Project Schedule and Cost Risk Analysis using Polaris®

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Hulett & Associates, LLC     Booz Allen Hamilton

September 2013

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Biographies

David Hulett Ph.D.

• 20 years quantitative schedule risk analysis, integrated cost-schedule risk analysis and project scheduling experience
• Author of risk management chapter in “Guide to the Project Management Body of Knowledge” (PMBOK® Guide)
• Lead for US Government Accountability Office (GAO) Scheduling Best Practices guide
• Author or two industry guides for schedule and integrated cost and schedule risk analysis
• Recognized for “significant contributions to the profession of project scheduling” by PMI College of Scheduling (2010)

Eric Druker CCE/A

• 8 years experience performing cost and schedule risk analysis for DoD, Intelligence, and Civilian government agencies as well as for commercial firms
• Lead for Booz Allen’s RealTime Analytics simulation technology capability (Polaris and Argo)
• Lead for Booz Allen’s JCL (integrated cost and schedule risk analysis) capability
• Performed first two JCLs at NASA
• 2009 and 2013 International Cost Estimating & Analysis Association (ICEAA) Analyst of the Year
• 2-time ICEAA Best Paper Award Winner
Polaris Overview

• Prototype built under NASA funding in 2009 to address gap in agency’s JCL (integrated cost and schedule risk analysis) capability
  – NASA found that, while several tools could do integrated cost and schedule risk analysis it was a primary focus of none of them

• First tool tailor made for integrated cost and schedule risk analysis
  – Compatible with MS Excel, MS Project, Primavera P6, and Active Risk Manager

• Uses Booz Allen’s RealTime Analytics Simulation Technology to achieve groundbreaking run-times

• In daily use on over 40 government programs across a variety of DoD, Intel, and Civilian agencies

• Overwhelming demand from government clients led Booz Allen to sell as COTS product in winter 2012
Agenda

• Some risk / uncertainty basics
  – Risk Drivers in series and in parallel
  – Correlation
  – Probabilistic activity
• Offshore Drilling Platform project schedule
• Adding Uncertainty to the activities’ durations
• Adding Risk Events from the Risk Register
• Integrating Cost and Schedule Risk Analysis
• Cost Uncertainty
• Cost responds to schedule risk
• Sensitivities
• Cost – completion date scatter diagram
There are 3 task dependent activities that do the work and one hammock (LOE) with the project management team to support the effort.
Import to Polaris

<table>
<thead>
<tr>
<th>UID</th>
<th>Activity</th>
<th>Start Date</th>
<th>End Date</th>
<th>Duration</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>29474</td>
<td>Polaris 3 Activity Case Study</td>
<td>1/1/2014</td>
<td>9/17/2014</td>
<td>186</td>
<td>$376,000</td>
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<td>92322</td>
<td>A1000 - Project Start</td>
<td>1/1/2014</td>
<td>1/1/2014</td>
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<td>$0</td>
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<td>92323</td>
<td>B1000 - Design</td>
<td>1/1/2014</td>
<td>3/21/2014</td>
<td>80</td>
<td>$64,000</td>
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<tr>
<td>92324</td>
<td>B1010 - Build</td>
<td>3/22/2014</td>
<td>8/18/2014</td>
<td>150</td>
<td>$240,000</td>
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<tr>
<td>92325</td>
<td>B1020 - Test</td>
<td>8/19/2014</td>
<td>9/17/2014</td>
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<td>$32,000</td>
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<tr>
<td>92326</td>
<td>Z9999 - Finish</td>
<td>9/18/2014</td>
<td>9/18/2014</td>
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<td>$0</td>
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<tr>
<td>92327</td>
<td>A1010 - PMT Hammock</td>
<td>1/1/2014</td>
<td>9/17/2014</td>
<td>260</td>
<td>$40,000</td>
</tr>
</tbody>
</table>
Specify the Risk Driver

In this example the Design Risk A has an 80% likelihood (occurs in 8,000 of 10,000 iterations) and an impact chosen from a triangular distribution of 90% - 110% - 125% of the original 80-day duration if it occurs
Add a Risk Driver to Design Activity

With one risk the P-80 duration of Design increases from 80 days to 89 days

The histogram “spike” represents the 20% likelihood of the risk’s not happening
Three Risks Applied to One Activity in Parallel

If the three 80% likely risks are applied in Parallel the P-80 duration for Design is 93 days.

