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Understanding and Managing Uncertainty in Schedules

Realistic Plans for Project Success

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MPUG Project Integration Month
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Project

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Where Project Managers and Microsoft® Meet

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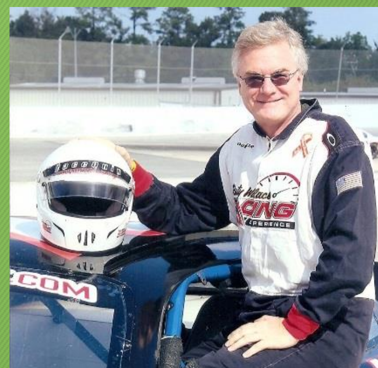

1981-1985 Worley Engineering (Planning Systems Manager)
1986-2006 Welcom (VP Development)
2006-2014 Deltek (Director Products and Strategy – Schedule & Risk)
2014- Barbecana Inc. (Chief Crazy Person)

Producing tools for organizations where outstanding project execution is a critical business requirement

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Objectives

- Explain how uncertainty can make our project models unrealistically optimistic.
- Show how we can improve our models to consider the impact of uncertainty.
- Identify the tasks in the schedule that are most likely to impact project success.
- Consider a technique for managing uncertainty during project execution.
- Reduce project management costs.

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Uncertainty / Sources of Risk

There are two basic types of uncertainty that we can consider

Estimate Uncertainty / Duration Risk

Estimate uncertainty is caused by a lack of knowledge

- We don't know exactly how long something will take
  - We can capture a range of estimates

Event Uncertainty / Unplanned Events aka Threats (Risks) and Opportunities

The impact of random events

- Something may or may not happen
  - We can plan for different eventualities

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The effect of uncertainty

- Variation of the project completion date
- Variation of the project cost
- Changes to the Critical Path
- Increased management effort
- Reduction in the perceived value of the project

So the purpose of modelling uncertainty is not just to understand the impact but also to help focus efforts to increase confidence and reduce management effort (reduce cost)

We already create great CPM models…

Critical Path Method calculates a single projection for a project completion date (Deterministic).

Every project, no matter how similar to projects before it, is always subject to some uncertainty.

This means that the only sure fact, for the project end date calculated by CPM, is that it will almost certainly be wrong.

Worse, the end date calculated by CPM is usually overly optimistic.

Here's why…

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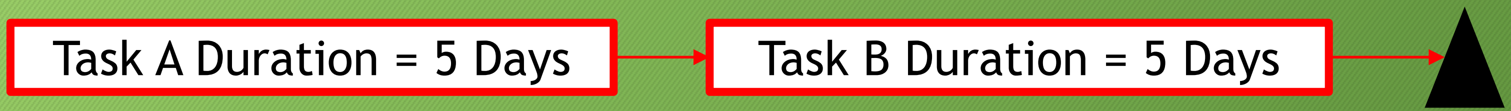
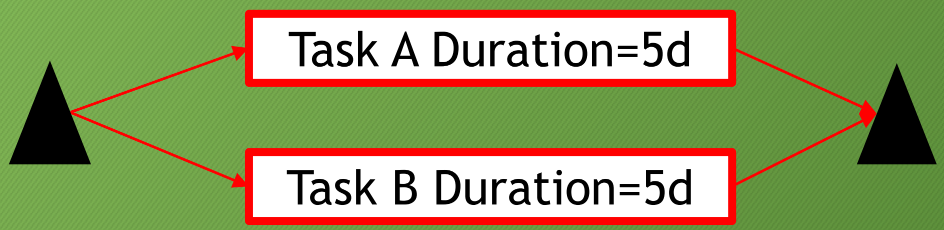
Consider two activities…



In this ‘serial’ example, if Task A is delayed, we can potentially make up the time while executing Task B.



In this ‘parallel’ example, if Task A is delayed, then the delivery is delayed regardless how well we perform on Task B.

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The Chance of Project Success

Let's tabulate the possible outcomes for Task A and B (and to simplify the table we'll count an on-time finish as early).

Task A	Task B	Project
Early/On-Time	Early/On-Time	Early/On-Time
Late	Early/On-Time	Late
Early/On-Time	Late	Late
Late	Late	Late

We know that the project will only complete on time if **both** Task A and B finish early or on-time. Of our four possible outcomes we can see this only happens one time. Any of the other three possible outcomes results in a late project completion (75% chance of failure!)

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One reason projects fail…

As the number of predecessors for any given activity increases, it becomes less likely that it will start on time.

This effect is called Merge Bias.

Merge Bias is the single biggest reason that project models, built using Critical Path Method (CPM), inherently produce an unrealistic forecast for project completion.

As the complexity of the project model increases, and the number of activities with multiple predecessors grows, the probability of attaining the deliverable dates, suggested by CPM, decreases.

So project failure may not be caused by poor estimating or execution, but simply by the fact that the plan was never realistic or achievable in the first place.

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Modelling Uncertainty

There have been two primary attempts to help model uncertainty in schedules.

Program/Project Evaluation and Review (PERT).

Captured a range of duration estimates for each task but then used an algebraic expression to convert that to a single duration for CPM analysis. This cannot quantify merge bias.

Monte Carlo Simulation / Schedule Risk Analysis (SRA)

Captures a range of duration estimates for each task and then simulates the execution of the project many times using different durations sampled from within the specified range for each task on each iteration of the simulation. This allows for the measurement of the impact of merge bias.

Can SRA really reduce project costs?

There is a perception that schedule risk analysis is an overhead forced on organizations by bid/contract requirements:

- It is perceived as time consuming (a lot of work)
- It is perceived as something only required to win the work
- It is perceived as little value for in-progress projects
- It is perceived as being a luxury overhead that costs money

Other objections:

- It's too advanced / we're not there yet
- I do my risk assessment based on cost
- It doesn't help me meet targets already set

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Opportunities for cost savings

Produce a more realistic forecast that reduces the likelihood of penalties for delays.

Reduce management effort by understanding in advance what might happen.

- Focus on the thing that matter
- Reduce reactive change meetings

Identify opportunities for schedule compression to meet contract requirements.

Use ‘schedule margin’ as an ongoing tool to manage expectations.

Surprises cost Money!

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Before we go any further…

We need a sound schedule!

- Project logic is present and correct.
- Project status/progress information is up-to-date.
- ‘Hard’ constraints (anything that prevents dates from pushing into the future) have been removed.
- Make sure support/management (Level of Effort) work is not driving the schedule.

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Assessing the impact of Merge Bias

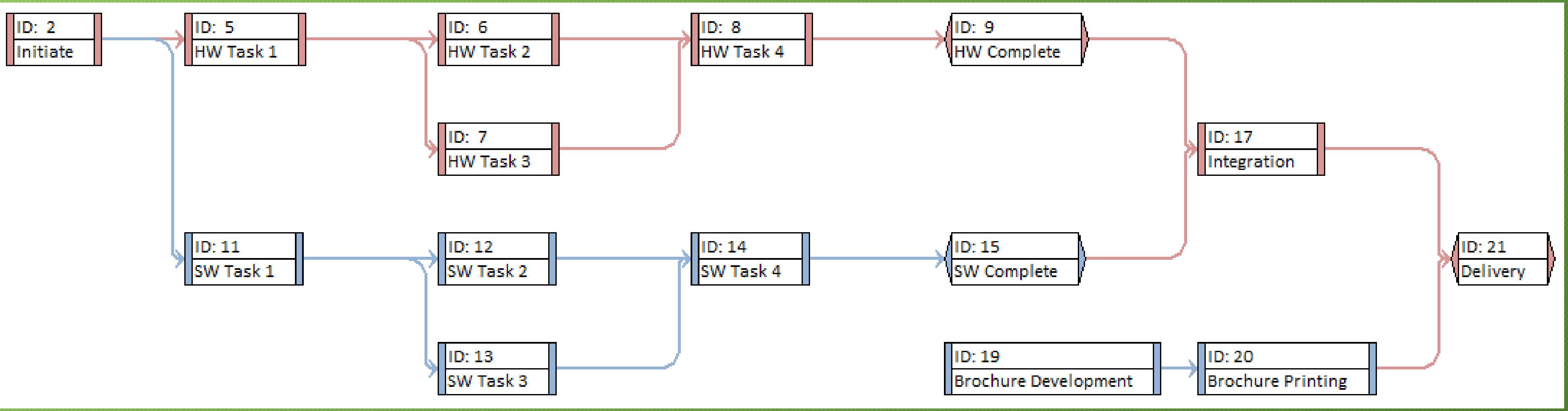
Merge Bias comes into play when there are multiple paths through a schedule – and they don't have to be critical paths.

