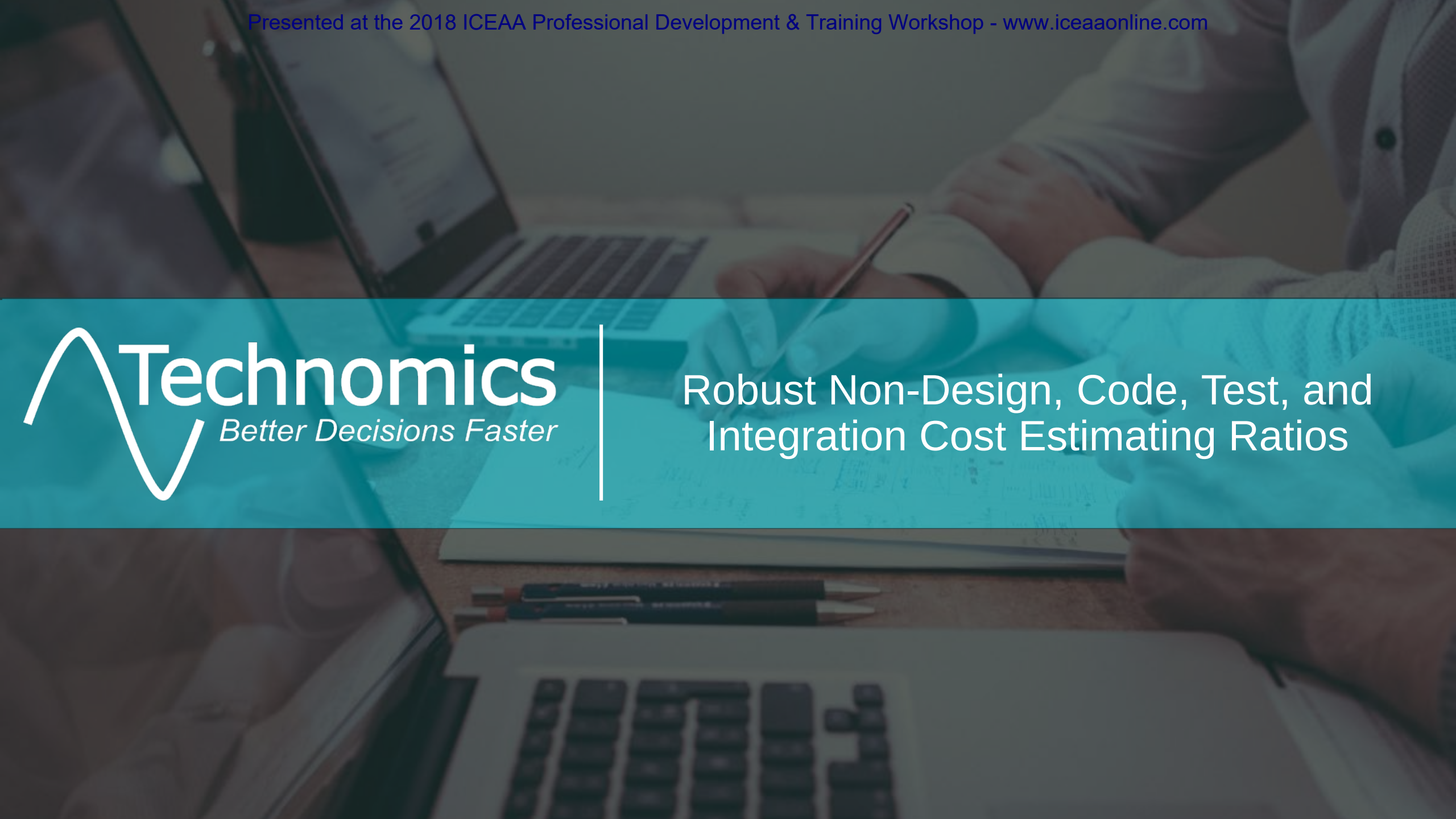
Presented at the 2018 ICEAA Professional Development & Training Workshop - www.iceaaonline.com



Technomics
Better Decisions Faster

Robust Non-Design, Code, Test, and Integration Cost Estimating Ratios

Overview of Presenters

Britt Staley

- Lead Cost Analyst at Technomics, Inc. supporting the Department of Defense
- Prior to to joining Technomics, was a cost analyst supporting Naval Surface Warfare Center, Dahlgren Division and a statistician at the U.S. Census Bureau.
- Served five years in the US Army as an Intelligence Analyst and has a Master's in Applied Economics from Georgetown University.

Nicole Robertson

- Senior Associate at Technomics, Inc. supporting the Department of Defense.
- Prior to joining Technomics, was a microbiologist supporting Naval Surface Warfare Center, Dahlgren Division.
- Has a Bachelor's in Biology from Morehead State University

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Today's Presentation

- Background
- Assumptions
- Data
- Graphical Analysis
- Cost Estimating Ratios (CERs) Development Approach
- CERs
  - Program Management
  - Systems Engineering / Systems Analysis
  - Integrated Logistics Support
  - Modeling & Simulation
  - Combat System Integration & Test
  - Site Integration & Support
- Conclusion

Background

- Total software development comprises
  - Design, code, test, and integration (DCTI) costs
  - Non-DCTI (NDCTI) cost –typically represents **50%** or more of the cost estimate
- Typical software development costs estimating methodology
  - DCTI cost = f(software size, productivity, & labor rates)
  - NDCTI cost = f(DCTI cost) and/or level of effort
- This presentation provides improved NDCTI cost estimating methodology
  - Builds upon "Reliable Non-DCTI Cost Estimating Relationships", Goucher & Staley (2017)
    - Non-DCTI costs are not level of effort as determined
  - Application of Lessons Learned – Thanks everyone!

Comparative Category	2017 Results	2018 Results
Methodology	Analysis of Averages	OLS Regression Analysis
Data	Historic Cost Data from 3 Programs	Historic Cost Data from 18 Programs
ESLOC	Average: 651K (200K – 1,470K)	Average: 447K (46.9K – 1,470K)
CERs	PM, SE, ILS, M&S, Sites I&S, S I&T	Same
Coverage	12 years	16 years

Assumptions

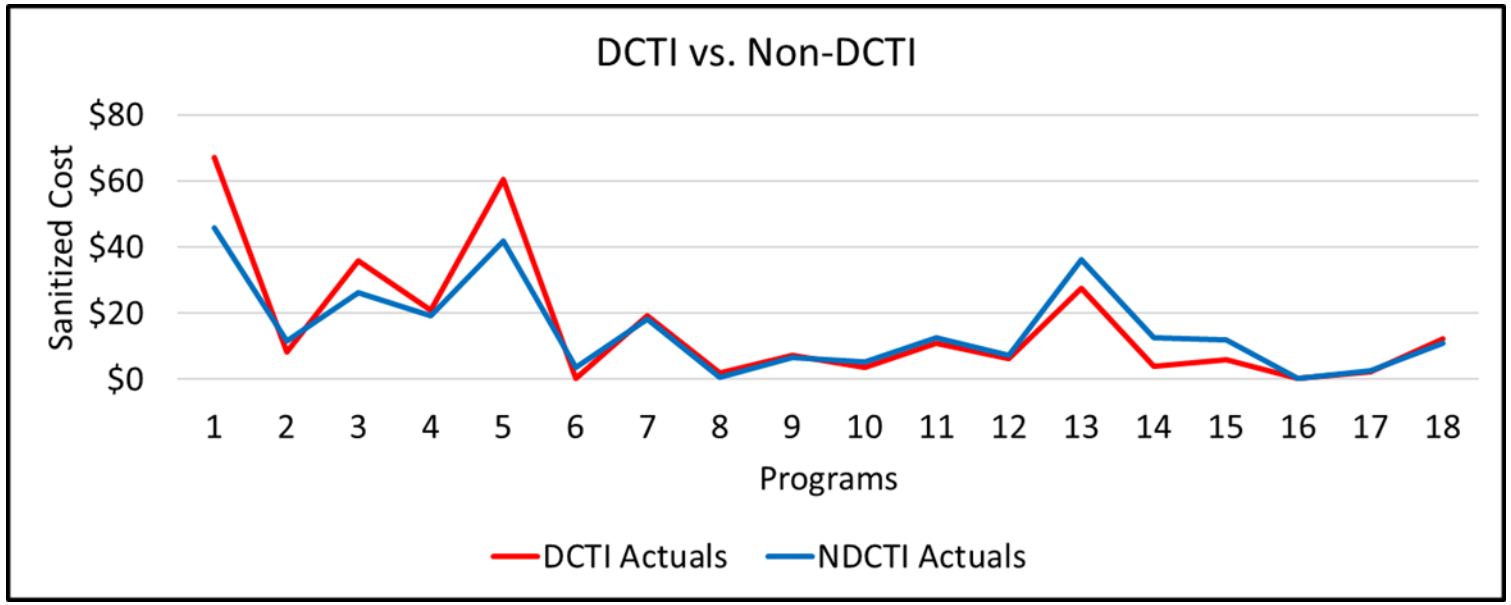
- NDCTI = f(DCTI)
  - When DCTI increases / decreases, so to do Non-DCTI costs
  - There is a linear relationship between NDCTI and DCTI
- Field Testing is not included in analysis
  - Field Test requirements tend to be unique and highly variable

Non-DCTI Sub-Elements	
Program Management (PM)	Systems Engineering & Analysis (SE/SA)
Integrated Logistics Support (ILS)	Modeling & Simulation (M&S)
Sites Integration & Support (Sites I&S)	System Integration & Test (S I&T)

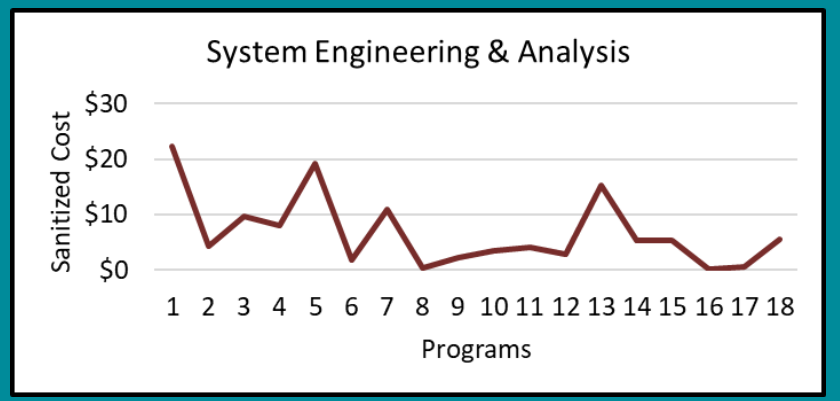
Data

- Contract Performance Report (CPR) data for 18 command & control software development efforts
  - DCTI & NDCTI costs are separately identifiable
  - Software size: Average ~ 447K equivalent new source lines of code (ESLOC)
    - Low: 46.8K ESLOC
    - High: 1,470K ESLOC
  - Development effort status:
    - 90% are 95%-100% complete (software certification status)
    - 10% are <95% complete
- Data normalized to BY17$ for analysis
- Data sanitized (i.e., proportionately adjusted due to proprietary nature) for this presentation

