

# Use of the Risk Driver Method in Monte Carlo Simulation of a Project Schedule

Presented to the  
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& Training Workshop  
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# Risk Drivers Method Agenda

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- Risk Register identifies high-priority risks
- Explain “Risk Factors” approach
  - Risks have probability, impact
  - Risks are assigned to activities
- Compute Monte Carlo simulation results
- Estimate sensitivity and net effect of key risks
- Apply Risk Factors to simple space vehicle development schedule as an example
- Collecting risk data for the model
- How results are used to manage project risk



# Limitations with the Traditional 3-point Estimate of Activity Duration

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- Typical schedule risk analysis starts with the activity that is impacted by risks
  - Estimates the 3-point estimate for optimistic, most likely and pessimistic duration
  - Creates a probability distribution for activity duration
  - Performs Monte Carlo simulation
- Which risks cause the most overall schedule risk? These questions are typically answered by:
  - Sensitivity to activity durations
  - Criticality of activity durations



# Some Problems with Traditional Approach

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- Can tell which activities are crucial, but not directly which risks are driving
- Makes poor use of the Risk Register that is usually available
- Cannot decompose the overall schedule risk into its components BY RISK
  - Ability to assign the risk to its specific risk drivers helps with communication of risk causes and risk mitigation



# We Propose a Different Approach: Start with the Risks Themselves

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- Drive the schedule risk by the risks already analyzed in the Risk Register
- For each risk, specify:
  - Probability it will occur
  - Impact on time if it does
  - Activities it will affect
- Starting with the risks themselves gives us benefits
  - Links qualitative analysis to the quantitative analysis
  - Estimates the impact of specific risks for prioritized mitigation purposes
  - Correlations between activities happen automatically – never have to guess at these coefficients again, never get impossible matrices



# Simple Example of Risk Register Risks

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	Description	Optimistic	Most Likely	Pessimistic	Likelihood
1.	Technology may be more Difficult than Planned	100.00%	110.00%	130.00%	100.00%
2.	Technical Labor Productivity may Vary	90.00%	100.00%	115.00%	50.00%
3.	Construction Labor Productivity may Vary	90.00%	100.00%	115.00%	100.00%

- Use the Risk Factors feature in Pertmaster 8
- Collect probability and impact data on risks
- Load the risks
- Assign risks to schedule activities



# Risk Factors Mechanics (1)

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- The risk factor is assigned to one or several activities, affecting their durations by a multiplicative factor
  - E.g., the factor may be .90 for optimistic, 1.0 for most likely and 1.25 for pessimistic
  - These factors multiply the schedule durations of the activities to which they are assigned
- Risks can be assigned to one or more activities
- Activity durations can be influenced by one or more risks



# Risk Factors Mechanics (2)

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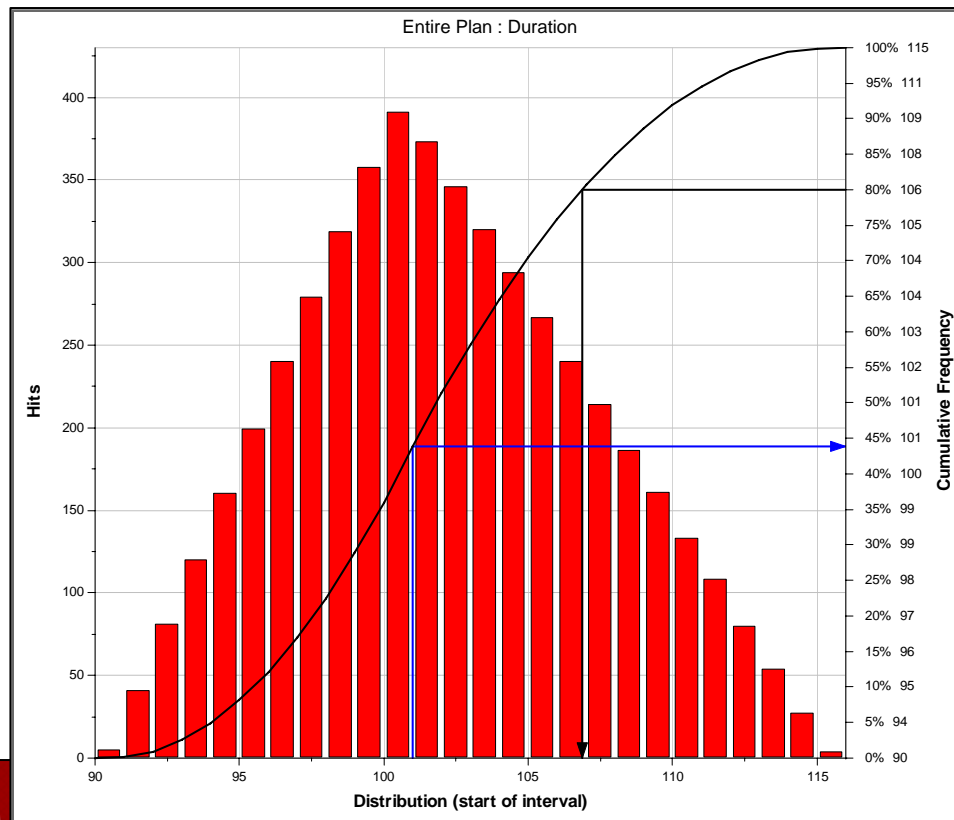
- Risk Factors are assigned a probability of occurring on any iteration.
  - When the risk occurs, the factor used is chosen at random from the 3-point estimate and operates on all activities to which it is assigned
  - When not occurring on an iteration the risk factor takes the value 1.0, a neutral value
- When an activity is influenced by more than one risk, their factors are multiplied together, if they happen, on any iteration



# Risk Factor Probability is 100%, Factor can be + or -

	Description	Optimistic	Most Likely	Pessimistic	Likelihood
1.	Construction Labor Productivity May Vary	90%	100%	115%	100%

Here the Ranges are based on deviations + and - from the Plan. Probability is 100%



For the examples we use an activity with 100 days in the schedule

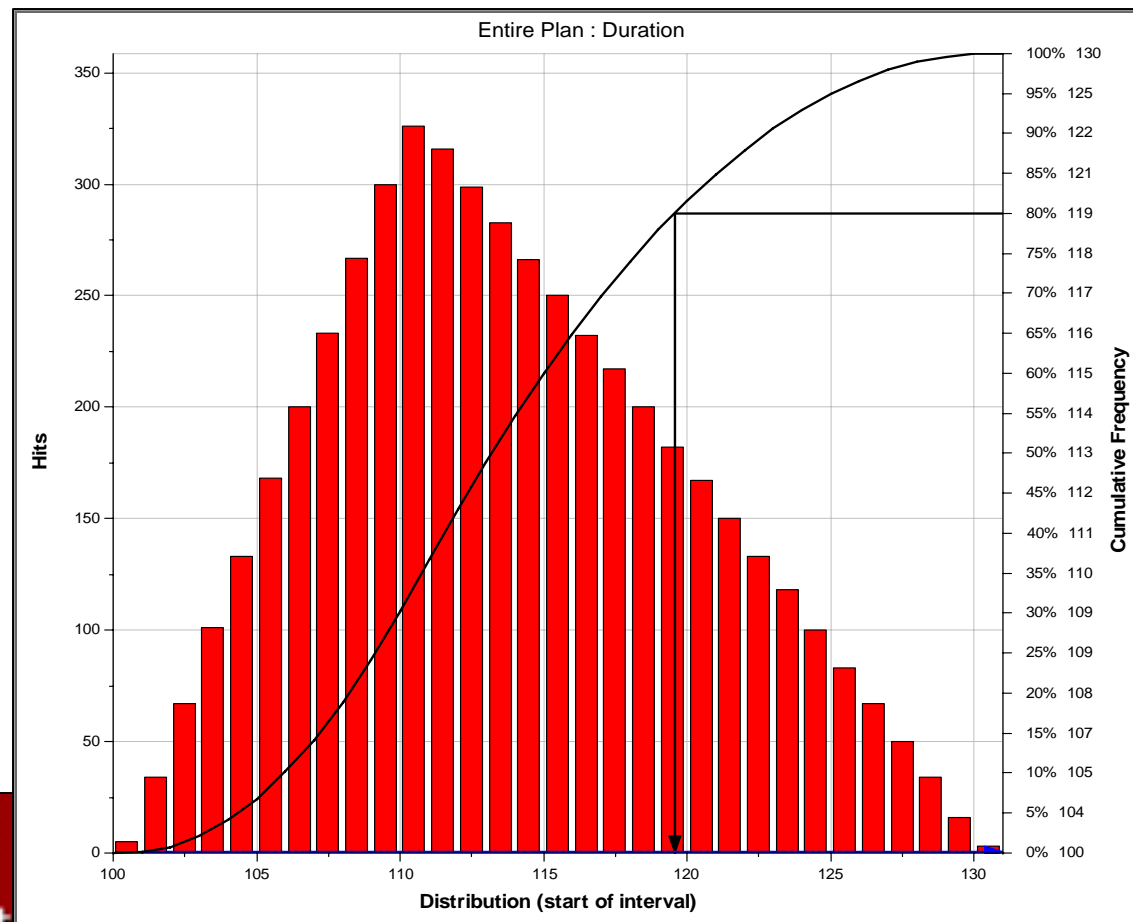


# Risk Factor

## Prob. = 100%, Factor is all Overrun

	Description	Optimistic	Most Likely	Pessimistic	Likelihood
1.	Technology may be More Difficult than Planned	100.00%	110.00%	130.00%	100.00%

