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 to develop a mission to Europa to look for Microbial Life
- 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

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

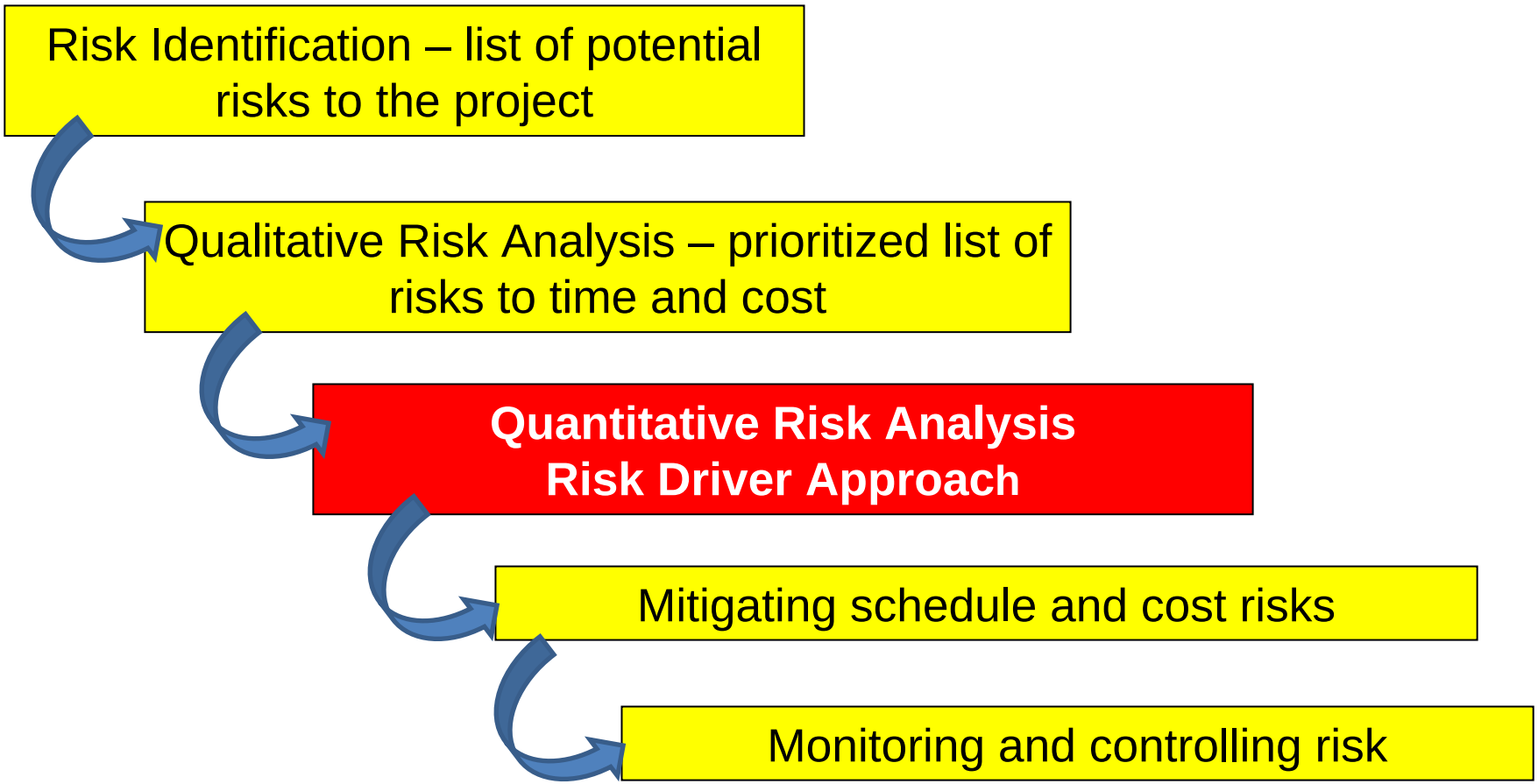
Some Problems with Traditional Approach

- 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
- This approach focuses on the risks, not on the risks' impact on activities

Flow Chart of Risk Management using the Risk Driver Approach



Three Types of Risk

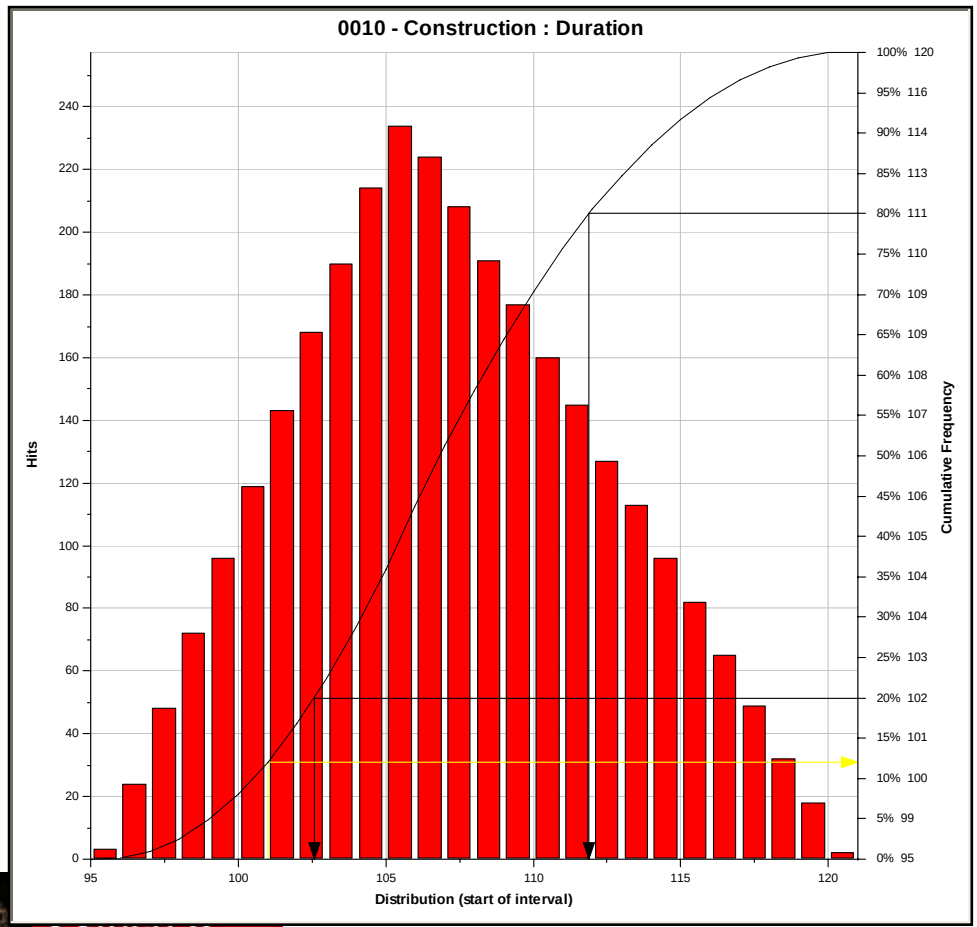
- Uncertainties, such as the level of labor productivity.
- Ambiguities, such as the accuracy of cost estimates and schedules
  - These always occur but may have a range of impacts
- Risk events that may or may not occur
  - These have both probability of occurring and impact ranges

