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Assuring Space Mission Success

Deferral Estimation Analysis Study

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Agenda

Deferral Estimation Analysis

- Introduction
- Phase 1: Survey of Historical Funding Profiles
  - *Approach and Methodology*
  - *Results*
- Phase 2: Deferred Funding Impacts “Rules of Thumb”
  - *Approach and Methodology*
  - *Observations and Results*
- Summary and Forward Work

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Introduction

Deferral Estimation Analysis

- Background
  - *Over the past few years, Aerospace has performed multiple studies to understand the drivers that cause cost and schedule growth in NASA projects including the Explanation of Change (EoC) and 40-Mission Studies*
  - *In an effort to build upon these prior studies, the NASA Cost Analysis Division (CAD) funded Aerospace to investigate the factors that lead to cost and schedule growth when a project's funding is deferred or constrained*

- Rationale
  - *In today's economic environment, funding delays are becoming commonplace for many NASA (and DoD) projects*
  - *Budgeting exercises often require quick responses to adjustments in funding profiles due to constraints/offsets/external direction*
  - *Full cost and schedule impacts resulting from such funding delays are not yet adequately understood*

Objective

Deferral Estimation Analysis

- Objective of Study
  - *Expand on the work completed to date with an emphasis on the correlation between deferred funding and cost and schedule growth*
    - Investigate the cost and schedule impacts of deferred funding on NASA missions with known funding cuts
  - *Apply Aerospace's General Error Regression Model (GERM) to the data collected and generate a series of "Rules of Thumb" to address the impacts of deferred funding on future projects*
    - Identify and segregate cost and schedule impacts not driven by funding cuts
    - Identify multivariable relationships that display high correlation to collected funding reduction data
  - *Identify useful metrics to begin tracking in other data sets (such as CADRes)*

- Study Approach
  - *Phase 1: Survey of Historical Funding Profiles*
  - *Phase 2: Deferred Funding Impacts "Rules of Thumb"*

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Phase 1: Survey of Historical Funding Profiles

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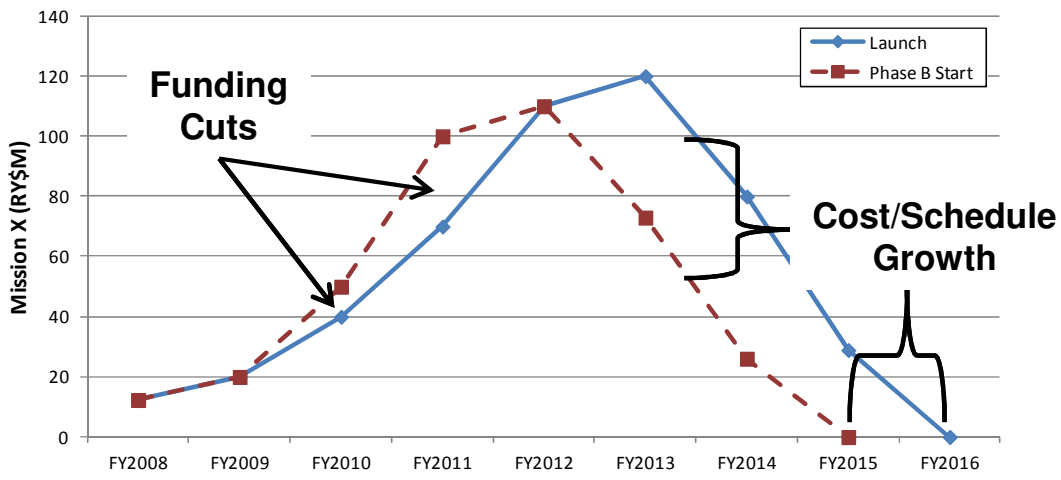
Phase 1: Survey of Historical Funding Profiles

Deferral Estimation Analysis

- Approach
  - *Leveraging EoC, CADRe, and mission milestone data sets, funding profile data was evaluated for NASA missions that have experienced deferred or constrained funding during development*
    - Data was collected for the total mission, at the WBS element level (PM/SE/MA, Spacecraft, and Instrument), and by phase
      - *Includes data at various milestones throughout development as well as actuals at launch*
    - Cost and schedule impacts were then quantified for identified funding reductions just prior to and after the funding cut occurred
  - *Data was used to identify relationships between deferred funding and total cost/schedule growth (including the timing and magnitude of funding cuts)*