We can very easily understand the possible impact of Merge Bias by making a few simple assumptions:

- Our estimates are reasonable
- We execute well against the estimates
- All tasks are subject to some uncertainty, and for the purposes of analysis, that uncertainty is symmetrical (just as likely to deliver each task early as late)

While these may seem very generous/unrealistic assumptions we can use them to quickly find out the potential impact of Merge Bias.

A simple project



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Add some symmetrical uncertainty

ID	Task Name	Remaining Duration	Duration Distribution Type	Duration Optimistic	Duration Most Likely	Duration Pessimistic
0	HW vs SW Demonstration	14 wks	Triangular	75%	100%	125%
1	Hardware vs Software	14 wks	Triangular	75%	100%	125%
2	Initiate	1 wk	Triangular	75%	100%	125%
3	Development	12 wks	Triangular	75%	100%	125%
4	Hardware	12 wks	Triangular	75%	100%	125%
5	HW Task 1	4 wks	Triangular	75%	100%	125%
6	HW Task 2	4 wks	Triangular	75%	100%	125%
7	HW Task 3	4 wks	Triangular	75%	100%	125%
8	HW Task 4	4 wks	Triangular	75%	100%	125%
9	HW Complete	0	Triangular			
10	Software	54 days	Triangular	75%	100%	125%
11	SW Task 1	18 days	Triangular	75%	100%	125%
12	SW Task 2	18 days	Triangular	75%	100%	125%
13	SW Task 3	18 days	Triangular	75%	100%	125%
14	SW Task 4	18 days	Triangular	75%	100%	125%
15	SW Complete	0	Triangular			
16	Integration	1 wk	Triangular	75%	100%	125%
17	Integration	1 wk	Triangular	75%	100%	125%
18	Marketing	3 wks	Triangular	75%	100%	125%
19	Brochure Development	2 wks	Triangular	75%	100%	125%
20	Brochure Printing	1 wk	Triangular	75%	100%	125%
21	Delivery	0	Triangular			

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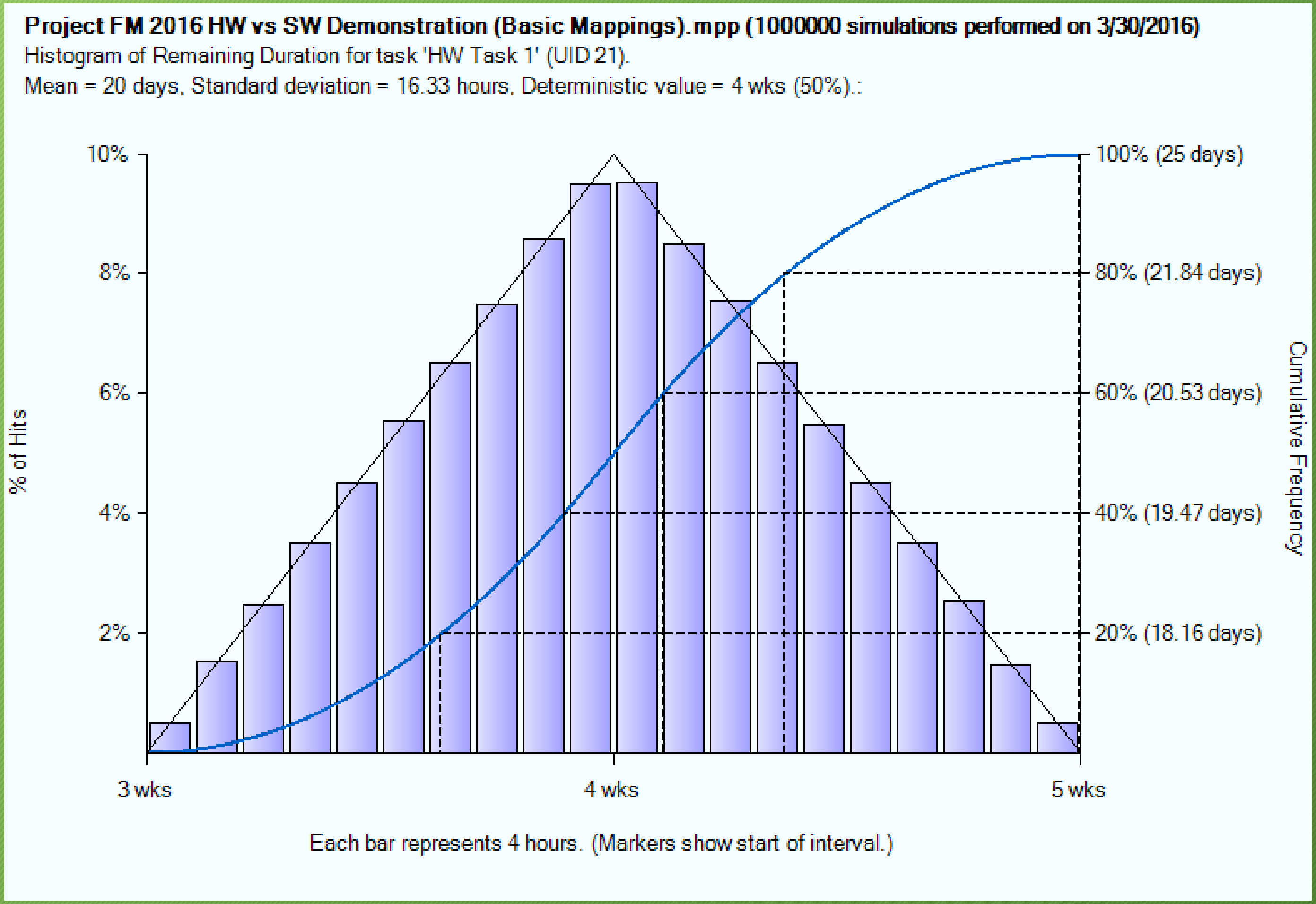
Symmetrical uncertainty on one activity



