Using Project Performance Data in Cost and Schedule Analysis

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June 2011

Agenda

- Overview
- Performance Metrics
- Updating Algorithm
- Initial Results

First Off…

People to thank who participated in this study:

John Sandberg (Tecolote)
Shu-Ping Hu (Tecolote)
Gayle Reese (Tecolote)
Rey Carpio (Tecolote)
Steve Wilson (NASA)

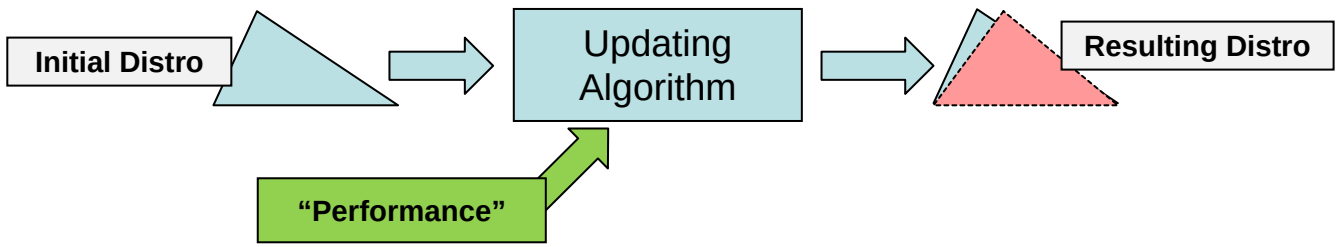
Why Use Performance Metrics?

- How are risk bounds currently assigned? Any issues?
  - Subject Matter Experts
    - Subjective
    - Tough to update over time
  - Estimating Relationships (CERs, SERs)
    - Not project-specific
    - Large uncertainty bounds
  - Analyst Judgment
    - Subjective
    - Not an expert opinion

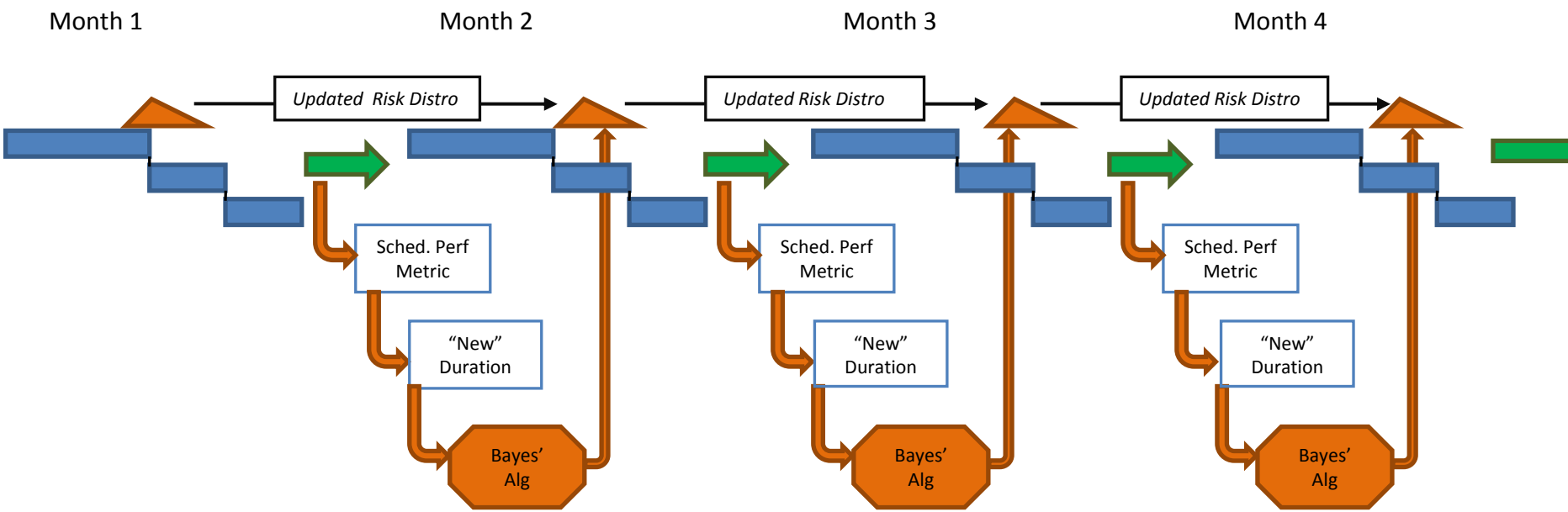
- Is there a way to use project-specific data gathered over time to update risk distributions?
  - Start with a typical method to assign the distribution, but update it over time