- Mission Set
  - *Launched*
    - Aquarius
    - Juno
    - Kepler
    - OCO
    - SDO
    - WISE
  - *In Development*
    - GRACE FO
    - ICESat-2
    - SMAP



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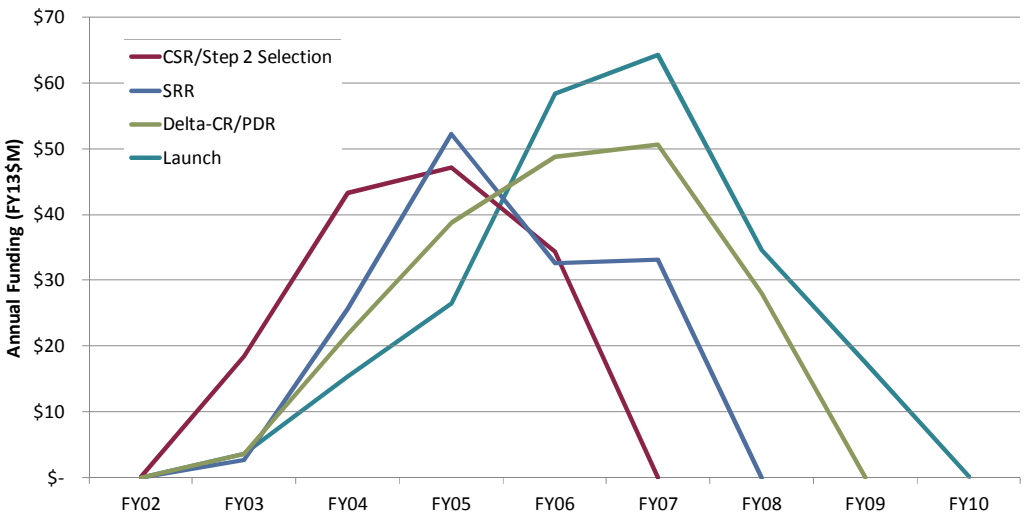
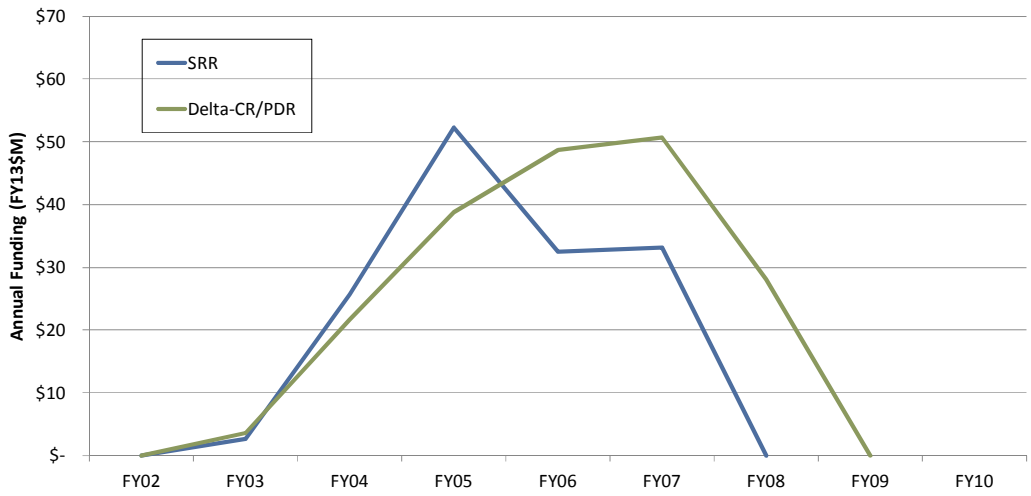
Funding Reduction Identification

Methodology



- Potential budget cuts were determined by comparing funding profiles from Project milestone data (CADRes)
- Budgets before and after suspected cuts were isolated and analyzed
  - *In this example, funding cuts identified early in Phase B were compared to the SRR budget*



- Multiple metrics were then quantified for each identified funding reduction to represent a collection of both dependent and independent variables
  - *Necessary to facilitate multivariable regression for Phase 2*