Examples of Three 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% of the time



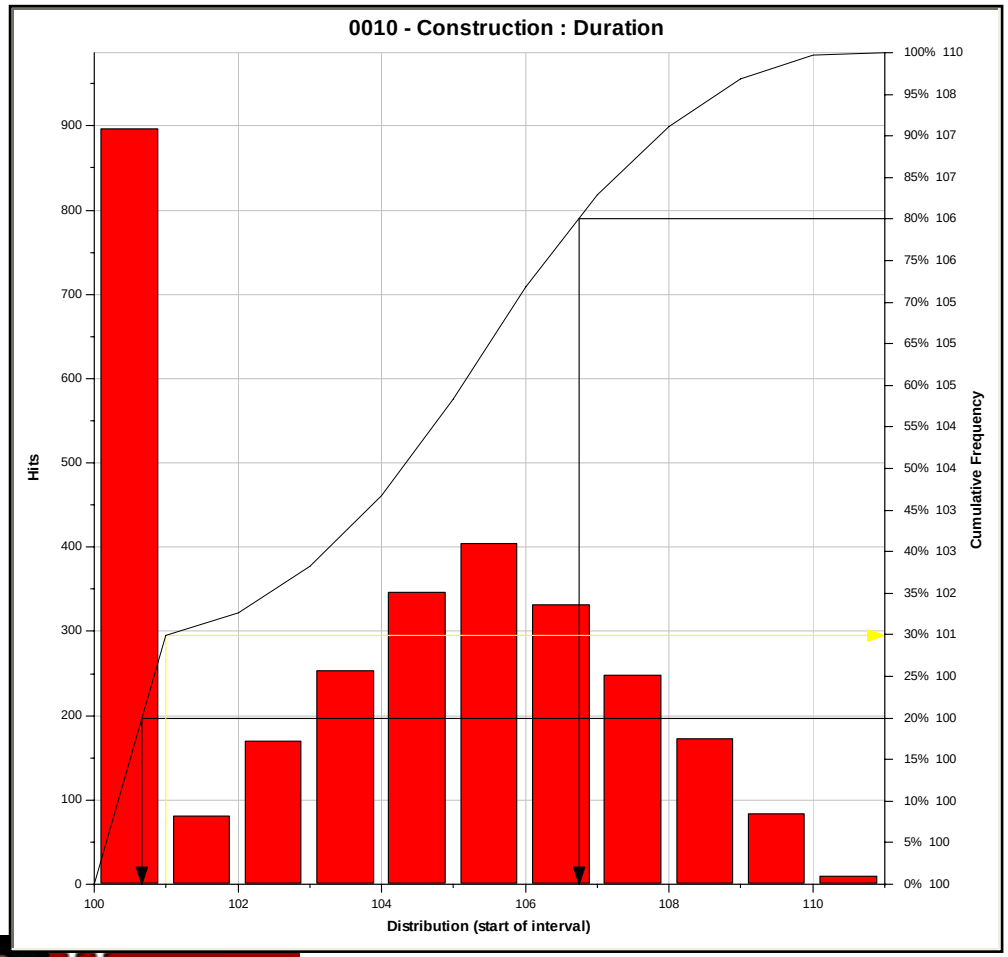
Schedule inaccuracy operates in 100% of the time (all iterations). On a construction activity of 100 days duration the results are triangular

The construction labor productivity risk would look similar to this figure

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%

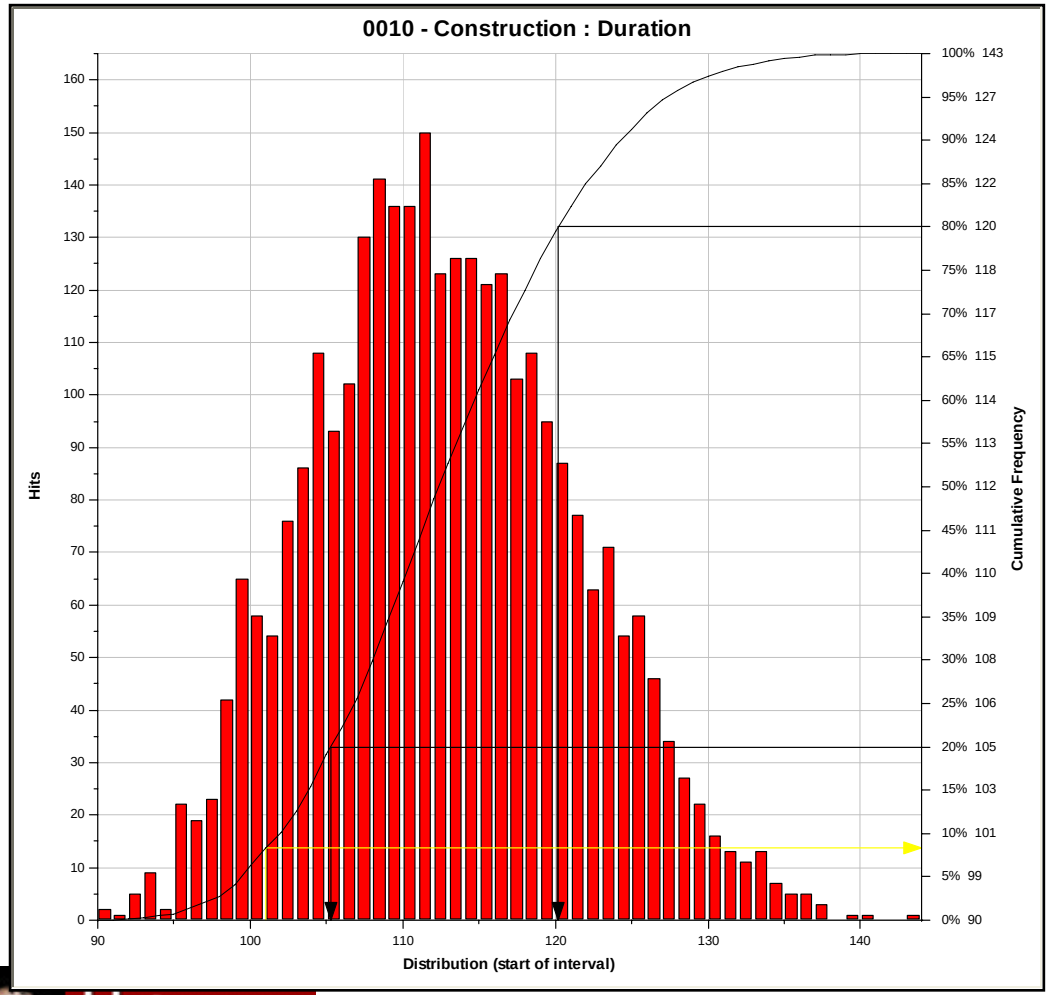


Here a risk event, the possible unavailability of quality key staff, occurs 70% of the time. Hence, in 30% (900) of the 3,000 iterations the original duration of construction, 100 days, is correct. In 70% (2,100) of the iterations, the duration is longer than 100 days as a triangle