Here the Plan is the Optimistic Value. Probability is 100%



# Assigning a Probability Less than 100%

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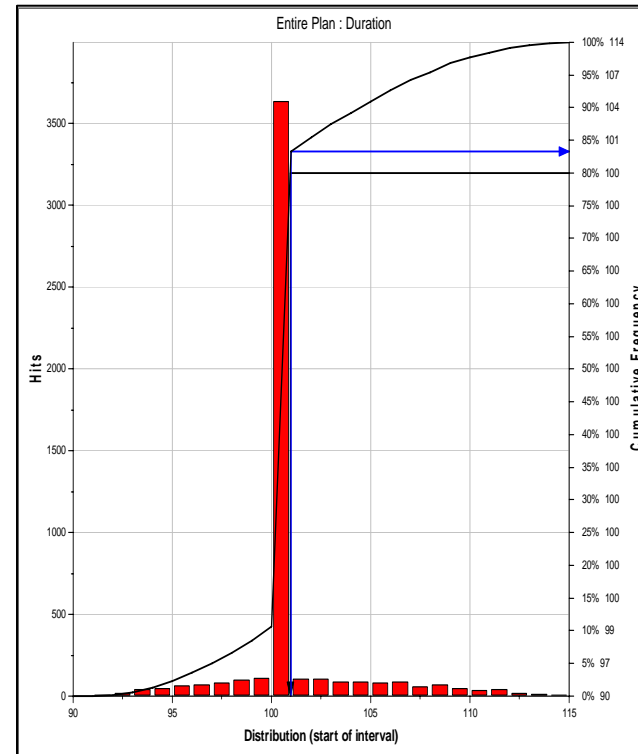
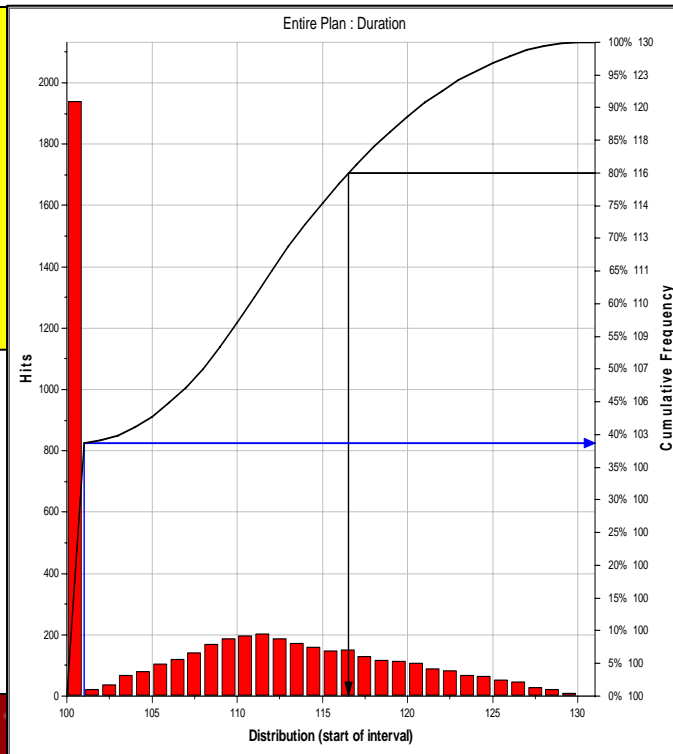
- The essence of a “risk” is its uncertainty in two dimensions:
  - Uncertainty of its occurrence, specified by a probability
  - Uncertainty of its impact, specified by a range of durations
- If the risk may or may not occur, we specify the probability that it will occur
  - The risk occurs and affects the activities it is assigned to on X% of the iterations, chosen at random, the multiplicative factor used is chosen at random from the range of data input by the user
  - On (1 – X)% of the iterations, Factor takes 1.0 value



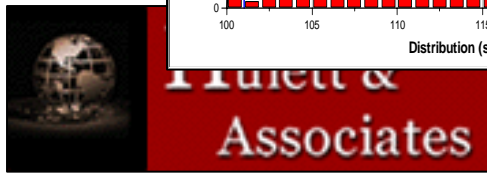
# Assigning a Probability Less than 100%

	Description	Optimistic	Most Likely	Pessimistic	Likelihood
1.	Technology may be more Difficult than Planned	100.00%	110.00%	130.00%	60.00%
2.	Construction Labor Productivity May Vary	90.00%	100.00%	115.00%	30.00%

Spike contains 40% of the probability



Spike contains 70% of the probability



# Assigning More than One Risk to an Activity

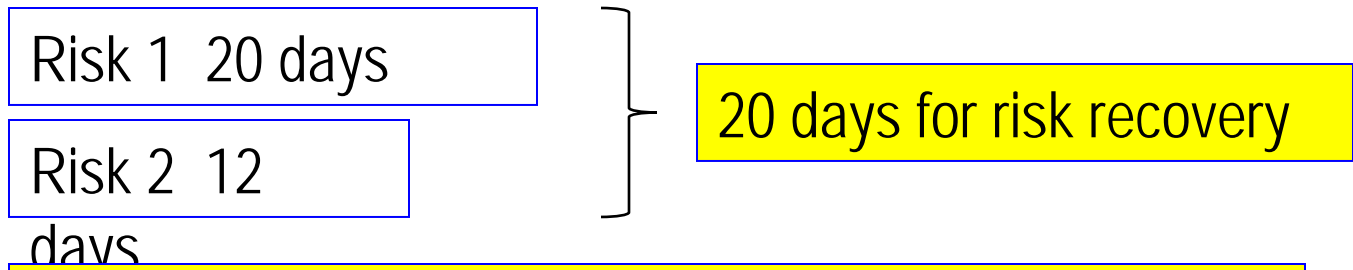
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- If more than one risk is acting on an activity, the resulting ranges are the multiplication of the percentages
- This is reality – an activity is often affected by multiple risks
- Two cases are shown next:
  - When both risks are 100% likely to occur
  - When both risks are < 100% likely to occur
- In each case, the computer simulation creates the uncertainty range on an activity's duration – it is not estimated

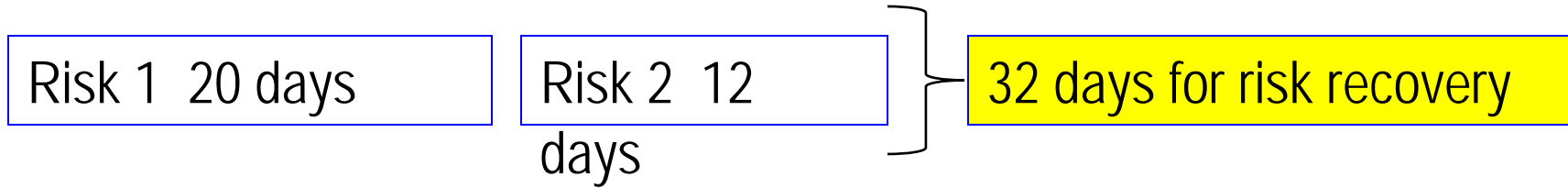


# Parallel and Series Risks – Additive – used with Risk Register

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If these two risks are parallel, they can be recovered simultaneously



If these two risks are series, they can not be recovered simultaneously so the duration is longer



# Parallel and Series Risks – Multiplicative – Used with Risk Drivers (RiskFactors)

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Risk 1 1.2 factor

Risk 2 1.05 factor

Use 1.2 Factor, the largest factor only

If these two risks are parallel, they can be recovered simultaneously

Risk 1 1.2 factor

Risk 2 1.05 factor

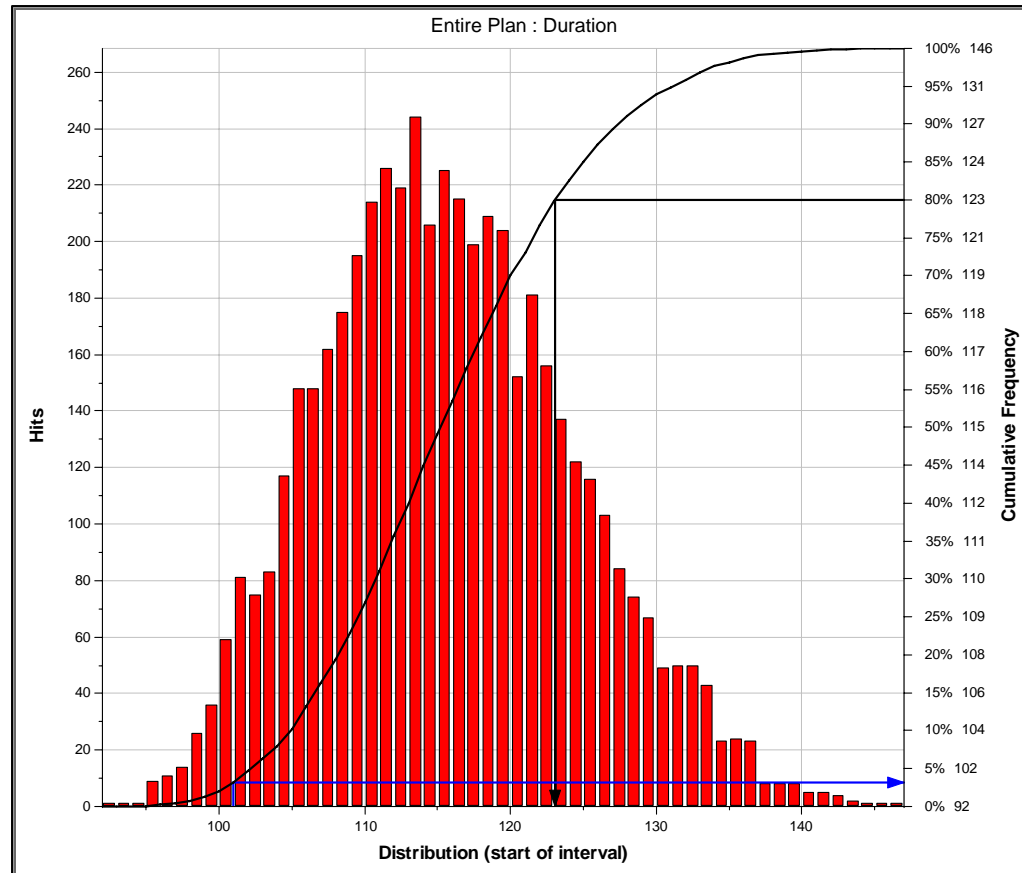
Use  $(1.2 \times 1.05 = 1.26)$  Factor, multiply the two