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Phase 1 Metrics

Deferral Estimation Analysis

- Independent Variables
  - *Funding reduction magnitude*
    - Total Reduction – Reduction relative to initial budget
    - Current Year % – % funding reduction over the fiscal year affected by the cut
      - *If multiple fiscal years were affected, an average of those years is used*
  - *Reduction timeline*
    - Notification – Time relative to Phase B start when project was notified there would be a funding cut
    - Reduction Start – Time relative to Phase B start when funding cut began
    - Reduction End – Time relative to Phase B start when funding cut ended
    - Reduction Span – Difference between Reduction Start and Reduction End, representing time span of reduction

- Dependent Variables
  - *Cost Growth*
    - Cost growth during Phase B, Phase C, Phase D, and total cost growth
  - *Schedule Growth*
    - Schedule growth during Phase B, Phase C, Phase D, and Phase B-D schedule growth

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Phase 1 Results

Deferral Estimation Analysis

- Metrics were collected in two ways:
  - *Absolute data (raw actuals)*
  - *Normalized data (as illustrated below)*
- Metrics were also collected by Phase and WBS
  - *Phase B, C, and D*
  - *WBS: PM/SE/MA, Spacecraft, Instruments*

Dependent Variables
Independent Variables

	Reduction Timeline % (rel to Phase B Start)			% Funding Reduction		% Schedule Growth				% Cost Growth			
Mission	Notification	Reduction Start	Reduction End	Total % Reduction	Current Yr % Reduction	Phase B	Phase C	Phase D	Phase B-D	Phase B	Phase C	Phase D	Total
Aquarius	15%	15%	34%	8%	33%	11%	7%	20%	10%	-11%	48%	10%	30%
JUNO	-34%	-34%	40%	48%	57%	49%	13%	17%	24%	34%	10%	-1%	18%
Kepler R1	-2%	0%	43%	30%	50%	19%	-2%	-35%	1%	29%	4%	41%	14%
Kepler R2	33%	33%	49%	6%	18%	0%	61%	-15%	22%	-4%	58%	-19%	30%
OCO	23%	23%	42%	7%	22%	0%	19%	63%	22%	5%	17%	75%	25%
SDO R1	10%	10%	42%	6%	12%	0%	6%	17%	8%	-5%	13%	35%	15%
SDO R2	40%	40%	78%	3%	6%	0%	14%	-8%	6%	0%	9%	-16%	3%
WISE R1	4%	4%	21%	9%	27%	31%	31%	5%	28%	-5%	55%	38%	39%
WISE R2	20%	20%	39%	9%	34%	0%	0%	64%	7%	-5%	-1%	58%	4%
GRACE FO	-9%	23%	43%	2%	11%	13%	46%	-40%	-2%	15%	56%	-48%	-1%
ICESat-2 R1	-38%	-38%	4%	20%	50%	-21%	18%	-33%	-5%	11%	24%	-40%	18%
ICESat-2 R2	14%	44%	64%	3%	14%	29%	-2%	0%	5%	24%	-4%	11%	5%
SMAP	-17%	-17%	32%	34%	46%	57%	42%	13%	39%	12%	14%	-14%	19%

* negative growth values represent a reduction
** negative timeline values represent a notification or reduction occurring prior to Phase B start

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Phase 2: Deferred Funding Impacts “Rules of Thumb”

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Phase 2: Deferred Funding Impacts "Rules of Thumb"

