Integrated Cost & Schedule Risk Analysis (ICSRA)

Improving Project Performance Through Advanced Risk Analysis

2014 ICEAA Conference – San Diego, CA

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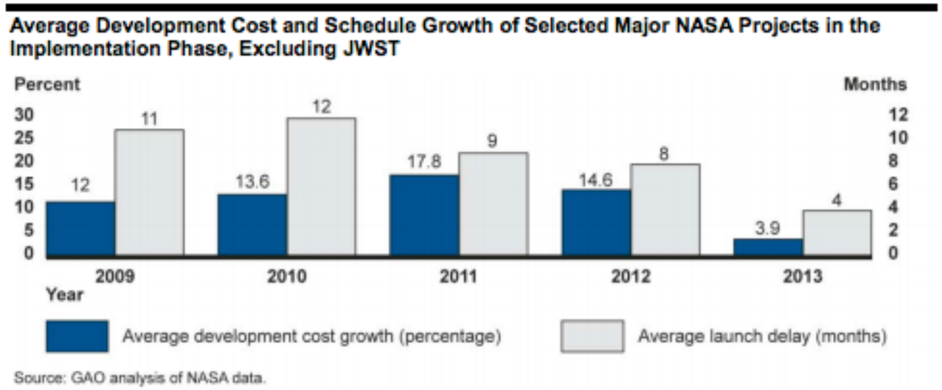
ICSRA in government started at NASA to address the lack of integration of project control disciplines

- In 2009, NASA was facing a challenge of extraordinary cost and schedule growth across their portfolio of programs
- In response, NASA created their Joint Confidence Level (JCL) policy requiring programs be budgeted and planned based on integrated cost and schedule risk analyses.
- The JCL approach is the NASA name for Integrated Cost Schedule Risk Analysis or ICSRA.
- Impact of JCL policy was immediate and measurable: In 2013, the Government Accountability Office conducted an independent review of NASA programs finding cost growth and schedule delays had been reduced to 1/3rd of 2009 levels, mainly because of better estimating of cost and schedule taking into account project risks.



Source: NASA – Assessments of Selected Large-Scale Projects. GAO Report: GAO-13-276SP. April 2013

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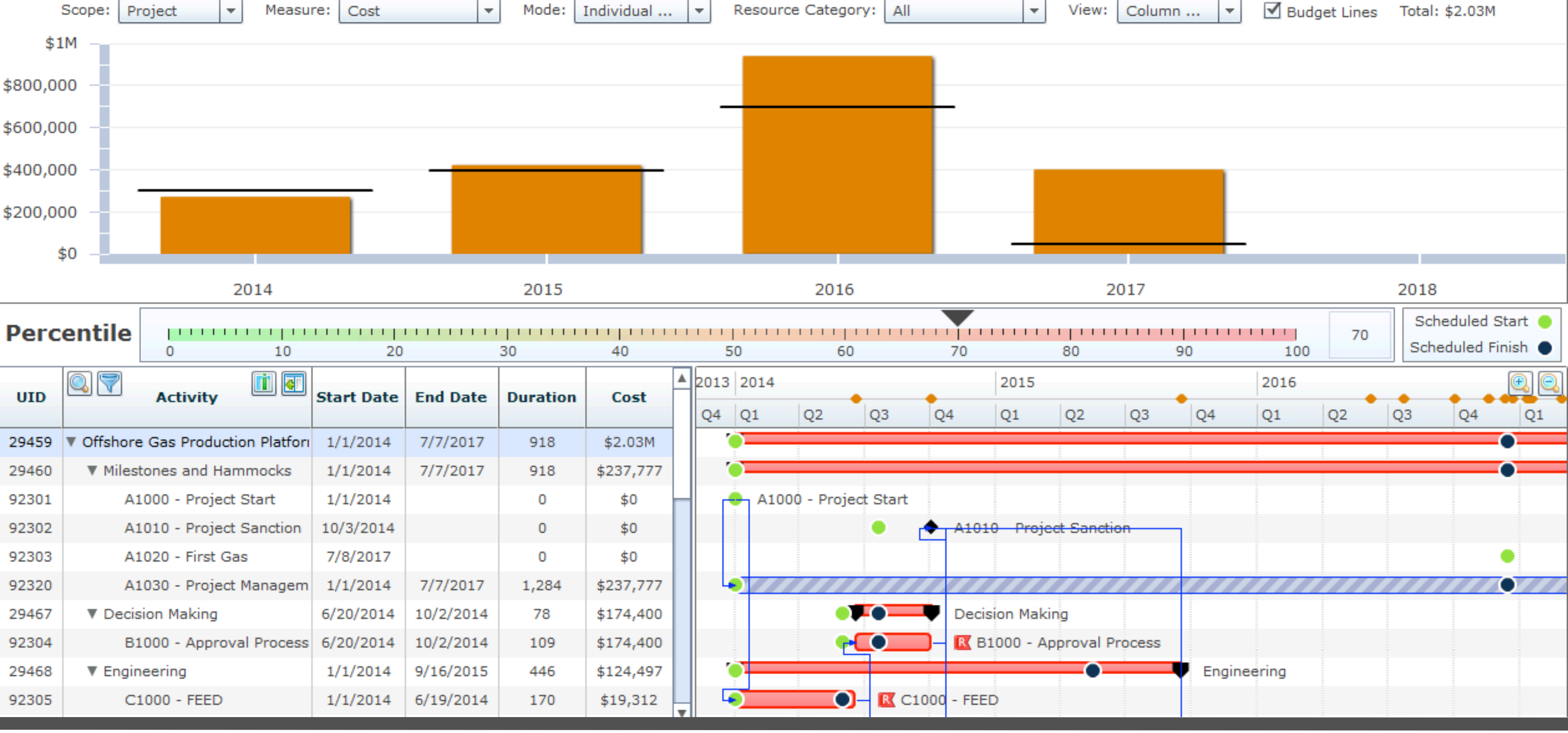
ICSRA typically involves four steps

1. Integrate
   - ICSRA integrates cost estimates, schedules, and risk registers into a single analytical model, providing a cohesive view of the three project controls functions
2. Predict
   - ICSRA forecasts future cost and schedule growth allowing project managers to identify challenge areas and set reserve levels based on quantitative analysis
3. Analyze
   - Analysis should be used to identify lead sources of cost and schedule risk, empowering the project management team to identify actions for improving project performance
4. Mitigate
   - Analysis should be set up so that project managers can run what-if analyses in real-time to test out impacts of mitigative actions



ICSRA Model Demo

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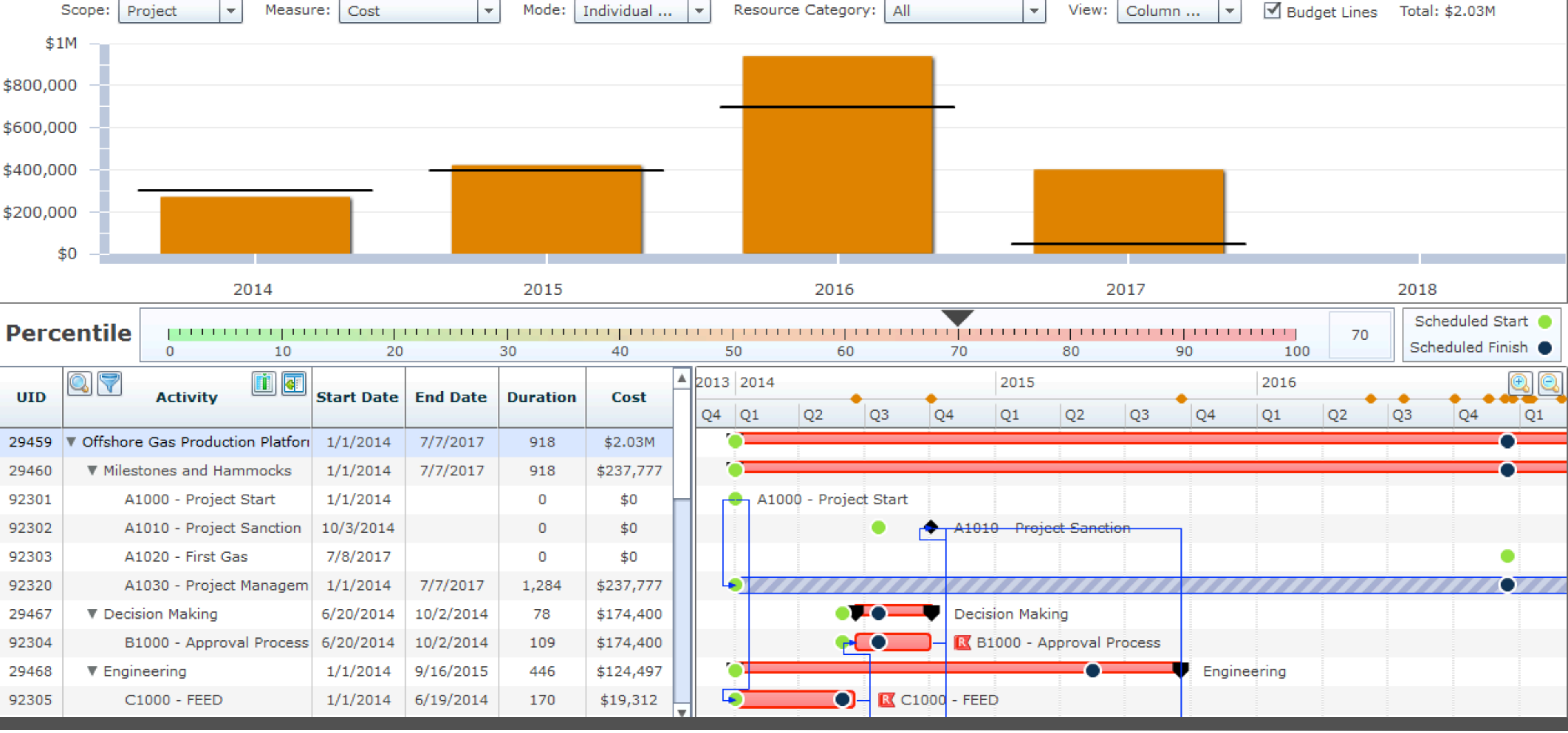

ICSRA Training

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Today's training will provide you with the opportunity to gain hands-on experience with one product optimized for ICSRA

- Training is not meant to be comprehensive but rather to provide a primer on how to perform an ICSRA
  - One, two, and three day ICSRA training courses – including Polaris tool training - are available from the Booz Allen Hamilton/Hulett & Associates team
  - Jumpstart consulting support is also available if you would like help standing up a ICSRA capability within your organization
- Agenda:
  - Fundamental theory of ICSRA
  - Preparing a schedule for ICSRA
  - Preparing a cost estimate for ICSRA
  - Preparing a risk register for ICSRA
  - Quantifying Uncertainty
  - Performing a ICSRA and analyzing the results

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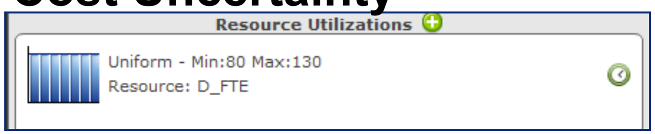
ICSRA models are typically analyzed using Monte Carlo simulations with inputs described as distributions

- The fundamental theory of Integrated Cost Schedule Risk Analysis is:
  - If we can view cost, schedule, and risk as uncertain events, and assign probability distributions to them, then we can use Monte Carlo Simulations to predict their combined impact on project performance

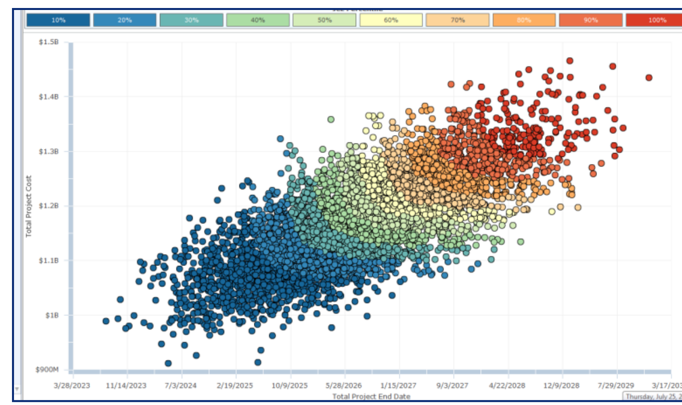
Schedule Uncertainty

Cost Uncertainty



Risk Events/Drivers

POLARIS =



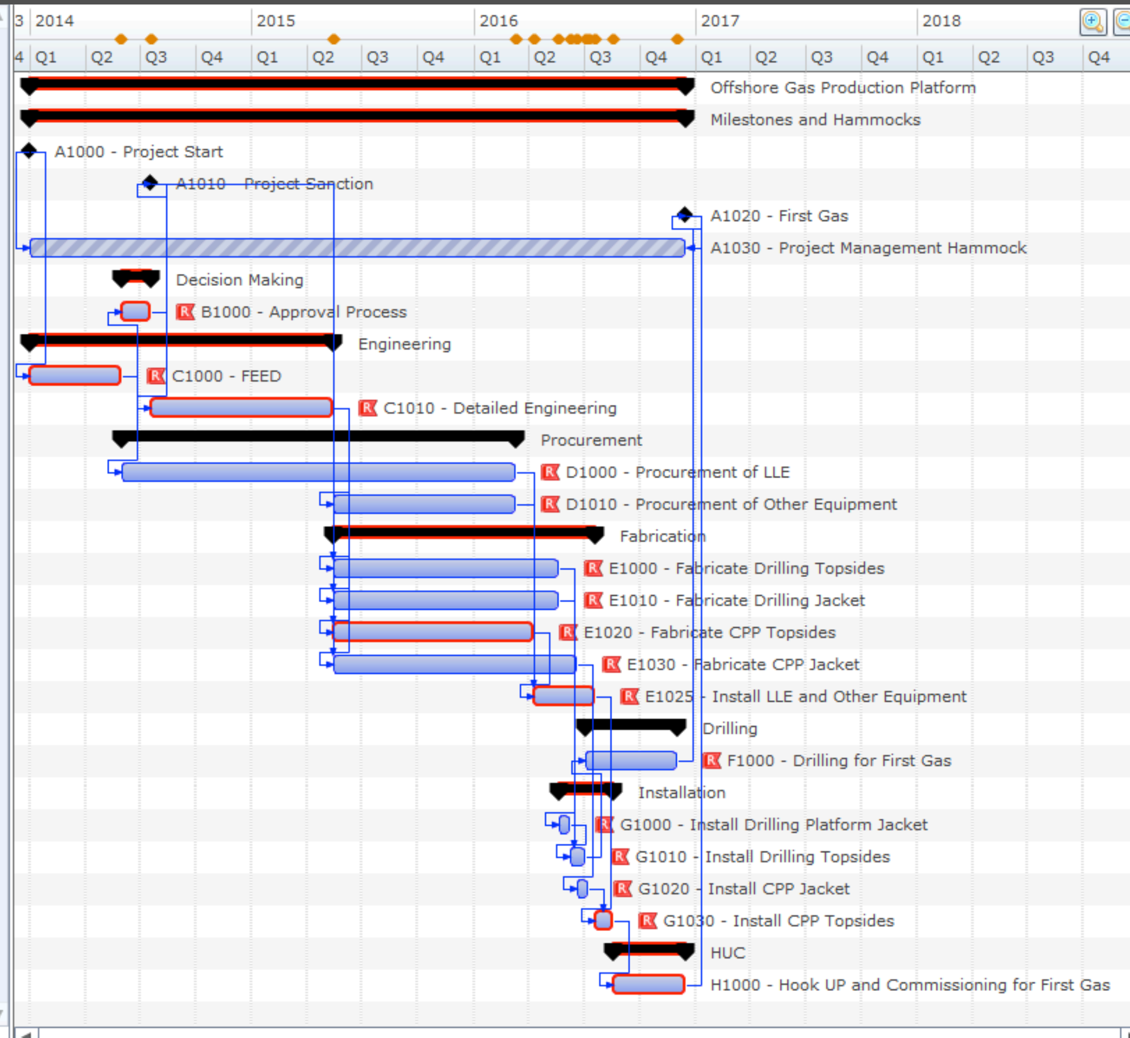
5,000 Simulation Trials

Polaris uses a transparent and well documented methodology, endorsed by NASA and DoD and used by commercial companies, to predict cost and schedule growth

- ICSRA allows uncertainty to be defined around all of the project controls artifacts
- Schedule
  - Schedule uncertainty can be quantified around baseline durations
  - Uncertainty can represent inherent variability, estimating error and estimating bias
- Cost
  - Uncertainty can be applied around the burn rate for time-dependent costs and around the total cost for time-independent costs
  - Phasing profiles allow costs to be spread according to when they are likely to occur
- Risk
  - Risk events are quantified in terms of their probability of occurrence, and cost and schedule impacts to various tasks in the schedule should they occur
  - Risks can be applied as additive (discrete risks) or multiplicative (risk drivers)
  - Risks can be applied to multiple activities, and some activities will have multiple risks

Baseline schedule shows the cost estimate, schedule, and risk register in a single cohesive view

UID	Activity	Start Date	End Date	Duration	Cost
29459	▼ Offshore Gas Production Platfor	1/1/2014	12/15/2016	772	$1.65M
29460	▼ Milestones and Hammocks	1/1/2014	12/15/2016	772	$200,000
92301	A1000 - Project Start	1/1/2014		0	$0
92302	A1010 - Project Sanction	7/20/2014		0	$0
92303	A1020 - First Gas	12/16/2016		0	$0
92320	A1030 - Project Managem	1/1/2014	12/15/2016	1,080	$200,000
29467	▼ Decision Making	5/31/2014	7/19/2014	35	$80,000
92304	B1000 - Approval Process	5/31/2014	7/19/2014	50	$80,000
29468	▼ Engineering	1/1/2014	5/15/2015	358	$96,000
92305	C1000 - FEED	1/1/2014	5/30/2014	150	$16,000
92306	C1010 - Detailed Enginee	7/20/2014	5/15/2015	300	$80,000
29469	▼ Procurement	5/31/2014	3/10/2016	464	$425,000
92307	D1000 - Procurement of L	5/31/2014	3/10/2016	650	$250,000
92308	D1010 - Procurement of C	5/16/2015	3/10/2016	300	$175,000
29470	▼ Fabrication	5/16/2015	7/18/2016	306	$656,000
92309	E1000 - Fabricate Drilling	5/16/2015	5/19/2016	370	$160,000
92310	E1010 - Fabricate Drilling	5/16/2015	5/19/2016	370	$80,000
92311	E1020 - Fabricate CPP To	5/16/2015	4/9/2016	330	$240,000
92312	E1030 - Fabricate CPP Jac	5/16/2015	6/18/2016	400	$96,000
92321	E1025 - Install LLE and Ot	4/10/2016	7/18/2016	100	$80,000
29471	▼ Drilling	7/4/2016	11/30/2016	108	$80,000
92313	F1000 - Drilling for First G	7/4/2016	11/30/2016	150	$80,000
29472	▼ Installation	5/20/2016	8/17/2016	64	$47,200
92314	G1000 - Install Drilling Pla	5/20/2016	6/8/2016	20	$8,000
92315	G1010 - Install Drilling To	6/9/2016	7/3/2016	25	$13,600
92316	G1020 - Install CPP Jacke	6/19/2016	7/8/2016	20	$9,600
92317	G1030 - Install CPP Topsi	7/19/2016	8/17/2016	30	$16,000
29473	▼ HUC	8/18/2016	12/15/2016	86	$64,000
92319	H1000 - Hook UP and Con	8/18/2016	12/15/2016	120	$64,000



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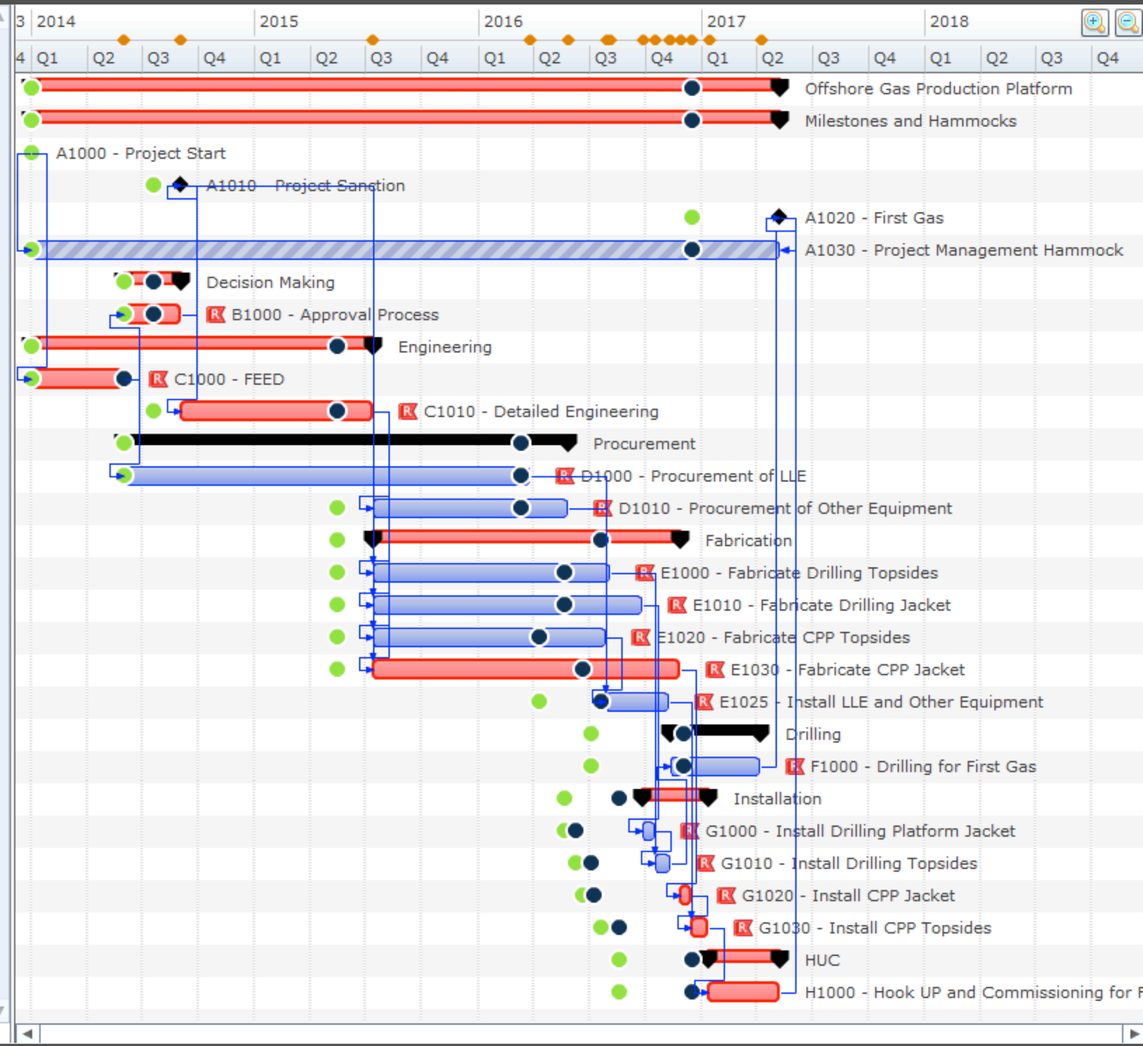
In this iteration of the simulation, the critical path has shifted and both cost and schedule grew considerably