Applying risks in series or parallel only matters when two or more risks occur together in any iteration.
If the three 80% likely risks are applied in Series the P-80 duration for Design is 103 days. Applying risks in series or parallel only matters when two or more risks occur together in any iteration.
Adding Risk Drivers to the 3 Activities

For simplicity, each risk driver has 80% probability of occurring and impacts of 90% - 110% - 125%. Each activity has only one risk assigned.
One Path, Three Activities, Three Risks

The schedule date is 17 September 2013
The P-80 date is 16 October 2014
Uncertainty Applied to All Activities

Templated Uncertainty applies 3-point estimates (or other distributions) directly to the activities’ durations. 100% likely. Different ranges can be placed on different types of activities using Category.
Schedule Risk from Uncertainty
No Correlation

Uncertainty (100% likely) of triangular 0.8 – 1.1 – 1.4 no correlation
P-80 is 31 October 2014
In this case correlation is applied directly to the uncertain durations. We have chosen 100% correlation as the maximum, but that is the user’s choice. Also all 3 activities’ durations are correlated, the strongest correlation available
Schedule Risk Uncertainty Adding 100% Correlation

With perfect (100%) correlation the P-80 date is 10 November 2014
Add the Prospect of Failing the Test

Use a discrete risk with an impact measured in days to add a discrete duration to the testing activity, here with a 30% probability and a recovery time of 100d – 120d 200d
Possibility of Failing the Test

Given a 30% chance of failing the test and a recovery period as specified, the P-80 date is 11 February 2015. A bi-modal distribution may be created.
Next Steps

• Interest in conducting Polaris pilot?
Contact Information

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ADDITIONAL ANALYSIS
Offshore Gas Production Platform

Primavera P6 Schedule with Costs

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Name</th>
<th>Remaining Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Budgeted Total Cost</th>
<th>Total Float</th>
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<td>Total</td>
<td>Offshore Gas Production Platform</td>
<td>772</td>
<td>01-Jan-14</td>
<td>15-Dec-16</td>
<td>$1,648,200.00</td>
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<td>1.1</td>
<td>Milestones and Hammocks</td>
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<td>15-Dec-16</td>
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<td>Project Start</td>
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<td>$0.00</td>
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<td>Project Sanction</td>
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<td>19-Jul-14</td>
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<td>0</td>
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<td>A1020</td>
<td>First Gas</td>
<td>0</td>
<td>15-Dec-16</td>
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<td>$0.00</td>
<td>0</td>
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<tr>
<td>A1030</td>
<td>Project Management Hammock</td>
<td>1080</td>
<td>01-Jan-14</td>
<td>15-Dec-16</td>
<td>$200,000.00</td>
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<td>1.2</td>
<td>Decision Making</td>
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<td>31-May-14</td>
<td>19-Jul-14</td>
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<td>E1000</td>
<td>Approval Process</td>
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<td>19-Jul-14</td>
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<td>1.3</td>
<td>Engineering</td>
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<td>FEED</td>
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<td>30-May-14</td>
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<td>C1010</td>
<td>Detailed Engineering</td>
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<td>$80,000.00</td>
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<td>1.4</td>
<td>Procurement</td>
<td>650</td>
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<td>10-Mar-16</td>
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<tr>
<td>D1000</td>
<td>Procurement of LLE</td>
<td>650</td>
<td>31-May-14</td>
<td>10-Mar-16</td>
<td>$250,000.00</td>
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<td>D1010</td>
<td>Procurement of Other Equipment</td>
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<td>10-Mar-16</td>
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<td>1.5</td>
<td>Fabrication</td>
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<td>18-Jul-16</td>
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<td>E1000</td>
<td>Fabricate Drilling Topsides</td>
<td>370</td>
<td>18-May-15</td>
<td>15-May-16</td>
<td>$160,000.00</td>
<td>35</td>
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<td>E1010</td>
<td>Fabricate Drilling Jacket</td>
<td>370</td>
<td>18-May-15</td>
<td>15-May-16</td>
<td>$80,000.00</td>
<td>15</td>
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<tr>
<td>E1020</td>
<td>Fabricate CPP Topsides</td>
<td>330</td>
<td>18-May-15</td>
<td>09-Apr-16</td>
<td>$240,000.00</td>
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<td>E1025</td>
<td>Install LLE and Other Equipment</td>
<td>160</td>
<td>10-Apr-16</td>
<td>18-Jul-16</td>
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<td>E1030</td>
<td>Fabricate CPP Jacket</td>
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<td>18-Jun-16</td>
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<td>1.6</td>
<td>Drilling</td>
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<td>04-Ju-16</td>
<td>30-Nov-16</td>
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<td>F1000</td>
<td>Drilling for First Gas</td>
<td>150</td>
<td>04-Ju-16</td>
<td>30-Nov-16</td>
<td>$80,000.00</td>
<td>15</td>
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<tr>
<td>1.7</td>
<td>Installation</td>
<td>90</td>
<td>20-May-16</td>
<td>17-Aug-16</td>
<td>$47,000.00</td>
<td>0</td>
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<td>G1000</td>
<td>Install Drilling Platform Jacket</td>
<td>20</td>
<td>20-May-16</td>
<td>05-Jun-16</td>
<td>$8,000.00</td>
<td>15</td>
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<tr>
<td>G1010</td>
<td>Install Drilling Topsides</td>
<td>25</td>
<td>09-Jun-16</td>
<td>03-Jul-16</td>
<td>$13,600.00</td>
<td>15</td>
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<tr>
<td>G1020</td>
<td>Install CPP Jacket</td>
<td>20</td>
<td>19-Jun-16</td>
<td>08-Jul-16</td>
<td>$9,600.00</td>
<td>10</td>
</tr>
<tr>
<td>G1030</td>
<td>Install CPP Topsides</td>
<td>30</td>
<td>29-Jul-16</td>
<td>17-Aug-16</td>
<td>$16,000.00</td>
<td>0</td>
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<tr>
<td>1.8</td>
<td>HUC</td>
<td>120</td>
<td>18-Aug-16</td>
<td>15-Dec-16</td>
<td>$64,000.00</td>
<td>0</td>
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<tr>
<td>H1000</td>
<td>Hook UP and Commissioning for Fire</td>
<td>120</td>
<td>18-Aug-16</td>
<td>15-Dec-16</td>
<td>$64,000.00</td>
<td>0</td>
</tr>
</tbody>
</table>
Resources

