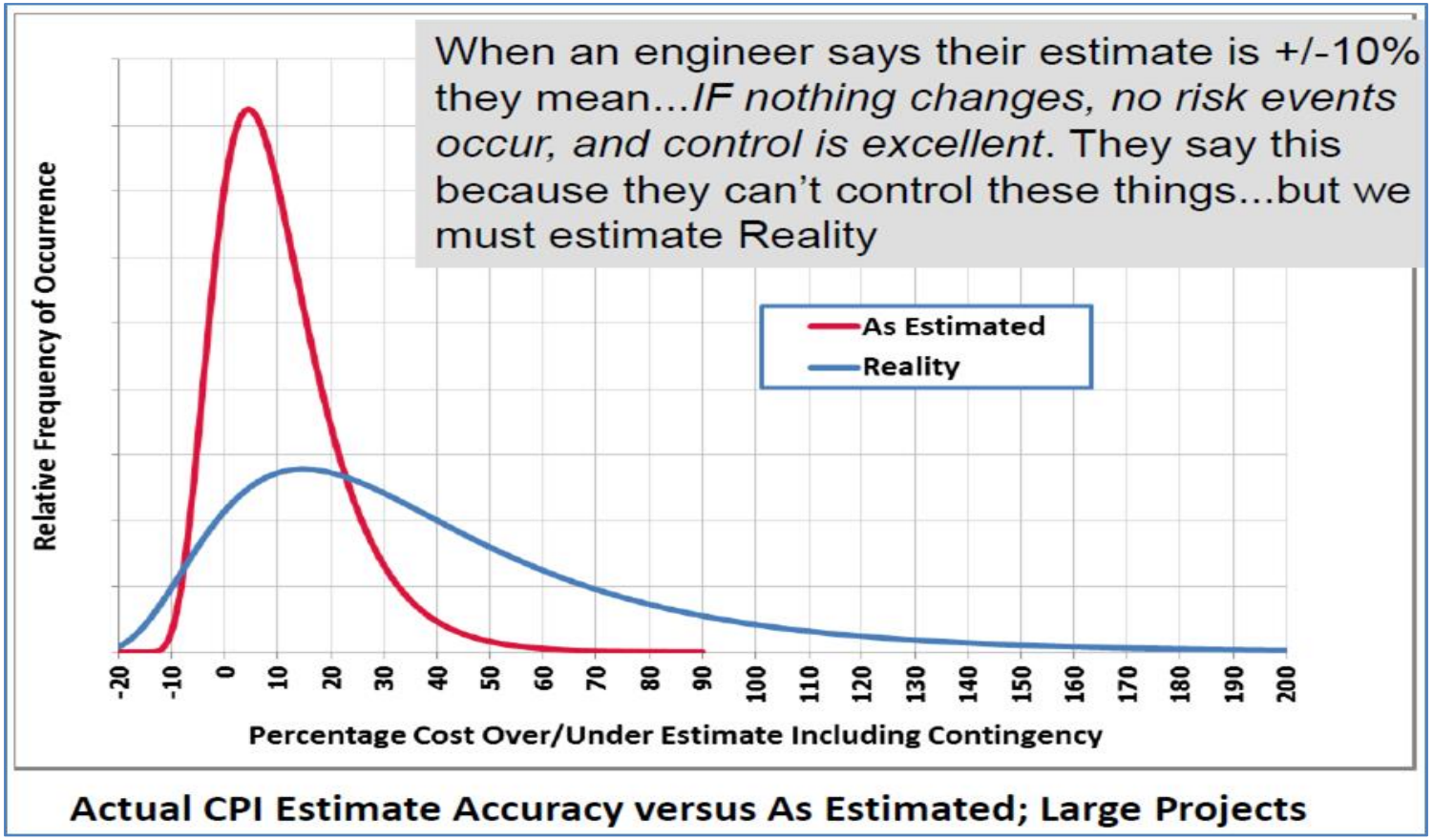
JCL-80 compared with P-80 Results

Histogram/Cumulative Distributions (P-80) and Joint Confidence Level (JCL-80) Results with Project-Specific Risks and Uncertainty		
Baseline		
Finish Date	4/4/2020	
Budgeted Cost	$1.70	Billions
Risk Analysis Results		
Schedule	Date	Months added
P-80	1/27/2021	9.8
JCL-80	3/14/2021	11.3
Difference	46	1.5
Cost	Billions	Dollars Added (billions)
P-80	2.27	$0.58
JCL-80	2.31	$0.61
Difference	0.04	