If these two risks are series, they can not be recovered simultaneously

# Two Risks affect One Activity using Factors that Occur 100% - placed in Series

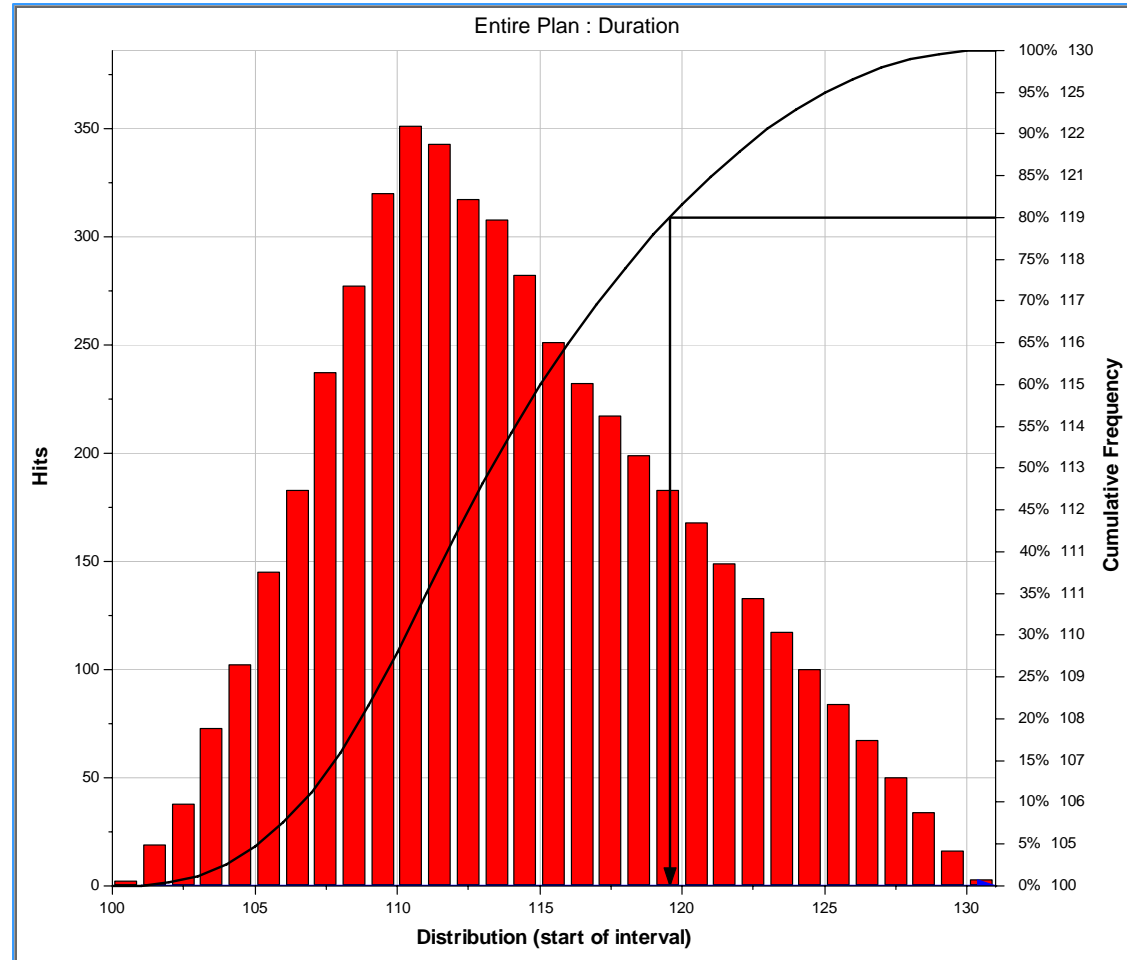
	Description	Optimistic	Most Likely	Pessimistic	Likelihood
1.	Technology may be more Difficult than Planned	100%	110%	130%	100%
2.	Technical Labor Productivity May Vary	90%	100%	115%	100%

Risks in series, P80 is 123 days



# Two Risks affect One Activity using Factors that Occur 100% - in Parallel

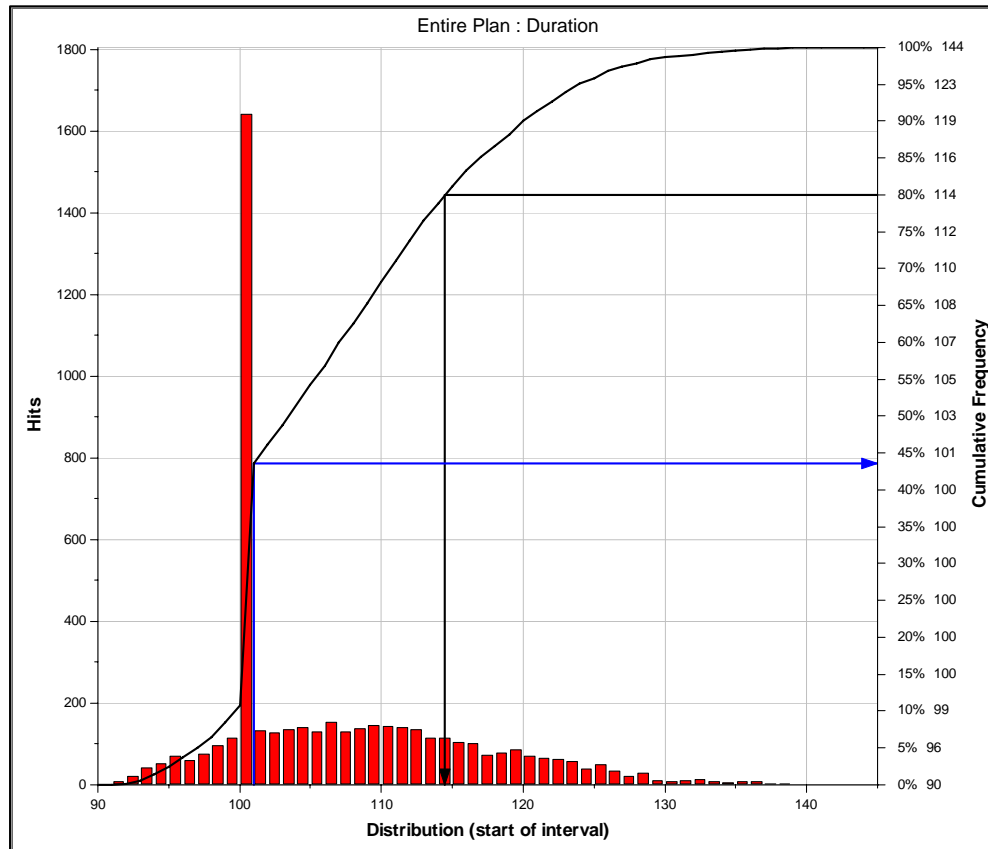
Risks in parallel, P80 is 119 days



# Two Risks with Less than 100% Probability Affecting one Activity – Risks in Series

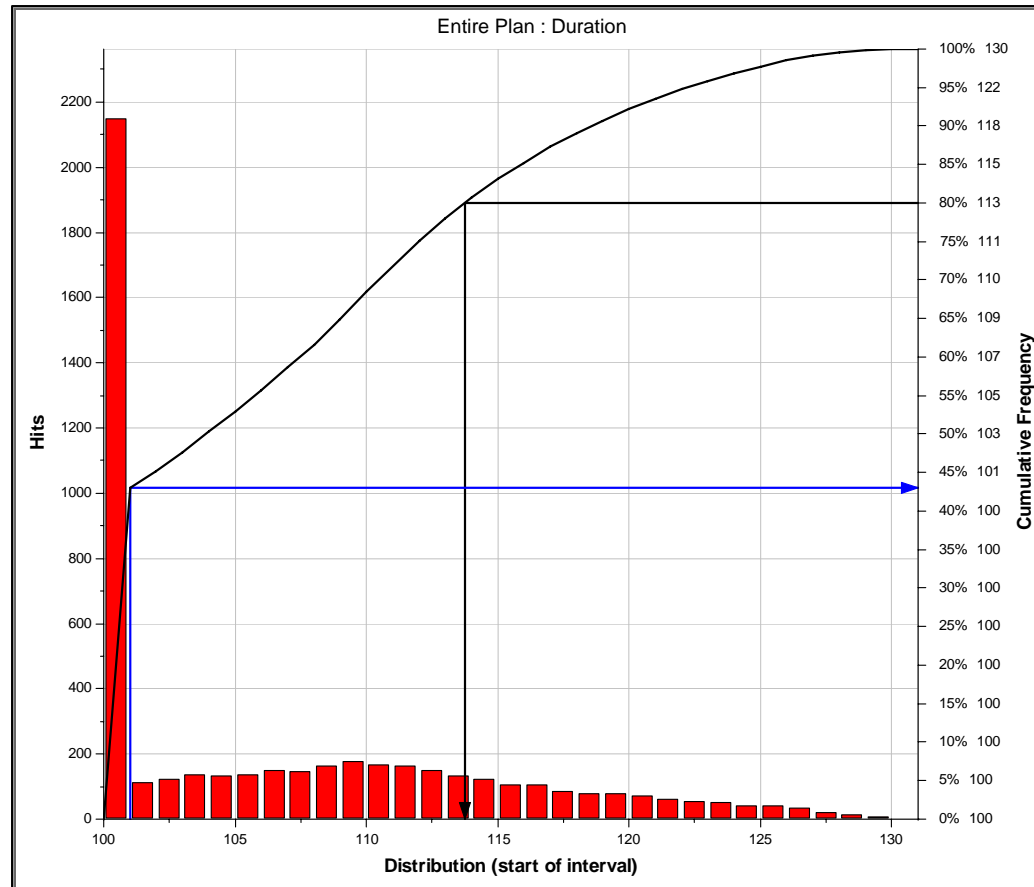
	Description	Optimistic	Most Likely	Pessimistic	Likelihood
1.	Technology may be more Difficult than Planned	100.00%	110.00%	130.00%	40.00%
2.	Technical Labor Productivity May Vary	90.00%	100.00%	115.00%	50.00%

The spike at 100 days represents (1) the likelihood that neither risk occurs [60% x 50% = 30%] and (2) the chance that 100 days is picked when one or both occur.