Resources are generalized and intended to put the entire (not-risk-adjusted) budget into the schedule.

Resources are designated Labor or Material. Labor resources are cost time-dependent and will cost more if the activity takes longer. Material resources are cost time-independent, may be risky but not because of schedule risk. These resources and the activity durations are based on 7-day calendars to avoid any weekend effects. Of course Polaris can handle calendars.
Schedule Imported into Polaris
Details, such as “Task has no predecessors” are shown. The “High Duration” is highlighted. Activities are long because the schedule is summary with 3 years’ duration shown in 17 activities and 3 milestones.
Add Basic Uncertainty and Estimating Error to Schedule Durations

This range (.9 – 1.05 – 1.2) represents basic uncertainty and a slightly-biased estimating error. These will probably have to be lived with since they are inherent, not events that can be mitigated. These will be applied to all activities or can be applied differentially to activity types as reference ranges.
Schedule Risk with Inherent Uncertainty and Duration Estimating Bias

The P-9- date of 28 March 2017 uses the default correlation value of 30%. With correlation at 0% the date is 20 March 2017. With 100% correlation it is 5 April 2017.
Cost Risk with Uncertainty and Schedule Estimating Error Only

Cost Estimate is $1.65 billion
P-80 is $1.75 billion with uncertainty and schedule estimating error
Cost and time are 92% correlated since cost varies only as durations cause time-dependent resource cost to vary.
Here, the risk “Installation productivity may not be as good as assumed” is assigned to all 4 Installation activities. It is assigned 30% probability and a triangular distribution with multiplicative factors of .9 - 1.1 - 1.20. For simplicity all Risk Drivers have the same impact but they have their own probabilities.
Schedule Risk with Risk Drivers Added

The P-80 date is now 21 July 2017. The Risk Drivers added nearly 4 months.
Cost risk is now $1.87 billion at P-80, all due to longer durations. There is no cost risk except that caused by the effect of schedule risk on time-dependent resources.
There is no cost risk except that caused by the effect of schedule risk on time-dependent resources. Cost finish date correlation is 92%.
Add Cost Burn Rate Uncertainty for Risk Drivers with Labor Resources

For cost of labor resources there may also be uncertainty on the daily rate, we have used $0.95 – 1.05 – 1.15$ for each.

The Cost Factor generates cost uncertainty independent of the schedule risk.

