# Integrated Cost – Schedule Risk Analysis Using the Risk Driver Approach

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

- 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
- Which risks cause the most overall schedule risk? These questions are typically answered by:
  - Criticality or sensitivity of activities
- 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

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

- 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
- <u>Starting with the risks themselves</u> 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

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# Simple Example of Risk Register Risks

| | Description | Optimisitic | Most Likely | Pessimisitic | 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

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# Risk Factors Mechanics

- 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

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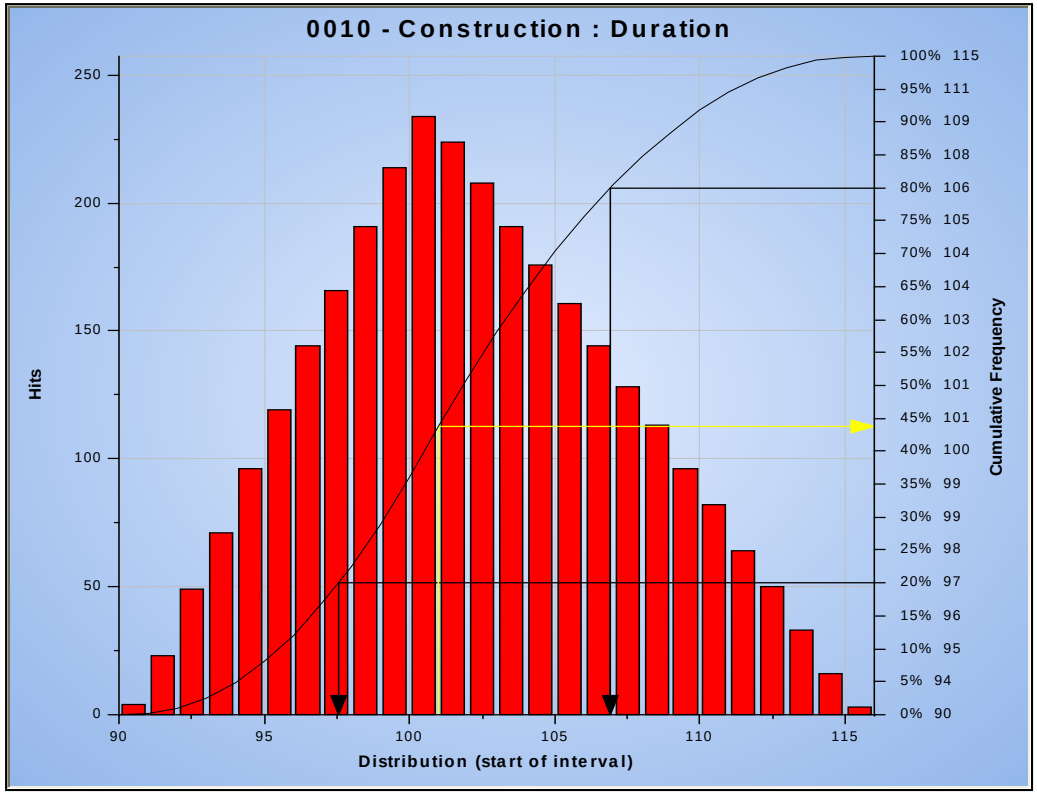
# Risk Factor
# Probability is 100%, Factor can be + or -

| | Description | Optimisitic | Most Likely | Pessimisitic | 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%

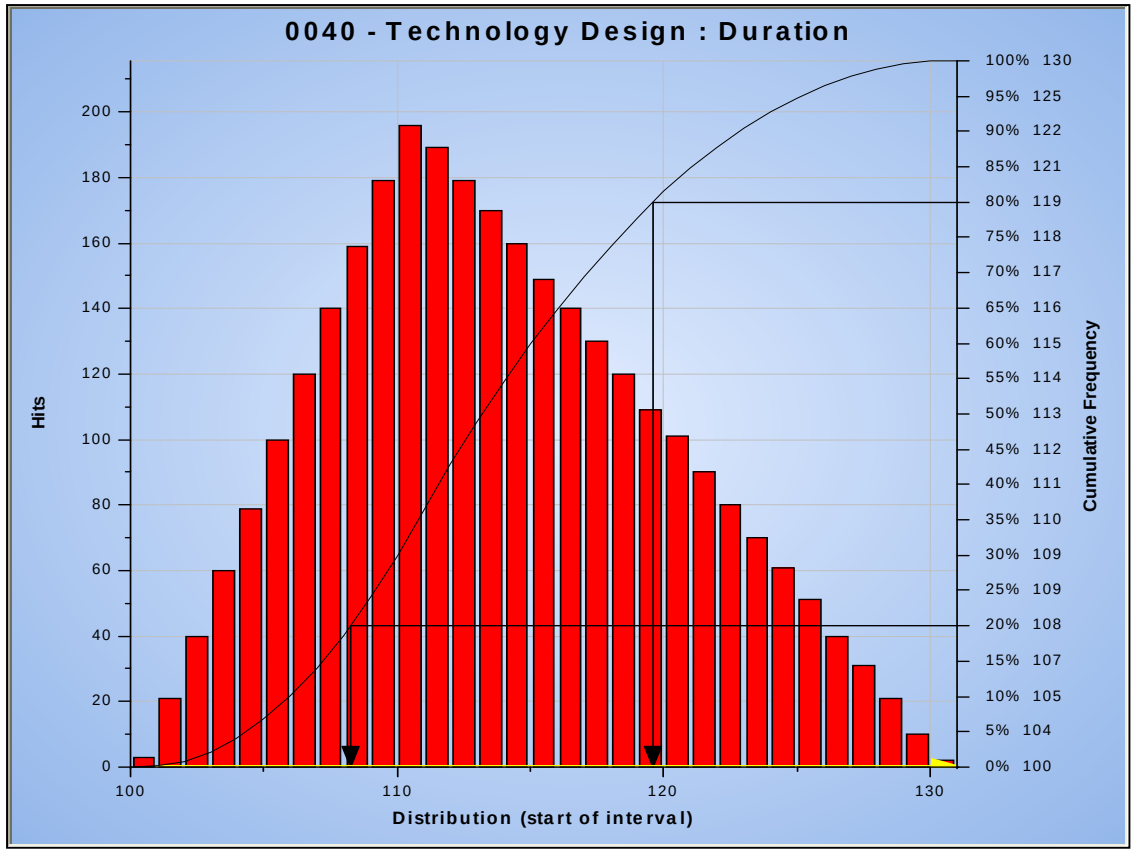



For the examples we use an activity with 100 days in the schedule

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

| | Description | Optimisitic | Most Likely | Pessimisitic | 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%



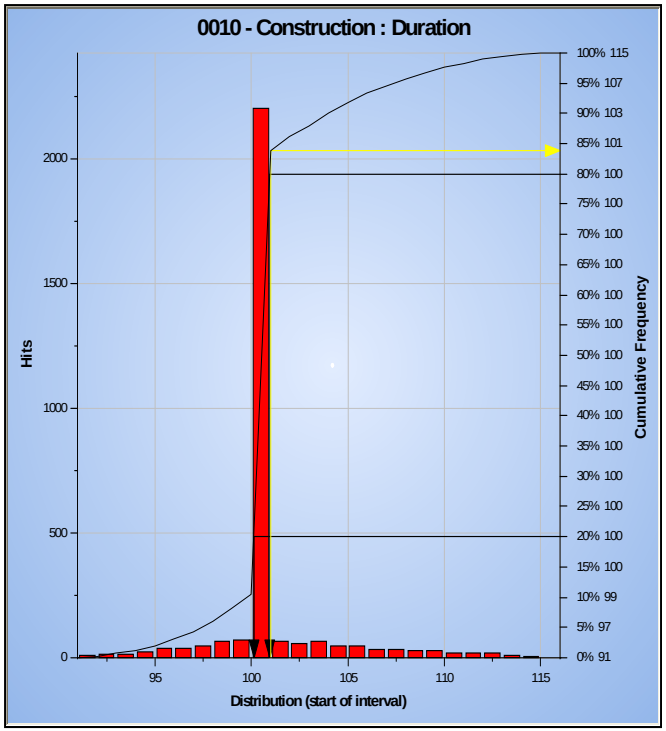
# Assigning a Probability Less than 100%

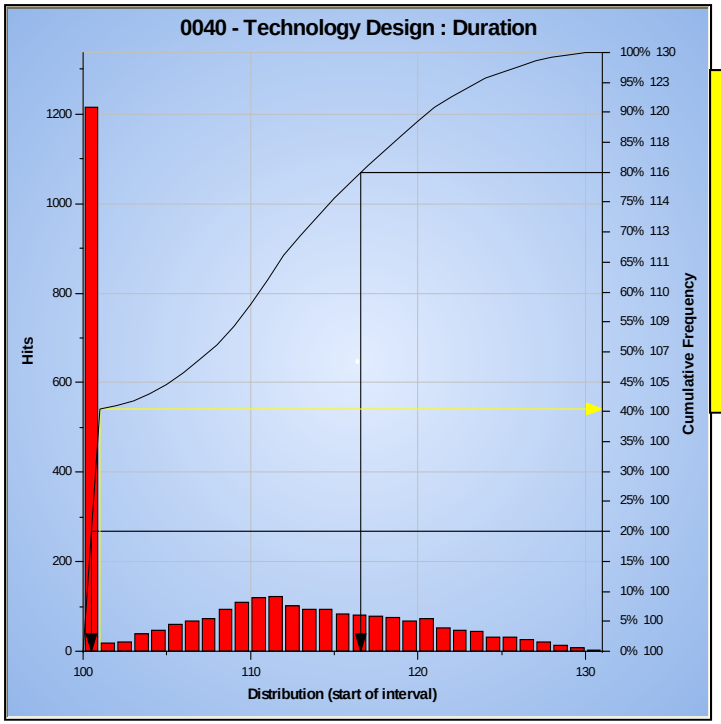
- The essence of a "risk" is its uncertainty in two dimensions:
  - Uncertainty of its <u>occurrence</u>, specified by a probability
  - Uncertainty of its <u>impact</u>, specified by a range of durations
- If the risk may or may not occur, we specify the probability that it will occur
  - The risk occurs 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 | Optimisitic | Most Likely | Pessimisitic | 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 70% of the probability




