Programmatic Estimating Tool

Parametric-based cost, schedule, & phasing health check

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PET Evolved from Earlier NASA Research Studies

PERFT

- Deliver a Weibull-based budget-phasing model to NASA
- Provide a tool for both program and satellite-level estimates

PIERS

- Investigate relationship between PERFT accuracy metric and its relationship with both cost and schedule
- Leverage the same dataset

PET

- Deliver tools that utilize methodology developed in PIERS
- Use other NASA methods for estimating both cost and schedule

Baseline Models Currently in PET

- Cost: QuickCost v5.0 satellite model
  - Developed by Joe Hamaker, 2011
  - Spacecraft bus and instruments, n=131

- Schedule: NASA Schedule Estimating Relationships (SERs)
  - Developed by MCR, 2010
  - SER # 34 (planetary, n=22) and SER #5 (non-planetary, n=52)
  - Time from system Requirements Review (SRR) to first launch availability

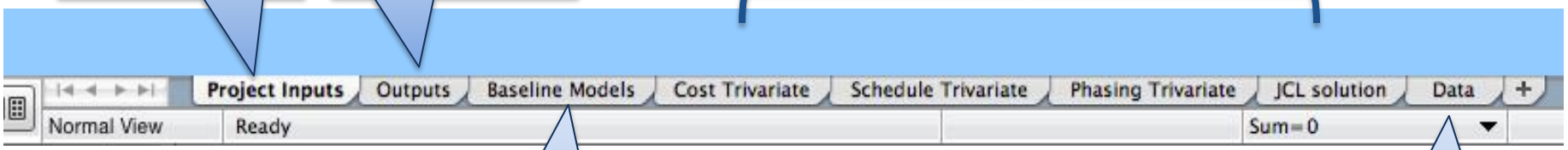
- Phasing: Phasing Estimating Relationship Model (PERM) for spacecraft
  - Developed by Tecolote Research and Burgess Consulting, 2013
  - Spacecraft bus and instruments: Budget from SRR through launch (n=37)

PET is 8 Linked Worksheets

All user inputs on first tab

All PET outputs on second tab

Math for evaluating the trivariate distribution in various combinations of conditions



Baseline Cost, Schedule, and Phasing Models are implemented here

Implement new baseline models on these two sheets

Residuals from three baseline models are here.

PET Input Sheet

Descriptive data used to run all three models on one sheet

Project Inputs

Yellow cells are input cells

Interplanetary	Near Earth or Interplanetary?
AO	AO or Directed?
Yes	GFE Hardware?
12/21/14	SRR Date
6.0	Planned months from SRR to PDR
44.0	Planned months from SRR to first launch

300	BOL Power (W)
250	Total Dry Mass (kg)
36	Design Life (mo.)
30%	Instrument Complexity (Percentile)
40%	Bus New Design (Percentile)
60%	Instrument New Design (Percentile)

Then Year Budget for WBS line items 5.0 (all payloads) and 6.0 (spacecraft bus)

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
14.00	22.00	16.00	10.00	7.00	0.00	0.00	0.00	0.00	0.00

2014	Base Year
$ 64.28	Planned Cost (BY14$M) for WBS line items 5.0 (all payloads) and 6.0 (spacecraft bus)

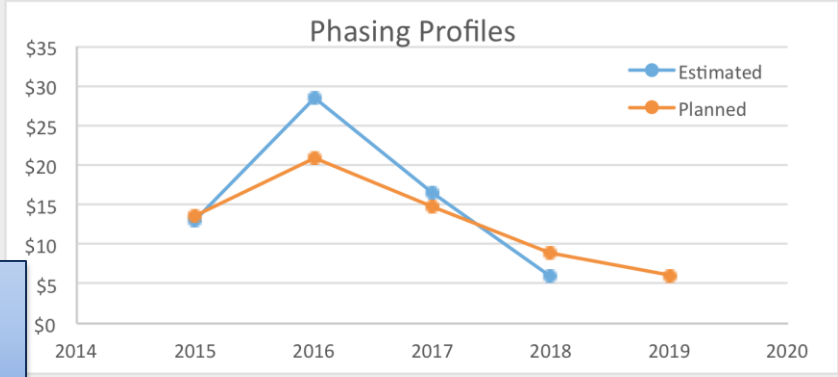
Planned schedule, cost, and budget for comparison and evaluation

