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Integrated Cost-Schedule Risk Analysis using Risk Drivers and Prioritizing Risks

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Agenda

- Integrating cost and schedule risk analysis
- The Risk Driver method
- The schedule for an offshore gas production platform project
- Risk Register risks and their parameters
- Schedule Risk analysis results and priority risks
- Cost Risk analysis results and priority risks
- Risk Mitigation scenarios

Why Integrate Cost and Schedule Risk Analysis? (1)

- Many cost risk analyses assume that the schedule is fixed at the baseline and do not account for the impact of schedule risk
- Other cost risk analyses take ad hoc account of schedule risk but not through the schedule itself or from a schedule risk analysis result
- This analysis shows that project cost and time are related and that we can model that relationship directly

Why Integrate Cost and Schedule Risk Analysis? (2)

- Driving cost risk by schedule risk where appropriate:
  - Results in a better estimate of cost risk
  - Helps to understand where the risk comes from
  - Points to mitigation of risks that can affect both cost and schedule
  - Is based in the project schedule so we can see the time-profile of cash flow, risk adjusted

Results from Integrated Cost and Schedule Risk Analysis

- The likelihood of schedule and cost success
- The schedule and cost contingency reserve needed for desired level of certainty
- The list of risks to schedule and to cost in ranked order of priority
  - Assists risk mitigation
- Probabilistic cash flow

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Integrating Cost and Schedule Risk Analysis

- Some costs (labor, rigs, barges) are determined by changes in duration
  - Cost risk is driven by schedule risk since these resources cost more if they work longer
  - Cost risk may also be affected by uncertain burn rate/day
- Other costs (equipment, material) are uncertain, but not because of activity duration

Traditional 3-point Estimates of Duration

- Traditional schedule risk analysis starts with the activity that is impacted by risks
  - Estimates the 3-points for optimistic, most likely and pessimistic duration
  - Creates a probability distribution for activity duration
  - Performs Monte Carlo simulation
- Can we tell the high priority risks? This question is typically answered by:
  - Sensitivity – activities that are correlated with total time risk
  - Criticality – activities that are most likely on the critical path

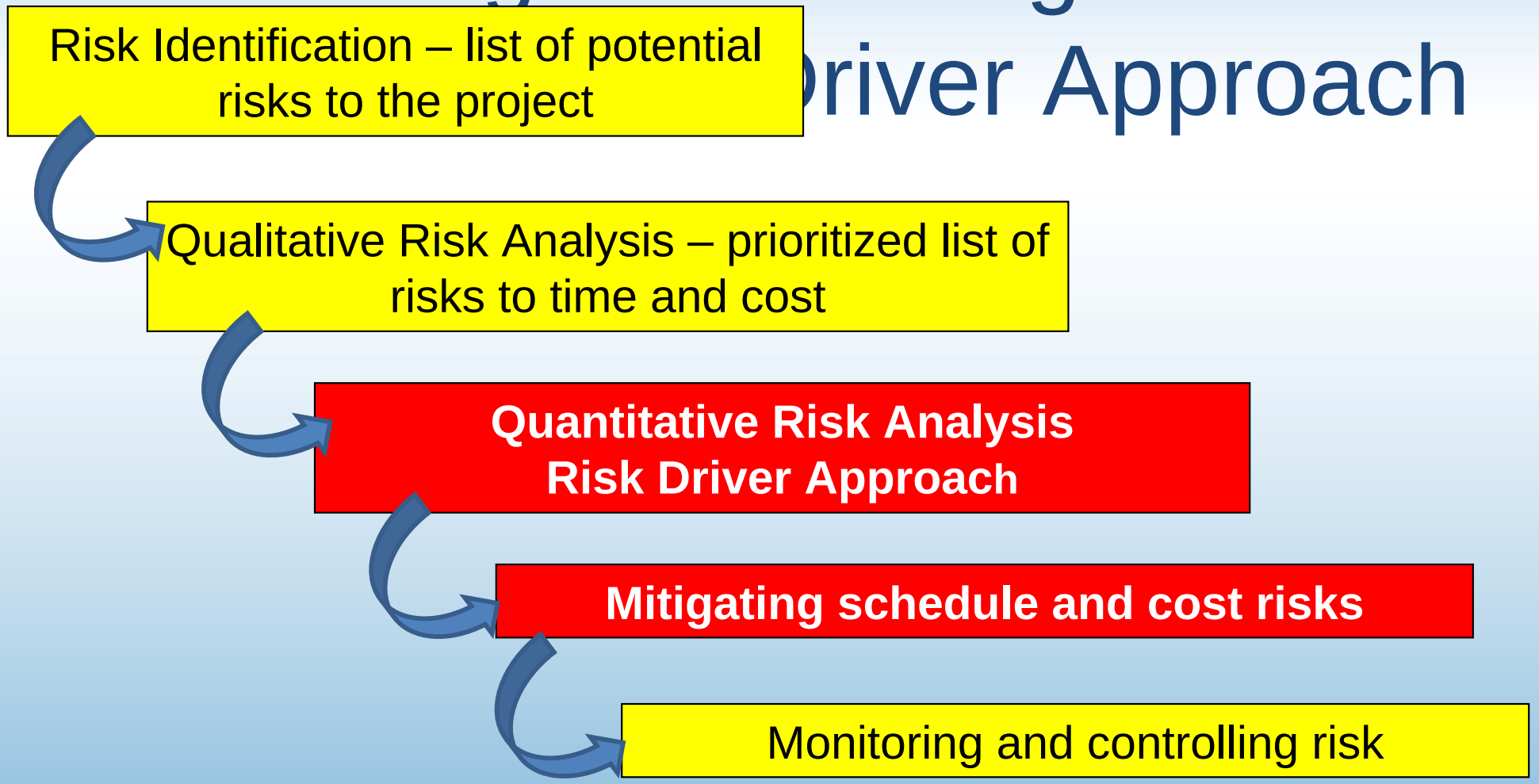
Some Problems with Traditional Approach

- Makes poor use of the Risk Register that is usually available
- Can tell which activities or schedule paths are crucial, but not which risks are driving
  - Traditional approaches cannot prioritize risks, only activities or paths

We Propose the Risk Driver Approach: Start with the Risks Themselves

- Drive the schedule risk directly by the risks already analyzed in the Risk Register
- For each risk, specify:
  - Probability it will occur – proportion of iterations it affects activity durations
  - Impact on time if it does – in terms of multiplicative factors
  - Activities it will affect
- <u>This approach focuses on the risks, not on the risks' impact on activities</u>

