



NAVAIR Systems Engineering Development & Implementation Center (SEDIC)

Applied Leading Indicator (ALI) Initiative

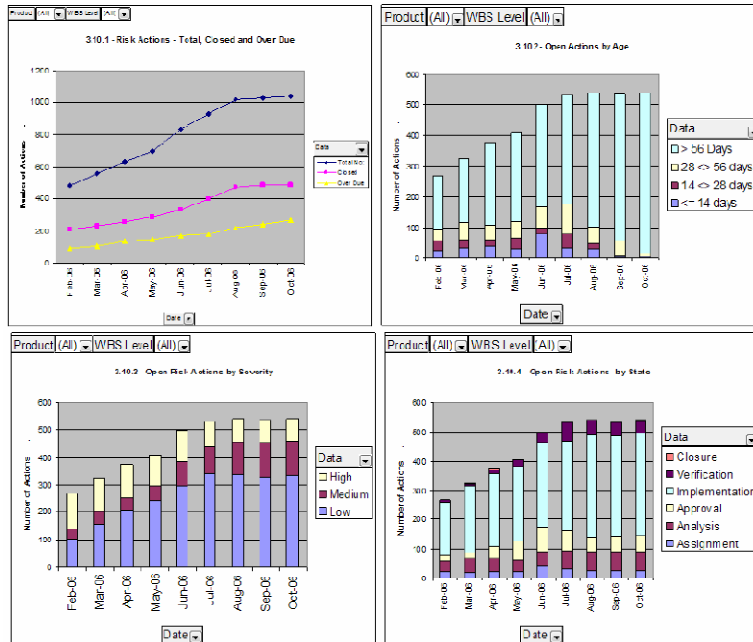
Greg Hein (Booz Allen Hamilton)

24 June 2009

Applied Leading Indicator (ALI) Goal

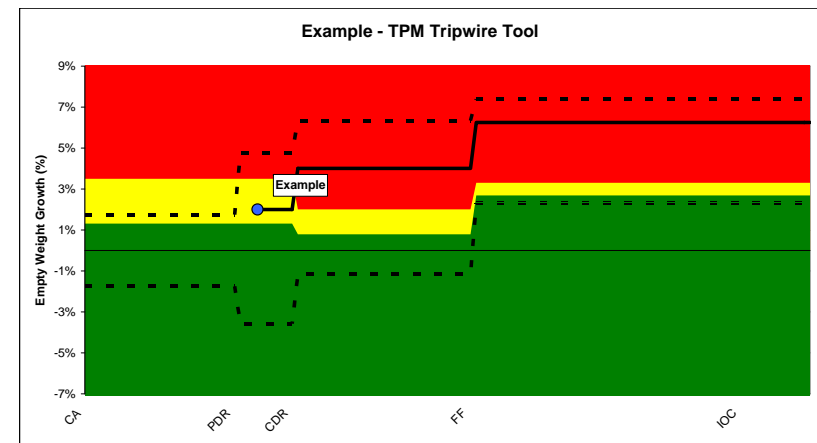


“Traditional” Leading Indicators



A set of metrics using trends to date (from a single program) along with subjective SME experience to provide a qualitative forecast of technical metric health