PET Outputs: Baseline Model Results

- Baseline unadjusted estimates from QuickCost, PERM, and the SER
- Independently run
- Differences between project plan and baseline expectations

Baseline Outputs - Expected cost, schedule, and phasing profiles based on the baseline models (no conditions)

	Estimated	Planned	Units	Residual
Cost	$ 70.18	$ 64.28	BY14$M	-8%
Phasing	43%	37%		-5%
Schedule	35.1	44.0	months	25%



Baseline model results. Phasing result is translated to PERM's metric*

Program plan as input by user.

Difference between plan and baseline model results

*Average cumulative percent budgeted between 20% and 60% time. Useful to compare overall degree of front/back-loading.

PET Outputs: Programmatic Health Check

- Differences compared to conditional mean in each area
  1. Given the schedule and phasing plan, what is the expected cost residual? How far off is the plan?
  2. Given the planned cost and budget, what is the expected schedule?

Program Health Check - Assesses program health based on standard deviations from the conditional mean

	Residual	Health
Cost	-8%	YELLOW
Phasing	-5%	GREEN
Schedule	25%	YELLOW

	Standard Deviations from the baseline mean				
	+1 σ	+0.5 σ	Cdn. μ	-0.5 σ	-1 σ
Cost	55%	35%	15%	-5%	-25%
Phasing	8%	3%	-1%	-6%	-11%
Schedule	30%	13%	-3%	-20%	-36%

Difference between plan and baseline model results

Expected cost, schedule, or phasing residual, given the project plan in the other two areas

PET Outputs: Cost Conditional Probability

- Probability that cost target will be met, given the schedule and phasing plan

Conditional Probabilities -
Probability of meeting cost, given phasing and schedule constraints

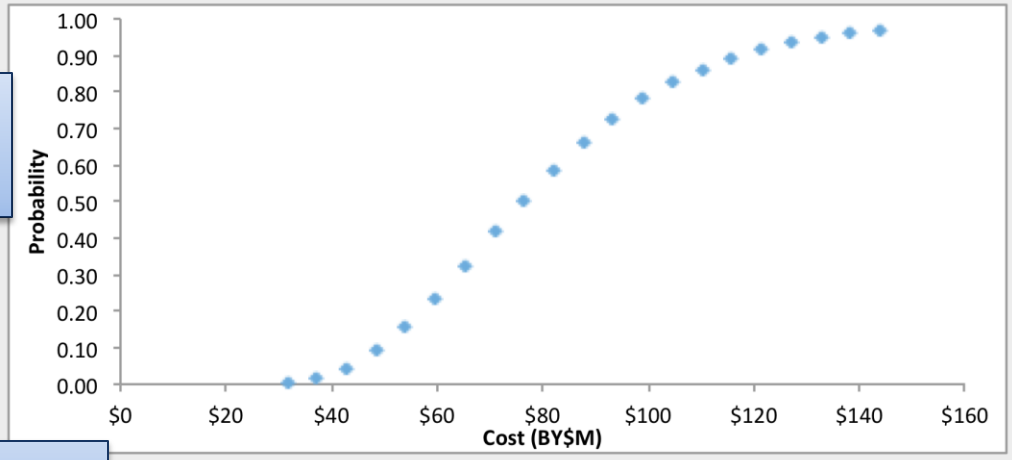
	Residual
Cost	-8%
Phasing	-5%
Schedule	25%

Conditional probability of meeting cost target

Probability of Cost under plan, given Phasing, Schedule
P(X1 < -0.08 | X2, X3) = 31%

Desired Probability Level: 50%
50th Percentile Cost: $ 76.17

User can enter a desired probability level



PET Outputs: Schedule Conditional Probability

- Probability that schedule target will be met, given the cost target and phasing plan