Compare what Risk Analysis Typically Predicts vs. What Actually Happens



Source: John K. Hollmann, PE, "Reliable Risk Quantification for Project Cost and Schedule", AACE International webinar December 15, 2015

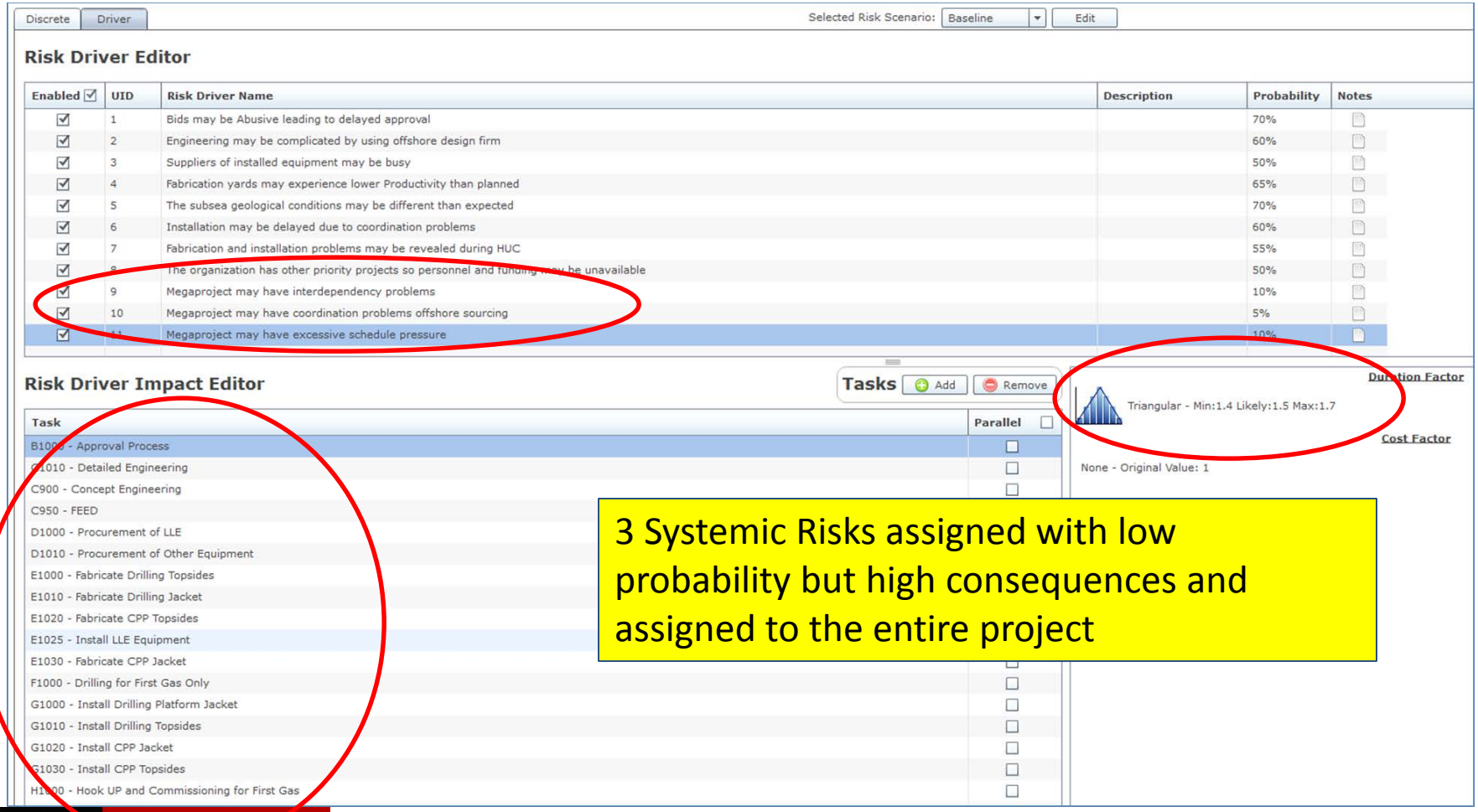
Incorporate Systemic Risks into the Monte Carlo Simulation (MCS)