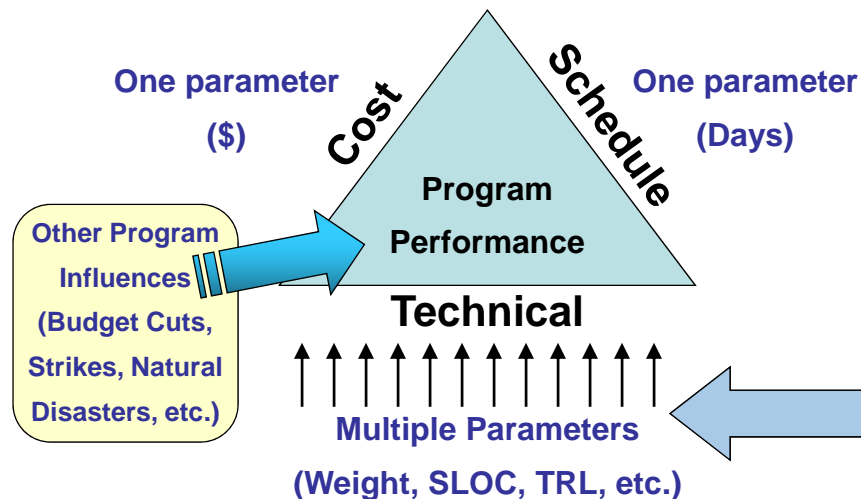
SEDIC Applied Leading Indicators



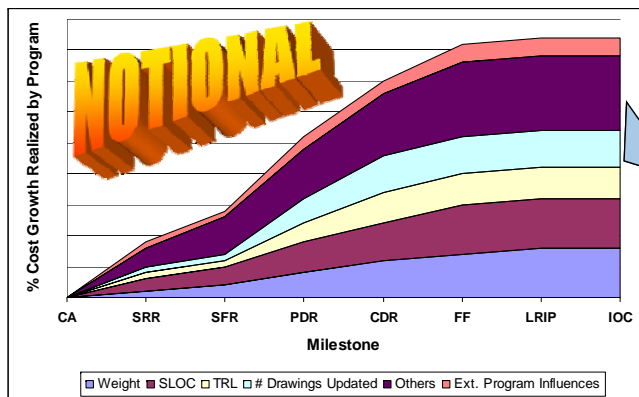
A tool using complete historical trends (from numerous programs across the organization) to provide a quantitative forecast of technical metric health applied to overall program performance

Applied Leading Indicators provide a quantitative, prognostic evaluation of the “goodness” of each technical metric as it relates to overall Program Performance

Applied Leading Indicator (ALI) Overarching Vision



- Each Applied Leading Indicator will relate ONE technical metric to a measure of overall program performance
- Each ALI will only explain a portion of the total impact to overall Program Performance; using multiple Leading Indicators together will explain progressively more of the total impact
- ALIs will NEVER explain 100% of the total impact to Program Performance (due to the “Other Program Influences” that cannot be modeled)
- Additional ALIs will be pursued based on technical metrics which account for the highest levels of change in overall Program Performance
- ALIs will be combined in a single tool to provide a suite of ALIs that APMSEs and PMs can use prognostically to help make informed decisions regarding program execution

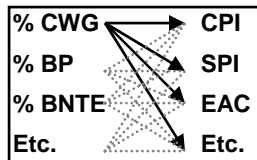


Each ALI addresses one technical metric – Multiple ALIs will be combined to reveal more of the total program performance “picture” and provide a more useful suite of tools

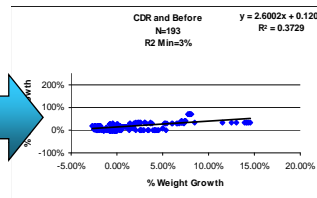
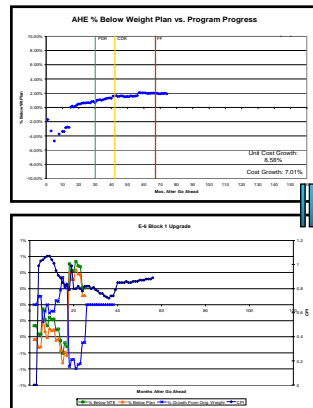
Tool Development Methodology



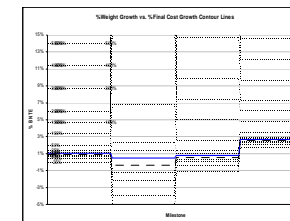
STEP 1: Perform Correlation Test on technical versus program performance parameter "pairs" (i.e. weight vs. cost) to identify strong relationships



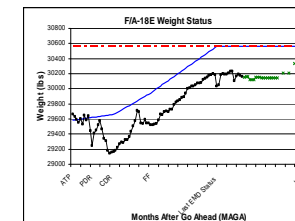
STEP 2: Perform Regression Test on selected pairs for same t values. Then, quantify relationships with mathematical expressions



STEP 3: Use equations derived in STEP 2 to generate program performance parameter contours over time

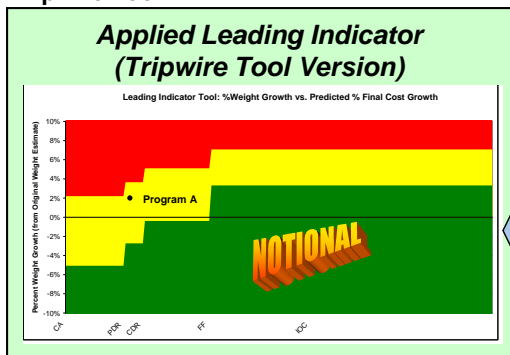


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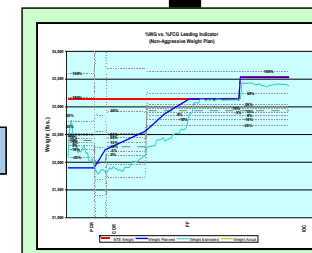
STEP 4: Combine contours from STEP 3 with existing Program technical parameter charts to produce resultant Leading Indicator Charts

