Unknowns, Systemic Risks and Risk Prioritization in Schedule Risk Analysis

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Secretary Rumsfeld's use of "Unknown Unknowns"

In February 2002 DOD Secretary Donald Rumsfeld stated:

"Reports that say that something hasn't happened are always interesting to me, because as we know:

> There are known knowns; there are things we know we know.
>
> We also know there are known unknowns; that is to say we know there are some things we do not know.
>
> But there are also unknown unknowns -- the ones we don't know we don't know.

And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones."

(source: http://en.wikipedia.org/wiki/There_are_known_knowns cited January 26, 2015)

Uncertainty including Inherent Variability, Estimating Error, Estimating Bias

- Inherent variability in project activities that arise because people and organizations cannot do things reliably on plan
- Estimating error – attaches to all types of estimates
- Estimating bias – estimates may be slanted, usually toward shorter durations, to make desired project results

"There are No Facts About the Future"

Lincoln Moses, Statistician and Administrator of Energy Information in the US DOE 1977 Annual Report to Congress)

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Uncertainty

- Uncertainty in schedule duration is similar to "common cause" variation related to six sigma management, 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/)
- Hence application of uncertainty alone establishes the earliest date that risk mitigation can achieve even if individual risks were fully mitigated

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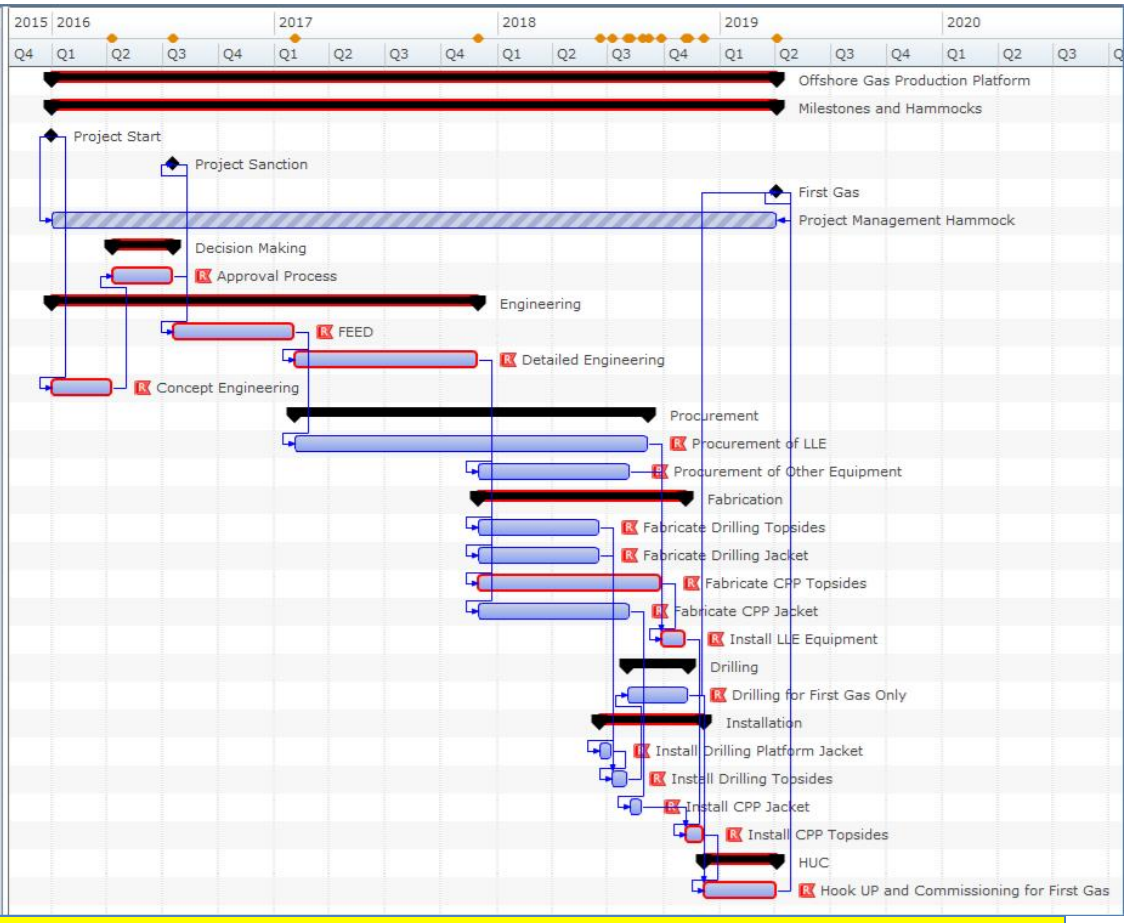
Example Schedule: Offshore Gas Production Platform Project

Case Study On Application of Uncertainty and Risk

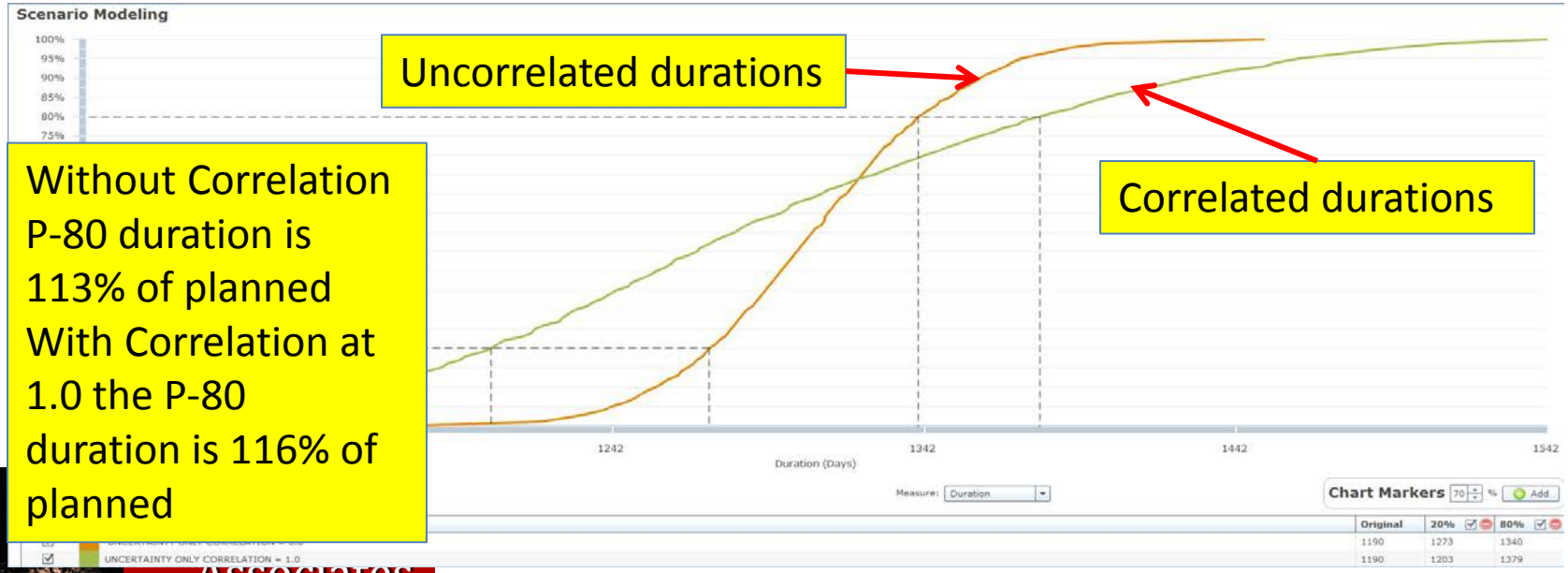
UID	Task	Start Date	End Date	Duration	Cost
Gas Platform	▼ Offshore Gas Production Platfor	01/01/2016	04/04/2019	1,190	$1.717M
Gas Platform	▼ Milestones and Hammocks	01/01/2016	04/04/2019	1,190	$400,000
A1000	Project Start	01/01/2016		0	$0
A1010	Project Sanction		07/18/2016	0	$0
A1020	First Gas		04/04/2019	0	$0
A1030	Project Management Ham	01/01/2016	04/04/2019	1,190	$400,000
Gas Platform	▼ Decision Making	04/10/2016	07/18/2016	100	$8,000
B1000	Approval Process	04/10/2016	07/18/2016	100	$8,000
Gas Platform	▼ Engineering	01/01/2016	11/30/2017	700	$256,000
C950	FEED	07/19/2016	02/03/2017	200	$80,000
C1010	Detailed Engineering	02/04/2017	11/30/2017	300	$160,000
C900	Concept Engineering	01/01/2016	04/09/2016	100	$16,000
Gas Platform	▼ Procurement	02/04/2017	09/06/2018	580	$350,000
D1000	Procurement of LLE	02/04/2017	09/06/2018	580	$250,000
D1010	Procurement of Other Equ	12/01/2017	08/07/2018	250	$100,000
Gas Platform	▼ Fabrication	12/01/2017	11/05/2018	340	$536,000
E1000	Fabricate Drilling Topsides	12/01/2017	06/18/2018	200	$80,000
E1010	Fabricate Drilling Jacket	12/01/2017	06/18/2018	200	$80,000
E1020	Fabricate CPP Topsides	12/01/2017	09/26/2018	300	$240,000
E1030	Fabricate CPP Jacket	12/01/2017	08/07/2018	250	$104,000
E1025	Install LLE Equipment	09/27/2018	11/05/2018	40	$32,000
Gas Platform	▼ Drilling	08/03/2018	11/10/2018	100	$80,000
F1000	Drilling for First Gas Only	08/03/2018	11/10/2018	100	$80,000
Gas Platform	▼ Installation	06/19/2018	12/05/2018	170	$47,200
G1000	Install Drilling Platform Ja	06/19/2018	07/08/2018	20	$8,000
G1010	Install Drilling Topsides	07/09/2018	08/02/2018	25	$13,600
G1020	Install CPP Jacket	08/08/2018	08/27/2018	20	$9,600
G1030	Install CPP Topsides	11/06/2018	12/05/2018	30	$16,000
Gas Platform	▼ HUC	12/06/2018	04/04/2019	120	$40,000
H1000	Hook UP and Commission	12/06/2018	04/04/2019	120	$40,000