UID	Activity	Start Date	End Date	Duration	Cost
29459	▼ Offshore Gas Production Platfor	1/1/2014	5/8/2017	874	$1.92M
29460	▼ Milestones and Hammocks	1/1/2014	5/8/2017	874	$226,666
92301	A1000 - Project Start	1/1/2014		0	$0
92302	A1010 - Project Sanction	9/2/2014		0	$0
92303	A1020 - First Gas	5/9/2017		0	$0
92320	A1030 - Project Managem	1/1/2014	5/8/2017	1,224	$226,666
29467	▼ Decision Making	6/1/2014	9/1/2014	66	$148,800
92304	B1000 - Approval Process	6/1/2014	9/1/2014	93	$148,800
29468	▼ Engineering	1/1/2014	7/12/2015	398	$99,840
92305	C1000 - FEED	1/1/2014	5/31/2014	151	$16,107
92306	C1010 - Detailed Enginee	9/2/2014	7/12/2015	314	$83,733
29469	▼ Procurement	6/1/2014	5/26/2016	519	$425,000
92307	D1000 - Procurement of L	6/1/2014	3/25/2016	664	$250,000
92308	D1010 - Procurement of C	7/13/2015	5/26/2016	319	$175,000
29470	▼ Fabrication	7/13/2015	11/26/2016	360	$823,705
92309	E1000 - Fabricate Drilling	7/13/2015	8/3/2016	388	$177,471
92310	E1010 - Fabricate Drilling	7/13/2015	9/26/2016	442	$101,085
92311	E1020 - Fabricate CPP To	7/13/2015	7/28/2016	382	$293,859
92312	E1030 - Fabricate CPP Jac	7/13/2015	11/26/2016	503	$127,690
92321	E1025 - Install LLE and Ot	7/29/2016	11/8/2016	103	$123,600
29471	▼ Drilling	11/10/2016	4/7/2017	107	$79,467
92313	F1000 - Drilling for First G	11/10/2016	4/7/2017	149	$79,467
29472	▼ Installation	9/27/2016	1/12/2017	78	$54,142
92314	G1000 - Install Drilling Pla	9/27/2016	10/15/2016	19	$8,113
92315	G1010 - Install Drilling To	10/16/2016	11/9/2016	25	$14,518
92316	G1020 - Install CPP Jacke	11/27/2016	12/14/2016	18	$9,223
92317	G1030 - Install CPP Topsi	12/15/2016	1/12/2017	29	$22,289
29473	▼ HUC	1/13/2017	5/8/2017	82	$61,867
92319	H1000 - Hook UP and Con	1/13/2017	5/8/2017	116	$61,867



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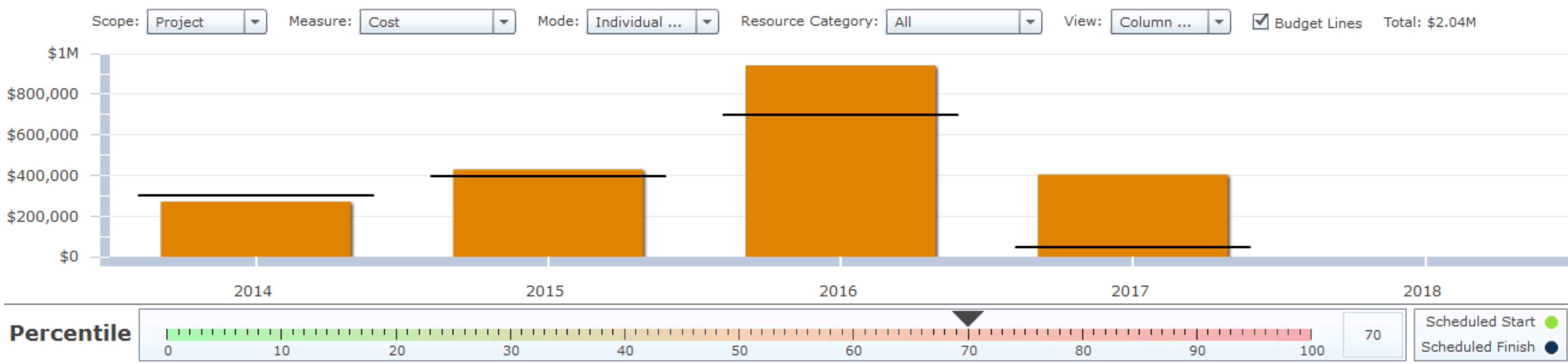
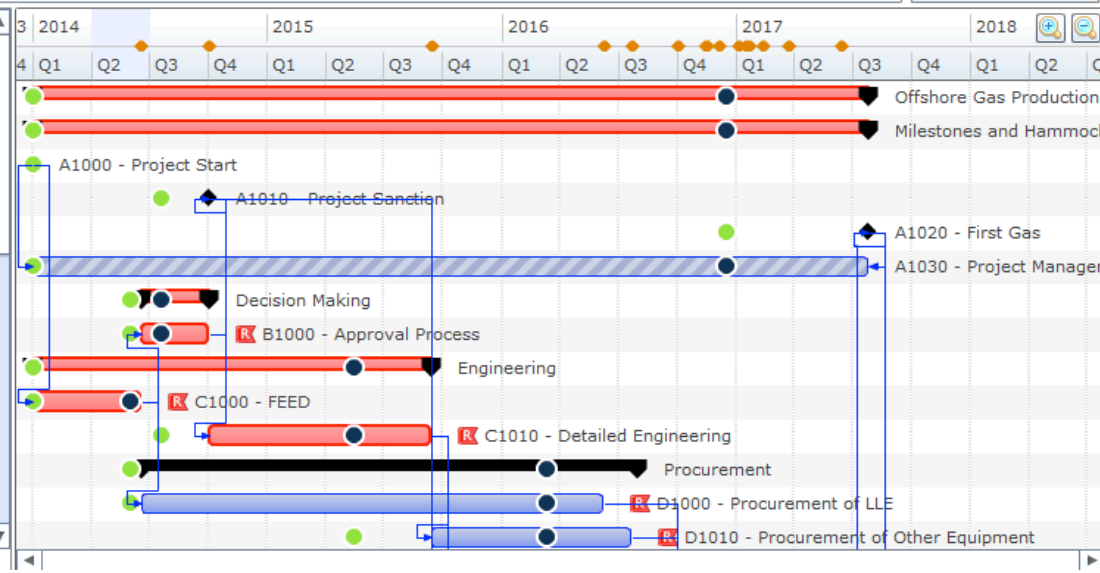
Thousands of iterations are combined to provide a risk-adjusted prediction of future cost and schedule growth



UID	Activity	Start Date	End Date	Duration	Cost
29459	▼ Offshore Gas Production Platfor	1/1/2014	7/26/2017	931	$2.04M
29460	▼ Milestones and Hammocks	1/1/2014	7/26/2017	931	$241,296
92301	A1000 - Project Start	1/1/2014		0	$0
92302	A1010 - Project Sanction	10/3/2014		0	$0
92303	A1020 - First Gas	7/27/2017		0	$0
92320	A1030 - Project Managem	1/1/2014	7/26/2017	1,303	$241,296
29467	▼ Decision Making	6/19/2014	10/2/2014	78	$176,000
92304	B1000 - Approval Process	6/19/2014	10/2/2014	110	$176,000
29468	▼ Engineering	1/1/2014	9/14/2015	444	$126,208
92305	C1000 - FEED	1/1/2014	6/18/2014	169	$19,163
92306	C1010 - Detailed Enginee	10/3/2014	9/14/2015	358	$107,773
29469	▼ Procurement	6/19/2014	7/29/2016	553	$447,676
92307	D1000 - Procurement of L	6/19/2014	6/8/2016	724	$272,676
92308	D1010 - Procurement of C	9/15/2015	7/21/2016	318	$175,000



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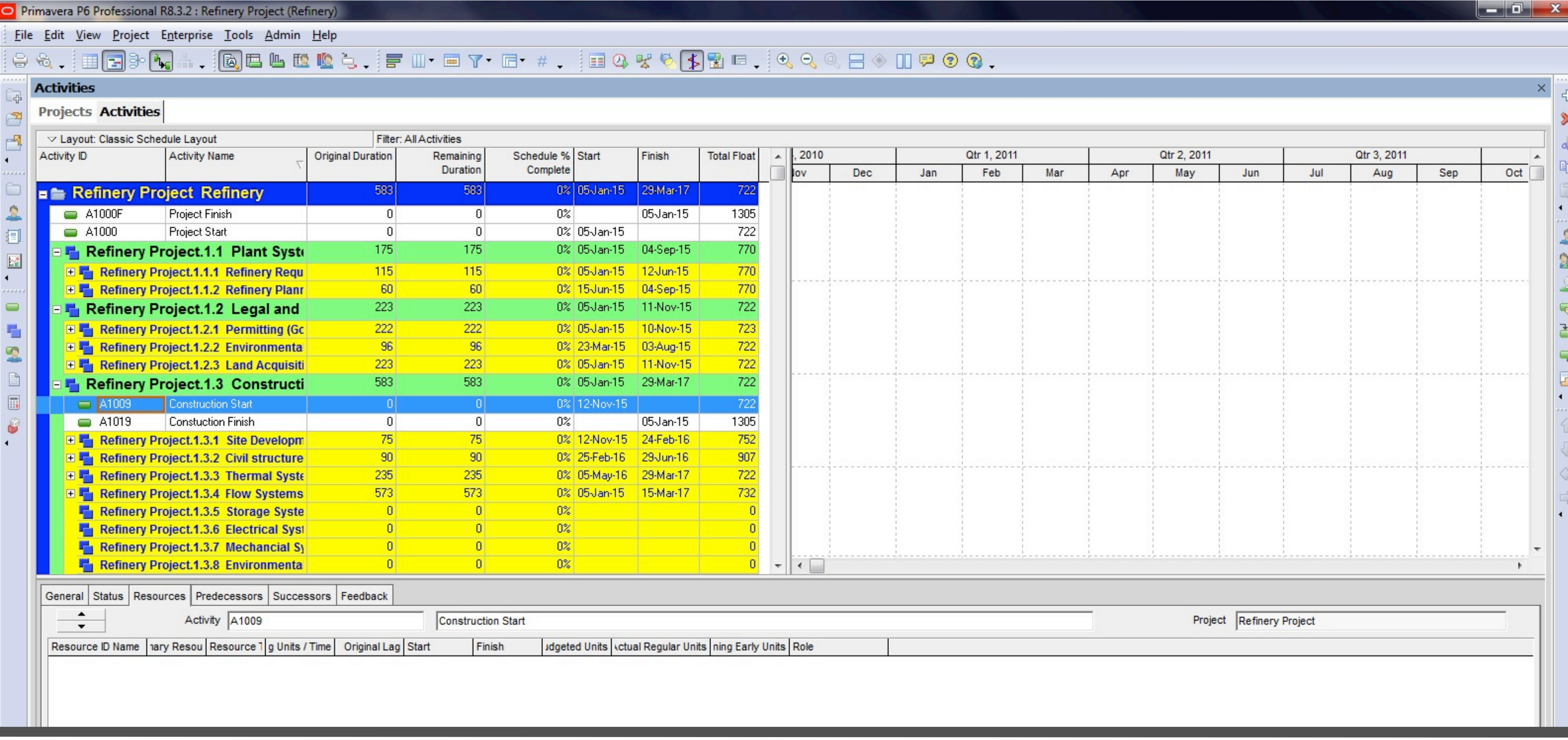

Preparing a Schedule for ICSRA

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The schedule is the most important component of a ICSRA as it is the backbone to which all other artifacts will link

- ICSRA simulations flex the schedules according to the applied uncertainty distributions and the risks that occur on any iteration; to that end, schedules must be conditioned prior to use in a ICSRA
  - A comprehensive schedule health check should be run to ensure the schedule is of high-quality
  - The schedule must be logically linked with no dangling activities to ensure downstream impacts of duration growth are captured.
  - Fundamentally, the dates should be determined by the logic and durations of their predecessors so if predecessors change the dates may change logically
  - Hard constraints should be removed and converted to “as soon as possible” or “start no earlier than” to allow the schedule to flex
  - Non-realistic relationships (such as artificial ones created across contracts) should be removed
- Since the ICSRA will calculate risk, which can then be used to set reserves, reserve should be removed from the schedule and the cost estimate
  - Some organizations have a policy of including schedule reserve as tasks within the schedule
  - These should be removed as otherwise they can push the schedule out further than realistic

Polaris has a built-in health check to provide a quick-look assessment of the schedule's quality against DCMA guidelines

Schedule Health Check DCMA | Rerun Schedule Health Check

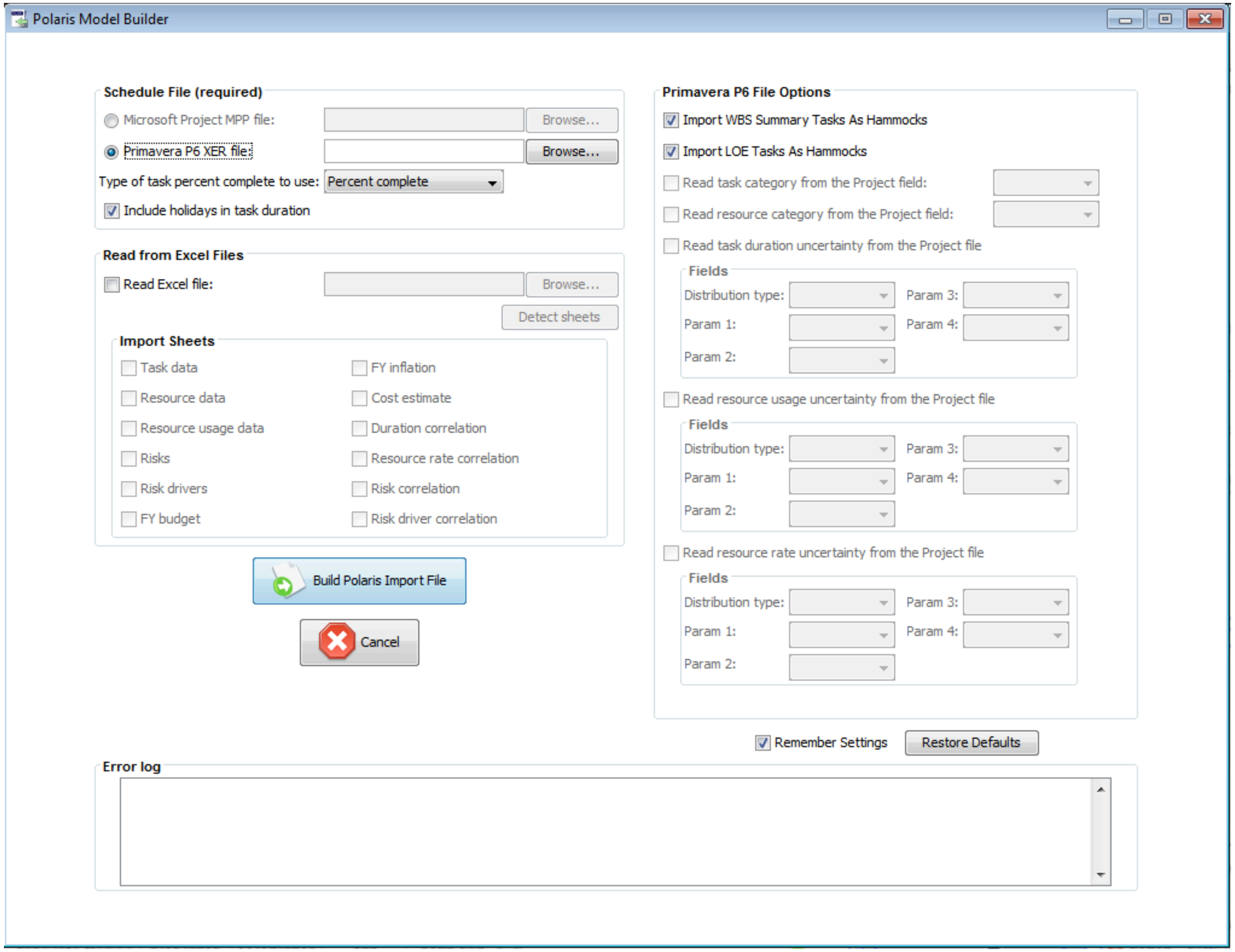
Metric	Score and Reason
Logic	5.3% (1/19 tasks) have a missing schedule relationship
Leads	0% (0/19 tasks) have lead time
Lags	0% (0/19 tasks) have lag time
Relationship Types	0% (0/19 tasks) have an improper schedule relationship
Hard Constraints	0% (0/19 tasks) have hard constraints
High Float	0% (0/19 tasks) have excessive float
Negative Float	0% (0/19 tasks) have negative float
High Duration	63.2% (12/19 tasks) have excessive duration
Invalid Forecast/Actual Dates	0% (0/19 tasks) have invalid dates
Resources	0% (0/20 tasks) have improper resources assigned
Missed Tasks	0% (0/19 tasks) have missed their finish dates
Critical Path Test	0 day(s) of float
Critical Path Length Index (CPLI)	1 CPLI
Baseline Execution Index (BEI)	1 BEI. 0% (0/0 tasks) prior to the status date were not completed

To check the viability of the schedule is to check it against CPM best scheduling practices.

There are 3rd party software packages such as Deltek Acumen FUSE, Steelray and the Primavera Risk Analysis Schedule Check report.

Filters, sorts and groupings of activities in the native schedule package can also be used.

Polaris imports schedules from Primavera P6 and Microsoft Project including the ability to import uncertainty inputs using custom fields



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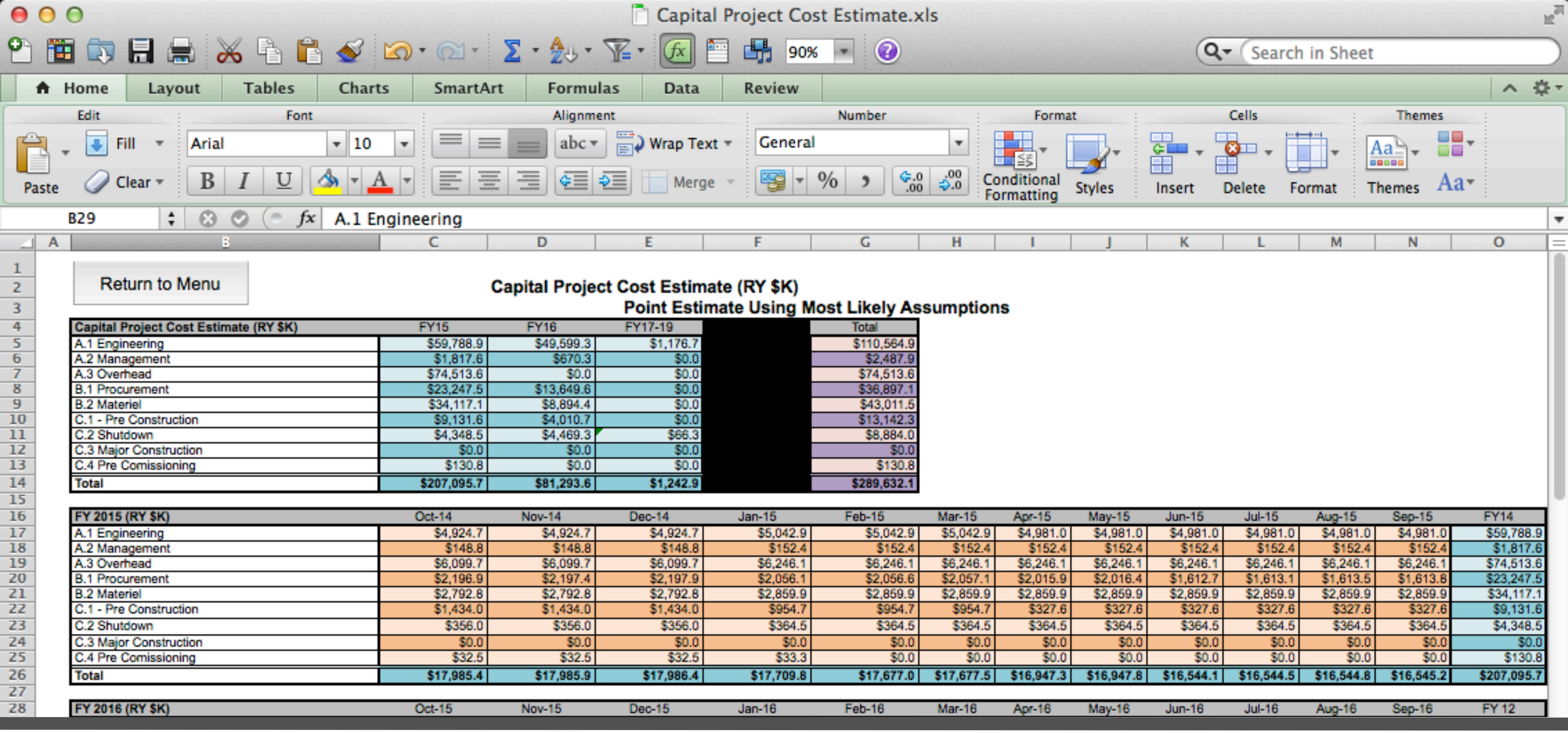

Capital Project Cost Estimate.xls

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Capital Project Cost Estimate (RY $K)

Point Estimate Using Most Likely Assumptions

Capital Project Cost Estimate (RY $K)	FY15	FY16	FY17-19		Total
A.1 Engineering	$59,788.9	$49,599.3	$1,176.7		$110,564.9
A.2 Management	$1,817.6	$670.3	$0.0		$2,487.9
A.3 Overhead	$74,513.6	$0.0	$0.0		$74,513.6
B.1 Procurement	$23,247.5	$13,649.6	$0.0		$36,897.1
B.2 Materiel	$34,117.1	$8,894.4	$0.0		$43,011.5
C.1 - Pre Construction	$9,131.6	$4,010.7	$0.0		$13,142.3
C.2 Shutdown	$4,348.5	$4,469.3	$66.3		$8,884.0
C.3 Major Construction	$0.0	$0.0	$0.0		$0.0
C.4 Pre Comissioning	$130.8	$0.0	$0.0		$130.8
Total	**$207,095.7**	**$81,293.6**	**$1,242.9**		**$289,632.1**