STEP 6: Incorporate valid models into overarching Tripwire Tool



STEP 5: Perform Val. & Ver. On resulting LI Chart/models to confirm adequate level of accuracy and applicability across NAVAIR programs

Data Subset	R-Squared Values		OTHER ISSUES??	OVERALL STATIST. SIGNIF.	UN-SCALED WCG ACCUR.	SENSITIV. ANALYSIS
	PDR	IOC				
+/- 6 Months Abroad Key MS Dates	5.11%	66.87%	N	POOR		
All Data - w/ Y-Intercept = 0	9.88%	66.15%	N	POOR		
All Data - w/ Y-Intercept = 0	8.85%	81.32%	Y	POOR		
Programs w/ HIGH Weight Changes Only	48.57%	99.47%	N	GOOD		
Programs w/ LOW Weight Changes Only	0.01%	26.44%	N	GOOD		
Programs w/ VLO Capability	26.31%	50.73%	Y	POOR		
Programs w/ CTO Capability	46.41%	76.09%	N	GOOD		
Programs w/ Moving NTE	1.19%	50.73%	Y	POOR		
Programs w/ Static NTE	30.92%	76.09%	Y	POOR		
Programs w/ Aggressive Weight Plans	19.64%	43.56%	N	GOOD		
Programs w/ Conservative Weight Plans	3.54%	100.00%	Y	POOR		
Programs w/ Large Budgets	13.63%	94.35%	N	GOOD		
Programs w/ Small Budgets	20.67%	74.74%	N	GOOD		
Different PEOs??						
Different Missions??						



Applied Leading Indicator (Detailed Tool Version)

STEPS 1-6 Completed for Aircraft Status Weight TPM
Now Starting STEP 1 for Software TPMs/Metrics

Modeling V&V Results



- Completed V&V Tests on all models developed
- Unique pass/fail requirements developed for detailed tool and tripwire tool
 - Detailed Tool: 95% C.L., +/- 20% cost growth accuracy (dark green)
 - Tripwire Tool: 90% C.L., +/- 50% cost growth accuracy (light green)

Data Subset	R-Squared Values			OTHER ISSUES? ?	OVERALL STATIST. SIGNIF. TEST	UN-SCALED %CG ACCURACY TEST (+/-)	SENSITIV. ANALYSIS TEST
	CDR	FF	IOC				
ALL DATA	24.53%	39.09%	62.60%	N	GOOD	44.6%	GOOD
Aggressive Weight Plan	20.58%	37.93%	13.37%	N	GOOD	56.2%	N/A
Non-Aggressive Weight Plan	25.83%	55.05%	65.81%	N	GOOD	28.8%	GOOD
Static NTE Weight Limit	7.61%	46.76%	66.78%	N	GOOD	33.0%	GOOD
Dynamic NTE Weight Limit	32.50%	83.17%	98.93%	Y	POOR	26.1%	N/A
High Dollar	34.82%	46.87%	63.53%	Y	POOR	42.9%	N/A
Low Dollar	0.40%	41.68%	60.52%	Y	POOR	27.6%	N/A
VTOL	43.24%	44.16%	62.32%	Y	POOR	42.4%	N/A
CTOL	12.34%	5.19%	88.41%	Y	POOR	24.8%	N/A
Low Rate of Weight Change	32.03%	60.12%	85.50%	Y	POOR	23.1%	N/A
High Rate of Weight Change	20.79%	26.51%	30.87%	Y	POOR	47.5%	N/A
Derivative Design	0.44%	46.99%	85.50%	Y	POOR	27.4%	N/A
Original (New) Design	42.49%	52.43%	30.87%	Y	POOR	42.3%	N/A

3 models passed tests for “Tripwire” version of tool;
0 models passed tests for “Detailed” version of tool