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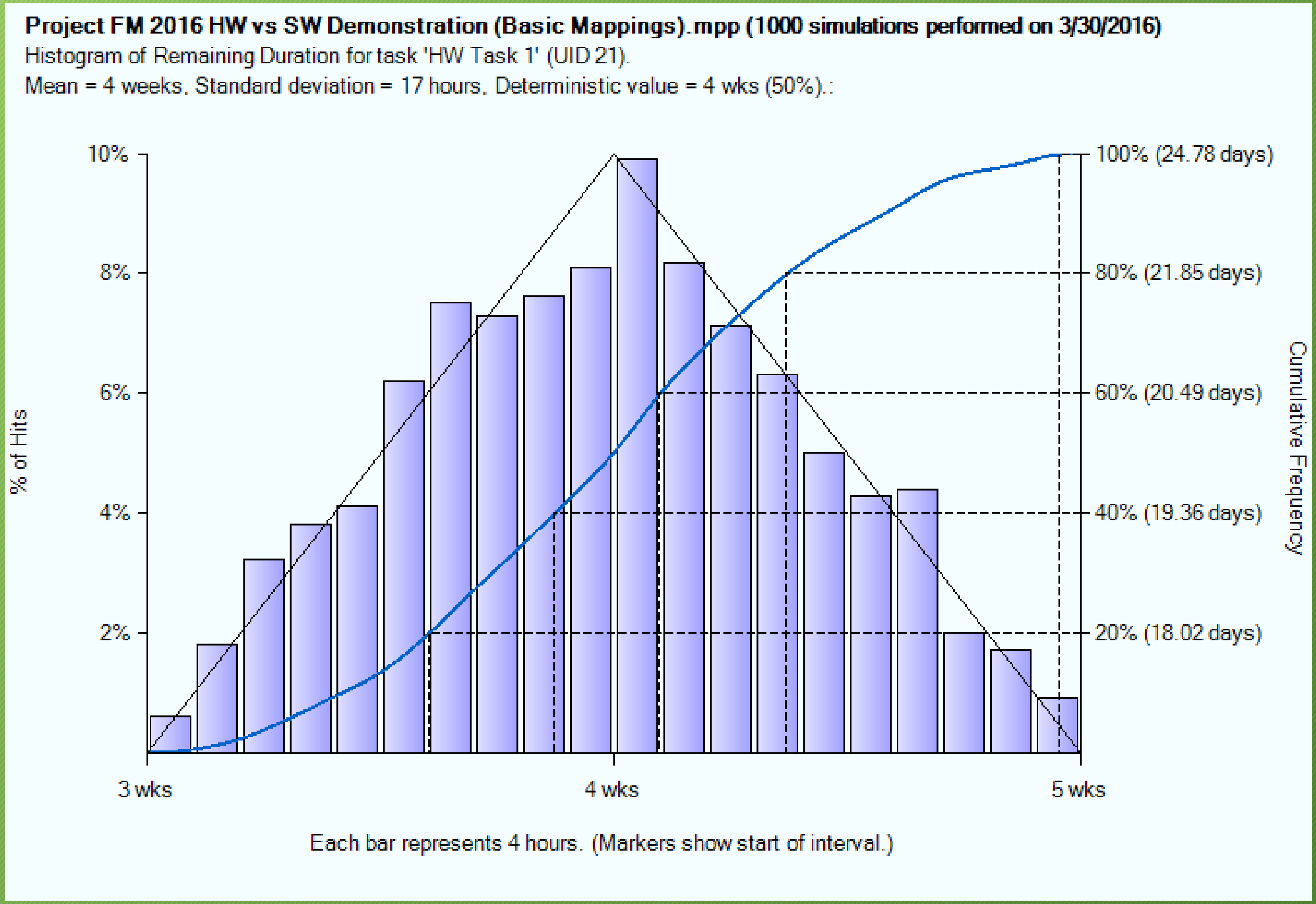
Do I need 1000000 simulations?



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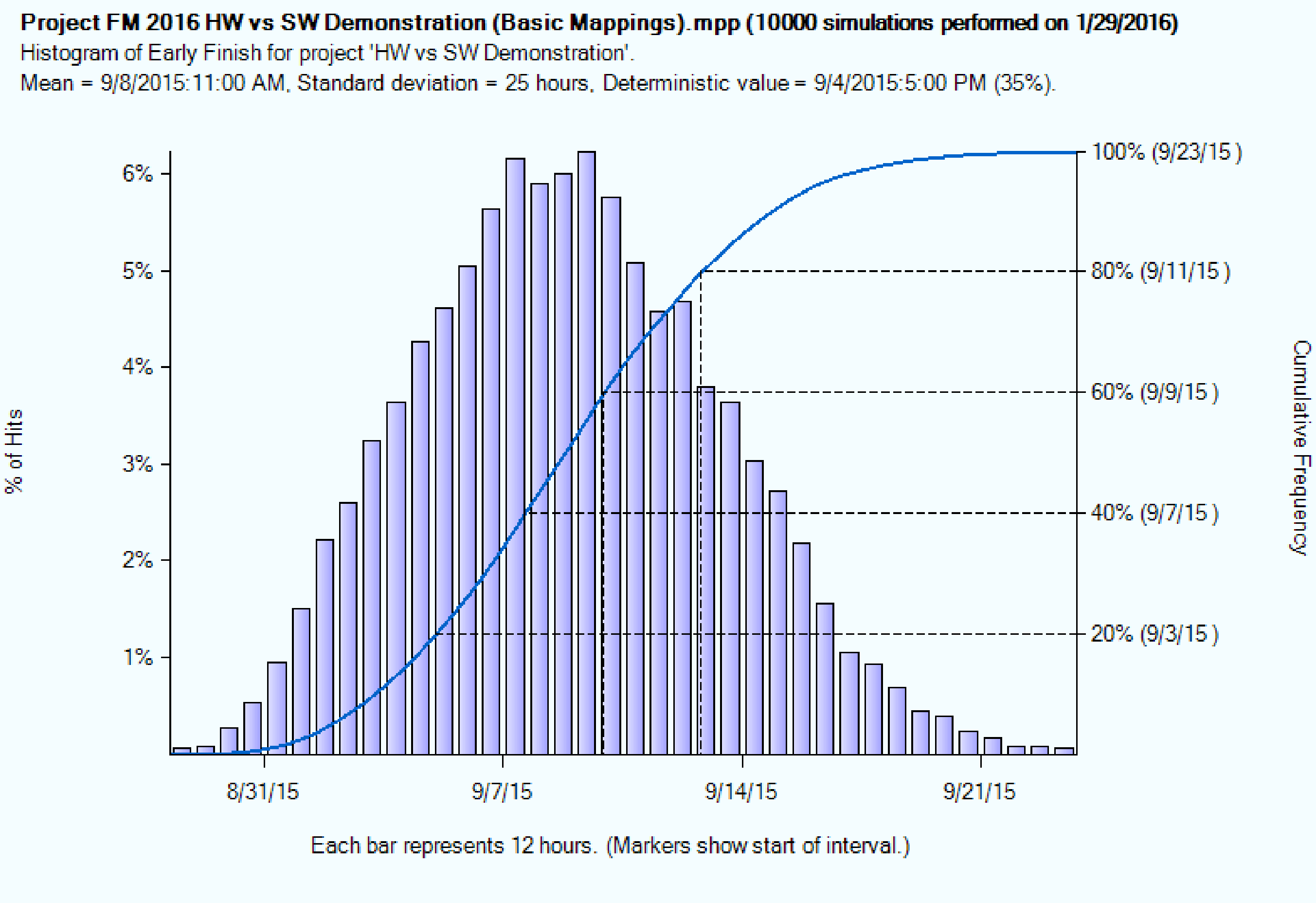
The effect of Merge Bias



Even with symmetrical uncertainty we only have a 35% chance of completing on time!

ID	Task Name	Merge Delay
8	HW Task 4	9.2 hrs
14	SW Task 4	8.12 hrs
17	Integration	1.32 hrs
21	Delivery	0.25 hr

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Hmmm…

OK, so we learned that Merge Bias may affect our ability to deliver, but the uncertainty we introduced was quite unrealistic and won’t it be a great deal of effort to get better data?