- Systemic Risks that include:
  - Technical complexity, new technology challenging
  - Scope not fully known
  - Process definition not complete
  - Megaproject complexity, size / duration, participants
  - Project organization, e.g., joint venture, multiple EPCs
  - Project management, scheduling and estimating process, bias
- These factors can be measured and their impact on project success estimated using parametric techniques

Inserting 3 Systemic Risks

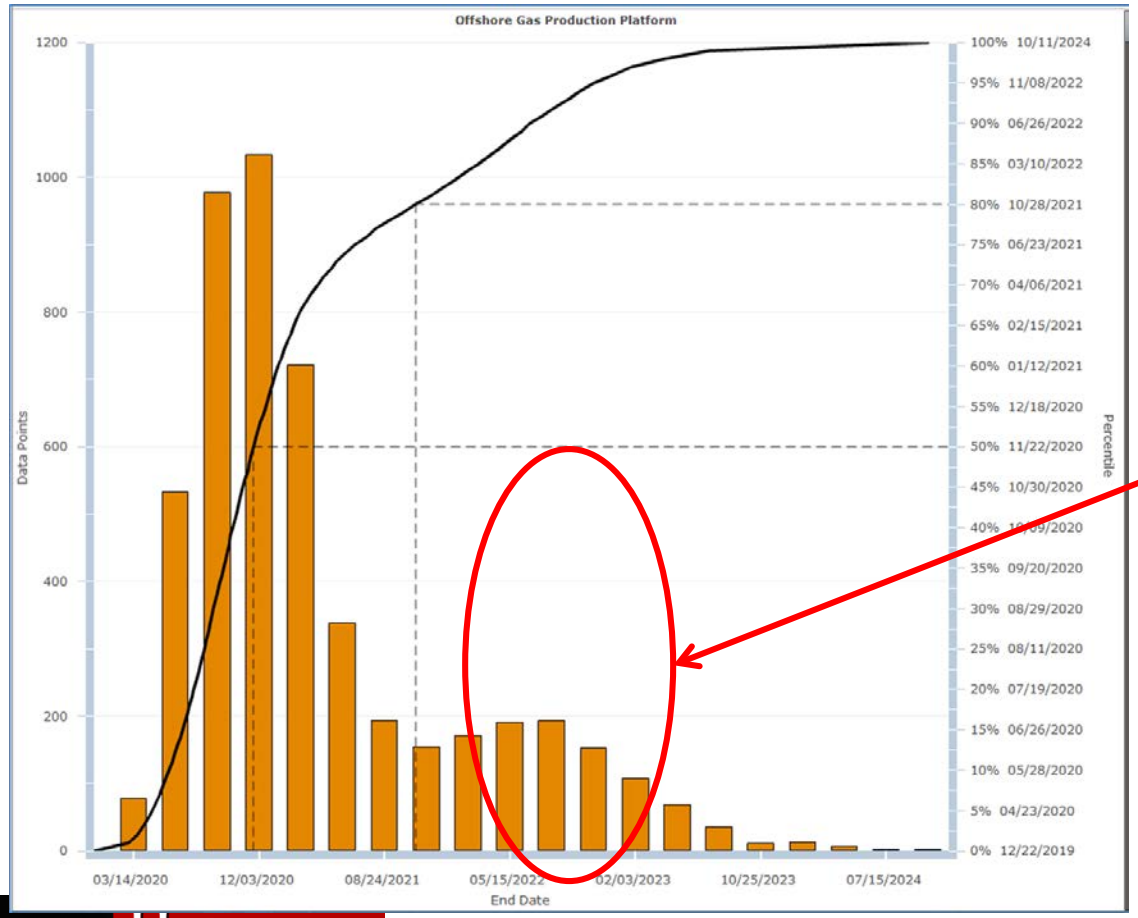
- Identifying the systemic risks and inserting them with appropriately-large impacts allows us to:
  - Specify the probability of occurrence
  - Identify the risks for risk mitigation
- In this case study, these megaproject risks:
  - May have interdependency issues between project elements
  - May have complex offshoring of supply chain and even EPC contractors
  - May have excessive schedule pressure “I want it sooner”

