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NATIONAL RECONNAISSANCE OFFICE

Schedule Execution Metrics (SEM)

A study of integrated master schedule data from the NRO EVM Central Repository for indicators of program stability, execution of the baseline, and early warning of schedule delay in the completion of major milestones

ICEAA May 2022

SUPRA ET ULTRA

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Contents

WHY perform this study
- Examples of SEM in Use
- Naval Post-Graduate School Study Take-Aways

HOW the study was completed
- Approach
- Definitions

RESULTS

Data Visualization Using Study Results

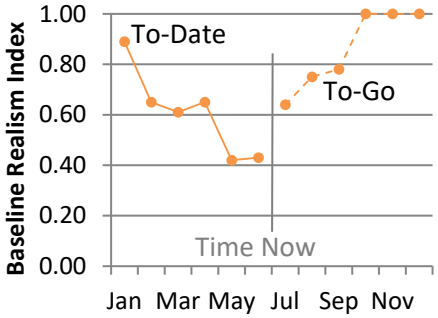
Context for the development of SEM

Situation: program was experiencing performance issues and senior leadership asked contractor and program office to present a one-slide performance summary to support management decision

Contractor assessment of performance:
Meeting schedule targets and performing better than cost targets, forecasting to complete without significant cost variance

Delivery	CUM SPI	CUM CPI	VAC
Total Program	0.99	1.12	
Element	0.96	1.18	
Element	0.98	1.04	
Element	0.99	1.16	

Program Office assessment of performance:
Steep downward trend in schedule execution and upward trend in forecasted finishes indicates a risk to the cost and schedule targets



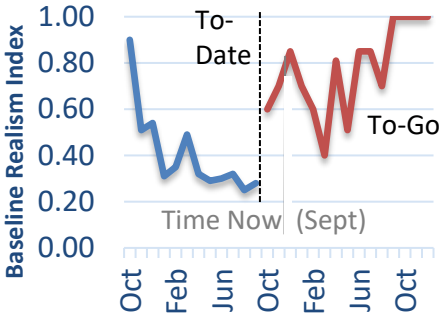
Effective use of Baseline Realism Index for early detection of signs that the contractor was not achieving the baseline plan

Context for the development of SEM

Situation: is an Over-Target Budget or Over-Target Schedule situation coming?

Baseline Realism Index:
Early Warning of schedule problems in December

EVM Metrics:
Early Warning of cost performance in June
Unfavorable indicators of cost performance in September
No indication of schedule delay in the summarized metrics



	CUM SPI	CUM CPI	VAC
October	1	0.99	
November	0.99	0.98	
December	0.99	0.98	
January	0.99	0.99	
February	0.97	0.97	
March	0.98	0.98	
April	0.98	0.96	
May	0.98	0.95	
June	0.96	0.94	
July	0.97	0.93	
August	0.97	0.92	
Time Now → September	0.97	0.87	

Baseline Realism Index provided earlier indications of a problem than the standard Earned Value metrics and analysis

Schedule Execution Metrics Timeline

NRO created Baseline Realism Index and branded SEM

Special Interest Analysis

2016-2017 Iterative process to develop Schedule Execution Metrics that can be used to analyze key program in turmoil: We developed objective indicators to determine how the program is performing against the plan after a re-set, and signs of stabilization versus continued turmoil.

Senior Scheduler and tool developer, Ed Knox

Standardization and Tool Deployment

2018-2019 Schedule Execution Metrics defined at NRO and tools developed to ensure consistency

Research and Benchmark

2019 Pilot Study, Preliminary SEM Thresholds

2021 Naval Post graduate School Capstone Project

This study identifies characteristics of the 6-12 months leading up to significant schedule growth or major milestone impact

Senior NRO leadership is seeking data driven metrics predictive of future performance

SEM Use and Opportunities

- Schedule Execution Metrics are a breakthrough in schedule analysis at NRO
  - Shift the focus from schedule health to schedule execution
  - Provide objective measures to program managers for schedule performance trends and realistic schedule forecasts
  - Provide data-driven answer to DNRO Question request for data driven early warning of cost and schedule issues

- SEM Use
  - Independent Schedule Assessment
  - Program Management Business Rhythm
  - Custom Directorate and Office Program Dashboards

- SEM Opportunities
  - Based on program data in the EVM Central Repository, how can SEM be interpreted to provide early warning or schedule growth, giving leadership an opportunity to make decisions?

Metric Definitions (1 of 3)

Metric	Definition	Analytic Value	Range
Workoff 6-month moving average	Percentage of total completions in any period that are more than 30 calendar days late. This is an indicator of how much time is being spent each period getting caught up	How much of the work being done is "catch-up"?	Lower is better Theoretical Bounds: 0.00 to 1.00 Dataset: 0.00 to 0.94
Workoff Trend	Linear trend representing 6-month increment of Workoff	Is the program catching up or falling further behind?	Negative is better Dataset: -0.63 to 0.24
BRI 6-month moving average	Baseline Realism Index Percentage of planned events that actually finished in the planning period. This is an indicator of how well the contractor is following the plan in the period	Is the contractor executing the plan?	Higher is better Theoretical Bounds: 0.00 to 1.00 Dataset 0.00 to 1.00
BRI Trend	Linear trend representing 6-month increment of BRI	Is performance falling off of the plan, or getting back on plan?	Positive is better Dataset: -0.24 to 0.42
BRI cum	Cumulative Baseline Realism Index Percentage of planned events that actually finished since the beginning of the program. This is an indicator of how well the contractor is following the plan.	Cumulatively, is the program on plan?	Higher is better Dataset: 0.34 to 1.00
BPI 6-month moving average	Baseline Progress Index Percentage of planned events that actually finished in or before the planning period. This is an indicator of how many of the planned events in the period have actually be accomplished	Is the contractor keeping up with planned work?	Higher is better Theoretical Bounds: 0.00 to 1.00 Dataset: 0.00 – 1.00
BPI Trend	Linear trend representing 6-month increment of BPI	Is the program falling behind or catching up?	Positive is better Dataset: -0.20 to 0.47
FRI 6-month moving average	Forecast Realism Index Percentage of forecasted events that actually finished in the forecast period. This is an indicator of how well the contractor is accomplishing the forecast for the period.	Can the contractor achieve last month's forecasted finishes?	Higher is better Theoretical Bounds: 0.00 to 1.00 Dataset: 0.21 to 0.96
FRI Trend	Linear trend representing 6-month increment	Is forecast execution getting better or worse?	Positive is better Dataset: -0.18 to 0.20