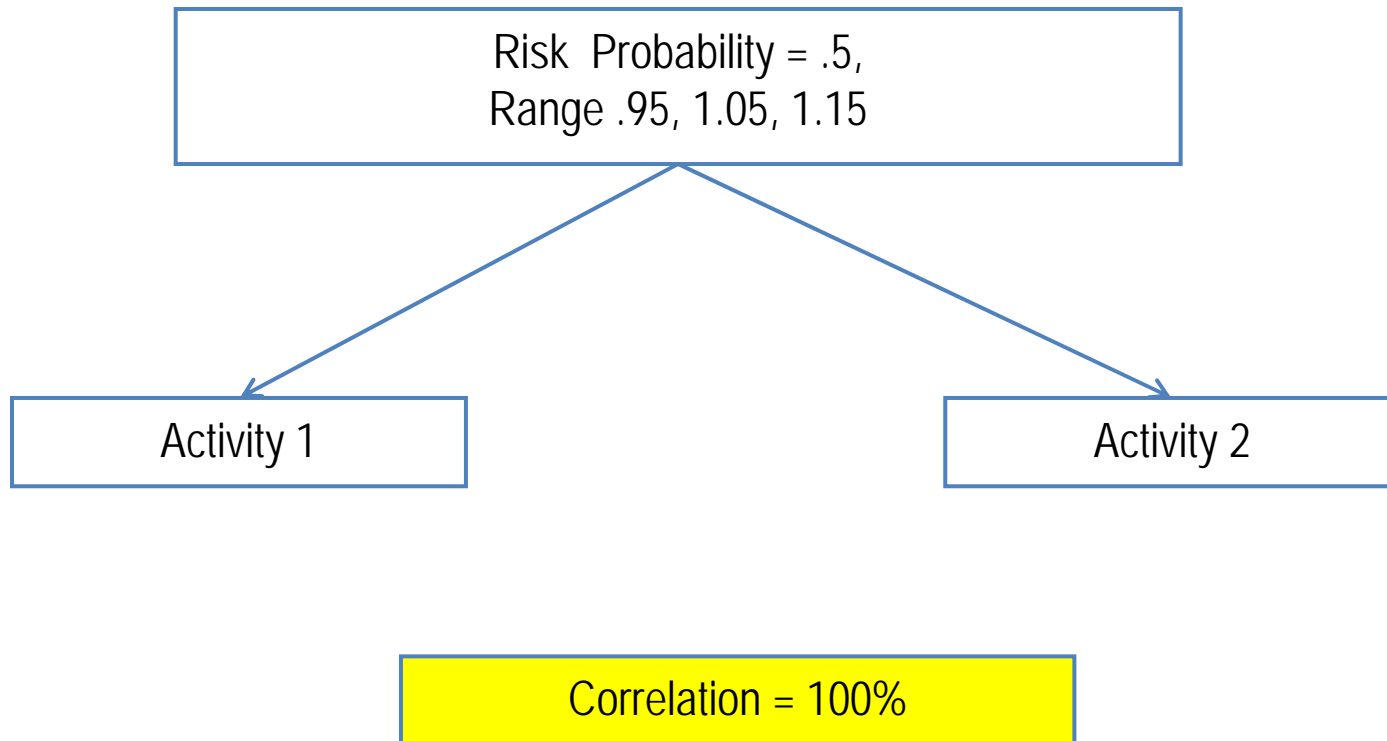
# Two Risks with Less than 100% Probability Affecting one Activity – Risks in Parallel

With one risk's having a minimum range of 100%, it cannot be less than 100 days

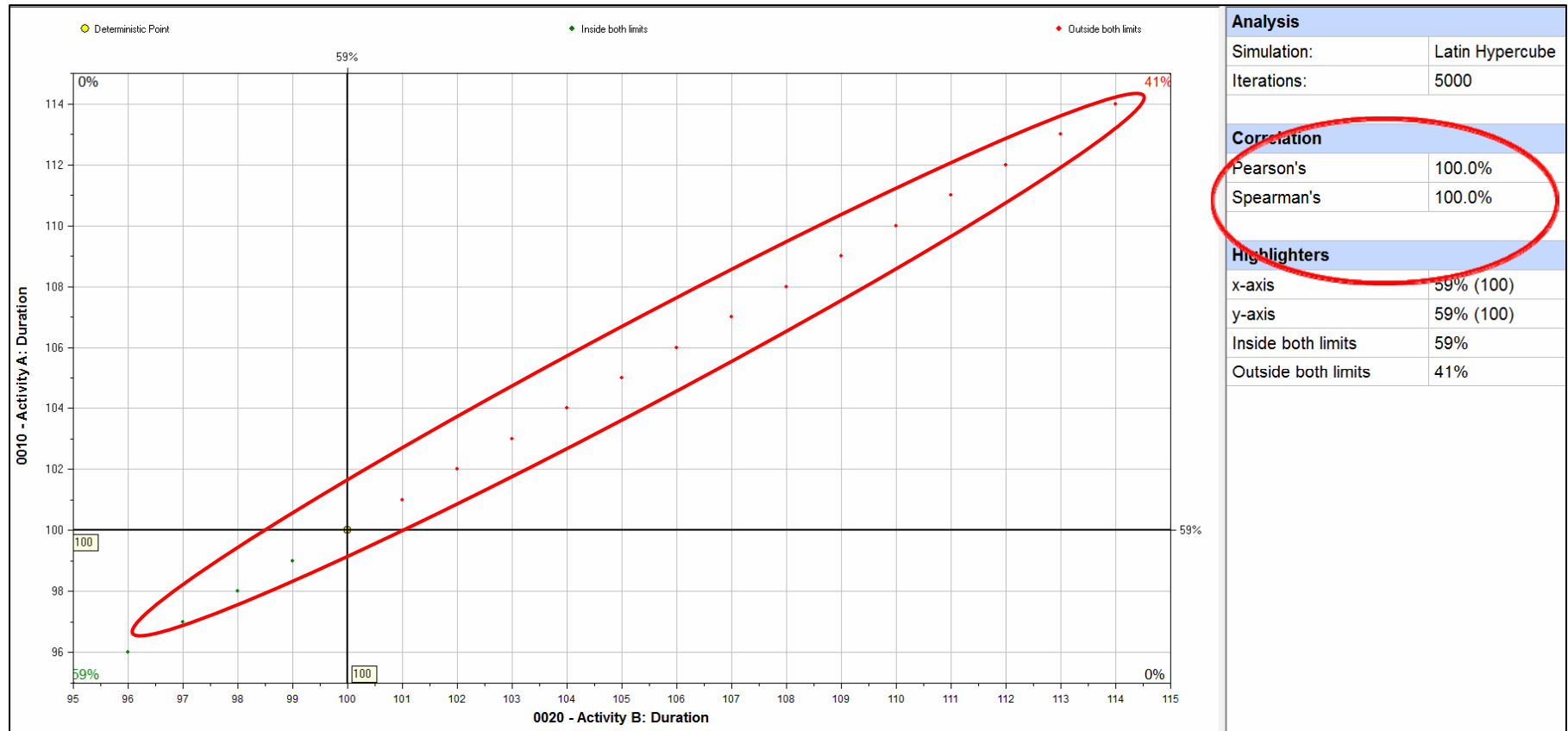


# Risk Factors Model How Correlation Occurs Coefficients are Calculated (1)

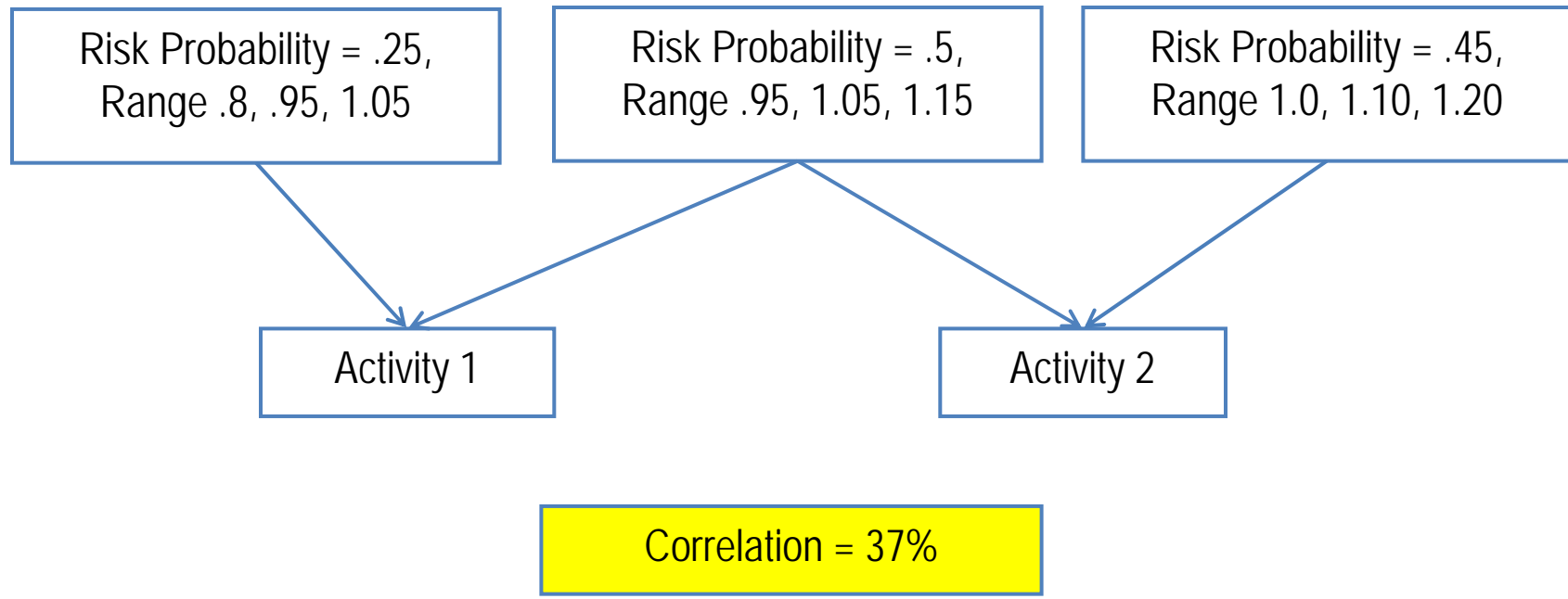
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# Scatter showing 100% Correlation