Objectives & Assumptions

- Objectives
  - Develop a framework to incorporate performance data into cost and schedule confidence level activities
    - Identify data requirements
    - Propose methodology for implementation
    - Test mathematical proof-of-concept
- Ground Rules & Assumptions
  - Study focuses on **schedule duration** and schedule performance parameters
  - Study focuses on updating the **mode or mean** of a given distribution on a schedule duration
    - Triangle, Log-normal distributions
  - Mathematically, a Bayesian algorithm is used as the mechanic to update risk distributions



Overall Concept



The risk distribution adjusts as performance data changes throughout the project's lifetime

Which Performance Data to Use?

EVM

- EVM?
  - We tried, but…
  - Increases in Estimates at Complete **not** related to schedule increases will still cause increases in duration estimates – schedule not necessarily a function of cost
  - Duration calculations are performed on WBS elements, while most schedule analyses are performed on schedule task elements (no clear WBS-schedule task mapping)
  - EV data is prone to errors/ manipulation, and how dollars are accounted for may result in significant swings in duration calculations from month to month
  - Since dollars form the basis of the EV and PV metrics, material and subcontractor values may have a larger impact to the schedule calculation than they should

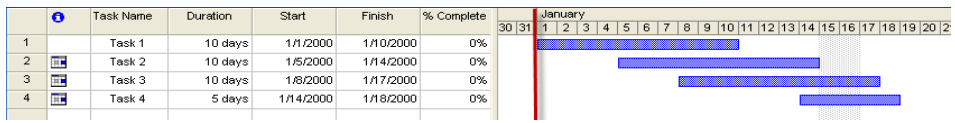
Numerous problems calculating a duration metric from something inherently dollar-based

Which Performance Data to Use?

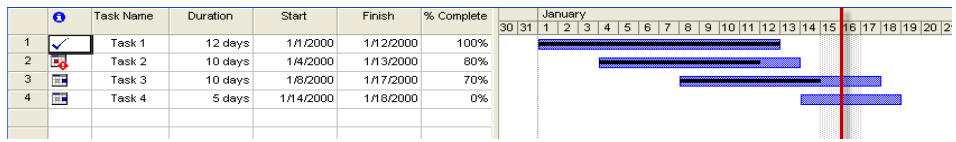
Other Metrics

- Custom-built metric
  - Compares periodic project schedules as they occur over time
  - Task-level
  - Generates performance metrics based on progress over the previous month
  - Critical path analysis, analysis by subsystem
- Generates new duration estimates based off performance
  - Performance metrics gauge percent complete of a current month vs the baseline plan
  - Expand or shrink duration accordingly

Time Period 1



Time Period 2



Which Performance Data to Use?