Offshore Gas Production Platform Construction project, 3+ years and $1.7 billion.
Using Polaris© from Booz Allen Hamilton

Correcting for Inherent Variability, Estimating Error and Bias

- Schedule uncertainty exhibiting inherent variation, estimating uncertainty and bias with ranges of .9, 1.05 and 1.3
- To replicate the estimated overall project ranges by using these parameters for individual activities we need to correlate the uncertainty



Without Correlation P-80 duration is 113% of planned
With Correlation at 1.0 the P-80 duration is 116% of planned

Variation Caused by Known Unknowns

- Project-specific risks are:
  - Characterized by probability of occurring that is usually less than 100%
  - Represent “root causes” of variation in durations
  - May be reducible by risk mitigation actions
- These are specified during risk interviews and implemented with:
  - Estimated probabilities
  - Impact ranges (3-point estimates of multiplicative factors called Risk Drivers”) if they occur
  - The activities or cost elements they influence

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Project-Specific Risks, Pre-Mitigated

- 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. The improvement from risk mitigation is limited by the date determined by uncertainty alone

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Applying Known Unknowns: Project-Specific Risk Drivers to the Offshore Platform

Risk Driver Editor

Risk Drivers Add

Enabled ☑	UID	Risk Driver Name	Description	Probal
☑	1	Bids may be Abusive leading to delayed approval		60%
☑	2	Engineering may be complicated by using offshore design firm		40%
☑	3	Suppliers of installed equipment may be busy		30%
☑	4	Fabrication yards may experience lower Productivity than planned		55%
☑	5	The subsea geological conditions may be different than expected		45%
☑	6	Installation may be delayed due to coordination problems		55%
☑	7	Fabrication and installation problems may be revealed during HUC		40%
☑	8	The organization has other priority projects so personnel and funding may be unavailable		35%
☐	9	Megaproject may have interdependency problems		20%
☐	10	Megaproject may have coordination problems offshore sourcing		10%
☐	11	Megaproject may have excessive schedule pressure		15%

Risk Driver Impact Editor

Tasks Add Remove

Task	Parallel ☐
B1000 - Approval Process	☐
C1010 - Detailed Engineering	☐
D1000 - Procurement of LLE	☐
D1010 - Procurement of Other Equipment	☐
E1000 - Fabricate Drilling Topsides	☐
E1010 - Fabricate Drilling Jacket	☐
E1020 - Fabricate CPP Topsides	☐
E1030 - Fabricate CPP Jacket	☐
F1000 - Drilling for First Gas Only	☐
G1000 - Install Drilling Platform Jacket	☐
G1010 - Install Drilling Topsides	☐

Duration Factor

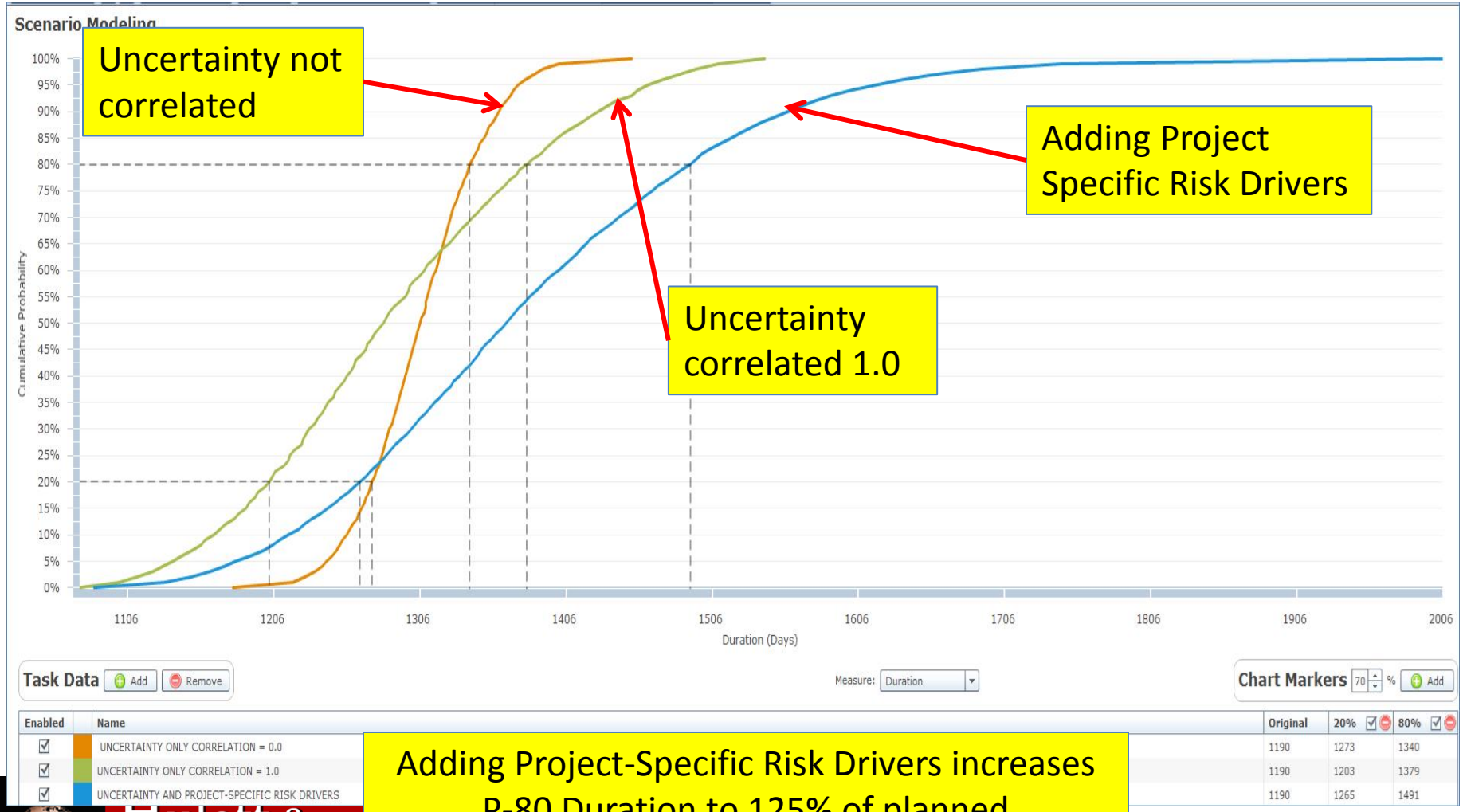
Triangular - Min:0.95 Likely:1.05 Max:1.25

Cost Factor

None - Original Value: 1

There are 8 project-specific Risk Drivers including one Organizational Risk Driver assigned to all tasks. Probability and impact multiplier ranges are specified, risks are assigned to activities. A risk can affect many activities, and activities can be affected by several risks.