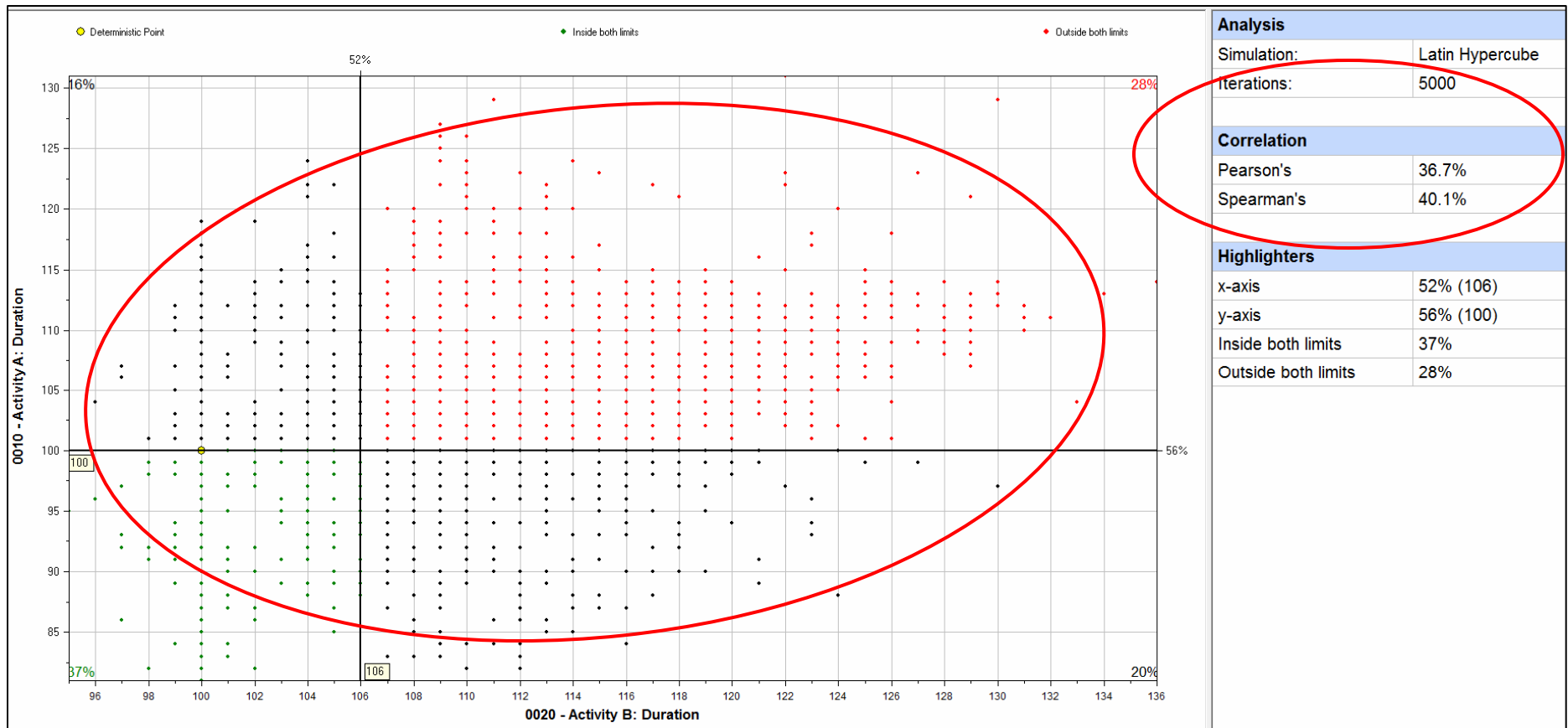


# Risk Factors Model How Correlation Occurs Coefficients are Calculated (2)

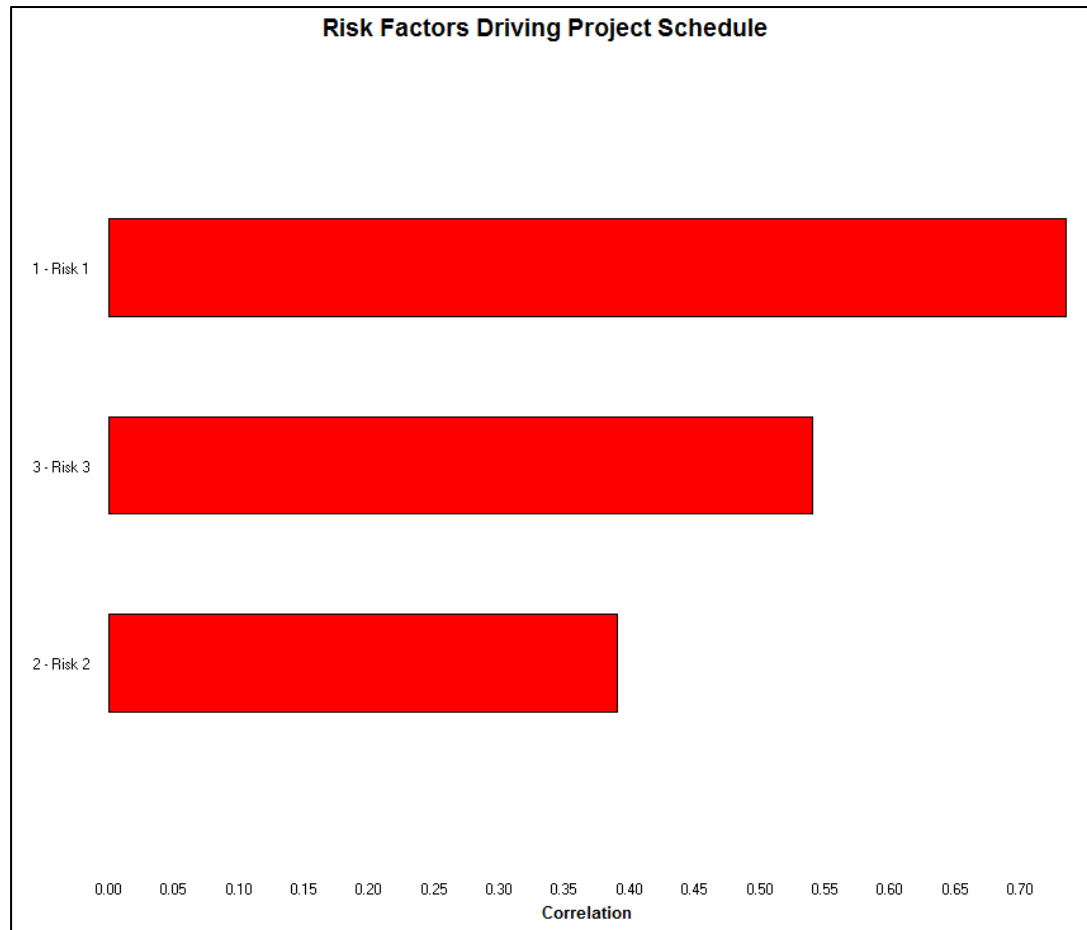


Correlation is modeled as it is caused in the project  
Correlation coefficients are generated, not guessed

# Scatter showing 37% Correlation



# Sensitivity to the Risk Factors



Risk 1 is more important since it affects both Activity A and Activity B

United States Government Accountability Office  
Applied Research and Methods

**GAO**

Work package:  
Install first floor joists

- 1. Install first floor joists and blocking
- 2. Install ceiling joists and blocking
- 3. Install ceiling joists and blocking
- 4. Install ceiling joists and blocking
- 5. Install ceiling joists and blocking
- 6. Install ceiling joists and blocking
- 7. Install ceiling joists and blocking
- 8. Install ceiling joists and blocking
- 9. Install ceiling joists and blocking
- 10. Install ceiling joists and blocking

DURATION

- 20 days
- 10 days
- 8 days
- 6 days
- 5 days
- 4 days
- 3 days
- 2 days
- 1 day

finish

start

Planning

- Program 1 day
- Project 2 days
- Phase 3 days
- Task 4 days
- Phase 5 days
- Task 6 days
- Phase 7 days
- Task 8 days
- Phase 9 days
- Task 10 days

Scheduling

Task Name	Start	End
Task 1	1/1/12	1/15/12
Task 2	1/15/12	1/30/12
Task 3	1/30/12	2/15/12
Task 4	2/15/12	2/30/12
Task 5	2/30/12	3/15/12
Task 6	3/15/12	3/30/12
Task 7	3/30/12	4/15/12
Task 8	4/15/12	4/30/12
Task 9	4/30/12	5/15/12
Task 10	5/15/12	5/30/12

**GAO Schedule Assessment Guide**

Best Practices for project schedules

"From May 30, 2012 - April 30, 2013, GAO is seeking input and feedback on this Exposure Draft from all interested parties. See page 2 for more information."

May 2012  
GAO-12-120G



<http://www.gao.gov/products/GAO-12-120G>

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# Schedule Check Report in Pertmaster

ORACLE <sup>®</sup>		Schedule Check Report	
PRIMAVERA RISK ANALYSIS			
<b>Plan Summary</b>			
Title	Offshore Gas Production Project		
File name	C:\Documents and Settings\David Hulett\My Documents\PERTMASTER Course\Pertmaster Cases\Offshore Gas Production Project.plan		
Plan finish date	20 Mar 15	Tasks with no progress	27
Plan remaining duration	1540	In progress tasks	0
Normal tasks	15	Completed tasks	0
Summary tasks	9	Total tasks	27
Milestone tasks	3	Resource assignments	0
Hammock tasks	0	Budget cost	\$0.00
Monitor tasks	0	Remaining cost	\$0.00
Calendars	4	Actual cost	\$0.00
Links	28	Total cost	\$0.00
Resources	6		
<b>Report Summary</b>			
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	3		
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	0		
Total number of items found	6		



# Using Acumen FUSE for Best Practices

The screenshot displays the Acumen FUSE software interface. The main window shows a project named 'USCP VHF Radio Program' with a snapshot date of 6/22/2009. The interface includes a ribbon menu at the top with various tool categories like Projects, Dashboard, Analysis, Logic, Forensics, Metrics, Scripts, and Fields. A central area shows a Gantt chart with task bars in green, blue, and red. To the right, a 'Ribbon Analyzer' table provides a summary of project metrics.