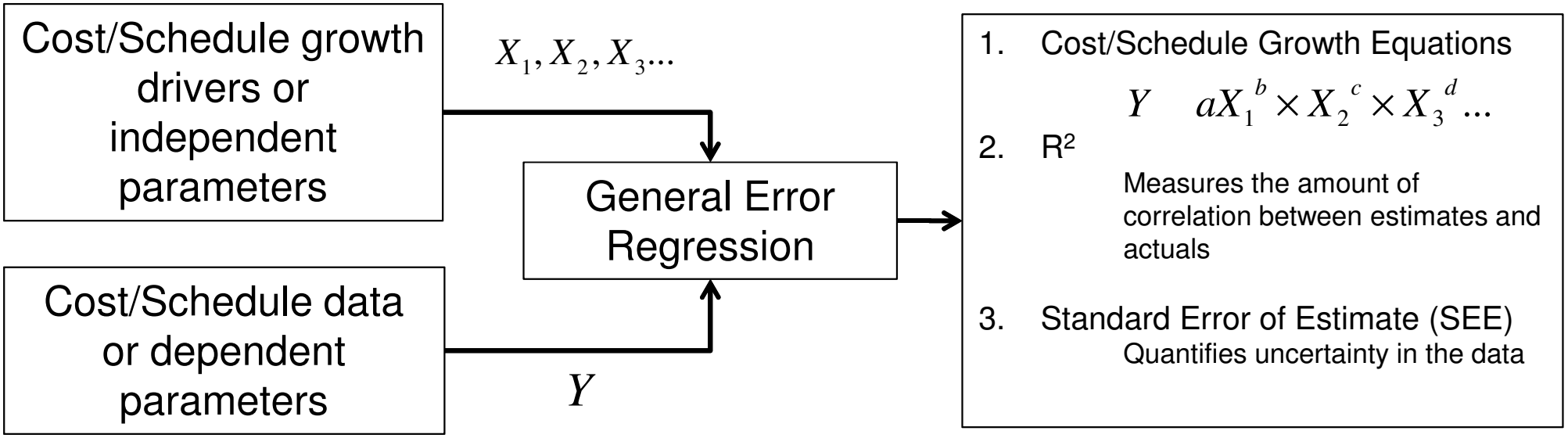
Deferral Estimation Analysis

- Approach
  - *Phase 2 applies Aerospace's General Error Regression Model (GERM) to the data collected in Phase 1 to generate a series of "Rules of Thumb" to address the impacts of deferred funding on future projects*
    - Identify multi-variable relationships that display high correlation to the collected funding reduction data from Phase 1
      - *Independent variables: funding cut magnitude, reduction timeline, notification timeline, etc.*
      - *Dependent variables: schedule growth, cost growth, etc.*
    - Identify useful metrics to begin tracking in other data sets (such as CADRes)

- Objective
  - *Develop "Rules of Thumb" to answer the following questions:*
    - For each dollar deferred in year X, what is the increase in development cost and delay in LRD?
    - When is the optimal point in a project's development to reduce funding in order to minimize the long-term impacts to cost and schedule?
    - Is there a threshold where the magnitude of a funding reduction results in significantly higher cost and/or schedule growth?
    - Is there a funding profile resistant to the impact of deferred funding?

General Error Regression Model (GERM)

Methodology



- Start with a single variable, X_1
- Examine additional cost growth or schedule growth drivers (X_2, X_3, etc.) until the best statistical values are obtained
- Verify the quality of the equations based on the values of R^2 and SEE

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Metrics Prioritization

Methodology

- In order to narrow the field of potential variable combinations to run through GERM, the correlation between each individual independent and dependent variable was analyzed
- Mission and WBS correlation metrics
  - *Correlation +/- 0.5 is indicated in red text and represents more significant correlation*
  - *Schedule growth shows less correlation compared to cost growth*

Normalized Total Mission Growth Data Correlation

	% Schedule Growth				% Cost Growth			
	Mission Phase B-D	PM/SE/MA Phase B-D	Spacecraft Phase B-D	Instrument Phase B-D	Mission Total	PM/SE/MA Total	Spacecraft Total	Instrument Total
Notification %	-0.01	-0.06	-0.06	-0.06	-0.01	-0.56	-0.01	-0.21
Reduction Start %	-0.18	-0.29	-0.29	-0.29	-0.25	-0.62	-0.22	-0.40
Reduction End %	-0.10	-0.03	-0.03	-0.03	-0.50	-0.22	-0.14	-0.73
Total Reduction %	0.37	0.47	0.43	0.74	0.12	0.12	0.23	0.11
Current Yr %	0.20	0.19	0.10	0.55	0.25	-0.03	0.01	0.32
Notification (months)	-0.01	-0.09	-0.09	-0.09	0.02	-0.57	-0.04	-0.22
Reduction Start (months)	-0.18	-0.32	-0.32	-0.32	-0.23	-0.62	-0.24	-0.40
Span (months)	-0.04	-0.02	-0.02	-0.02	-0.43	-0.26	-0.15	-0.74
Total Reduction $	0.38	0.51	0.40	0.65	0.03	0.20	0.26	0.03
Notification (Phase)	0.05	-0.10	-0.10	-0.10	0.07	-0.43	-0.05	-0.12
Reduction (Phase)	-0.14	-0.37	-0.37	-0.37	-0.34	-0.59	-0.33	-0.57