Adding Project Specific Risk Drivers



Adding Project-Specific Risk Drivers increases P-80 Duration to 125% of planned

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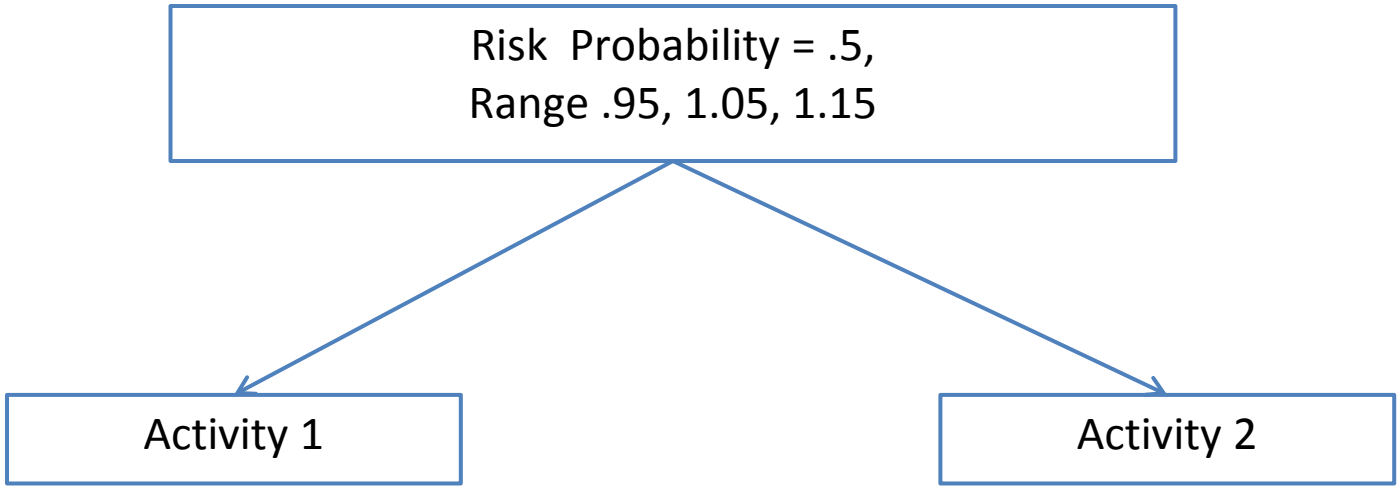
Short Digression on Risk Drivers and Correlation

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



Correlation = 100%

We are very bad at estimating correlation coefficients directly

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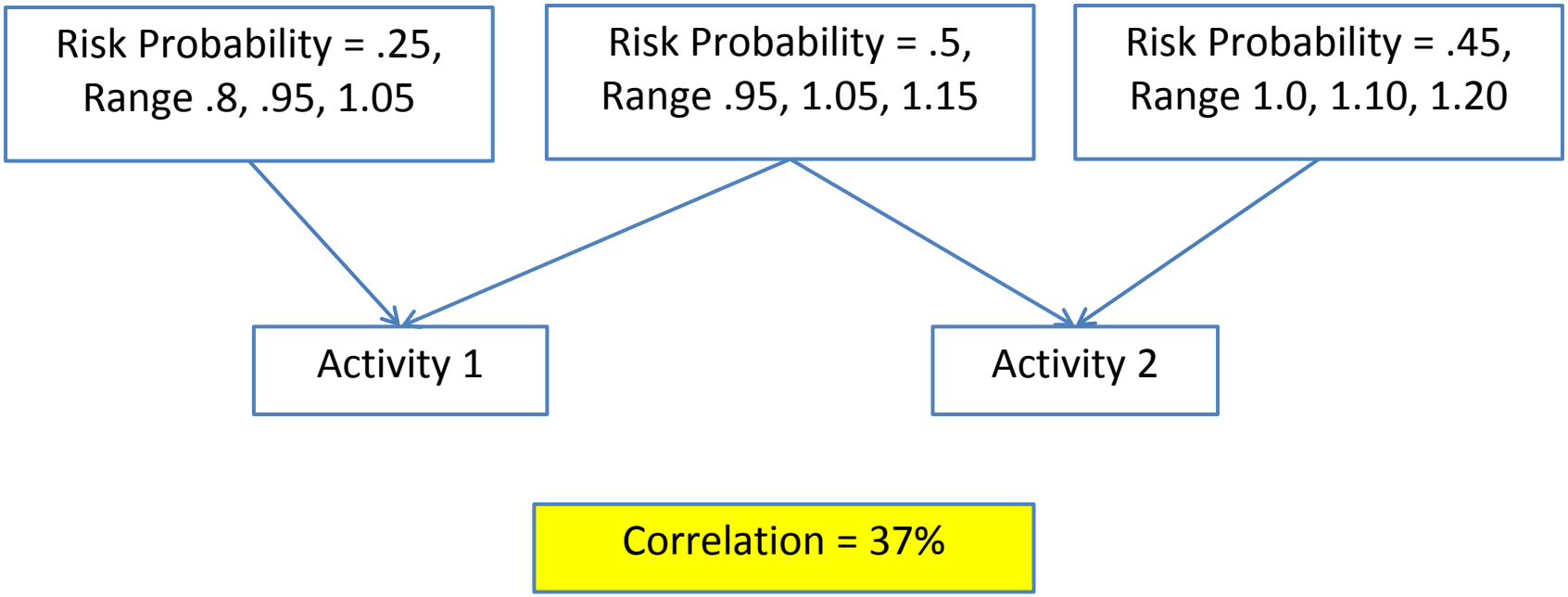
Risk Factors Model How Correlation Occurs Coefficients are Calculated (2)



- 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

Unknown Unknowns May Not be Unknowable

- Interviews or workshops on risk often focus on risks and uncertainties that are close-in or actually happening now
  - This myopia leads to insufficient consideration of future risks
- It is arguable that <u>some unknown unknowns are not truly unknowable but just have not been thought of yet</u>
  - This may be due to a lack of attention to risks that may occur "down the road" or hard to think about
- Since these risks are "unknown" right now:
  - Extra effort to focus on down-stream risks during the risk interviews could improve our understanding of risks, including making some of these "Unknown Unknowns" known

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Add a Fourth Category of "Unknown Knowns"

- Psychoanalytic philosopher Slavoj Zizek says that beyond these three categories there is a fourth, the unknown known, that which we intentionally refuse to acknowledge that we know
- German sociologists Daase and Kessler (2007) agree with a basic point of Rumsfeld in stating that the cognitive frame for political practice may be determined by the relationship between *what we know, what we do not know, what we cannot know*, but Rumsfeld having left out *what we do not like to know*

http://en.wikipedia.org/wiki/There_are_known_knowns, Cited 12/26/2015)

Risk Interviews vs. Risk Workshops (1)

- Risk Interviews provide a safe environment to discuss both Unknown Unknowns and Unknown Knowns
- Specifically, Unknown Knowns
  - We find that **the Risk Register is always incomplete**
  - Many of the risk events found to be most important in determining the schedule risk results are not in the Risk Register at all
  - These can be safely discussed in one-on-one interviews where confidentiality is promised
- In these interviews new risks are discussed, whether they are hurtful to the project or embarrassing
  - Responding to open-ended questions, interviewees are encouraged to talk about "the good, the bad and the ugly"

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Risk Interviews vs. Risk Workshops (2)

- We need to avoid the ostrich approach to risk management. Identify, talk about and quantify the Unknown Knowns, the "elephant in the room," and tell unbiased results
- Risk interviews provide a confidential environment where individuals can talk in depth without being afraid of being embarrassed, pressured or subjected to "shoot the messenger"
- Conversely, Risk Workshops often are places where social pressures or group dynamics limit debate
  - Groupthink – prefer unanimity, discourage dissent
  - "Moses factor" – adopting influential person's ideas
  - Cultural Conformity – decisions match the group's norms

David Hillson and Ruth Murray-Webster, Understanding and Managing Risk Attitude 2005

Risk Interviews Help Identify Unknown Unknowns and Unknown Knowns

- Think about risks later in the project that may have been ignored as “unknown” at first glance
- Suggest risks from experience to see if the interviewee has forgotten some that apply
- Ask open ended questions to elicit the interviewee’s own concerns about the project, with a pledge that nobody will be able to connect their name with any information they share