Data


DCTI vs. Non-DCTI
Sanitized Cost
$80
$60
$40
$20
$0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Programs
DCTI Actuals
NDCTI Actuals


Program Management
Sanitized Cost
$15
$10
$5
$0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Programs


System Engineering & Analysis
Sanitized Cost
$30
$20
$10
$0
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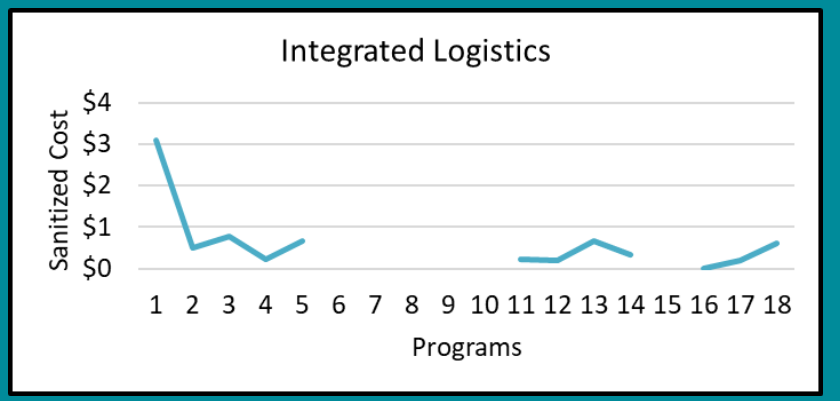
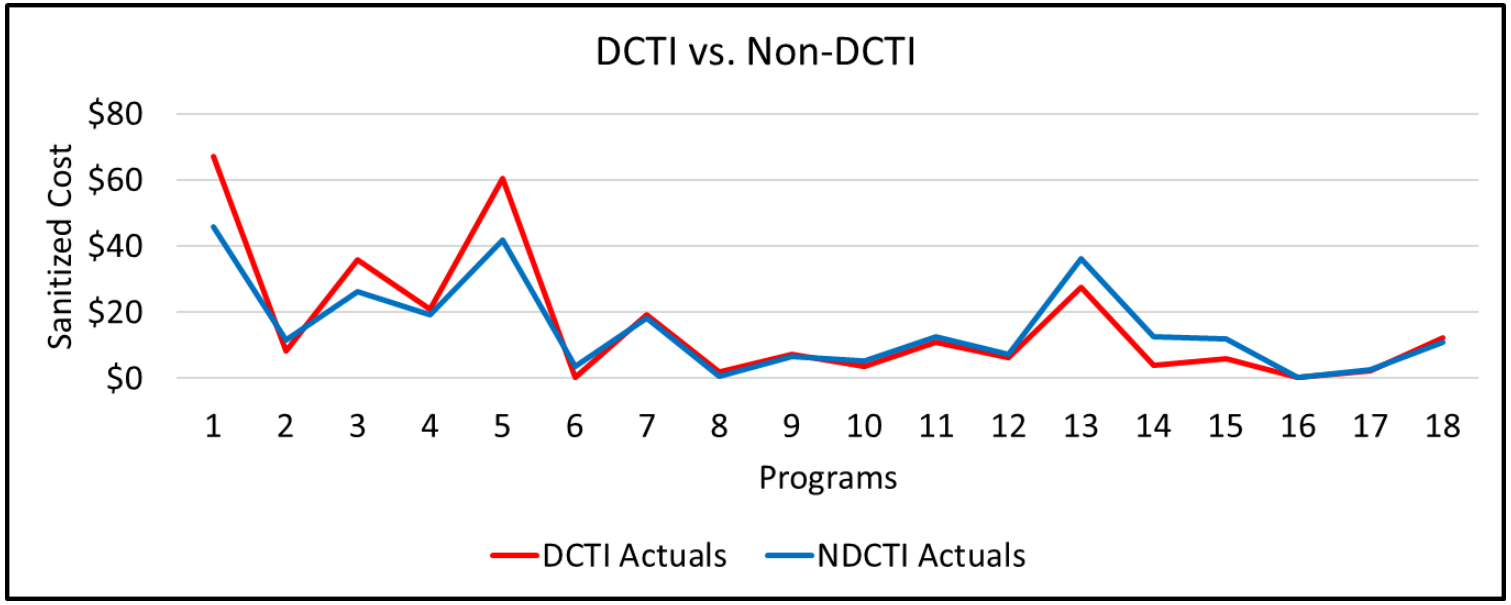
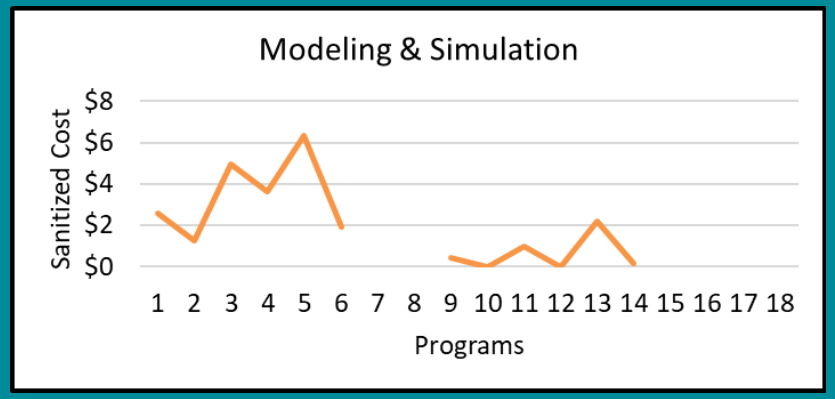
Programs


Integrated Logistics
Sanitized Cost
$4
$3
$2
$1
$0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Programs

Data


DCTI vs. Non-DCTI
Sanitized Cost
$80
$60
$40
$20
$0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Programs
DCTI Actuals
NDCTI Actuals


Modeling & Simulation
Sanitized Cost
$8
$6
$4
$2
$0
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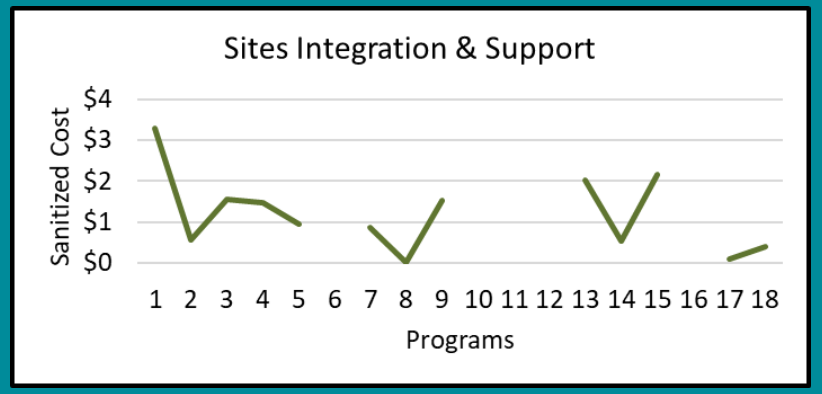
Programs


Sites Integration & Support
Sanitized Cost
$4
$3
$2
$1
$0
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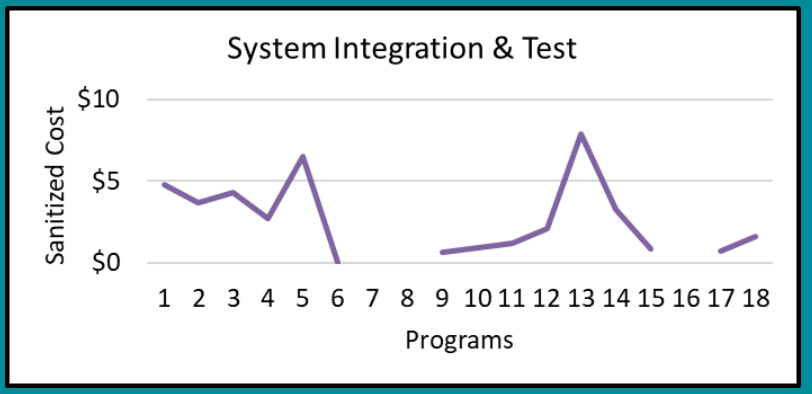
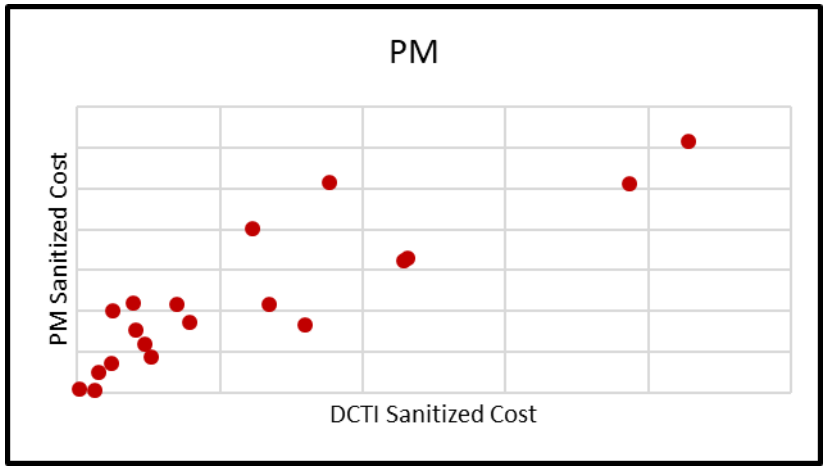
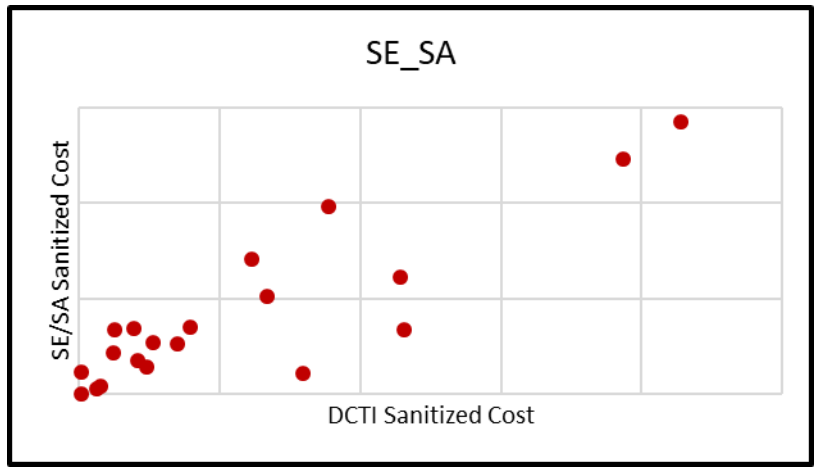
Programs