Adding Systemic Risks



3 Systemic Risks assigned with low probability but high consequences and assigned to the entire project

Complexity and Pressure Combined

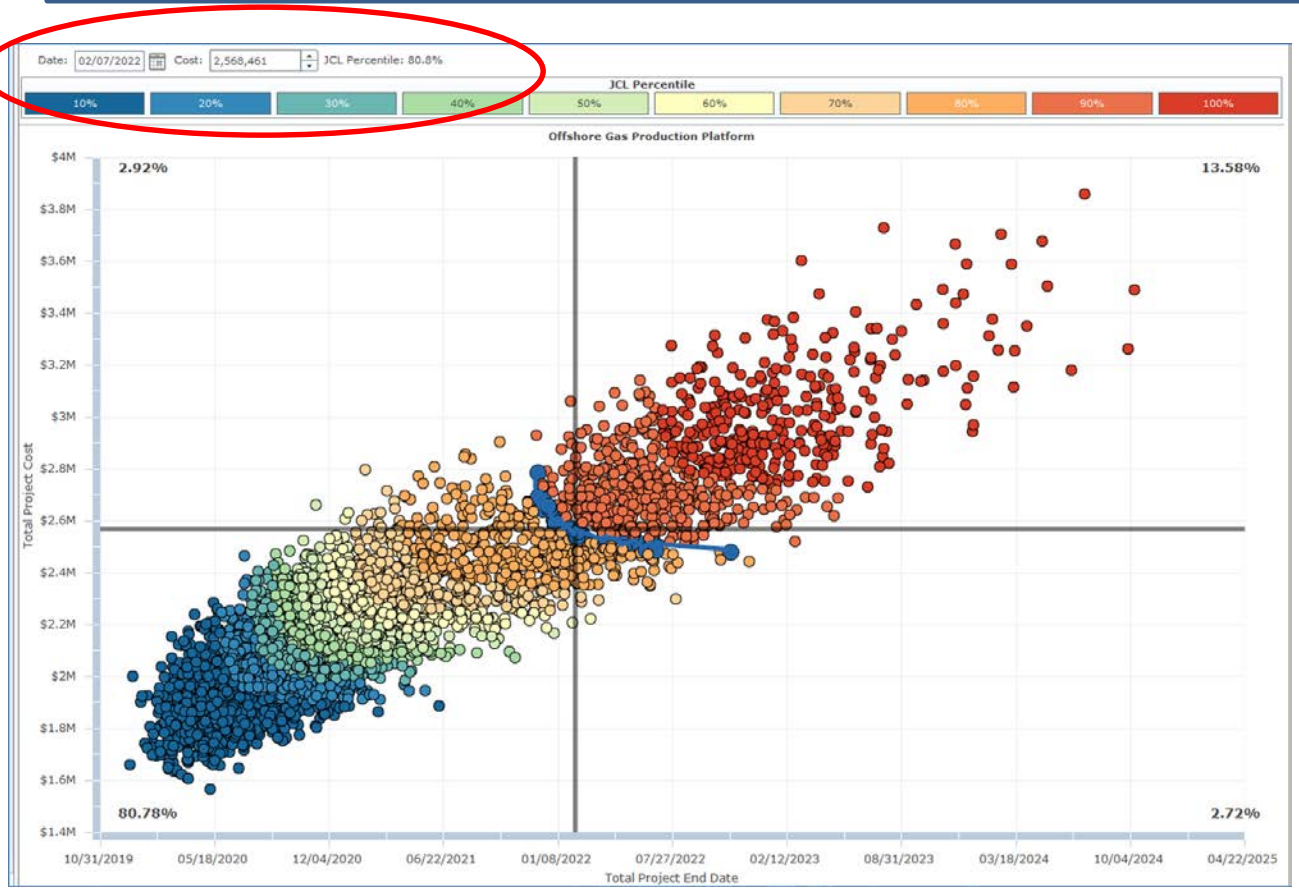


Many projects are within tolerances (+ - 20%) but some have serious problems, with overruns nearer to 70%.

Hollmann, John, "Risk Analysis on the Edge of Chaos," Cost Engineering (© AACE International), January/February 2015

In our case: P-80 ➔10/28/21 or about 19 months total