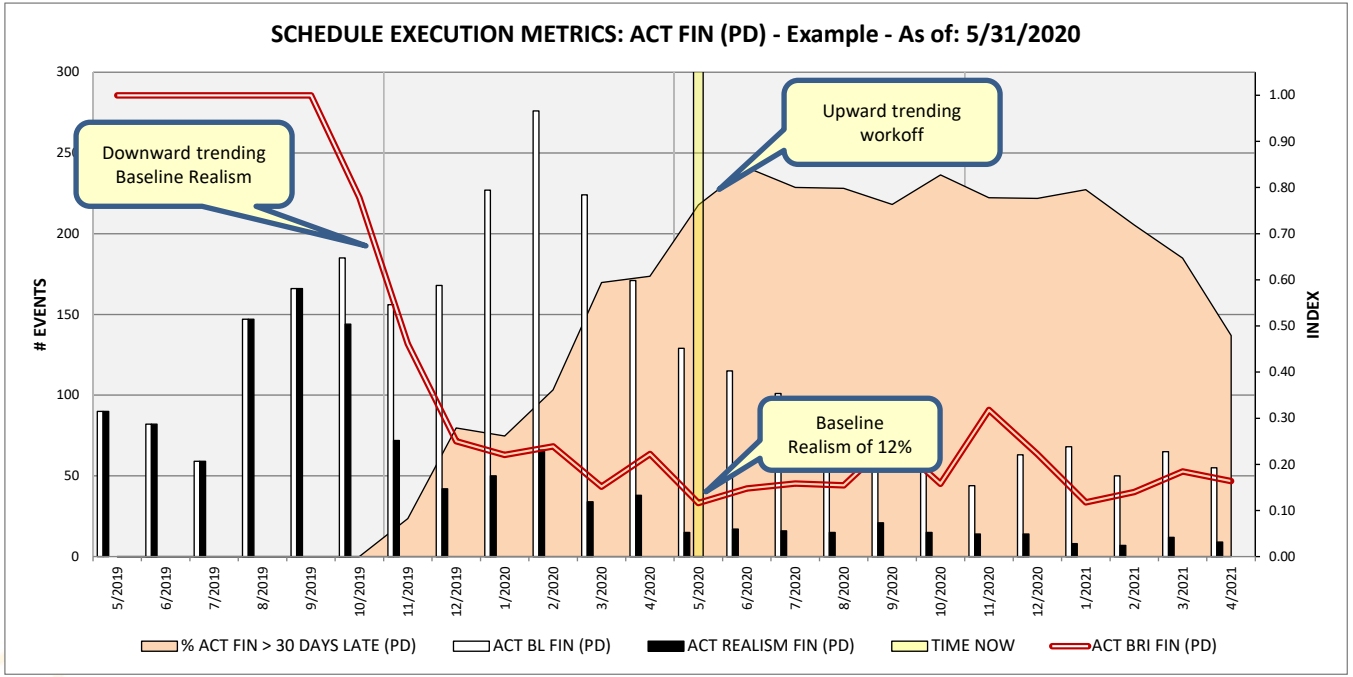
Metric Definitions (2 of 3)

Metric	Definition	Analytic Value	Range
BEI cum	Cumulative Baseline Execution Index Percentage of total events that actually finished in the planning period. This is an indicator of the contractor's pace of work	Pace of work to date	Higher is better <1.0 indicates falling behind =1.0 indicates on plan >1.0 indicates catch-up Dataset: 0.66 to 46.41
TC-BEI	To-Complete Baseline Execution Index Number of all Remaining finishes divided by number of remaining baseline finishes	Provides insight into how many more activities are left versus what was planned Can identify compression of significant activity in the remaining time	Above 1.00 indicates potential performance risk <1.0 indicates fewer than planned =1.0 indicates on plan >1.0 indicates more than planned Dataset: 0.00 to 2.02
Delta (BEI vs TC-BEI)	Change in efficiency needed to achieve the forecast	Assess whether the forecast is realistic based on pace of work to date	> 0.00 indicates potential performance risk > 0 indicates more efficiency in future than in past (potentially unachievable forecast) Dataset: -1.35 to 46.25

Metric Definitions (3 of 3)