Flow Chart of Risk Management using the Risk Driver Approach



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Three Types of Risk

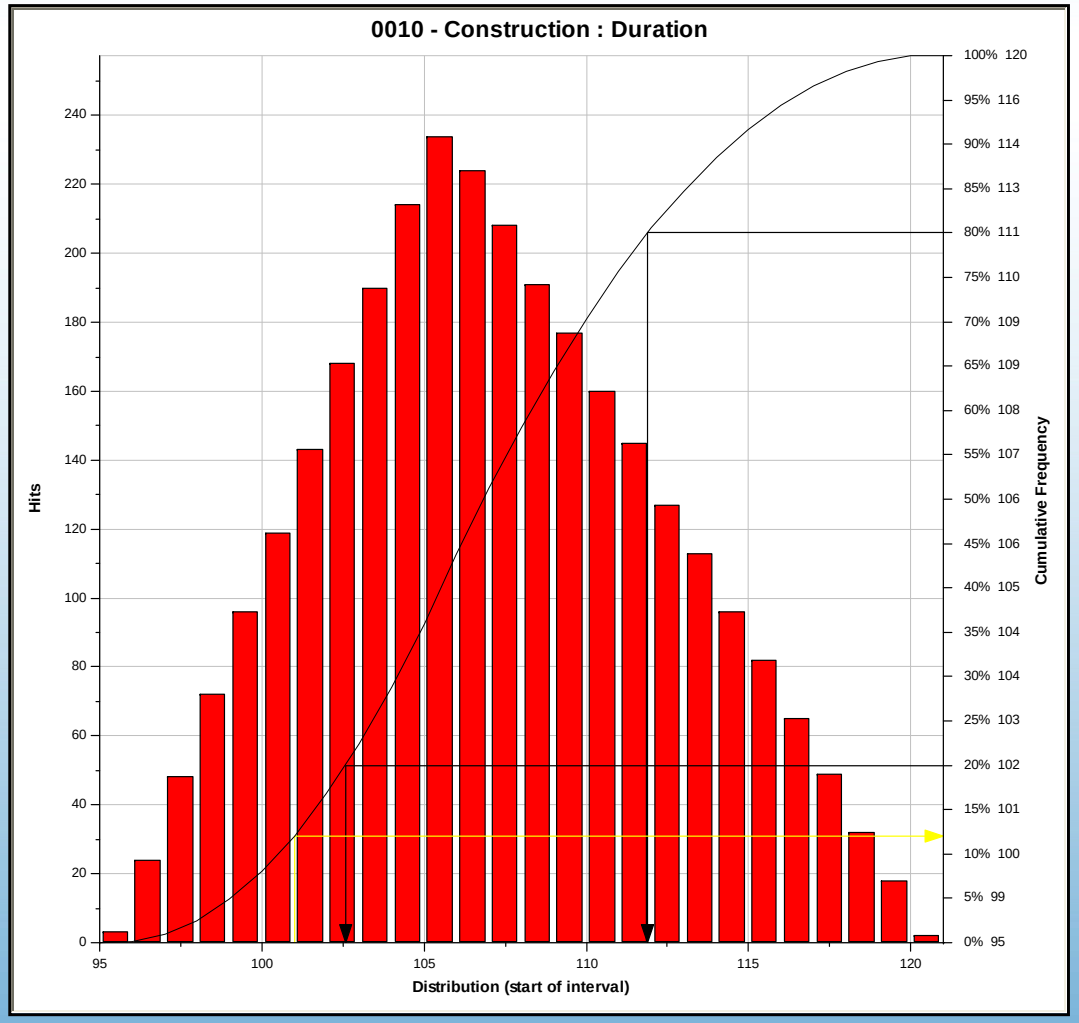
- Uncertainties, such as the level of labor productivity.
- Ambiguities, such as the accuracy of cost estimates and schedules
  - These always occur but may have a range of impacts
- Risk events that may or may not occur
  - These have both probability of occurring and impact ranges

Examples of Risk Types

	Description	Likelihood	Dur Min	Dur Likely	Dur Max
1.	Schedule is inaccurate, immature	100.00%	95.00%	105.00%	120.00%
2.	Construction Labor Productivity May Vary	100.00%	90.00%	100.00%	115.00%
3.	Quality, key personnel may be unavailable	70.00%	100.00%	105.00%	110.00%

- Schedule immaturity is an ambiguity. It has 100% probability of occurring and its impact range is both good and bad
- Construction labor productivity is an uncertainty that, compared to the assumption, could be lower or higher
- The possibility of quality, key personnel unavailability is a risk event. It may or may not occur, and in this case its impact is never to the good

Uncertainty and Ambiguity Risks Occur 100%



Schedule inaccuracy operates in 100% of the time (all iterations). On a construction activity of 100 days duration the results are triangular

The construction labor productivity risk would look similar to this figure

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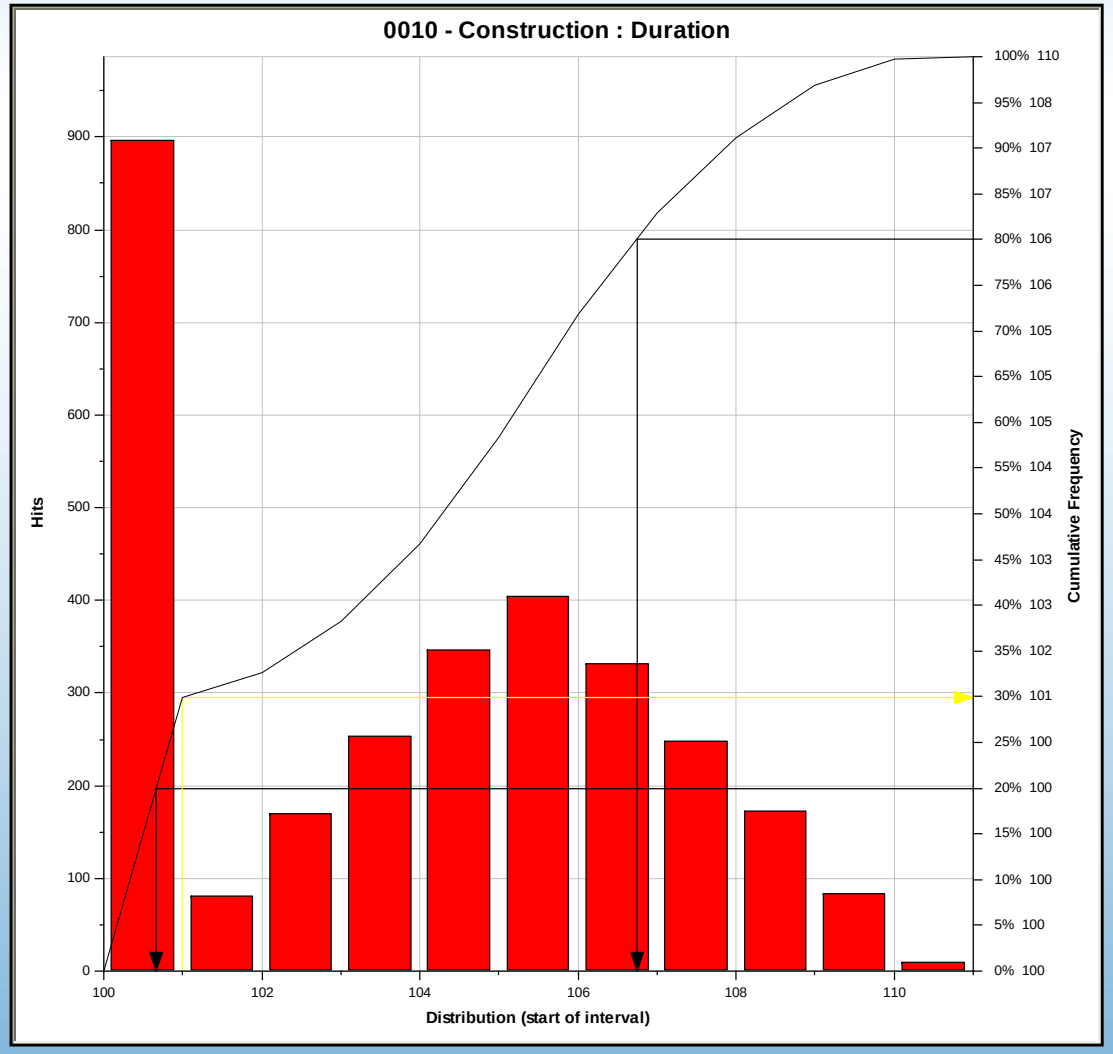
Risk Events are Described by their Probability and Impact

- If probability is < 100%, the risk will occur in that percentage of iterations, chosen at random
- On an iteration if the risk occurs, a factor chosen at random from its impact range (following a triangular distribution) will multiply the duration of the activities to which it is assigned
- If the risk does not occur the multiplicative factor is 100% with no effect on duration

Risk Events occur with a Probability < 100%



Here a risk event, the possible unavailability of quality key staff, occurs 70% of the time. Hence, in 30% (900) of the 3,000 iterations the original duration of construction, 100 days, is correct. In 70% (2,100) of the iterations, the duration is longer than 100 days as a triangle