Spike contains 40% of the probability

# Assigning
# More than One Risk to an Activity

- 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

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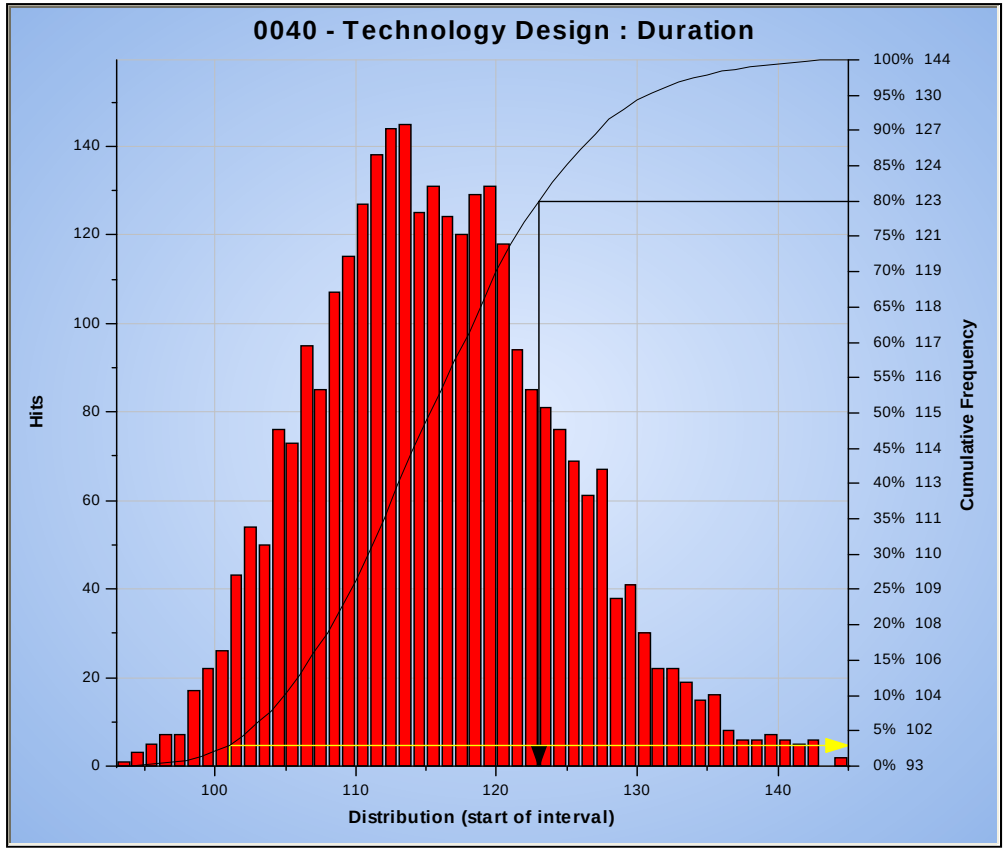
# Two Risks affect One Activity using Factors that Occur 100%

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

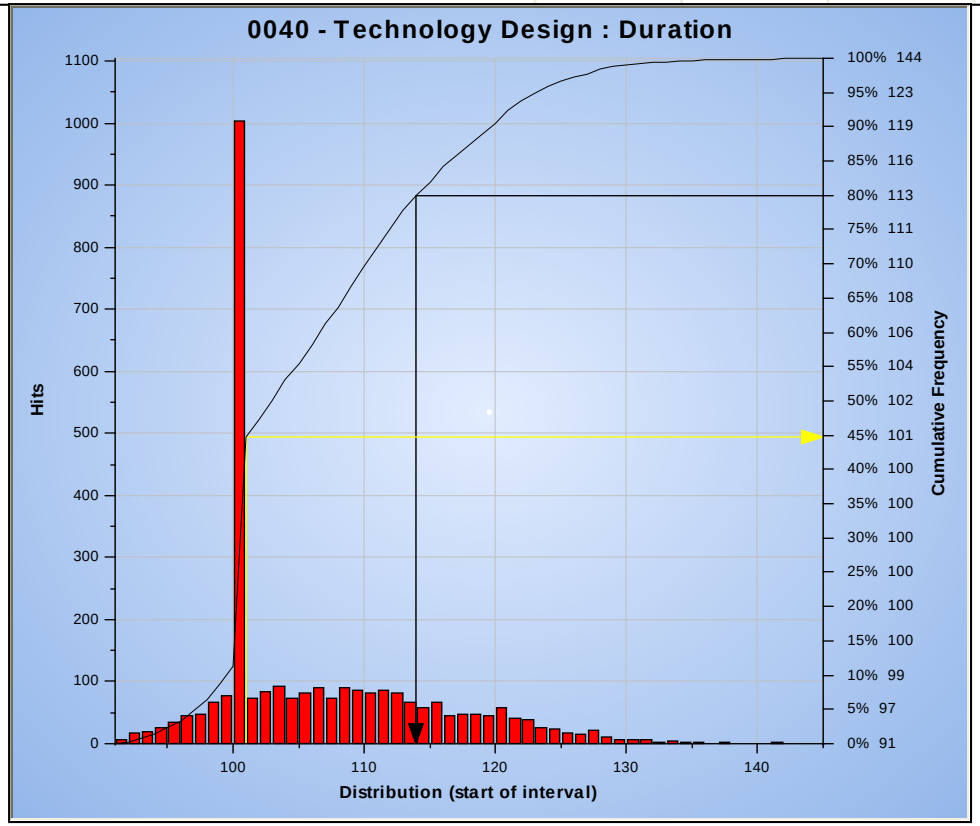
Range from 90 to 150 days, Peak about 113 days



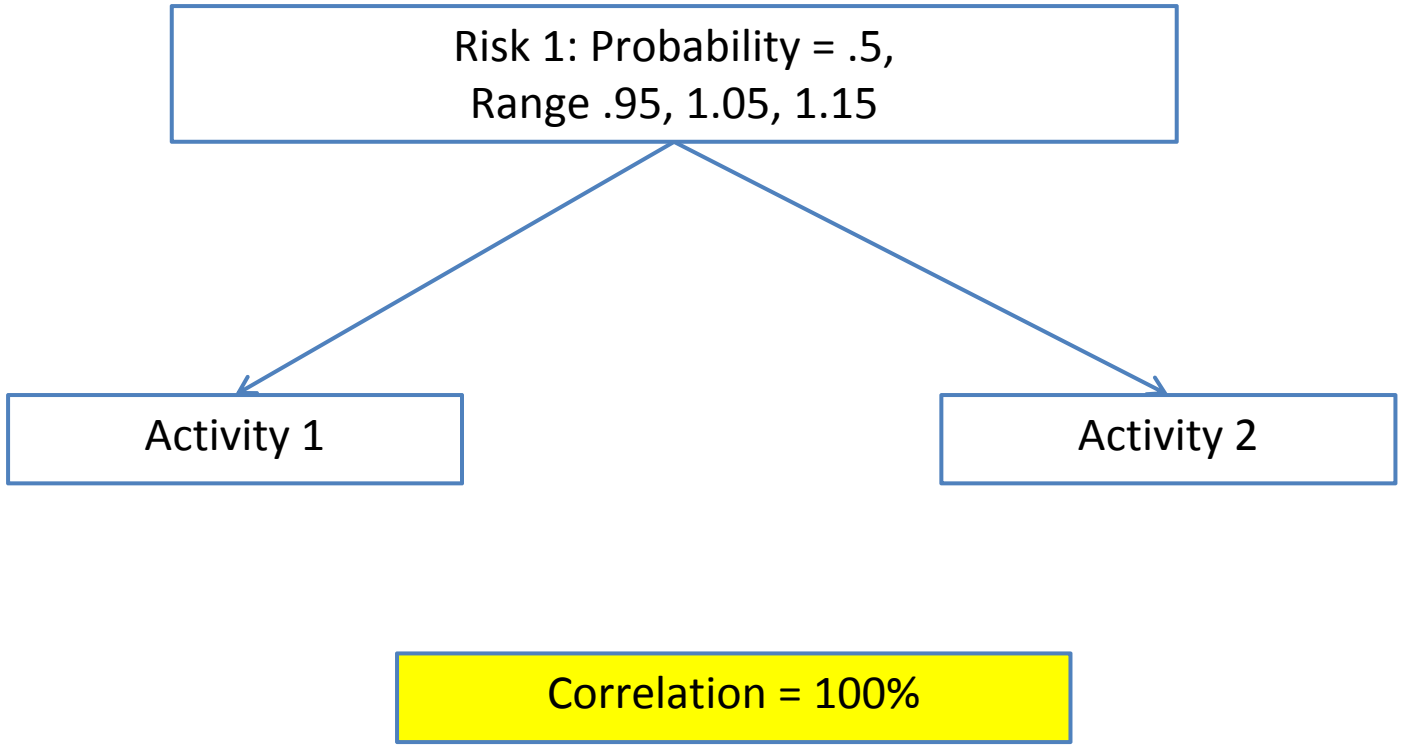
# Two Risks with Less than 100% Probability Affecting one Activity

| | Description | Optimisitic | Most Likely | Pessimisitic | 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 and (2) the chance that 100 days is picked when one or both occur