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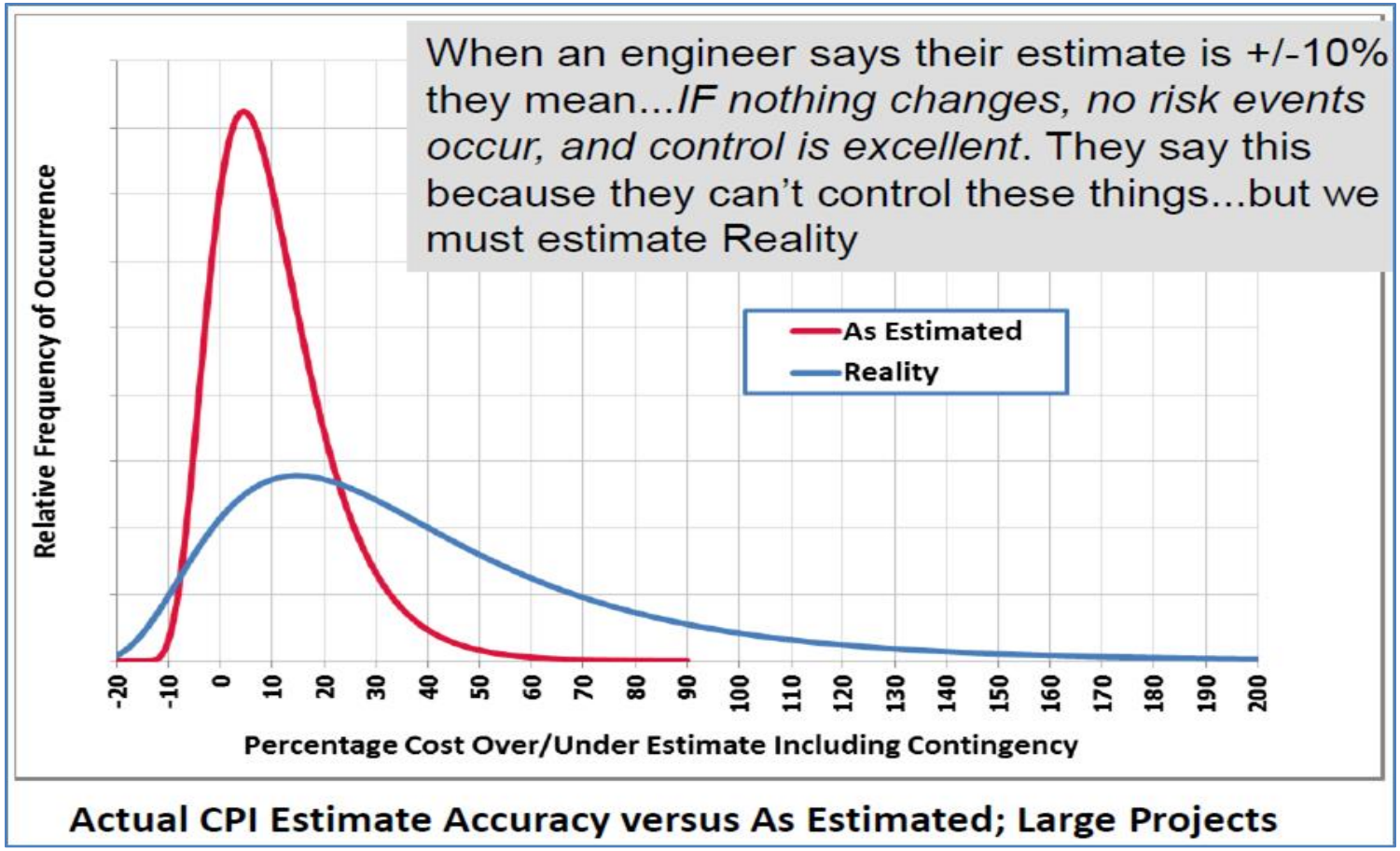
Considering Systemic Risks

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)

- There are some who believe that Monte Carlo, by building risk from the bottom up, does not deal with 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
- Some argue that these factors can be measured and their impact on project success estimated using parametric techniques

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Alternative Approach to Incorporate Systemic Risks

- **Systemic Risks**; use a rule-of-thumb to get a 3-point (triangular) distribution

Cost	Best or Low	About **–0.5X** the point value
	Worst or High	About **3.0X** the point value
Execution Duration	Best or Low	About **–0.2X** the point value
	Worst or High	About **2.2X** the point value

- **Project-Specific Risks**; for each critical risk, estimate *low, most likely and high* impacts which, multiplied by probability, gives a 3-point distribution of expected value
- Include these in a **Monte-Carlo Simulation** using a spreadsheet and add-in like @Risk

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

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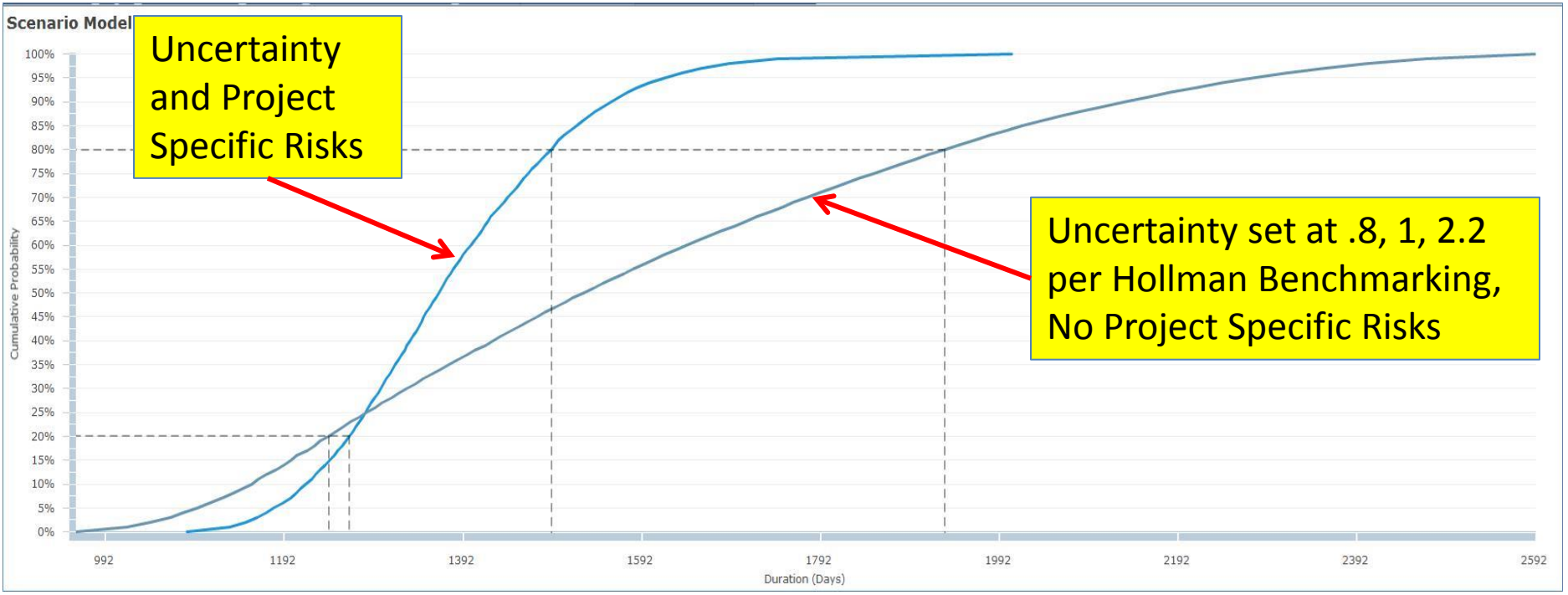
Effect of Simply using Hollmann's Correction for Actuals



P-80 for Uncertainty and Project Specific Risks = 125% of scheduled
P-80 for Uncertainty set at .8, 1, 2.2 without Project Specific Risks = 162% of scheduled
No information about which risks caused this difference beyond the wider ranges

Inserting 3 Megaproject Systemic Risks with Original Uncertainty

- 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 are:
  - May have interdependency issues between project elements (20%, 1.4, 1.5, 1.7 assigned to all activities)
  - May have complex offshoring of supply chain and even EPC contractors (10%, 1.3, 1.4, 1.6 all activities)
  - May have excessive schedule pressure "I want it sooner" (15%, 1.2, 1.3, 1.5 all activities)