Probability of meeting schedule, given cost and phasing constraints

	Residual
Cost	-8%
Phasing	-5%
Schedule	25%

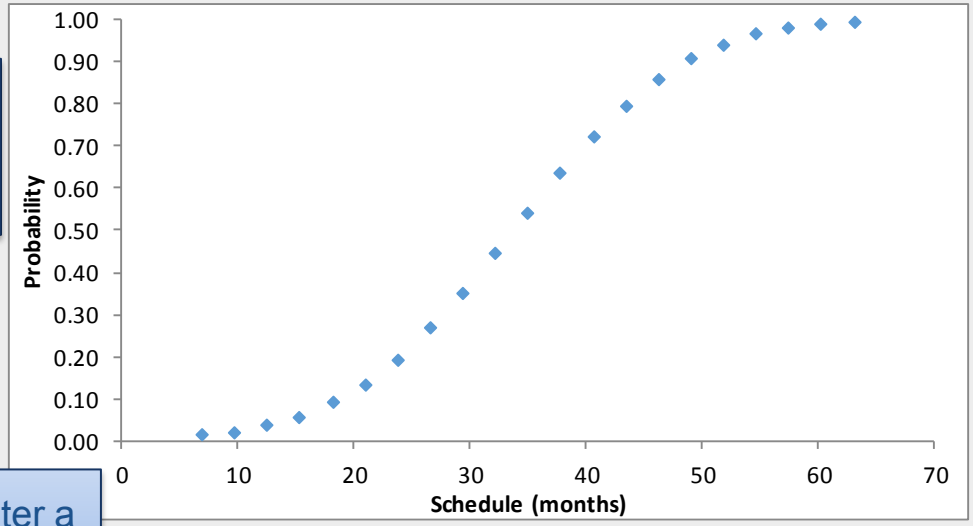
Conditional probability of meeting schedule target

P(X3 < 0.25 | X1, X2) = 81%

Desired Probability Level: 50%

50th Percentile Schedule: 34.0

User can enter a desired probability level



Joint Conditional Probabilities

- Probability that both cost and schedule will be met, given a phasing profile

Probability of meeting both cost and schedule, given a phasing constraint

	Residual
Cost	-8%
Phasing	-5%
Schedule	25%

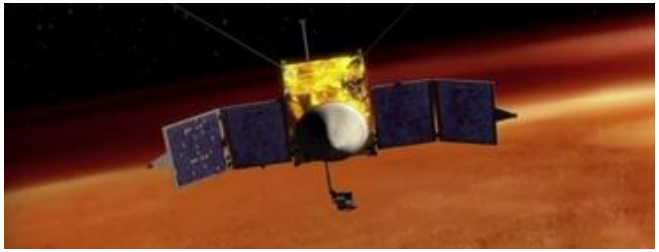
Joint probability of both Schedule and Cost under plan, given Phasing

P(X1 < -0.08, X3 < 0.25 | X2) = 32%

PET in Action: MAVEN Example

Example: MAVEN at SRR

- Mars Atmosphere and Volatile Evolution Mission
  - GSFC-led project
  - Lockheed Martin spacecraft
  - Fixed launch: 20-day launch window
- Baseline plan entered into PET:



Interplanetary	Near Earth or Interplanetary?
AO	AO or Directed?
No	GFE Hardware?

4000	BOL Power (W)
716	Total Dry Mass (kg)
12	Design Life (mo.)

8/11/09	SRR Date
11.7	Planned months from SRR to PDR
51.3	Planned months from SRR to first launch

75%	Instrument Complexity (Percentile)
40%	Bus New Design (Percentile)
60%	Instrument New Design (Percentile)