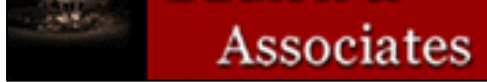
Critical	Insuffici ent D...	Merge Hotsp...	Missing Prede...	Open Start	Missing Succes...	Open Finish	Lags	Constra int	More than...	Wrong Status	Score
15 (2%)	115 (12%)	195 (16%)	1 (0%)	16 (1%)	4 (0%)	16 (1%)	73 (6%)	11 (1%)	573 (83%)	7 (1%)	50%

Below the ribbon analyzer, a 'Phase Analyzer' table lists various project metrics:

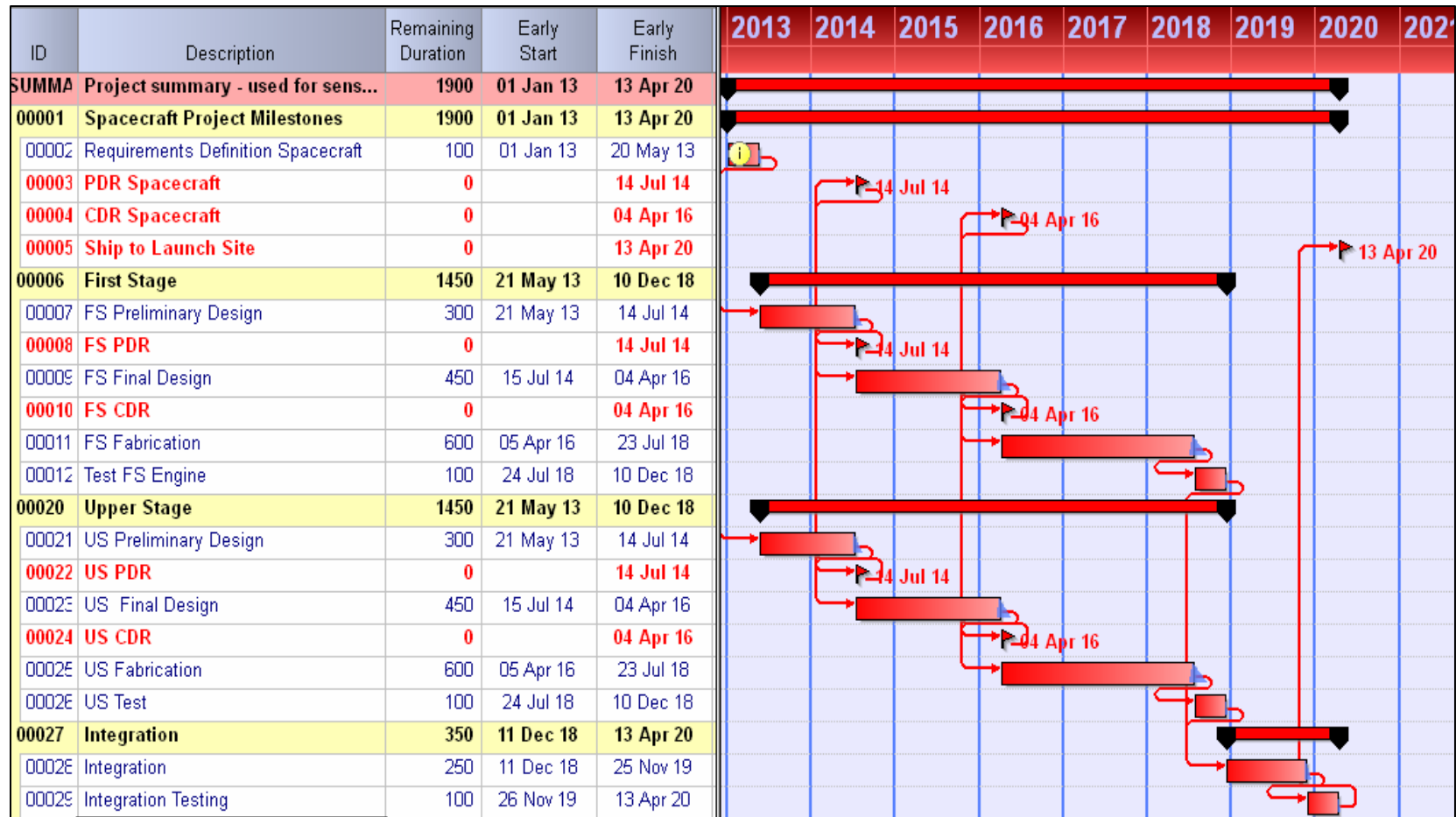
Metric	Count	Percentage
Critical	15	2%
Number of Lags	133	11%
Number of Leads	12	1%
Merge Hotspot	193	16%
Missing Predece...	1	0%
Open Start	16	1%
Missing Successo...	3	0%
Open Finish	16	1%
Lags	73	6%
...	11	1%
...	573	83%
...	7	1%
...	115	12%

At the bottom right, an 'Open Start in Project' table lists specific tasks:

#	ID	Description	Project
1	987	Capitol Visitors Center (CVC): Fiber Optic Termin...	USCP VHF Radio Program IMS_2012-07-31
2	988	Capitol Visitors Center (CVC): Fiber Optic Testing	USCP VHF Radio Program IMS_2012-07-31
3	582	LOC Jefferson Fiber Optic Termination	USCP VHF Radio Program IMS_2012-07-31
4	733	LOC Madison: Fiber Optic Termination	USCP VHF Radio Program IMS_2012-07-31
5	407	Russell SOB: Fiber Optic Termination	USCP VHF Radio Program IMS_2012-07-31
6	583	LOC Jefferson Fiber Optic Testing	USCP VHF Radio Program IMS_2012-07-31
7	408	Russell SOB: Fiber Optic Testing	USCP VHF Radio Program IMS_2012-07-31
8	956	US Capitol: Fiber Optic Termination	USCP VHF Radio Program IMS_2012-07-31
9	957	US Capitol: Fiber Optic Testing	USCP VHF Radio Program IMS_2012-07-31
10	1299	NAWCAD/STI: As-Built Documentation Effort	USCP VHF Radio Program IMS_2012-07-31



# Simple 2-Stage Space Vehicle Schedule



Software used: Pertmaster v. 8.7

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# Two Types of Risk

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- Inherent variability including duration estimating error – uncertainty – Probability = 100%
  - Used Quick Risk of -5% and +10%, could be reference ranges for different types of activities
  - Could use reference ranges that would differ by type of activity
- Discrete risks derived from Risk Register – Probability < 100%
  - Summarized from detailed Risk Register
  - These have a probability of occurring and an impact on specific activities if they do
  - Parallel to their Risk Register information



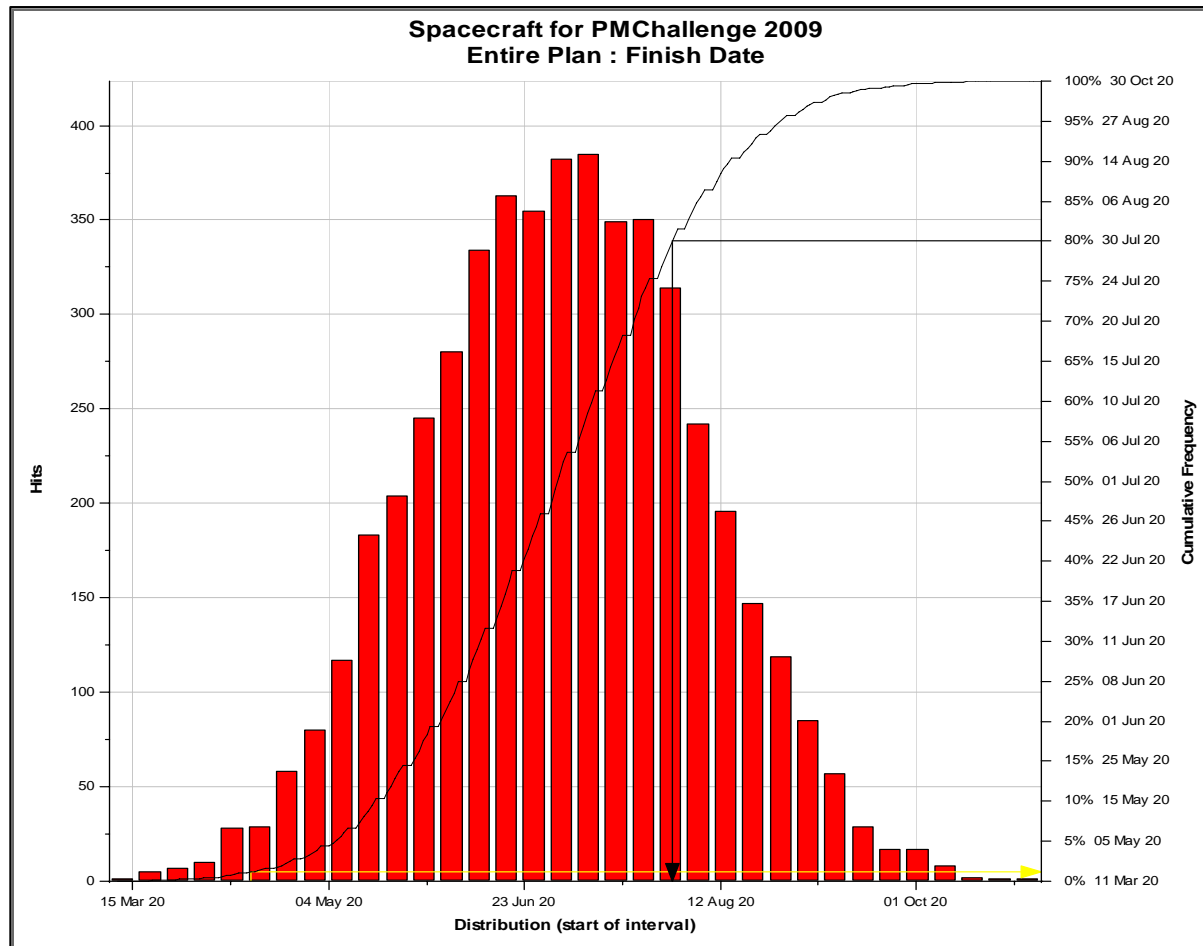
# Standard 3-point Range Representing Inherent Variability and Duration Estimating Error