P-80 cost ➔ 2.49 or about $793 million (47%) over baseline (without contingency)

Scatterplot with Systemic Risks Added



The 80th percentile is approaching the second mode in the histogram

JCL-80 finish date ➔ 2/7/22 or about 22.2 months beyond scheduled finish date

JCL-80 cost ➔ $2.57 billion or about +$873 million (+ 51%) from baseline

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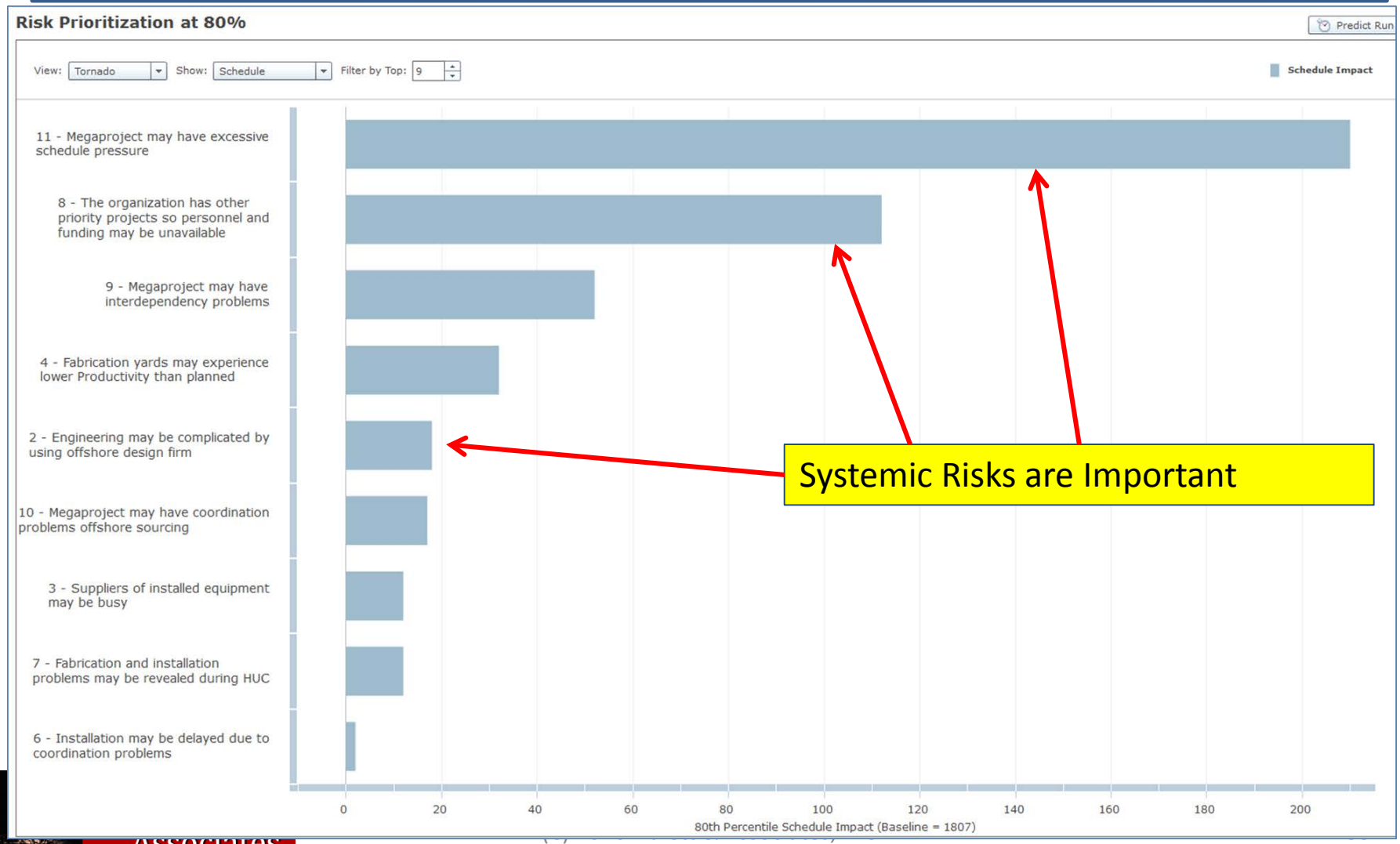
Picture of Prioritized Risks Selected by their Days Saved at P-80