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

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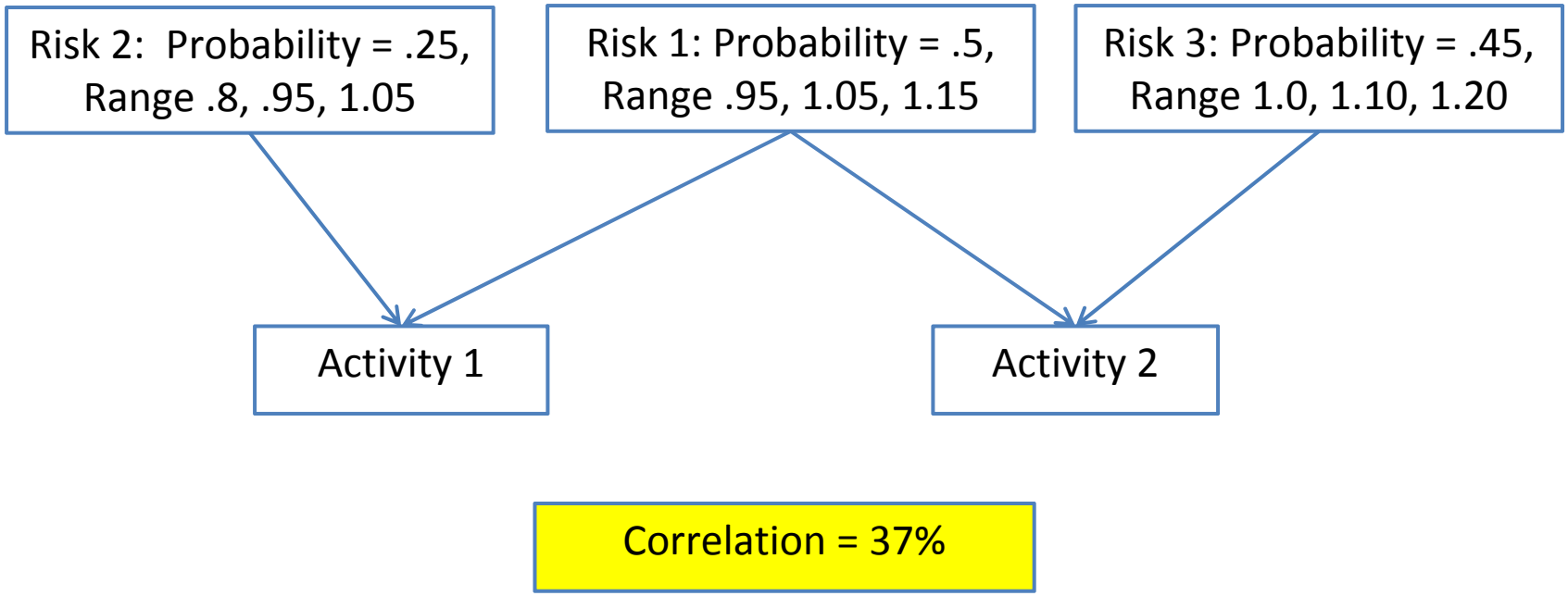
# Risk Factors Model How Correlation Occurs Coefficients are Calculated (2)




**Correlation is modeled as it is caused in the project**
**Correlation coefficients are generated**
**We do not have to estimate correlation coefficients anymore**

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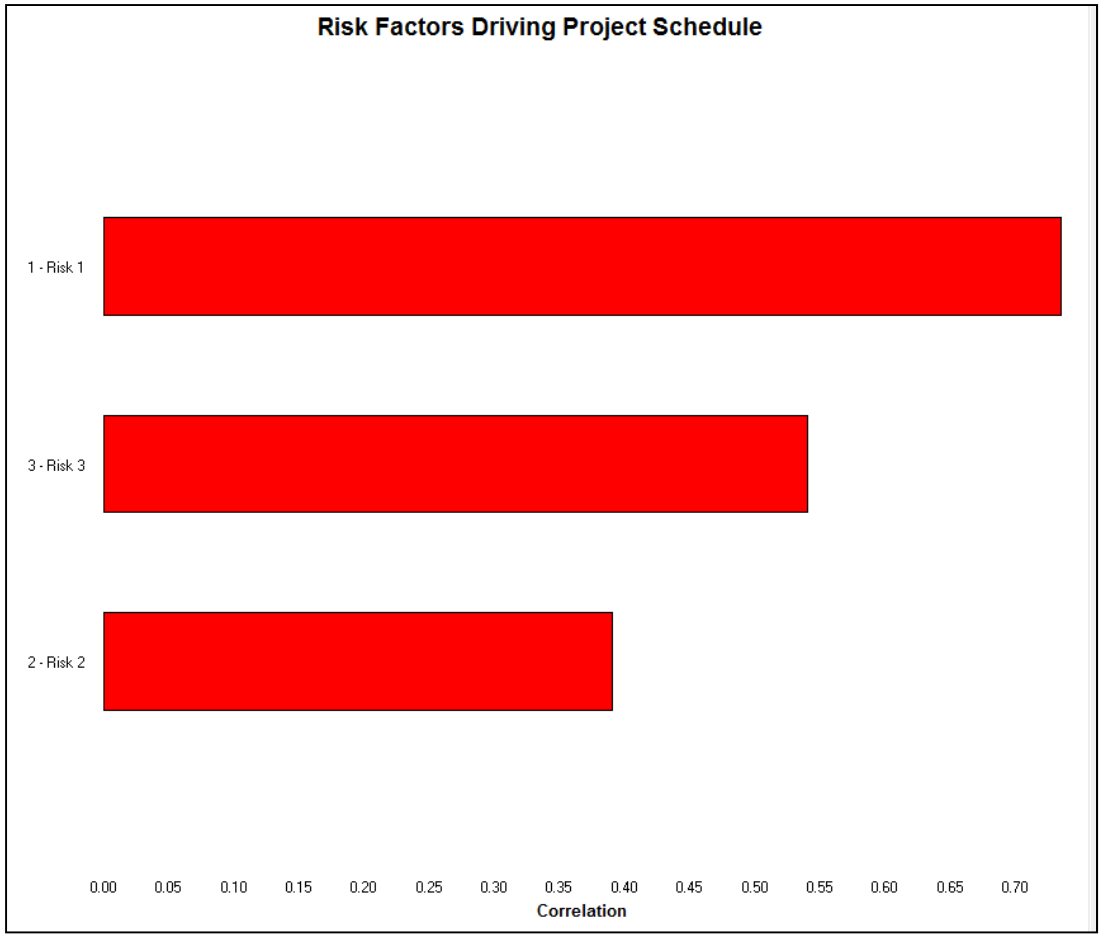
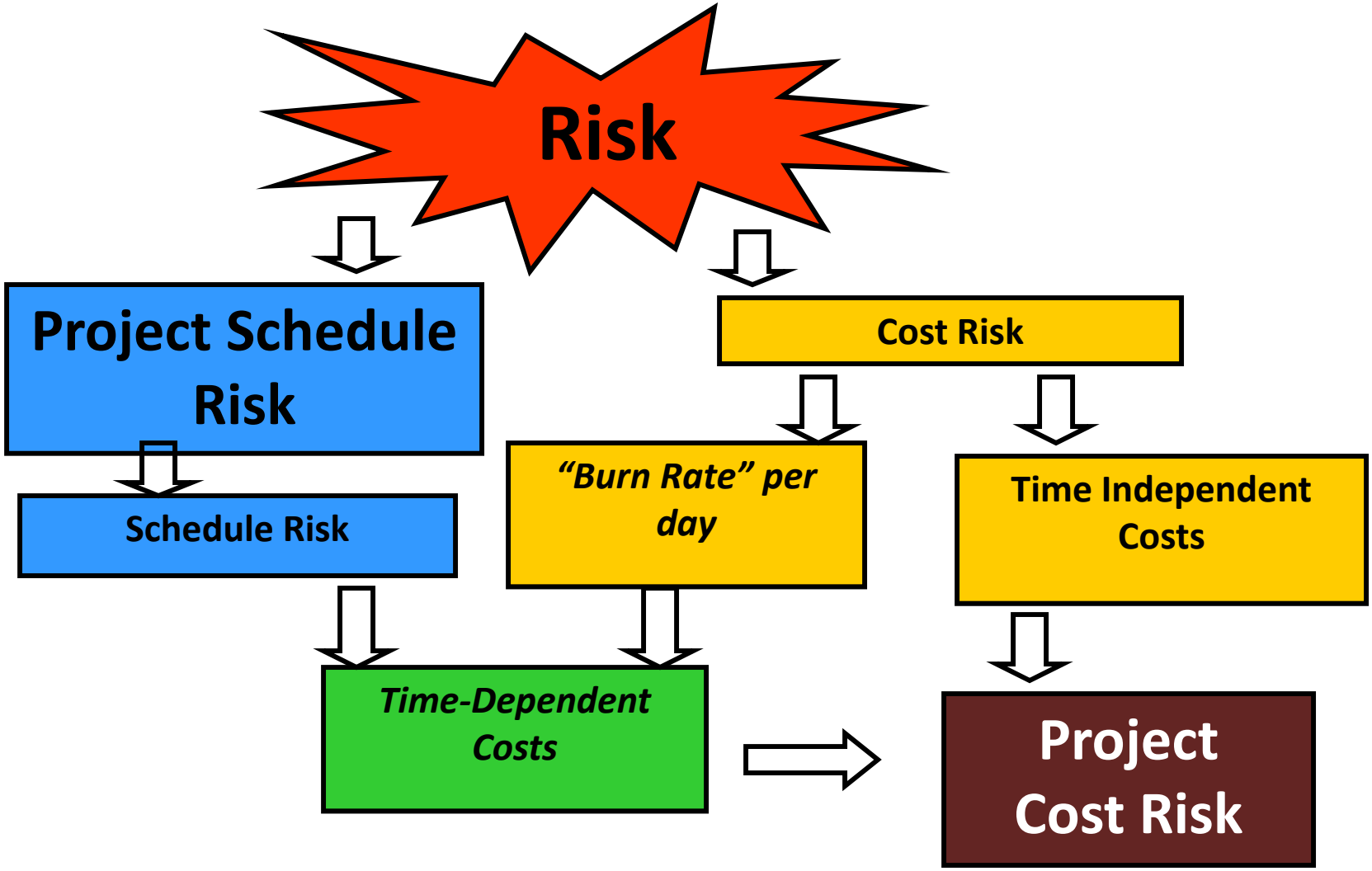
# Sensitivity to the Risk Factors




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

# Cost and Schedule Risk Integration



# Cost Risk Analysis using the Schedule

- The time duration of the tasks can be the basis of the cost estimates for <u>time-dependent resources</u>
  - Assign the resources to the tasks and calculate their cost per day (budget / days)
  - The cost of each task is calculated in each iteration by multiplying the days required by the dollars per day
- There are some <u>time-independent resources</u> that may be uncertain but do not respond to time
  - Total cost may vary but not because of variable duration
- The simulation software (Primavera Risk Analysis is used here) will distinguish these different types of resources and handle appropriately

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# Use a Case Study to Illustrate the Integration of Cost and Schedule Risk

- This case is a simplified schedule of an off-shore gas production project
- Use Risk Drivers approach
- Assign summary resources to the activities
- Results include:
  - Schedule risk and cost risk histograms and cumulative distributions
  - Prioritizing risks to time and to cost
  - Scatter diagram of cost and time
  - Probabilistic cash flow