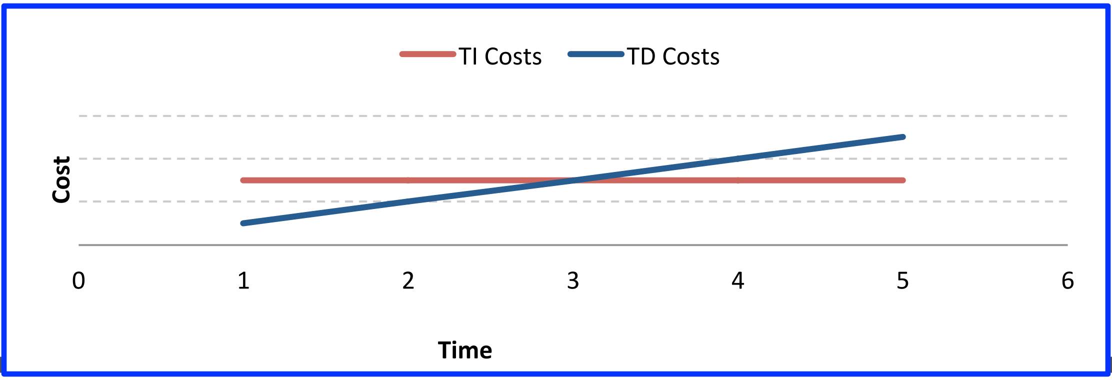
FY 2015 (RY $K)	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	FY14
A.1 Engineering	$4,924.7	$4,924.7	$4,924.7	$5,042.9	$5,042.9	$5,042.9	$4,981.0	$4,981.0	$4,981.0	$4,981.0	$4,981.0	$4,981.0	$59,788.9
A.2 Management	$148.8	$148.8	$148.8	$152.4	$152.4	$152.4	$152.4	$152.4	$152.4	$152.4	$152.4	$152.4	$1,817.6
A.3 Overhead	$6,099.7	$6,099.7	$6,099.7	$6,246.1	$6,246.1	$6,246.1	$6,246.1	$6,246.1	$6,246.1	$6,246.1	$6,246.1	$6,246.1	$74,513.6
B.1 Procurement	$2,196.9	$2,197.4	$2,197.9	$2,056.1	$2,056.6	$2,057.1	$2,015.9	$2,016.4	$1,612.7	$1,613.1	$1,613.5	$1,613.8	$23,247.5
B.2 Materiel	$2,792.8	$2,792.8	$2,792.8	$2,859.9	$2,859.9	$2,859.9	$2,859.9	$2,859.9	$2,859.9	$2,859.9	$2,859.9	$2,859.9	$34,117.1
C.1 - Pre Construction	$1,434.0	$1,434.0	$1,434.0	$954.7	$954.7	$954.7	$327.6	$327.6	$327.6	$327.6	$327.6	$327.6	$9,131.6
C.2 Shutdown	$356.0	$356.0	$356.0	$364.5	$364.5	$364.5	$364.5	$364.5	$364.5	$364.5	$364.5	$364.5	$4,348.5
C.3 Major Construction	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
C.4 Pre Comissioning	$32.5	$32.5	$32.5	$33.3	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$130.8
Total	**$17,985.4**	**$17,985.9**	**$17,986.4**	**$17,709.8**	**$17,677.0**	**$17,677.5**	**$16,947.3**	**$16,947.8**	**$16,544.1**	**$16,544.5**	**$16,544.8**	**$16,545.2**	**$207,095.7**

FY 2016 (RY $K)	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	FY 12

Preparing a Cost Estimate for ICSRA

Mapping the cost estimate to the schedule ensures consistency across the artifacts and enables analysts to transition from a SRA to a ICSRA

- The first step in importing a cost estimate for a ICSRA is mapping it to the schedule
  - Mapping is facilitated if the cost estimate and the schedule adhere to the same WBS
  - This mapping can be performed at any level although it is typically above the lowest level of detail in the schedule
  - This mapping typically uncovers inconsistencies between the two artifacts – particularly if the schedule contains any resources - that should be corrected before the analysis continues
- Costs are then divided into one of two categories time-independent (TI) or time-dependent (TD)
  - TD costs are those that grow and contract as the schedule grows and contracts (e.g., Labor, rented equipment)
  - TI costs grow and contract independently of the schedule (ignoring inflation effects) (e.g., installed equipment, materials)



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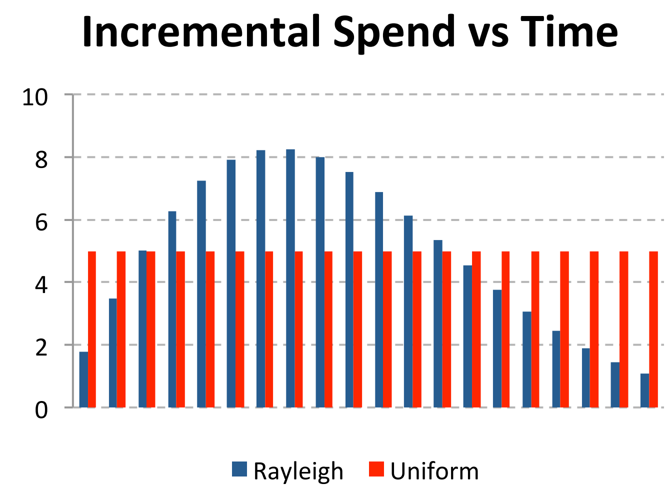
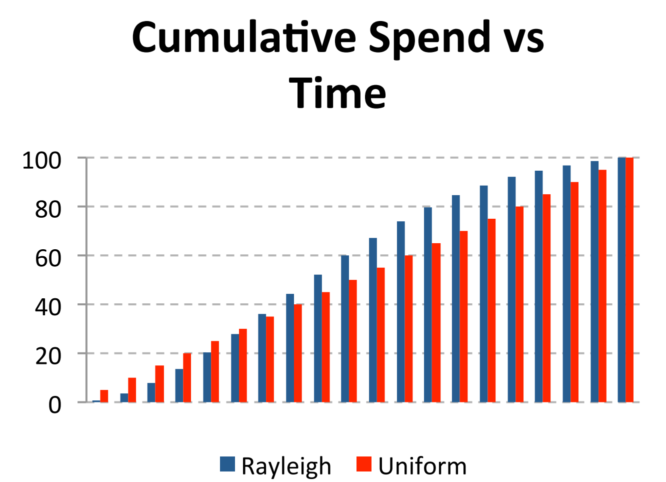
Mapping the cost estimate to the schedule ensures consistency across the artifacts and enables analysts to transition from a SRA to a ICSRA

- When Polaris imports a cost estimate it automatically converts it to a dollar/day burn rate that, when applied to the schedule, will replicate the cost estimate
- Selecting a phasing profile allows costs to be phased realistically as the schedule grows and contracts
  - Many of the commonly used cost estimating phasing profiles are included in Polaris
- As the simulation runs, Polaris calculates the cost impact of schedule growth
  - For each iteration, the cost is adjusted (up or down) according to the change in schedule and dollar/day burn rate
  - The cost is then dynamically re-phased according to the selected phasing profile to provide a realistic view of when costs are likely to occur





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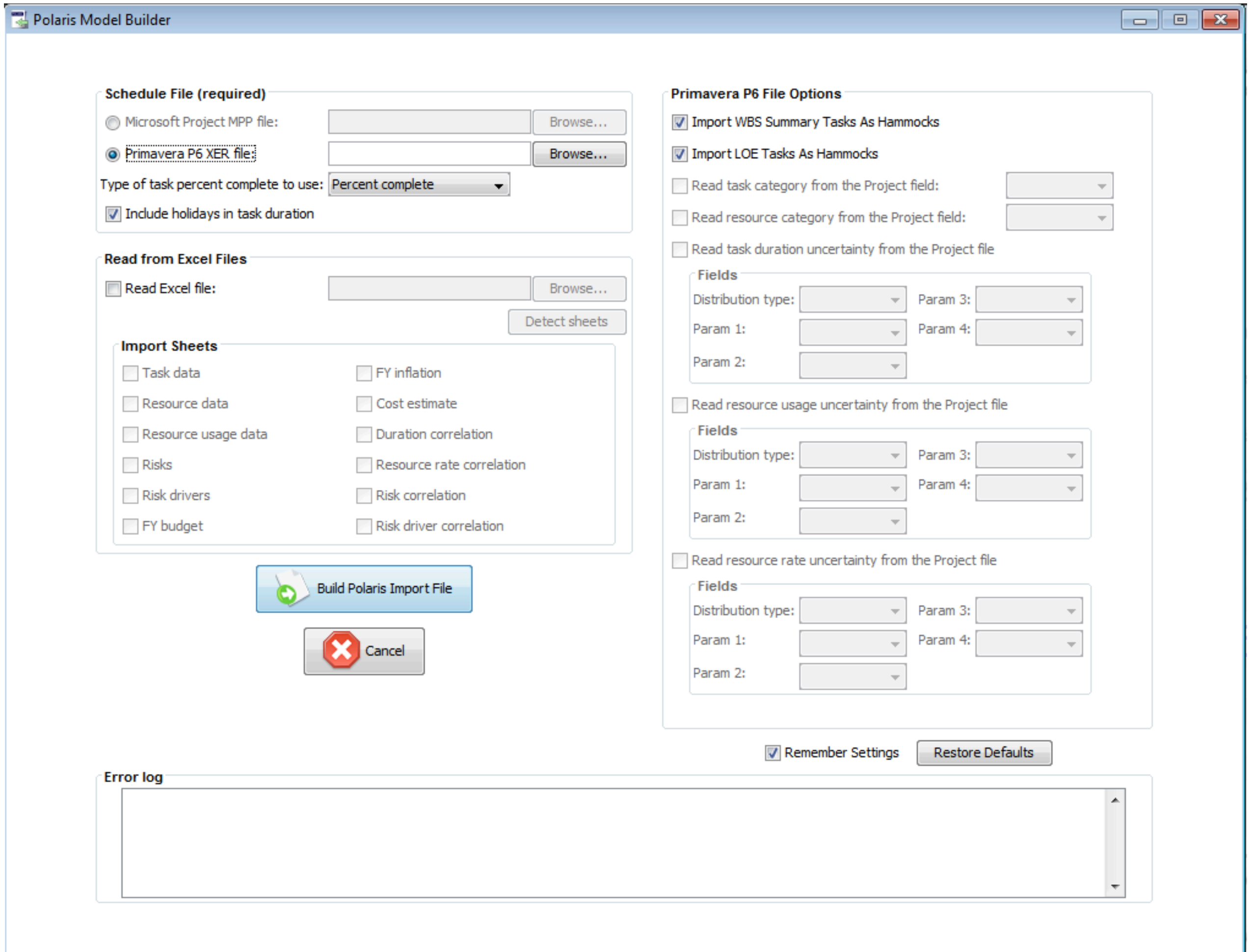
Polaris imports cost estimates from Project, Primavera, or Excel – the last of which allows costs to be entered at total value, which will then automatically be converted to burn rates



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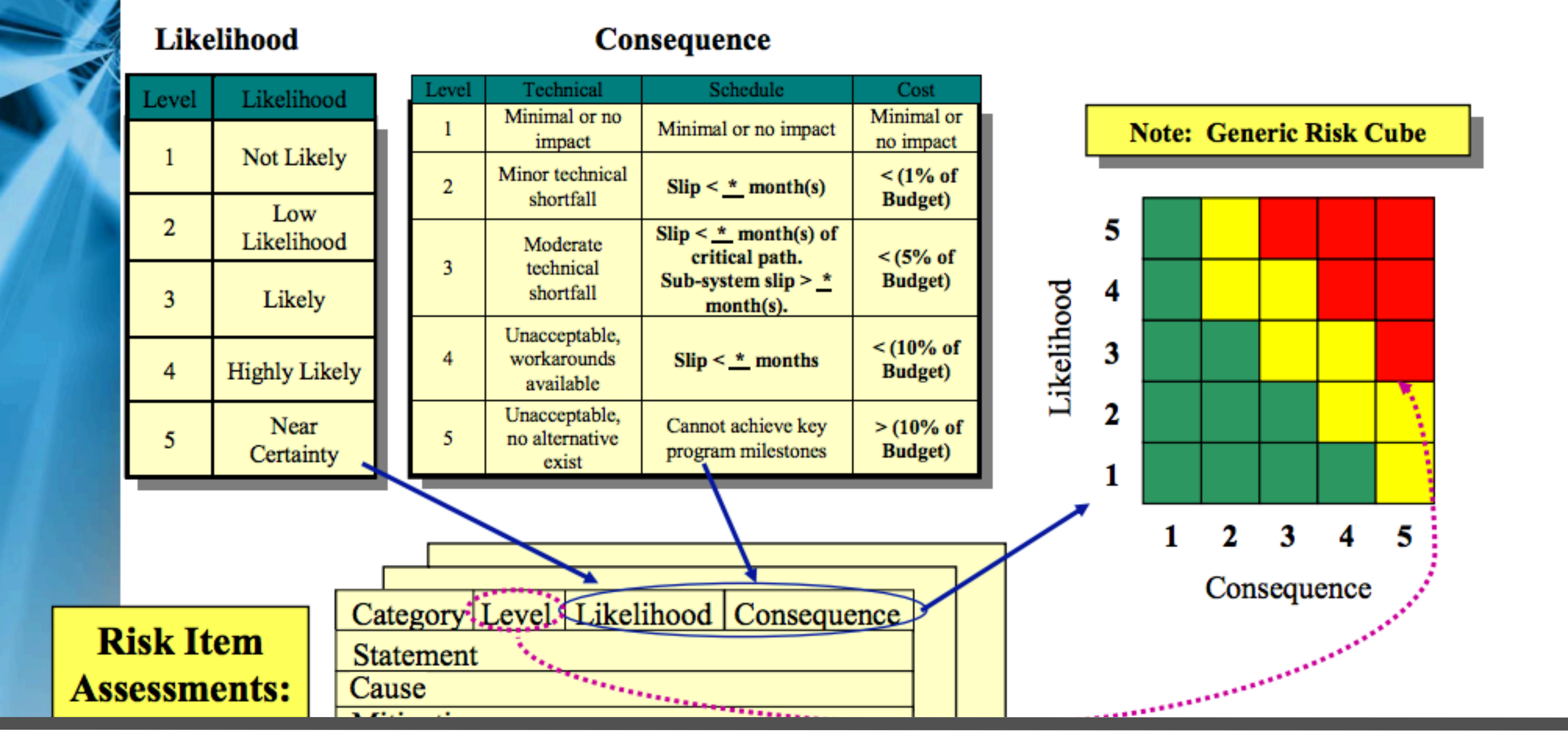

Likelihood

Level	Likelihood
1	Not Likely
2	Low Likelihood
3	Likely
4	Highly Likely
5	Near Certainty

Consequence

Level	Technical	Schedule	Cost
1	Minimal or no impact	Minimal or no impact	Minimal or no impact
2	Minor technical shortfall	**Slip < _*_ month(s)**	**< (1% of Budget)**
3	Moderate technical shortfall	**Slip < _*_ month(s) of critical path. Sub-system slip > _*_ month(s).**	**< (5% of Budget)**
4	Unacceptable, workarounds available	**Slip < _*_ months**	**< (10% of Budget)**
5	Unacceptable, no alternative exist	Cannot achieve key program milestones	**> (10% of Budget)**

Preparing a Risk Register for ICSRA

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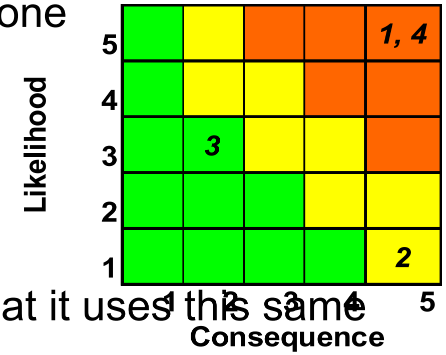
Mapping the risk register to the schedule and cost estimates allows downstream impacts to be calculated and enables better risk mitigation

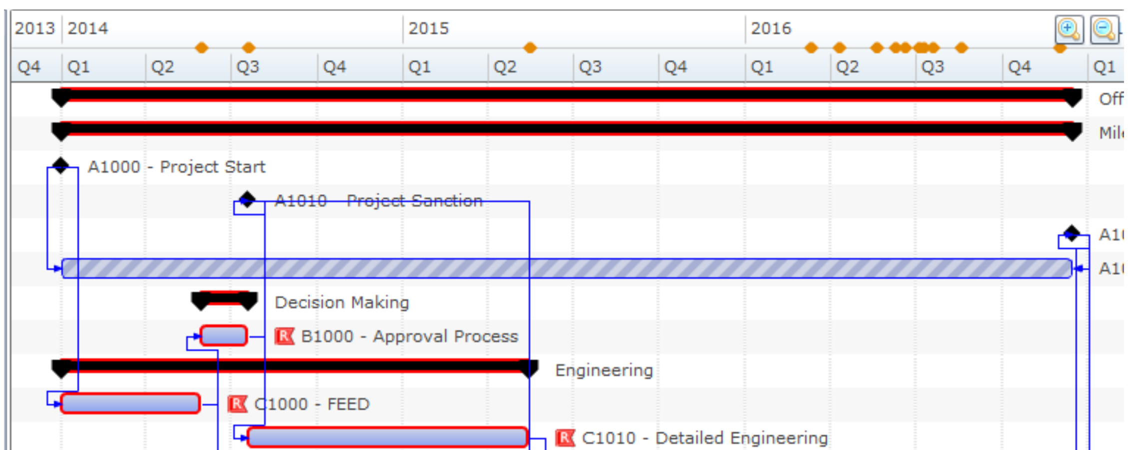
- All risk management methods result in the production of a “Risk Register” (or “Risk Log”)
- Risk registers typically contain, at minimum, the following information for each risk:
  - Description of the risk; typically written as an IF-THEN statement
  - Probability, or likelihood factor, that the risk occurs
  - Impact, or impact factor, should the risk occur on the final milestone
  - Risk score (generally likelihood factor x impact factor)
  - Planned response should the risk occur, recovery impact
  - Mitigation plan for the risk, action before the risk occurs



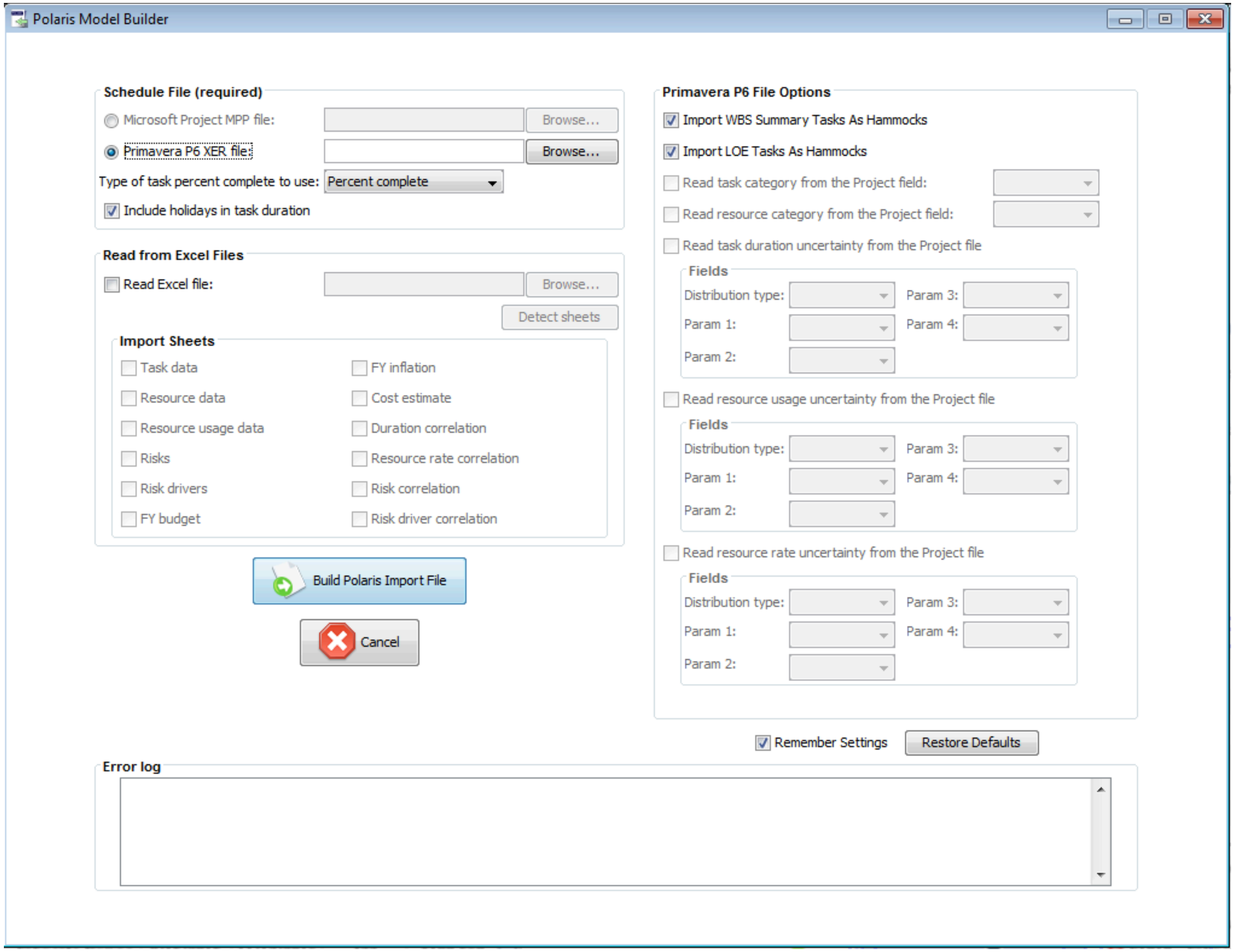
- ICSRA is compatible with all risk management methodologies in that it uses this same information to model the risk within Polaris
  - ICSRA, however, does require one additional, key-piece of information: the task within the schedule that is impacted by the risk
  - This is how ICSRA gives far more insight into risks than the simple “risk score” metric

Mapping the risk register to the schedule and cost estimates allows downstream impacts to be calculated and enables better risk mitigation

- True ICSRA software allows the modeling of risks in many ways:
  - Each risk can impact multiple activities and a single activity can be impacted by multiple risks
  - Risk impacts can occur in serial or parallel depending on the type of risk
  - Risks can be discrete (additive to the duration) or drivers (multiplicative applied to duration). Risk impacts generally are specified in ranges, often using the 3-point estimate
  - Opportunities (uncertain events with a positive impact) can also be modeled
- Polaris' risk timeline allows projects to look at the risks temporally as well as to see where they are clustered within the schedule
  - This quickly identifies when/where the riskiest areas of the project are or where there may have been shortcomings in risk identification



Polaris imports the risk register from Excel or from enterprise risk management tools through Excel macros