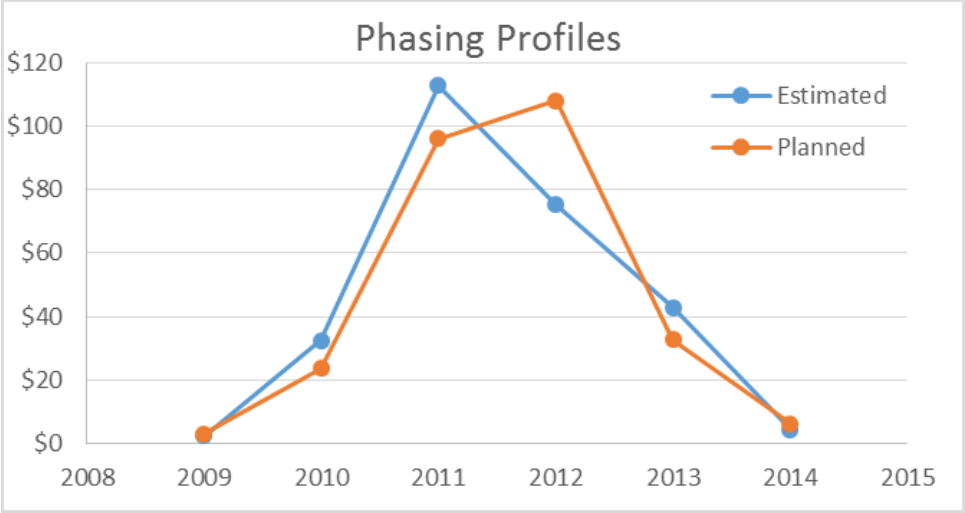
Then Year Budget for WBS line items 5.0 (all payloads) and 6.0 (spacecraft bus)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2.79	22.06	91.33	103.90	32.07	6.13	0.00	0.00	0.00	0.00

2014	Base Year
$ 269.80	Planned Cost (BY14$M) for WBS line items 5.0 (all payloads) and 6.0 (spacecraft bus)

MAVEN: Baseline Evaluation

	Estimated	Planned	Units	Residual
Cost	$ 291.23	$ 269.80	BY14$M	-7%
Phasing	34%	28%		-6%
Schedule	59.1	51.3	months	-13%



- Cost and schedule estimates are a bit aggressive, and phasing is slightly back-loaded

MAVEN – Health Check

	Residual	Health
Cost	-7%	GREEN
Phasing	-6%	GREEN
Schedule	-13%	GREEN

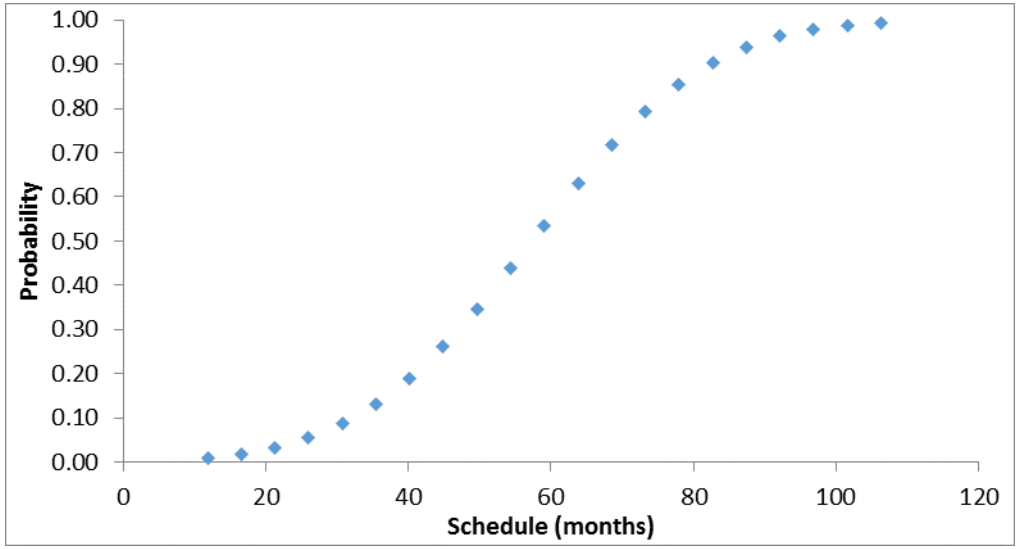
	Standard Deviations from the baseline mean				
	+1 σ	+0.5 σ	Cdn. μ	-0.5 σ	-1 σ
Cost	41%	23%	5%	-13%	-32%
Phasing	8%	3%	-2%	-7%	-11%
Schedule	30%	14%	-3%	-19%	-36%

- This section compares the baseline plan to the conditional distributions in all three areas
- Everything is within one-half standard deviation of the conditional means, which gets a “green”

MAVEN – Schedule Target

Given SRR plans (phasing and total budgeted cost) what is the confidence that this schedule will be met?