Absolute Total Mission Growth Data Correlation

	Schedule Growth (months)				Cost Growth (FY14$M)			
	Mission Phase B-D	PM/SE/MA Phase B-D	Spacecraft Phase B-D	Instrument Phase B-D	Mission Total	PM/SE/MA Total	Spacecraft Total	Instrument Total
Notification %	0.10	-0.01	-0.01	-0.01	-0.41	-0.66	-0.43	-0.57
Reduction Start %	-0.09	-0.26	-0.26	-0.26	-0.59	-0.64	-0.50	-0.61
Reduction End %	-0.03	0.02	0.02	0.02	-0.39	-0.02	0.12	-0.77
Total Reduction %	0.30	0.47	0.41	0.73	0.54	0.23	0.77	-0.01
Current Yr %	0.13	0.20	0.07	0.53	0.44	0.04	0.37	0.09
Notification (months)	0.11	-0.04	-0.04	-0.04	-0.36	-0.65	-0.45	-0.57
Reduction Start (months)	-0.08	-0.28	-0.28	-0.28	-0.55	-0.64	-0.51	-0.61
Span (months)	0.18	0.44	0.44	0.44	0.50	0.88	0.84	0.19
Total Reduction $	0.31	0.50	0.39	0.64	0.60	0.33	0.87	0.08
Notification (Phase)	0.15	-0.06	-0.06	-0.06	-0.17	-0.50	-0.40	-0.39
Reduction (Phase)	-0.06	-0.33	-0.33	-0.33	-0.48	-0.56	-0.45	-0.78

Dependent Variables
Independent Variables

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Phase 2 Observations

Deferral Estimation Analysis

- Based on the correlation analysis and subsequent regression attempts, multiple key observations have been made with respect to the impacts from funding reductions
  - *Schedule Growth*
    - Given the current mission data set and independent variables identified, the schedule growth exhibited in response to a funding cut appears to be relatively unpredictable
    - Substantiated by the low correlation identified with nearly all the independent variables and the low R^2 and high SEE from multiple regression attempts
      - *Consistent in the analysis conducted by Phase and by WBS*
  - *Cost Growth*
    - Total cost growth in absolute dollars exhibit higher correlation with multiple independent variables and promising regression statistics
      - *Particularly true at the PM/SE/MA, Spacecraft, and Instrument WBS levels*
    - Absolute cost growth by Phase and all normalized cost growth metrics have not exhibited the same modeling potential with consistently lower correlation and undesirable regression statistics
  - *Key Metrics*
    - Based on the current collection of regression results, 4 independent variables consistently produce the highest R^2 and lowest SEE
      - *Total reduction ($), reduction span (months), reduction phase, and notification phase*