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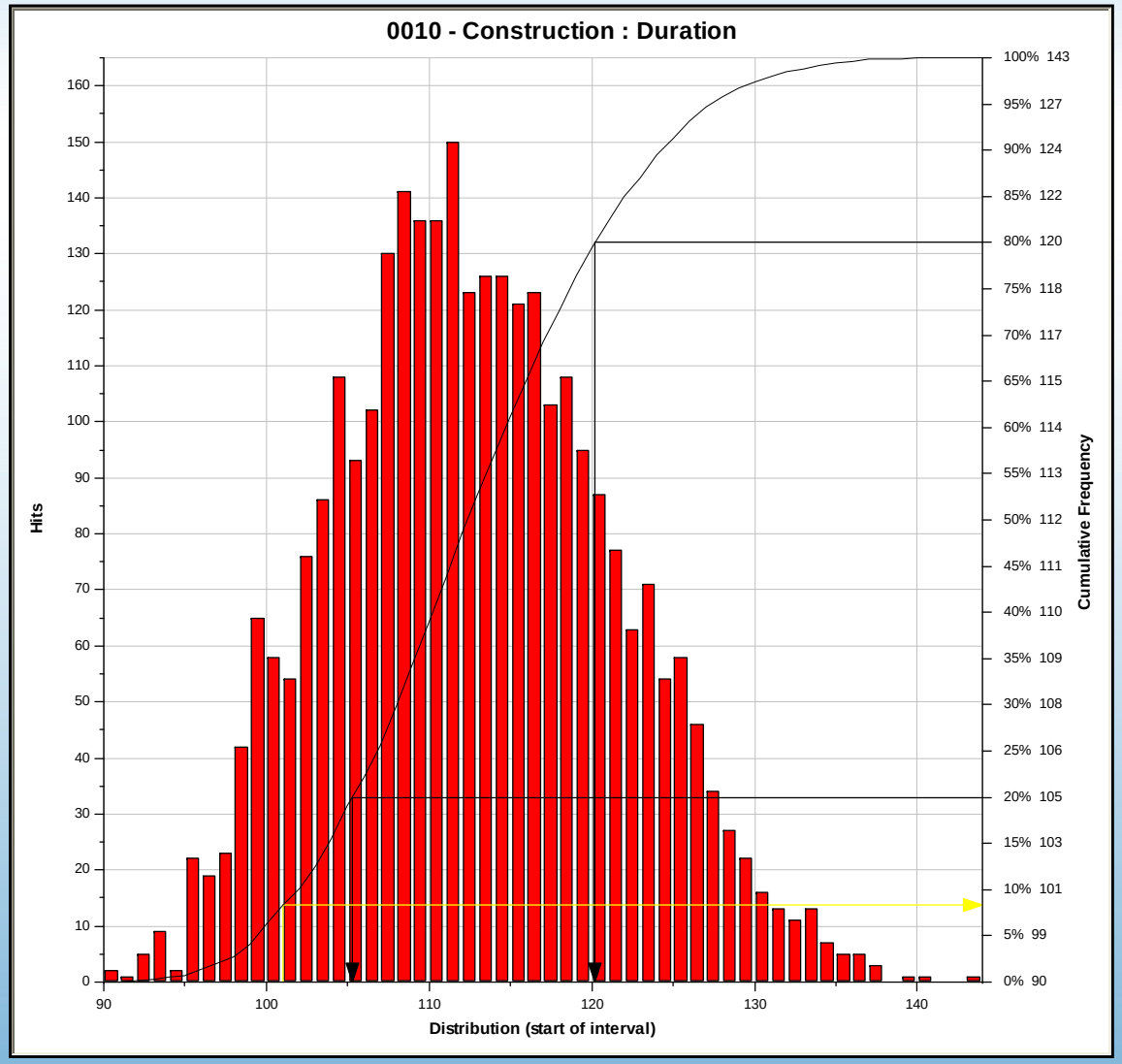
Risk Driver Strategy

- Risks are usually higher-level strategic risks rather than tactical or technical risks
- Data about risks is derived from in-depth interviews
- A risk is usually assigned to several activities
- An activity may have several risks assigned

A Construction Activity with Three Risks Assigned



The interaction of the three risks produces the expected histogram.
In traditional 3-point risk estimating, the analyst and interviewees must approximate the result of three risks on duration. The Risk Driver analysis computes the distribution.

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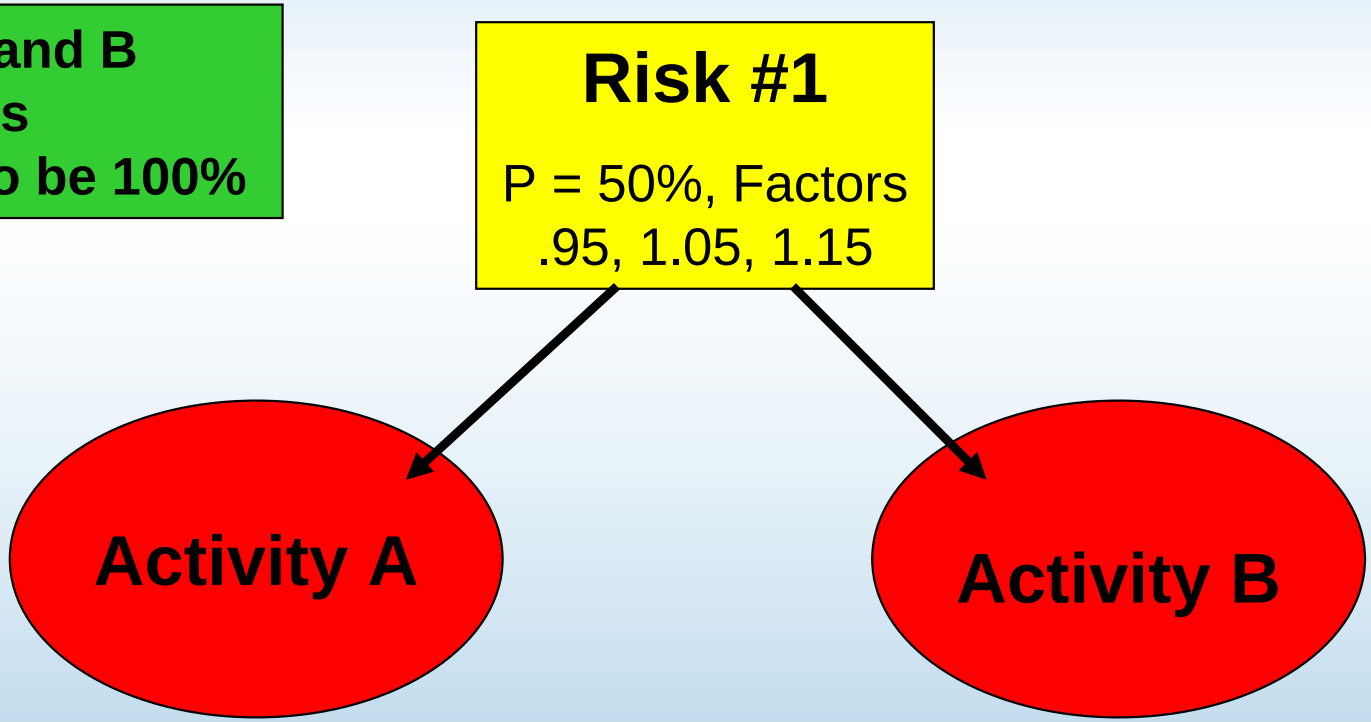
Risk Drivers Avoid the Need to Estimate the Correlation Coefficient