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

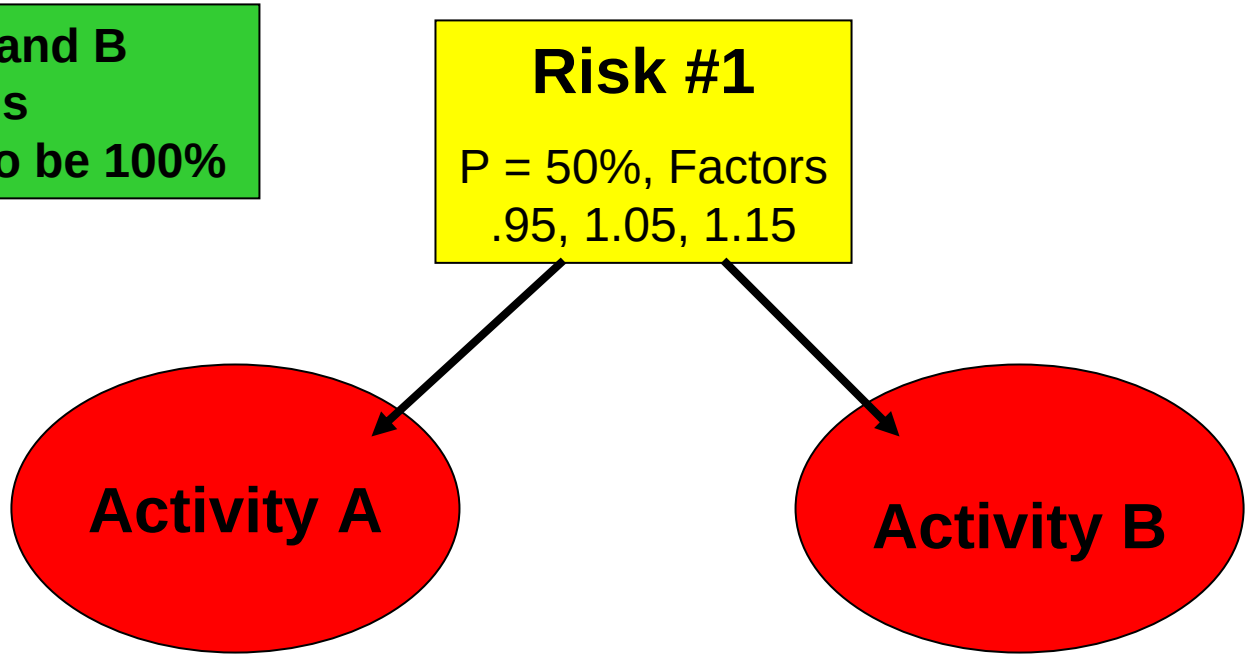
A Construction Activity with Three Risks Assigned



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.

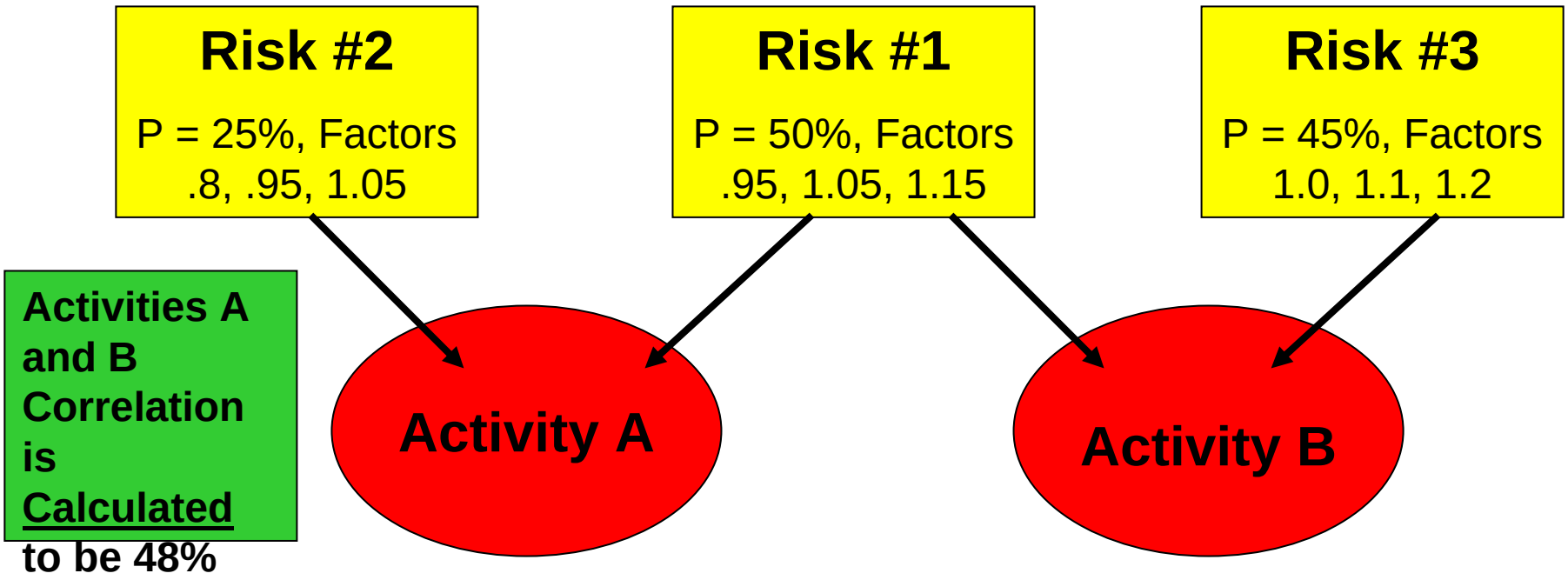
Risk Drivers Avoid the Need to Estimate the Correlation Coefficient

Activities A and B Correlation is Calculated to be 100%



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

Risk Factors Model How Correlation Occurs (2)