Tripwire Tool – Design Requirements



- Provides a quantitative, early indication of technical metric health as it relates to overall program performance
- Sufficient accuracy to allow programs to initiate investigative action to mitigate technical metric trends, as appropriate
- Very little data entry & maintenance required
- Most interpretation of results provided by the tool itself
 - Minimized interpretation error by user
- Additional tool capabilities can be developed as part of pilot programs (if desired) – Detailed Tool Version

ALI Tripwire Tool design based on VOC inputs from AIR-4.1, PEO Leadership, and Engineering SMEs

ALI Tripwire Tool Design - Inputs



Advanced Leading Indicator Tripwire Tool - Weight Growth vs. EMD Program Final Cost Growth

PROTOTYPE TOOL VERSION - NOT INTENDED FOR PROGRAM USE

EDIT PROGRAM ATTRIBUTES

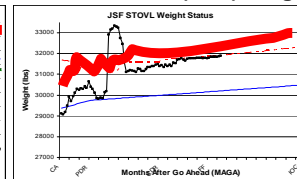
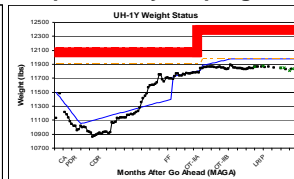
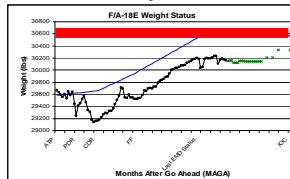
Program Name:

What is the Starting Plan to Perform Weight? lbs

Final NTE Weight? lbs

(Plan to NTE Margin)

Select the picture that best represents your program's Not-To-Exceed (NTE) weight limit over time.



☐ Static NTE

☐ Static NTE w/OTB

☐ Dynamic NTE

Aircraft's initial weight estimate:

lbs

Aircraft's current weight estimate:

lbs

Program Milestone Inputs:

(mm/dd/yyyy)

EMD Contract Award
 Preliminary Design Review (PDR)
 Critical Design Review (CDR)
 First Flight (FF)
 Initial Operating Capability (IOC)

Date of current weight estimate

Enter Program
Into Database

Cancel and
Return to Output

Clear Form

ALI Tripwire Tool Design – Program Specific Output



Example ▼

Edit Program in Database

Add Program to Database

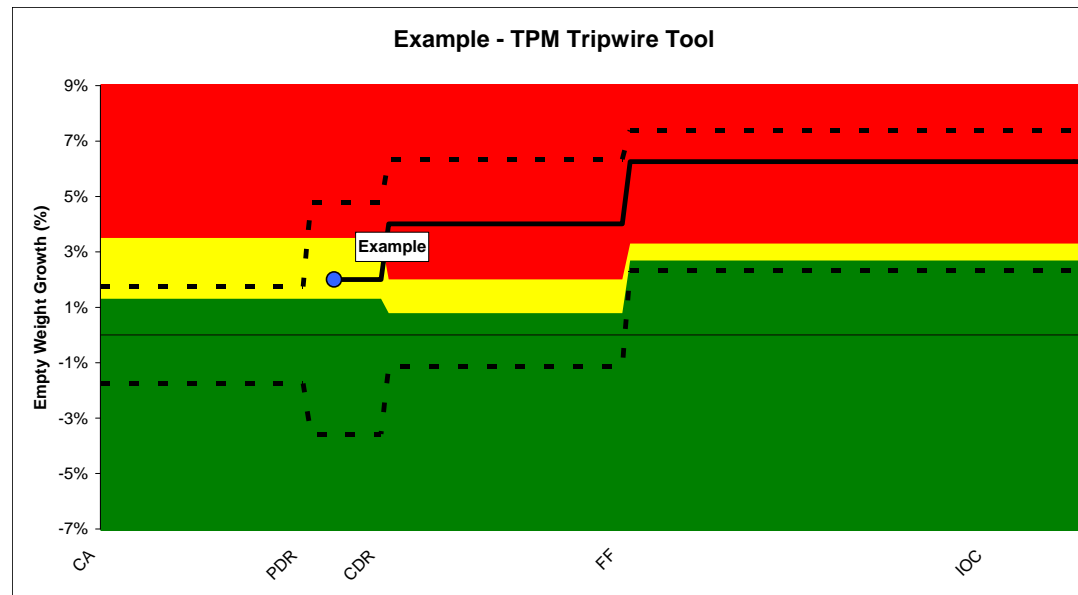
Delete Program From Database

% Cost Growth Threshold Limits

Green/Yellow	15%
Yellow/Red	40%

Apply User Settings

Apply Default Settings



LEGEND	
Program Performance Threshold Colors:	
	> 40% Historical Cost Growth
	15% - 40% Historical Cost Growth
	< 15% Historical Cost Growth
Dot Color Code:	
	Weight Impact on Cost is Unknown
	Weight has a Moderate Impact on Cost
	Weight has a Significant Impact on Cost
Projection Lines	
	+/- 1-Sigma NAVAIR Historical Weight Performance Range
	Projected Weight Growth