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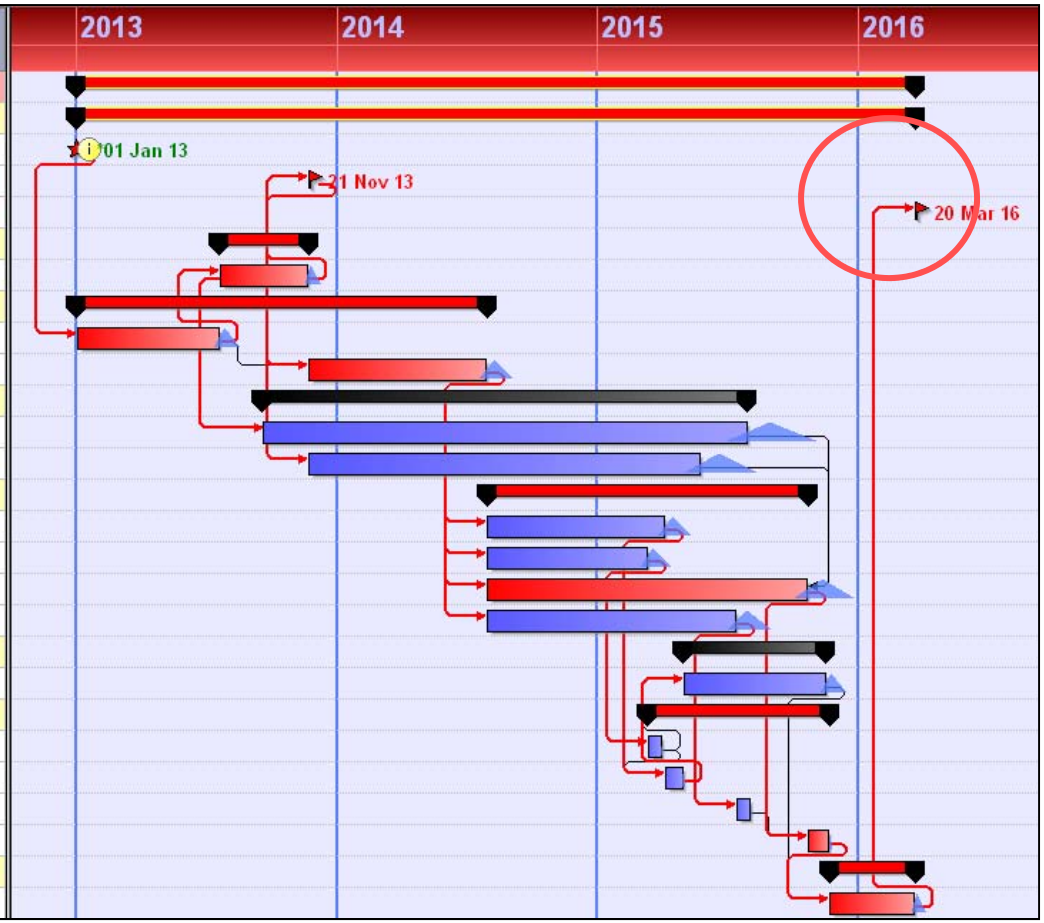
# Offshore Gas Production: Baseline Schedule shows First Gas on 20 MAR 2016

| ID | Description | Remaining Duration | Start | Finish |
|---|---|---|---|---|
| 000001 | Offshore Gas Production Project | 1175 | 01 Jan 13 | 20 Mar 16 |
| 000002 | Milestones | 1175 | 01 Jan 13 | 20 Mar 16 |
| 000003 | Project Start | 0 | *01 Jan 13 | |
| 000004 | Project Sanction | 0 | | 21 Nov 13 |
| 000005 | First Gas | 0 | | 20 Mar 16 |
| 000006 | Decision Making | 125 | 20 Jul 13 | 21 Nov 13 |
| 000007 | Approval Process | 125 | 20 Jul 13 | 21 Nov 13 |
| 000008 | Engineering | 575 | 01 Jan 13 | 29 Jul 14 |
| 000009 | FEED | 200 | 01 Jan 13 | 19 Jul 13 |
| 000010 | Detailed Engineering | 250 | 22 Nov 13 | 29 Jul 14 |
| 000011 | Procurement | 680 | 18 Sep 13 | 29 Jul 15 |
| 000012 | Procurement of LLE | 680 | 18 Sep 13 | 29 Jul 15 |
| 000013 | Procurement of Equipment | 550 | 22 Nov 13 | 25 May 15 |
| 000014 | Fabrication | 450 | 30 Jul 14 | 22 Oct 15 |
| 000015 | FAB Drilling Topsides | 250 | 30 Jul 14 | 05 Apr 15 |
| 000016 | FAB Drilling Jacket | 225 | 30 Jul 14 | 11 Mar 15 |
| 000017 | FAB CPP Topsides | 450 | 30 Jul 14 | 22 Oct 15 |
| 000018 | FAB CPP Jacket | 350 | 30 Jul 14 | 14 Jul 15 |
| 000019 | Drilling | 200 | 01 May 15 | 16 Nov 15 |
| 000020 | Drilling for First Gas | 200 | 01 May 15 | 16 Nov 15 |
| 000021 | Installation | 255 | 12 Mar 15 | 21 Nov 15 |
| 000022 | Install Drilling Platform Jacket | 20 | 12 Mar 15 | 31 Mar 15 |
| 000023 | Install Drilling Topsides | 25 | 06 Apr 15 | 30 Apr 15 |
| 000024 | Install CPP Jacket | 20 | 15 Jul 15 | 03 Aug 15 |
| 000025 | Install CPP Topsides | 30 | 23 Oct 15 | 21 Nov 15 |
| 000026 | Hook-up and Commissioning | 120 | 22 Nov 15 | 20 Mar 16 |
| 000027 | HUC CPP for First Gas | 120 | 22 Nov 15 | 20 Mar 16 |



# Resources and Cost
# Total Project = $1,473 million

| ID | Description | Remaining Duration | Start | Finish | Resource Loading | Total Cost |
|---|---|---|---|---|---|---|
| 000001 | Offshore Gas Production Project | 1175 | 01 Jan 13 | 20 Mar 16 | | $1,473,445.00 |
| 000002 | Milestones | 1175 | 01 Jan 13 | 20 Mar 16 | | $0.00 |
| 000003 | Project Start | 0 | *01 Jan 13 | | | $0.00 |
| 000004 | Project Sanction | 0 | | 21 Nov 13 | | $0.00 |
| 000005 | First Gas | 0 | | 20 Mar 16 | | $0.00 |
| 000006 | Decision Making | 125 | 20 Jul 13 | 21 Nov 13 | | $300.00 |
| 000007 | Approval Process | 125 | 20 Jul 13 | 21 Nov 13 | PMT[Normal] | $300.00 |
| 000008 | Engineering | 575 | 01 Jan 13 | 29 Jul 14 | | $73,500.00 |
| 000009 | FEED | 200 | 01 Jan 13 | 19 Jul 13 | PMT[Normal];ENG[Normal] | $21,000.00 |
| 000010 | Detailed Engineering | 250 | 22 Nov 13 | 29 Jul 14 | PMT[Normal];ENG[Normal] | $52,500.00 |
| 000011 | Procurement | 680 | 18 Sep 13 | 29 Jul 15 | | $678,900.00 |
| 000012 | Procurement of LLE | 680 | 18 Sep 13 | 29 Jul 15 | PMT[Normal];PROC[Spread] | $353,400.00 |
| 000013 | Procurement of Equipment | 550 | 22 Nov 13 | 25 May 15 | PMT[Normal];PROC[Spread] | $325,500.00 |
| 000014 | Fabrication | 450 | 30 Jul 14 | 22 Oct 15 | | $495,625.00 |
| 000015 | FAB Drilling Topsides | 250 | 30 Jul 14 | 05 Apr 15 | PMT[Normal];FAB[Spread] | $103,750.00 |
| 000016 | FAB Drilling Jacket | 225 | 30 Jul 14 | 11 Mar 15 | PMT[Normal];PROC[Spread] | $81,125.00 |
| 000017 | FAB CPP Topsides | 450 | 30 Jul 14 | 22 Oct 15 | PMT[Normal];FAB[Normal] | $209,000.00 |
| 000018 | FAB CPP Jacket | 350 | 30 Jul 14 | 14 Jul 15 | PMT[Normal];PROC[Spread] | $101,750.00 |
| 000019 | Drilling | 200 | 01 May 15 | 16 Nov 15 | | $121,000.00 |
| 000020 | Drilling for First Gas | 200 | 01 May 15 | 16 Nov 15 | PMT[Normal];DRILL[Normal] | $121,000.00 |
| 000021 | Installation | 255 | 12 Mar 15 | 21 Nov 15 | | $57,920.00 |
| 000022 | Install Drilling Platform Jacket | 20 | 12 Mar 15 | 31 Mar 15 | PMT[Normal];INST[Normal] | $10,100.00 |
| 000023 | Install Drilling Topsides | 25 | 06 Apr 15 | 30 Apr 15 | PMT[Normal];INST[Normal] | $15,250.00 |
| 000024 | Install CPP Jacket | 20 | 15 Jul 15 | 03 Aug 15 | PMT[Normal];INST[Normal] | $12,120.00 |
| 000025 | Install CPP Topsides | 30 | 23 Oct 15 | 21 Nov 15 | PMT[Normal];INST[Normal] | $20,450.00 |
| 000026 | Hook-up and Commissioning | 120 | 22 Nov 15 | 20 Mar 16 | | $46,200.00 |
| 000027 | HUC CPP for First Gas | 120 | 22 Nov 15 | 20 Mar 16 | PMT[Normal];HUC[Normal] | $46,200.00 |