Tool Output

Name	Start1	Finish1	Duration1	Percent Complete1	Data Date1	ADWP1	Start2	Finish2	Duration2	Percent Complete2	Data Date2	ADWP2	Start Slip	Finish Slip	Delta ADWP	PDWS	PDWP
Task Names Intentionally Obscured	1/6/14	3/26/15	318.375	0.00%	7/31/09	0	5/29/14	11/30/15	392.31	0.00%	12/31/09	0	104.0d	178.0d	0	0	0
	6/20/14	9/15/14	60	0.00%	7/31/09	0	5/29/14	8/22/14	60	0.00%	12/31/09	0	0.0d	0.0d	0	0	0
	12/29/14	3/26/15	60	0.00%	7/31/09	0	11/24/14	2/23/15	60	0.00%	12/31/09	0	0.0d	0.0d	0	0	0
	3/3/14	3/2/15	260	0.00%	7/31/09	0	9/1/14	3/1/16	391	0.00%	12/31/09	0	131.0d	262.0d	0	0	0
	9/2/14	9/2/14	0	0.00%	7/31/09	0	9/1/14	9/1/14	0	0.00%	12/31/09	0	0.0d	0.0d	0	0	0
	3/2/15	3/2/15	0	0.00%	7/31/09	0	3/2/15	3/2/15	0	0.00%	12/31/09	0	0.0d	0.0d	0	0	
	9/23/05	4/7/15	2487.96	24.00%	7/31/09	1006	9/23/05	3/18/16	2735.69	26.00%	12/31/09	1115	0.0d	249.0d	109	110	49.759
	9/23/05	4/7/15	2487.96	42.00%	7/31/09	1006	9/23/05	2/18/15	2454	46.00%	12/31/09	1115	0.0d	0.0d	109	110	99.518
	9/23/05	9/18/08	780	100.00%	7/31/09	780	9/23/05	9/18/08	780	100.00%	12/31/09	780	0.0d	0.0d	0	0	0
	9/19/08	9/19/08	0.125	100.00%	7/31/09	0.125	9/19/08	9/19/08	0.125	100.00%	12/31/09	1	0.0d	0.0d	0.875	0	0
	[illegible]	[illegible]	0	0.00%	[illegible]	0	2/18/15	2/18/15	0	0.00%	12/31/09	0	0.0d	0.0d	0	0	0

Task Name

Time Period 1

Time Period 2

Perf Metrics by Task

ADWP	7396.5
PDWS	6951.0
PDWP	4622.5
Schedule Variance = PDWP - PDWS	-2328.5
Schedule Performance Index = PDWP	0.665
Schedule Cost Performance Index = P	0.625
Schedule Cost Index = SPI * SCPI	0.416

Project Perf Metrics

New Duration Estimate
By Task

Updating Algorithm

- Bayesian inference
  - Statistical inference that uses data to update the probability of a hypothesis being true
  - Mechanics exist for normal, log-normal distributions already, but not triangular
  - Study uses research started by Ares Corps' *"Bayesian Update of Triangular Distributions"* for triangular distros

$$f_{T|t_{obs}}(t) = \frac{L(\beta|t_{obs})f_T(t)}{\int_{-\infty}^{\infty} L(\beta|t_{obs})f_T(t)dt}$$

- Two pieces to utilize Bayes' Theorem
  - *A priori* distribution (SME initial distro)
  - Observational data (new data points derived from performance metrics)

$$\mu' = \frac{\frac{\mu_0}{\sigma_0} + \frac{\sum_{i=1}^{n} t_{obs_i}}{\sigma^2}}{\frac{1}{\sigma_0^2} + \frac{n}{\sigma^2}}$$

$$\sigma' = \left(\frac{1}{\sigma_0^2} + \frac{n}{\sigma^2}\right)^{-\frac{1}{2}}$$

$$\mu' = \frac{P + t_{obs}}{2}$$

$$\sigma' = \sqrt{\frac{Q^2}{2}}$$

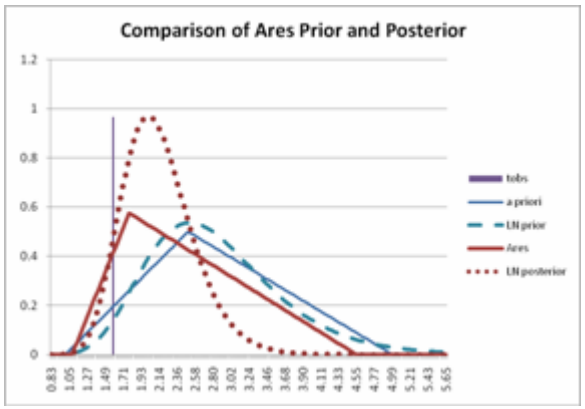
$$\mu_T' = \frac{a + c + b + 3t_{obs}}{6} \quad (3)$$