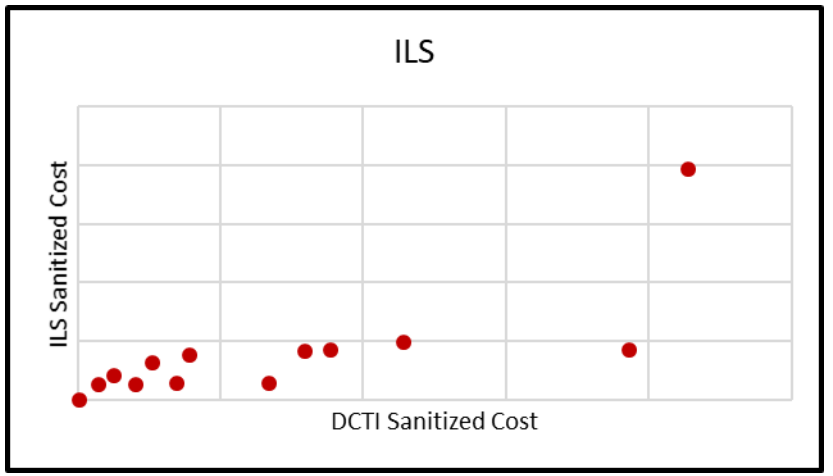

System Integration & Test
Sanitized Cost
$10
$5
$0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Programs

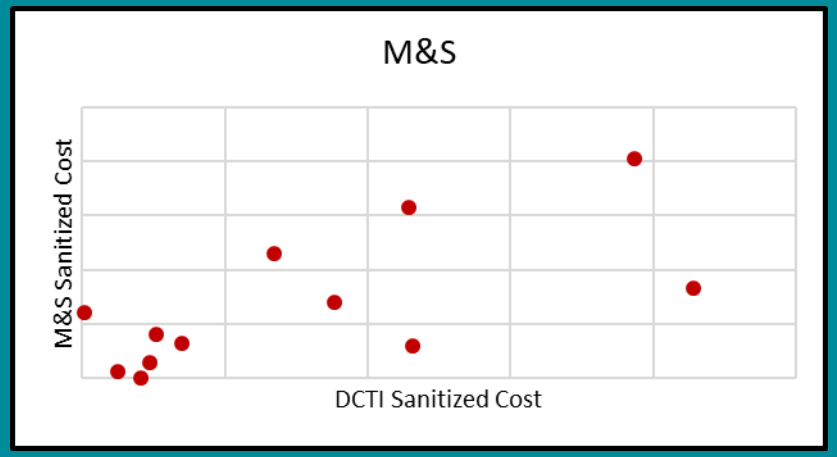
Graphical Analysis

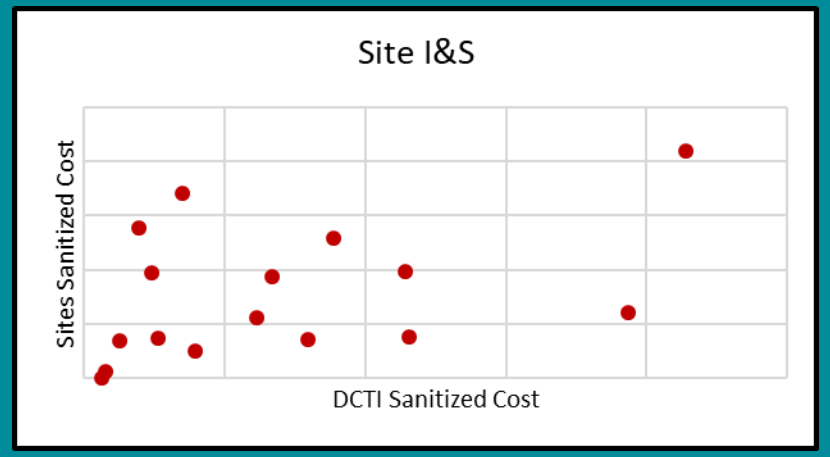
Graphs reflect sanitized CPR data for 18 software development efforts

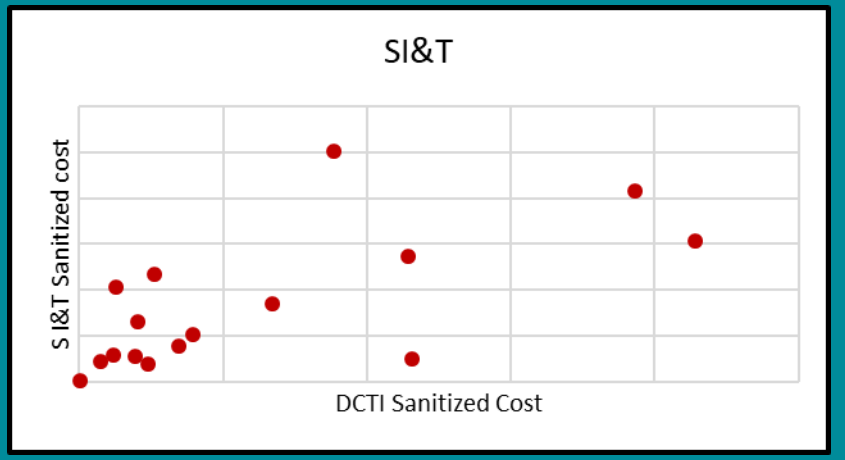












CER Development Approach

- Analysis Methodology:
  - Cull 1: Ordinary Least Squares Regression Analysis

$y = a + b * DCTI$	$y = b * DCTI$
$y = a + b * ESLOC$	$y = b * ESLOC$

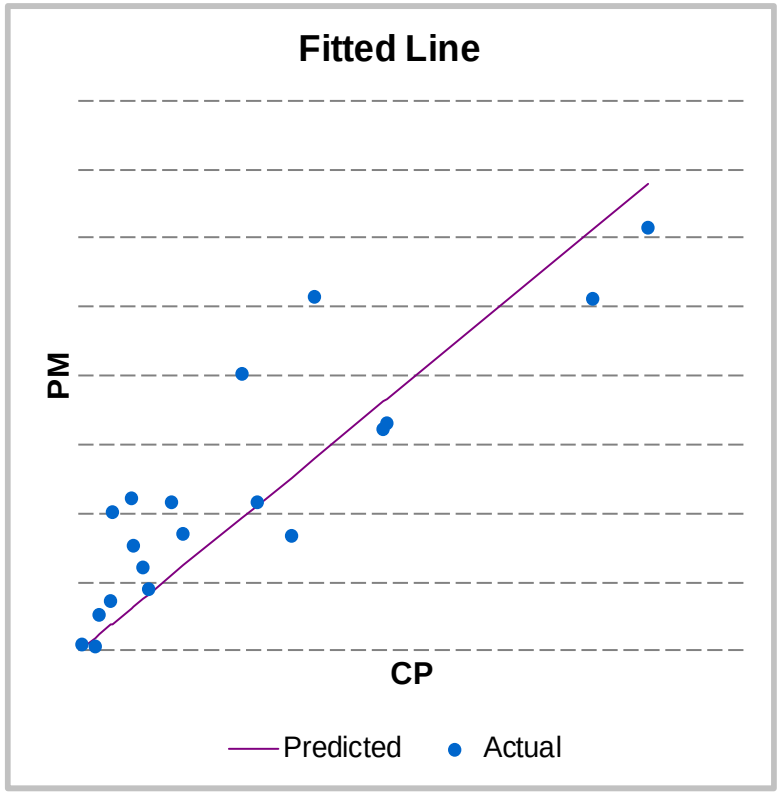
  - Cull 2: Two-tailed hypothesis test for significance. $H_0: \beta = 0$
  - Cull 3: Outlier detection, analysis, and removal
  - Cull 4: Two-tailed hypothesis test for equal means. $H_0: \beta_1 = \beta_2$
    - i.e. is removing the outlier statistically significant

$$T = \frac{\hat{\beta}_1 - \hat{\beta}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

Program Management CER

$$PM = 15.84\% * DCTI$$

Variable	Coefficient	Std Dev of Coef	T-Statistic (Coef/SD)
CP	0.1584	0.0142	11.1169



PM includes:

Business and financial management

Quality assurance standards and adherence

Data and configuration management

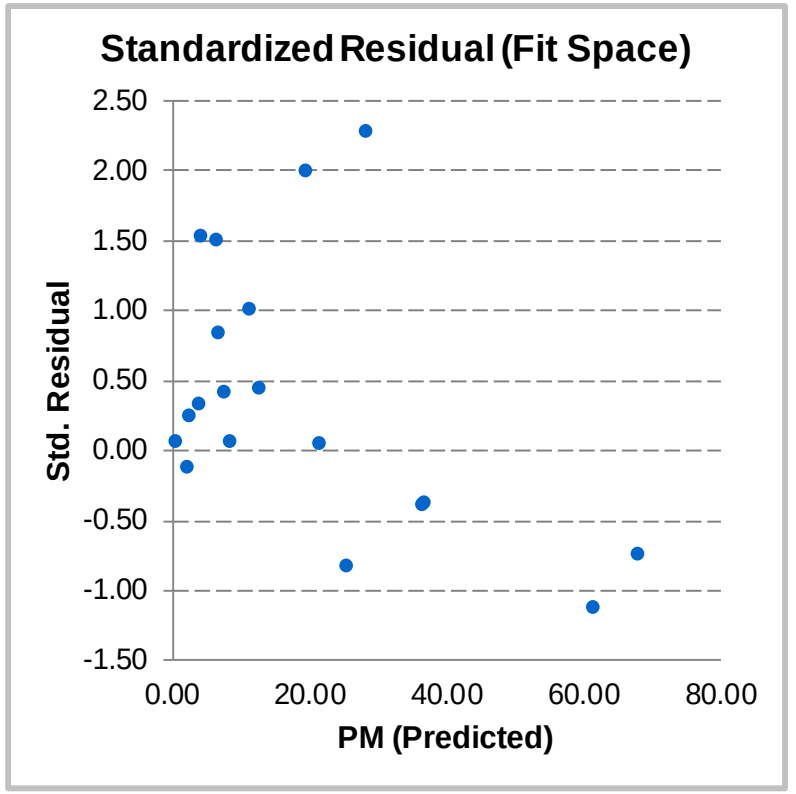
Program planning

Program evaluation

Adj R-Squared = 86.58%

Standard Error = 10.55

CV = 45.52%



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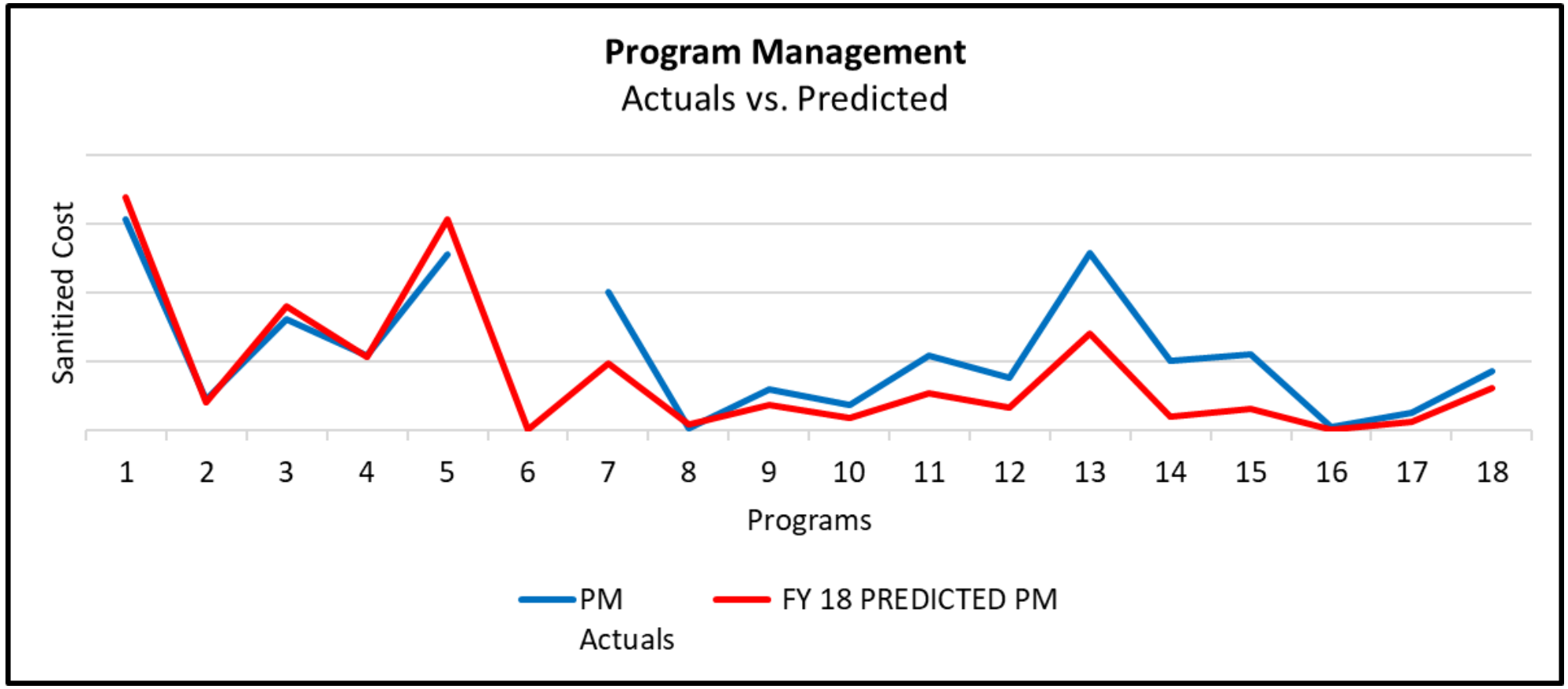
Program Management CER Performance

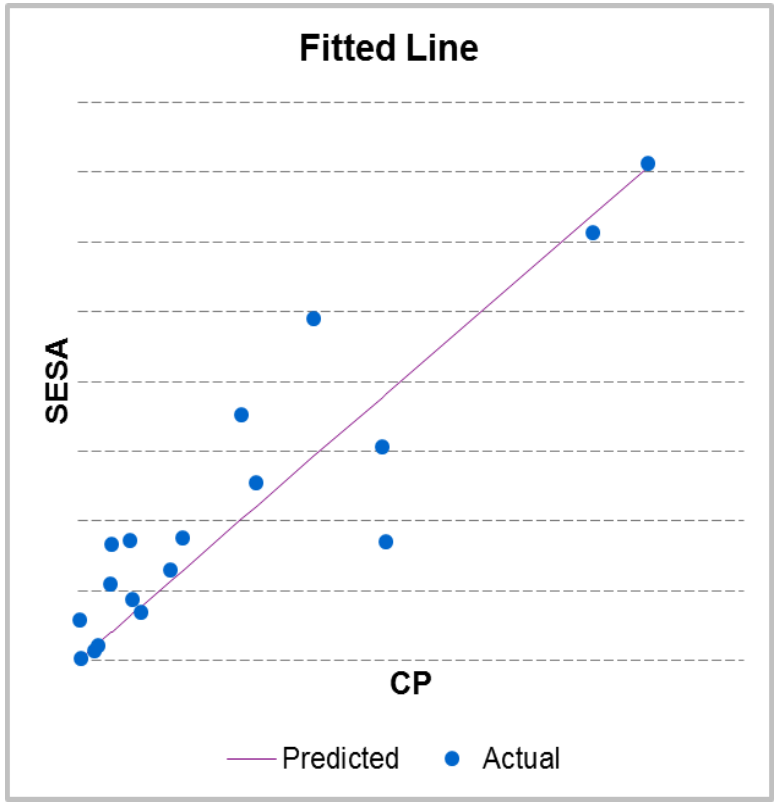


- Program management
  - Tracks well across programs

Systems Engineering / Analysis CER

$$SESA = 33.01\% * DCTI$$

Variable	Coefficient	Std Dev of Coef	T-Statistic (Coef/SD)
CP	0.3301	0.0262	12.5954



SESA Comprises

engineering oversight and support functions including:

System level coordination

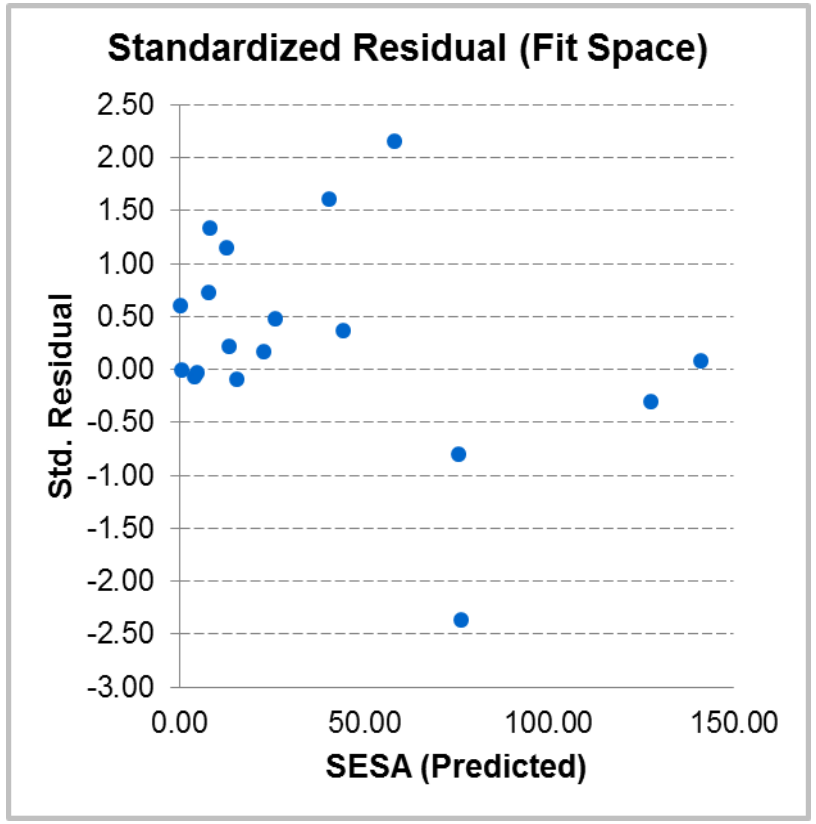
Planning and integration

Special projects

Adj R-Squared = 89.75%

Standard Error = 18.90

CV = 43.53%



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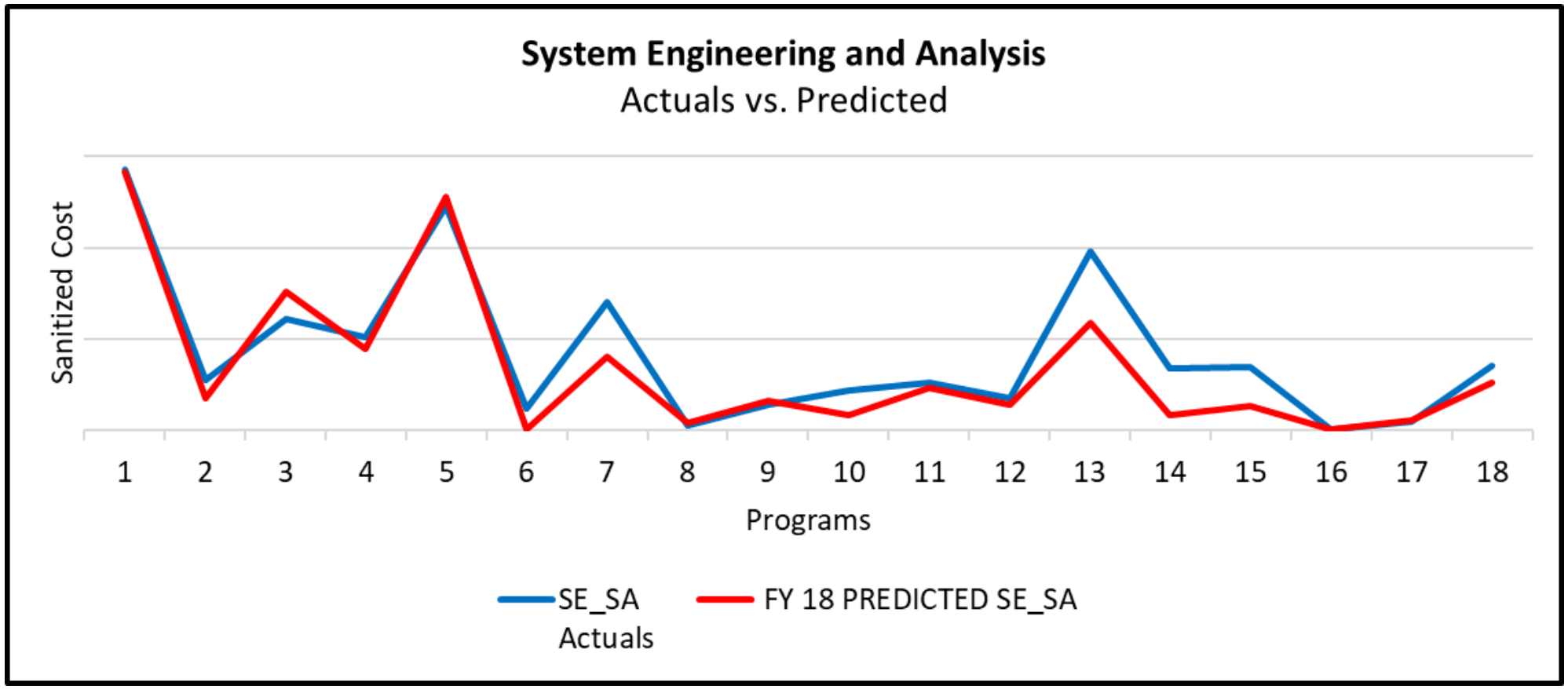
Systems Engineering / Analysis CER Performance