Summary 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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# Duration Estimating Uncertainty

| ID | Description | Remaining Duration | Start | Finish | Minimum Duration | Most Likely | Maximum Duration |
|---|---|---|---|---|---|---|---|
| **000001** | **Offshore Gas Production Project** | **1175** | **01 Jan 13** | **20 Mar 16** | | | |
| **000002** | **Milestones** | **1175** | **01 Jan 13** | **20 Mar 16** | | | |
| **000003** | **Project Start** | **0** | ***01 Jan 13** | | | | |
| **000004** | **Project Sanction** | **0** | | **21 Nov 13** | | | |
| **000005** | **First Gas** | **0** | | **20 Mar 16** | | | |
| **000006** | **Decision Making** | **125** | **20 Jul 13** | **21 Nov 13** | | | |
| 000007 | Approval Process | 125 | 20 Jul 13 | 21 Nov 13 | 119 | 131 | 144 |
| **000008** | **Engineering** | **575** | **01 Jan 13** | **29 Jul 14** | | | |
| 000009 | FEED | 200 | 01 Jan 13 | 19 Jul 13 | 190 | 210 | 230 |
| 000010 | Detailed Engineering | 250 | 22 Nov 13 | 29 Jul 14 | 238 | 263 | 288 |
| **000011** | **Procurement** | **680** | **18 Sep 13** | **29 Jul 15** | | | |
| 000012 | Procurement of LLE | 680 | 18 Sep 13 | 29 Jul 15 | 646 | 714 | 782 |
| 000013 | Procurement of Equipment | 550 | 22 Nov 13 | 25 May 15 | 523 | 578 | 633 |
| **000014** | **Fabrication** | **450** | **30 Jul 14** | **22 Oct 15** | | | |
| 000015 | FAB Drilling Topsides | 250 | 30 Jul 14 | 05 Apr 15 | 238 | 263 | 288 |
| 000016 | FAB Drilling Jacket | 225 | 30 Jul 14 | 11 Mar 15 | 214 | 236 | 259 |
| 000017 | FAB CPP Topsides | 450 | 30 Jul 14 | 22 Oct 15 | 428 | 473 | 518 |
| 000018 | FAB CPP Jacket | 350 | 30 Jul 14 | 14 Jul 15 | 333 | 368 | 402 |
| **000019** | **Drilling** | **200** | **01 May 15** | **16 Nov 15** | | | |
| 000020 | Drilling for First Gas | 200 | 01 May 15 | 16 Nov 15 | 190 | 210 | 230 |
| **000021** | **Installation** | **255** | **12 Mar 15** | **21 Nov 15** | | | |
| 000022 | Install Drilling Platform Jacket | 20 | 12 Mar 15 | 31 Mar 15 | 19 | 21 | 23 |
| 000023 | Install Drilling Topsides | 25 | 06 Apr 15 | 30 Apr 15 | 24 | 26 | 29 |
| 000024 | Install CPP Jacket | 20 | 15 Jul 15 | 03 Aug 15 | 19 | 21 | 23 |
| 000025 | Install CPP Topsides | 30 | 23 Oct 15 | 21 Nov 15 | 29 | 32 | 35 |
| **000026** | **Hook-up and Commissioning** | **120** | **22 Nov 15** | **20 Mar 16** | | | |
| 000027 | HUC CPP for First Gas | 120 | 22 Nov 15 | 20 Mar 16 | 114 | 126 | 138 |

The estimate is that durations are underestimated
The range, on all activities, is 95% – 105% - 115% of the estimated duration

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# Risk Drivers Used

Schedule Impact Ranges

Cost Impact Ranges

| | | Schedule Impact Ranges | | | Cost Impact Ranges | | | |
|---|---|---|---|---|---|---|---|---|
| | Risk Name | Min | Most Likely | Max | Min | Most Likely | Max | Probability |
| 1 | Company's Engineers may vary in Experience | 90% | 110% | 130% | 95% | 100% | 110% | 85% |
| 2 | MTO, Specs may not be ready for ITB | 100% | 105% | 125% | 100% | 105% | 110% | 60% |
| 3 | May have trouble interfacing phases | 100% | 110% | 120% | 90% | 105% | 115% | 40% |
| 4 | Subsea conditions may not be as expected | 95% | 100% | 115% | 95% | 100% | 110% | 20% |
| 5 | LLE suppliers may be busy | 80% | 95% | 110% | 95% | 105% | 115% | 20% |
| 6 | Quality engineers at Fabricators may be inexperienced | 100% | 100% | 100% | 100% | 105% | 110% | 60% |
| 7 | Scope growth may be greater than expected | 105% | 110% | 125% | 100% | 105% | 110% | 60% |
| 8 | HUC resources may not be as experienced as needed | 100% | 115% | 130% | 95% | 105% | 115% | 20% |

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.

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# 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 | | | | | |

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# Some Risks are Parallel and Some Series

| ID | Description | Remaining Duration | Start | Finish | RiskFactors |
|---|---|---|---|---|---|
| 000001 | Offshore Gas Production Project | 1175 | 01 Jan 13 | 20 Mar 16 | |
| 000002 | Milestones | 1175 | 01 Jan 13 | 20 Mar 16 | |
| 000003 | Project Start | 0 | *01 Jan 13 | | |
| 000004 | Project Sanction | 0 | | 21 Nov 13 | |
| 000005 | First Gas | 0 | | 20 Mar 16 | |
| 000006 | Decision Making | 125 | 20 Jul 13 | 21 Nov 13 | |
| 000007 | Approval Process | 125 | 20 Jul 13 | 21 Nov 13 | (1,2(P)) |
| 000008 | Engineering | 575 | 01 Jan 13 | 29 Jul 14 | |
| 000009 | FEED | 200 | 01 Jan 13 | 19 Jul 13 | (1,2(P)) |
| 000010 | Detailed Engineering | 250 | 22 Nov 13 | 29 Jul 14 | (1,2(P));(7) |
| 000011 | Procurement | 680 | 18 Sep 13 | 29 Jul 15 | |
| 000012 | Procurement of LLE | 680 | 18 Sep 13 | 29 Jul 15 | (5,1(P));(7) |
| 000013 | Procurement of Equipment | 550 | 22 Nov 13 | 25 May 15 | (1,2(P));(7) |
| 000014 | Fabrication | 450 | 30 Jul 14 | 22 Oct 15 | |
| 000015 | FAB Drilling Topsides | 250 | 30 Jul 14 | 05 Apr 15 | (1,2(P));(6) |
| 000016 | FAB Drilling Jacket | 225 | 30 Jul 14 | 11 Mar 15 | (1,2(P));(6) |
| 000017 | FAB CPP Topsides | 450 | 30 Jul 14 | 22 Oct 15 | (1,2(P));(7,6) |
| 000018 | FAB CPP Jacket | 350 | 30 Jul 14 | 14 Jul 15 | (1,2(P));(7,6) |
| 000019 | Drilling | 200 | 01 May 15 | 16 Nov 15 | |
| 000020 | Drilling for First Gas | 200 | 01 May 15 | 16 Nov 15 | (4) |
| 000021 | Installation | 255 | 12 Mar 15 | 21 Nov 15 | |
| 000022 | Install Drilling Platform Jacket | 20 | 12 Mar 15 | 31 Mar 15 | (1(P));(6) |
| 000023 | Install Drilling Topsides | 25 | 06 Apr 15 | 30 Apr 15 | (1,3(P));(7,6) |
| 000024 | Install CPP Jacket | 20 | 15 Jul 15 | 03 Aug 15 | (1(P));(6) |
| 000025 | Install CPP Topsides | 30 | 23 Oct 15 | 21 Nov 15 | (1,3(P));(7,6) |
| 000026 | Hook-up and Commissioning | 120 | 22 Nov 15 | 20 Mar 16 | |
| 000027 | HUC CPP for First Gas | 120 | 22 Nov 15 | 20 Mar 16 | (1,3,8(P)) |

If several risks are assigned to any task we may put some in parallel (can be recovered simultaneously) and some in series (recovery will take all resources so cannot be recovered simultaneously with other risks)
In this case, risks 6 and 7 have been placed in series

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# Parallel and Series Risks – Additive

Risk 1  20 days

Risk 2  12 days

20 days for risk recovery

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

Risk 1  20 days

Risk 2  12 days

32 days for risk recovery

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

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# Parallel and Series Risks – Multiplicative

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 x 1.05 = 1.26) Factor, multiply the two

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

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# Summary Schedule Risk Analysis Results

| Schedule Risk Analysis | | | | |
|---|---|---|---|---|
| Date Results for First Gas | | | | |
| Baseline Date | 20-Mar-16 | | | |
| Risk Analysis Results | P-5 | P-50 | P-80 | P-95 |
| | 2-Jul-16 | 4-Nov-16 | 6-Jan-17 | 14-Mar-17 |
| Months from Baseline | 3.4 | 7.5 | 9.6 | 11.8 |
| Duration Results To First Gas | | | | |
| | Days | | | |
| Baseline Duration | 1,906 | | | |
| Risk Analysis Results | P-5 | P-50 | P-80 | P-95 |
| | 2,010 | 2,135 | 2,198 | 2,265 |
| Percentage from Baseline | 5% | 12% | 15% | 19% |

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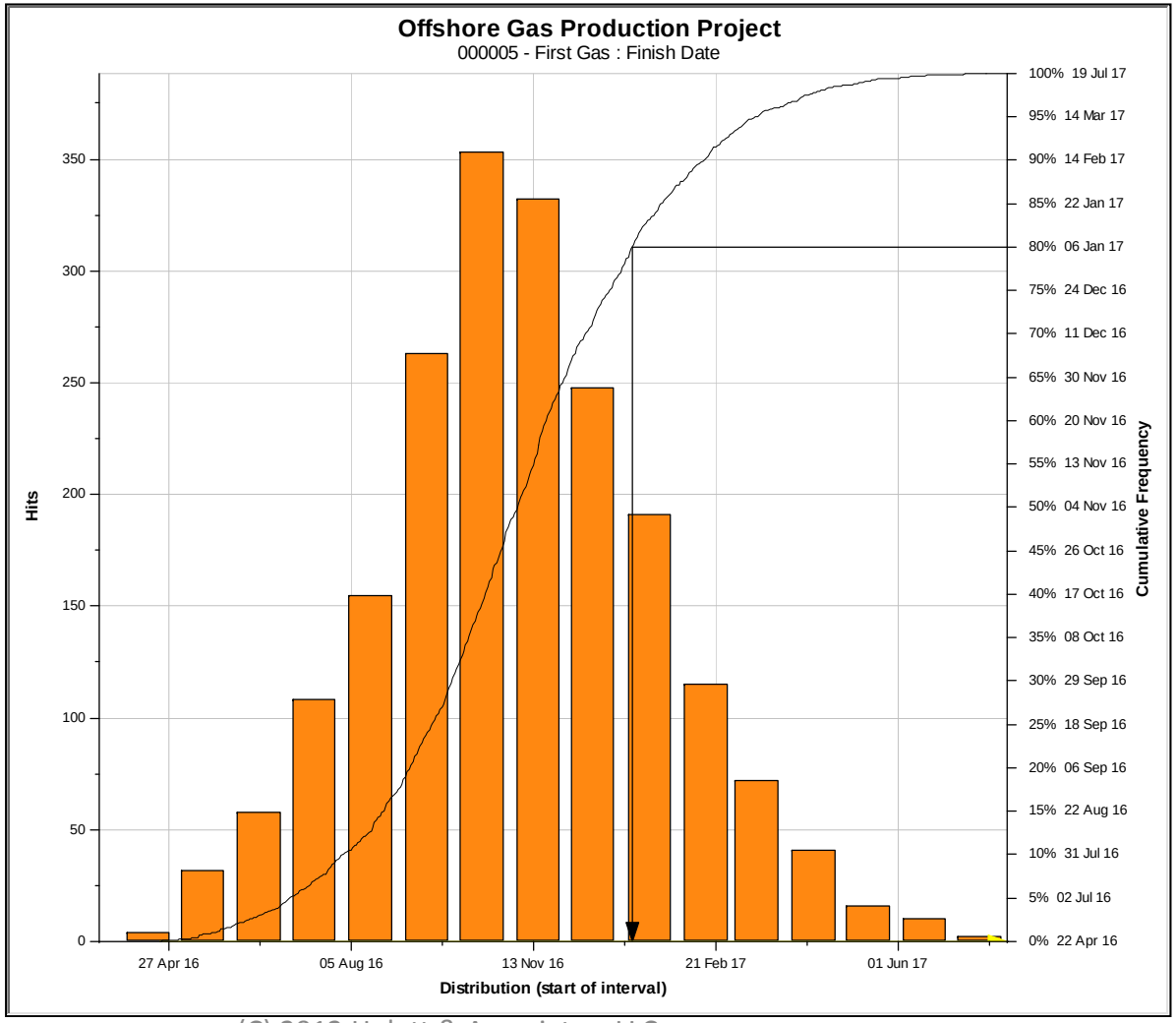
# Completion Date – First Gas