ID	Description	Remaining Duration	Early Start	Early Finish	2013	2014	2015	2016	2017	2018	2019	2020	2021	Minimum Duration	Most Likely	Maximum Duration	
SUMMA	Project summary - used for sens...	1900	01 Jan 13	13 Apr 20	[Gantt bar]												
00001	Spacecraft Project Milestones	1900	01 Jan 13	13 Apr 20	[Gantt bar]												
00002	Requirements Definition Spacecraft	100	01 Jan 13	20 May 13	0									95	100	110	
00003	PDR Spacecraft	0		14 Jul 14													
00004	CDR Spacecraft	0		04 Apr 16													
00005	Ship to Launch Site	0		13 Apr 20													
00006	First Stage	1450	21 May 13	10 Dec 18	[Gantt bar]												
00007	FS Preliminary Design	300	21 May 13	14 Jul 14										285	300	330	
00008	FS PDR	0		14 Jul 14													
00009	FS Final Design	450	15 Jul 14	04 Apr 16										428	450	495	
00010	FS CDR	0		04 Apr 16													
00011	FS Fabrication	600	05 Apr 16	23 Jul 18										570	600	660	
00012	Test FS Engine	100	24 Jul 18	10 Dec 18										95	100	110	
00020	Upper Stage	1450	21 May 13	10 Dec 18	[Gantt bar]												
00021	US Preliminary Design	300	21 May 13	14 Jul 14										285	300	330	
00022	US PDR	0		14 Jul 14													
00023	US Final Design	450	15 Jul 14	04 Apr 16										428	450	495	
00024	US CDR	0		04 Apr 16													
0002E	US Fabrication	600	05 Apr 16	23 Jul 18										570	600	660	
0002E	US Test	100	24 Jul 18	10 Dec 18										95	100	110	
00027	Integration	350	11 Dec 18	13 Apr 20	[Gantt bar]												
0002E	Integration	250	11 Dec 18	25 Nov 19										238	250	275	
0002E	Integration Testing	100	26 Nov 19	13 Apr 20										95	100	110	

Inherent variability and estimating error: Optimistic - 5% Pessimistic +10%



# Results with Inherent Variability and Duration Estimating Error Only



Deterministic: 13 APR 2020 is 1%

P-80 is 30 JUL 20, about 3.5 months later than planned

Spread from P-5 to P-95 is 5 MAY 20 to 27 AUG 20 for 3.7 months



# Risk Analysis on Space Vehicle Project

## Risk Factors are from Risk Register

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Risk	Min	Most Likely	Max	Likelihood
Requirements have not been decided	95%	105%	120%	70%
Several alternative designs considered	95%	100%	115%	60%
New designs not yet proven	90%	103%	112%	40%
Fabrication requires new materials	95%	105%	115%	50%
Lost know-how since last full spacecraft	100%	100%	105%	30%
Funding from Congress is problematic	90%	105%	115%	70%
Schedule for testing is aggressive	100%	120%	130%	100%

- Seven risk factors have been identified and quantified.
- Each Risk has probability assigned
- Five have optimistic ranges possible, two are pure threats



# Risks Assigned to Activities (1)

Risk	Requirements Definition	FS Preliminary Design	FS Final Design	FS Fabrication	Test FS Engine
Requirements Not Complete	X				
Alternative Designs Possible		X			
Designs Not Proven			X		
New Materials in Fabrication				X	
Lost Know-How				X	
Funding Problematic		X	X	X	X
Testing Schedule Aggressive					X



# Risks Assigned to Activities (2)

Risk	US Preliminary Design	US Final Design	US Fabrication	US Test	Integration	Integration Testing
Requirements Not Complete						
Alternative Designs Possible	X					
Designs Not Proven		X				
New Materials in Fabrication			X			
Lost Know-How			X		X	
Funding Problematic	X	X	X	X	X	X
Testing Schedule Aggressive				X		X