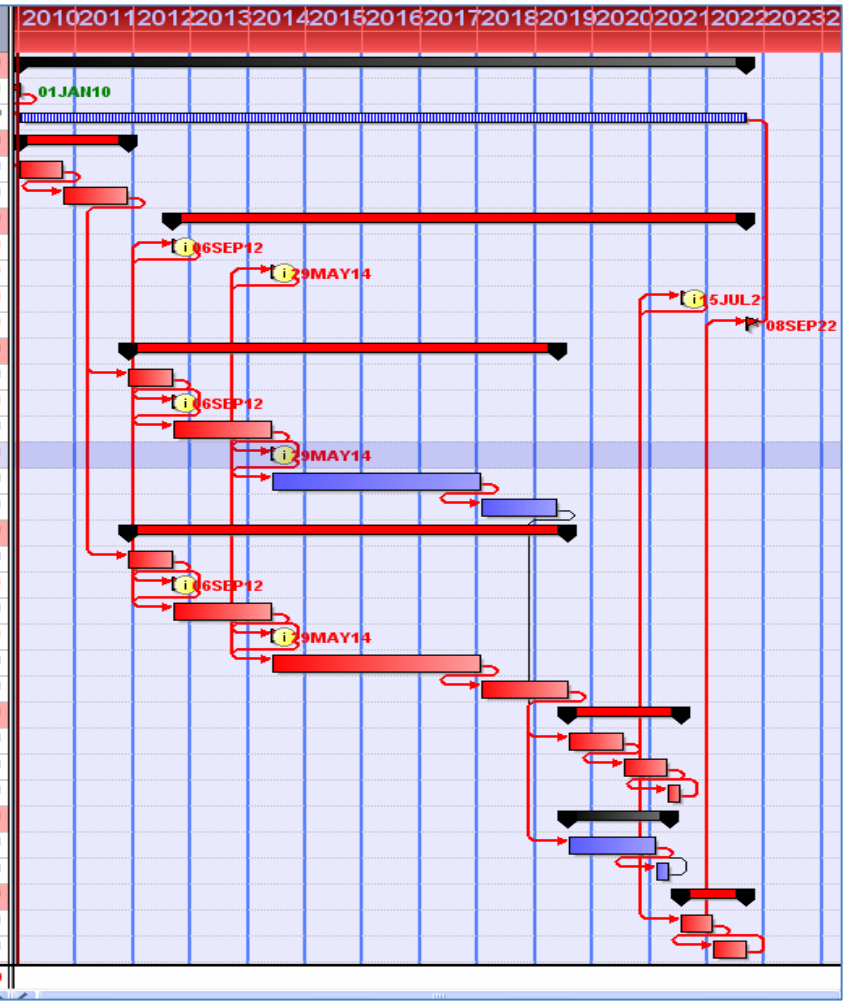


Risk Drivers model correlation as it is caused in the project based on the common (Risk # 1) and confounding (Risks # 2 and #3) risks affecting pairs of activities

The correlation coefficient is the result, not the assumption

Case Study: Hypothetical Voyage to Europa to Probe for Evidence of Microbial Life

ID	Description	Remaining Duration	Start	Finish	Total Finish Float	Total Cost
000001	**Program Initiation**	**3310**	**01JAN10**	**08SEP22**	**0**	**$99,300.00**
000002	**Program Start**	**0**	**01JAN10**		**0**	**$0.00**
000003	*Program Management Team*	*3310*	*01JAN10*	*08SEP22*	*0*	*$99,300.00*
000004	**Decision Process and Requireme...**	**500**	**01JAN10**	**01DEC11**	**0**	**$40,000.00**
000005	Decision Process	200	01JAN10	07OCT10	0	$10,000.00
000006	Requirements Definition Trade Studies	300	08OCT10	01DEC11	0	$30,000.00
000007	**Europa Probe Program Milestones**	**2610**	**07SEP12**	**08SEP22**	**0**	**$0.00**
000008	**PDR Europa Probe**	**0**		**06SEP12**	**0**	**$0.00**
000009	**CDR Europa Probe**	**0**		**29MAY14**	**0**	**$0.00**
000010	**Ship to Launch Site**	**0**		**15JUL21**	**0**	**$0.00**
000011	**Ready to Launch**	**0**		**08SEP22**	**0**	**$0.00**
000012	**Probe**	**1950**	**02DEC11**	**23MAY19**	**0**	**$695,000.00**
000013	Probe Preliminary Design	200	02DEC11	06SEP12	0	$20,000.00
000014	**Probe PDR**	**0**		**06SEP12**	**0**	**$0.00**
000015	Probe Final Design	450	07SEP12	29MAY14	0	$112,500.00
000016	**Probe CDR**	**0**		**29MAY14**	**0**	**$0.00**
000017	Probe Build	950	30MAY14	18JAN18	50	$475,000.00
000018	Probe Test	350	19JAN18	23MAY19	50	$87,500.00
000019	**Science Packages**	**2000**	**02DEC11**	**01AUG19**	**0**	**$802,500.00**
000020	Design Science Packages	200	02DEC11	06SEP12	0	$20,000.00
000021	**Science Packages PDR**	**0**		**06SEP12**	**0**	**$0.00**
000022	Science Packages Final Design	450	07SEP12	29MAY14	0	$112,500.00
000023	**Science Packages CDR**	**0**		**29MAY14**	**0**	**$0.00**
000024	Science Packages Build	950	30MAY14	18JAN18	0	$570,000.00
000025	Science Packages Test	400	19JAN18	01AUG19	0	$100,000.00
000026	**Integration**	**510**	**02AUG19**	**15JUL21**	**0**	**$105,500.00**
000027	Integrate Probe and Science Packages	250	02AUG19	16JUL20	0	$62,500.00
000028	Integration Testing Probe/Science Pac...	200	17JUL20	22APR21	0	$40,000.00
000029	Probe/Science Packages Ship to Site	60	23APR21	15JUL21	0	$3,000.00
000030	**Launch Vehicle**	**460**	**02AUG19**	**06MAY21**	**50**	**$116,000.00**
000033	Launch Vehicle Build	400	02AUG19	11FEB21	50	$110,000.00
000035	Launch Vehicle Ship to Site	60	12FEB21	06MAY21	50	$6,000.00
000036	**Integrate Vehicle and Payload at S...**	**300**	**16JUL21**	**08SEP22**	**0**	**$82,500.00**
000037	Integrate Vehicle and Probe-Science	150	16JUL21	10FEB22	0	$45,000.00
000038	Test Integrated Vehicle-Payload	150	11FEB22	08SEP22	0	$37,500.00
TOTALS						$1,940,800.00



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Risk Analysis on Space Vehicle Project
Risk Factors are from Risk Register

			Schedule Impact Factors			Cost Impact Factors		
Risk #	Risk	Probability	Min	Most Likely	Max	Min	Most Likely	Max
1	Requirements have not been decided	80%	95%	110%	120%	95%	105%	110%
2	Several alternative designs considered	100%	80%	110%	130%	100%	110%	120%
3	New instruments not yet proven	60%	95%	110%	120%	95%	100%	110%
4	Fabricaton requires new materials	50%	100%	105%	115%			
5	Lost know-how since last new-concept probe	50%	95%	105%	120%	100%	110%	120%
6	Funding from Congress is problematic	70%	90%	105%	115%			
7	Schedule may be aggressive	100%	95%	110%	120%			
8	Cost estimate is based on immature data	100%				100%	110%	120%