First Gas Baseline Date = 20MAR16 is < 1% likely to occur P-80 is 6Jan17

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# Prioritize Risks that Cause Schedule Contingency to the P-80

| Explain the Schedule Contingency to the P-80 | | | |
|---|---|---|---|
| | P-80 Date | Take Risks Out: | |
| All Risks In | 6-Jan-17 | Days Saved | % of Contingency |
| Specific Risks Taken Out in Order | | | |
| Company's engineers may vary in experience | 14-Nov-16 | 53 | 18% |
| MTO, Specs may not be ready for the ITB | 5-Oct-16 | 40 | 14% |
| Scope growth may be more than expected | 1-Jul-16 | 96 | 33% |
| May have problems interfacing phases | 24-Jun-16 | 7 | 2% |
| HUC resources may not be experienced | 19-Jun-16 | 5 | 2% |
| Uncertainty | | | |
| Duration Estimating | 20-Mar-16 | 91 | 31% |
| Total Contingency | | 292 | 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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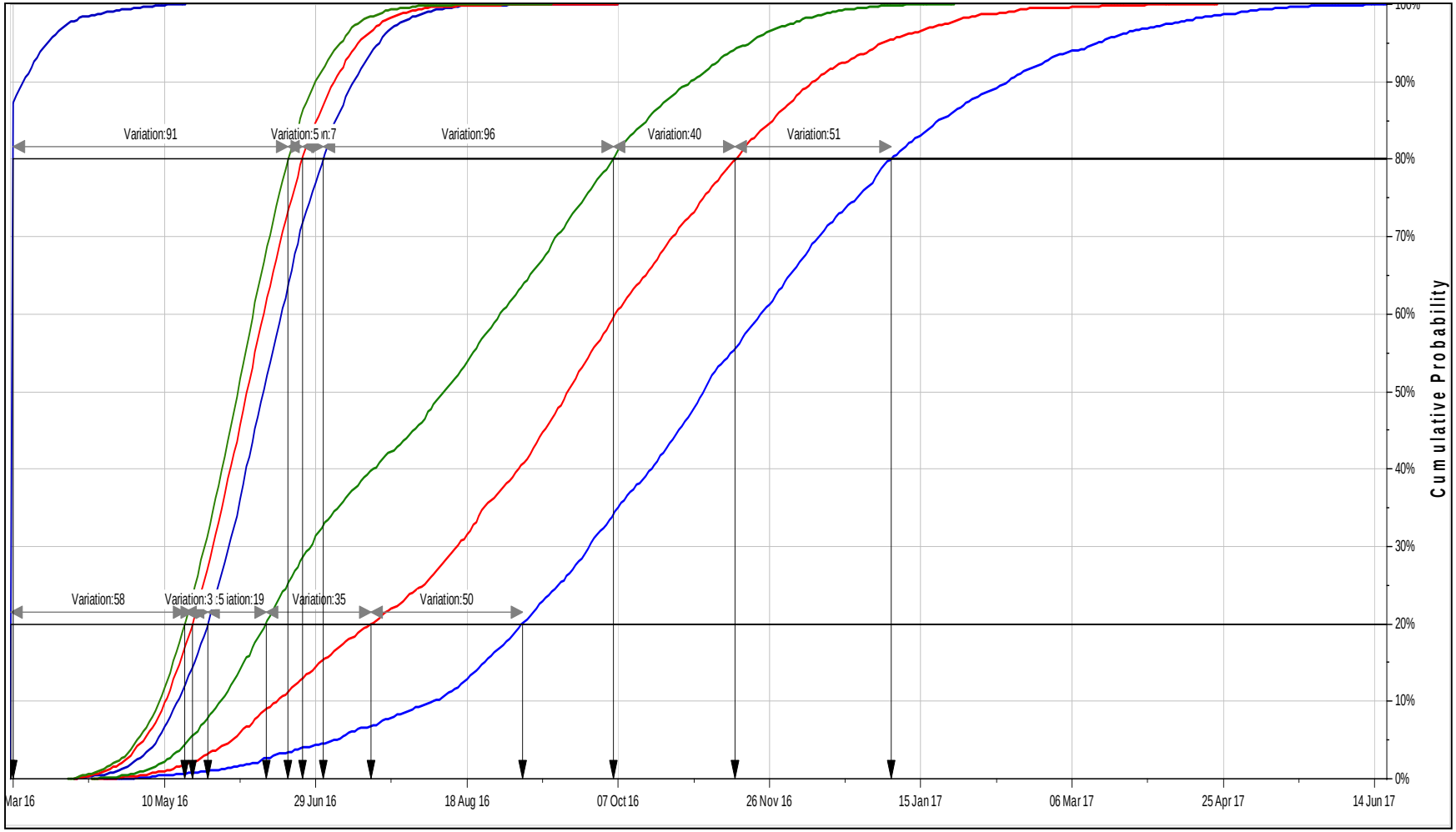
# Picture of
# Taking Risks out in Priority Order



# Summary Cost Risk Analysis Results

| Cost Risk Analysis Total Project | | | | |
|---|---|---|---|---|
| | $ millions | | | |
| Baseline Cost | 1,473 | | | |
| | P-5 | P-50 | P-80 | P-95 |
| Risk Analysis Results | 1,541 | 1,667 | 1,736 | 1,808 |
| Dollars from Baseline | 68 | 194 | 263 | 335 |
| Percent from Baseline | 5% | 13% | 18% | 23% |

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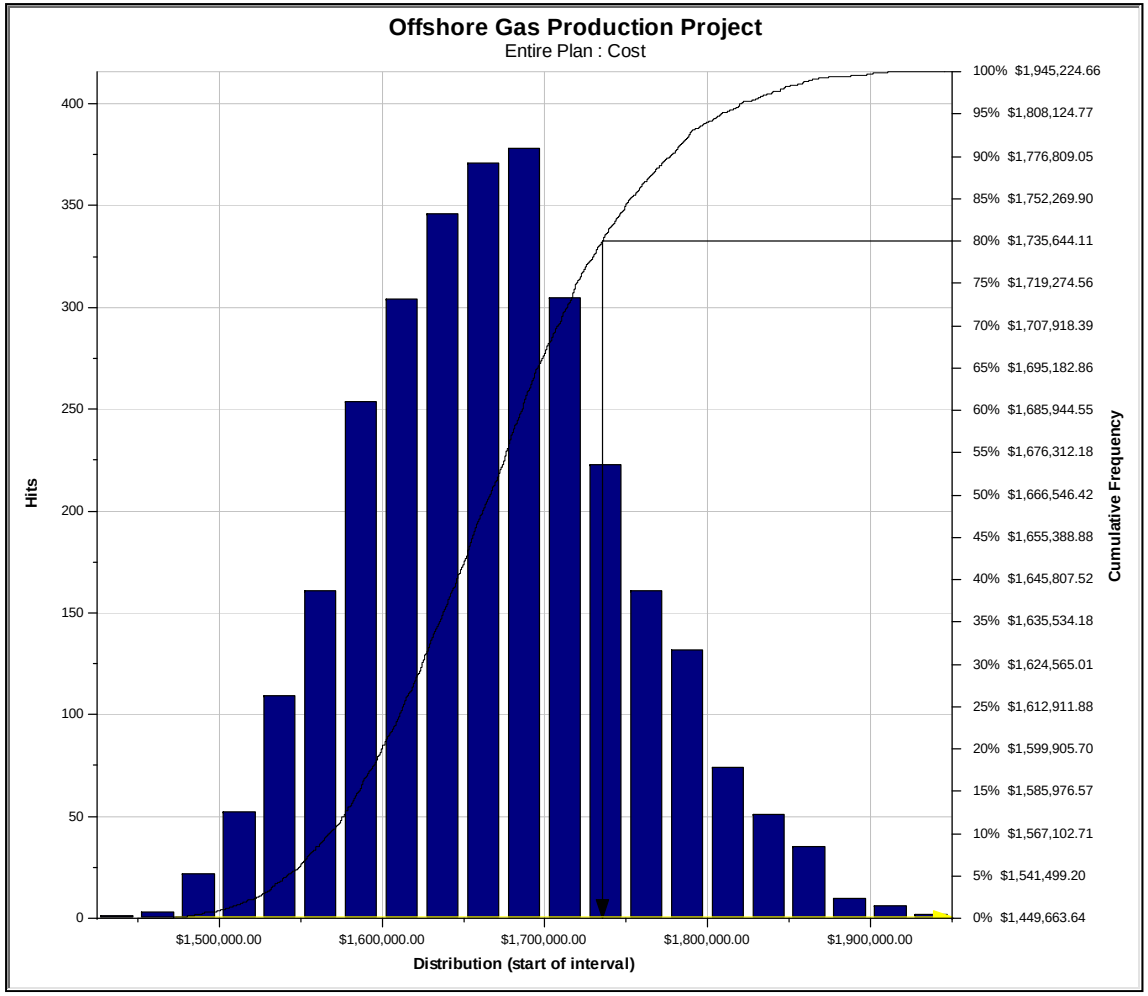
# Cost Risk Analysis Results