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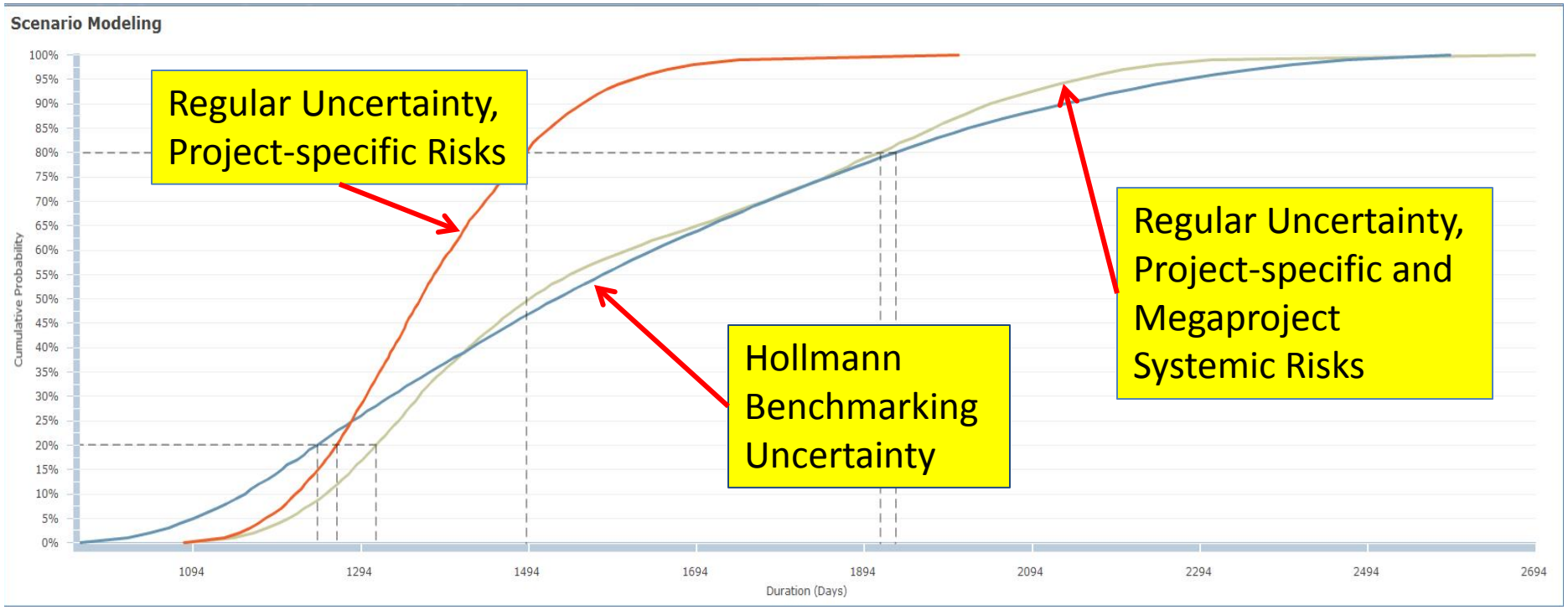
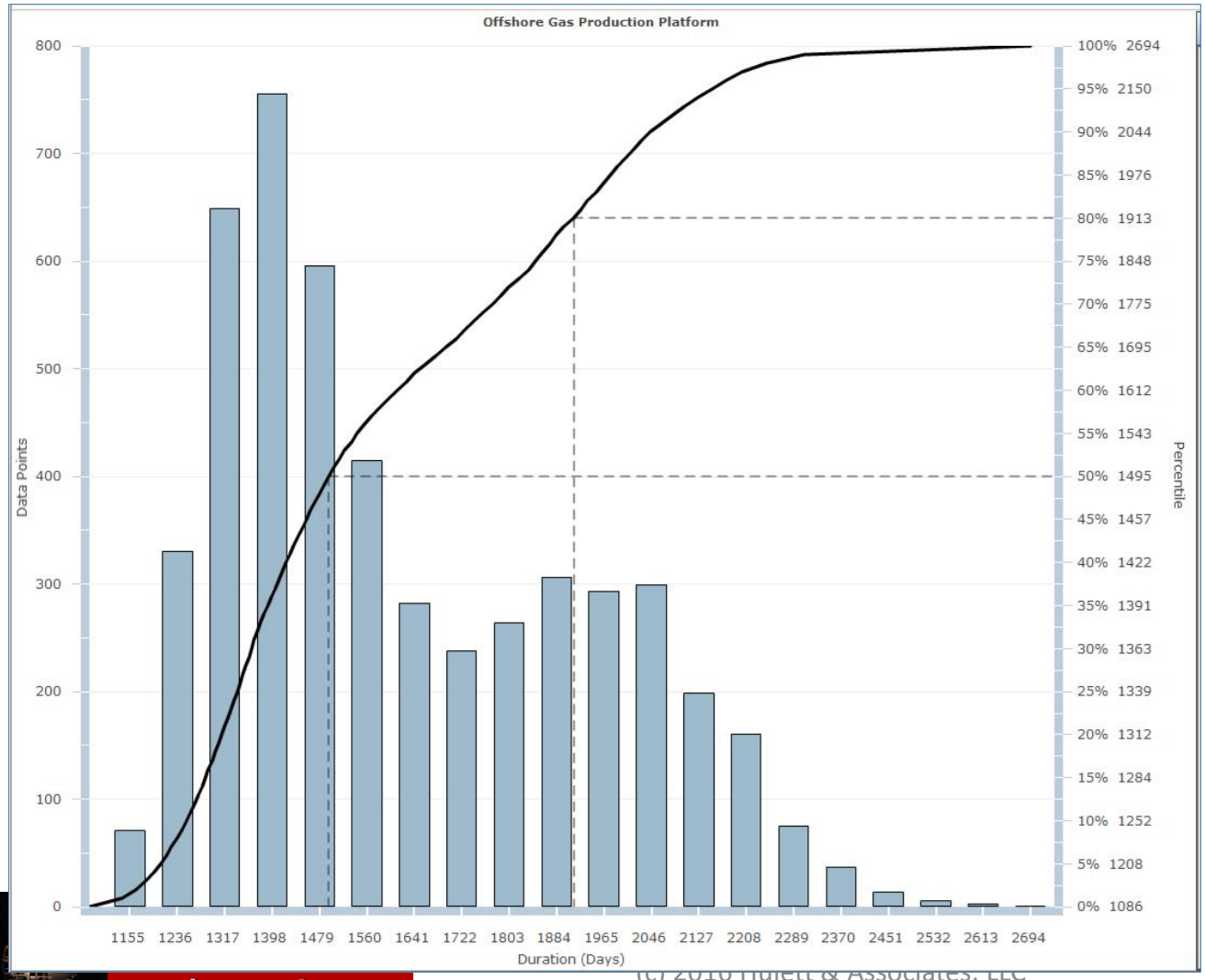
Individual Systemic Risks with Regular Uncertainty Approximates Hollmann



Parameters for specific Megaproject Systemic Risks are challenging, need to be selected based on historical data

We need to be sure to include the systemic risks with the right probability and impact ranges based on data into the Monte Carlo simulation

Results for Total Project Duration from MCS



Some suggest that megaprojects that come in at 25% or less (cost) over the sanction budget are considered successful. This curve shows that about 50% do so.

The P-80 duration is 1,913 days about 61% overrun of schedule

Results are Similar to those for Cost Provided by IPA

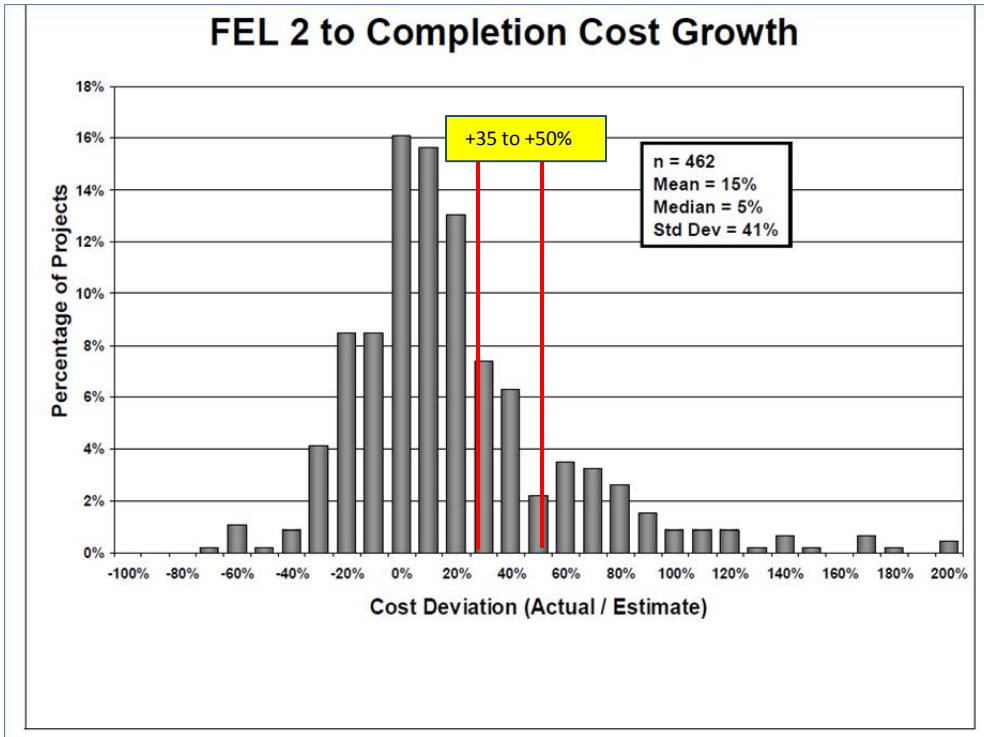


Figure 8 - Cost Deviation Results for FEL 2 Estimates Compared to Actual Costs

"Quantifying Estimate Accuracy and Precision for the Process Industries: A Review of Industry Data" Alexander Ogilvie, Robert A. Brown, Jr., Fredrick P. Biery and Paul Barshop from IPA. IPA's Front End Loading (FEL) 2 is "Scoping Facility Planning," comparable to AACE International Class 4 estimates which gets a high range of +30% to +50%. <u>This is not high enough</u>