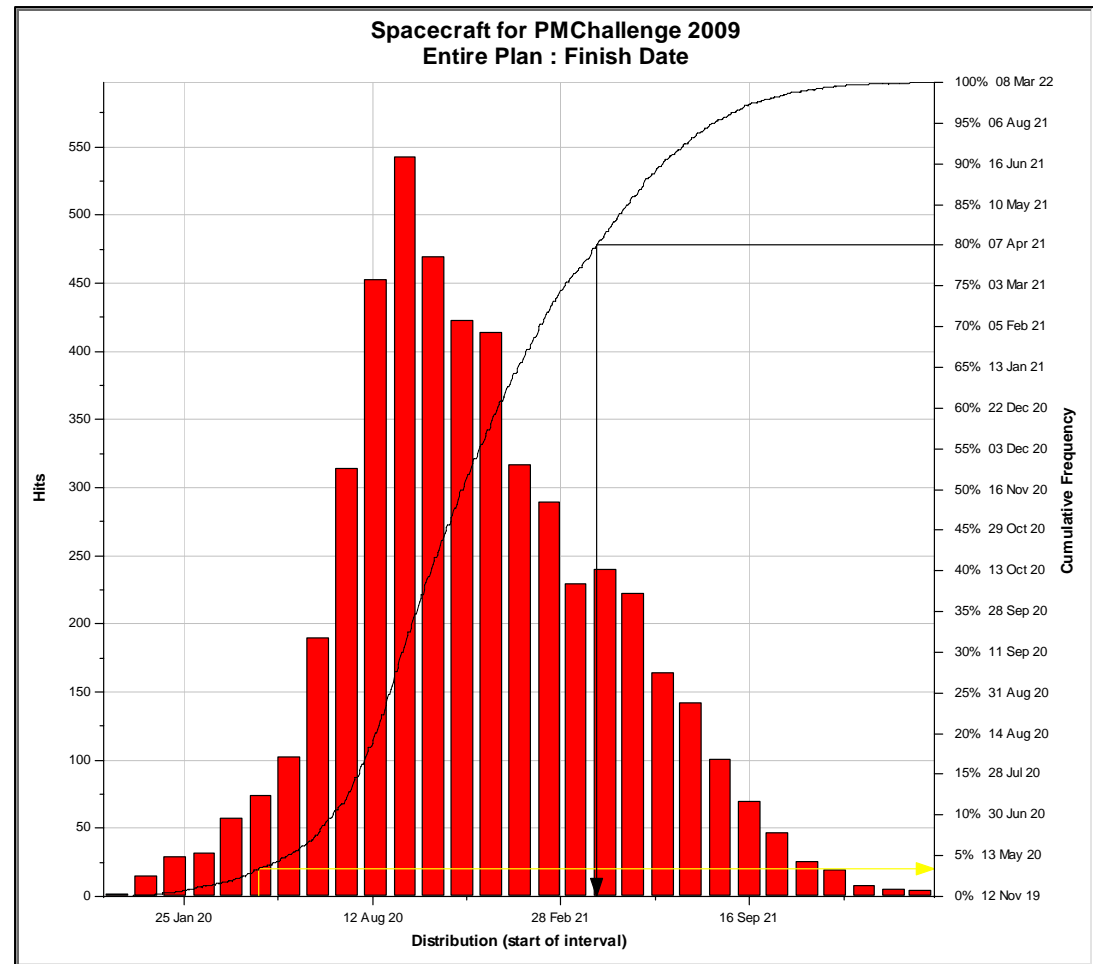


# Results Adding Risk Factors to the Background Risk

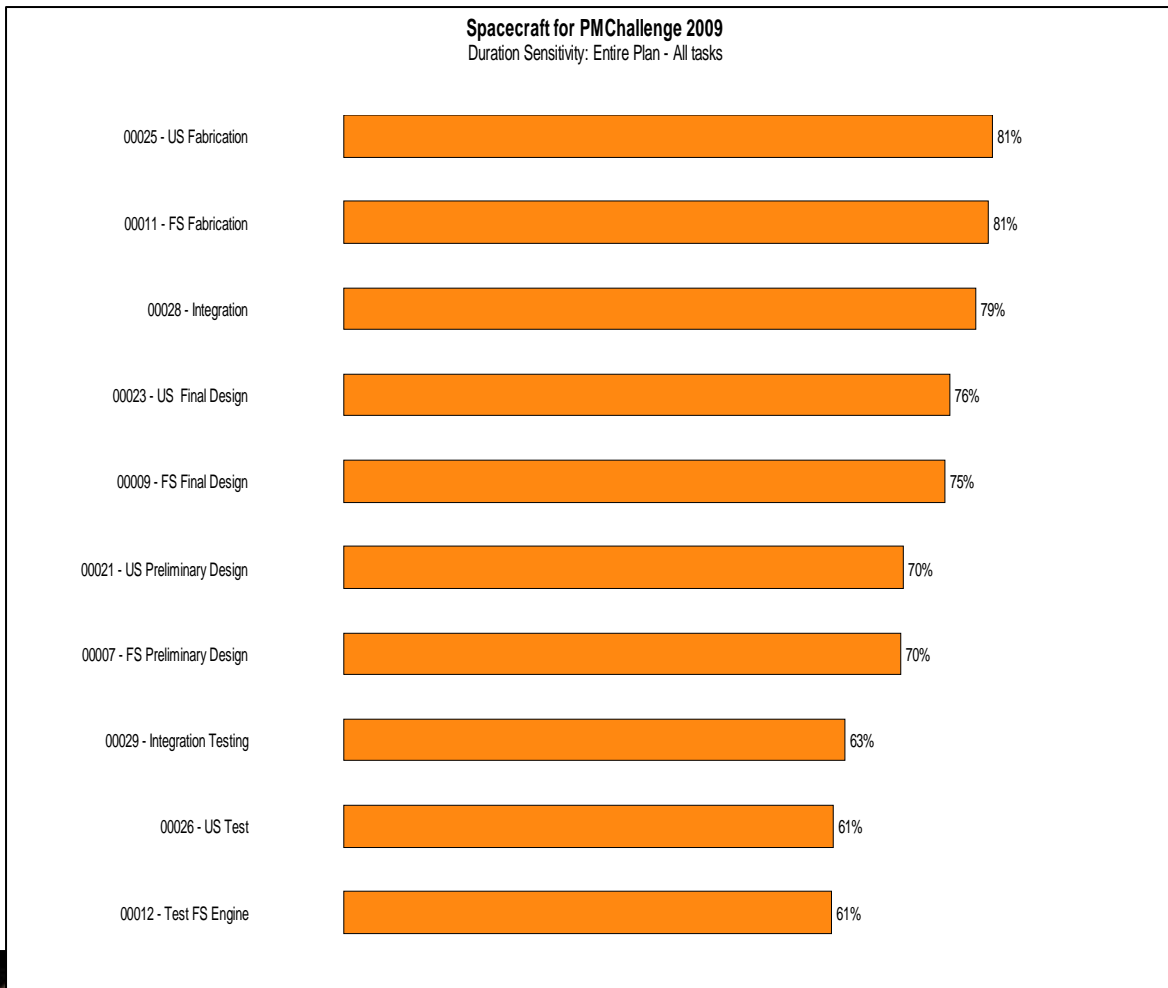
Baseline 13 APR 20 is only 3% likely

80<sup>th</sup> percentile is 7 APR 21, 11.8 months later

Spread P-5 to P-95 is 13May20 to 6 Aug 21, for ~ 15 months



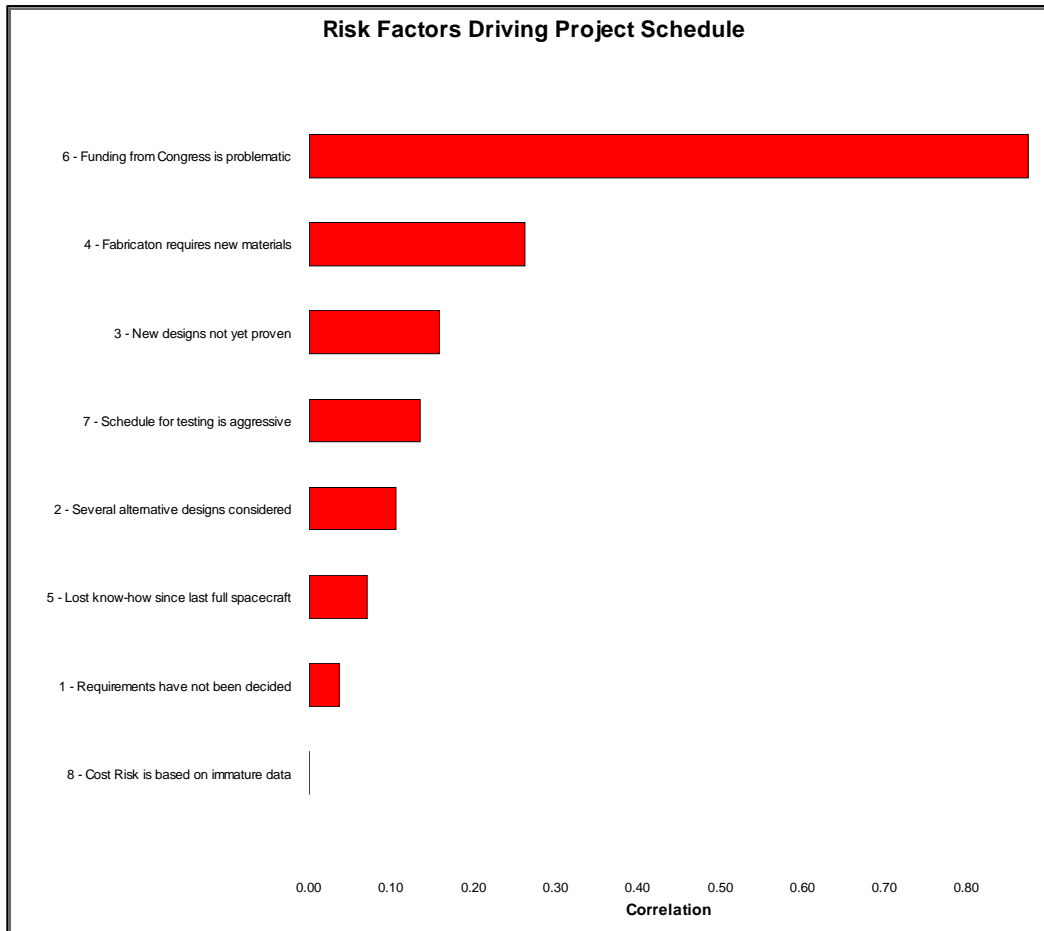
# Activity Tornado Chart from All-In Simulation



Risky Activities:  
Fabrication, Integration,  
Final Design, Preliminary  
Design, Testing  
All are correlated with the  
finish date > 60%

These are activities /  
paths, NOT RISKS

# Risk Factor Tornado from All-In Simulation



The main RISK, however, is funding from Congress, which affected all activities in this model.

This is the main risk to mitigate, if possible

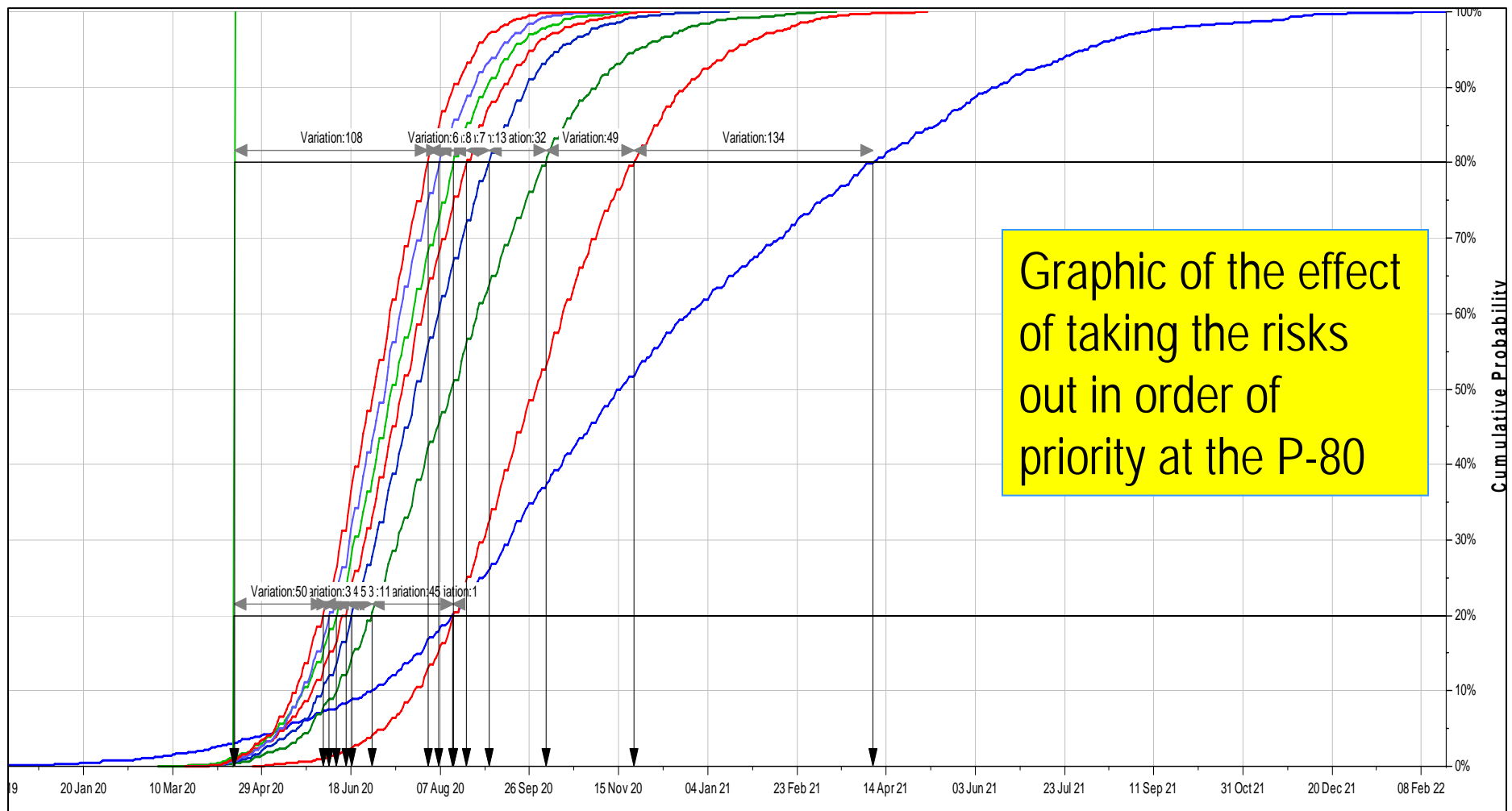


# Contribution of Each Risk to the Contingency (1)

Explain the Contingency to the P-80			
	P-80 Date	Take Risks Out:	
All Risks In	7-Apr-21	Days Saved	% of Contingency
Specific Risks Taken Out in Order			
Funding	23-Nov-20	135	38%
Testing Schedule	5-Oct-20	49	14%
New Materials	3-Sep-20	32	9%
Alternative Design	21-Aug-20	13	4%
Requirements	14-Aug-20	7	2%
New Design	6-Aug-20	8	2%
Lost Know How	31-Jul-20	6	2%
Uncertainty			
Natural Variation & Estimating Error	13-Apr-20	109	30%
Total Contingency		359	100%



# Contribution of Each Risk to the Contingency (2)



Graphic of the effect of taking the risks out in order of priority at the P-80

# Mitigating the Most Important Risk

Effect of Partially Mitigating the Risk with the Highest Priority					
	Min	Most Likely	Max	Likelihood	P-80 Date
Funding from Congress is problematic	90%	105%	115%	70%	7-Apr-21
Mitigation: Mount an "educational campaign" to convince Congress of the scientific and Congressional district employment benefits to funding this project.					
Impact on the parameters	90%	105%	115%	30%	5-Jan-21

Mitigating the risk is estimated to reduce the probability from 70% to 30% but, if the risk happens, the impact range remains the same. This saves 92 calendar days at the P-80 target level of confidence



# Summary (1)

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- The focus is on the risks, not their impact
- Risks “explain” the need for a contingency
- Management appreciates this focus on risks
- Risk interviews are conducted at 5,000 foot level, where people typically think of risk
- Interviews go faster, stick to the substance



## Summary (2)

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- Use Risk Register for quantitative analysis
- Specific risks can be quantified and assigned to schedule activities
  - Quantification is probability and impact
  - A risk can affect several activities
  - An activity can be affected by several risks
- Risk Factors can be combined with other more traditional approaches such as 3-point estimates for inherent variability risk, estimating error or for probabilistic branching