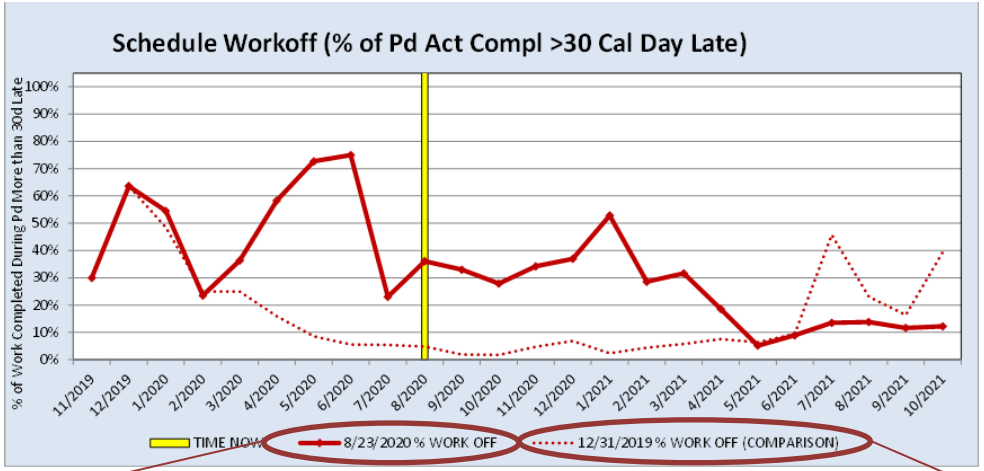
Metric	Definition	Analytic Value	Range
CPI (6-month increment)	Cost Performance Index: $\frac{\text{Budgeted Cost of Work Performed}}{\text{Actual Cost of Work Performed}}$	Work accomplished for every dollar spent	Higher is better Dataset: 0.79 to 1.09
SPI (6-month increment)	Schedule Performance Index: $\frac{\text{Budgeted cost of Work Performed}}{\text{Budgeted Cost of Work Scheduled}}$	Amount of work accomplished relative to the plan	Higher is better Dataset: 0.78 to 1.11
MR/ETC (last month of increment)	Management Reserve divided by Estimate to Complete	On-contract resources to accomplish unplanned in scope tasks	Dataset: 0% to 32%
VAC% (last month of increment)	Variance at Complete divided by Budget at Complete	Magnitude of overrun or underrun	<0 indicates unfavorable variance Dataset: -30% to 11%
VAC% Trend	Linear trend representing 6-month increment	Whether the forecast is improving or worsening	Negative means getting worse Dataset: -0.08 to 0.05
TCPI	To-Complete Performance Index: $\frac{\text{Budget at Complete} - \text{Budgeted Cost of Work Performed}}{\text{Estimate at Complete} - \text{Actual Cost of Work Performed}}$	Cost efficiency required to achieve the EAC	Above 1.00 indicates potential performance risk < CPI, contractor expects productivity to worsen = CPI, forecast consistent with past performance > CPI, contractor expects productivity to improve Dataset: 0.74 to 2.45

SEM Example: *objective, performance driven independent schedule assessment*



SEM quantified schedule performance and supported an acquisition decision

SEM Example: Schedule Workoff Forecast *supporting Program Management*



The solid line shows the % of tasks forecast to be more than 30 days late, as of the 8/31/2020 IMS

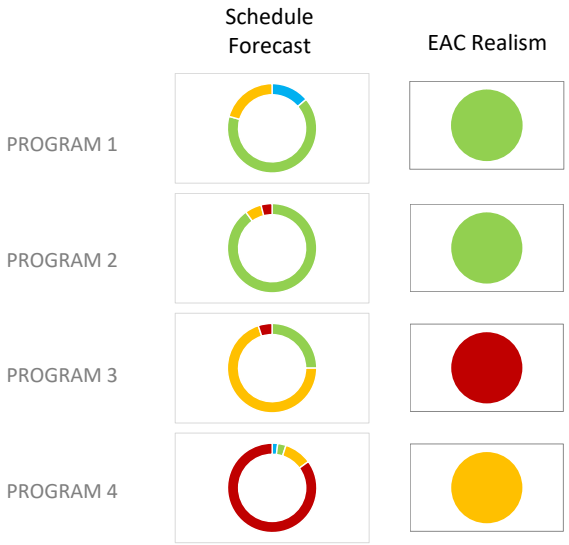
The dotted line shows the % of tasks forecast to be more than 30 days late, as of the 2/31/2019

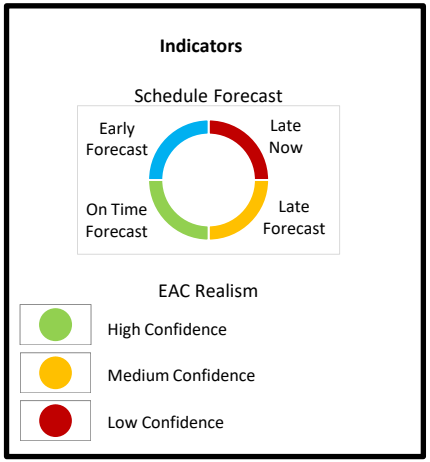
Interpretation and Next Steps: Are there resources available to complete the months already planned tasks plus the % of tasks from previous months. Is there a plan to catch up? Has the ETC been updated to reflect tasks finishing later?

(U) Additional analysis can identify tasks that keep slipping, float of late activities, and margin to recover schedule

SEM provides change visualization and focuses attention on risk areas

SEM Example: *portfolio analysis dashboard*



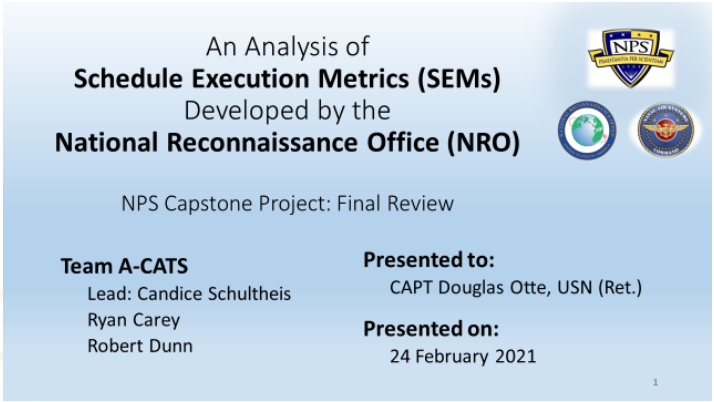


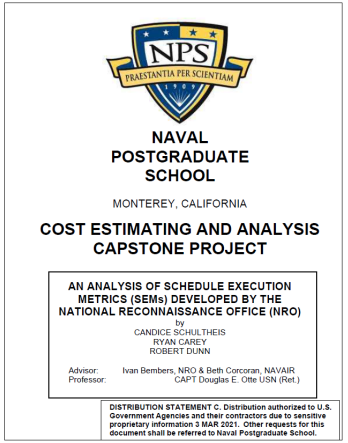
SEM enhances collaboration between program control and budget functions providing data-driven input to the discussion of realistic EACs

Academic Year 2020-21, NRO sponsored a study at Naval Post-Graduate School

- To address an NRO senior leadership perception that IPM Analysis relied on anecdotal trends and professional judgement rather than data driven methods, we initiated a collaboration to explore data science methods and statistics for predictive analysis
- The Naval Post-Graduate School Capstone Project Study was supervised by Karen Mislick, sponsored by Ivan Bembers, NRO and Beth Corcoran, John Scaparro and Bruce Koontz, NAVAIR using NRO Methods with NAVAIR unclassified dataset