PROTOTYPE TOOL VERSION - NOT INTENDED FOR PROGRAM USE

Example Program's current status weight suggests it is currently Yellow (performing slightly better than the NAVAIR average), but is projected to be red in the future (based on historical trends) – Weight is currently a moderate driver for cost

ALI Tripwire Tool Design – Program Summary Output



Populate Summary
Matrix

Clear Summary
Matrix

PROTOTYPE TOOL VERSION - NOT INTENDED FOR PROGRAM USE

**Projected Cost Growth vs. Milestone
Aircraft Summary Matrix**

Projected Cost Growth	> 40% Cost Growth				
	15% - 40% Cost Growth		Example		
	< 15% Cost Growth	Death Star		Enterprise	
		PDR	CDR	FF	IOC
		Milestone			

Snapshot summary of current technical metric health for multiple programs

Red/Yellow/Green Thresholds



- Thresholds indicate if weight performance puts a particular program in the company of historical NAVAIR programs that did/did not perform well overall*
 - Green: Weight performance is similar to historical programs that executed well (*did not experience a Minor Nunn-McCurdy breach; <15% cost growth*)
 - Yellow: Weight performance is similar to historical programs that executed satisfactorily (*experienced less than NAVAIR average cost growth; 15-40% cost growth*)
 - Red: Weight performance is similar to historical programs that did NOT execute well (*experienced greater than NAVAIR average cost growth; > 40% cost growth*)

CPI = BCWP / ACWP

BCWP --> Original CBB

ACWP --> Final Cost

CPI --> Original CBB / Final Cost

CPI Thresholds (per AIR-4.2)

Red	< 0.9
Yellow	0.9 - 0.95
Green	> 0.95

$$\%FCG = (\text{Final Cost} - \text{Original CBB}) / \text{Original CBB}$$

$$\%FCG = (\text{Final Cost} / \text{Original CBB}) - (\text{Original CBB} / \text{Original CBB})$$

$$\%FCG = (\text{Final Cost} / \text{Original CBB}) - 1$$

$$\%FCG = (1 / \text{CPI}) - 1$$

CPI	%FCG
0.9	11.1%
0.95	5.3%

%FCG Thresholds (based on AIR-4.2 CPI Thresholds)

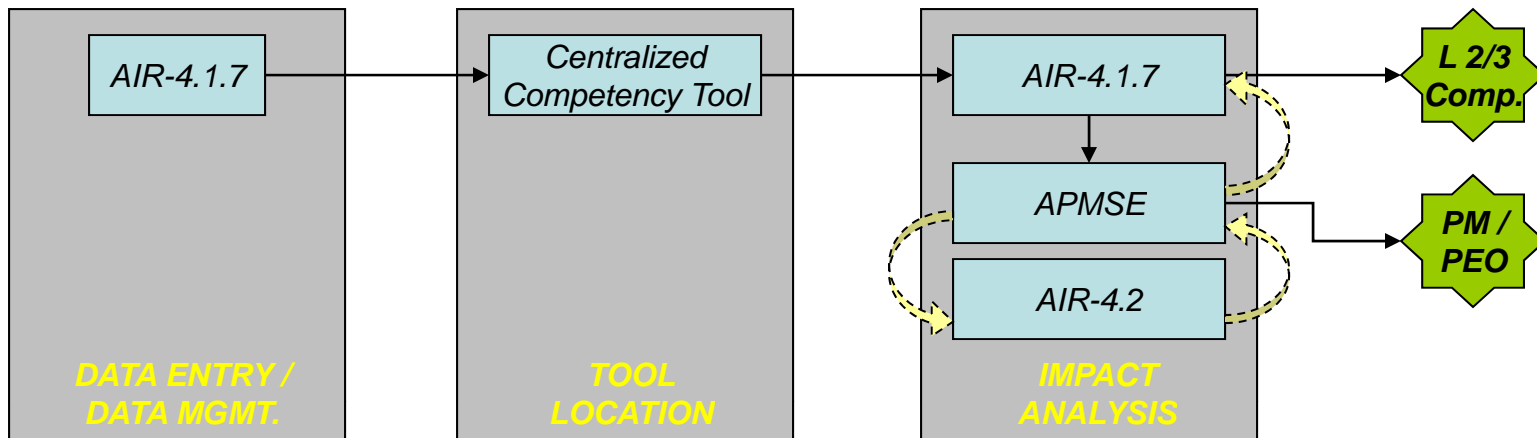
Red	>11.1%
Yellow	5.3% - 11.1%
Green	<5.3%