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Identify tasks for estimate refinement

ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Optimistic Finish of Project	Pessimistic Finish of Project
5	HW Task 1	4 wks	91%	91%	57%	03Sep15	15Sep15
8	HW Task 4	4 wks	91%	91%	57%	03Sep15	15Sep15
7	HW Task 3	4 wks	46%	46%	29%	07Sep15	14Sep15
6	HW Task 2	4 wks	45%	45%	28%	07Sep15	14Sep15
17	Integration	1 wk	100%	100%	16%	07Sep15	09Sep15
2	Initiate	1 wk	100%	100%	16%	07Sep15	09Sep15
11	SW Task 1	18 days	9%	9%	5%	08Sep15	10Sep15
14	SW Task 4	18 days	9%	9%	5%	08Sep15	10Sep15
12	SW Task 2	18 days	4%	4%	3%	08Sep15	09Sep15
13	SW Task 3	18 days	4%	4%	2%	08Sep15	09Sep15

Based on our simplistic assumptions, the sensitivity tornado chart can highlight the tasks that are affecting the deliverable outcome and gives us an indication of tasks worth the effort of estimate verification and refinement.

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Refining Estimates

Monte Carlo simulation uses a range of estimates for tasks - often called 3-Point estimates

- Optimistic
- Most Likely
- Pessimistic

These estimates can be captured as specific durations or as percentages of the remaining duration.

A distribution type can also be specified to control where samples are likely to be taken between the three estimates.

This is starting to sound complicated and time consuming…

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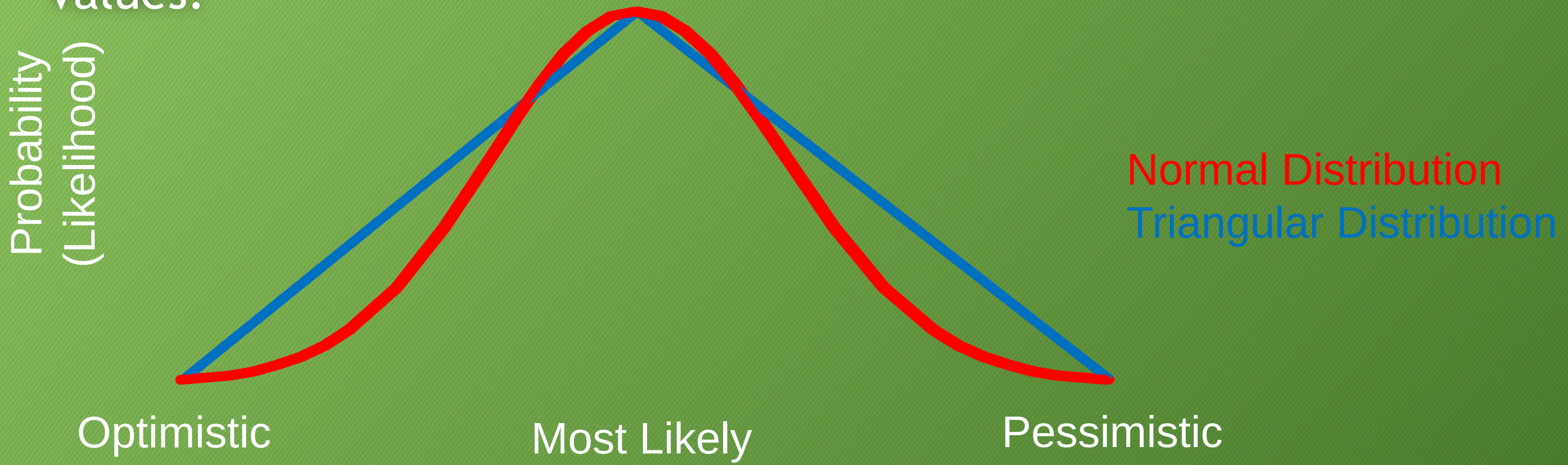
Estimate Uncertainty - Probability Distributions

The durations sampled in the range specified by the optimistic, most likely, and pessimistic durations, can be weighted using a probability distribution.

This allows us to define how likely sampled durations are to be closer to the Most Likely vs Optimistic and Pessimistic values.



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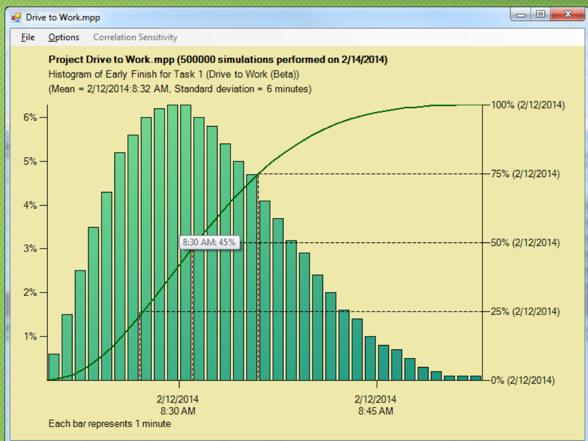
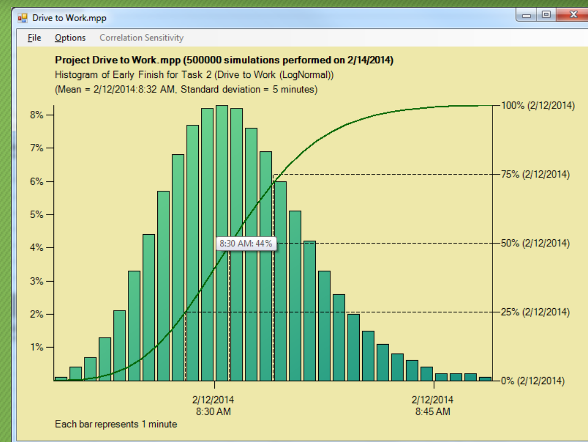
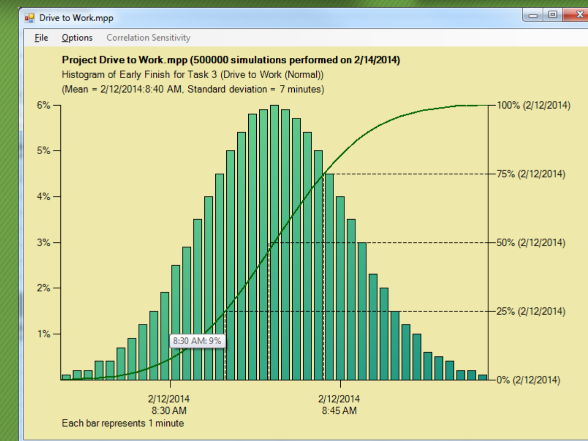
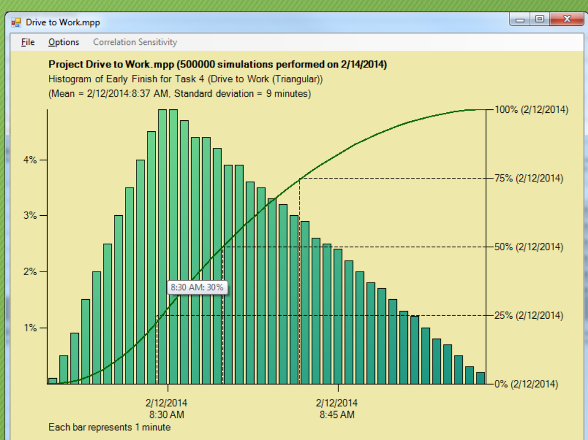
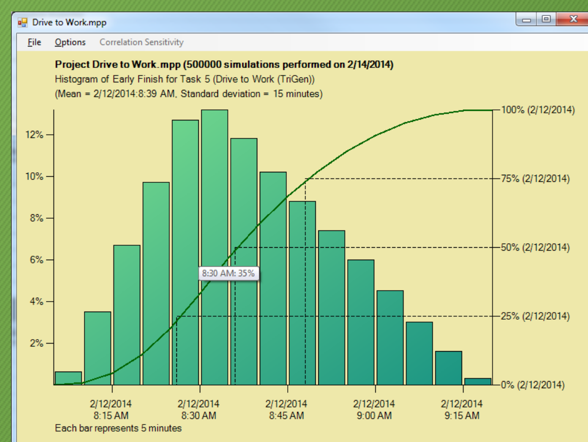
Distribution Types