Study Results: Final Briefing and Report





HOW Was this SEM Study Performed

- Metric Definitions
- Increment Assessment
- Analysis Approach
- Calculating 6-month increment and Trend metrics

The study segment programs into 6-month increments

Current Period (monthly) metrics

- Fluctuation from one month to the next due to status date cut-off
- Too sporadic to be meaningful
- 1-period “snapshots” do not provide insight into trends

6-month Increment Metrics

- Smooths out the monthly metrics into trends
- Meaningful increment to objectively assess whether there was a milestone slip or schedule reset
- Relevant increment for applying to analysis

Program Metrics

- Hard to develop meaningful summary SEM for 5-10 year programs. Cumulative metrics at the end of a program mask the problems and recovery during execution
- NPS Finding: the program assessment of favorable or unfavorable, after a decade-long program, is not evident in the early data, making it hard to train the model.

6-month increments are predictive of schedule execution in the coming 6-12 months

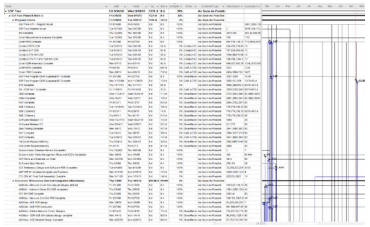
Assessment for each 6-month Increment: *separating the current period noise from trends observable in 6-month segments*

Definition of "RED", "YELLOW", "GREEN" for 6-month increments
RED: Significant schedule growth (>6 months schedule delay in major milestone) or major milestone impacts (schedule restructure or replan) Note: a RED increment could have very favorable metrics due to a schedule baseline reset or very unfavorable metrics due to periods the program is not executing the old plan while finalizing the new plan
YELLOW: Approaching Red in 6 months or 12 months Note: YELLOW increments are the focus of this study: early warning of the schedule growth or milestone impact
GREEN: Changes to forecast date of major milestones ≤ 6 months

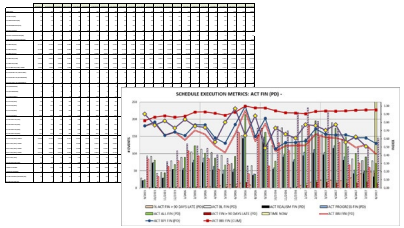
Each program has multiple increment assessments

Analysis Approach

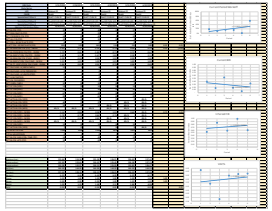
Contractor IMS



SEM



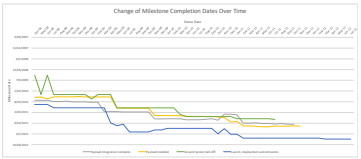
6-month moving average, trends



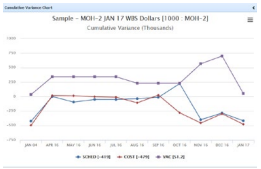
CALCULATE METRICS FROM INTEGRATED MASTER SCHEDULE

ANALYZE PERFORMANCE TO ASSESS 6-MONTH INCREMENTS

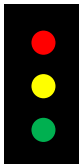
Milestone Performance



EVM Performance



6-Month Increment Assessment



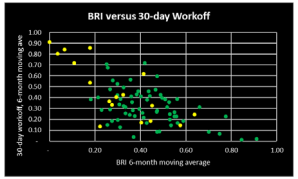
Significant schedule growth

Issue Emerging

No Issue

Connect schedule metrics and trends with milestone and EVM performance to develop thresholds that predict significant schedule growth

Analysis

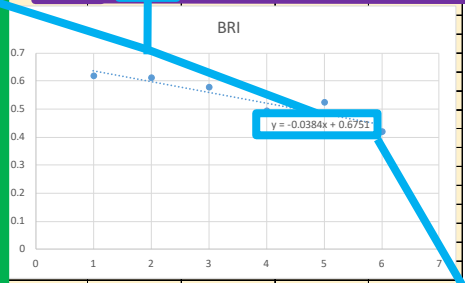


Using SEM Tool Output to develop metrics for the study
Example Calculations, 6-month Baseline Realism Index moving average and trend