- System Engineering
  - Tracks well across programs

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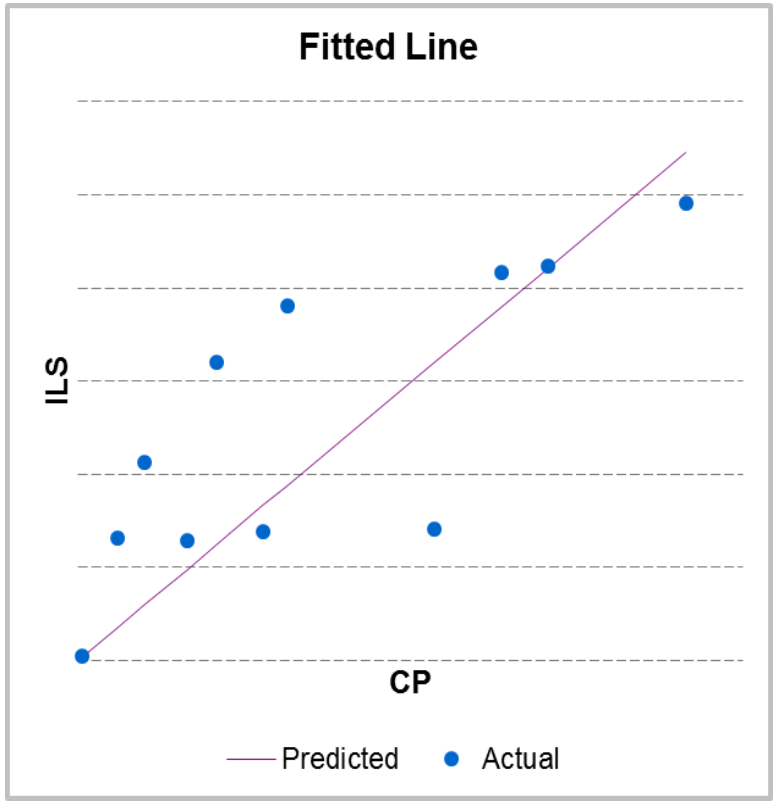
Integrated Logistics Support CER

$$ILS = 2.39\% * DCTI$$

Variable	Coefficient	Std Dev of Coef	T-Statistic (Coef/SD)
CP	0.0239	0.0032	7.4718



ILS includes

Oversight and coordination of IL requirements and process

Management of supply chain

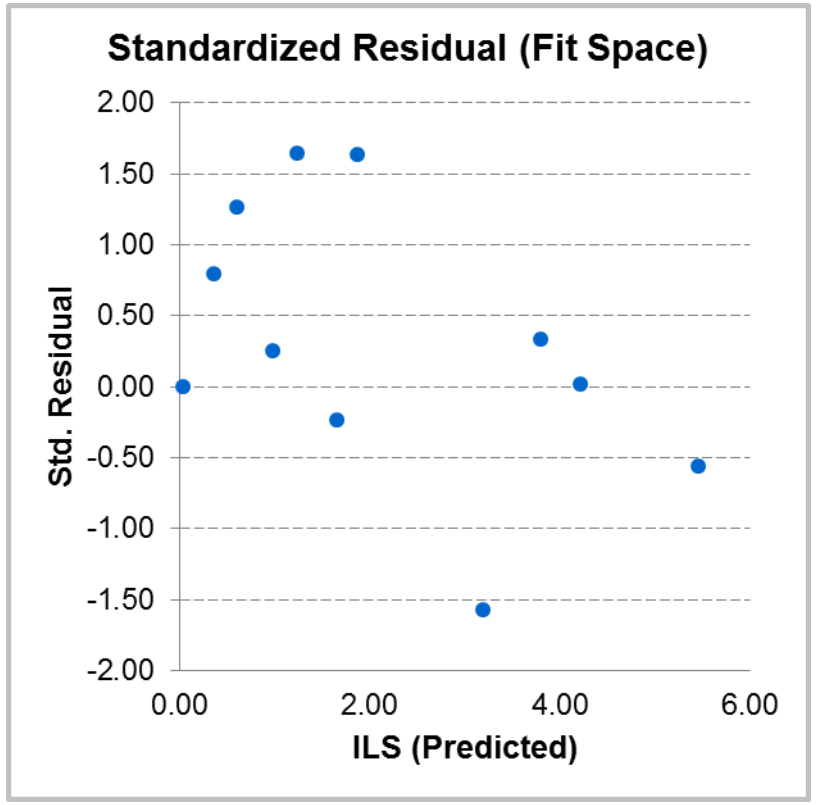
Development of technical manuals

Training support

Adj R-Squared = 83.29%

Standard Error = 1.20

CV = 47.64%



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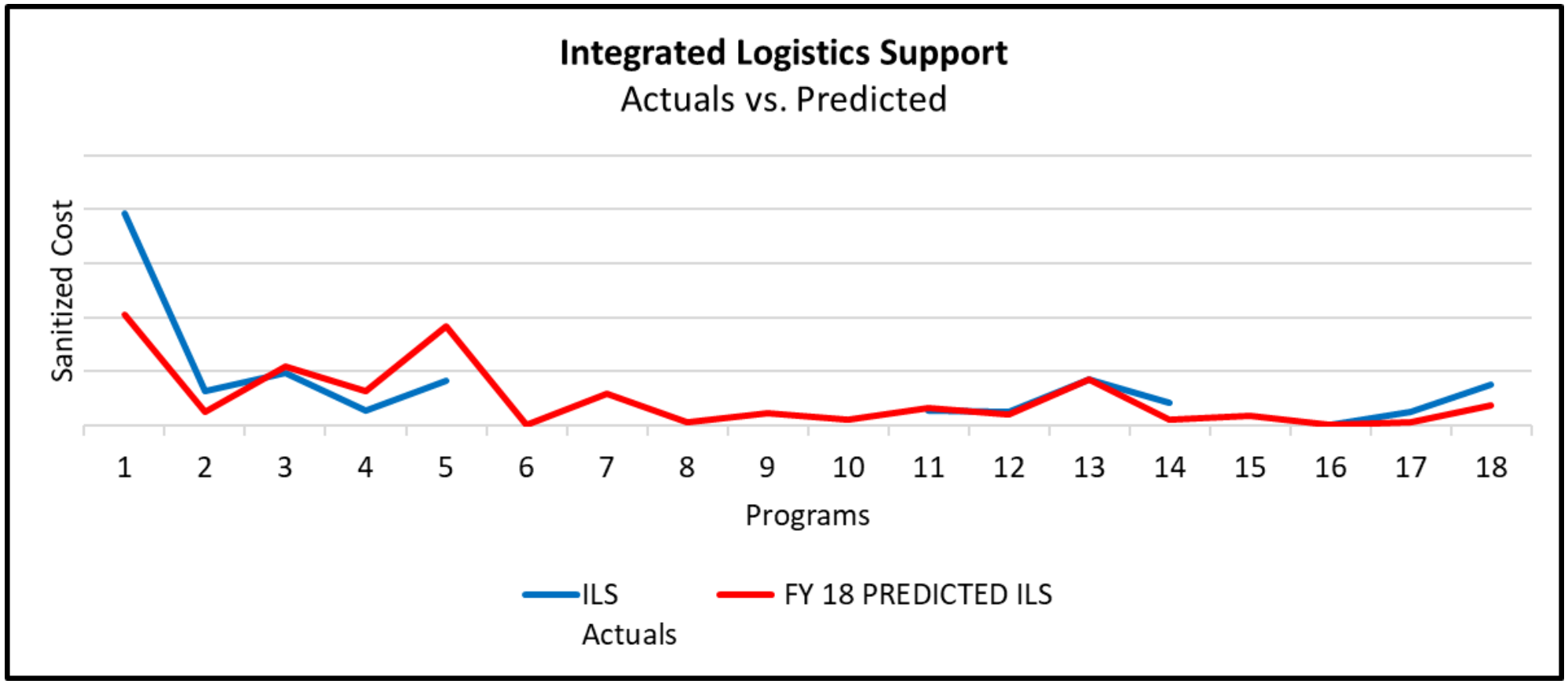
Integrated Logistics Support CER Performance

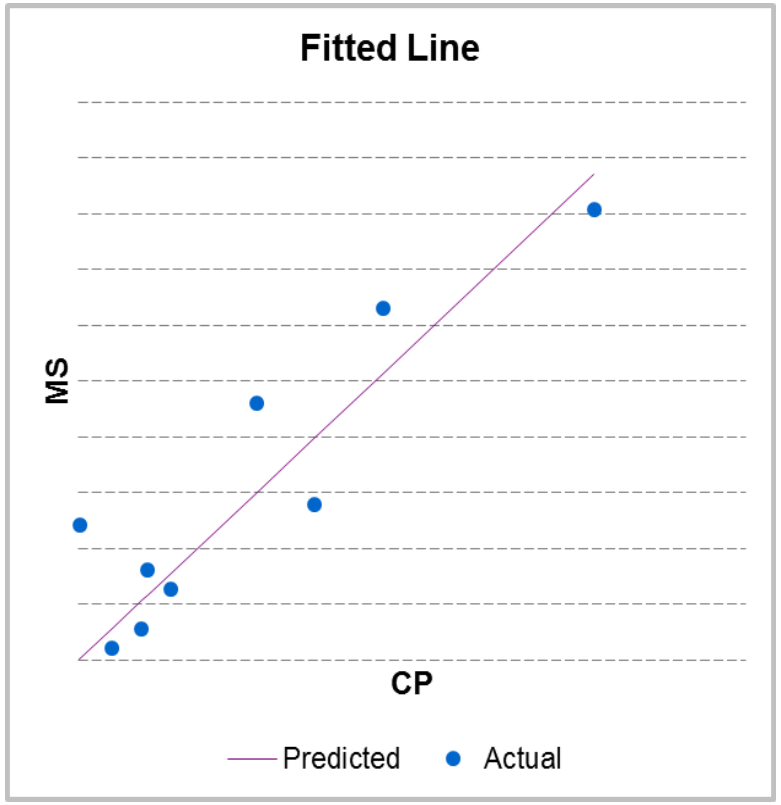


- Integrated Logistics
  - Tracks relatively well for majority of programs where data is present

Modeling & Simulation CER

$$M\&S = 11.26\% * DCTI$$

Variable	Coefficient	Std Dev of Coef	T-Statistic (Coef/SD)
CP	0.1126	0.0120	9.3590



M&S comprises

the effort to develop simulated environments within which a computer program can be tested