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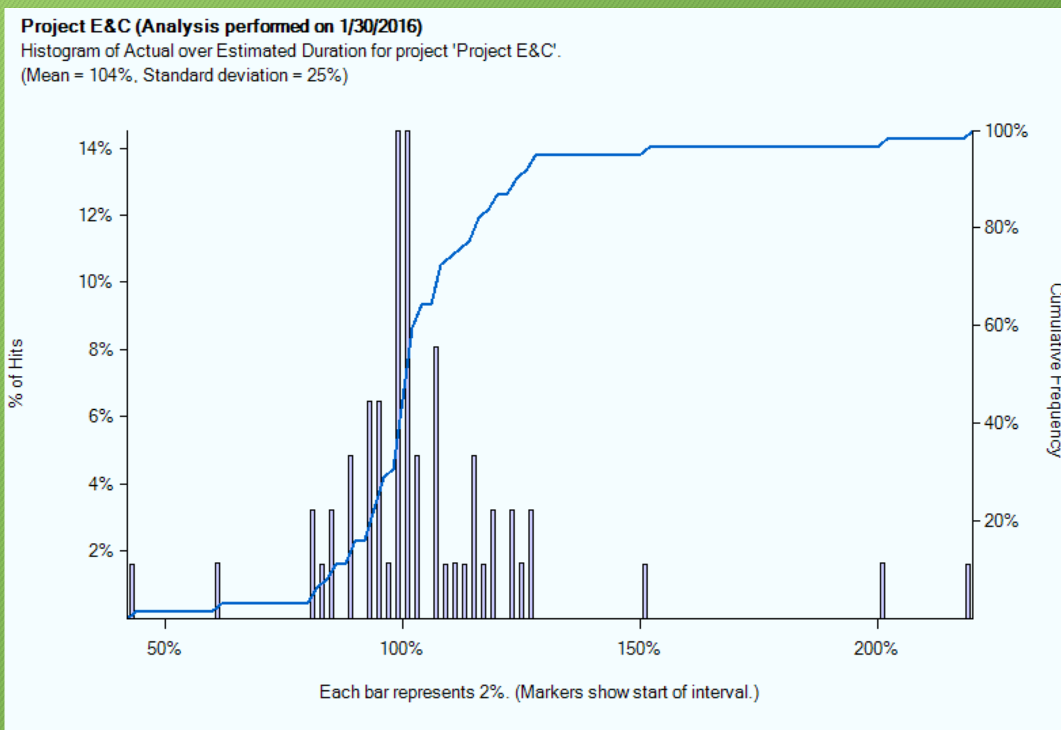
Which Distribution?

General Guidance

- Use historical data to determine an appropriate distribution
- Unless there is a compelling reason, do not use Uniform
- In the absence of specific guidance, use Triangular or Lognormal
- Use Beta or Triangular if you need to specify the degree of skew (e.g. transportation)
- Use Confidence Limits if the estimator wants to hedge

It's more important to get good duration estimates than worry about distribution types…

Historical Data Analysis



This historical analysis of all projects in our E&C division clearly shows that using a beta distribution with an Optimistic value of 90%, Most Likely of 100% and Pessimistic of %130 would be defensible.

The outliers may be data entry errors, short duration tasks, or threats that were not correctly identified as discrete tasks.

The Estimate Confidence approach

Categorize duration estimates using simple 'estimate confidence' scoring systems:

- Hardware – High Confidence/Low Risk
- Hardware – Low Confidence/High Risk
- Software – High Confidence/Low Risk
- Hardware – Low Confidence/High Risk
- Earthworks – High Confidence/Low Risk
- Earthworks – Low Confidence/High Risk

Development		**60 days**
Hardware		**60 days**
HW Task 1	HW Low Risk	20 days
HW Task 2	HW Low Risk	20 days
HW Task 3	HW Low Risk	20 days
HW Task 4	HW Low Risk	20 days
HW Complete		0 days
Software		**54 days**
SW Task 1	SW High Risk	18 days
SW Task 2	SW High Risk	18 days
SW Task 3	SW High Risk	18 days
SW Task 4	SW High Risk	18 days
SW Complete		0 days

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Define what 'confidence' means

	Distribution Type	Optimistic	Most Likely	Pessimistic
Hardware High Confidence/Low Risk	Normal	95%	100%	105%
Hardware Low Confidence/High Risk	Beta	95%	100%	110%
Software High Confidence/Low Risk	Beta	90%	100%	120%
Software Low Confidence/High Risk	Triangular	95%	110%	150%
Earthworks High Confidence/Low Risk	Beta	90%	100%	130%
Earthworks Low Confidence/High Risk	Beta	90%	110%	130%

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And apply that to the SRA

ID	Task Name	Remaining Duration	Duration Distribution Type	Duration Optimistic	Duration Most Likely	Duration Pessimistic	Duration Confidence Interval (%)	Early Finish Histogram
0	⊟ HW vs SW Demonstration	14 wks	(None)					NA
1	⊟ Hardware vs Software	14 wks	(None)					NA
2	Initiate	1 wk	(None)					NA
3	⊟ Development	12 wks	(None)					NA
4	⊟ Hardware	12 wks	(None)					NA
5	HW Task 1	4 wks	Normal	90%	100%	110%	100%	NA
6	HW Task 2	4 wks	Normal	90%	100%	110%	100%	NA
7	HW Task 3	4 wks	Normal	90%	100%	110%	100%	NA
8	HW Task 4	4 wks	Normal	90%	100%	110%	100%	NA
9	HW Complete	0	(None)					NA
10	⊟ Software	54 days	(None)					NA
11	SW Task 1	18 days	Triangular	90%	120%	150%	100%	NA
12	SW Task 2	18 days	Triangular	90%	120%	150%	100%	NA
13	SW Task 3	18 days	Triangular	90%	120%	150%	100%	NA
14	SW Task 4	18 days	Triangular	90%	120%	150%	100%	NA
15	SW Complete	0	(None)					NA
16	⊟ Integration	1 wk	(None)					NA
17	Integration	1 wk	(None)					NA
18	⊟ Marketing	3 wks	(None)					NA
19	Brochure Development	2 wks	(None)					NA
20	Brochure Printing	1 wk	(None)					NA
21	Delivery	0	(None)					NA

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And the result is…

Despair and Disbelief!