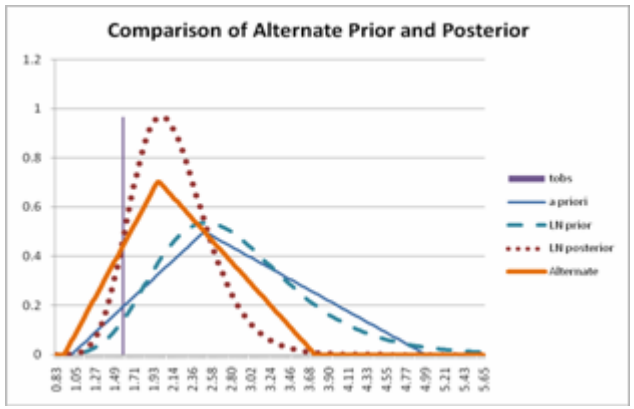
$$\sigma_T' = \frac{1}{6}\sqrt{a^2 + c^2 + b^2 - ab - ac - bc} \quad (4)$$

$$x_T' = \mu_T' + \frac{\sqrt{2}}{2}(x - \mu_T) \quad (5)$$

Updating Algorithm

- Fundamental difference from Ares Corps' method: allowing movement of high and low bounds





- Caveats to using Bayesian inference
  - For triangular distributions, currently assuming skew is held constant
    - Bayes' update uses assumption of symmetry
  - Bayesian updating **will** shrink the standard deviation
    - Using this technique iteratively on distros that have already been updated with Bayesian inference may result in an unrealistically small SD
    - This scenario was tested
- Algorithm food for thought: How much "weight" do we want to give the original SME distro?

Initial Results

- Real-world NASA project data
  - Six consecutive monthly schedules
  - Isolated ten tasks that had progress occurring over that time span
- Initial risk distributions assigned using analyst's judgment
- New durations calculated using custom-built metric

- Three scenarios
  - Monthly performance data
  - Cumulative performance data
  - "Decayed" Monthly performance data
    - *A priori* distribution is the **previous month's** distribution, instead of the original distribution

Initial Results

Example Output

Task Name	Perf Month 0				Perf Month 1				Perf Month 2			
	Init Dur	Low	Mode	High	New Dur	Low	Mode	High	New Dur	Low	Mode	High
A	571	550	571	625	522	529	544	583	700	618	633	671
B	691	680	691	710	684	679	687	701	726	700	708	721
C	701	650	701	710	686	660	696	703	728	681	717	724
D	861	850	861	960	825	829	837	907	751	792	800	870
E	951	925	951	975	1018	966	984	1001	1082	998	1016	1033
F	963	900	963	1200	1019	934	979	1147	1083	967	1011	1179
G	1014	1000	1014	1500	1024	977	986	1330	766	847	857	1201
H	1047	900	1047	1100	1027	940	1043	1081	1094	973	1077	1115
I	1118	1118	1118	1250	1346	1223	1223	1316	1102	1101	1101	1194
J	902	800	902	1000	902	830	902	972	902	830	902	972