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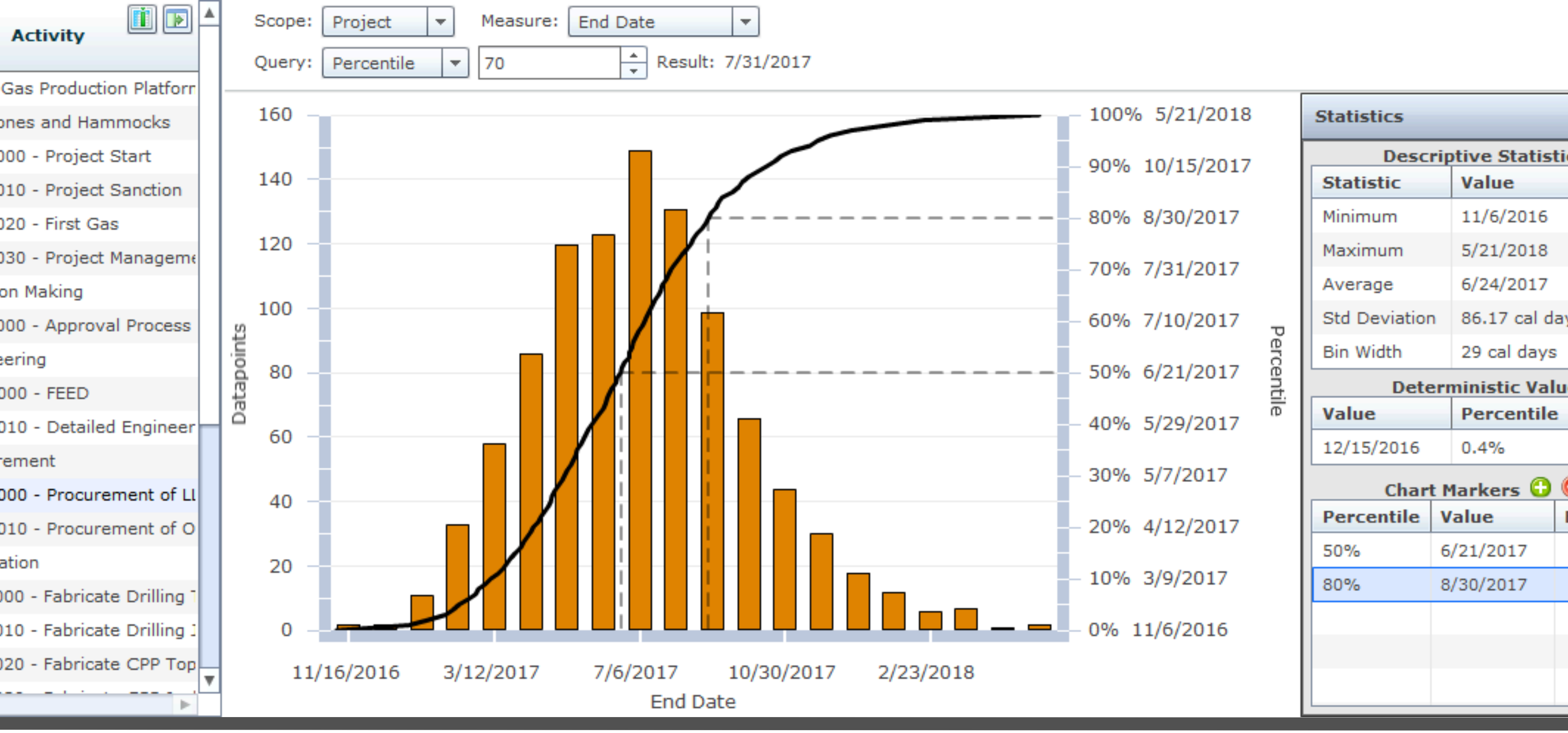

Quantifying Risk & Uncertainty

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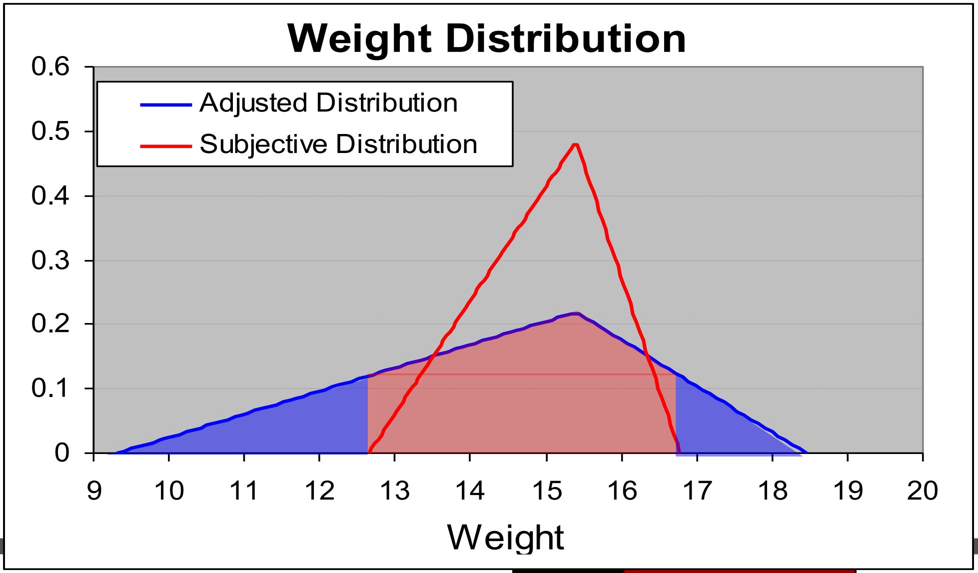
How an analyst chooses to quantify uncertainty has the largest impact on the results in the model and is the most important piece of the risk analysis

- Analysts should use the three following methods, in decreasing order of preference, to quantify uncertainty distributions
  - The Math: Where analytical approaches (such as parametrics) have been used to develop the baseline estimate there is generally an associated method for quantifying uncertainty
  - The Data: Statistical analysis can be performed on an organizations historical data to quantify the uncertainty around the estimate or the likelihood of occurrence/impact of a risk
  - SME Judgment: Subject Matter experts can also provide uncertainty distributions so long as their input is carefully gathered and incorporated into the model (see next slide)
- True ICSRA software incorporates a wide array of probability distributions, quantified in both days and as a percentage of the baseline duration, to provide a wide range of options for accurate modeling
- Of late there has been a shift in some tools to move away from quantitative analysis and towards more qualitative (high-medium-low) levels of risk
  - While quick, these approaches lack transparency and the ability to leverage organizational data for more accurate modeling

Where SME judgment has been used to develop a distribution, be careful to correct for bias and systemic underestimation of uncertainty

- When evoking risk distributions you should be careful not to anchor the SME at the baseline duration
  - Most schedules are biased towards success, anchoring distributions around the planned finish will result in an unrealistically optimistic analysis
  - Rather than asking for a low and a high around a baseline, ask for a low, most likely, and high
  - The Most Likely value may not be equal to the duration in the schedule.
- When capturing the low and high values, keep in mind that multiple studies – including several in the oil/gas field – have shown that SMEs tend to capture no more than 60-70% of total uncertainty
  - Built into Polaris is the tri-gen distribution, which automatically adjusts SME provided distributions to account for this fact



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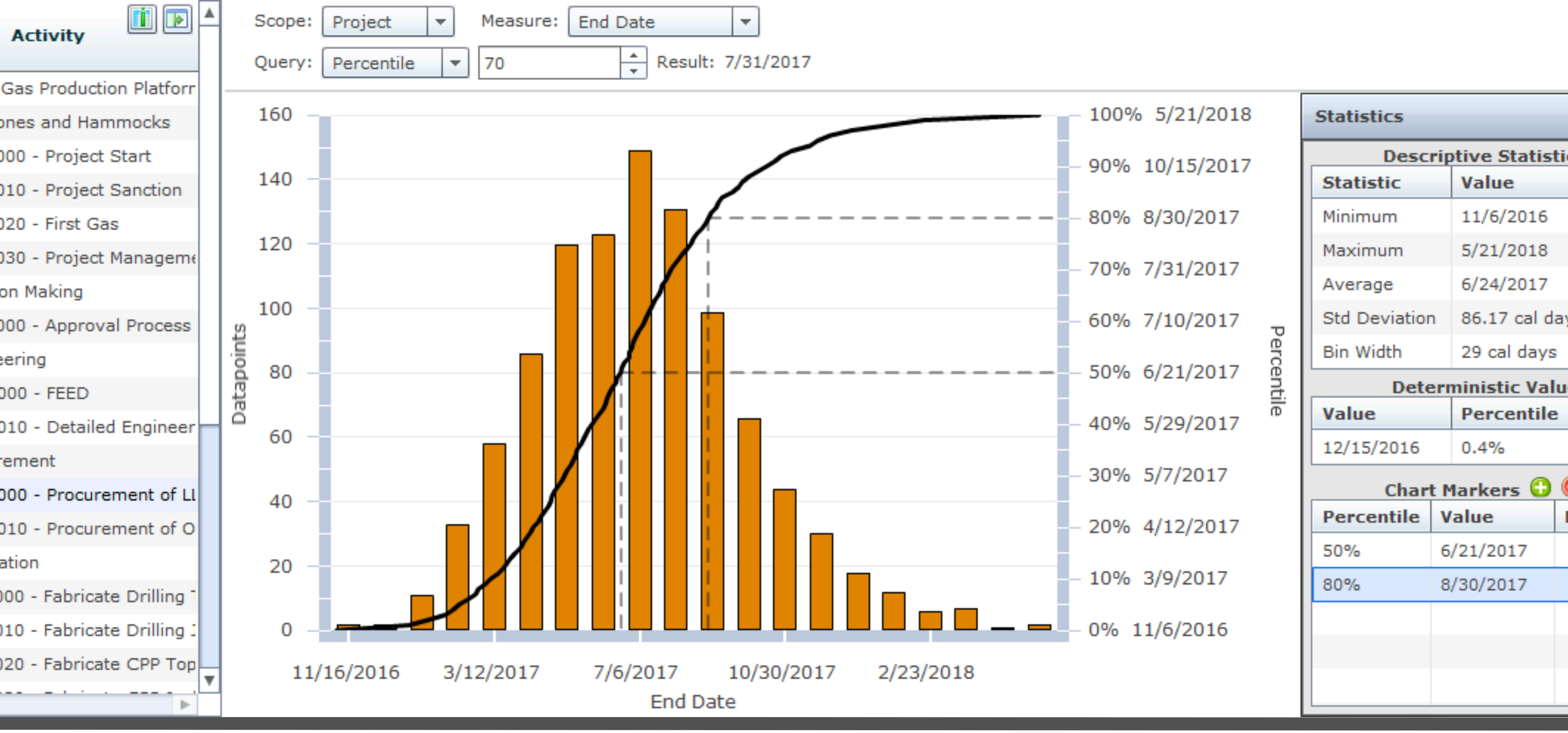

Performing a ICSRA and analyzing the results

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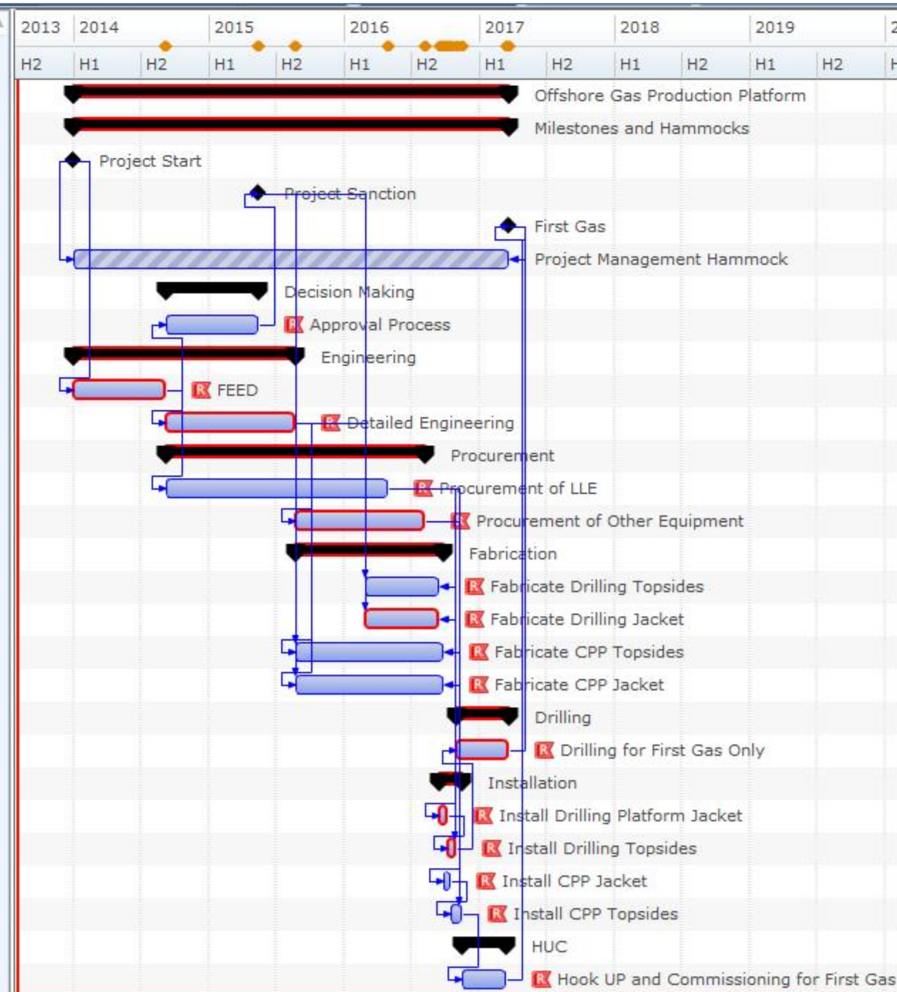
ICSRA provides unparalleled insights into the drivers of cost and schedule risk and how to mitigate them

- Predict – ICSRA provides forecasts for future cost and schedule growth – along with many other valuable metrics – allowing project managers to optimize reserve levels and contingency plans
  - Risk adjusted cost estimate, by year, at all levels of the project
  - Risk adjusted schedule estimate, at all levels of the project
  - Probabilistic critical path
  - Combined cost / schedule scatter plots showing the likelihood of meeting both cost and schedule
- Analyze – ICSRA prioritizes the sources of cost and schedule growth by days and by dollars at a desired level of certainty, allowing project managers to identify potential mitigative actions
  - Prioritization methods model inputs contributing most to cost and schedule growth including both uncertainties and risks
  - Analysis can be parsed down to all levels of the schedule
- Mitigate – ICSRA allows project managers to test out mitigative actions for reducing project cost and schedule growth, and to see their effect
  - Mitigating risks
  - Adding or removing scope
  - Accelerating or decelerating work

Use Offshore Gas Production Platform Resource-Loaded Schedule

UID	Task	Start Date	End Date	Duration	Cost
Gas Pla	▼ Offshore Gas Production Platfor	1/1/2014	3/20/2017	1,175	$1.57M
Gas Pla	▼ Milestones and Hammocks	1/1/2014	3/20/2017	1,175	$200,000
A1000	Project Start	1/1/2014		0	$0
A1010	Project Sanction		5/15/2015	0	$0
A1020	First Gas		3/20/2017	0	$0
A1030	Project Management Ham	1/1/2014	3/20/2017	1,175	$200,000
Gas Pla	▼ Decision Making	9/8/2014	5/15/2015	250	$80,000
B1000	Approval Process	9/8/2014	5/15/2015	250	$80,000
Gas Pla	▼ Engineering	1/1/2014	8/23/2015	600	$96,000
C1000	FEED	1/1/2014	9/7/2014	250	$16,000
C1010	Detailed Engineering	9/8/2014	8/23/2015	350	$80,000
Gas Pla	▼ Procurement	9/8/2014	8/7/2016	700	$425,000
D1000	Procurement of LLE	9/8/2014	4/29/2016	600	$250,000
D1010	Procurement of Other Equ	8/24/2015	8/7/2016	350	$175,000
Gas Pla	▼ Fabrication	8/24/2015	9/26/2016	400	$576,000
E1000	Fabricate Drilling Topsides	3/1/2016	9/16/2016	200	$160,000
E1010	Fabricate Drilling Jacket	3/1/2016	9/16/2016	200	$80,000
E1020	Fabricate CPP Topsides	8/24/2015	9/26/2016	400	$240,000
E1030	Fabricate CPP Jacket	8/24/2015	9/26/2016	400	$96,000
Gas Pla	▼ Drilling	11/1/2016	3/20/2017	140	$80,000
F1000	Drilling for First Gas Only	11/1/2016	3/20/2017	140	$80,000
Gas Pla	▼ Installation	9/17/2016	11/15/2016	60	$47,200
G1000	Install Drilling Platform Ja	9/17/2016	10/6/2016	20	$8,000
G1010	Install Drilling Topsides	10/7/2016	10/31/2016	25	$13,600
G1020	Install CPP Jacket	9/27/2016	10/16/2016	20	$9,600
G1030	Install CPP Topsides	10/17/2016	11/15/2016	30	$16,000
Gas Pla	▼ HUC	11/16/2016	3/15/2017	120	$64,000
H1000	Hook UP and Commission	11/16/2016	3/15/2017	120	$64,000



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Add Basic Uncertainty and Estimating Error to Schedule Durations

Templated Uncertainty Editor Apply ☑ Replace Existing Distributio

Templates Add Remove Edit Filters

Priority	Filter	Schedule Uncertainty
1	Approval	Triangular - Min:0.9 Likely:1 Max:1.25
2	Engineering	Trigen - Min:0.9 Likely:1.05 Max:1.2 UncertCap:0.8
3	Procurement	Triangular - Min:0.95 Likely:1 Max:1.2
4	Fabrication	Triangular - Min:0.9 Likely:1.05 Max:1.2
5	Drilling	Trigen - Min:0.85 Likely:1.05 Max:1.3 UncertCap:0.8
6	Installation	Triangular - Min:0.95 Likely:1.05 Max:1.3
7	HUC	Trigen - Min:0.85 Likely:1.1 Max:1.3 UncertCap:0.7

Different reference ranges are applied to different types of activities

Note that some are Trigen, correcting for under-estimating.

Five of these have a Most Likely multiplier > 1.0 indicating correcting for optimistic bias

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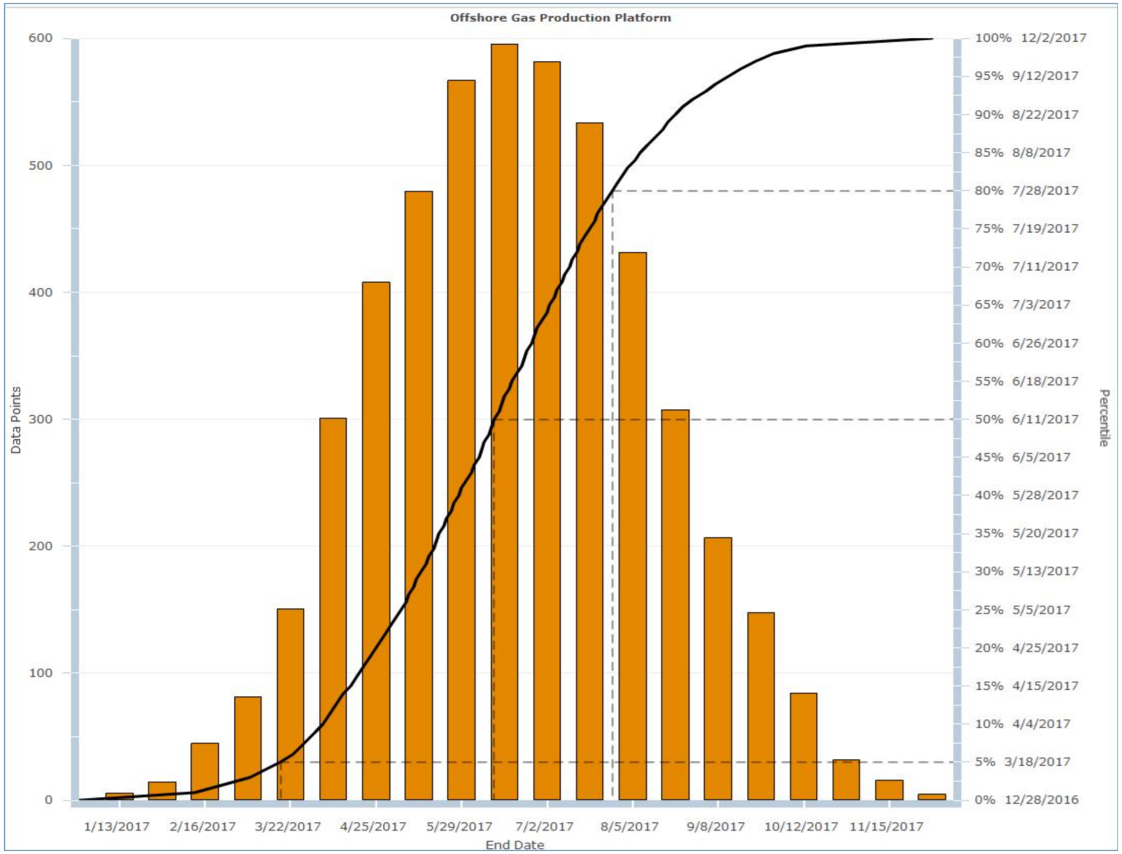
Schedule Risk with Inherent Uncertainty and Duration Estimating Bias

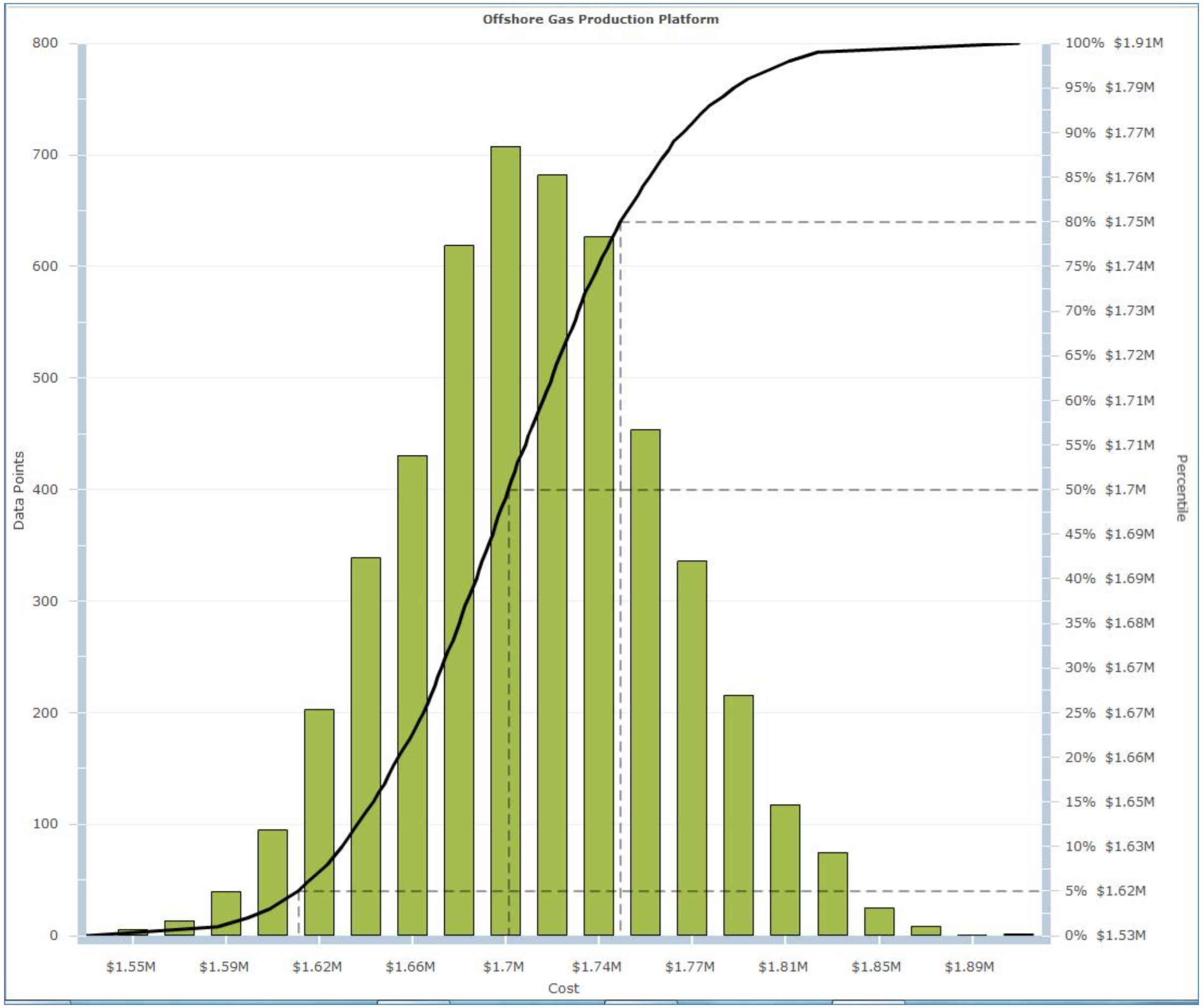


Schedule Date is 20 March 2017

P-80 is 28 July 2017, 4+ months later with uncertainty only

The P-80 date of 28 July 2017 uses correlation = 0.0. With correlation at 30% the date is 4 August 2017. With 100% correlation it is 2 September 2017