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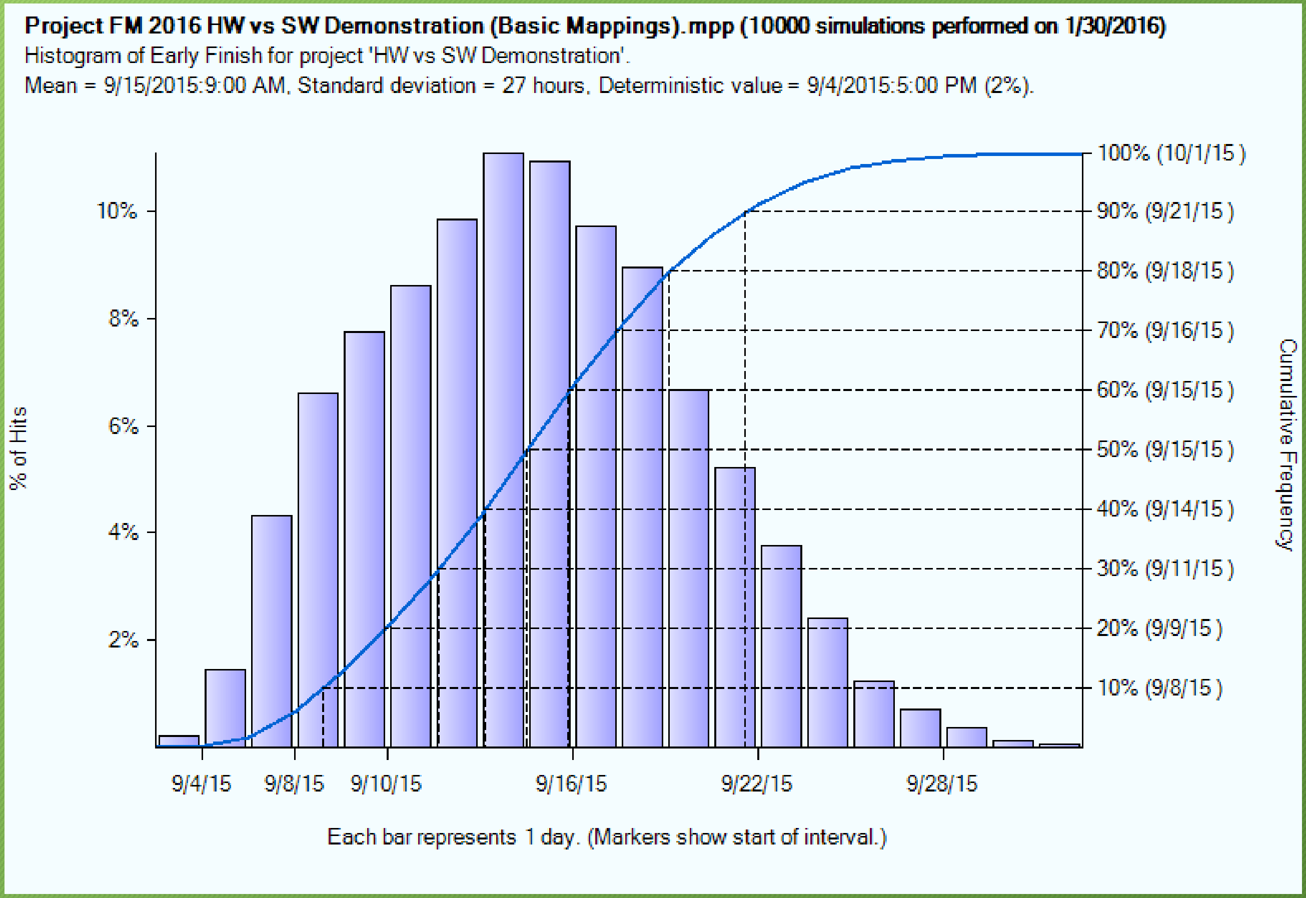
Only a 2% chance of success!



The Histogram shows the chance of finishing on a date while the S-Curve shows the chance of finishing by a date.

According to the simulation we have just a 2% chance of delivering on 9/4.

A more realistic date might be 9/21 for which we have an 80% chance.

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Why is SRA so depressing?

Forecasts from a project management process that includes schedule risk analysis are often unpalatable for two reasons:

1. Practitioners are more likely to validate the quality of the schedule which tends to push dates to the right
2. Schedule Risk Analysis tends to push dates even further to the right (Merge Bias). This is true even if estimates reflect the fact that historically an organization has been very good at estimating/executing individual tasks (Actual/Estimate=1)

The Critical Path Method (CPM) technique is inherently and unrealistically optimistic…

Like it or not, the results from SRA are generally more realistic.

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Is there good news?

Yes!

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Sensitivity Analysis

Sensitivity Analysis (often portrayed as a Tornado chart) identifies:

- Which activities are creating variability in deliverables
- Identifying critical / near critical work
- Opportunities for schedule compression
- Where to focus management effort

ID	Task Name	Remaining Duration	Percent Critical	Percent Critical (Sensitivity)	Sensitivity Index	Sensitivity Index 20.0 40.0 60.0	Optimistic Finish of Project	Pessimistic Finish of Project	2015 Sep 06 13 20
14	SW Task 4	18 days	93%	93%	60%		9/9/15 3:00PM	9/22/15 1:10PM	
11	SW Task 1	18 days	93%	93%	60%		9/9/15 3:00PM	9/22/15 1:10PM	
13	SW Task 3	18 days	47%	47%	30%		9/14/15 11:17AM	9/21/15 1:59PM	
12	SW Task 2	18 days	46%	46%	30%		9/14/15 11:19AM	9/21/15 1:56PM	
5	HW Task 1	4 wks	7%	7%	1%		9/15/15 8:50AM	9/16/15 9:01AM	
8	HW Task 4	4 wks	7%	7%	1%		9/15/15 8:50AM	9/16/15 9:01AM	
7	HW Task 3	4 wks	4%	4%	1%		9/15/15 8:54AM	9/15/15 4:26PM	
6	HW Task 2	4 wks	3%	3%	1%		9/15/15 8:55AM	9/15/15 4:08PM	

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Risk Adjusted Schedules

A Risk Adjusted Schedule shows when work will be performed at a specific level of confidence (e.g. P80)

Task Name	Early Start Expected Value	Early Finish Expected Value	Early Start Percentile (80%)	Early Finish Percentile (80%)
Hardware vs Softwar...	01Jun15 08:00	15Sep15 09:18	01Jun15 08:00	18Sep15 09:10
Initiate	01Jun15 08:00	05Jun15 17:00	01Jun15 08:00	05Jun15 17:00
Development	08Jun15 08:00	08Sep15 09:18	08Jun15 08:00	11Sep15 09:10
Hardware	08Jun15 08:00	31Aug15 10:59	08Jun15 08:00	01Sep15 10:16
HW Task 1	08Jun15 08:00	03Jul15 16:59	08Jun15 08:00	06Jul15 13:25
HW Task 2	03Jul15 16:59	31Jul15 17:00	06Jul15 13:26	03Aug15 15:18
HW Task 3	03Jul15 16:59	31Jul15 16:59	06Jul15 13:26	03Aug15 15:15
HW Task 4	03Aug15 10:59	31Aug15 10:59	04Aug15 08:44	01Sep15 10:16
Software	08Jun15 08:00	08Sep15 08:26	08Jun15 08:00	11Sep15 09:10
SW Task 1	08Jun15 08:00	07Jul15 13:47	08Jun15 08:00	09Jul15 13:41
SW Task 2	07Jul15 13:47	06Aug15 09:33	09Jul15 13:42	10Aug15 16:13
SW Task 3	07Jul15 13:47	06Aug15 09:31	09Jul15 13:42	10Aug15 16:14
SW Task 4	07Aug15 11:37	08Sep15 08:26	11Aug15 16:28	11Sep15 09:09
SW Complete	08Sep15 08:26	08Sep15 08:26	11Sep15 09:10	11Sep15 09:10
Integration	08Sep15 09:18	15Sep15 09:18	11Sep15 09:10	18Sep15 09:09
Delivery	15Sep15 09:18	15Sep15 09:18	18Sep15 09:10	18Sep15 09:10

Make commitments using the Risk Adjusted Schedule but manage using the original schedule

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I need to deliver sooner…

- The client provides the delivery date
- We ***have*** to launch in June 2018
- Funding expires at the end of December 2017

If we need to deliver by a specific date then SRA is the best tool for identifying where we need to improve the schedule to reach a level of ***confidence*** that we can achieve the required date.

It's ***planning to fail*** if you ignore data from SRA and just ***hope*** you can achieve the dates forecast by CPM.