Notice that the “EPC Contractor quality is questionable” is placed on all activities.” Notice the risks are inserted in series, not in parallel.
Cost Risk with Uncertainty added to the Burn Rate of Labor Resources

The P-80 for cost is now $1.95 billion
Scatter with uncertainty, schedule and Burn Rate Drivers

With Uncertainty and risk drivers on schedule and burn rate the correlation between cost and finish date is 84%
There was schedule risk on Procurement of Equipment but no cost risk since it is a material (time-independent resource). This action causes cost risk to affect total cost of procured equipment using \(0.85 - 1.1 - 1.3\).
Adding cost risk (burn rate, total procurement) The P-80 increases to $1.97 billion. The schedule risk is unaffected by adding cost risks
Uncertainty, Schedule Risk Drivers and Cost Risk Drivers

With cost risk added there is more scatter, the link between cost risk and schedule risk is looser – cost risk is greater even if the schedule were perfect. With cost risk added correlation is 84%
Schedule Criticality Index

Standard Criticality Index for activities
Sensitivity by Activity

Standard sensitivity tornado by activity
Impact on Schedule by Risk

Impact on finish date by RISK
Impact on Cost by Risk

Impact on cost of RISKS, includes direct impact on burn rate and time-independent costs and indirect impact from risks’ affecting time-dependent costs
View shows P-80 scenario

The P-80 results compared to planned start – Green = CPM Starts, Blue = CPM Finishes, Bars = P-80 dates
Where Risks are Assigned, the Planned Critical Path and Risk Criticality
Color shows Percentile Dates
Analysis shows project has three, parallel, critical paths – potentially creating a risk for significant schedule growth.
Scatter Plot with Trend Line and Color to Show Percentiles
Joint Cost-Time Confidence Level (JCL) at the 70th percentile as used by NASA
Prioritize Risks Using Tornado Chart

Repeat, showing the sensitivity of finish date to RISKS
# Prioritizing Risk Drivers to Finish First Gas at P-80

## Prioritized Risks to Schedule

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Risk Name</th>
<th>Baseline Date</th>
<th>P-80 Date</th>
<th>All Risks Included</th>
<th>Calendar Days Saved</th>
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<tbody>
<tr>
<td>6</td>
<td>EPC contractor quality is questionable</td>
<td>6-16-Dec-16</td>
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<td>31-May-17</td>
<td>51</td>
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<tr>
<td>4</td>
<td>Fabrication at a new shipyard is problematic</td>
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<td>9-May-17</td>
<td>22</td>
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<td>3</td>
<td>Equipment suppliers may be overloaded</td>
<td></td>
<td></td>
<td>15-Apr-17</td>
<td>24</td>
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<tr>
<td>1</td>
<td>Engineering resources may be lacking</td>
<td></td>
<td></td>
<td>30-Mar-17</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Installation productivity may not be as good as assumed</td>
<td></td>
<td></td>
<td>28-Mar-17</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Subsea Conditions are not well characterized</td>
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<td></td>
<td>16-Dec-16</td>
<td>102</td>
</tr>
</tbody>
</table>

Risk Tornado risk order is: 6 – 1 – 3 – 4 – 2 – 5
This priority order is: 6 – 4 – 3 – 1 – (2-5)
Prioritizing Risk Drivers to Cost
# Prioritizing Risk Drivers to Cost at P-80

<table>
<thead>
<tr>
<th>Prioritized Risks to Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Cost</td>
</tr>
<tr>
<td>P-80 Cost</td>
</tr>
<tr>
<td>All Risks Included</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Risk Name</th>
<th>Cost</th>
<th>Millions Saved</th>
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</thead>
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<td>6</td>
<td>EPC contractor quality is questionable</td>
<td>1.88</td>
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<td>Fabrication at a new shipyard is problematic</td>
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<td>Equipment suppliers may be overloaded</td>
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<td>2</td>
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<td>0.01</td>
</tr>
<tr>
<td>5</td>
<td>Subsea Conditions are not well characterized</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Inherent uncertainty and duration estimation error</td>
<td>1.65</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Compare to the Annual Budget

This view shows that the $1.65 billion is OK only at the 1st percentile.
Setting the Percentile to the 80th

This analysis shows where the project will overrun its annual budget if it’s total finish schedule is set at the P-80
Reviewing Resource Utilizations

This analysis shows the project’s installation resources are over utilized in 2016.
Project Schedule and Cost Risk Analysis using Polaris®