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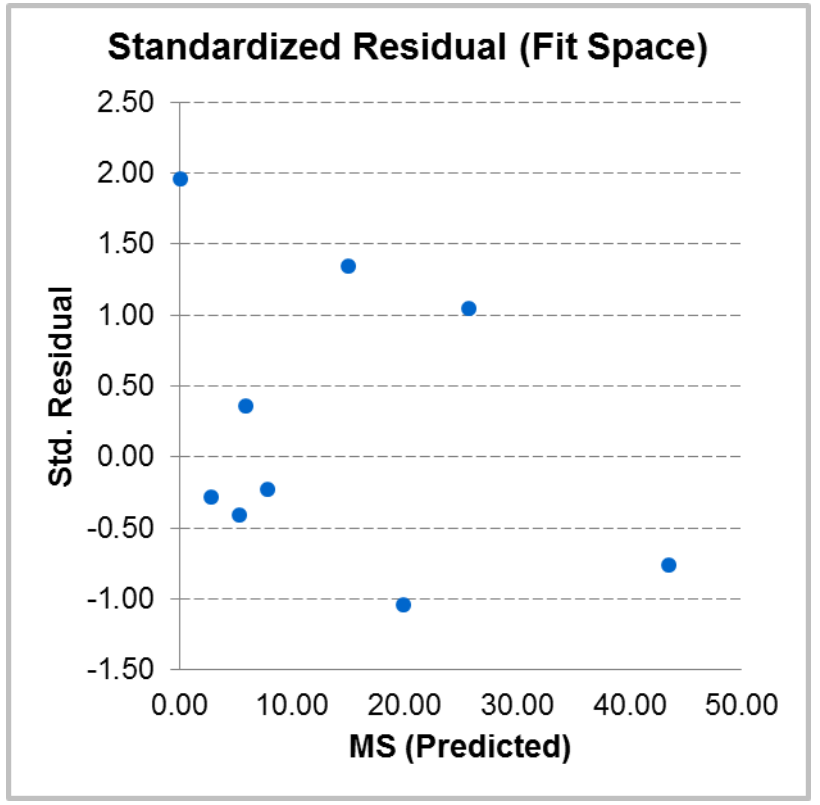
Adj R-Squared = 90.58%

Standard Error = 6.14

CV = 39.67%



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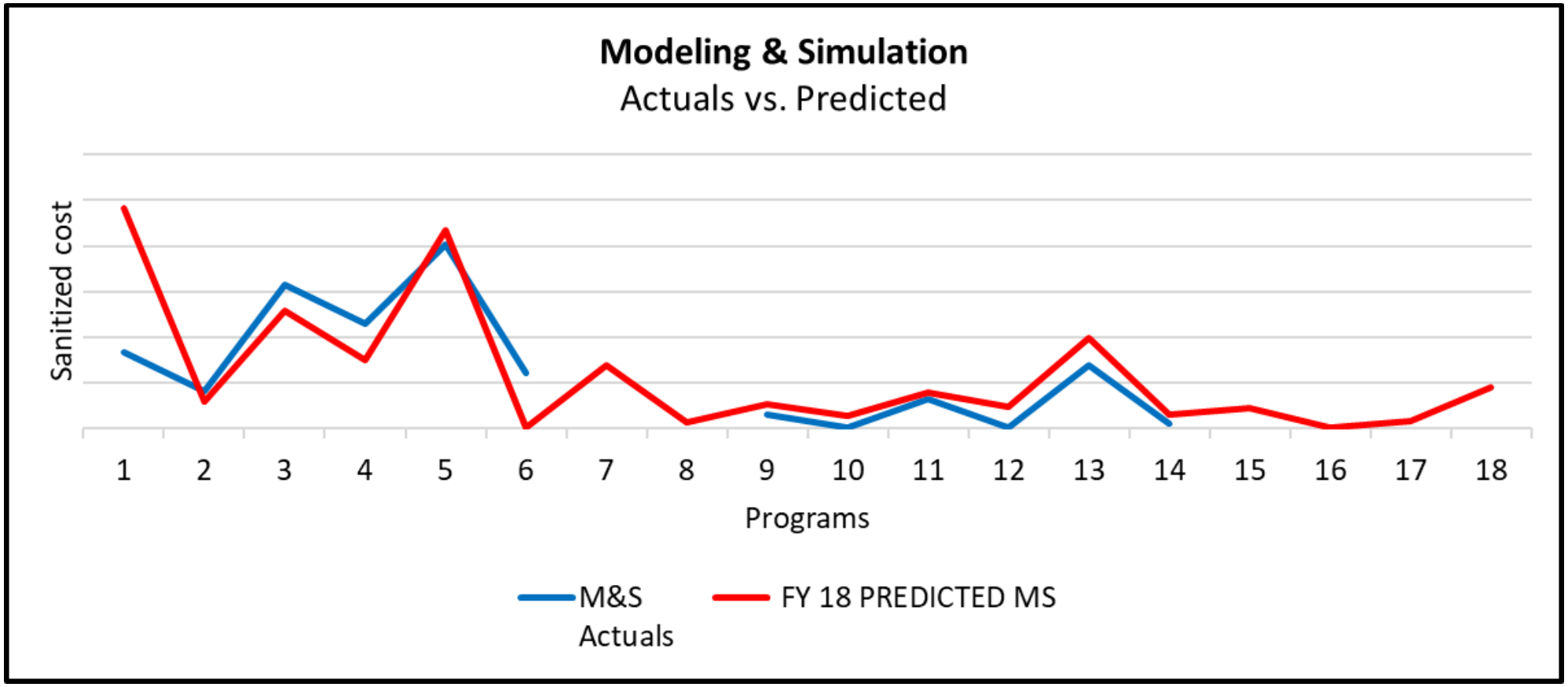
Modeling & Simulation CER Performance

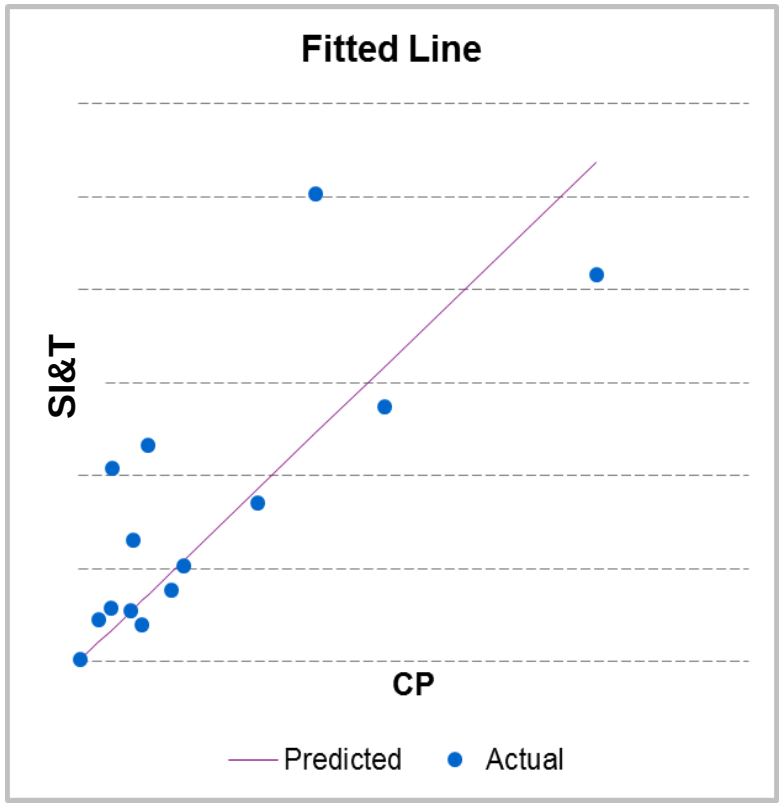


- Modeling & Simulation
  - Tracks relatively well for majority of programs where data is present

System Integration & Test CER

$$\mathbf{SI\&T = 13.90\% * DCTI}$$

Variable	Coefficient	Std Dev of Coef	T-Statistic (Coef/SD)
CP	0.1390	0.0203	6.8309