Paste 6 months of monthly metrics from SEM Tool

IMS Date	3/31/2017	4/30/2017	5/31/2017	6/30/2017	7/31/2017	8/31/2017
ACT BL FIN (PD)	157	190	140	85	80	79
ACT REALISM FIN (PD)	97	116	81	42	42	33
ACT PROGRESS FIN (PD)	103	123	91	52	49	43
ACT ALL FIN (PD)	161	174	147	100	90	71
ACT FIN > 30 DAYS LATE (PD)	17	15	14	15	18	14
% ACT FIN > 30 DAYS LATE (PD)	11%	9%	10%	15%	20%	20%
ACT BL REALISM FIN (PD) - INDEX	0.618	0.611	0.579	0.494	0.525	0.41
ACT BL PROGRESS FIN (PD) - INDEX	0.656	0.647	0.65	0.612	0.613	0.544
ACT BL EXECUTION FIN (PD) - INDEX	1.025	0.916	1.05	1.176	1.125	0.899
ACT BL REALISM FIN (CUM) - INDEX	0.94	0.937	0.942	0.948	0.953	0.953
ACT BL EXECUTION FIN (CUM) - INDEX	0.944	0.942	0.948	0.956	0.961	0.959
ACT BL TC-EXECUTION FIN (CUM) - INDEX	1.082	1.106	1.113	1.108	1.107	1.125
ACT DUR VAR >5 (100% CMPL)	40	33	31	24	35	25
ACT DUR VAR >5 (IN PROGRESS)	0	0	0	0	0	6
ACT DUR VAR >5 (UNSTARTED)	0	0	0	0	0	0
ACT (UNSTARTED)	0	0	0	0	0	0
ACT (IN PROGRESS)	0	0	0	0	0	12
ACT (100% CMPL)	161	174	147	100	90	59
ACT FC FIN (1PD)	220	172	120	115	118	145
ACT FC FIN (2PD)	369	286	238	224	256	252
ACT FC FIN (3PD)	482	394	321	337	346	369
ACT FC FIN (6PD)	725	631	548	557	617	614
ACT ACTUAL FIN (1PD)	155	133	67	72	60	#N/A
ACT ACTUAL FIN (2PD)	293	211	152	133	#N/A	#N/A
ACT ACTUAL FIN (3PD)	376	295	212	#N/A	#N/A	#N/A
ACT ACTUAL FIN (6PD)	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
ACT FC FIN (1PD) - INDEX	0.705	0.773	0.558	0.626	0.508	#N/A
ACT FC FIN (2PD) - INDEX	0.794	0.738	0.639	0.594	#N/A	#N/A
ACT FC FIN (3PD) - INDEX	0.78	0.749	0.66	#N/A	#N/A	#N/A
ACT FC FIN (6PD) - INDEX	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
ACT FC FIN (1PD)	220	172	120	115	118	145
ACT ACTUAL FIN (1PD)	155	133	67	72	60	#N/A
TOTAL ACTIVITIES	2055	2229	2376	2476	2566	2637
TOTAL MILESTONES	0	0	0	0	0	0
ACT BL FIN EARLY/ON-TIME (PD)	103	123	91	52	49	43
ACT BL FIN LATE (PD)	58	51	56	48	41	28

6-month Moving Ave	Trend
0.56	-0.034



BRI 6-Month Moving Average:

$$\frac{\text{SUM(ACT REALISM FIN (PD)}}{\text{Sum(ACT BL FIN (PD)}} = \frac{411}{731} = 0.56$$

BRI Trend
Plot Monthly ACT BL REALISM FIN (PD) Index

Plot a Trendline

Capture the slope of the trendline

= -0.0348

ACT: Activity
BL: Baseline
BRI: Baseline Realism Index
CWBS: Contract Work Breakdown Structure
FC: Forecast
FRI: Forecast Realism Index
FIN: Finish
PD: Period
UID: Unique Identifier
IMS: Integrated Master Schedule

RESULTS

SEM Thresholds Card

Performance Indicator	Condition	Metric	Threshold	Indicator
	On Plan	6-month moving average Baseline Realism Index (BRI) AND 6-month moving average 30-day workoff	≥ 0.65 AND <0.32	Favorable
	Smooth Sailing	6-month moving average Forecast Realism Index (FRI)	≥ 0.67	Favorable
	Monitor Closely	6-month moving average BRI	≤ 0.65	Consuming cost and schedule margin
		6-month moving average BRI (little to no cost or schedule margin)	≤ 0.45	Unfavorable
		6-month moving average BRI (cost and schedule margin available)	≤ 0.20	Unfavorable
		To Complete Baseline Execution Index (TC-BEI)	> 1.10	Optimistic Forecast
	Behind and trending worse	6-month BRI Trend AND 6-month moving average BRI	≤ -0.05 AND <0.80	Unfavorable
	Way off plan	6-month moving average BRI OR 6-month moving average Baseline Progress Index	≤ 0.20 OR ≤ 0.35	Unfavorable
	Overwhelmed by late tasks	6-month moving average 30-day workoff	≥ 0.80	Unfavorable
	Forecast does not reflect past performance	Delta (Baseline Execution Index (BEI) minus TC-BEI)	< -0.05	Unfavorable

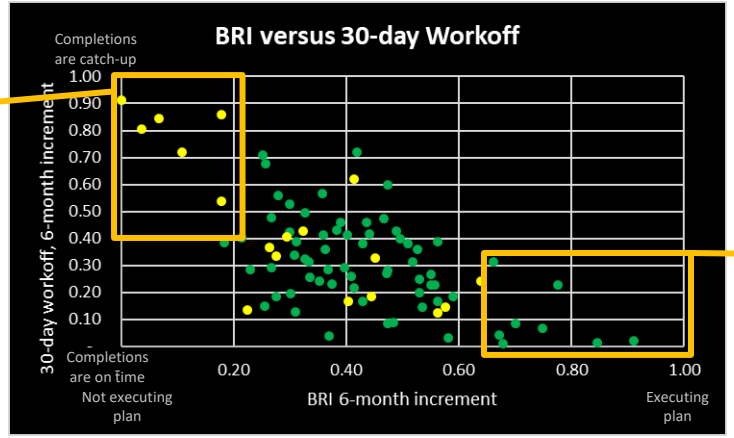
Metric: defined quantifiable performance measure used to track, monitor and assess schedule execution
Threshold: metric value cutoffs established to determine relative performance, used to understand the meaning of a metric
Indicator: interpretation of the metric based on performance against thresholds

Favorable: not likely to experience major milestone delay or program restructure in next 6-12 months
Unfavorable: likely to experience major milestone delay or program restructure in next 6-12 months

Baseline Realism Index versus Workoff

Way Off Plan
Low BRI and High Workoff

Poor schedule performance and spending time on late work



On Plan
High BRI and Low Workoff

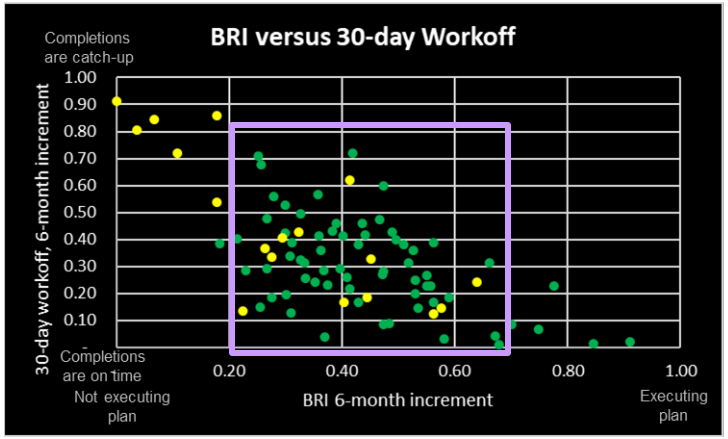
Favorable schedule performance and less time spent on late work