Mapping Risks to Activities

		Assignment of Risks to Activities						
Risk #	Risk	Decision	Probe	Sciences	Integrate Probe/Science	Launch Vehicle	Integrate Vehicle/Payload	PMT
1	Requirements have not been decided	X						
2	Several alternative designs considered	X						
3	New instruments not yet proven			X	X			
4	Fabricaton requires new materials		X		X			
5	Lost know-how since last new-concept probe		X	X	X			
6	Funding from Congress is problematic		X	X	X		X	
7	Schedule may be aggressive		X	X	X	X	X	
8	Cost estimate is based on immature data	X	X	X	X	X	X	X

Schedule and Cost Targets are Unlikely to be Met

Summary Risk Results						
	Base	Prob Base	P-10	P 50	P-80	P-90
Schedule Date	8-Sep-22	< 1%	14-Jul-23	27-Aug-24	30-Jul-25	13-Jan-26
Overrun of Schedule days			309	719	1,056	1,223
Overrun of Schedule %			7%	16%	23%	26%
Cost ($ millions)	1,941	< 1%	2,280	2,577	2,841	2,992
Overrun of Cost $			339	636	900	1,051
Overrun of Cost %			17%	33%	46%	54%

A launch of September 2022 may be in July 2025 without risk mitigation. In light of these results aggressive risk mitigation should be done

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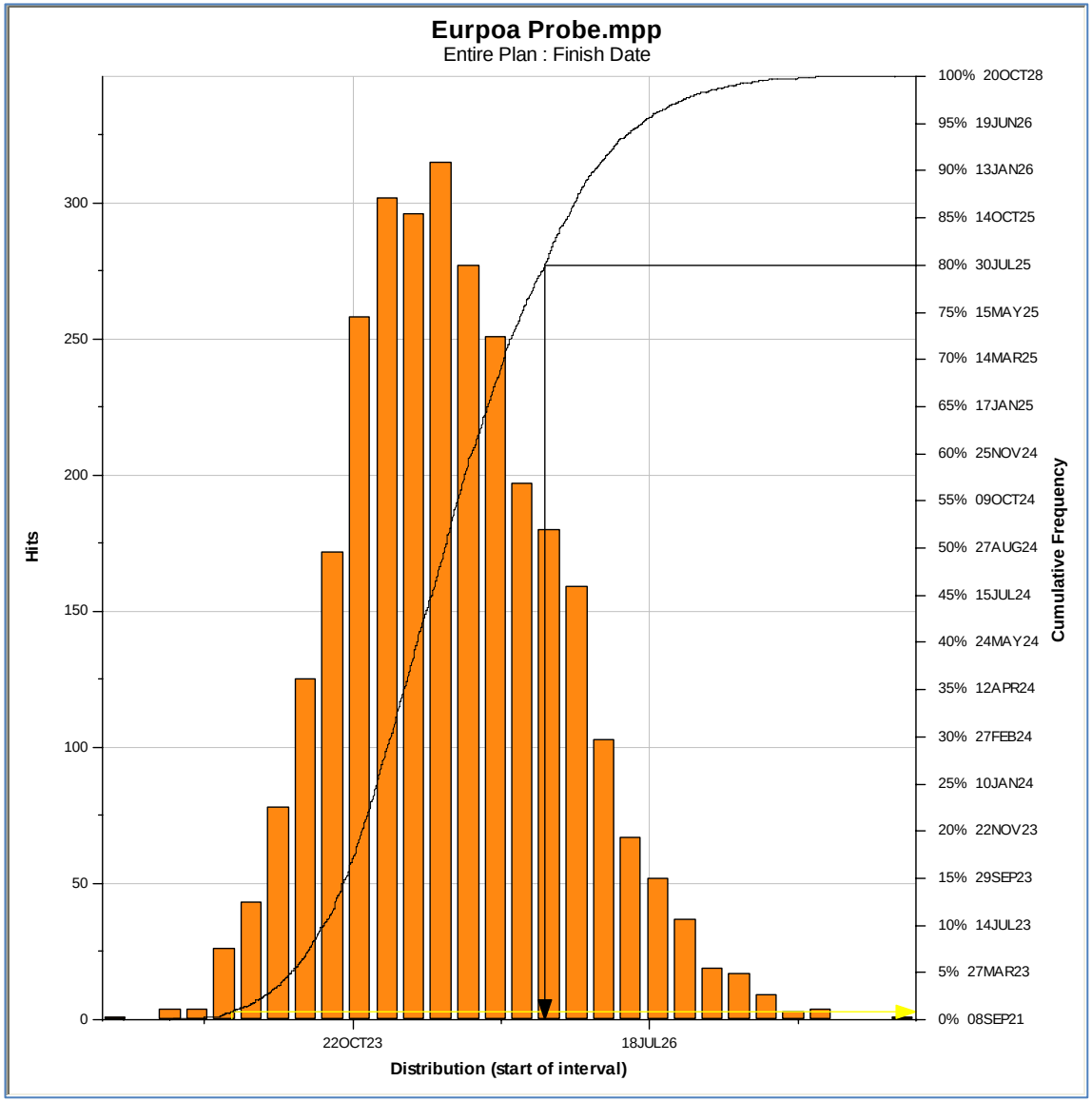
Examine the Probability of Meeting a 2022 Launch Date