Baseline Cost $1,473 mil
P-80 Cost
$1,736 mil
18% contingency



# Where is the Cost Risk – by Resource

| Cost Contingency Breakdown by Resource | | | |
|---|---|---|---|
| | $ millions | | |
| Resource | Baseline | P-80 | % Contingency |
| Project Management Team | 31 | 43 | 39% |
| Engineering | 70 | 96 | 36% |
| Installation | 57 | 78 | 36% |
| Fabrication | 300 | 399 | 33% |
| Hook Up & Commissioning | 45 | 60 | 32% |
| Procurement | 850 | 945 | 11% |
| Drilling | 120 | 132 | 10% |
| TOTAL PROJECT | 1,473 | 1736 | 18% |

| Cost Contingency Breakdown by Type of Resource | | | |
|---|---|---|---|
| | $ millions | | |
| Type | Baseline | P-80 | % Contingency |
| Materials (Equipment, raw materials) | 850 | 945 | 11% |
| Labor (including rented equipment) | 623 | 797 | 28% |

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# Analysis of the Sources of Cost Contingency

| Source of Cost Contingency at the P-80 | | |
|---|---|---|
| | Total Cost | Contingency |
| Total Cost All-Risks | 1,736 | |
| Baseline Cost | 1,473 | 262 |
| | | Contribution to Contingency |
| Take Out all Schedule Risks | 1,631 | 105 |
| Take Out all Cost Risks | 1,581 | 155 |
| Interaction of Cost/Schedule Risks | | 2 |
| Total Contingency | | 262 |

40% of the risk to cost comes from risk to schedule, a common finding

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# Priority Risks to Cost Measured at P-80

| Prioritize Risks to Cost at the P-80 | | | |
|---|---|---|---|
| | $ millions | | |
| Total Project, All Risks | 1,736 | | |
| Baseline cost | 1,473 | | |
| Take Out Risk Events one at a time: | | $ millions saved | % of total contingency |
| Scope Growth may be more than expected | 1,685 | 51 | 19% |
| Company's Engineers' may be inexperienced | 1,624 | 61 | 23% |
| MTO, Specifications may not be ready ITB | 1,550 | 74 | 28% |
| Quality engineers may be scarce @ FAB, Suppliers | 1,525 | 25 | 10% |
| Problems interfacing Phases | 1,519 | 6 | 2% |
| LLE Suppliers may be busy | 1,514 | 5 | 2% |
| Experienced HUC resources availability | 1,511 | 3 | 1% |
| Subsea conditions may not be as expected | 1,509 | 2 | 1% |
| Take out the 3-point estimates | | | |
| Schedule duration estimate are uncertain | 1,473 | 36 | 14% |
| | | 262 | 100% |

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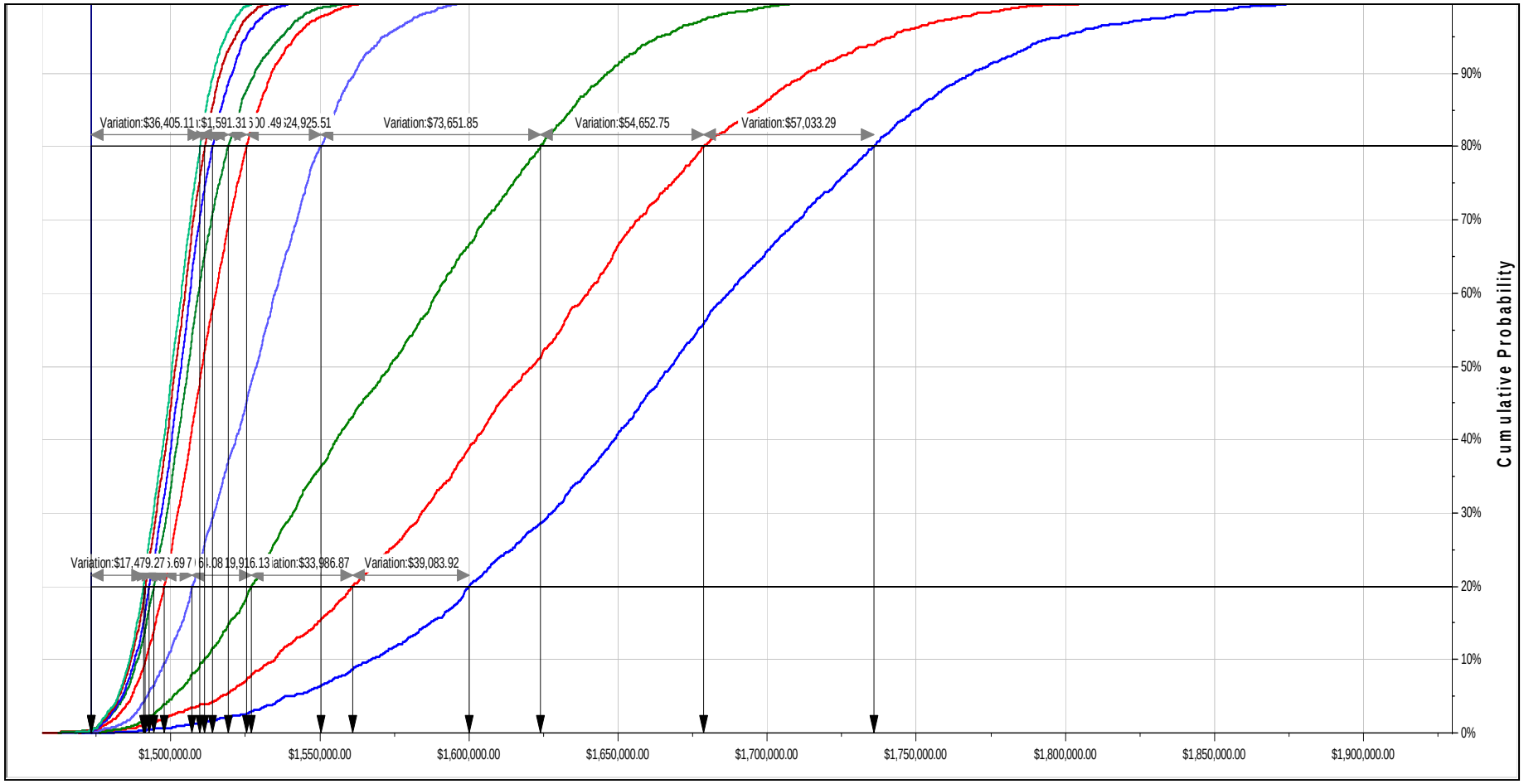
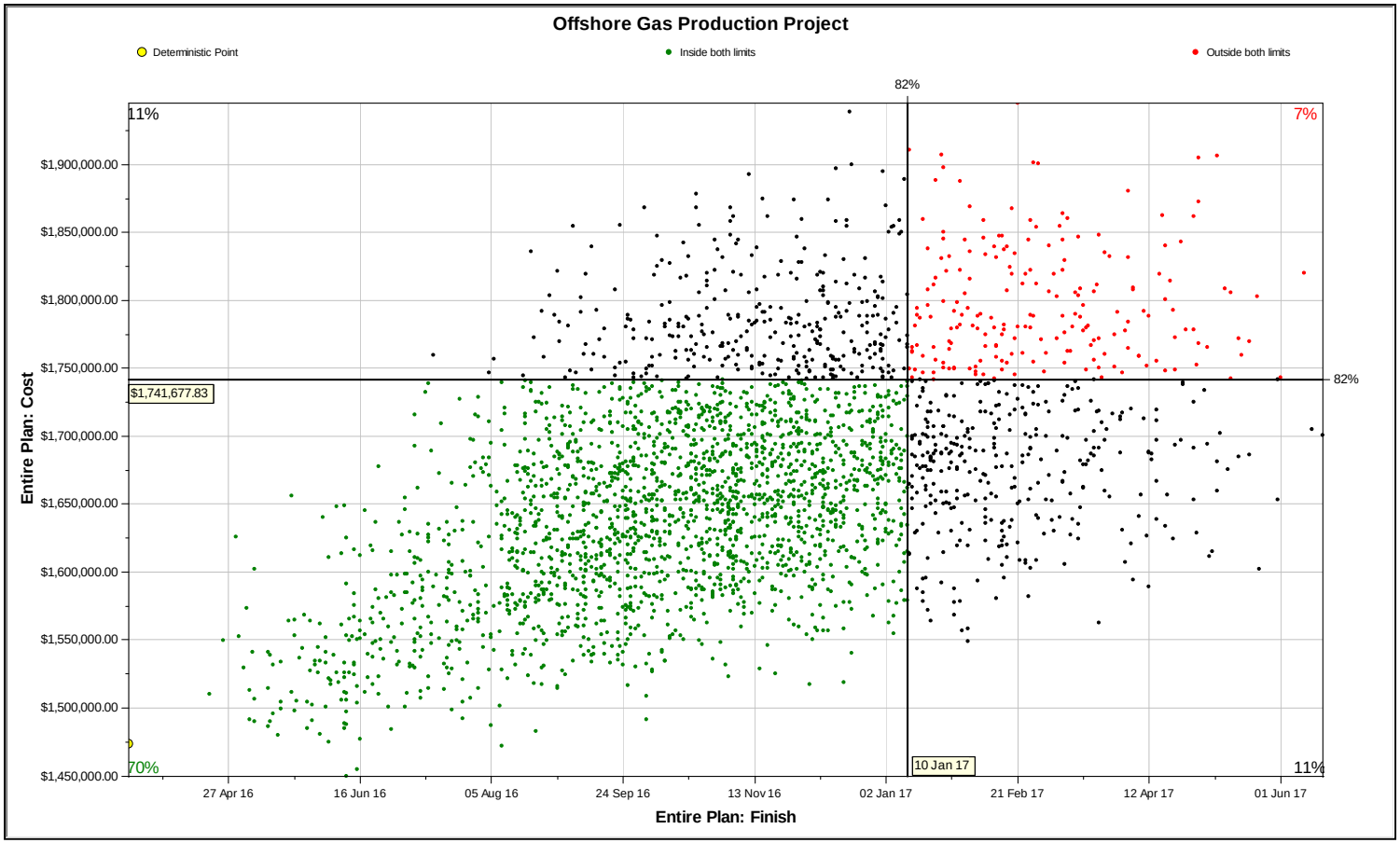
# Graphical Effect of Taking the Risks out One at a Time in Priority Order