SI&T includes

System level requirements

Multi-element integration and test

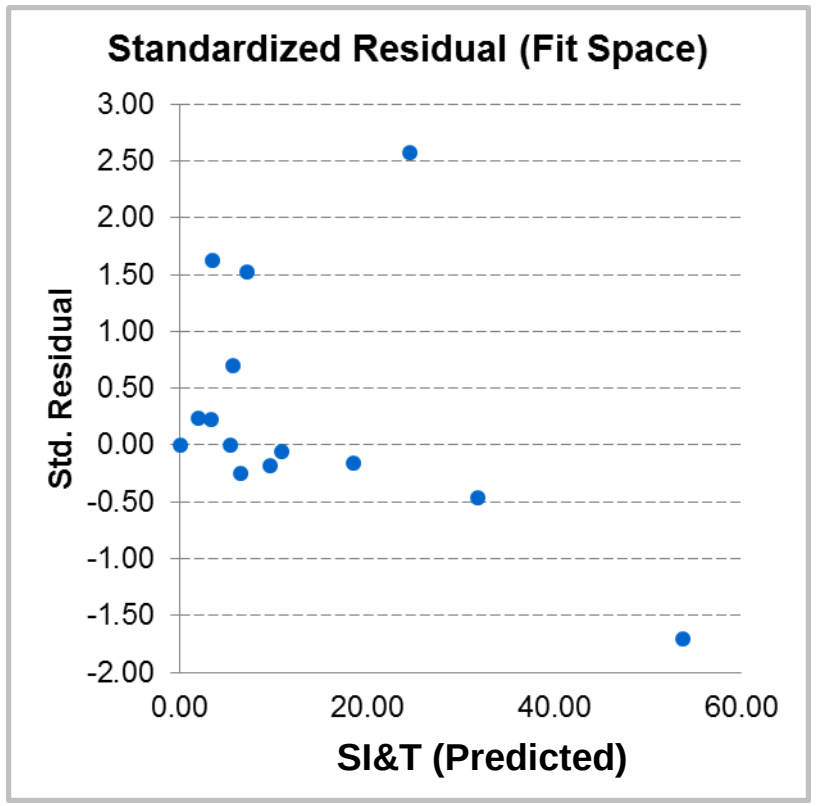
Test plans and procedures

Integration oversight

Adj R-Squared = 76.53%

Standard Error = 10.60

CV = 64.16%



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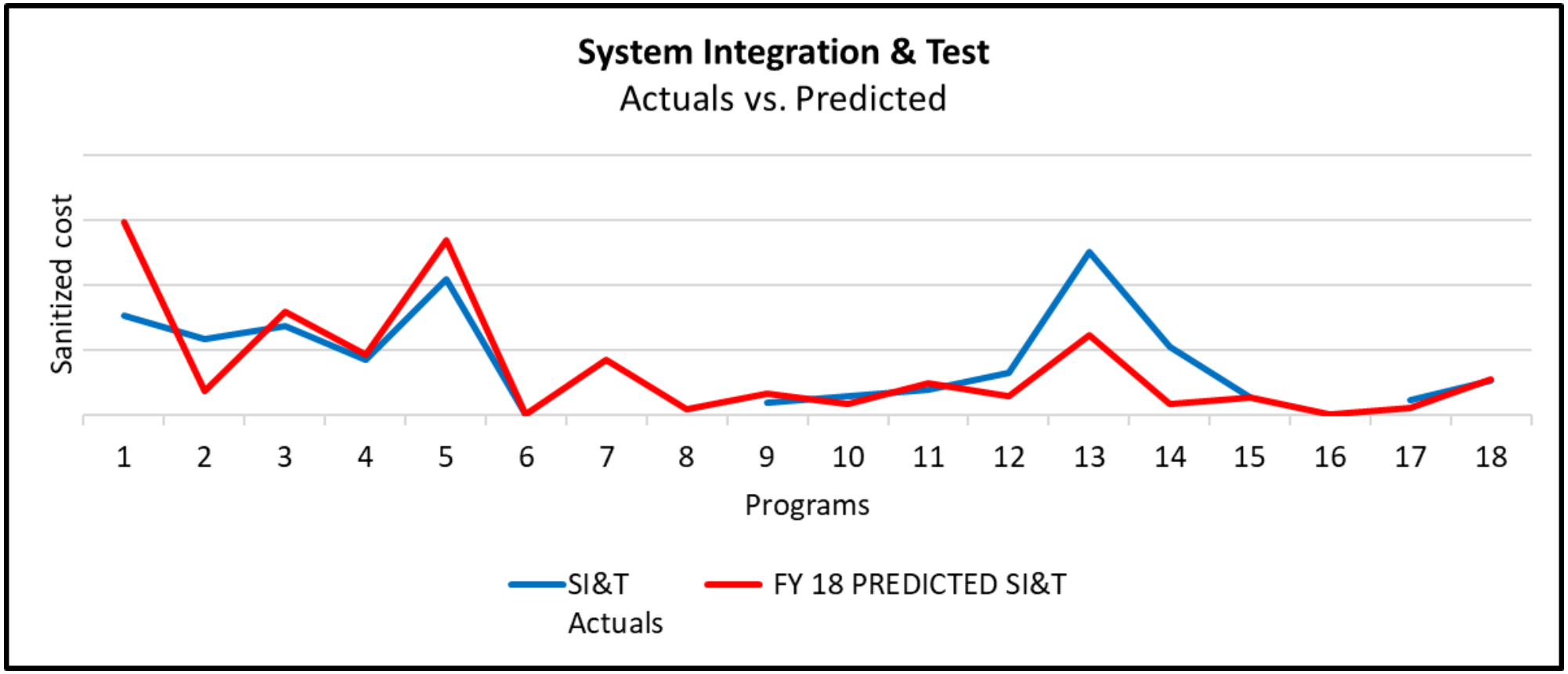
System Integration & Test CER Performance

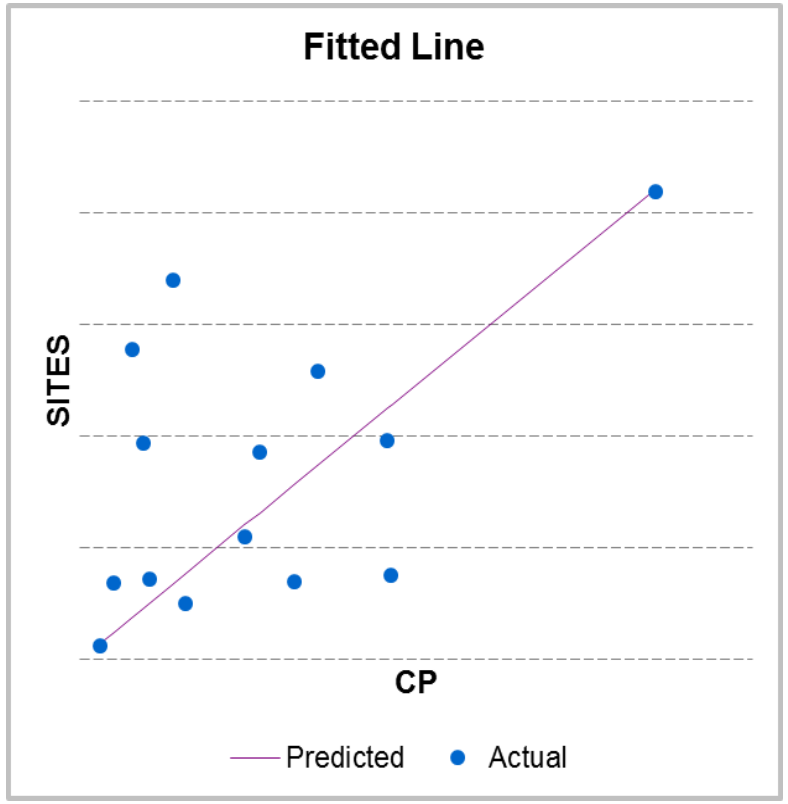


- System Integration & Test
  - Limited data across programs

Sites Integration & Support CER

$$\textbf{Sites I\&S} = 4.92\% * \textit{DCTI}$$

Variable	Coefficient	Std Dev of Coef	T-Statistic (Coef/SD)
CP	0.0492	0.0098	5.0322



Sites Integration & Support comprises

the effort to integrate, install, and test the design system at both training and test site facilities

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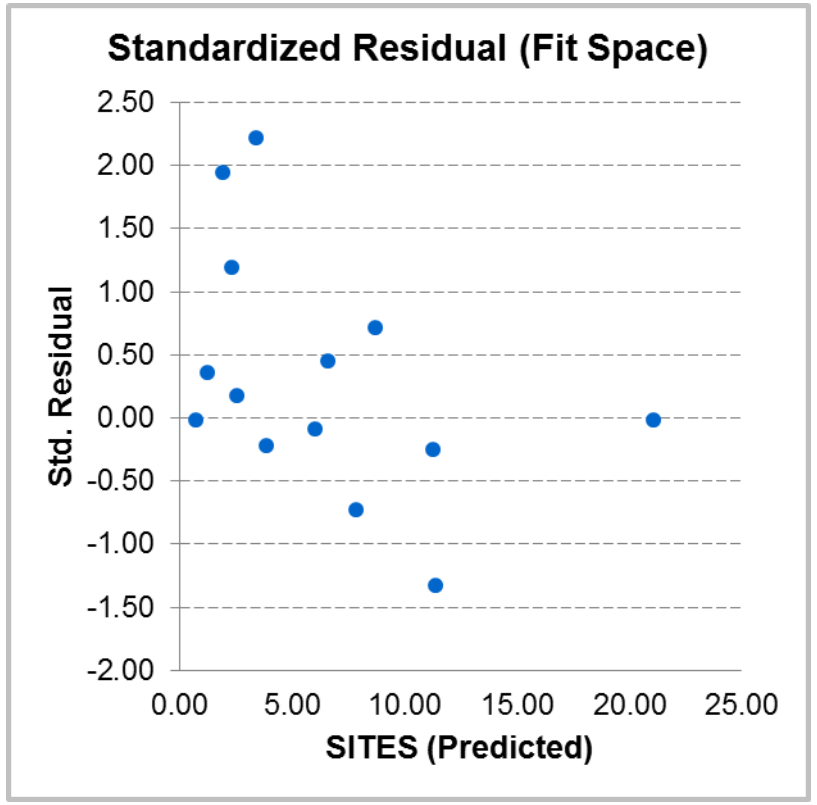
Adj R-Squared = 63.47%

Standard Error = 6.16

CV = 73.95%



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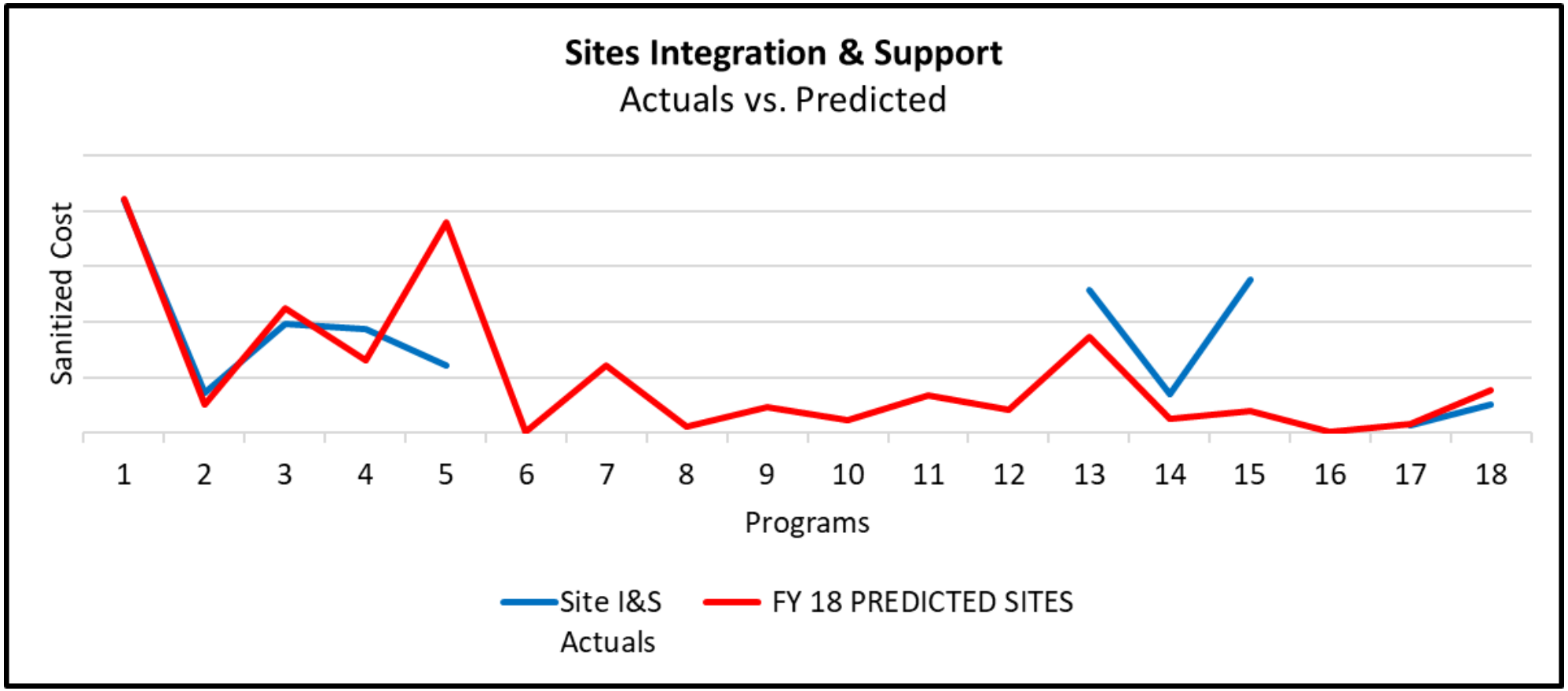
Sites Integration & Support CER Performance



- Sites Integration & Support
  - Limited data across programs
  - Relatively small portion of total cost