Target Launch Date:
8 SEP 2022
P-80 30 JUL 2025



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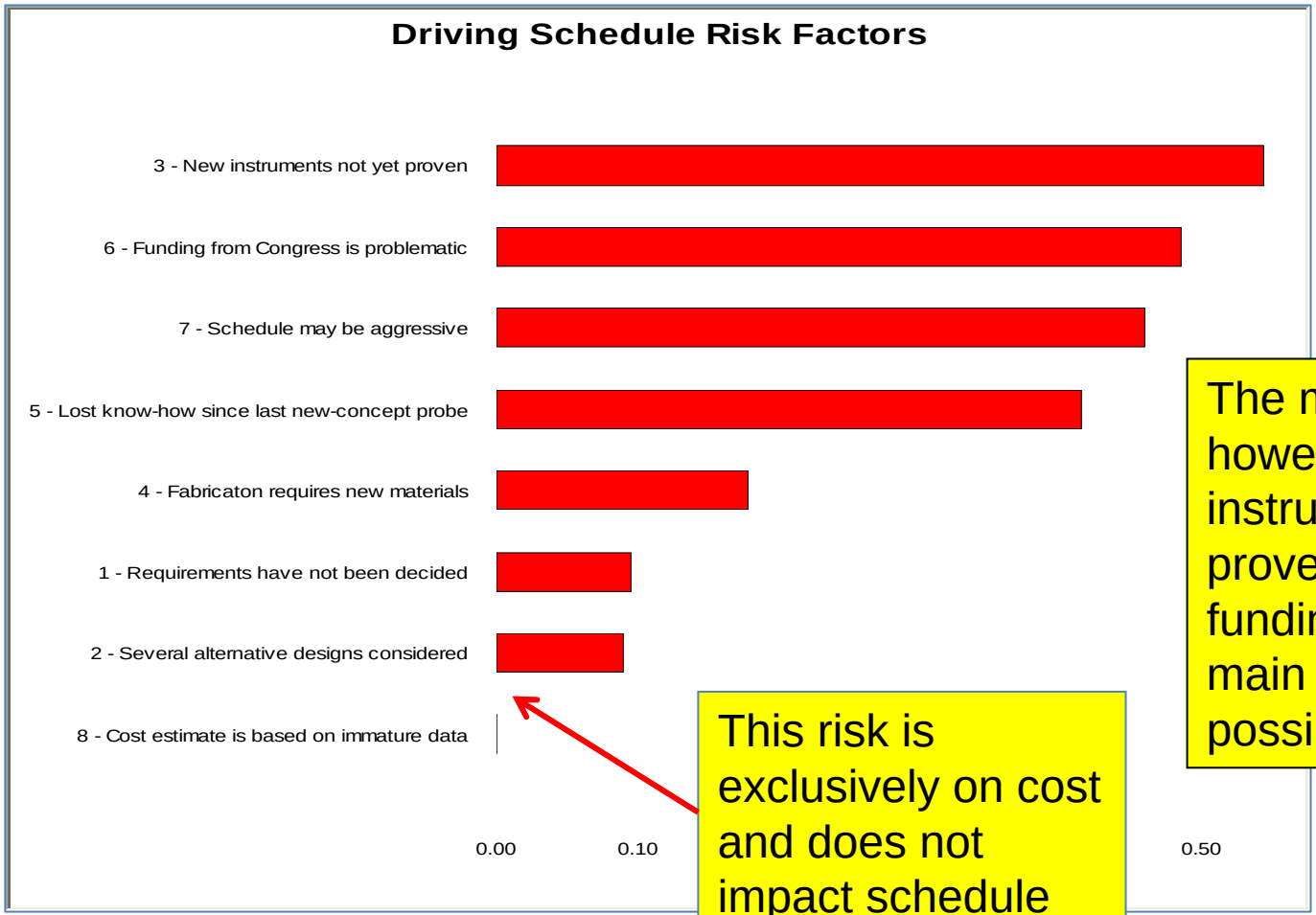
Risk Factor Tornado from All-In Simulation



The main RISK, however, is new instruments not yet proven, followed by funding. These are the main risks to mitigate, if possible

This risk is exclusively on cost and does not impact schedule

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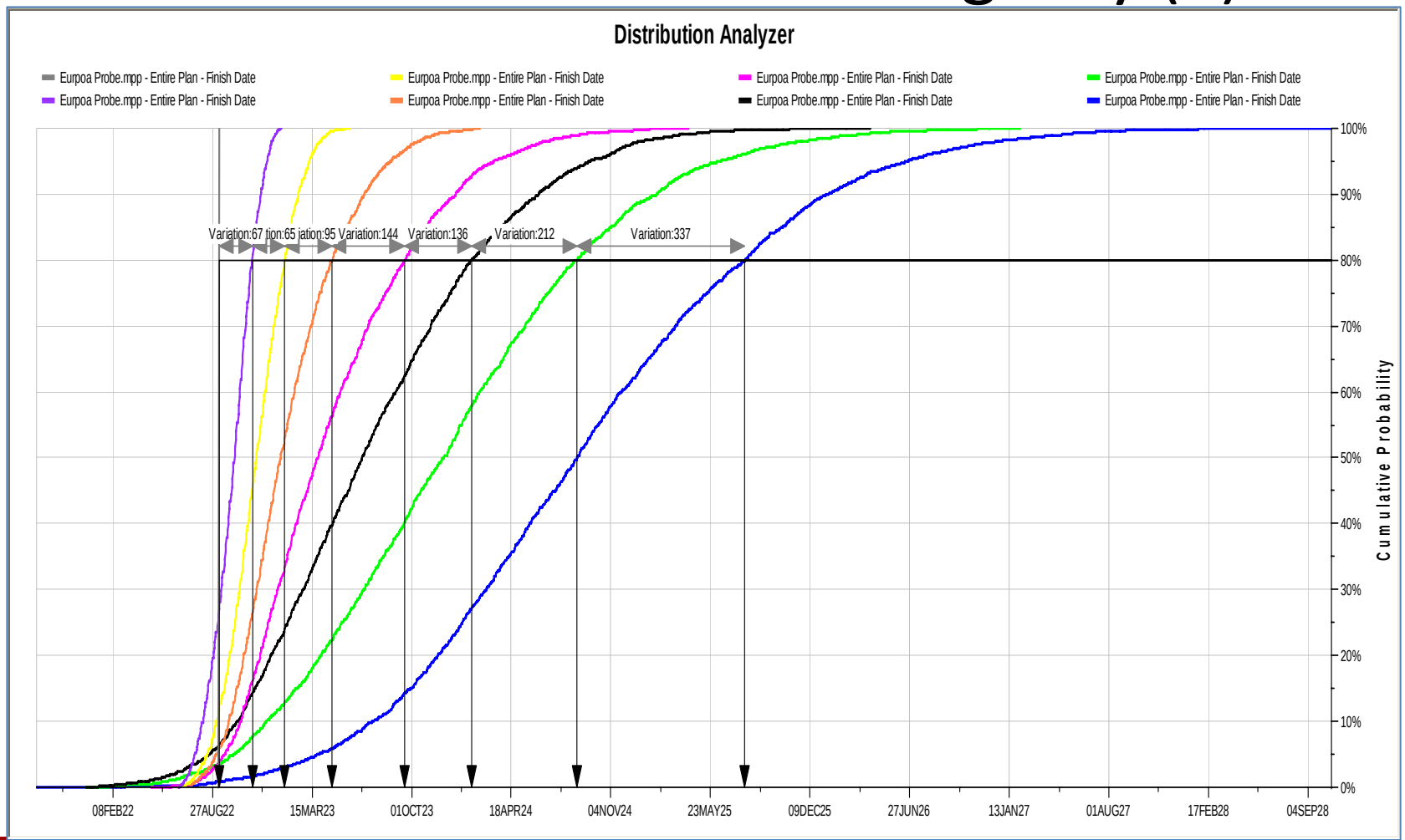
Contribution of Each Risk to the Time Contingency (1)