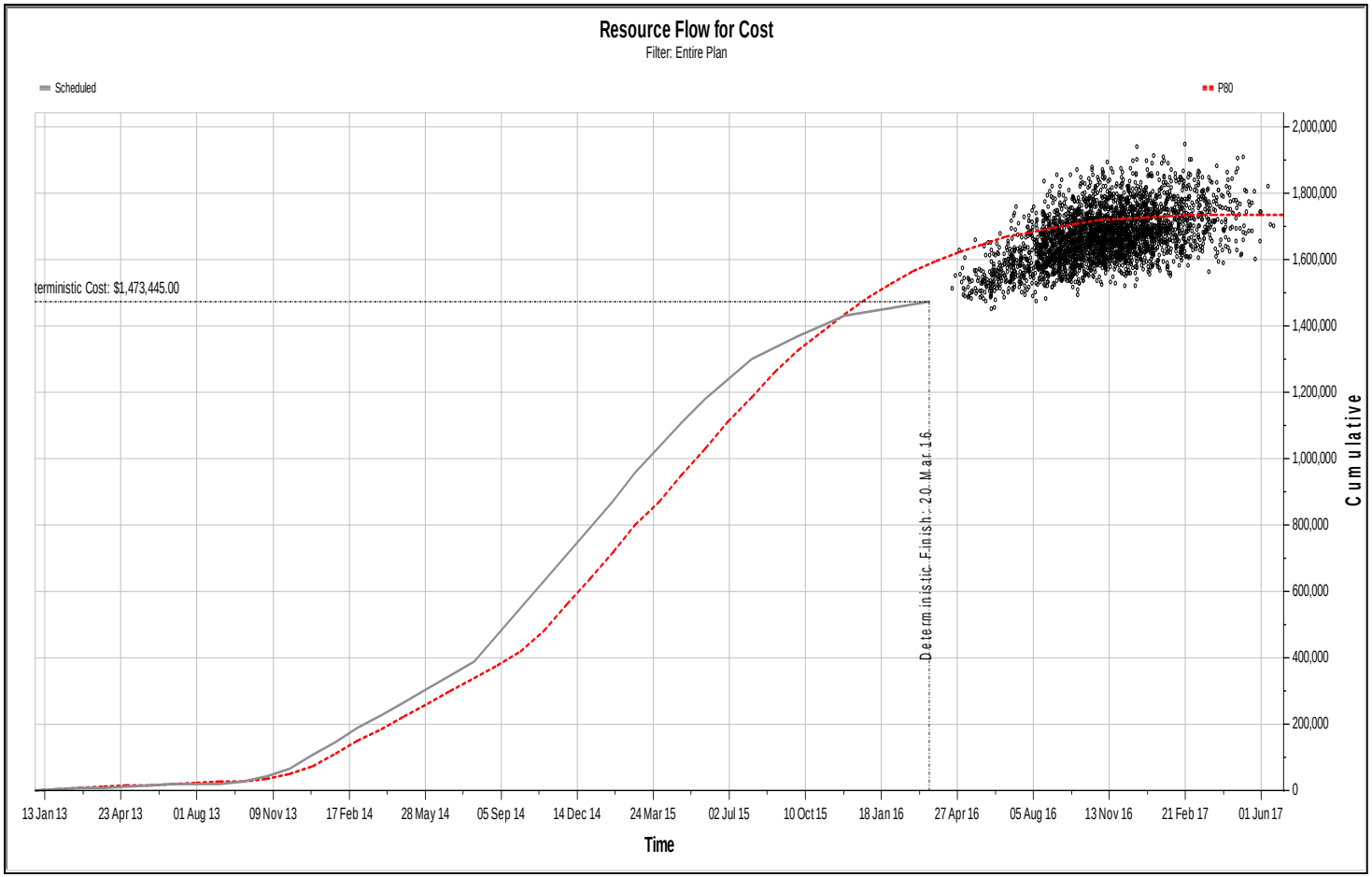


# Cost and Schedule are Correlated 51%




70% of the risk is in lower-left quadrant

# Probabilistic Cash Flow




Cumulative Monthly Cash Flow
- P-80
- Planned

# Analysis of a Risk Mitigation Scenario

| Risk Mitigation Scenario | | Schedule Impact | | | Cost Impact | | | First Gas Date | Project Cost ($ million) |
|---|---|---|---|---|---|---|---|---|---|
| | Probability | Low | Most Likely | High | Low | Most Likely | High | | |
| Risk to be Mitigated | Before Mitigation | | | | | | | | |
| Company's Engineers may be inexperienced | 85% | 90% | 110% | 130% | 95% | 100% | 110% | 6-Jan-17 | 1,735 |
| Proposed Mitigation: Increase Salaries for company Engineers to competitive levels | | | | | | | | | |
| | After Mitigation | | | | | | | | |
| Company's Engineers may be inexperienced | 20% | 90% | 100% | 110% | 100 | 105 | 115 | 14-Nov-16 | 1,714 |
| Improvement | | | | | | | | 53 | 21 |
| Cost of proposed Mitigation | | | | | | | | | 35 |
| Net Improvement from Mitigation | | | | | | | | 53 | -14 |

Spending $35 million for Engineers' salary is assessed to reduce the probability of this risk from 85% to 20%. Because the *schedule slippage is 53 days less* than before, there is $21 million we do not need to reserve and so the net cost impact of the mitigation at the P-80 is offset by $21 million, for a net cost of $14 million.

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# NASA Joint Confidence Level (JCL) policy

For implementation of each major program segment, all space flight and information technology programs are to be baselined or rebaselined and budgeted in accordance with the following:

a) There is a 70 percent probability (or a different probability that is approved by the decision authority) of achieving the stated life cycle cost and launch schedule

b) Projects are to be baselined or rebaselined and budgeted at confidence level consistent with the program's confidence level

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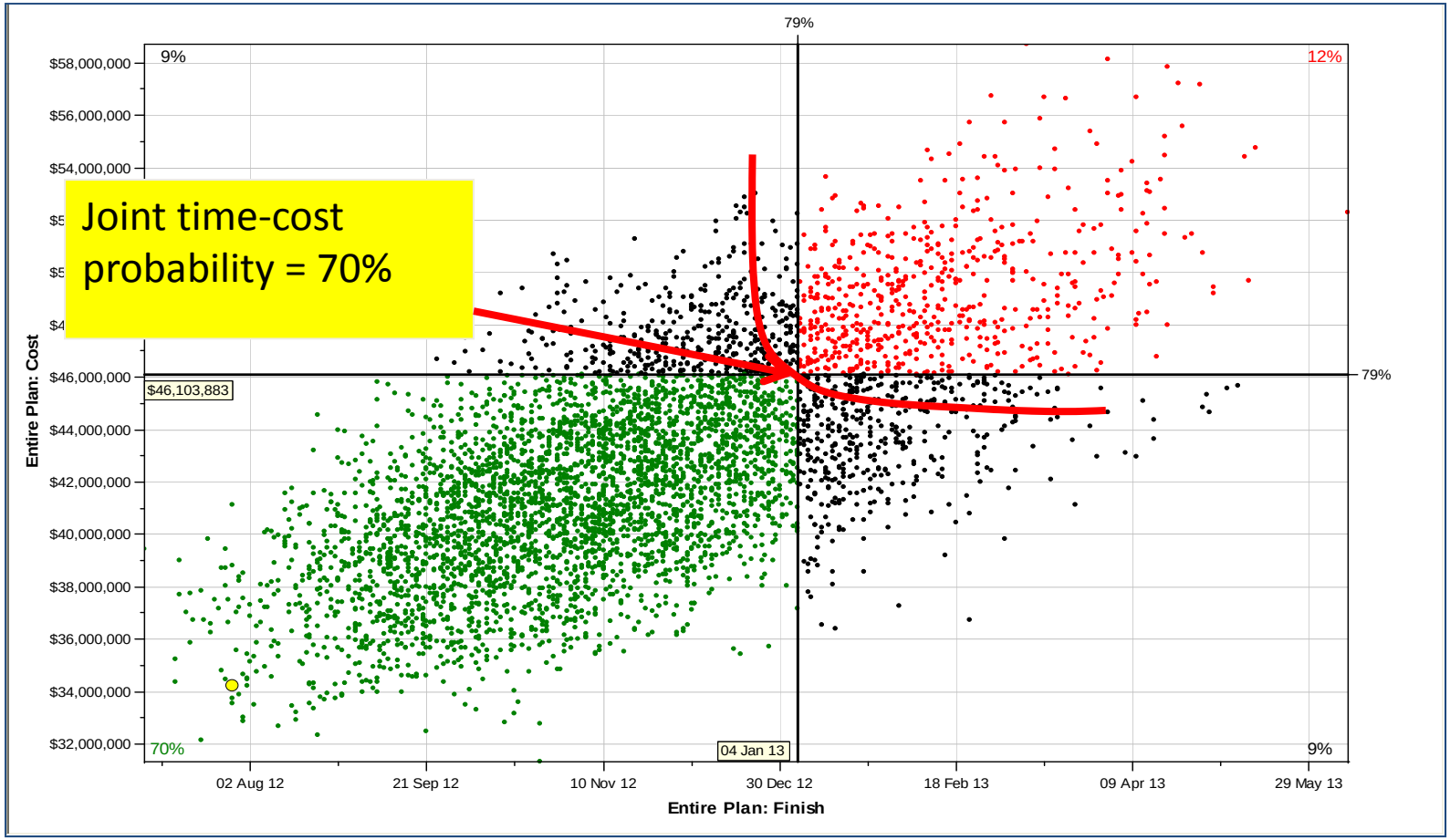
# JCL Results are on Indicated Contour Line




Joint time-cost probability = 70%

Time – Cost correlation is 69%

# Integrated Cost – Schedule Risk Analysis Using the Risk Driver Approach

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Hulett & Associates
24rd Annual International IPM Conference
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