Activities A and B Correlation is <u>Calculated</u> to be 100%



In the traditional approach to risk analysis, the correlation coefficient has to be estimated.
Risk Drivers model how correlation occurs and <u>the coefficient is a natural result of the model</u>

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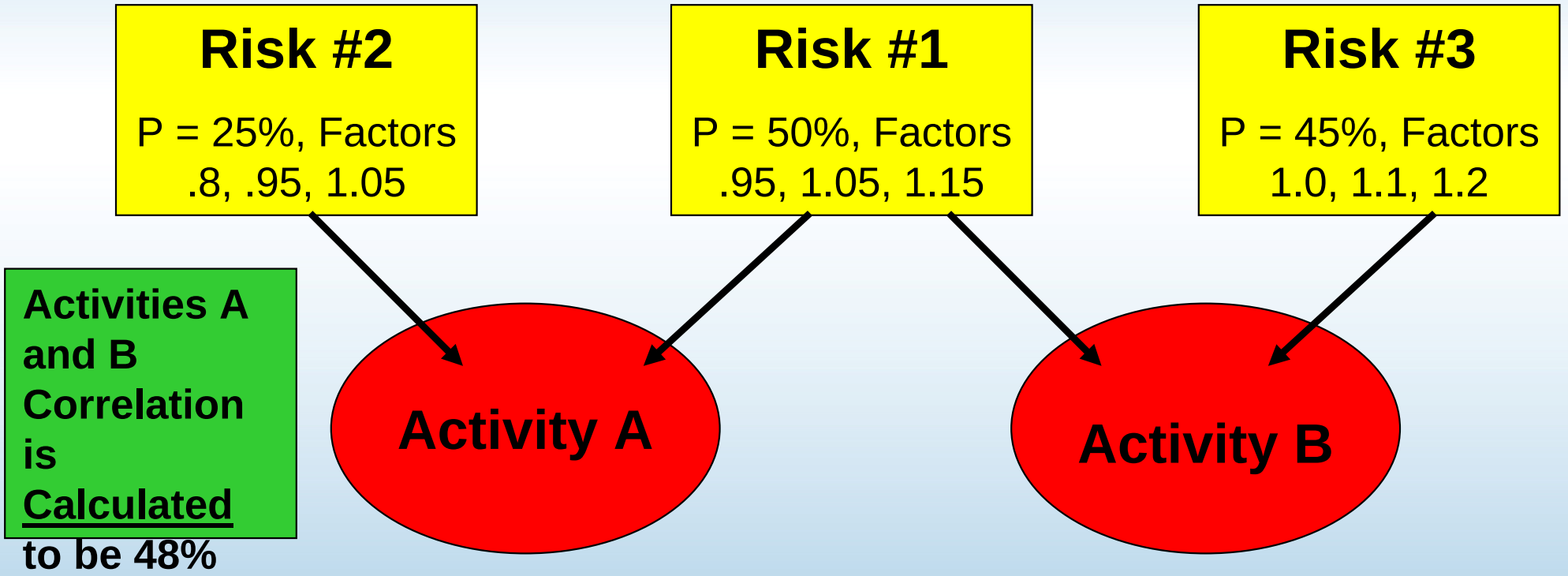
Risk Factors Model How Correlation Occurs (2)



Risk Drivers model correlation as it is caused in the project based on the common (Risk # 1) and confounding (Risks # 2 and #3) risks affecting pairs of activities

The correlation coefficient is the result, not the assumption

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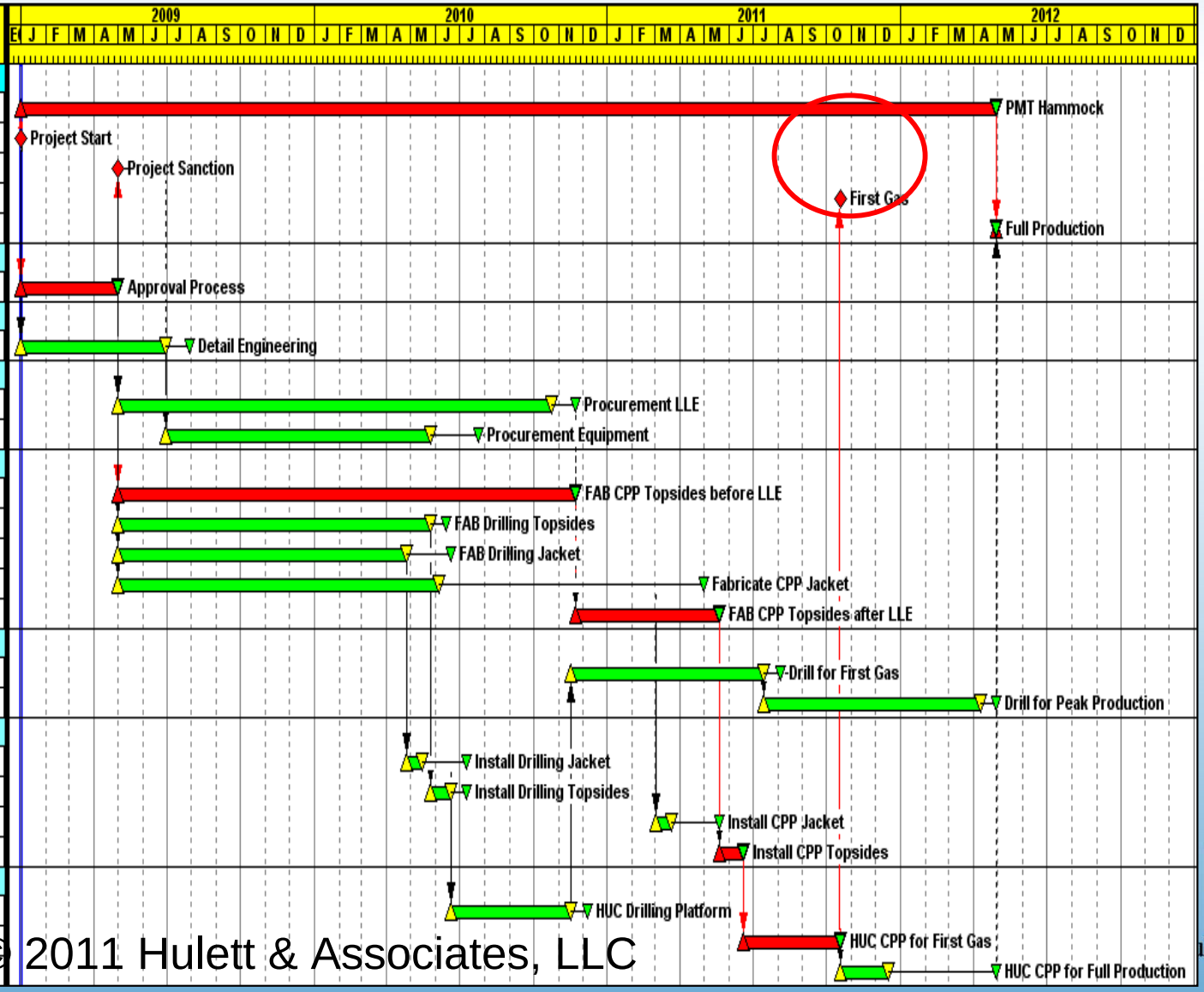
Baseline Schedule
First Gas at 17 OCT