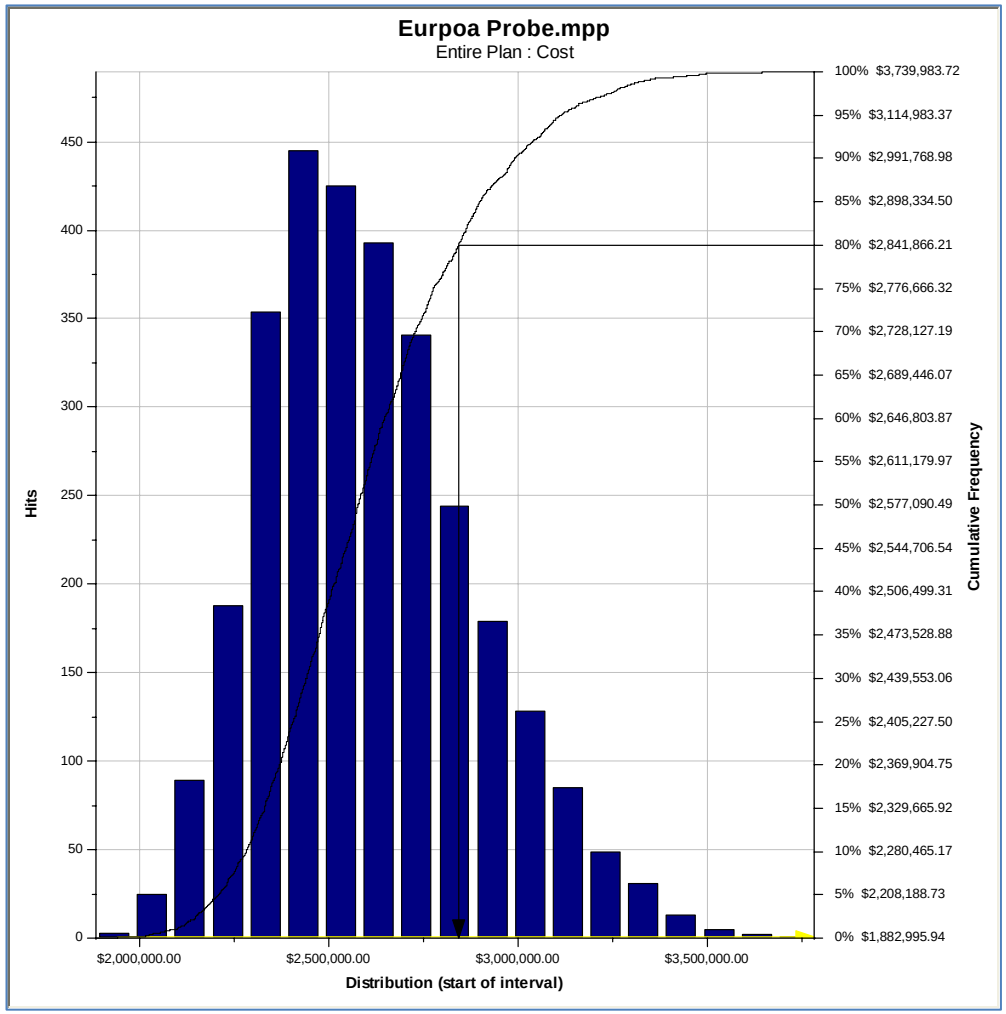
Explain the Contingency to the P-80 with Risks sorted by Priority			
	P-80 Date	Contribution of Risk	
All Risks In	30-Jul-25	Days Saved	% of Contingency
Specific Risks Taken Out in Order			
Schedule may be aggressive	27-Aug-24	337	32%
New instruments not yet proven	29-Jan-24	211	20%
Funding from Congress is problematic	15-Sep-23	136	13%
Lost know-how since last new-concept probe	24-Apr-23	144	14%
Fabricaton requires new materials	19-Jan-23	95	9%
Requirements have not been decided	23-Nov-22	57	5%
Several alternative designs considered	8-Sep-22	76	7%
Total Contingency		1,056	100%

Contribution of Each Risk to the Time Contingency (2)



With this Target Date, the Cost of Resulting Overruns Could be Substantial

Base cost = $1.9 billion
P-80 cost = $2.8 billion



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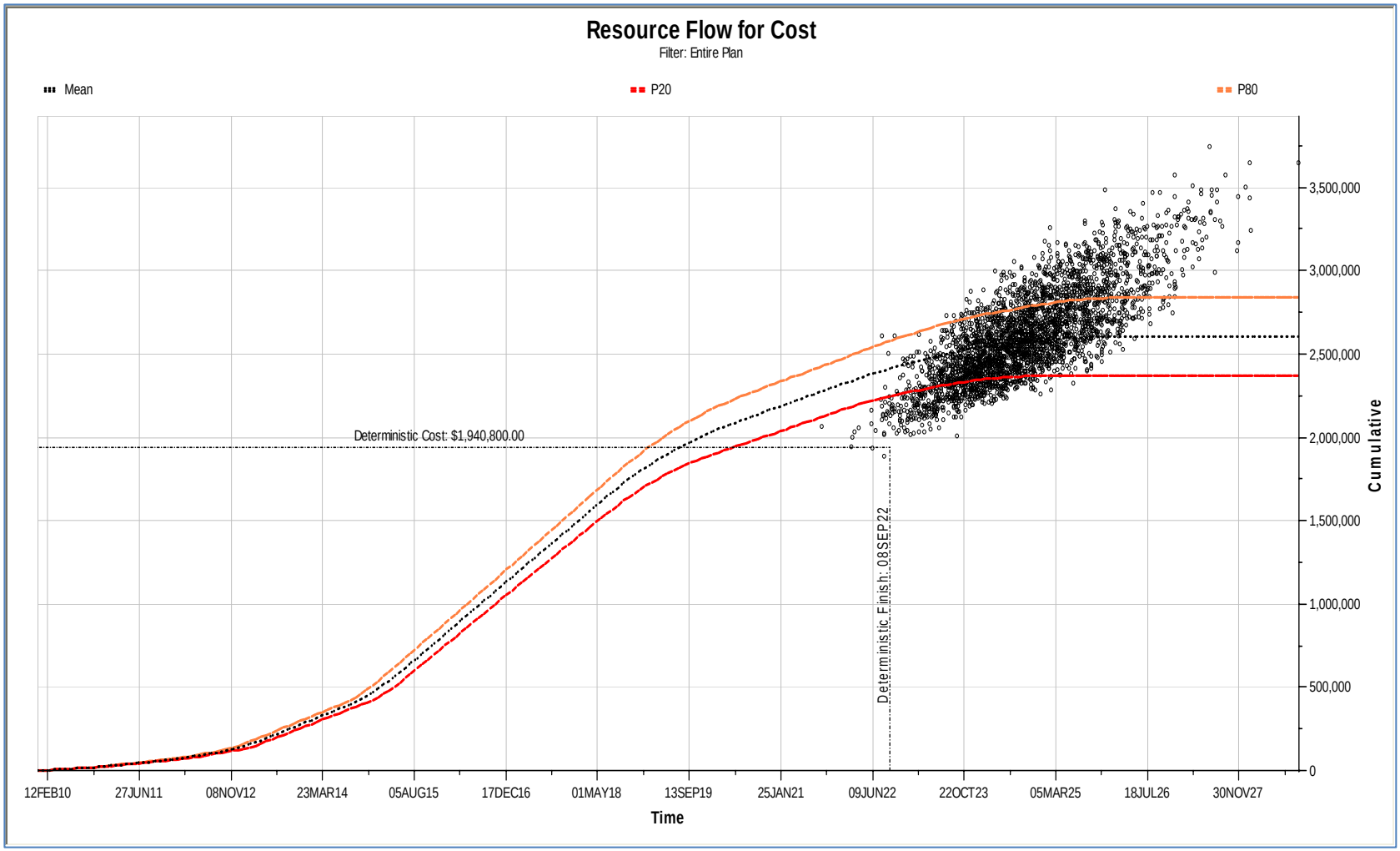
Contribution of Each Risk to the Cost Contingency