To have an acceptable probability of success, the CPM model typically needs to show a finish earlier than required.

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Event Uncertainty

Event uncertainty allows us to model Threats or Opportunities that may modify the execution of our project.

Threats might include a new prototype not meeting design criteria while opportunities could include a new manufacturing process becoming available.

Several different techniques can be used to model event uncertainty.

- Probabilistic branching allows us to specify a probability that a particular path through the project may be taken (useful for opportunities).
- Existence probability allows us to model threats as activities that may occur.
- Conditional branching allows us to specify that specific activities will be included if desired dates are not achieved.

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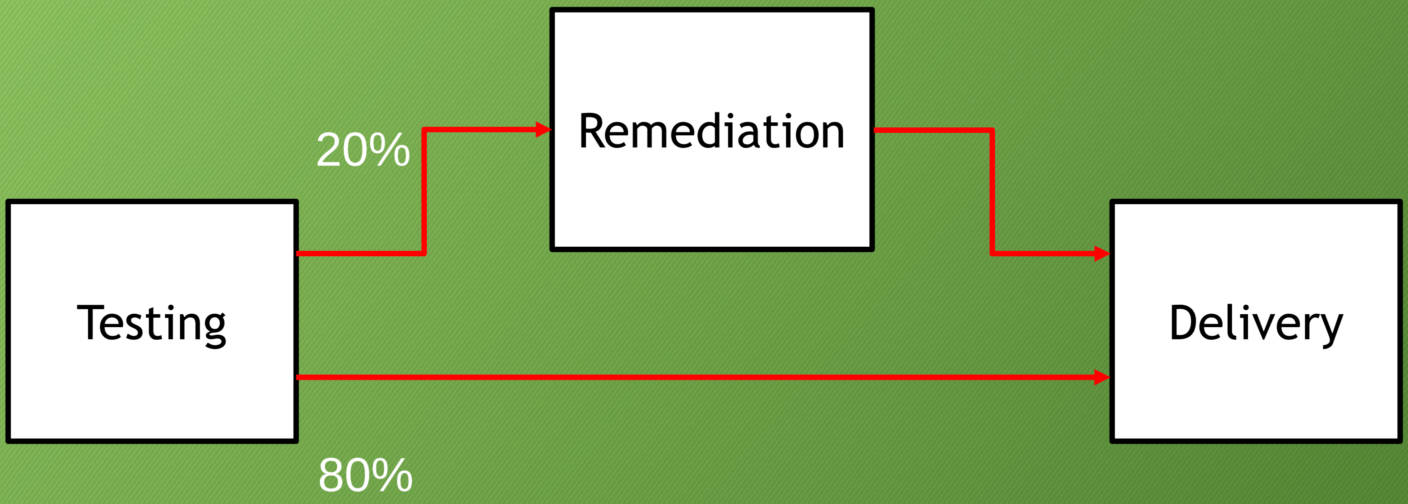
Probabilistic Branching

Allows us to model alternate plans



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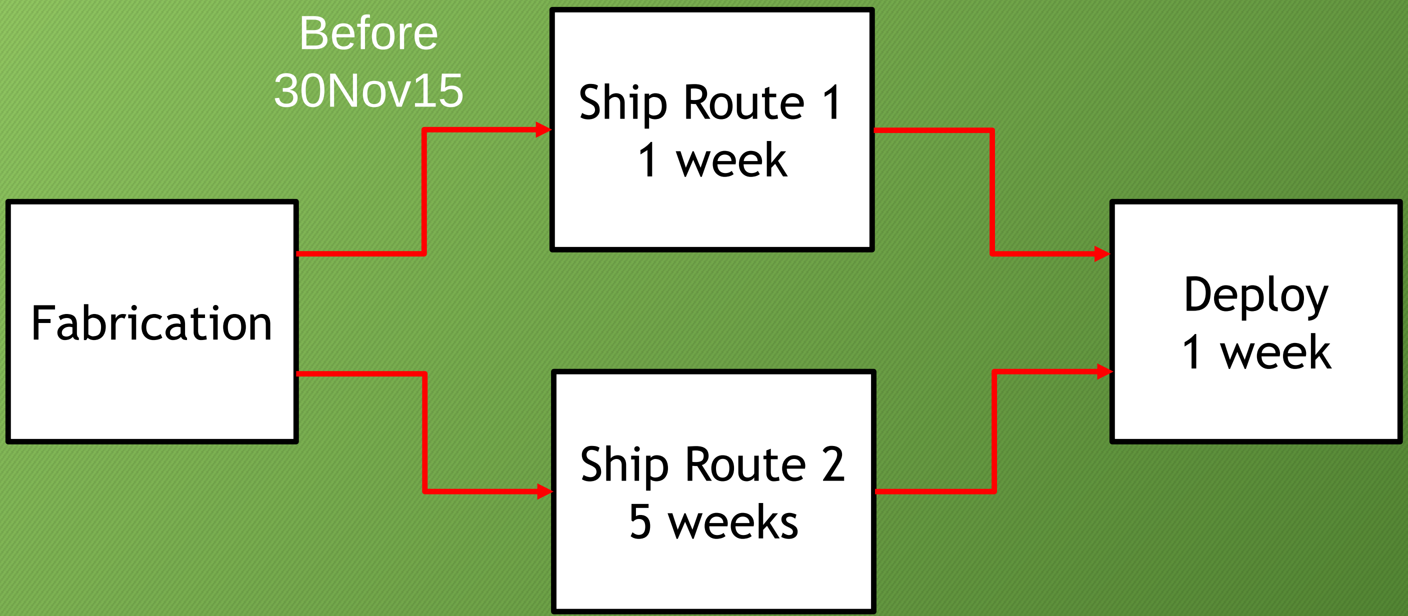
Conditional Branching

Allows us to revise the plan as dates change



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Schedule Margin

Cost engineers have Contingency

Schedulers have Schedule Margin!

The amount of additional time needed to achieve a significant event with an acceptable probability of success.

The best way to derive an appropriate schedule margin is Schedule Risk Analysis.

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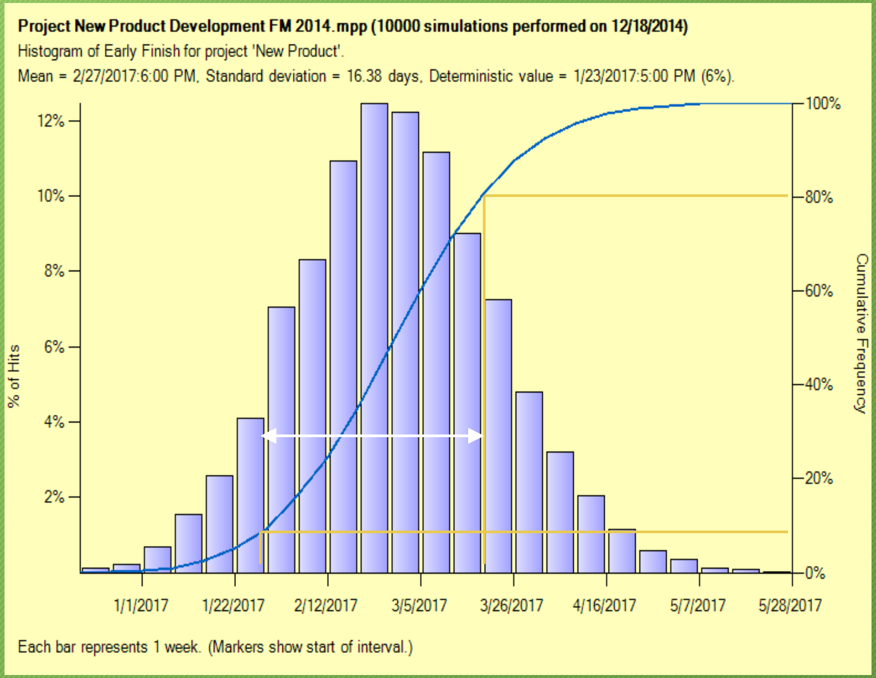
Calculating the Margin