- There is a 38% chance schedule target is met



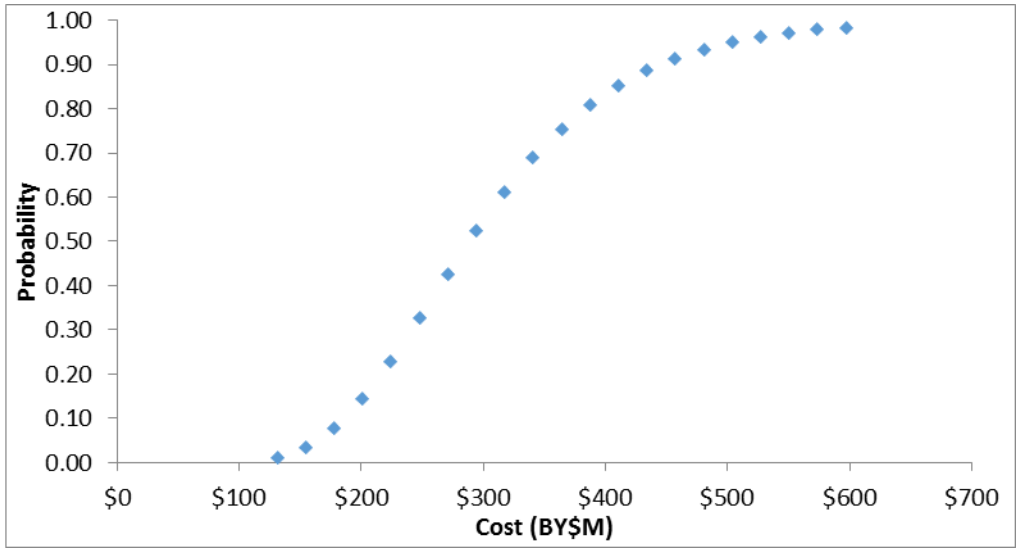
If schedule could be increased from 51 to 57 months, the probability would improve to 50%

Probability of Schedule under plan, given Cost, Phasing	
P(X3 < -0.13 | X1, X2) =	38%
Desired Probability Level:	50%
50th Percentile Schedule:	57.3

MAVEN – Cost Conditional Probability

- This is probability that planned cost will be met, given planned phasing and schedule
- There is a 42% chance cost is lower than the plan

	Estimated	Planned	Units	Residual
Cost	$ 291.23	$ 269.80	BY14$M	-7%



Probability of Cost under plan, given Phasing, Schedule	
P(X1 < -0.07 | X2, X3) =	42%
Desired Probability Level:	50%
50th Percentile Cost:	$ 288.21

If plan is increased to $288m, probability improves to 50%

MAVEN – Joint Conditional Probability

Probability of meeting both cost and schedule, given a phasing constraint

	Residual
Cost	-7%
Phasing	-6%
Schedule	-13%

17% probability of hitting both

Joint probability of both Schedule and Cost under plan, given Phasing

P(X1 < -0.07, X3 < -0.13 | X2) = 17%

	Residual
Cost	-7%
Phasing	35%
Schedule	-13%

We can get to 26% by changing to a very front-loaded profile

Joint probability of both Schedule and Cost under plan, gi

P(X1 < -0.07, X3 < -0.13 | X2) = 26%

	Residual
Cost	0%
Phasing	0%
Schedule	0%

JCL is only 30% if the project matches all three models from the start

Joint probability of both Schedule and Cost under plan, given Phasing

P(X1 < 0, X3 < 0 | X2) = 30%

Front-loading can increase the JCL to some extent without changing total cost or schedule

Summary

- PET is an innovative and simple-to-use tool to provide quick measures of cost, schedule, and/or phasing health
- PET is framework that can be extended to include other CERs, SERs, and PERs
- PET is available through NASA HQ OoE/CAD