Cost Risk with Uncertainty and Schedule Estimating Error Only



Cost Estimate is $1.57 billion

P-80 is $1.75 billion with uncertainty and schedule estimating error

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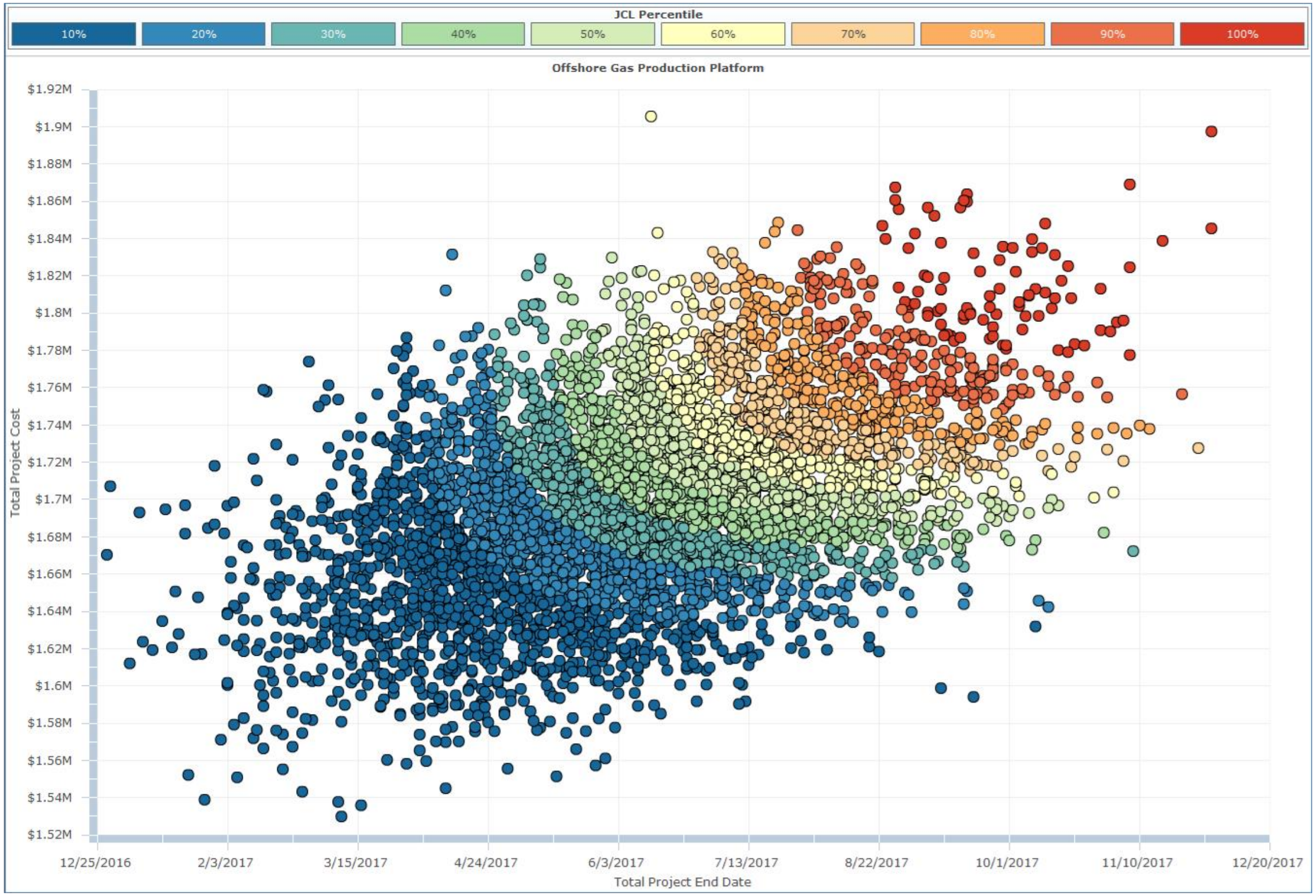
Cost – Finish Date Scatter



Cost and time are 46% correlated

Cost varies only as durations cause time-dependent resource cost to vary

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Add Risk Drivers & Apply to Activities' Durations

Discrete | Driver

Risk Driver Editor

Enabled ☑	UID	Risk Driver Name	Probability	Description	Notes
☑	1	Bids may be Abusive leading to delayed approval	60%		
☑	2	Engineering may be complicated by using offshore design firm	40%		
☑	3	Suppliers of installed equipment may be busy	30%		
☑	4	Fabrication yards may experience lower Productivity than planned	60%		
☑	5	The subsea geological conditions may be different than expected	75%		
☑	6	Installation may be delayed due to coordination problems	80%		
☑	7	Fabrication and installation problems may be revealed during HUC	85%		
☑	8	The organization has other priority projects so personnel and funding may be unavailable	65%		

Risk Driver Impact Editor

Tasks | Add | Remove

Task	In Parallel ☐
G1030 - Install CPP Topsides	☐
G1000 - Install Drilling Platform Jacket	☐
G1010 - Install Drilling Topsides	☐
G1020 - Install CPP Jacket	☐

Duration Factor

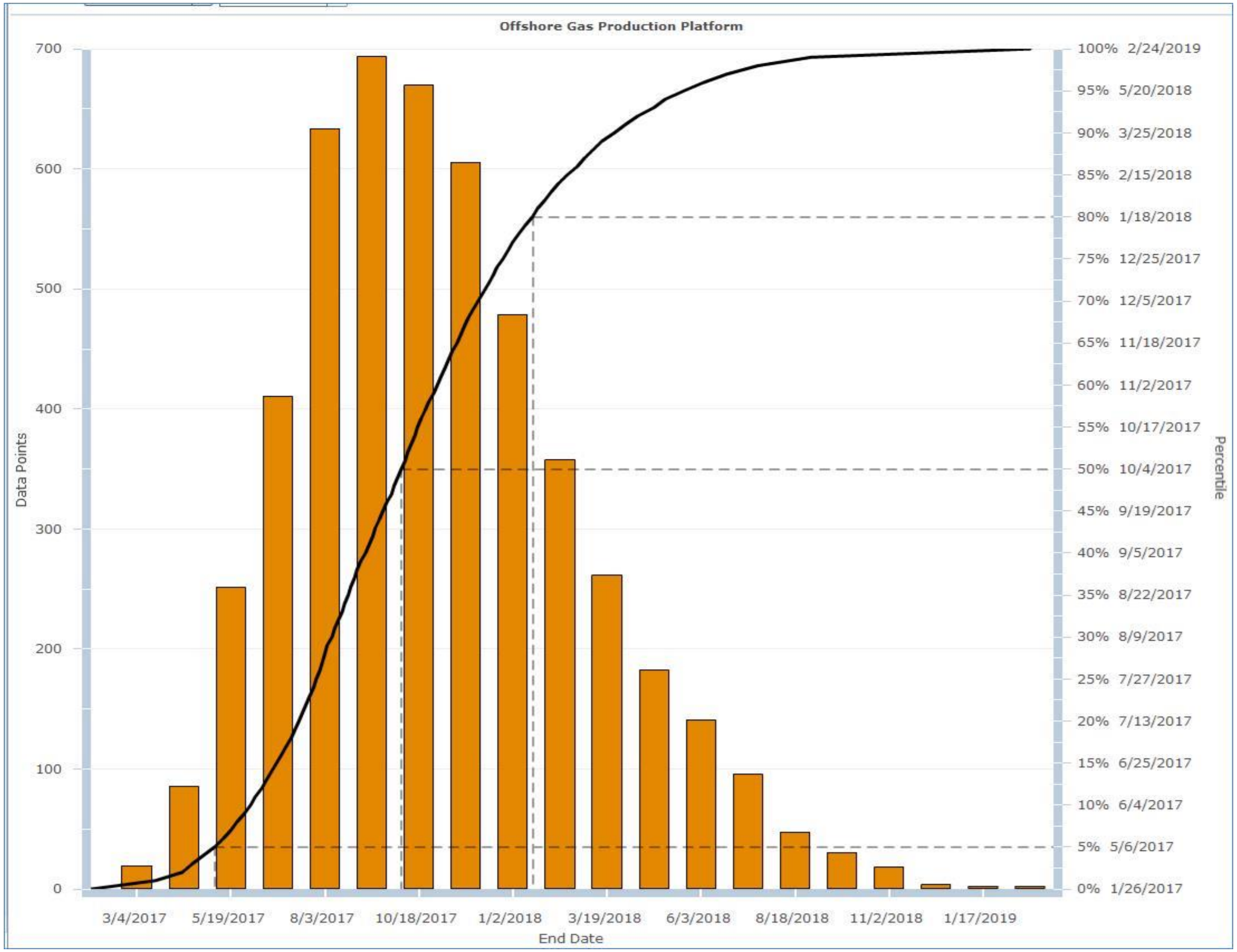
Triangular - Min:0.9 Likely:1.1 Max:1.3

Cost Factor

None - Original Value: 1

Here, the risk "Installation may be delayed due to coordination problems" is assigned to all 4 Installation activities. It is assigned 80% probability and a triangular distribution with multiplicative factors of .9 - 1.1 - 1.3. Risk drivers have different probabilities, impact ranges and activity assignments

Schedule Risk with Risk Drivers Added



The P-80 date is now 21 Ju18 January 2018. The Risk Drivers added nearly 6 months

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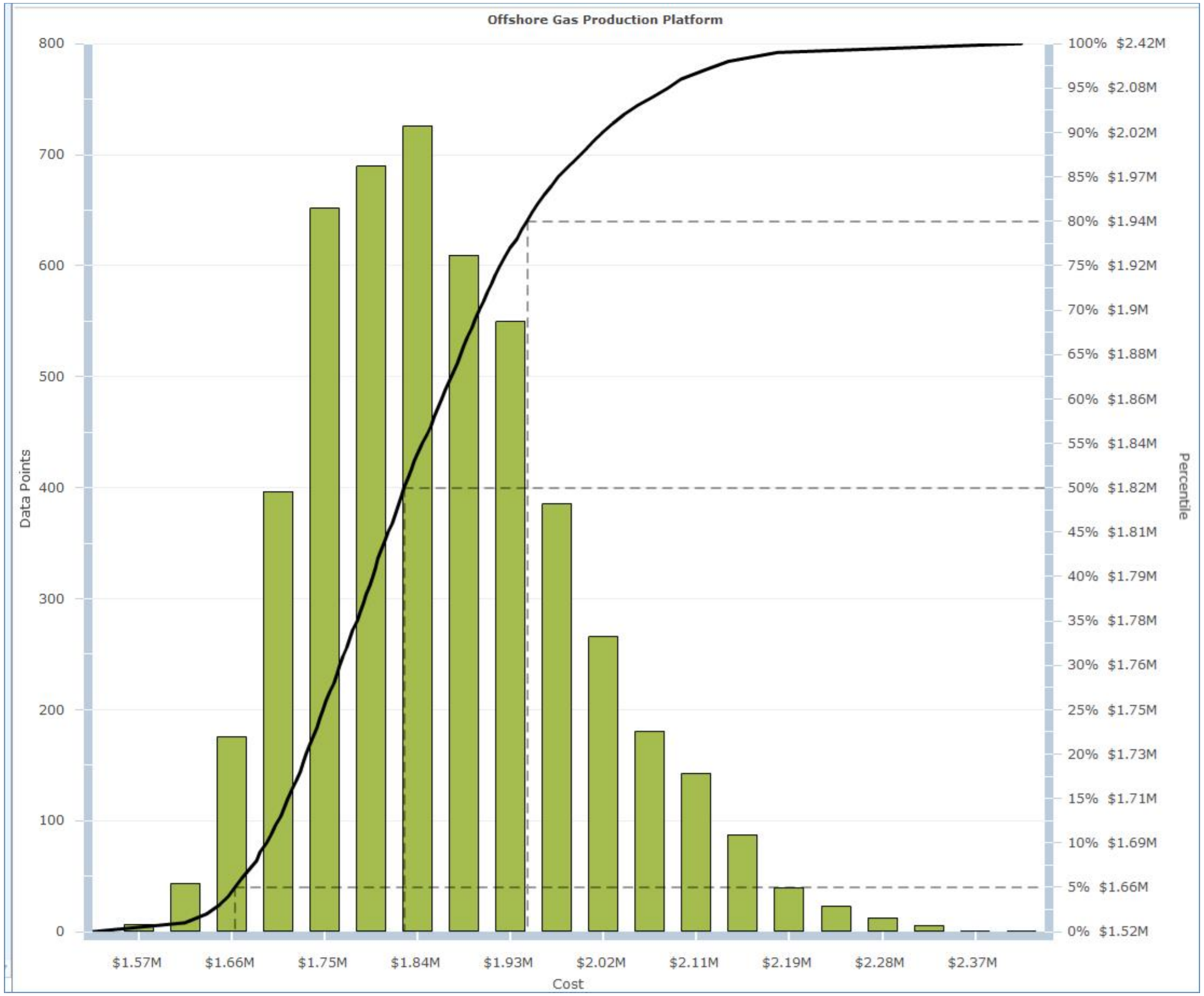
Cost Risk with Schedule Risk Drivers



Cost risk is now $1.94 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

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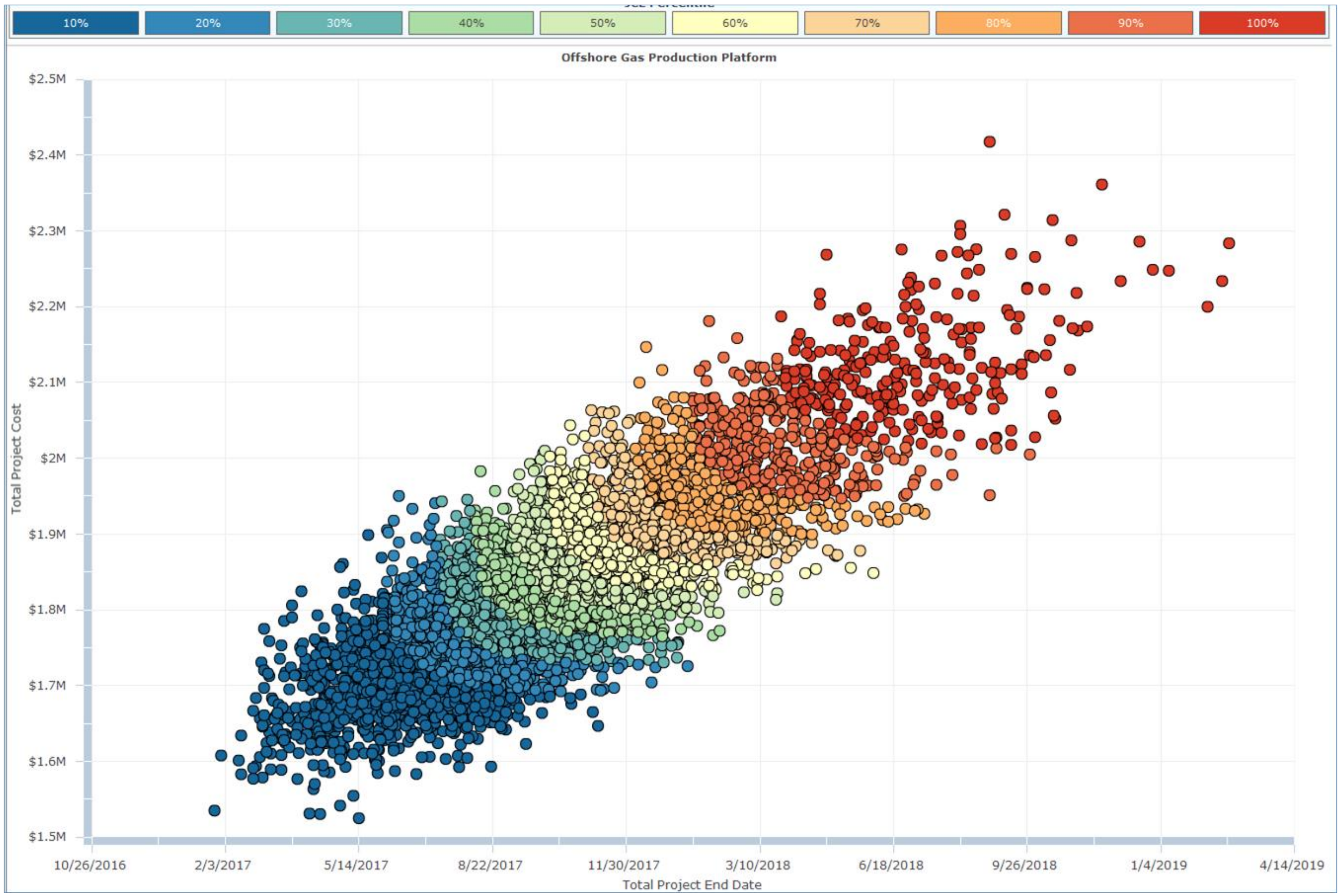
Cost – Finish Date Scatter with Schedule Risk Drivers Added



There is no cost risk except that caused by the effect of schedule risk on time-dependent resources. The cost – finish date correlation is 83%

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Add Cost Burn Rate Uncertainty for Risk Drivers with Labor Resources

Discrete | Driver

Risk Driver Editor

Enabled ☑	UID	Risk Driver Name	Probability	Description	Notes
☑	1	Bids may be Abusive leading to delayed approval	60%		
☑	2	Engineering may be complicated by using offshore design firm	40%		
☑	3	Suppliers of installed equipment may be busy	30%		
☑	4	Fabrication yards may experience lower Productivity than planned	60%		
☑	5	The subsea geological conditions may be different than expected	75%		
☑	6	Installation may be delayed due to coordination problems	80%		
☑	7	Fabrication and installation problems may be revealed during HUC	85%		
☑	8	The organization has other priority projects so personnel and funding may be unavailable	65%		

Risk Driver Impact Editor

Tasks | Add | Remove

Task	In Parallel ☐
B1000 - Approval Process	☐
C1000 - FEED	☐
C1010 - Detailed Engineering	☐
D1000 - Procurement of LLE	☐
D1010 - Procurement of Other Equipment	☐
E1000 - Fabricate Drilling Topsides	☐
E1010 - Fabricate Drilling Jacket	☐
E1020 - Fabricate CPP Topsides	☐
E1030 - Fabricate CPP Jacket	☐
F1000 - Drilling for First Gas Only	☐
G1000 - Install Drilling Platform Jacket	☐
G1010 - Install Drilling Topsides	☐
G1020 - Install CPP Jacket	☐
G1030 - Install CPP Topsides	☐
H1000 - Hook UP and Commissioning for First Gas	☐

Duration Factor

Triangular - Min:0.95 Likely:1.05 Max:1.2[illegible]

Cost Factor

Triangular - Min:0.95 Likely:1.05 Max:1.15

For cost of labor resources there may also be uncertainty on the daily rate. Each risk (except for that on Procurement) has its own burn rate range. The Cost Factor generates cost uncertainty independent of the schedule risk Notice that the "EPC Contractor quality is questionable" is placed on all activities." Also, notice the risks are inserted in series, not in parallel.

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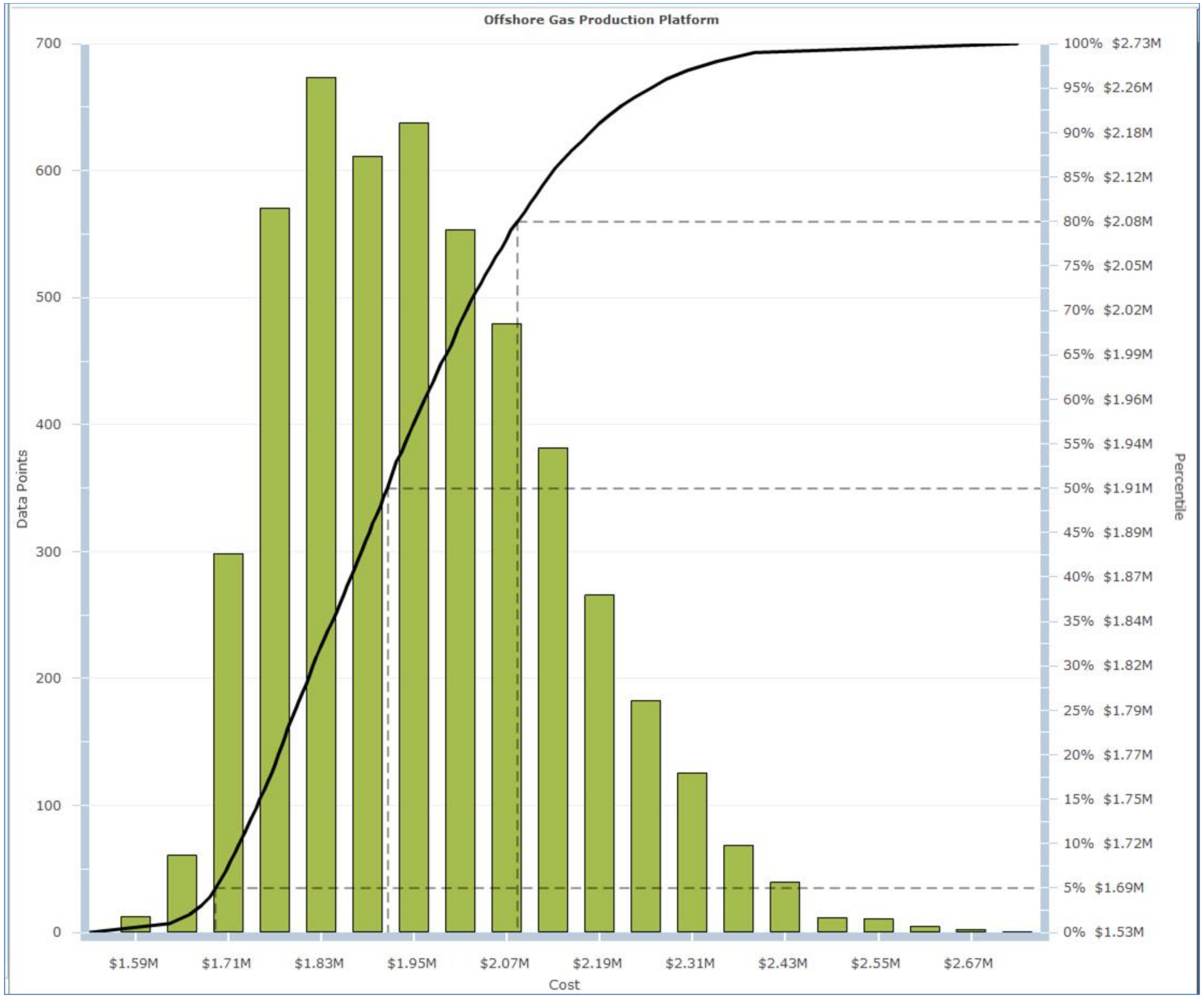
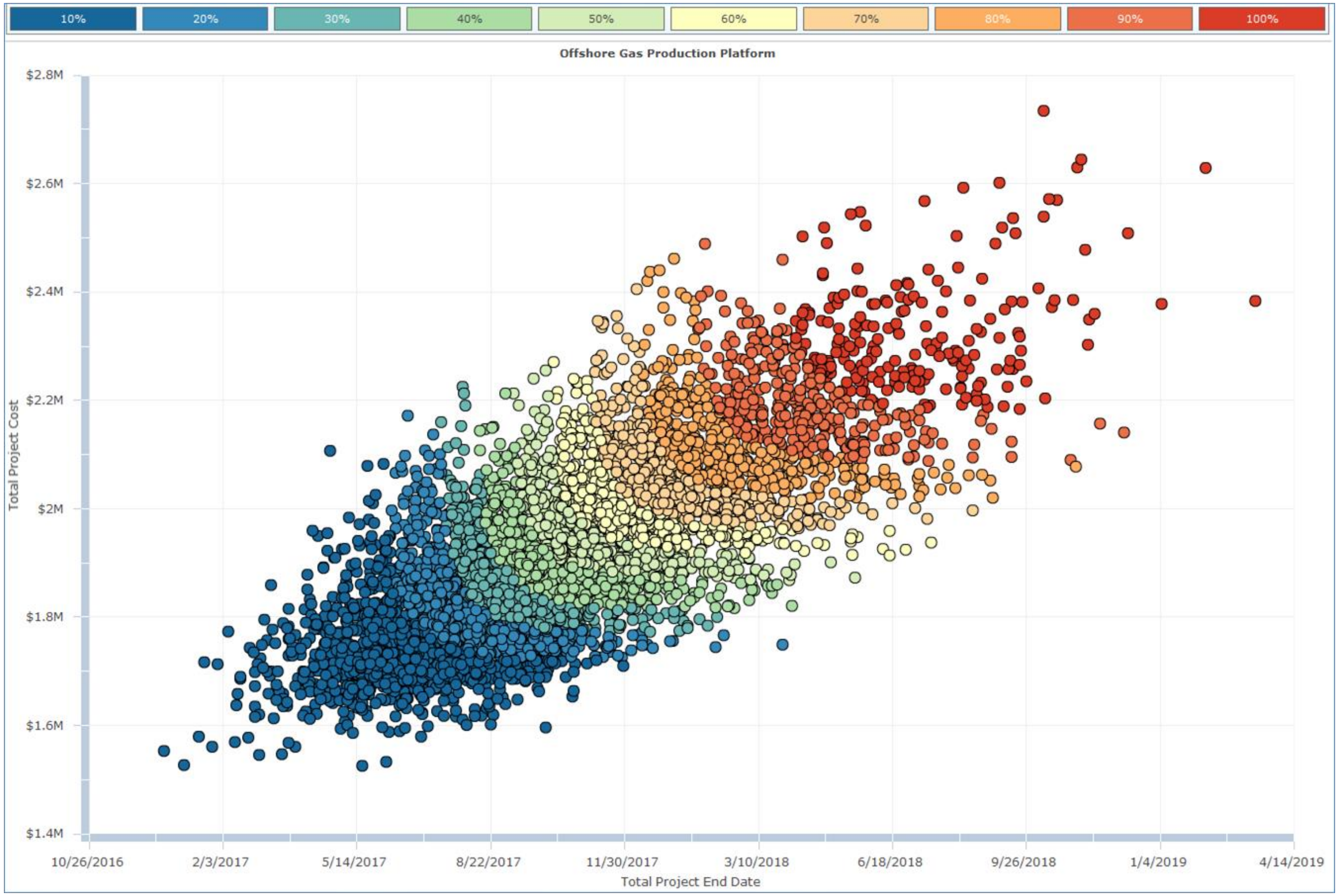
Cost Risk with Uncertainty added to the Burn Rate of Labor Resources