Activity ID	Activity Description	Orig Dur	Total Float	Early Start	Early Finish
Milestones					
H100	PMT Hammock	1,215*	0	01JAN09	29APR12
M100	Project Start	0	0	01JAN09	
M105	Project Sanction	0	0	01MAY09	
M110	First Gas	0	0		17OCT11
M120	Full Production	0	0	30APR12*	29APR12
Decision Making					
APP100	Approval Process	120	0	01JAN09	30APR09
Detailed Engineering					
DD100	Detail Engineering	180	30	01JAN09	29JUN09
Procurement					
PROC100	Procurement LLE	540	30	01MAY09	22OCT10
PROC110	Procurement Equipment	330	60	30JUN09	25MAY10
Fabrication					
FAB110	FAB CPP Topsides before LLE	570	0	01MAY09	21NOV10
FAB140	FAB Drilling Topsides	390	20	01MAY09	25MAY10
FAB130	FAB Drilling Jacket	360	55	01MAY09	25APR10
FAB100	Fabricate CPP Jacket	400	330	01MAY09	04JUN10
FAB120	FAB CPP Topsides after LLE	180	0	22NOV10	20MAY11
Drilling					
DRILL100	Drill for First Gas	240	20	17NOV10	14JUL11
DRILL110	Drill for Peak Production	270	20	15JUL11	09APR12
Installation					
INST120	Install Drilling Jacket	20	55	26APR10	15MAY10
INST130	Install Drilling Topsides	25	20	26MAY10	19JUN10
INST100	Install CPP Jacket	20	60	02MAR11	21MAR11
INST110	Install CPP Topsides	30	0	21MAY11	19JUN11
Hook Up & Commissioning					
HUC120	HUC Drilling Platform	150	20	20JUN10	16NOV10
HUC100	HUC CPP for First Gas	120	0	20JUN11	17OCT11
HUC110	HUC CPP for Full Production	60	135	18OCT11	16DEC11



Resources and Cost $1,677 million

Total Project			
Subtotal			1,677,745
Milestones			
H100	PMT Hammock	PMT	9,720
M100	Project Start		0
M105	Project Sanction		0
M110	First Gas		0
M120	Full Production		0
Decision Making			
APP100	Approval Process	PMT	300
Detailed Engineering			
DD100	Detail Engineering	PMT, DETAIL	18,540
Procurement			
PROC100	Procurement LLE	PMT, PROC	352,620
PROC110	Procurement Equipment	PMT, PROC	330,990
Fabrication			
FAB110	FAB CPP Topsides before LLE	PMT, FAB	163,020
FAB140	FAB Drilling Topsides	PMT, FAB	111,540
FAB130	FAB Drilling Jacket	PMT, FAB	102,000
FAB100	Fabricate CPP Jacket	PMT, FAB	113,095
FAB120	FAB CPP Topsides after LLE	PMT, FAB	51,480
Drilling			
DRILL100	Drill for First Gas	PMT, DRILL	108,360
DRILL110	Drill for Peak Production	PMT, DRILL	121,905
Installation			
INST120	Install Drilling Jacket	PMT, INST	26,060
INST130	Install Drilling Topsides	PMT, INST	32,575
INST100	Install CPP Jacket	PMT, INST	30,060
INST110	Install CPP Topsides	PMT, INST	45,090
Hook Up & Commissioning			
HUC120	HUC Drilling Platform	PMT, HUC	27,450
HUC100	HUC CPP for First Gas	PMT, HUC	21,960
HUC110	HUC CPP for Full Production	PMT, HUC	10,980

Resources are added to the activities
PMT = Project Management Team
Detail = Detailed Engineering
PROC = Procurement
FAB = Fabrication
DRILL = Drilling
INST = Installation
HUC = Hook-Up and Commissioning

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Risk Factors Used

Schedule Ranges | Cost Ranges

	Description	Likelihood	Dur Min	Dur Likely	Dur Max	Cost Min	Cost Likely	Cost Max
1.	C - Market costs for bulks and equipment is volatile	100.00%	100.00%	100.00%	100.00%	95.00%	102.00%	110.00%
2.	S - Experienced HUC resources may not be available	95.00%	95.00%	105.00%	120.00%			
3.	S - Company's Engineers vary in experience	100.00%	90.00%	102.00%	105.00%			
4.	C/S - Company's Engineers vary in experience -- PROC	100.00%	100.00%	105.00%	110.00%	90.00%	102.00%	105.00%
5.	S - Schedule is based on FEED only and is immature	100.00%	90.00%	105.00%	110.00%			
6.	S - MTO, Specs may not be ready for ITB -- FAB	50.00%	95.00%	105.00%	115.00%			
7.	C/S - MTO, Specs may not be ready for ITB -- PROC	50.00%	95.00%	105.00%	115.00%	95.00%	100.00%	110.00%
8.	S - May have problems interfacing Phases	75.00%	100.00%	105.00%	110.00%			
9.	C/S - May have problems interfacing Phases -- PROC	75.00%	100.00%	105.00%	110.00%	100.00%	102.00%	105.00%
10.	C - Cost estimate is inaccurate / immature	100.00%				90.00%	105.00%	110.00%
11.	S - Fabricators may be busy	90.00%	95.00%	105.00%	110.00%			
12.	C/S - Suppliers may be busy -- PROC	90.00%	95.00%	105.00%	110.00%	95.00%	105.00%	110.00%
13.	S - Quality engineers may be scarce at Fabricators	70.00%	100.00%	102.00%	107.00%			
14.	C/S - Quality engineers may be scarce at Suppliers	40.00%	100.00%	102.00%	107.00%	100.00%	102.00%	105.00%
15.	S - Scope Growth may Differ from Expectations	60.00%	95.00%	100.00%	110.00%			
16.	C/S - Scope Growth may Differ from Expectations - PROC	60.00%	95.00%	100.00%	110.00%	95.00%	100.00%	110.00%

These data are derived during in-depth interviews with project participants and others. The interviews focus on the Risk Register risks that are designated “high risk” for time and cost. Use Pertmaster Risk Expert

Assignment of Risk Drivers to Activities

Risk Driver	Activity Assignment							
	DETAIL	FAB	PROC	INSTAL	HUC	DRILL	PMT	APPROVAL
Market Costs for Bulks/Equipment Volatile		X	X	X		X		
Experienced HUC resources availability					X			
Company's Engineers' experience	X	X	X	X	X	X	X	X
Schedule Maturity	X	X	X	X	X	X		X
MTO, Specifications may not be ready ITB		X	X					X
Problems interfacing Phases		X	X	X	X			
Cost Estimate inaccurate / immature	X	X	X	X	X	X	X	
Fabricators and Suppliers may be busy		X	X					
Quality engineers may be scarce @ FAB, Suppliers		X	X					
Scope Growth may be more than expected		X	X					

Schedule Risk Analysis Results

Schedule Risk Analysis				
Date Results for First Gas				
Baseline Date	**17-Oct-11**			
Risk Analysis Results	**P-5**	**P-50**	**P-80**	**P-95**
	10-Nov-11	**7-Mar-12**	**11-May-12**	**13-Jul-12**
Months from Baseline	**0.8**	**4.7**	**6.8**	**8.9**
Duration Results To First Gas				
	Days			
Baseline Duration	**1,020**			
Risk Analysis Results	**P-5**	**P-50**	**P-80**	**P-95**
	1,044	**1,162**	**1,227**	**1,290**
Percentage from Baseline	**2%**	**14%**	**20%**	**26%**