Deterministic CPM = 1/23/2017

SRA P80 = 3/18/2017

Margin = 54 Calendar Days

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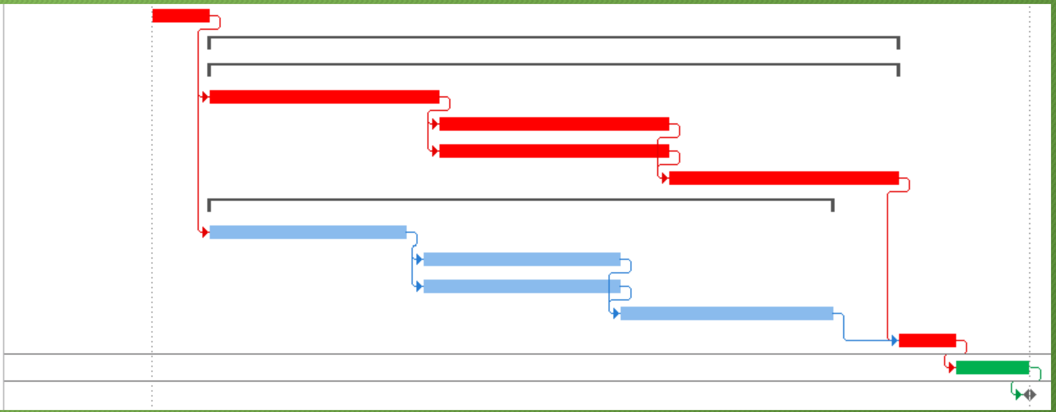
Including Schedule Margin

Initiate	5 days	100	5/21/14 8:00	5/27/14 5:00	
Development	**60 days**	**100**	**5/28/14 8:00**	**8/19/14 5:00**	
Hardware	**60 days**	**10.62**	**5/28/14 8:00**	**8/19/14 5:00**	
HW Task 1	20 days	10.62	5/28/14 8:00	6/24/14 5:00	1
HW Task 2	20 days	5.43	6/25/14 8:00	7/22/14 5:00	4
HW Task 3	20 days	5.19	6/25/14 8:00	7/22/14 5:00	4
HW Task 4	20 days	10.62	7/23/14 8:00	8/19/14 5:00	5,6
Software	**54 days**	**89.38**	**5/28/14 8:00**	**8/11/14 5:00**	
SW Task 1	18 days	89.38	5/28/14 8:00	6/20/14 5:00	1
SW Task 2	18 days	45.11	6/23/14 8:00	7/16/14 5:00	9
SW Task 3	18 days	44.28	6/23/14 8:00	7/16/14 5:00	9
SW Task 4	18 days	89.38	7/17/14 8:00	8/11/14 5:00	10,11
Integration	5 days	100	8/20/14 8:00	8/26/14 5:00	7,12
Schedule Margin	7 days	0	8/27/14 8:00	9/4/14 5:00 F	13
Delivery	0 days	100	9/4/14 5:00 F	9/4/14 5:00 F	14



The project manager/scheduler owns the margin and will track incursion/consumption of the margin in exactly the same way as a cost engineer allocates and tracks fiscal contingency

Milestone Schedule Margin

Task Name	Percent Critical	Merge Delay	Cruciality Index (Pearson)	Sensitivity Index
⊟ Hardware vs Software wCorrelat	100%	0	0%	NA
Initiate	100%	0	0%	0%
⊟ Development	100%	0	0%	NA
⊟ Hardware	7%	0	0%	NA
HW Task 1	7%	0	0%	1%
HW Task 2	4%	0	0%	1%
HW Task 3	3%	0	0%	1%
HW Task 4	7%	2.98 hrs	0%	1%
HW Complete	7%	0	0%	0%
⊟ Software	93%	0	0%	NA
SW Task 1	93%	0	61%	61%
SW Task 2	47%	0	29%	31%
SW Task 3	46%	0	31%	30%
SW Task 4	93%	9.87 hrs	59%	61%
SW Complete	93%	0	0%	0%
Integration	100%	0.9 hr	0%	0%
Delivery	100%	0	0%	0%

As well as obvious places like key interim deliverables, consider using Merge Delay to identify good places to allocate margin.

If you don't need the margin, great. Bring future work forward.

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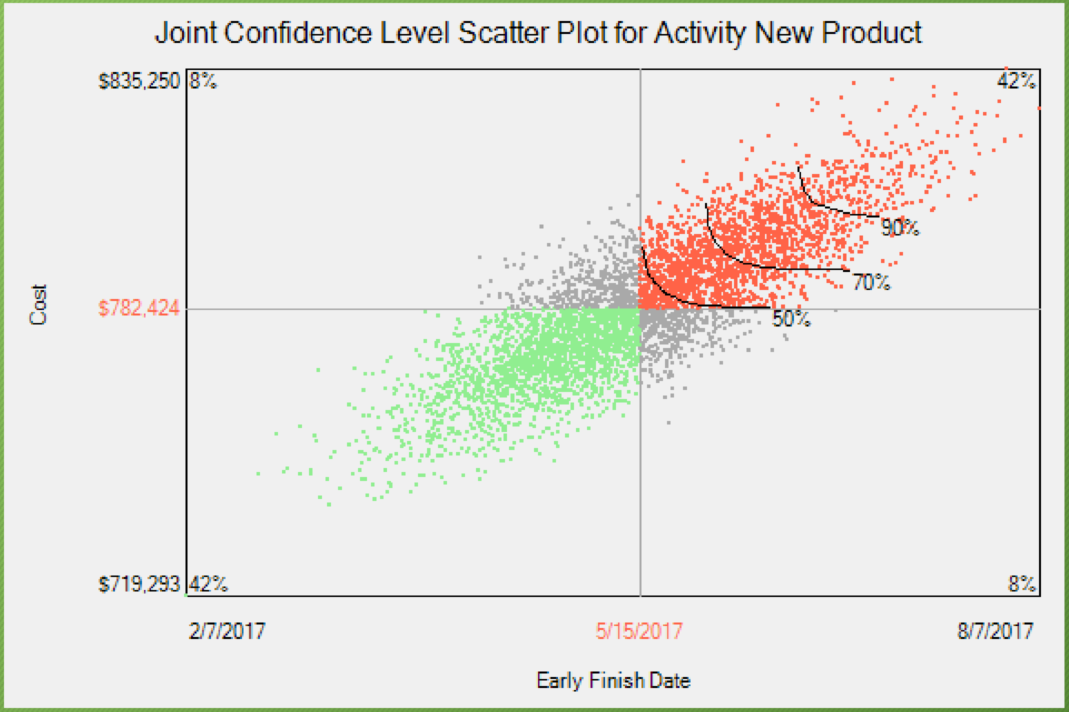
Combined Cost and Schedule



The Joint Confidence Limit scatter plot shows the chance of achieving both target cost and schedule delivery dates.

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Summary

- Schedule Risk Analysis is a valuable tool for making schedules more realistic and improving confidence.
- It's an iterative process. Initial results may be depressing but the technique helps identify areas for improvement
- Schedule Risk Analysis has almost no value if you just produce a histogram to satisfy a contract requirement
- Many organizations chose to commit to P80-95 delivery dates and have a high success rate which boosts confidence and profitability
- It doesn't have to be hard and saves money!

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Thank You

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