The P-80 for cost is now $2.08 billion

The burn rate risk has added $140 million at the P-80

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 75%

Add Uncertainty to Procurement Cost

Discrete | Driver

Risk Driver Editor

Enabled	UID	Risk Driver Name	Probability	Description	Notes
☑	1	Bids may be Abusive leading to delayed approval	60%		
☑	2	Engineering may be complicated by using offshore design firm	40%		
☑	3	Suppliers of installed equipment may be busy	30%		
☑	4	Fabrication yards may experience lower Productivity than planned	60%		
☑	5	The subsea geological conditions may be different than expected	75%		
☑	6	Installation may be delayed due to coordination problems	80%		
☑	7	Fabrication and installation problems may be revealed during HUC	85%		
☑	8	The organization has other priority projects so personnel and funding may be unavailable	65%		

Risk Driver Impact Editor

Tasks — Add — Remove

Task	In Parallel
D1000 - Procurement of LLE	☐
D1010 - Procurement of Other Equipment	☐

Duration Factor

Triangular - Min:1 Likely:1.05 Max:1.2

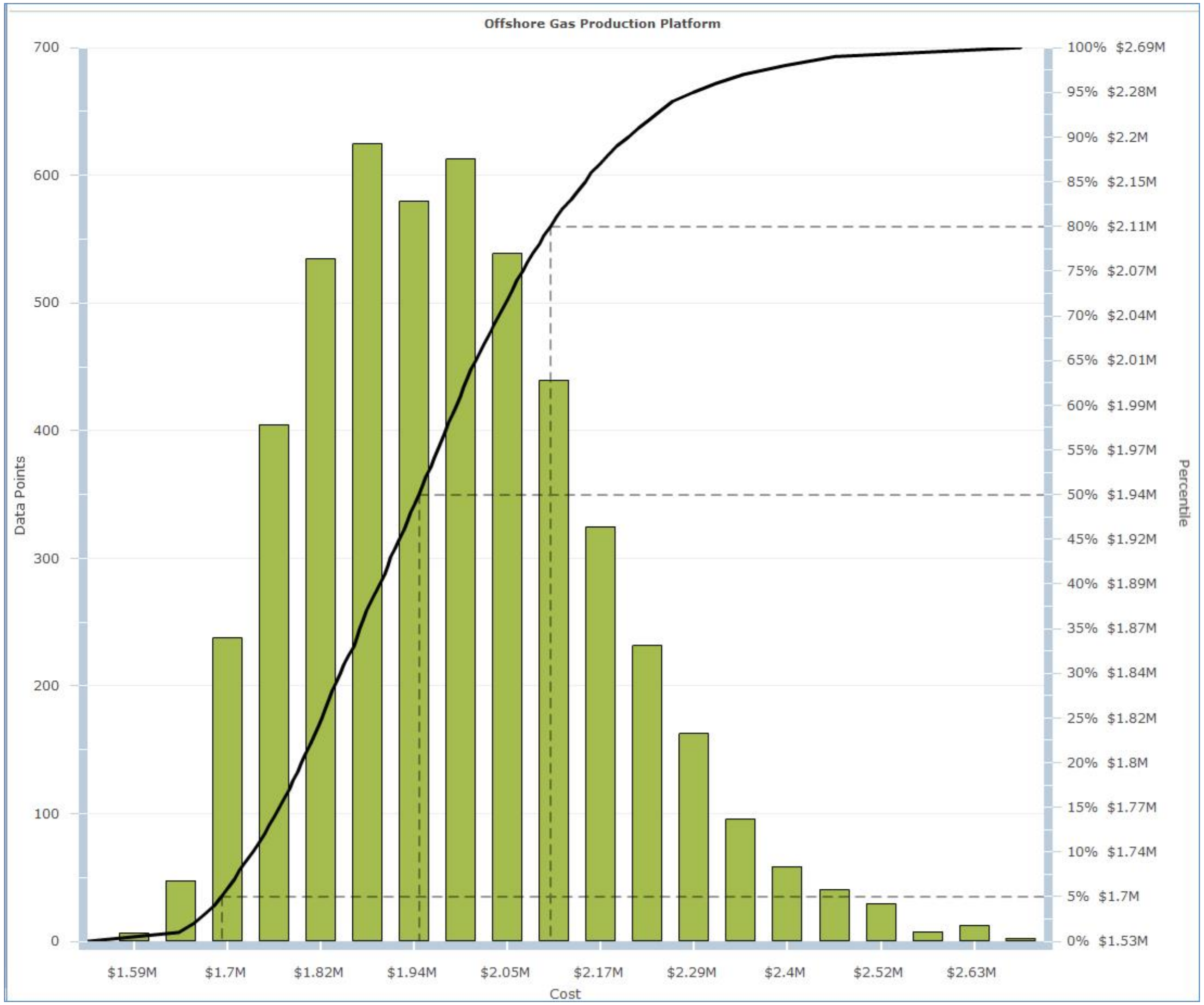
Cost Factor

Triangular - Min:0.9 Likely:1.15 Max:1.4

Uncertainty Type: Triangular
Min: 0.9
Likely: 1.15
Max: 1.4

There was schedule risk on Suppliers of Installed Equipment may be busy 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 .9 – 1.15 – 1.4

Cost Risk with Uncertainty, Schedule Risk Drivers and Cost Risk



Adding cost risk (burn rate, total procurement)

The P-80 increases to $2.11 billion.

The schedule risk is unaffected by adding cost risks

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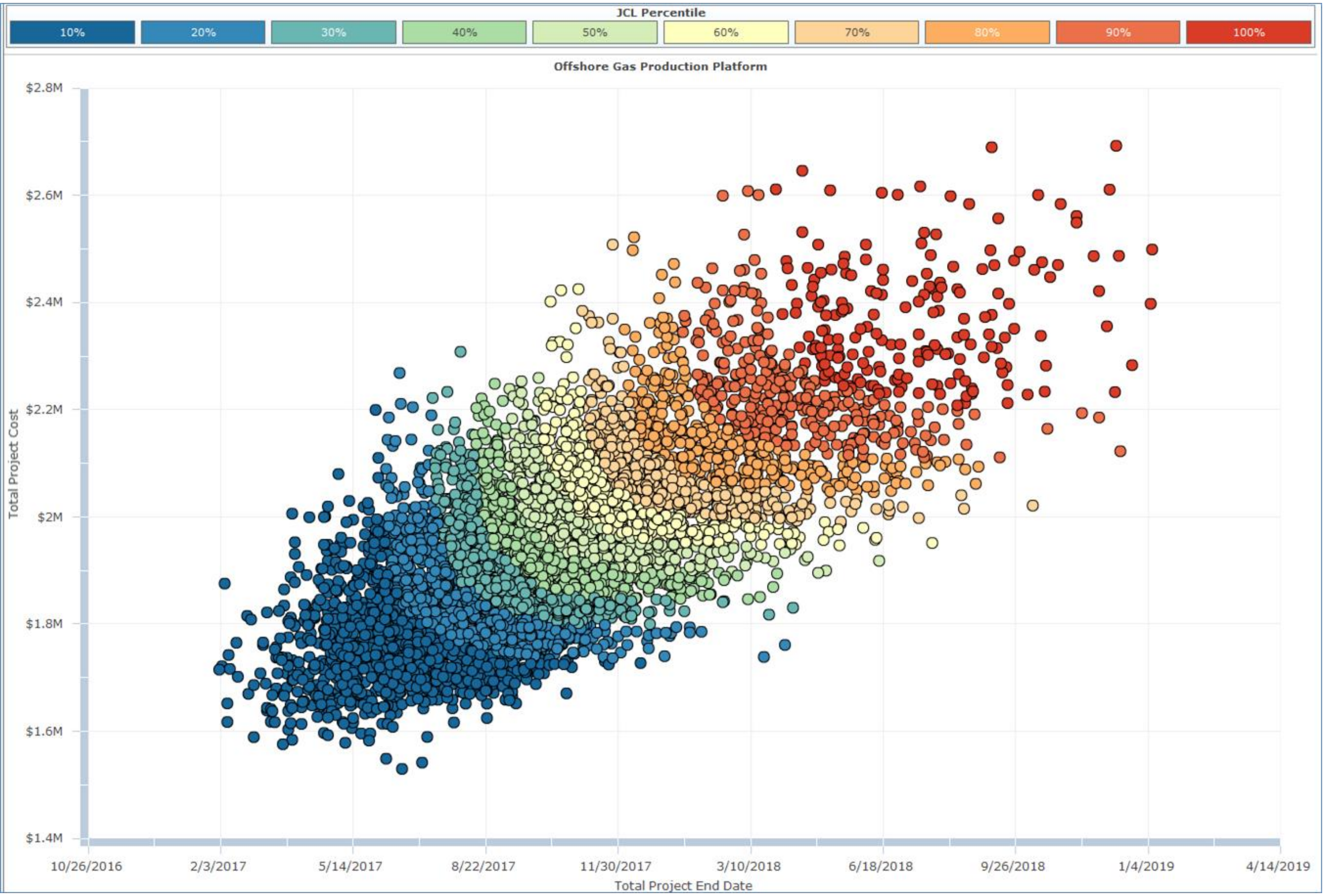
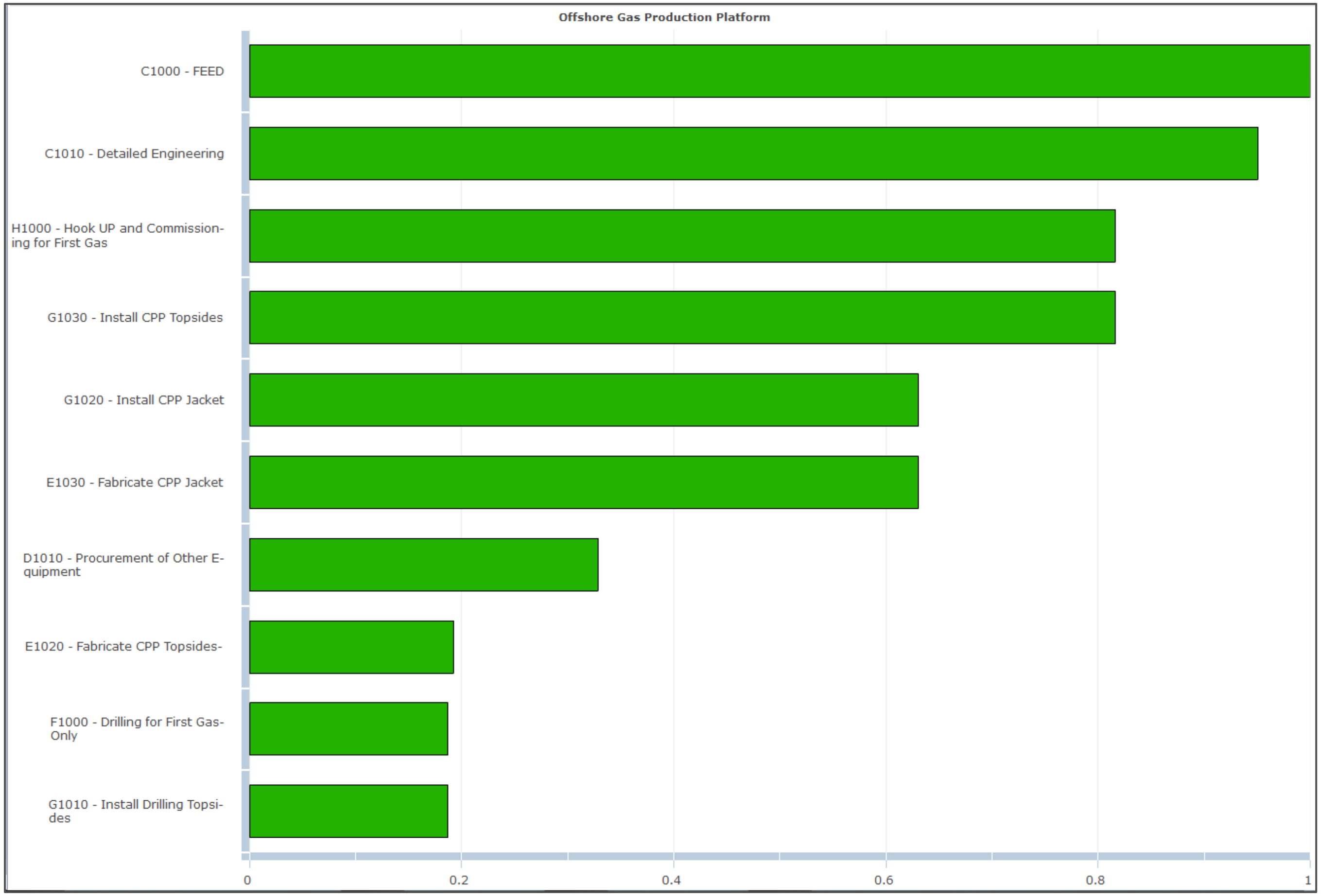
Uncertainty, Schedule Risk Drivers and Cost Risk Drivers



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 Fixed (vertical cross-section)

With cost risk added correlation is 71%

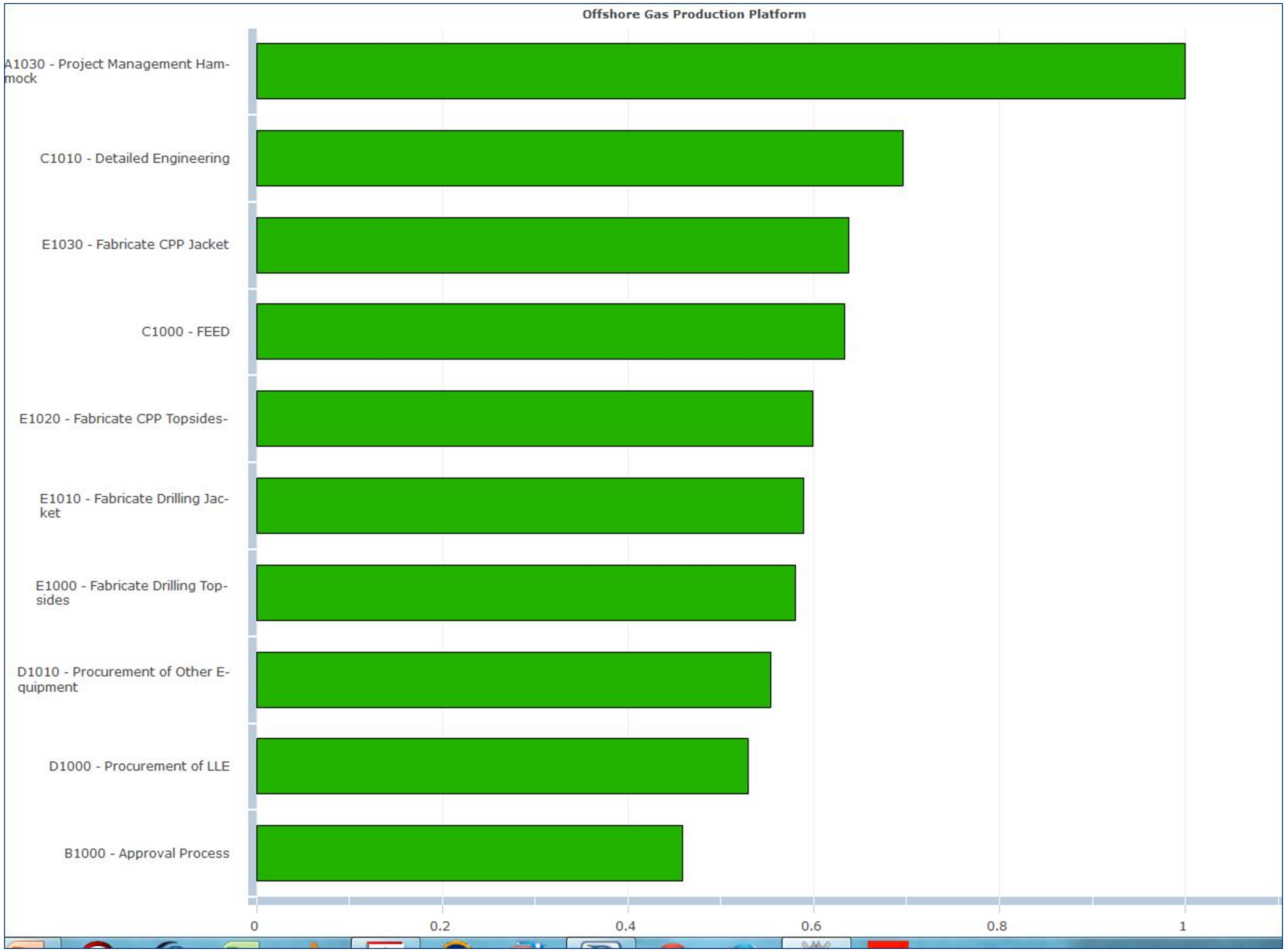
Schedule Criticality Index



Standard Criticality Index

Shows activities only, not risks

Schedule Duration Sensitivity by Activity



Standard sensitivity tornado by activity

Shows activities only, not risks

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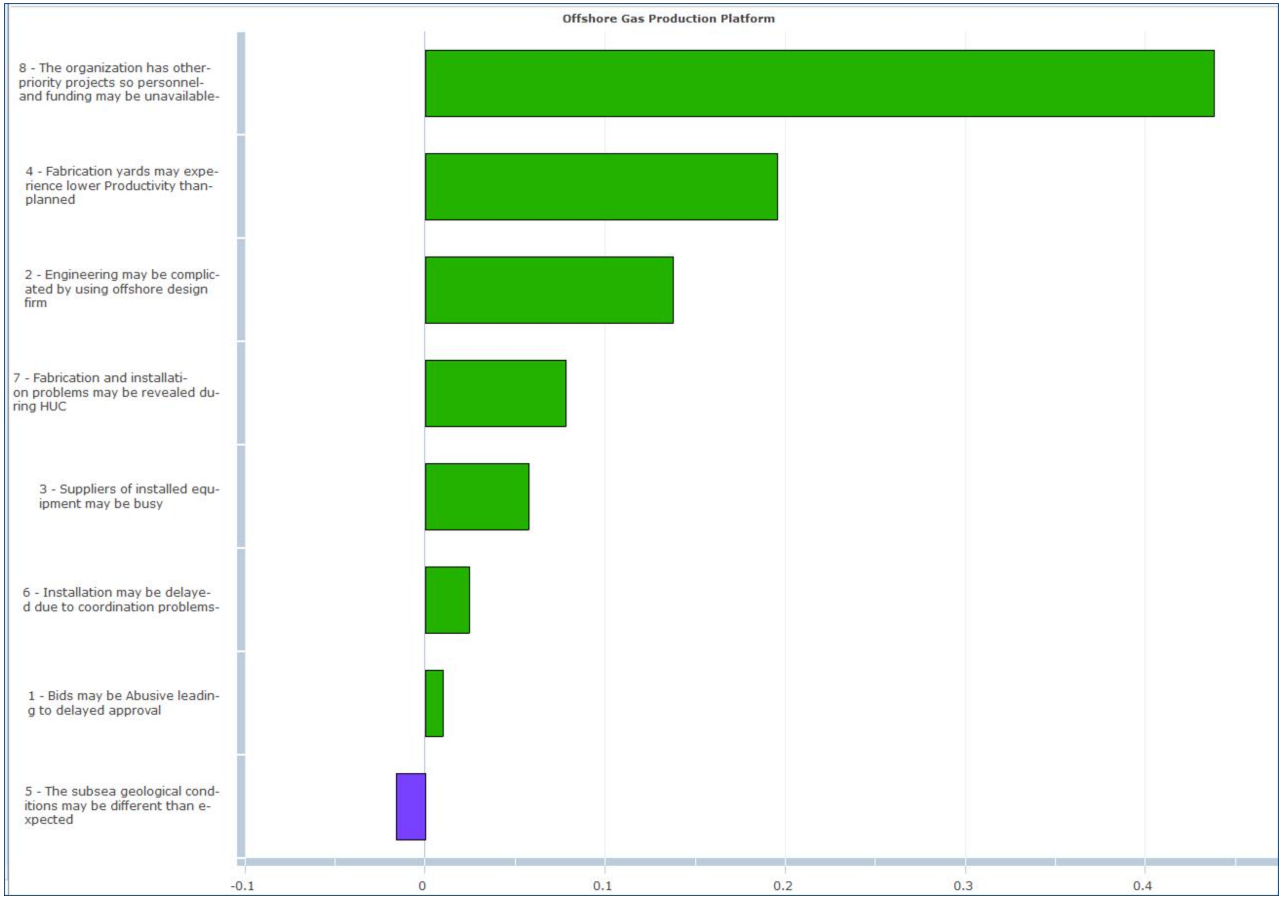
Impact on Schedule by Risk



Tornado shows impact on finish date by RISK.