On Plan: BRI > 0.65 and Workoff < 0.32 indicates schedule execution in the next 6-12 months
Way Off Plan: BRI < 0.20 and Workoff >0.40 indicates likely schedule growth or milestone impact in the next 6-12 months

Baseline Realism Index versus Workoff

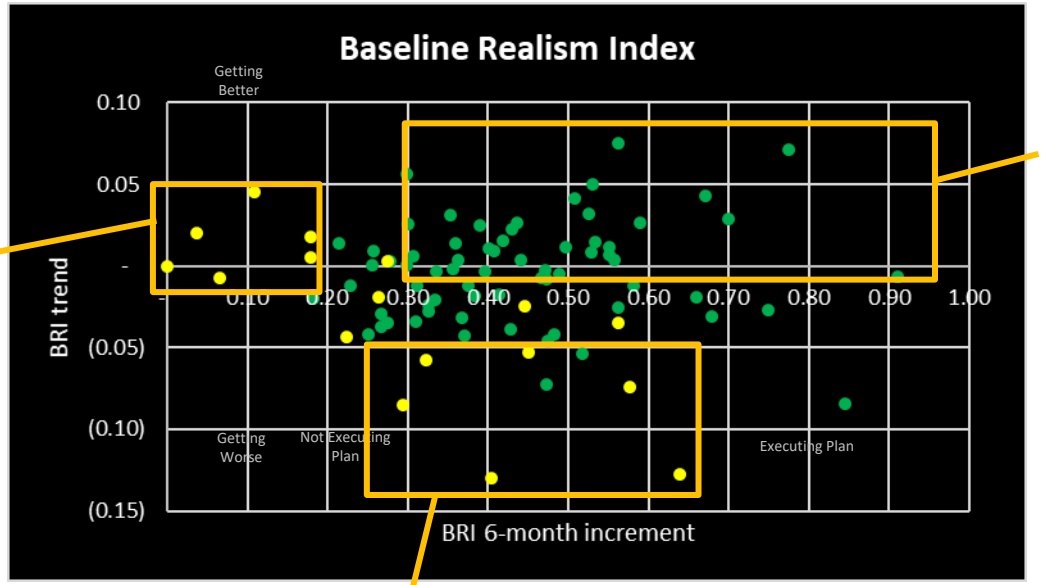
Consuming Cost and Schedule Margin
BRI > 0.20 and BRI < 0.65
Workoff < 0.70

- GREENs are primarily Major System Acquisitions, which have cost and or schedule margin to recover from deviations from the plan
- YELLOWs are primarily smaller programs, lower cost and schedule margin
- Major subcontracts, while not part of the dataset, share similar characteristics with the YELLOWs, with lower levels of cost and schedule margin



For programs without significant cost and schedule resources to absorb delay, BRI at or below 0.45 indicates high likelihood of significant schedule growth or major milestone impact in the next 6-12 months

Baseline Realism Index



Way Off Plan
Programs with Baseline Realism Index < 0.20

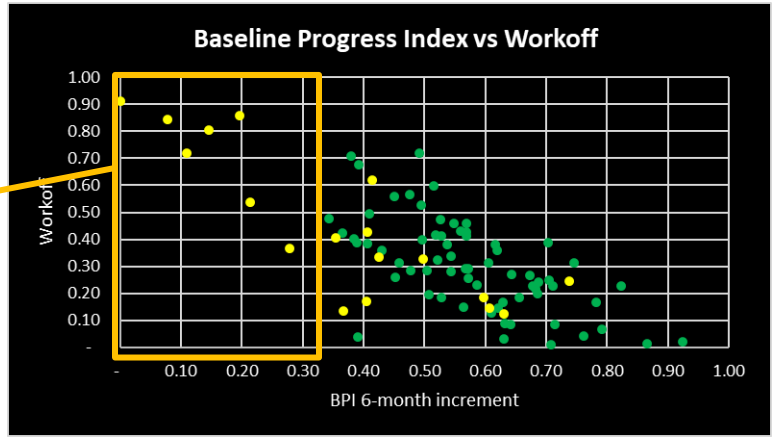
Getting By
Programs with Baseline Realism Index >0.30, and without a steep worsening trend

Behind and Trending Worse
Programs with steep worsening trend in Baseline Realism Index

BRI at or below 0.20 or steeply downward trending BRI indicates significant schedule growth or major milestone impact in the next 6-12 months