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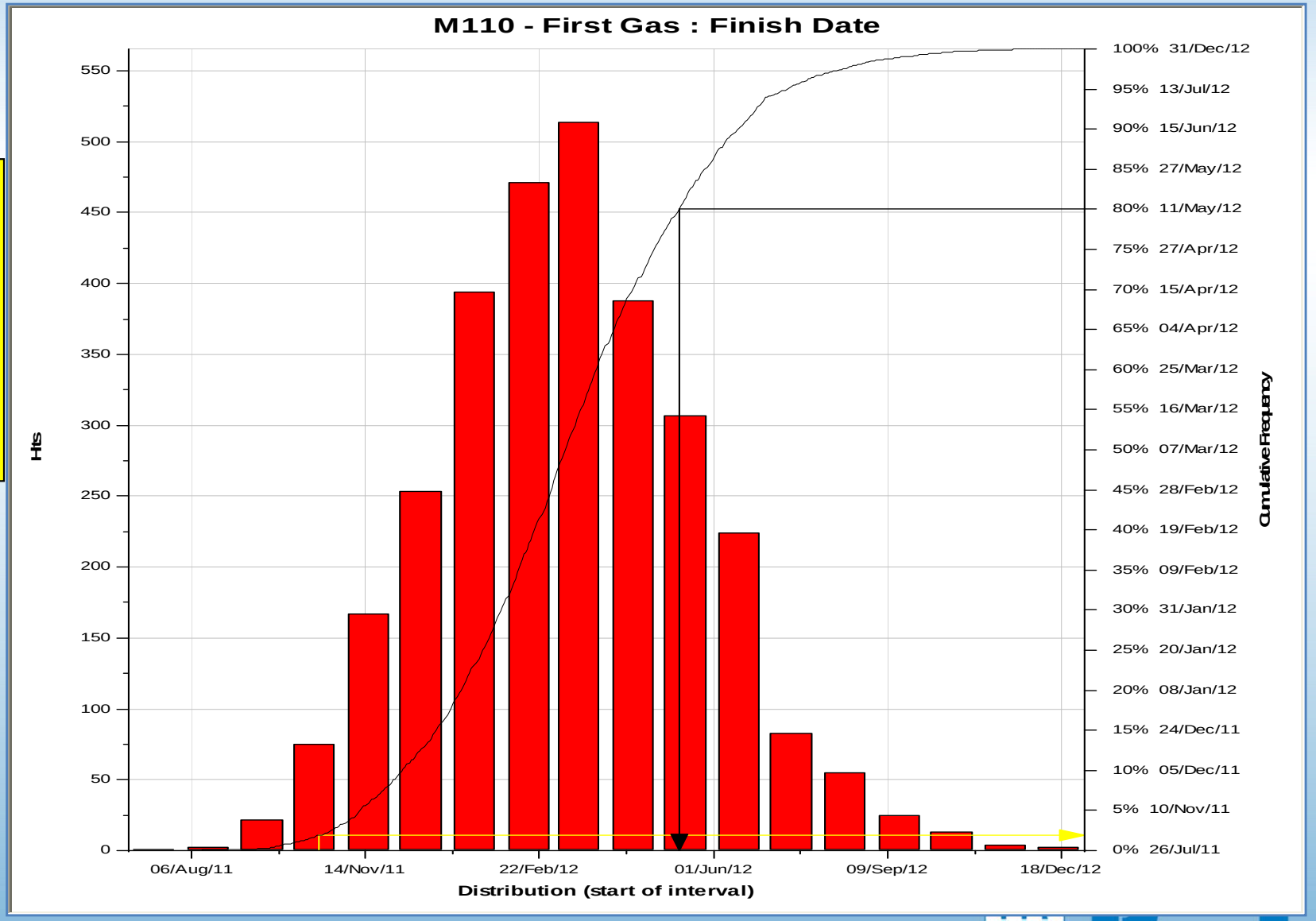
Completion Date

First Gas Baseline Date = 17 OCT 2011
P-80 = 11 May 2012



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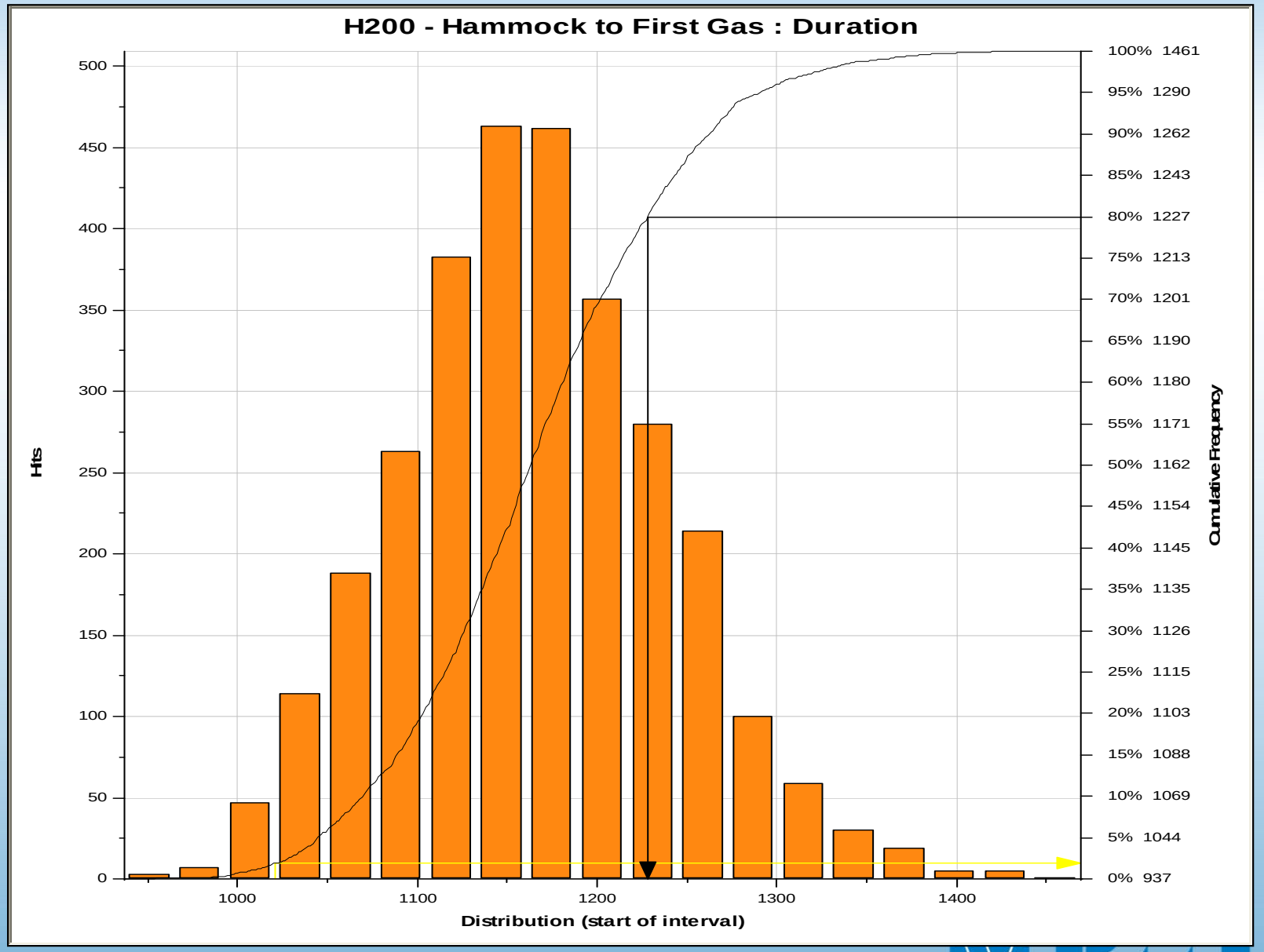
Schedule Duration

Baseline Duration to First Gas = 1,020 days
P-80 = 1,227 days



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Prioritize Risks that Cause Schedule Contingency

Prioritize Schedule Risks			
First Gas, All Risks	11-May-12	From the All-In P-80	
Take Out Risks in Priority Order:		Days Saved	% Saved
Problems interfacing Phases	27-Mar-12	45	22%
Schedule Immaturity	21-Feb-12	35	17%
MTO, Specifications may not be ready ITB	12-Jan-12	75	36%
Fabricators and Suppliers may be busy	16-Dec-11	27	13%
Quality engineers may be scarce @ FAB, Suppliers	29-Nov-11	17	8%
Company's Engineers' may be inexperienced	15-Nov-11	14	7%
Scope Growth may be more than expected	30-Oct-11	30	14%
Experienced HUC resources availability	17-Oct-11	13	6%
Total Contingency at the P-80		207	100%

The order of risks is the best order at each step in this table. However, because of the schedule's structure some "Days Saved" values show inversion.