Takes account of the probability of the risk, its impact if it happens and the activities it impacts, including whether they are risk critical or not

Correlation coefficients are hard to interpret. This is at the means, not at the P-80 level.

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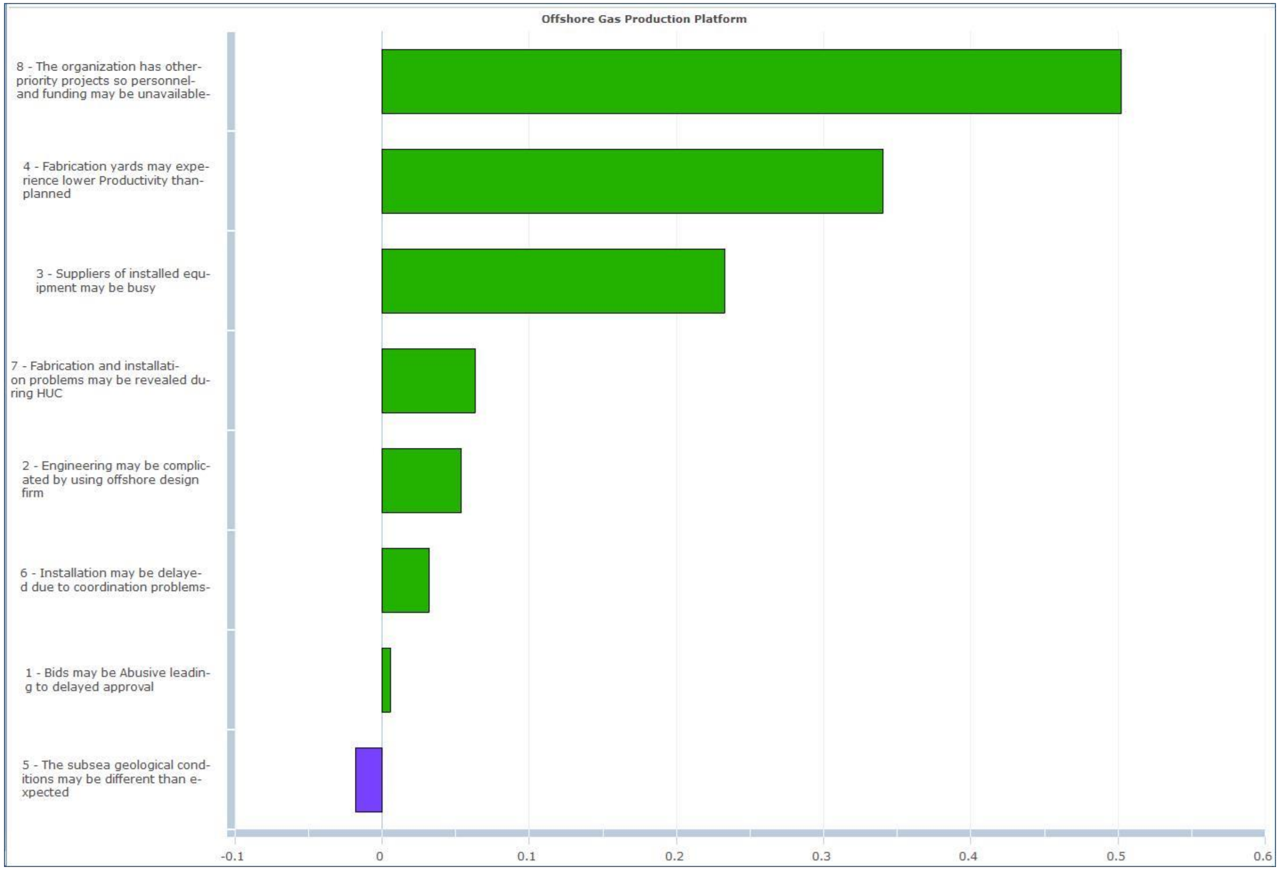
Impact on Cost by Risk



Impact on cost of RISKS

The order of the risks is slightly different, but these risk affect cost through their effect on schedule so much of the influence is the same.

Still, this is correlation with total project cost and not in dollars or at the P-80 level.

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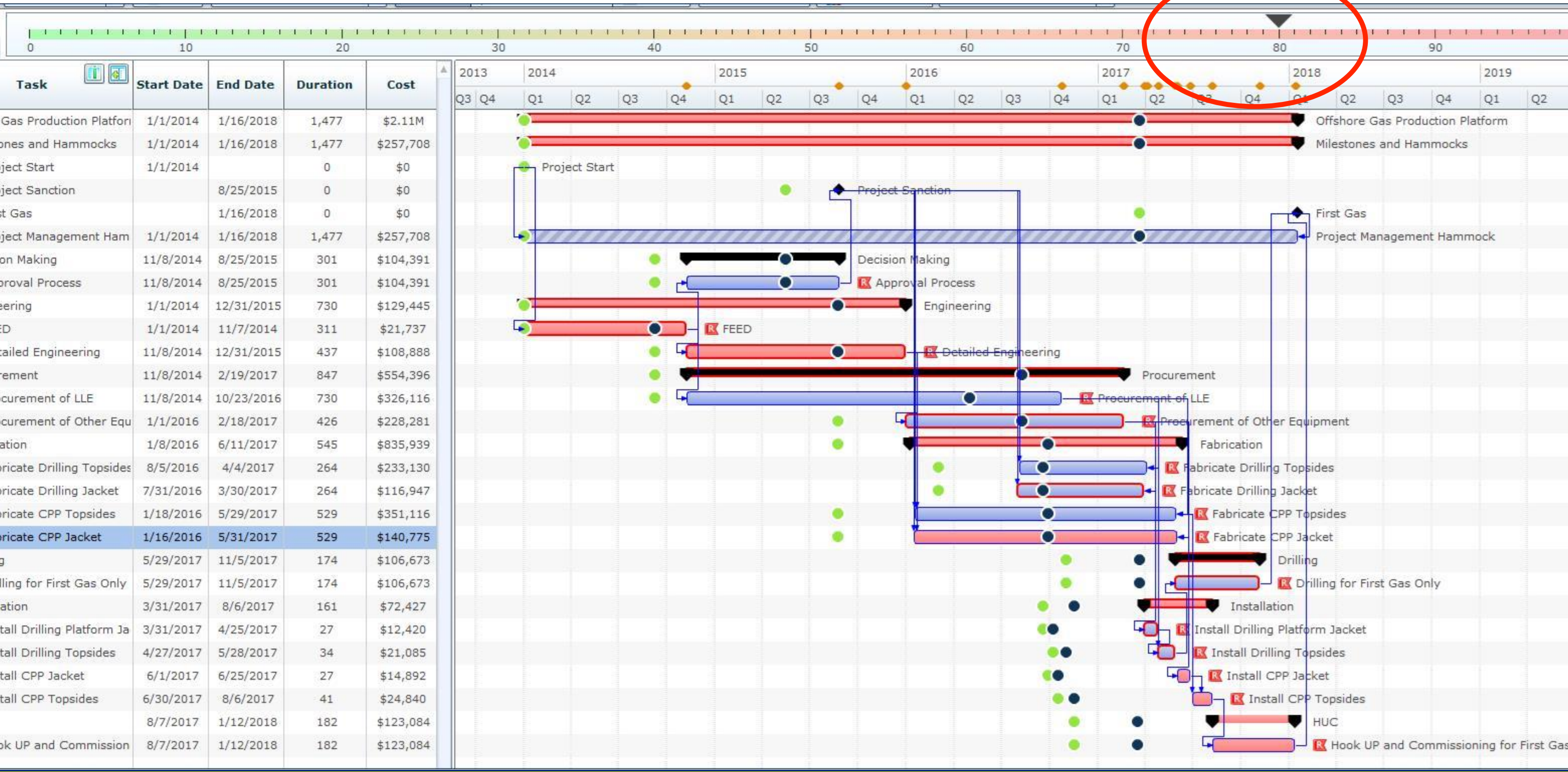
View shows P-80 scenario

Percentile

Cost of Delay

UID	Task	Start Date	End Date	Duration	Cost
Gas Pla	▼ Offshore Gas Production Platfor	1/1/2014	1/16/2018	1,477	$2.11M
Gas Pla	▼ Milestones and Hammocks	1/1/2014	1/16/2018	1,477	$257,708
A1000	Project Start	1/1/2014		0	$0
A1010	Project Sanction		8/25/2015	0	$0
A1020	First Gas		1/16/2018	0	$0
A1030	Project Management Ham	1/1/2014	1/16/2018	1,477	$257,708
Gas Pla	▼ Decision Making	11/8/2014	8/25/2015	301	$104,391
B1000	Approval Process	11/8/2014	8/25/2015	301	$104,391
Gas Pla	▼ Engineering	1/1/2014	12/31/2015	730	$129,445
C1000	FEED	1/1/2014	11/7/2014	311	$21,737
C1010	Detailed Engineering	11/8/2014	12/31/2015	437	$108,888
Gas Pla	▼ Procurement	11/8/2014	2/19/2017	847	$554,396
D1000	Procurement of LLE	11/8/2014	10/23/2016	730	$326,116
D1010	Procurement of Other Equ	1/1/2016	2/18/2017	426	$228,281
Gas Pla	▼ Fabrication	1/8/2016	6/11/2017	545	$835,939
E1000	Fabricate Drilling Topsides	8/5/2016	4/4/2017	264	$233,130
E1010	Fabricate Drilling Jacket	7/31/2016	3/30/2017	264	$116,947
E1020	Fabricate CPP Topsides	1/18/2016	5/29/2017	529	$351,116
E1030	Fabricate CPP Jacket	1/16/2016	5/31/2017	529	$140,775
Gas Pla	▼ Drilling	5/29/2017	11/5/2017	174	$106,673
F1000	Drilling for First Gas Only	5/29/2017	11/5/2017	174	$106,673
Gas Pla	▼ Installation	3/31/2017	8/6/2017	161	$72,427
G1000	Install Drilling Platform Ja	3/31/2017	4/25/2017	27	$12,420
G1010	Install Drilling Topsides	4/27/2017	5/28/2017	34	$21,085
G1020	Install CPP Jacket	6/1/2017	6/25/2017	27	$14,892
G1030	Install CPP Topsides	6/30/2017	8/6/2017	41	$24,840
Gas Pla	▼ HUC	8/7/2017	1/12/2018	182	$123,084
H1000	Hook UP and Commission	8/7/2017	1/12/2018	182	$123,084



The P-80 results compared to planned start: Green = CPM Starts, Blue = CPM Finishes, Bars = P-80 dates

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Color shows Percentile Dates

UID	Task	Start Date	End Date	Duration	Cost
Gas Pla	▼ Offshore Gas Production Platfor	1/1/2014	1/7/2019	1,833	$1.57M
Gas Pla	▼ Milestones and Hammocks	1/1/2014	1/7/2019	1,833	$200,000
A1000	Project Start	1/1/2014		0	$0
A1010	Project Sanction	3/10/2015	2/18/2016	346	$0
A1020	First Gas	2/3/2017	1/7/2019	704	$0
A1030	Project Management Ham	1/1/2014	1/7/2019	1,833	$200,000
Gas Pla	▼ Decision Making	7/12/2014	2/18/2016	587	$80,000
B1000	Approval Process	7/12/2014	2/18/2016	587	$80,000
Gas Pla	▼ Engineering	1/1/2014	8/19/2016	962	$96,000
C1000	FEED	1/1/2014	3/1/2015	425	$16,000
C1010	Detailed Engineering	7/12/2014	8/19/2016	770	$80,000
Gas Pla	▼ Procurement	7/12/2014	12/28/2017	1,266	$425,000
D1000	Procurement of LLE	7/12/2014	8/20/2017	1,136	$250,000
D1010	Procurement of Other Equ	5/3/2015	12/28/2017	971	$175,000
Gas Pla	▼ Fabrication	5/8/2015	6/4/2018	1,124	$576,000
E1000	Fabricate Drilling Topsides	10/9/2015	2/6/2018	852	$160,000
E1010	Fabricate Drilling Jacket	9/23/2015	2/6/2018	868	$80,000
E1020	Fabricate CPP Topsides	5/16/2015	6/4/2018	1,116	$240,000
E1030	Fabricate CPP Jacket	5/8/2015	4/6/2018	1,065	$96,000
Gas Pla	▼ Drilling	8/15/2016	12/13/2018	851	$80,000
F1000	Drilling for First Gas Only	8/15/2016	12/13/2018	851	$80,000
Gas Pla	▼ Installation	6/16/2016	7/8/2018	753	$47,200
G1000	Install Drilling Platform Ja	6/16/2016	3/11/2018	634	$8,000
G1010	Install Drilling Topsides	7/17/2016	4/18/2018	641	$13,600
G1020	Install CPP Jacket	6/27/2016	5/2/2018	675	$9,600
G1030	Install CPP Topsides	8/16/2016	7/8/2018	692	$16,000
Gas Pla	▼ HUC	9/18/2016	1/7/2019	842	$64,000
H1000	Hook UP and Commission	9/18/2016	1/7/2019	842	$64,000

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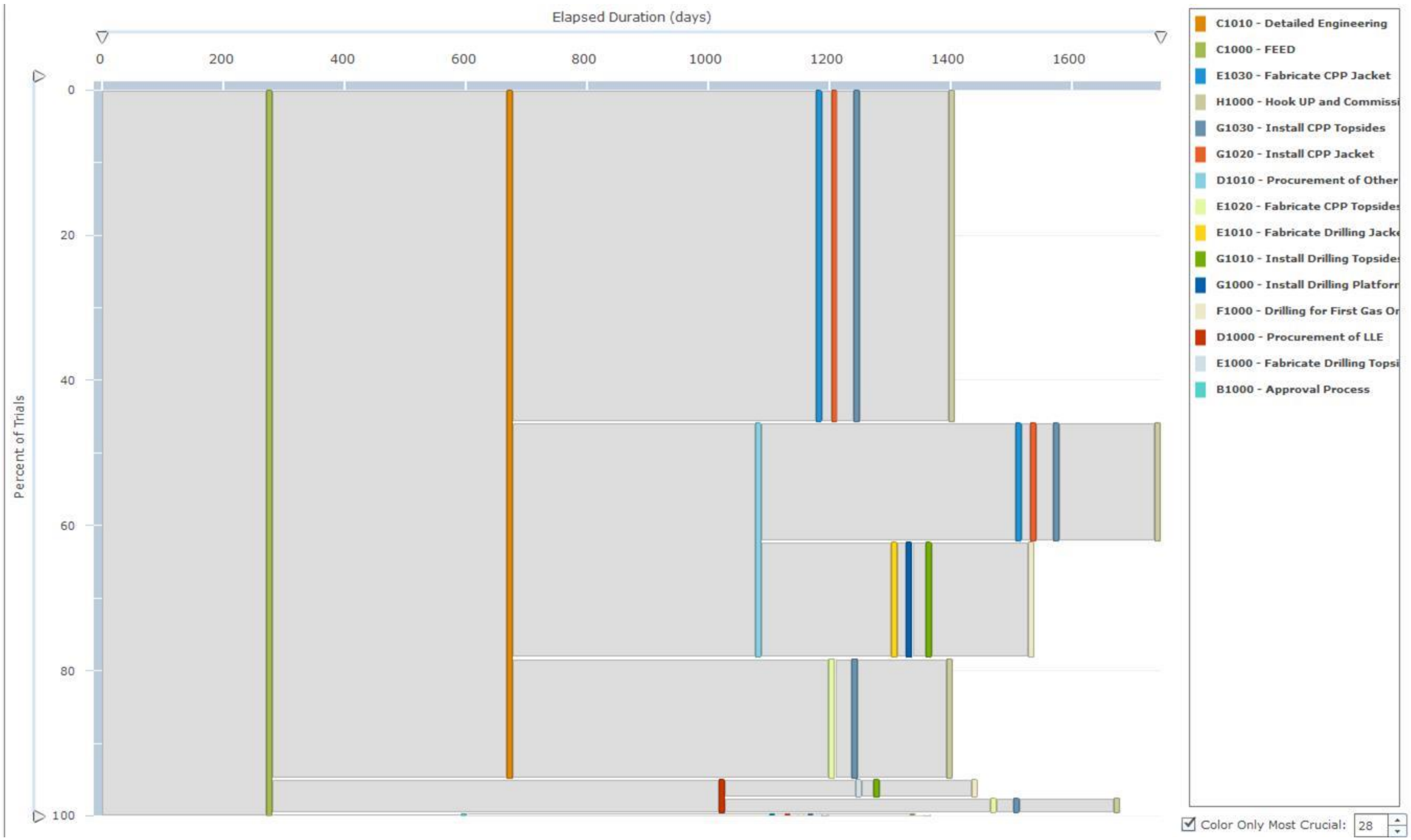
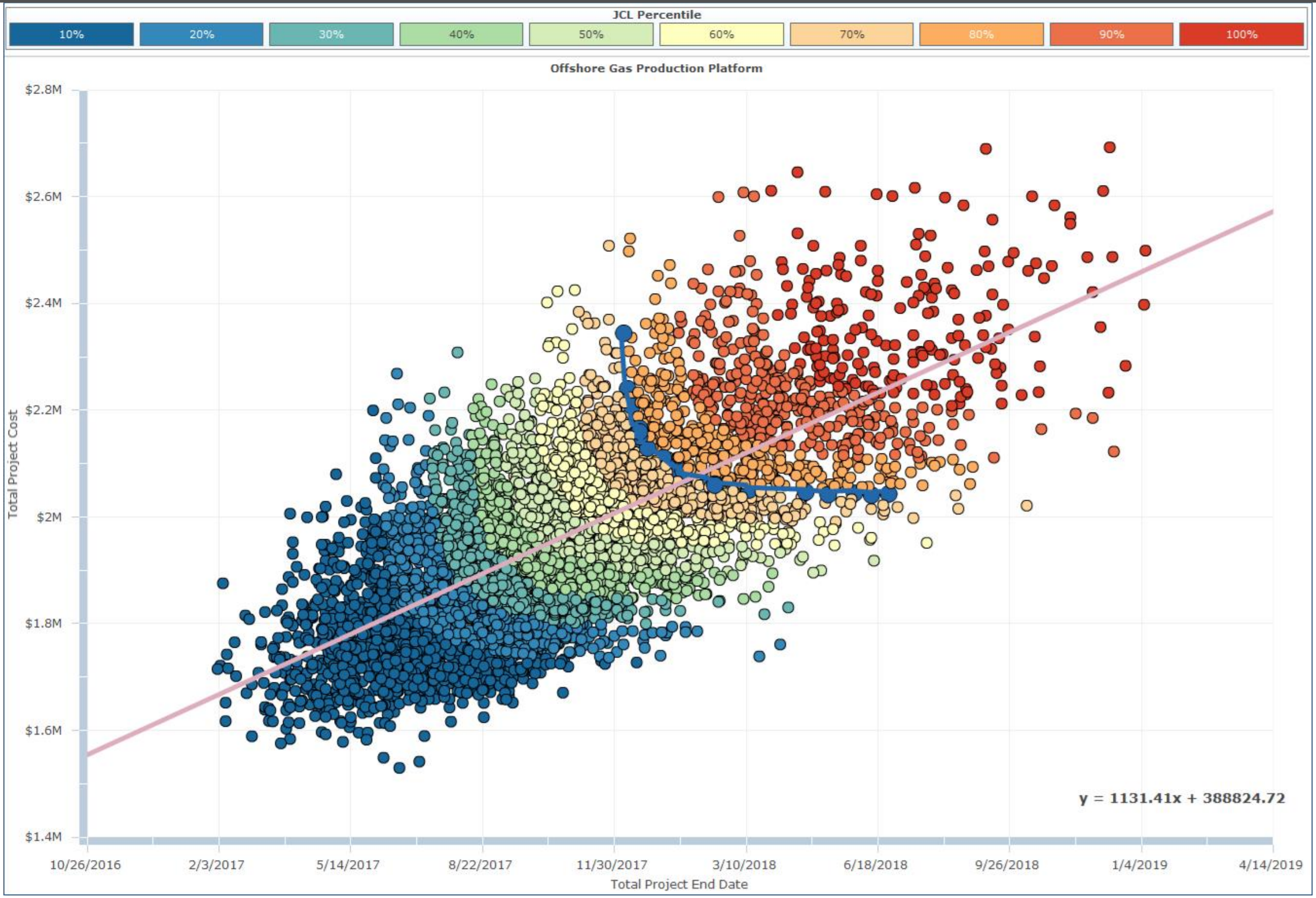
Reviewing Critical Path Tree



Analysis shows project has three, parallel, critical paths – potentially creating a risk for significant schedule growth

Associates

Scatter Plot with Trend Line and Color to Show Percentiles



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Iterative Approach to Prioritizing the Risk

- Purpose, which risks contribute the most days at the P-80 level
- Compute the Baseline with All Risks In
- Iteration # 1: Simulate with each risk disabled in turn, recording the P-80 date
  - The risk with the earliest P-80 date is 1st priority
  - Take it out for Iteration # 2
- Iteration # 2: Simulate the remaining risks, disabling each in turn, recording P-80, choose earliest. Take it out for Iteration # 3
- Etc.