Effect of Risks on Cost Contingency to the P-80		
All risks In	2,841	
Risks	Contribution to contingency	% of Contingency
C - Cost estimate is based on immature data	271	29%
S/C - Lost know-how since last new-concept probe	240	26%
S - Schedule may be aggressive	190	21%
S/C -New instruments not yet proven	95	10%
S - Funding from Congress is problematic	74	8%
S - Fabrication requires new materials	38	4%
S/C - Several alternative designs considered	6	1%
S/C - Requirements have not been decided	5	1%

The Year-to-Year Budget Could be Compromised



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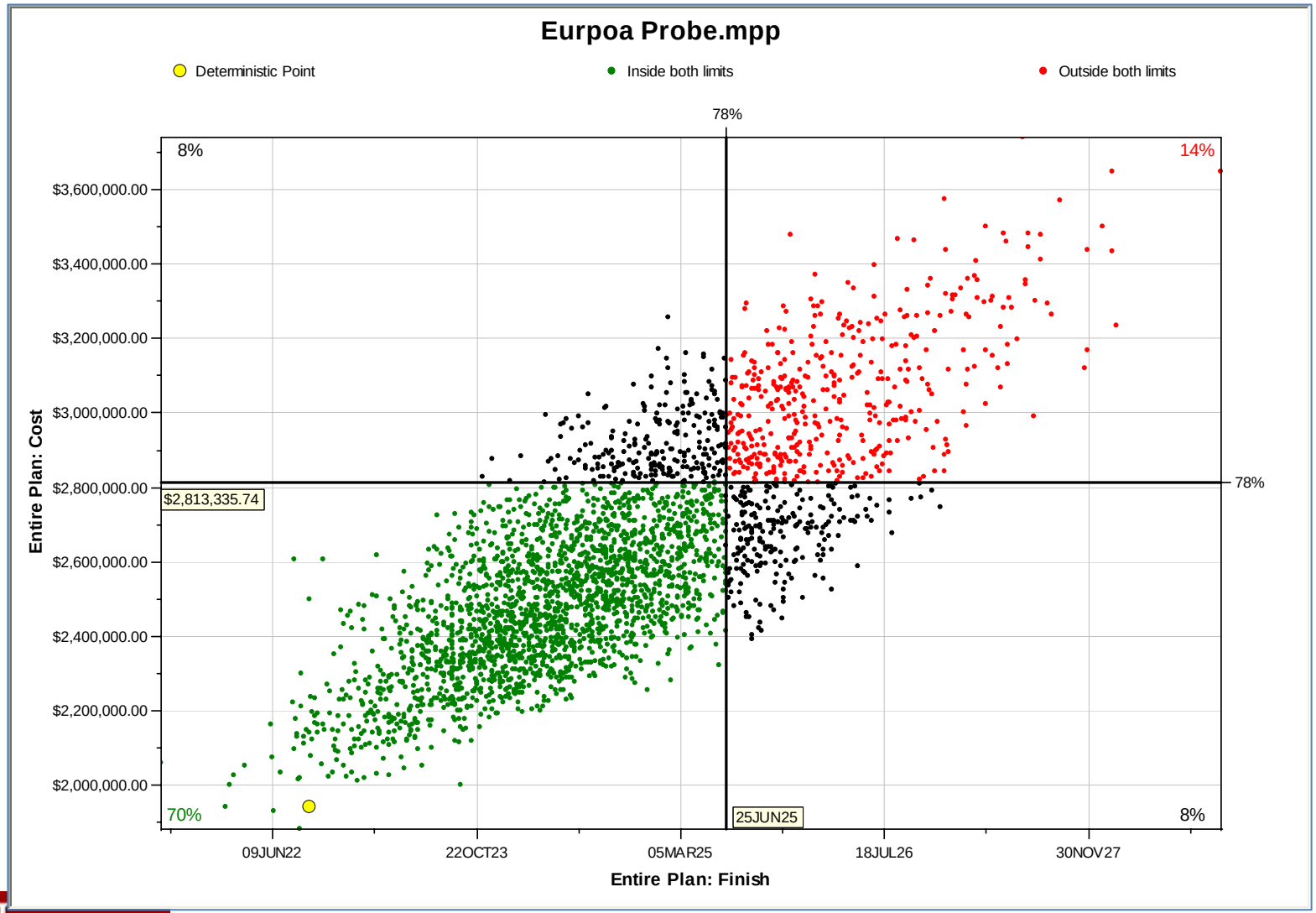
Scatter plot slope indicates that project delays will add to cost

Joint Confidence Level 70%



Analysis of a Risk Mitigation Scenario

Risk Mitigation Scenario									
		Schedule Risk Factors			Cost Risk Factors				
	%	Min	Most Likely	Max	Min	Most Likely	Max	Launch Date	Project Cost ($ million)
Risk to be Mitigated	Before Mitigation								
New Instruments Not Yet Proven	60%	95%	110%	120%	95%	100%	110%	30-Jul-25	2,841
Proposed Mitigation: Provide more testing of the instruments before integration at cost of $120 million									
	After Mitigation								
May have trouble interfacing Phases	**10%**	**95%**	**100%**	**105%**	**95%**	**100%**	**105%**	9-Dec-24	2,746
Improvement								233	95
Cost of proposed Mitigation									120
Net Improvement from Mitigation								**233**	**-25**

Spending $120 million for mitigation is assessed to reduce the probability of this risk from 60% to 10%. Because the *schedule slippage is 233 days less* than before, there is $95 million we do not need to reserve, paying for most of the $120 million cost of extra testing.

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

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