Initial Duration & Initial Risk Distribution

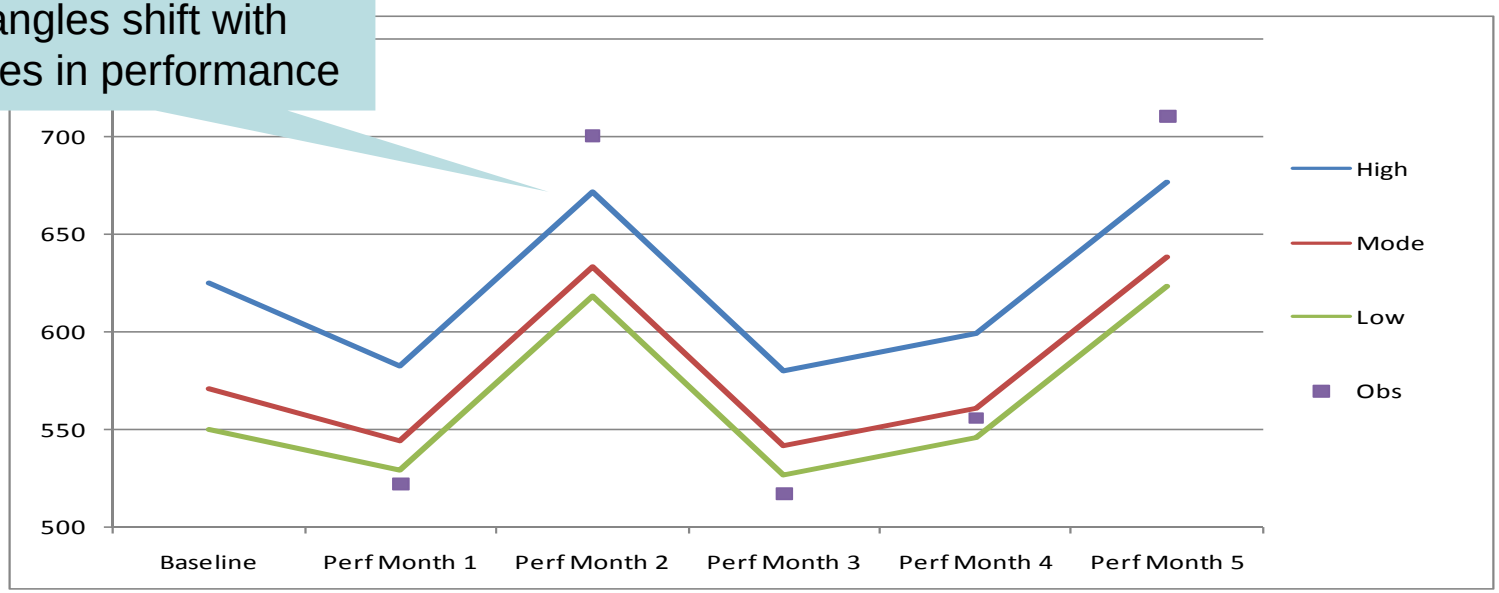
Updated Durations & Corresponding Distributions

Initial Results

Up Close Look at One Task

Monthly Data	Baseline	Perf Month 1	Perf Month 2	Perf Month 3	Perf Month 4	Perf Month 5
High	625	582.5	671.4	579.9	599.3	676.5
Mode	571	544.3	633.3	541.7	561.1	638.3
Low	550	529.5	618.4	526.9	546.3	623.4
Obs	--	522.2	700.1	517.0	555.8	710.1

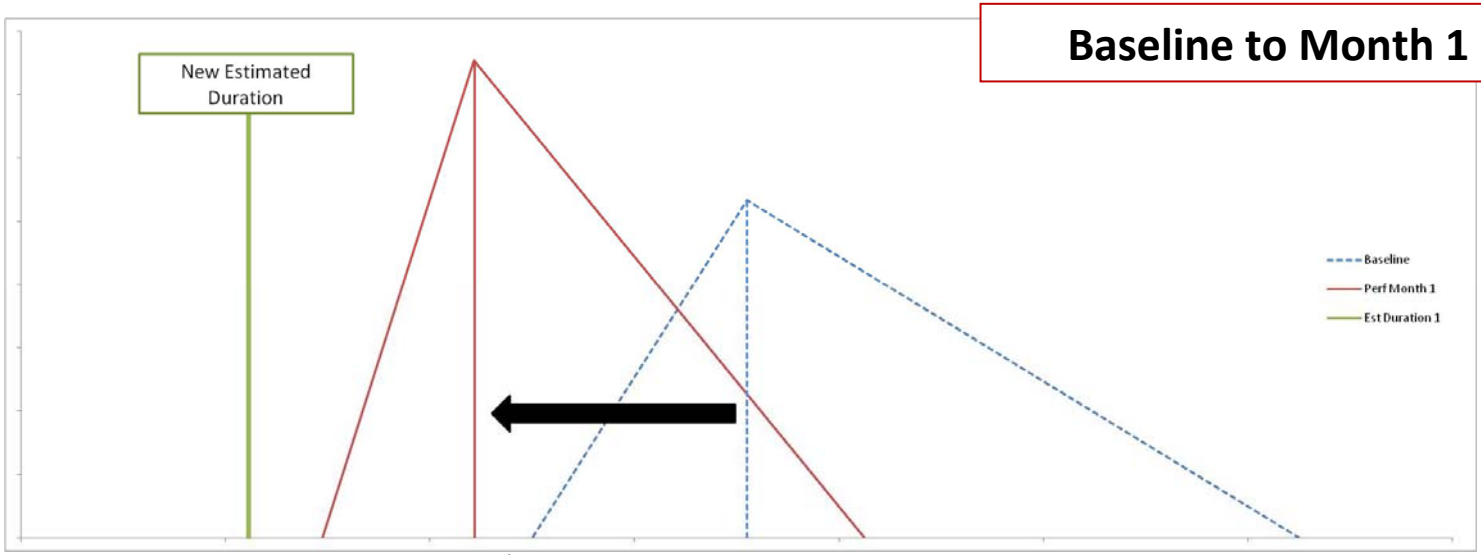
Triangles shift with changes in performance