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Progressively Fewer Risks are Considered as the Most Impactful Risk is Chosen at Each Level

Iterative Approach to Prioritizing Risks (Based on Days Saved at P-80)								
Risk #	1	2	3	4	5	6	7	8
Priority Level	**Abusive Bids**	**Offshore design firm**	**Suppliers Busy**	**Fab productivity**	**Geology unknown**	**Coordination during Installation**	**Problems at HUC**	**Resources may go to other projects**
1	X	X	X	X	X	X	X	**1**
2	X	X	X	**2**	X	X	X	
3	X	**3**	X		X	X	X	
4	X		X		X	X	**4**	
5	X		**5**		X	X		
6	X				X	**6**		
7	**7**				X			
8					**8**			

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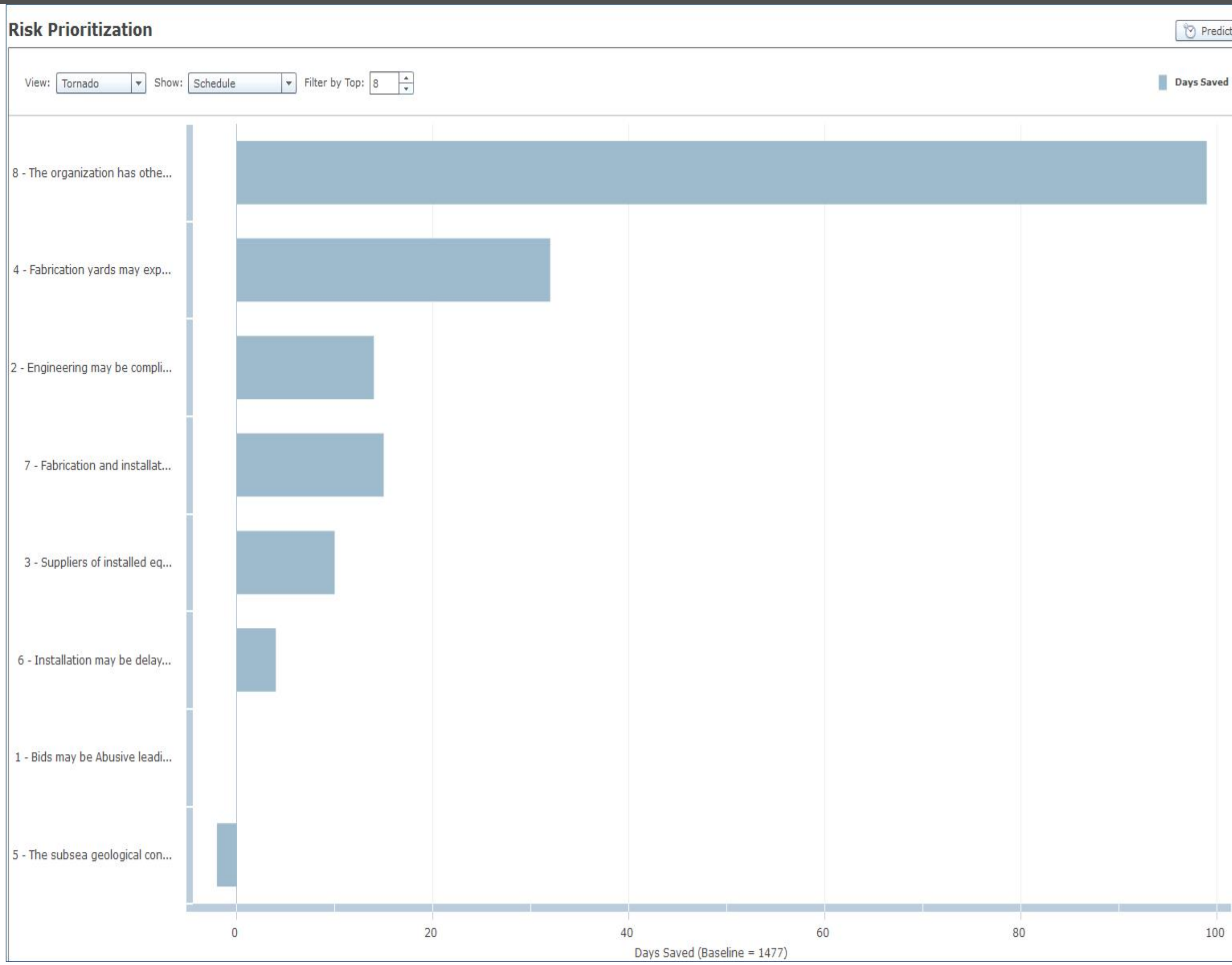
Prioritize Risks Using Iterative Simulations to Pick Most Important Risks to Schedule



Risks prioritized as they affect the finish date

These are prioritized at the P-80 level and in days saved if they were fully mitigated, in priority order

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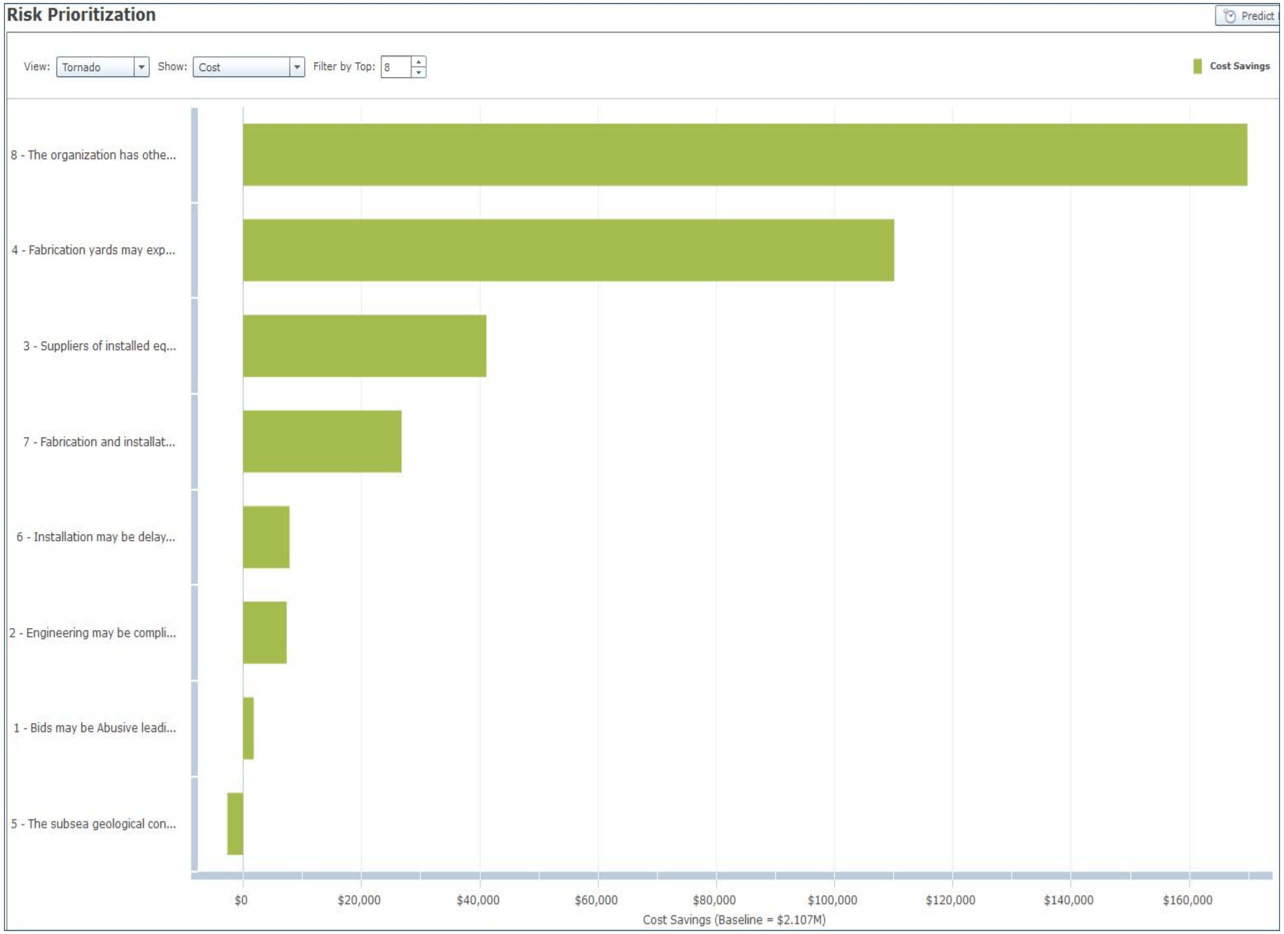
Prioritizing Risk Drivers to Finish First Gas at P-80

Gas Platform-1 - Risk Prioritization to Schedule (80%)		
UID	Name	Days Saved
8	The organization has other priority projects so personnel and funding may be unavailable	99
4	Fabrication yards may experience lower Productivity than planned	32
2	Engineering may be complicated by using offshore design firm	14
7	Fabrication and installation problems may be revealed during HUC	15
3	Suppliers of installed equipment may be busy	10
6	Installation may be delayed due to coordination problems	4
1	Bids may be Abusive leading to delayed approval	0
5	The subsea geological conditions may be different than expected	-2
	TOTAL DAYS SAVED RISK DRIVERS	**172**
	Uncertainty, estimating error and bias	130
	TOTAL DAYS SCHEDULE CONTINGENCY	**302**

Prioritizing Risks to Cost



Risks prioritized by their impact on Cost

The order of risks is different for Risks 2, 3 and 6

These risks are calibrated at the P-80 in dollars saved when they are removed

Prioritizing Risk Drivers to Total Cost at the P-80 Level

Gas Platform-1 - Risk Prioritization to Total Cost (80%)		
UID	Name	Cost Saved $ Millions
8	The organization has other priority projects so personnel and funding may be unavailable	$169,824
4	Fabrication yards may experience lower Productivity than planned	$110,115
3	Suppliers of installed equipment may be busy	$41,135
7	Fabrication and installation problems may be revealed during HUC	$26,789
6	Installation may be delayed due to coordination problems	$7,849
2	Engineering may be complicated by using offshore design firm	$7,357
1	Bids may be Abusive leading to delayed approval	$1,781
5	The subsea geological conditions may be different than expected	($2,669)
	TOTAL COST FROM RISK DRIVERS	**$362,180**
	Cost Risk from Uncertainty, Estimating Error / Bias	$180,000
	TOTAL COST CONTINGENCY RESERVE AT P-80	**$542,180**

The program is now ready to address Risk Mitigation

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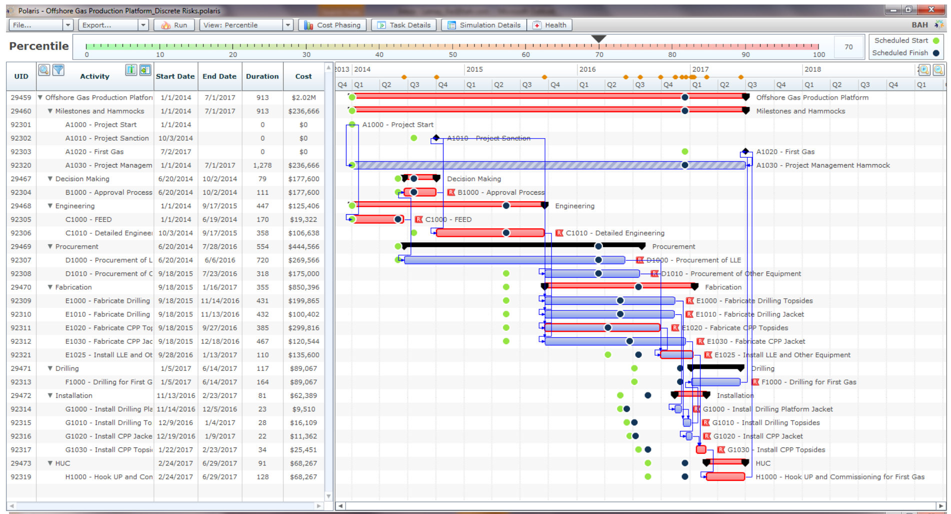
Predict (Gantt View Percent and Color Confidence)

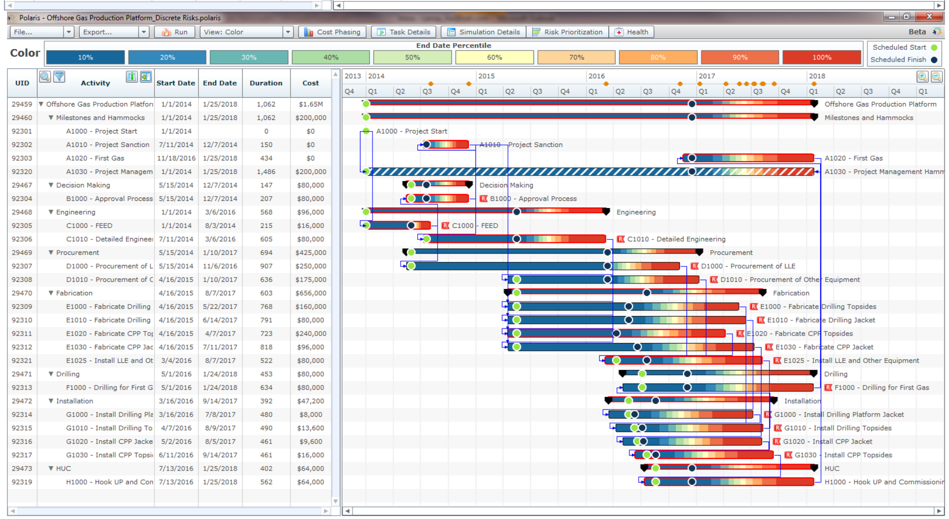
Percentile view allows the user to select their confidence level, represented as a %. By sliding the bar to the left or right, decreasing or raising respectively, the model will display different outputs for start, finish and duration.

Note the Progress Bars exceed the planned start and finish dates noted as Green and Black Dots.

Critical path is outlined in Red.

Risks are flagged in the Gantt.





Color view displays the Progress Bars with a color that corresponds to a %. As the confidence % grows the Progress Bars on the Gantt will change colors. **Planned start and finish dates noted as Green and Black Dots**

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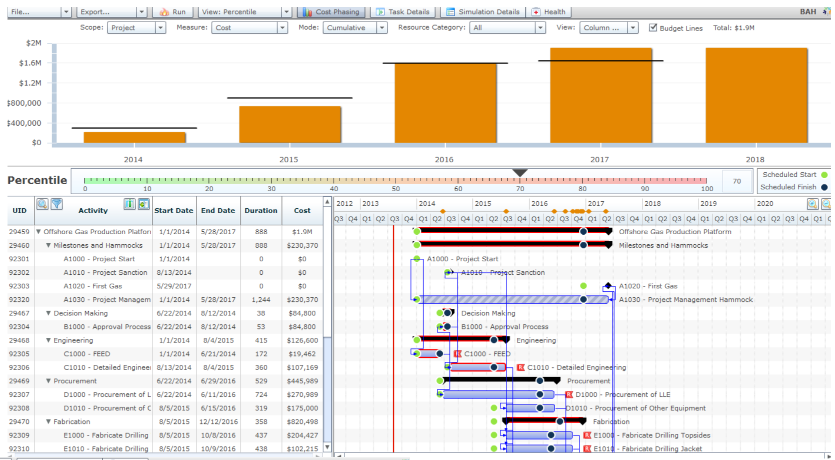
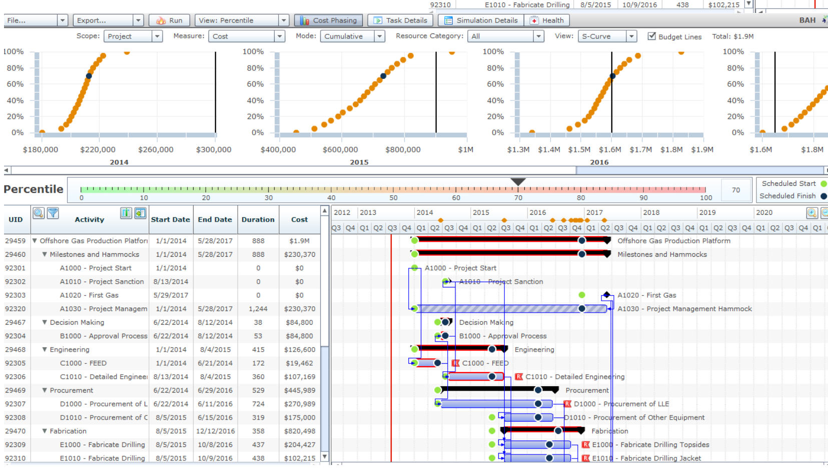
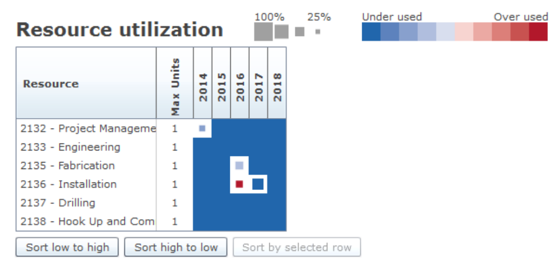
Predict (Cost Phasing and Resource Utilization)

Cost Phasing allows the user to select their confidence level, and then show the projected cost (orange) and current budget (black). This can be displayed as both bar chart, S-Curve, cumulative costs, individual period, project and task. This can be broken down into years, quarters or months in the output





Resource Utilization Heat Map displays utilization of resources throughout the project. This can be used to help level resources or forecast where additional resources may be needed.



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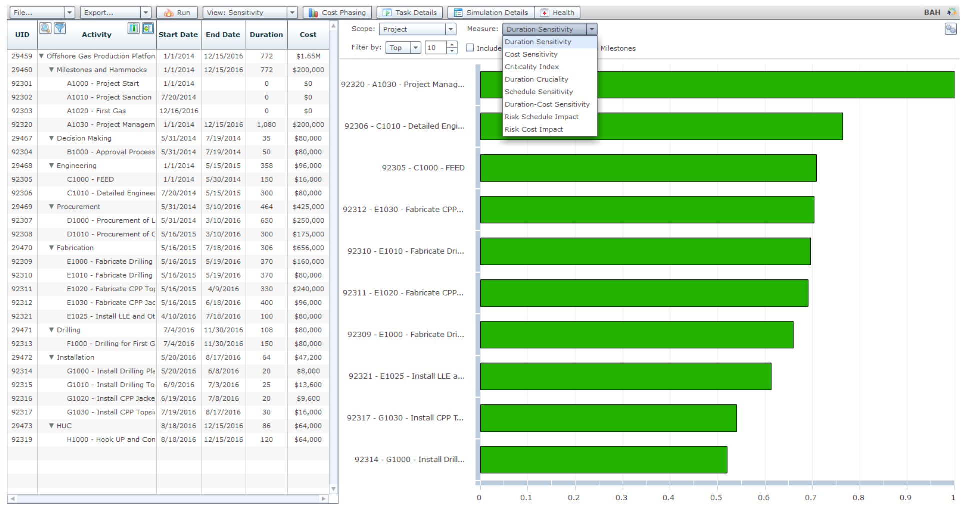
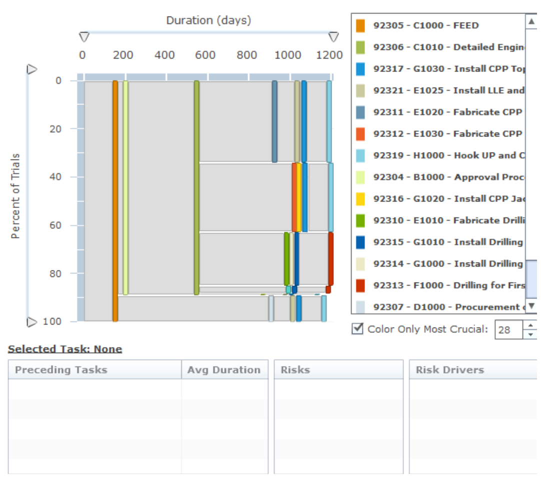
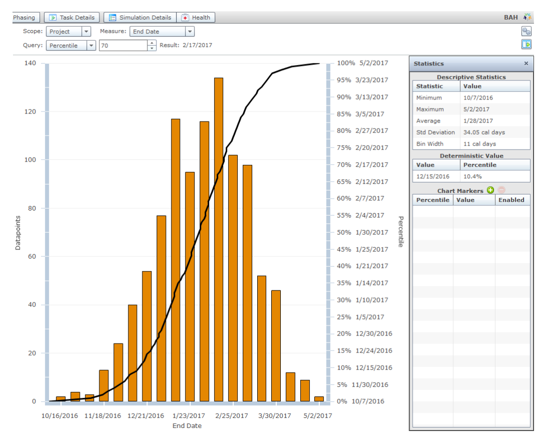
Analyze (Sensitivity, Critical Path Tree, CDF/PDF Charts)

Sensitivity Chart displays the tasks and risks that are driving duration, cost and critical path within the project.



Critical Path Tree shows the probability that a task or tasks will land on the critical path as the project progresses.





CDF/PDF Chart displays the S-Curve output of the simulation. The confidence level can be adjusted by the user to show different results. The CDF/PDF chart can display project dates, task dates, project cost, task costs, durations as well as others

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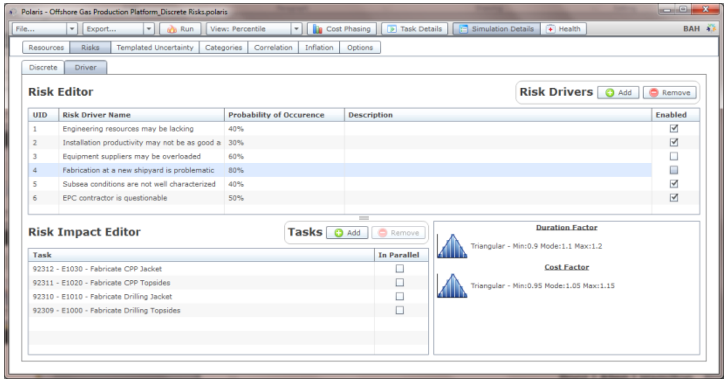
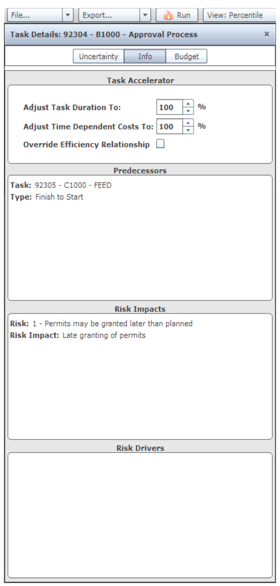
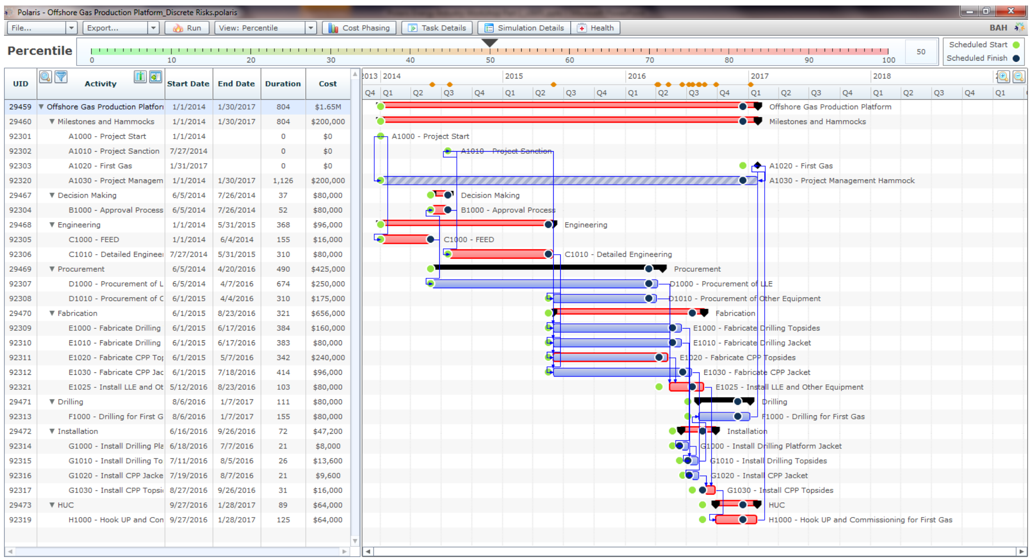
Mitigate (Risk Sheet and Percentile View)



Risk Sheet takes into account the % of occurrence, the impact of the risk both duration and cost and applies those factors to the tasks/ activities selected by the user. Risks and risk perimeters can be removed or changed within Polaris to model mitigation actions



**Once Risks are mitigated uncertainty is adjusted the model is re-run and the user can compare the results of the mitigation. Tasks can also be accelerated or decelerated as a part of the analysis and the results to cost and schedule displayed in the Gantt.*



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