Risk Prioritization and Risk Mitigation Illustrated

Problems with Typical Risk Prioritization Approaches

- Risk prioritization usually involves presenting:
  - Standard tornado diagrams based on correlation between activities and finish date
  - Risk tornado diagrams, based on correlation between risks and finish date
  - Correlation-based tornados have problems with risks that may or may not occur
  - Risk criticality based on activities' being on the critical path
- None of these methods give management what they need to assess mitigations
  - Risks prioritized at the P-80, not means as in correlation
  - Risks measured in days saved if mitigated
  - Risks have to be the arguments driving MCS to do this

Prioritizing Risks using MCS 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**			

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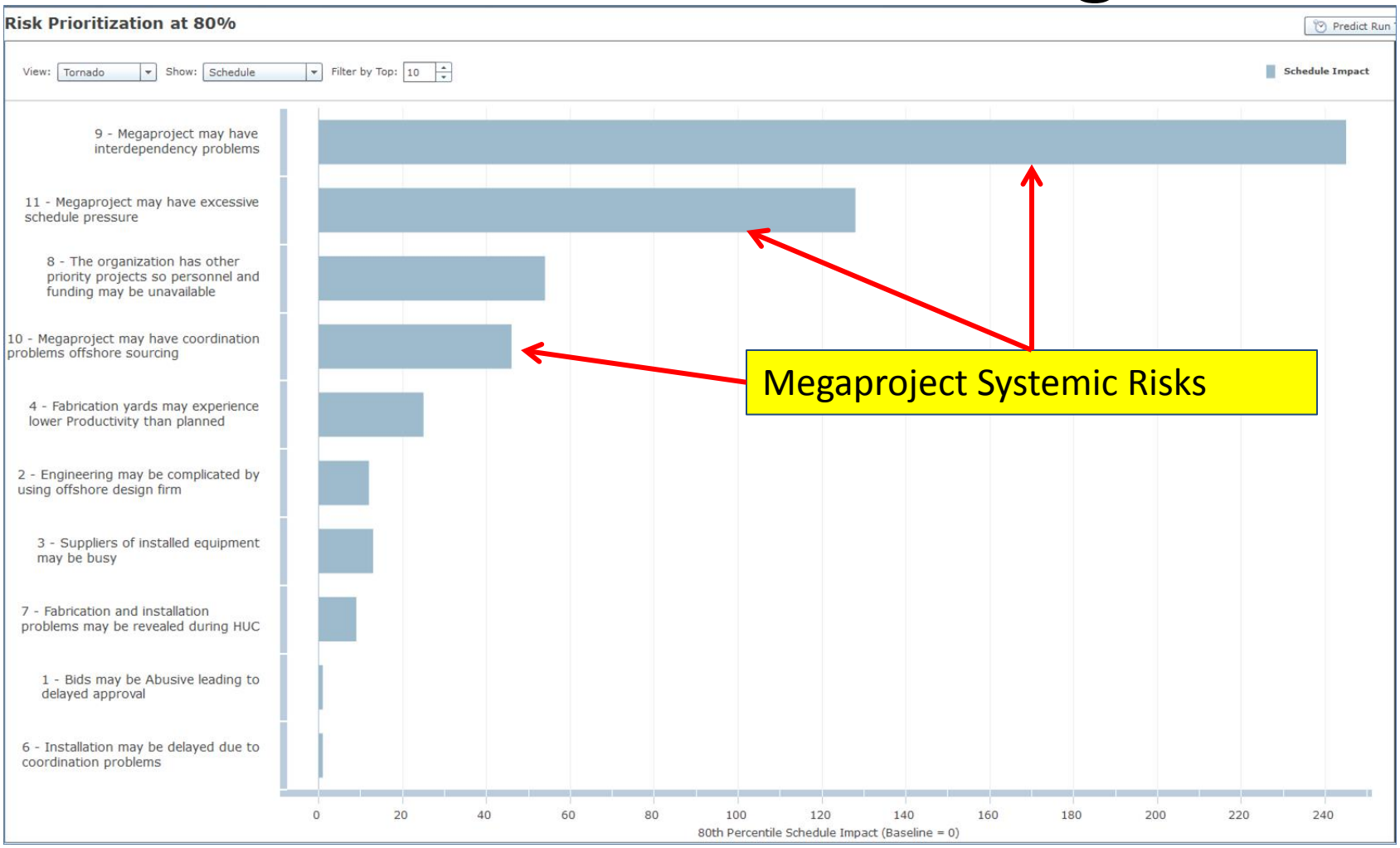
Risk Prioritization for Mitigation



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Risk Prioritization Results for Risk Mitigation Workshop

Risk Prioritization at P-80 with Days Saved	
Name	Days Saved
Megaproject may have interdependency problems	245
Megaproject may have excessive schedule pressure	128
The organization has other priority projects so personnel and funding may be unavailable	54
Megaproject may have coordination problems offshore sourcing	46
Fabrication yards may experience lower Productivity than planned	25
Engineering may be complicated by using offshore design firm	12
Suppliers of installed equipment may be busy	13
Fabrication and installation problems may be revealed during HUC	9
Bids may be Abusive leading to delayed approval	1
Installation may be delayed due to coordination problems	1
The subsea geological conditions may be different than expected	0
Days Saved from Project Specific and Systemic Risks	534
Days Contributed by Uncertainty alone	189
Total Days contingency at P-80	723

Risk Mitigation Workshop(s)

- This is a workshop with the project manager, deputy PM, team leads, controls personnel, SMEs with experience
- Use the prioritized risk list
  - Start at the top
  - Working on risks lower on the priority list will not be effective. Those risks are not important until the top risk is dealt with as much as possible
  - Determined by the <u>structure of the schedule and which paths are risk critical – changes as risks are mitigated</u>

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Sample Risk Mitigation Entry

Risk: The organization has other priority projects so personnel and funding may be unavailable							
		Probability	Low	Most Likely	High	P-80 Date	P-80 Cost ($ billions)
Pre-Mitigated parameters		65%	95%	105%	125%	1/22/2018	$2.13
Mitigation Action	Establish this project as top priority - needs top management action and commitment						
Post -Mitigated parameters		**15%**	**95%**	**100%**	**115%**	**10/20/2017**	**$1.99**
Risk Owner:	S. Smith					Days saved	Cost Saved
Date of Action:	Within 1 month				Results	94	$0.14

Risk is not completely mitigated. Cost saved is the reduction of cost contingency reserve held for schedule risk. For Net Cost Saved subtract the $20 million cost of mitigation