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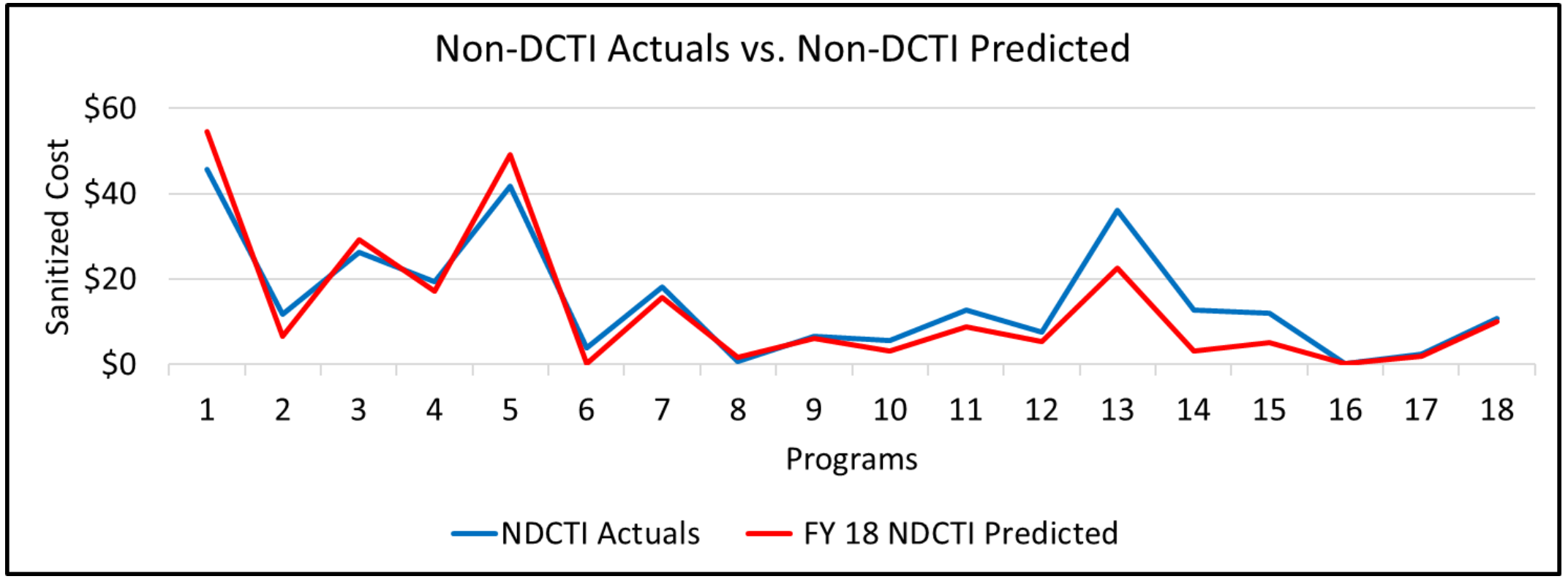
In The Aggregate…



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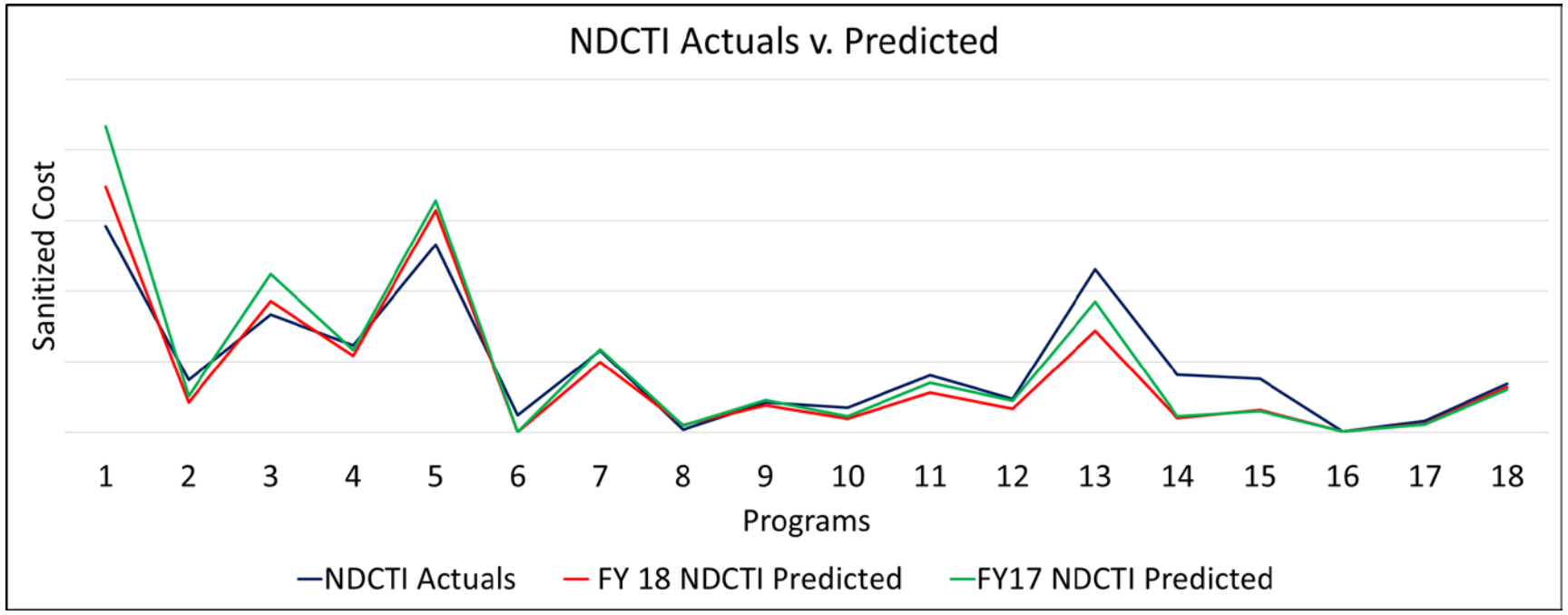
Comparison of 2017/2018 Research Results

CER	2017	2018
PM	PM = 15.31% * DCTI, CV = 5.7%	$\boldsymbol{PM = 15.84\% * DCTI}$, CV = 45.52%
SE / SA	SESA = 36.48% * DCTI, CV = 8.0%	$\boldsymbol{SESA = 33.01\% * DCTI}$, CV = 43.53%
ILS	ILS = 2.85% * DCTI, CV = 62.2%	$\boldsymbol{ILS = 2.39\% * DCTI}$, CV = 47.64%
M&S	M&S = 11.83% DCTI, CV = 59.3%	$\boldsymbol{M\&S = 11.26\% * DCTI}$, CV = 39.6%
SI&T	SIT = 20.91% DCTI, CV = 91.9%	$\boldsymbol{S\,I\&T = 13.90\% * DCTI}$, CV = 64.16%
Sites I&S	Sites I&S = 6.32% DCTI, CV = 19.4%	$\boldsymbol{Sites\ I\&S = 4.92\% * DCTI}$, CV = 73.95%



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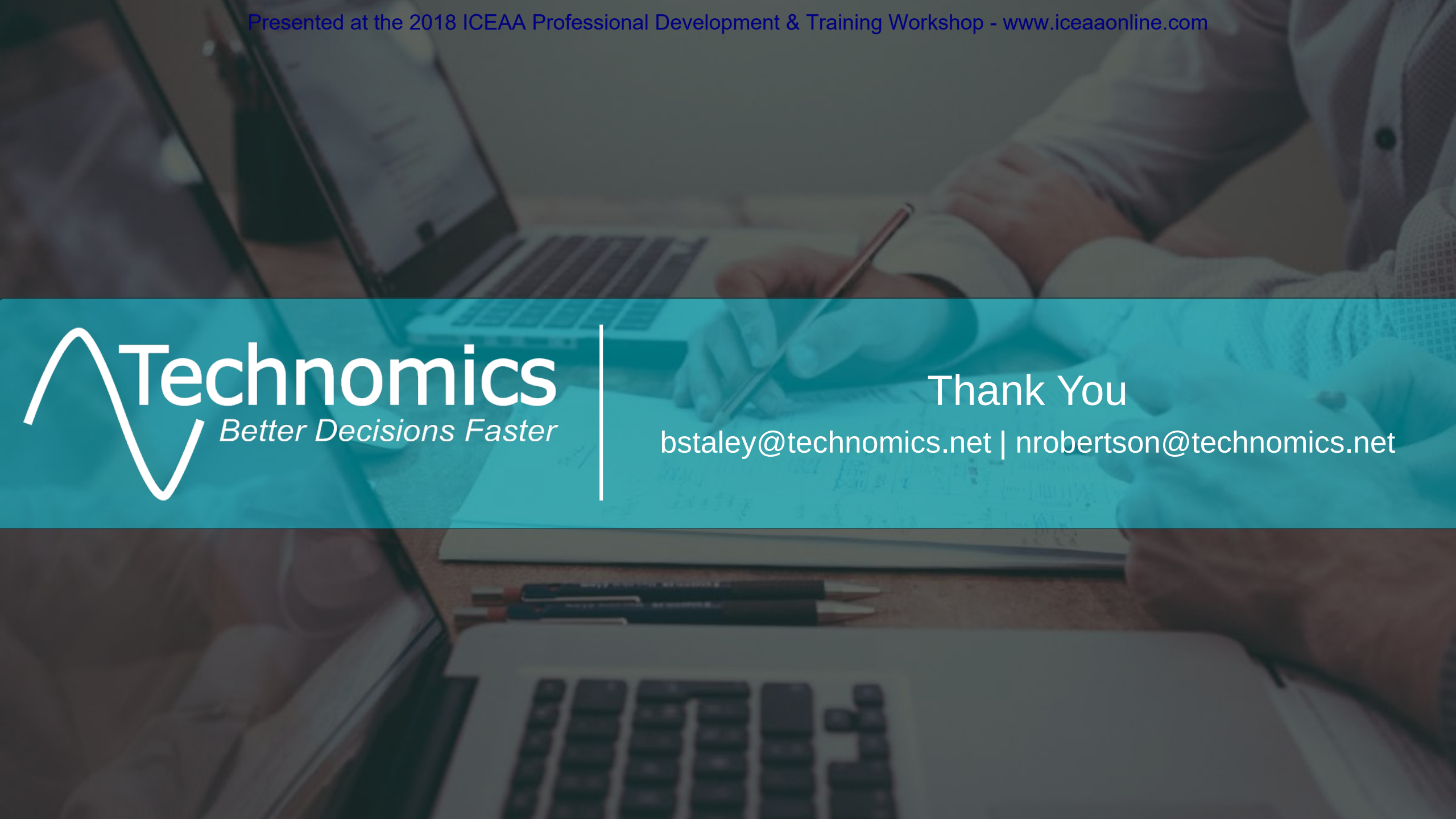
Future Research

Gaps in Dataset – *Investigate the nature of missing data*

Cluster Analysis – Evaluate significance of CERs for programs of varying size/complexity

Capturing DCTI –Productivity & Growth Rate Analysis



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Thank You

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