Initial Results

Risk Distributions Changing Over Time

Baseline to Month 1

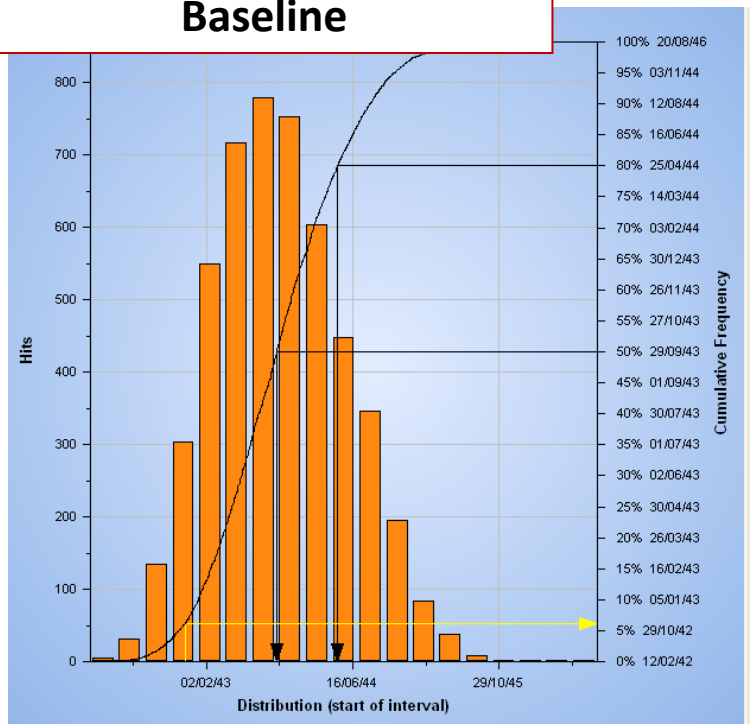


Month 1 to Month 2

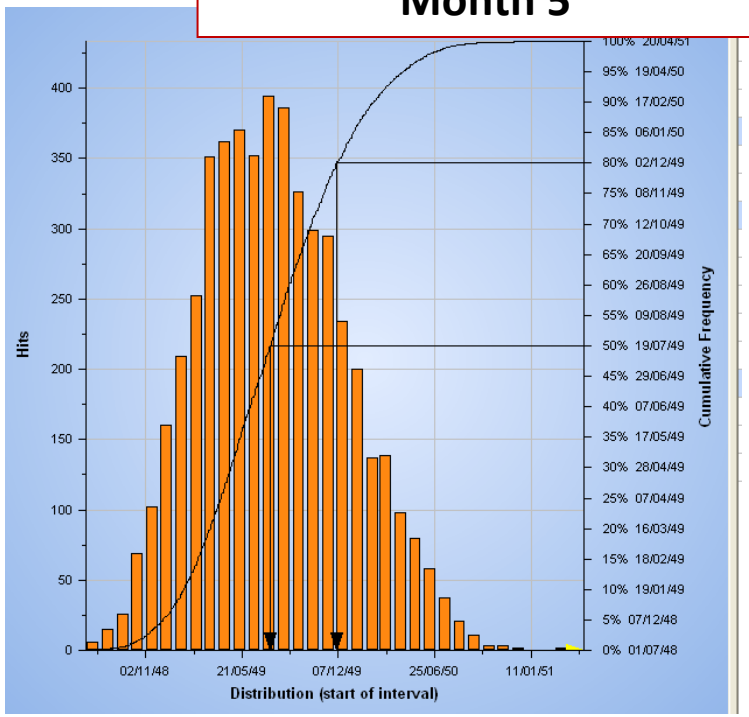
Month 2 to Month 3

Initial Results

Baseline



Month 5

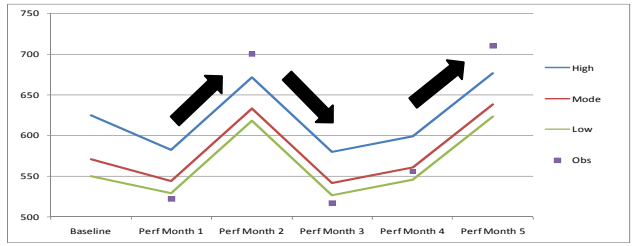


- Task durations were **not** updated
- Risk distributions **were** updated to reflect new uncertainty bounds
- Mean shifted to right from Baseline to Month 5
- Less uncertainty (50%-80% Difference was 206 days for Baseline, 136 days for Month 5)

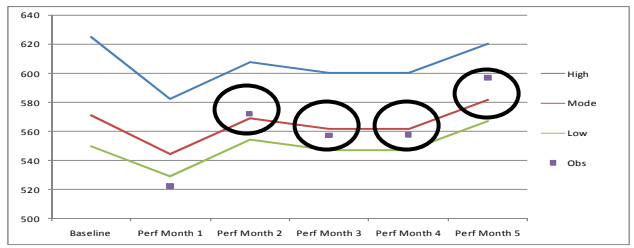
Data restructured for demonstration purposes

Initial Results

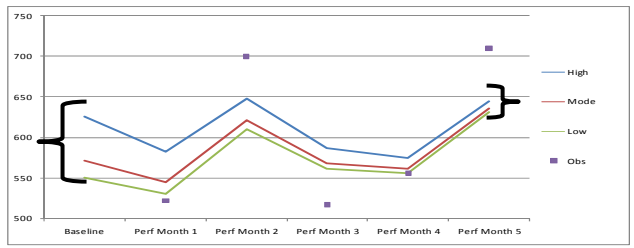
- Monthly performance data
  - Large swings in estimated duration
  - Triangles shift almost as much as changes in estimated duration

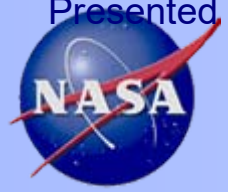


- Cumulative performance data
  - Moderate swings in estimated duration
  - Triangle mode closely parallels new estimated duration



- "Decayed" Monthly performance data
  - Triangle range narrows considerably
    - From 75 days to 13 days over 6 months
  - Not currently recommended for use





Conclusions

- Framework for updating risk distributions with performance metrics
  - EVM not ideal for updating schedule risk
    - Custom-built metrics easier to use, more intuitive
  - Using Bayesian inference, updating normal, log-normal, and now triangular distributions possible
- "Real-World" tests
  - Triangular distributions **do** move with performance
  - Using monthly performance data may result in large swings in final estimates
    - Cumulative better?
  - Currently always using the Initial/SME distro as the *A priori* distribution
    - Gives some weight to SME distro
    - Standard Deviation may narrow too much too quickly otherwise
- Eventual toolset development

Questions?