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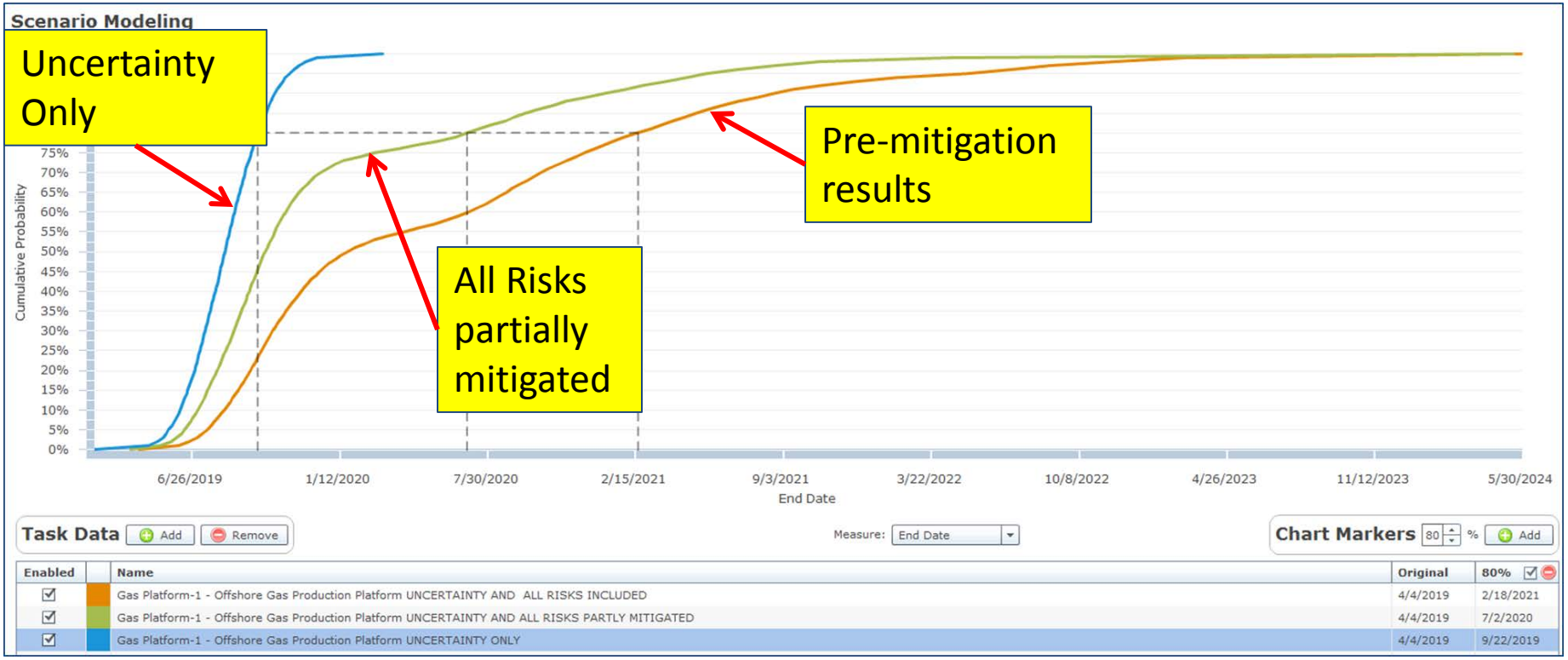
Creating the Post-Mitigated Scenario

- A risk post-mitigated scenario can be constructed in the software
  - Partially mitigate each risk, in this case just by reducing probability by half
  - Estimate the cost of the risk, in this case each risk's mitigation = $50 million
  - Run the post mitigated scenario
- When schedule risks are mitigated the cost contingency reserve can be reduced since some was held for schedule growth
- However, the cost of the project now includes the assumed $50 million cost of each mitigation

Partially Mitigate all Risks – Finish Date



Mitigating all risks (Here, just reducing the probability by half) moves the P-80 date by total mitigation time of about 7.5 months.

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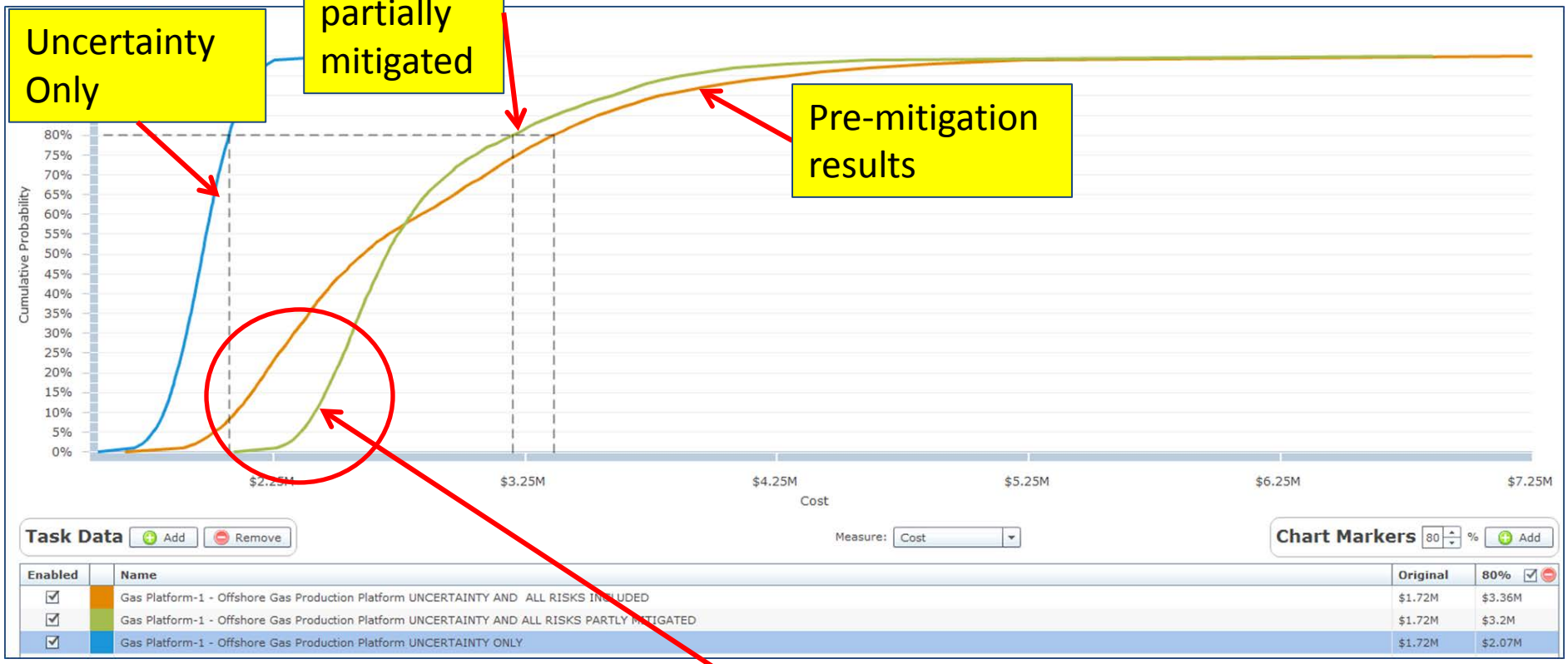
Partially Mitigate all Risks – Total Cost



Notice the effect of the mitigation costs – in the red circle – these are included and still there is some cost savings, largely from the schedule risk mitigation

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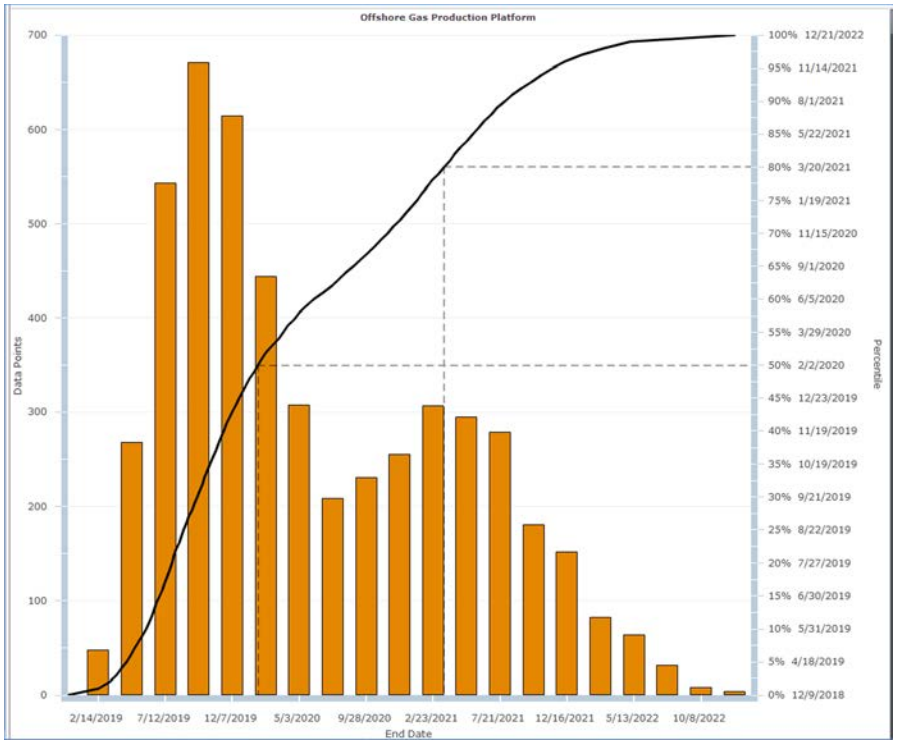
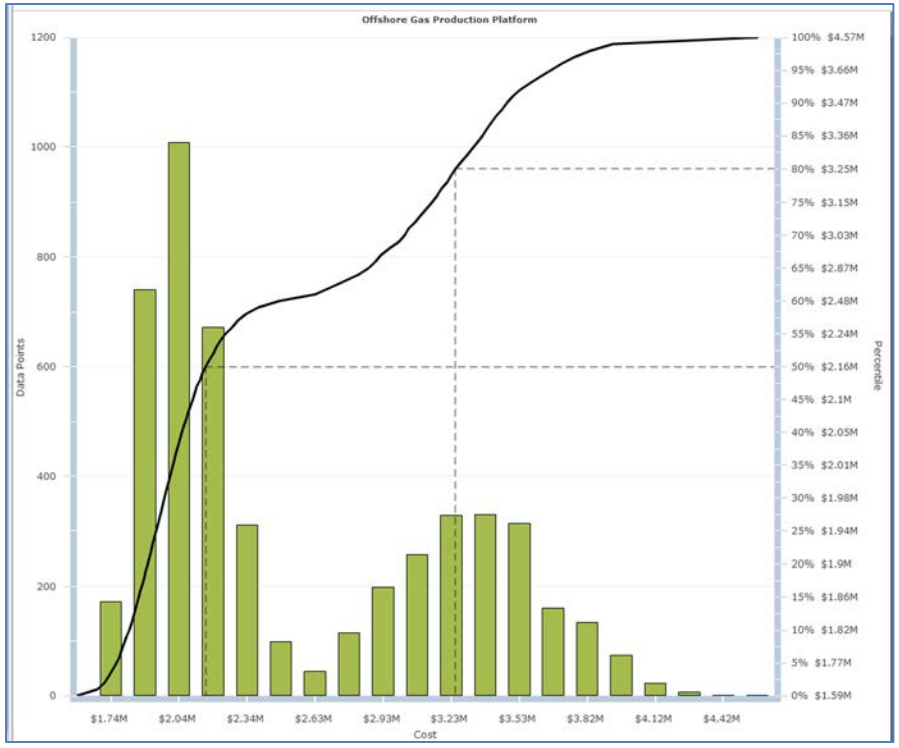
Use the Joint Confidence Level (e.g., JCL-80) from the Integrated Cost-Schedule Risk Analysis