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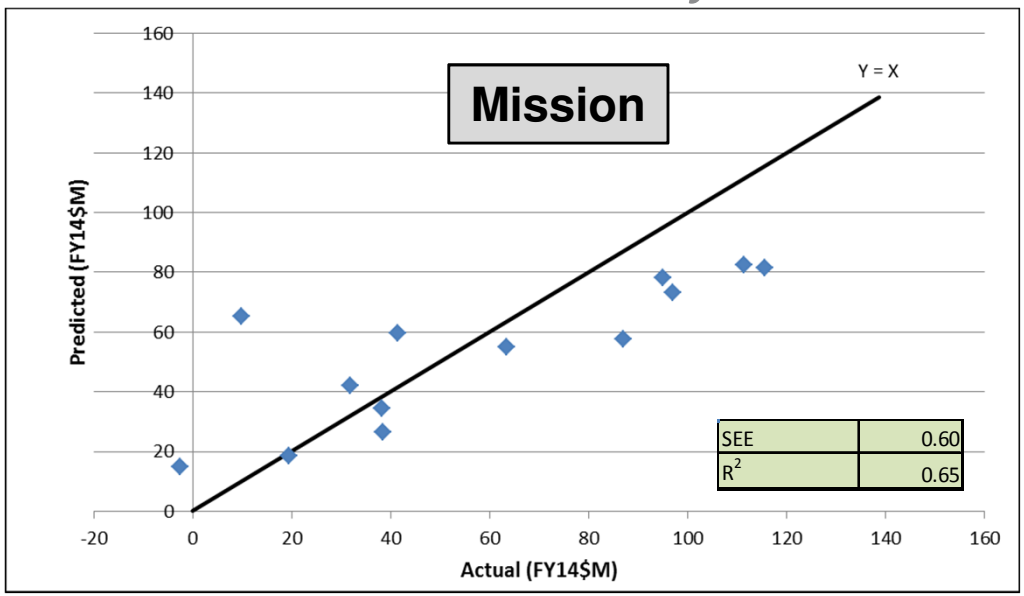
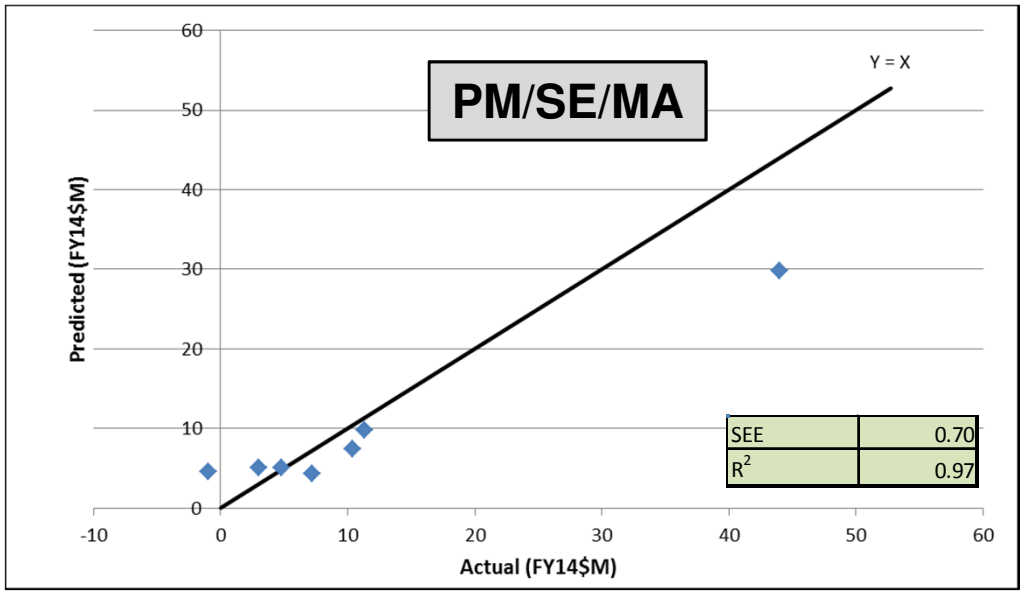
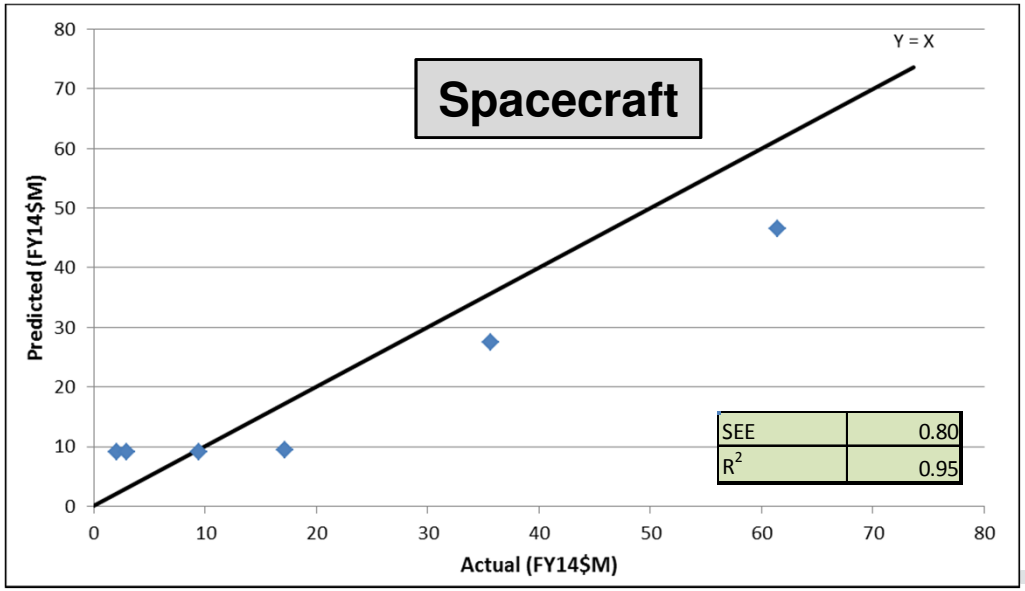
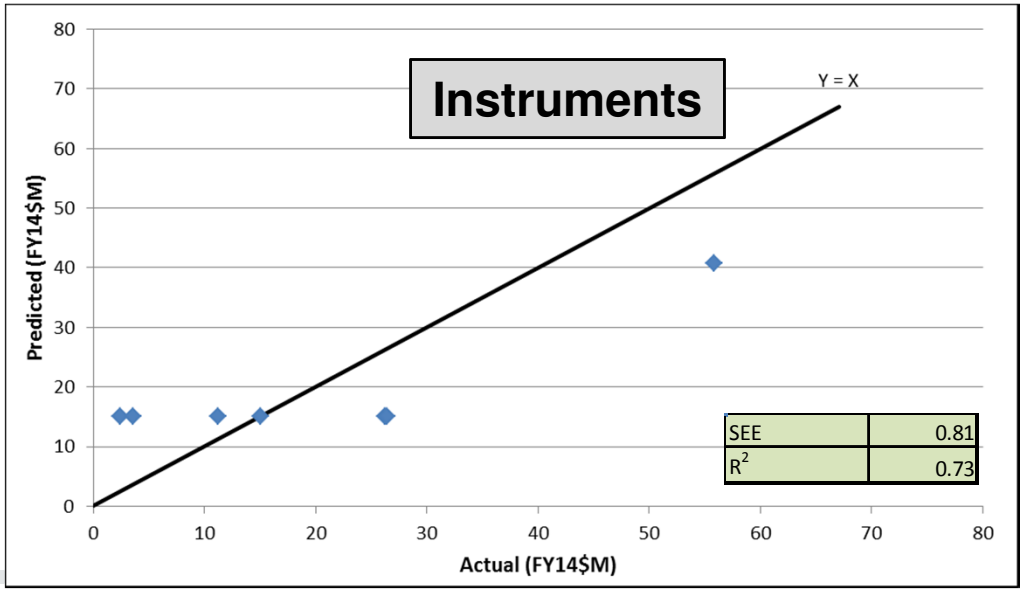
Phase 2 Cost Preliminary Results

Deferral Estimation Analysis









Cost growth regression trends look promising for determining rules of thumb to address impacts from deferred funding cuts

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Summary and Forward Work

Deferral Estimation Analysis

- Summary
  - *Given the limited dataset, establishing a series of "Rules of Thumb" with respect to deferred funding has proven challenging*
    - Isolating cost and schedule growth due solely to deferred funding has been particularly difficult
  - *Development of "Rules of Thumb" for mission and WBS-level cost growth is showing promise*
    - Trends associated with schedule growth resulting from constrained funding remains illusive
- Forward Work
  - *Regression Maturation and Evaluation*
    - Aerospace team continues to explore various regression techniques to improve the statistical significance of results produced
    - Inspection of the regression equations and testing of the "Rules of Thumb" in a modeling environment are planned to be preformed to improve confidence in the results
  - *Investigation of Outliers*
    - Two consistent outliers have been identified in the dataset in nearly all regressions performed
    - Initial investigations indicate that the distinguishing factor may be tied to the level of UFE being held by these projects and their ability to absorb a portion of the funding cuts with UFE
  - *Exploration of New Metrics*
    - Aerospace team also continues to explore additional metrics, such as UFE levels and profile shape, to add further dimensions to the analysis

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