Iterative Approach to Prioritizing Risks (Based on Days Saved at P-80)								
Risk #	1	2	3	4	5	6	7	8
Priority Level (Iteration #)	Abusive Bids	Offshore design firm	Suppliers Busy	Fab productivity	Geology unknown	Coordination during Installation	Problems at HUC	Resources may go to other projects
1	X	X	X	X	X	X	X	**1**
2	X	X	X	**2**	X	X	X	
3	X	**3**	X		X	X	X	
4	X		X		X	X	**4**	
5	X		**5**		X	X		
6	X				X	**6**		
7	**7**				X			
8					**8**			

Risks Prioritized at the P-80 Confidence Level measured in “Days Saved”



Associates

Risks Prioritized to P-80 and Days Saved, plus Effect of Uncertainty

Risks Prioritized to P-80	
Name	Days Saved
Megaproject may have excessive schedule pressure	210
The organization has other priority projects so personnel and funding may be unavailable	112
Megaproject may have interdependency problems	52
Fabrication yards may experience lower Productivity than planned	32
Engineering may be complicated by using offshore design firm	18
Megaproject may have coordination problems offshore sourcing	17
Suppliers of installed equipment may be busy	12
Fabrication and installation problems may be revealed during HUC	12
Installation may be delayed due to coordination problems	2
Bids may be Abusive leading to delayed approval	0
The subsea geological conditions may be different than expected	0
Contingency due to Project-Specific and Systemic Risks	467
Contingency due to Uncertainty	150
Total Contingency	617