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Summary Cost Risk Analysis Results

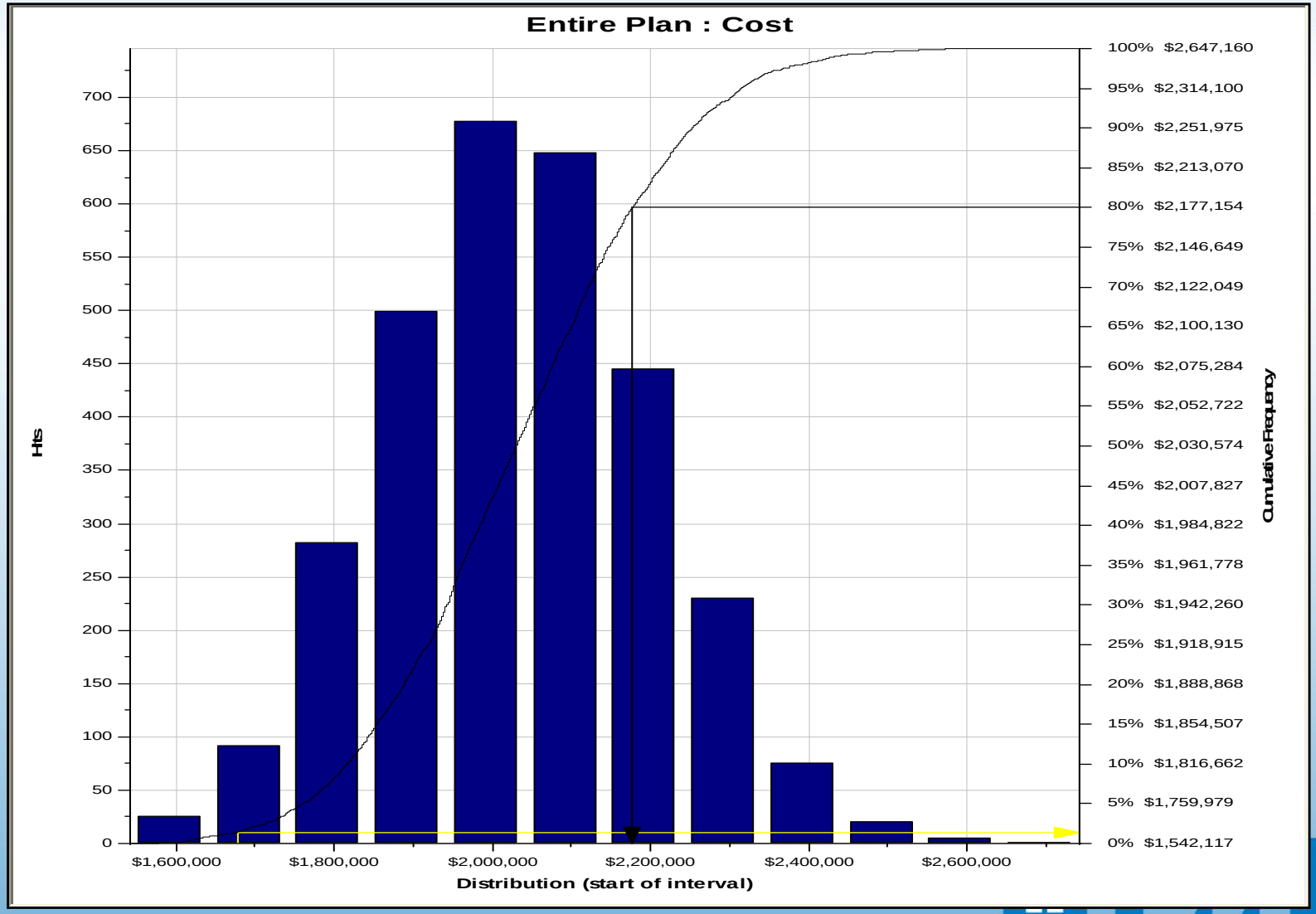
Cost Risk Analysis Total Project				
	$ millions			
Baseline Cost	1,678			
	P-5	P-50	P-80	P-95
Risk Analysis Results	1,760	2,031	2,177	2,314
Dollars from Baseline	82	353	499	636
Percent from Baseline	5%	21%	30%	38%

Cost Risk by Resource

Cost Contingency Breakdown by Resource			
	$ millions		
Resource	Baseline	P-80	% Contingency
Procurement	681	993	46%
Fabrication	532	681	28%
Drilling	230	256	12%
Installation	134	155	16%
Hook Up & Commissioning	59	72	21%
Project Management Team	24	30	23%
Detailed Engineering	18	20	11%
TOTAL PROJECT	1,678	2,177	30%

Cost Risk Analysis Results

Baseline Cost = $1,678 billion
P-80 = 2.177 billion



Sources of Cost Contingency

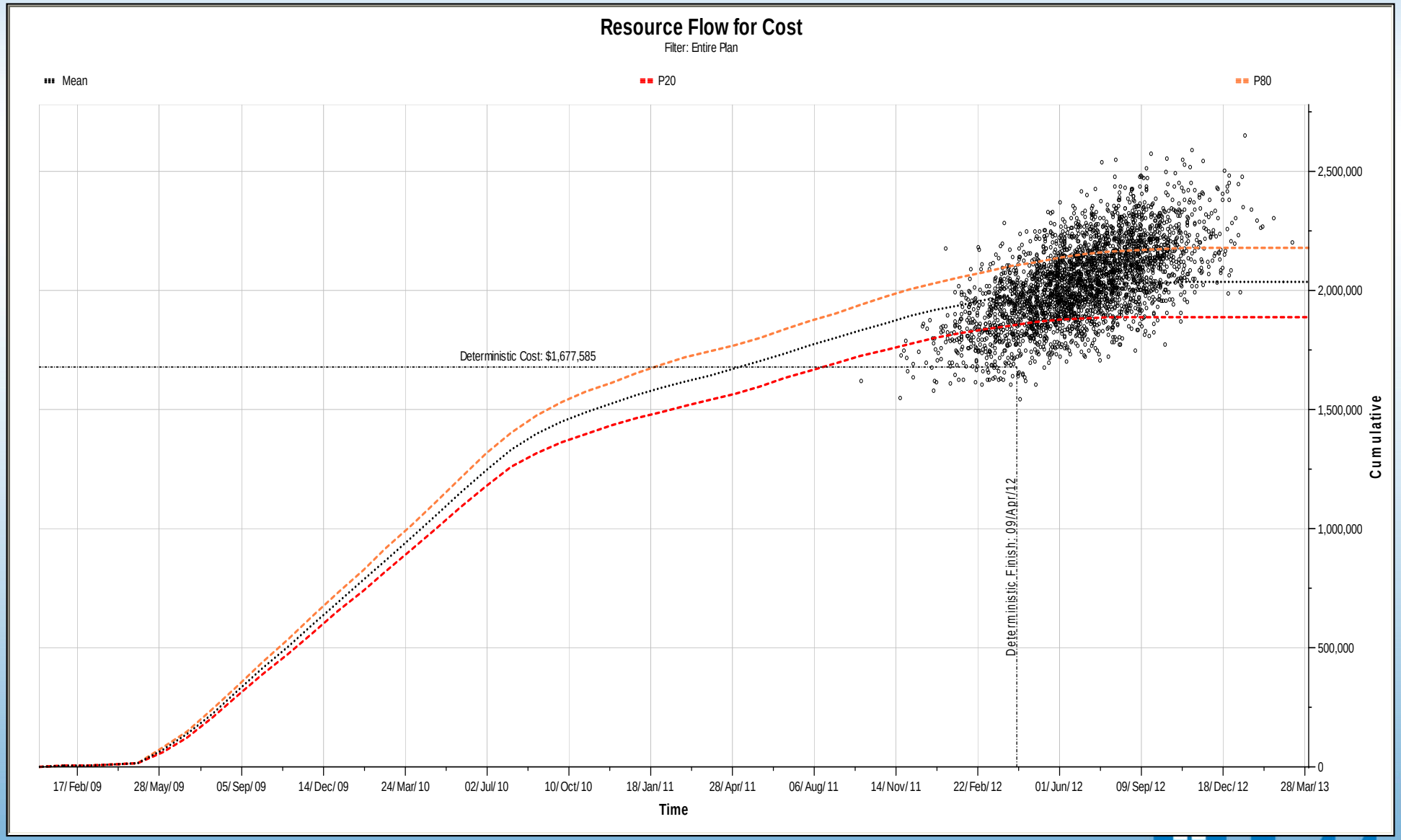
Source of Cost Contingency at the P-80		
	Total Cost	Contingency
Total Cost All-Risks	2,177	
Baseline Cost	1,678	499
		Contribution
Take out Schedule Risks	1,878	299
Take out Cost Risks	1,995	182
Interaction of Cost/Schedule Risks		18
Total Contingency		499