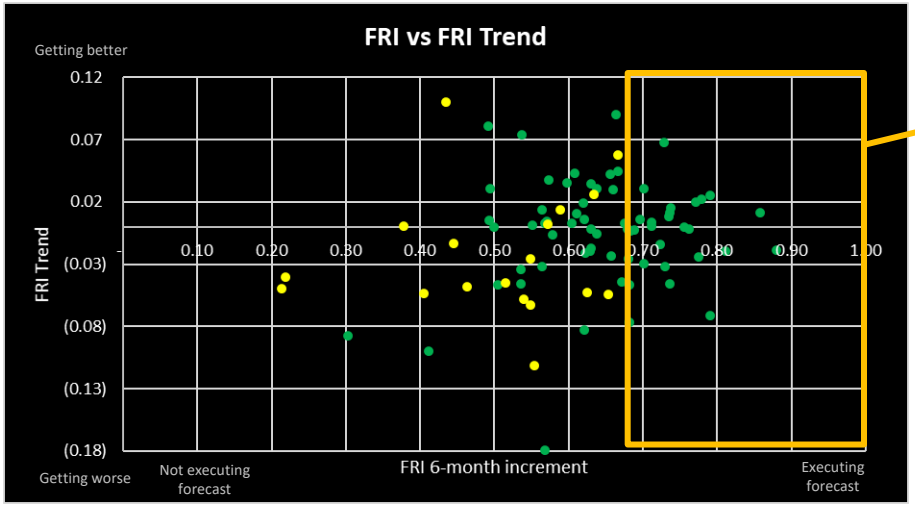
Baseline Progress Index

Way Off Plan
Programs with Baseline Progress Index < 0.35



BPI < 0.35 is an unfavorable indicator

Forecast Realism Index



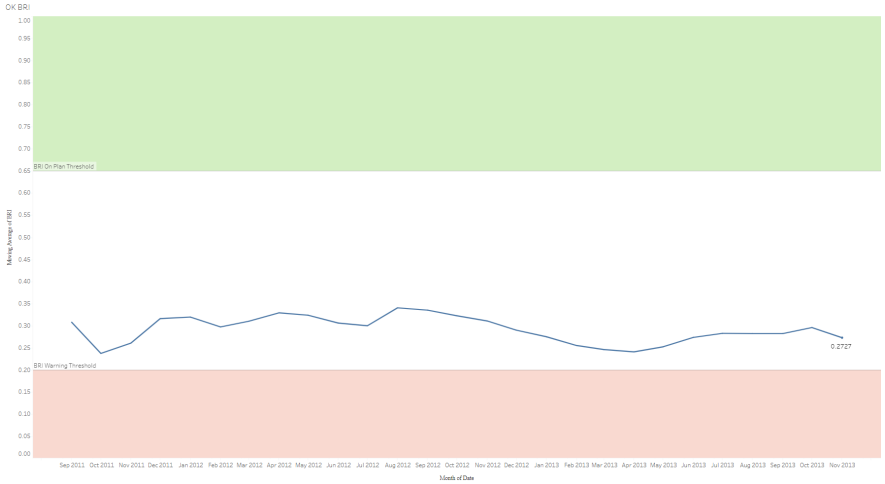
Smooth Sailing
Forecast Realism Index > 0.67

FRI > 0.67 is a strong indicator of favorable schedule execution in the coming 6-12 months

DATA VISUALIZATION EXAMPLES

Example Analysis: Baseline Realism Index

Example On-Time Program

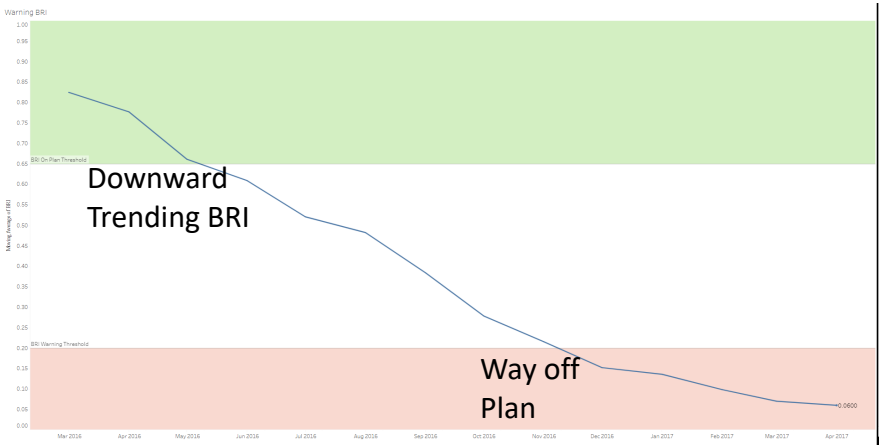


Non-predictive BRI

Neither above the "On Plan" threshold nor below the "Way Off Plan" threshold

The contractor has the opportunity to recover schedule variance prior to major milestone slip

Example Late-Milestone Program



Warning BRI

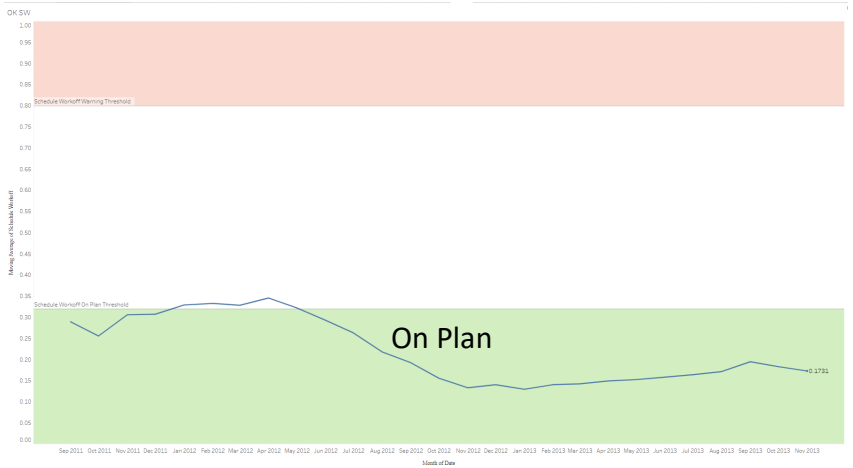
Downward trending, and below "Way Off Plan" threshold

Indicating that the contractor is increasing off plan

Historic schedule performance indicates milestone slip or replan imminent

Schedule Workoff Burden

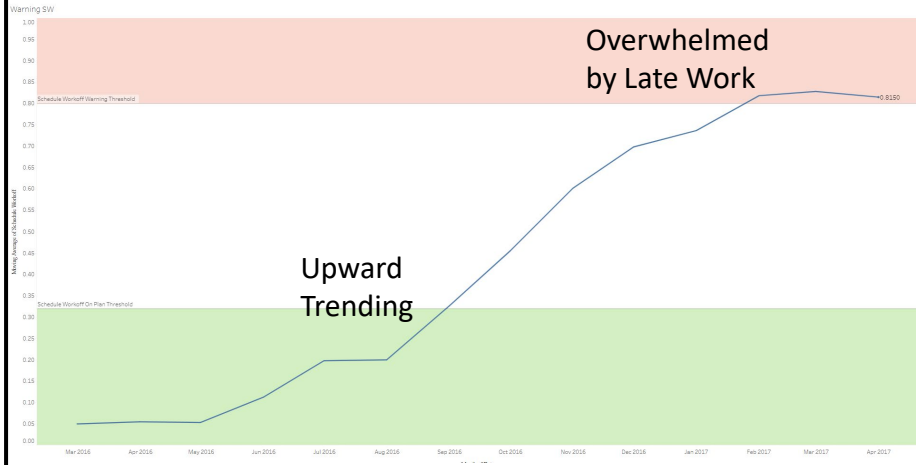
Example On-Time Program



Schedule workoff burden below the "On Plan" threshold

Indicates the level of workoff is sustainable and will not cause a major milestone slip