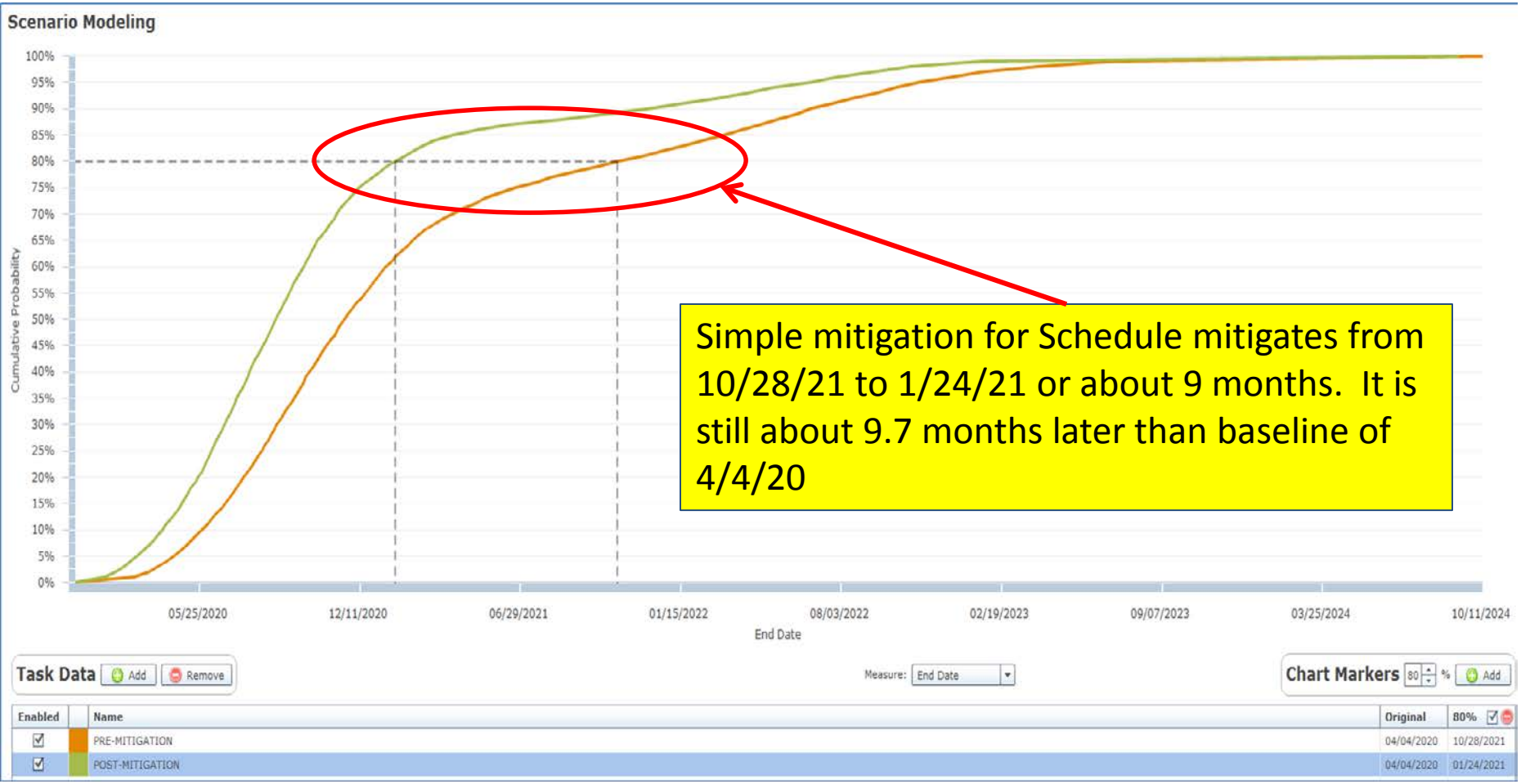
Risk Mitigation

- Risks can be mitigated but usually not completely
- Mitigation actions are:
  - New, not known to the interviewees, different from yesterday
  - Committed to by management so funded, staffed, monitored and reported on
- Once agreed to, estimate the owner, cost and timing of the mitigation
- Estimate the improvement to risk parameters