Priority Risks to Cost Measured at P-80

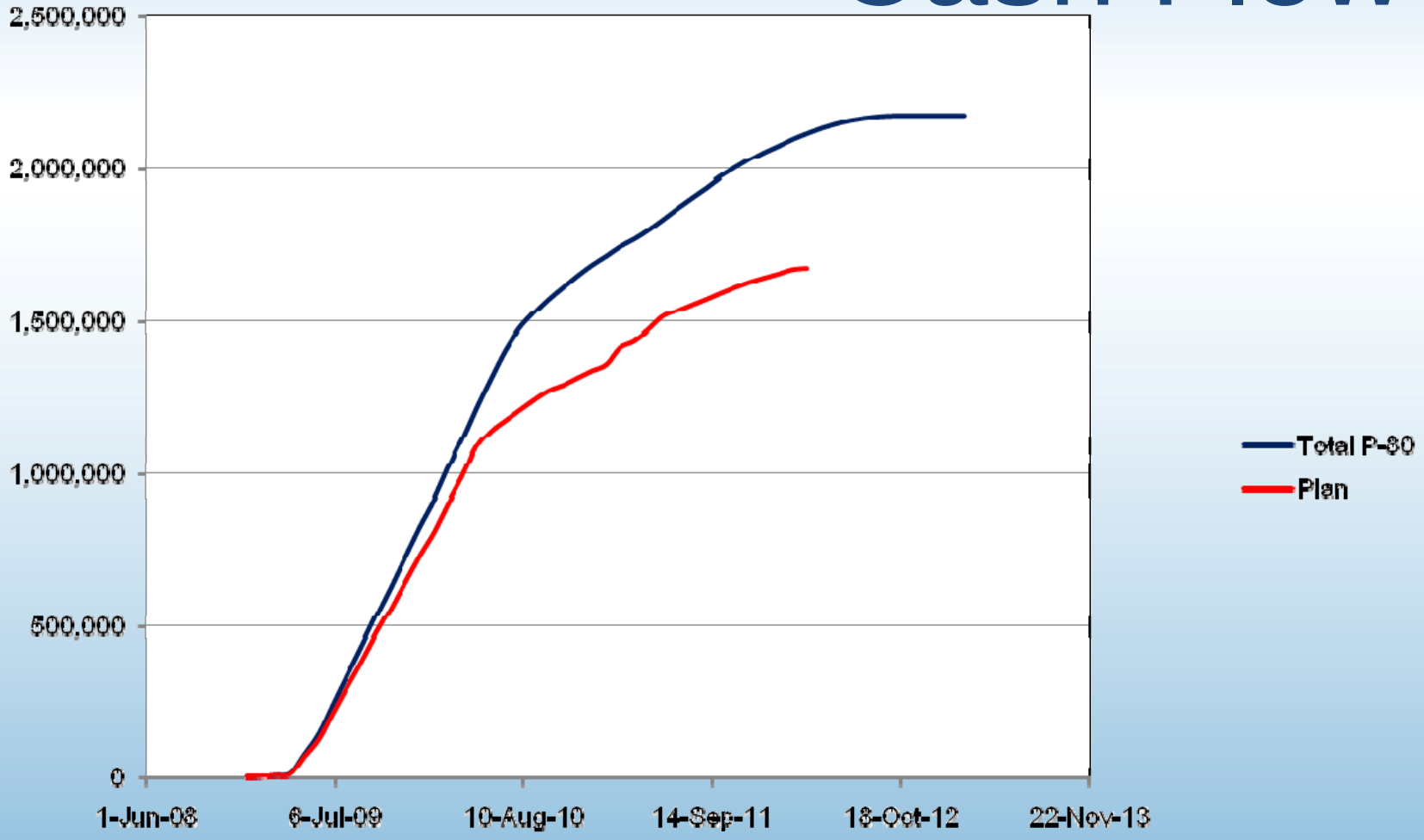
Prioritize Risks to Cost at the P-80		
Risk Type		**$ millions**
	Total Project, All Risks	**2,177**
	Baseline cost	**1,678**
	Take Out Risks one at a time:	**$ saved**
S	**Problems interfacing Phases**	**91**
S	**Fabricators and Suppliers may be busy**	**84**
S	**Schedule Immaturity**	**56**
C	**Market Cost for Bulks and Equip. volatile**	**53**
C	**Cost Estimate is immature and inaccurate**	**53**
S	**MTO, Specifications may not be ready ITB**	**50**
S	**Company's Engineers' may be inexperienced**	**35**
S	**Quality engineers may be scarce @ FAB, Suppliers**	**33**
S	**Scope Growth may be more than expected**	**28**
S	**Experienced HUC resources availability**	**4**

The top three risks to cost are schedule risks

Probabilistic Cash Flow



Probabilistic vs. Planned Cash Flow



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Risk Mitigation Scenario

Risk Mitigation Scenario						
	%	Low	Most Likely	High	First Gas Date	Project Cost ($ million)
Risk to be Mitigated	Before Mitigation					
May have trouble interfacing Phases	**75%**	100%	105%	110%	11-May-12	2,177
Proposed Mitigation: Hire Integration Staff Engineers and Place them with Fabricators and Suppliers						
	After Mitigation					
May have trouble interfacing Phases	**20%**	100%	105%	110%	9-Apr-12	2,113
Improvement					32	64
Cost of proposed Mitigation						20
Net Improvement from Mitigation					32	44

Spending $20 million for additional staff is assessed to reduce the probability of this risk from 75% to 20%. Because the *schedule slippage is 32 days less* than before, there is $64 million we do not need to reserve and so the net cost impact at the P-80 is actually a *savings of $44 million*.

Summary Integrated Cost and Schedule Risk

- Integrating cost and schedule risk analysis provides
  - Better estimates of cost risk than those ignoring schedule
  - Insight into the contribution of schedule risk to cost risk
- Analyzing cost and schedule risk in the same simulation fully integrates the two
  - Schedule slips will cause added cost for labor, rented barges and drill rigs, hence…
  - Mitigating schedule risk can reduce the need for contingency reserve of cost as well as of time

Summary
Risk Driver Approach

- Focuses on the actual risks, not the impact of risks on activity durations or cost elements
- Allows prioritization of specific risks and hence facilitates the focus on risk mitigation
- Enables risk interviews on the Risk Register items that are strategic and fundamental. Interviews are shorter and more informative than 3-point estimates on activities
- Models correlation naturally as it occurs in projects
- Links qualitative and quantitative risk analysis explicitly
- Models risk mitigation to cost and schedule with impacts on each

Thank You
For Attending!

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