Example Late-Milestone Program



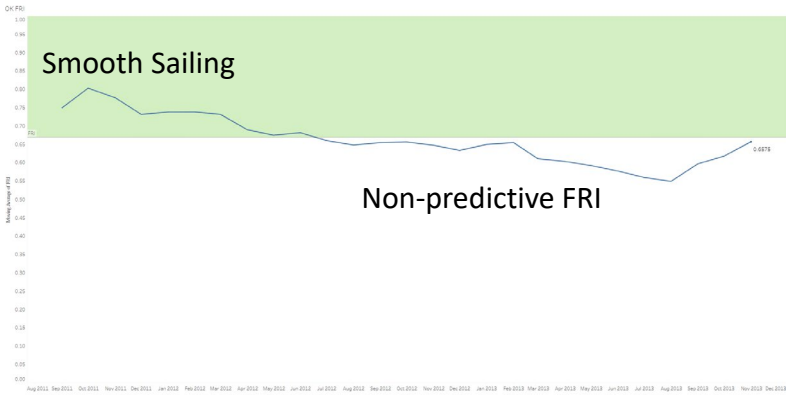
Upward trending workoff burden above "Overwhelmed by Late Tasks" threshold

Historic schedule performance indicates milestone slip or replan is likely in next 6-12 months

Forecast Realism Index

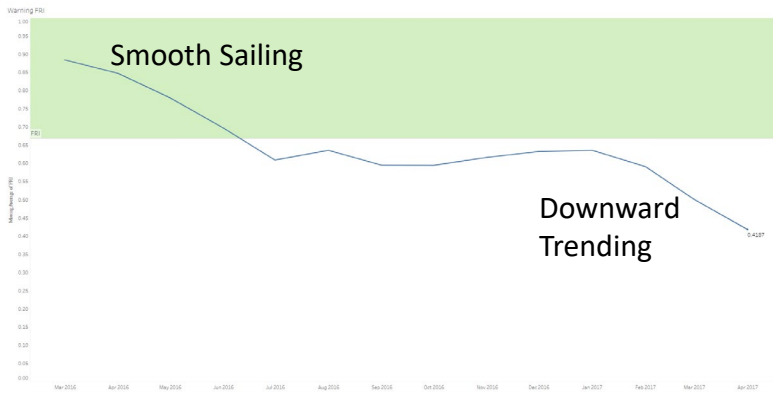
Both programs experience "Smooth Sailing" when FRI > 0.67, no milestone slip is likely in the next 6-12 months

Example On-Time Program



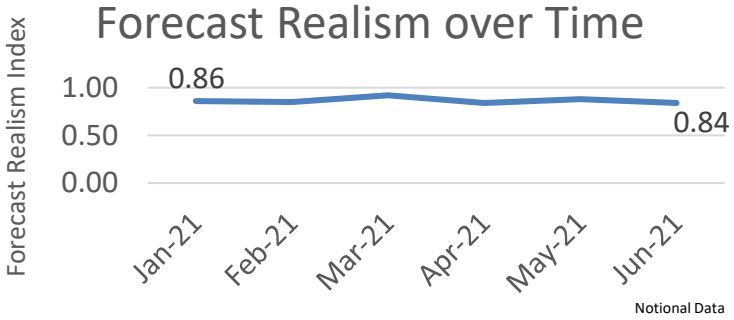
Non-predictive FRI
Not in the Smooth Sailing Range; there is no unfavorable threshold for this metric

Example Late-Milestone Program



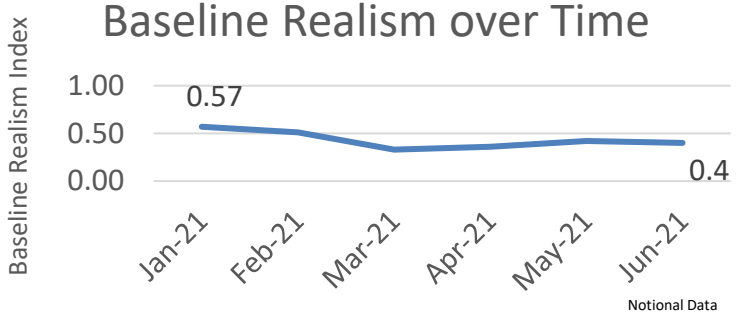
Non-Predictive FRI
Although there is no unfavorable threshold for this metric, it is trending unfavorably and may be an early warning

Examples of data-driven SEM statements



"Smooth Sailing"

The 6-month moving average FRI of 0.87 indicates the program is executing the schedule and not likely to experience major milestone slip in the next 6-12 months.



"Off Plan without resources to recover"

The 6-month moving average BRI of 0.43 indicates the program is deviating from the baseline plan. Decisions about program future need to be made in the coming 6-12 months if the program does not have cost and schedule margin to absorb significant delay.

How do we apply this going forward?

- Strengthens program office schedule analysis, independent schedule assessments and portfolio dashboards by providing reference points
- Applicable Space Programs (hardware, software), because programs in the data set includes a robust sample size across directorates and offices
- Early warning of schedule growth gives leaders time for course correction; window of time for decisions such as increasing cost to maintain schedule or performing a replan
- Can be calculated on the entire IMS, or a filtered portion focusing on a payload, increment, or capability
- Enables data driven methods to determine required course corrections to avoid a point of no return, or confirms that the contractor has “turned the corner” after experiencing issues and is executing the plan

What do we get out of the study? Enables new data driven methods for early warning of schedule performance problems to avoid late discovery and risk of program failure