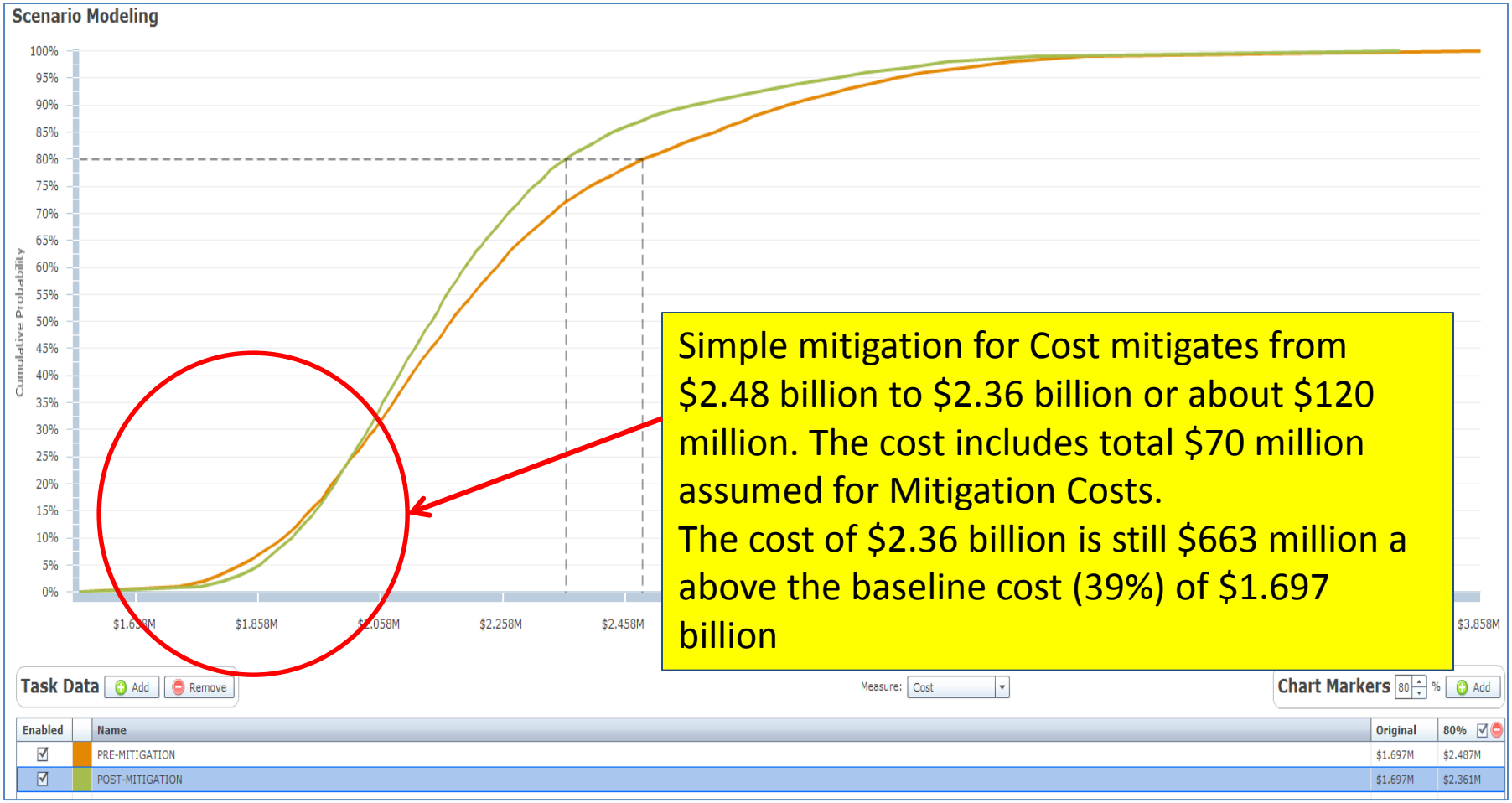
Mitigation Strategy and Simple Scenario

- Prioritize the risks according to days saved
- Recognize that as schedule risk is addressed, the indirect effect on cost risk will be good
- Each risk mitigation has a cost and that cost will be added, so cost risk will represent two conflicting forces
- Simple scenario,
  - Cut probability in half
  - Add $5 million to project specific risk cost and $10 million to systemic risk for cost of risk mitigation

Compare
Pre- and Post-Mitigation Schedule



Compare
Pre- and Post-Mitigation Cost



Summary

- Get a good schedule per GAO Best Practices
- Add costs as time-dependent and time-independent resources
- Interview for good Risk Data
- Model uncertainty
- Model project-specific and systemic risks using Risk Drivers
- Use JCL-80 as promise dates and costs
- Prioritize the risks @ P-80 and days saved
- Mitigate risks partially, recording mitigation costs
- Commit to the risk mitigations

Quantitative Cost-Schedule Risk Analysis in the 2015 LFM

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