Integrated Cost-Schedule Risk Analysis Using the Joint Confidence Level (JCL)

- When we have an integrated cost-schedule risk analysis we have the opportunity to determine cost and end date targets that can both be met
- These turn out to be somewhat higher and later than the targets when considered separately
- We prefer the JCL-80 to the P-80

Cost and Schedule Risk Analysis with Systemic Risks



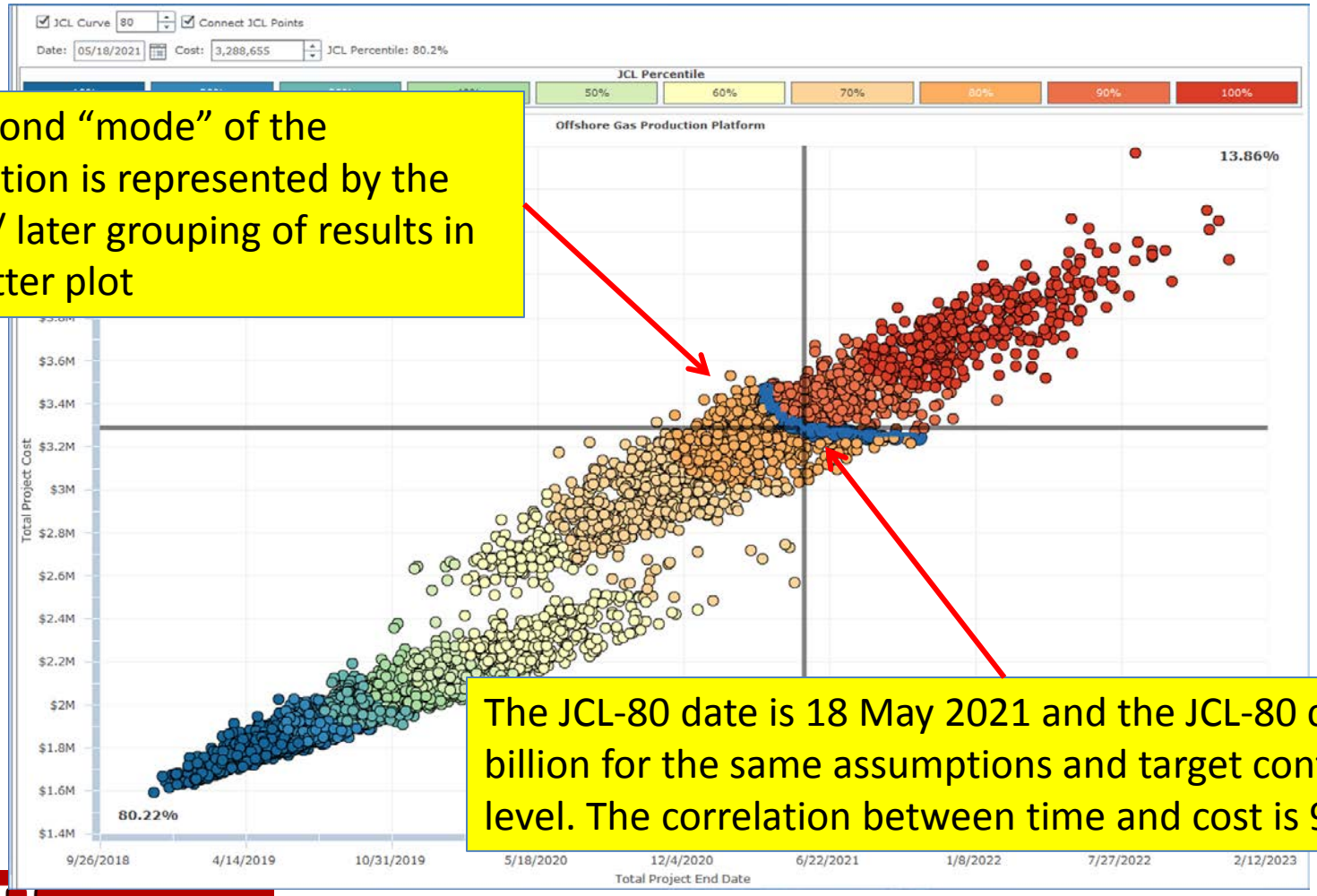


P-80 for end date is March 20, 2021

P-80 for cost is $3.25 billion

Integrated Cost-Schedule Risk JCL Scatterplot Results with Systemic Risks

The second "mode" of the distribution is represented by the higher / later grouping of results in the scatter plot



The JCL-80 date is 18 May 2021 and the JCL-80 cost is $3.3 billion for the same assumptions and target confidence level. The correlation between time and cost is 97%

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Summary (1)

- Unknown Unknowns may not be unknowable today, but some may become known during confidential interviews
  - Myopia: many risks people discuss even in confidential interviews are happening now or in the near future
  - Encourage a focus on the “far future” of the project may reveal these, Unknown may become Known with effort

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Summary (2)

- A new category of "Unknown Knowns," or those risks which are known to exist but are not talked about, is addressed
  - SMEs may be unwilling to discuss these risks in a risk workshop with others (e.g., the "boss") in the room
- Confidential interviews allow interviewees to discuss "unknown knowns" and they introduce risks not included in the current Risk Register
  - Open ended questions often reveal important, embarrassing or potentially dangerous risks that are not talked about
  - Once introduced, other team members seem to be able to contribute to quantifying those "unspoken risks"
  - These "interview risks" are often more impactful than the risks in the Risk Register

Summary (3)

- Monte Carlo simulation methods have been challenged to address systemic risks
  - Some say that systemic risks are best captured by parametric analysis
  - Monte Carlo can specify probability of occurring on this particular project
- We show how systemic risks, often identified with megaprojects, can be handled in MCS, compared to simple expanding the uncertainty ranges
- Project results databases need to be created or mined if they exist to determine the impact multipliers for systemic risks.

Summary (4)

- Risk mitigation decisions are greatly helped with prioritized risks
- Risks need to be prioritized at the target level of certainty, e.g., P-80
- Risks prioritization needs to supply some metric that management can use in a benefit / cost analysis, e.g., “days saved” even if assuming perfect mitigation
- These tables have been useful in mitigation workshops

Summary (5)

- The P-80 level for the end date and the project cost are typically used for specifying confident finish and cost costs
- But if we have costs on the schedule and perform integrated cost-schedule risk analysis the Joint Confidence Level (JCL) can provide targets that are both 80% likely
- These JCL-80 targets are typically later and larger than the P-80 targets, depending on the level of correlation between time and cost

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Unknowns, Systemic Risks and Risk Prioritization in Schedule Risk Analysis

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