%FCG Thresholds (based on Nunn-McCurdy breach and current NAVAIR avg.)

Red	>40%
Yellow	15%-40%
Green	<15%

* *Eventually the input will be a combination of weight and other technical parameters; and cost growth will be one of many measures of overall program performance.*

Implementation Approach



- **Weight and Mass Properties Group (AIR-4.1.7) will run tool and provide output to Program Chief Engineers (APMSE)**
 - Allows for central data entry/maintenance POC
 - Utilizes existing AIR-4.1.7/APMSE comms
 - Allows for central POC for SEDIC support and tool maintenance
 - Facilitates future SEDIC data collection for continuous tool/model refinement
 - Facilitates thorough/accurate impact analysis of results
 - Facilitates periodic program-specific AND summary reports to PMs/PEOs/ Competency Leadership
- **Currently performing 6-12 Month Pilot to prove tool concept/utility**
 - CH-53K & BAMS development programs



ALI Detailed Methodology

- **Public Release**
 - Would allow other organizations to replicate ALI Tools using their data
 - Contains **NO** data / **NO** program specific information
 - Detailed methodology steps only
 - Potentially a future Annex to current INCOSE LI Guide

Weight TPM Tripwire Tool

- **Release to NAVAIR (Distribution Statement D)**
 - Contains data (models), but **NO** program specific information
 - Contains equations representing historical NAVAIR program performance

Future ALI Priorities



	<u>Technical Parameter</u>	<u>vs.</u>	<u>Overall Program Performance Parameter</u>	
1.	Status Empty Weight	vs.	Cost Growth – COMPLETE	
2.	Engineering Staffing	vs.	Cost Growth – IN-WORK	AIR-4.2/PPT Collaboration
3.	Work Product Approval (Task Completion)	vs.	Cost Growth	
4.	Engineering Staffing	vs.	Schedule/Technical Performance	
5.	Work Product Approval (Task Completion)	vs.	Schedule/Technical Performance	
6.	Software	vs.	Cost Growth – IN-WORK	
7.	DoDAF Metrics	vs.	Cost Growth	
8.	Requirements	vs.	Cost/Schedule/Technical Performance	
9.	SETR Action Closure	vs.	Cost/Schedule/Technical Performance	
10.	Status Max Speed	vs.	Cost/Schedule/Technical Performance	
11.	R/M/A Metrics	vs.	Cost/Schedule/Technical Performance	
12.	Status Weight	vs.	Schedule/Technical Performance	
13.	Software	vs.	Schedule/Technical Performance	
14.	Program Risks	vs.	Cost/Schedule/Technical Performance	
15.	DoDAF Metrics	vs.	Schedule/Technical Performance	
16.	Status Bandwidth	vs.	Cost/Schedule/Technical Performance	

Getting raw data will be a significant factor regarding future ALI prioritization



***NAVAIR Systems Engineering
Development & Implementation Center
(SEDIC)***

Applied Leading Indicator (ALI) Initiative

BACK UP SLIDES

Weight Models Developed – STEP 2



Affinitization Categories → Weight Models

PROGRAM NAME	All Data Model	Weight Plan	Weight Change	Budget	TakeOff	NTE Limit	Deriv / Orig
Limits	Entire Pop.	<> 3% WG planned	<> 2000 lbs WG	<> \$2B KTR EMD	CTOL vs. VTOL	Static vs. Dynamic	New vs. Mod.
E-2D AHE	All	Agg	Low	Low	CTOL	Static	Deriv
BAMS	All	NonAgg	Low	Low	CTOL	Static	Deriv
CH-53K	All	NonAgg	High	High	VTOL	Dynamic	Deriv
E-6 BLK1	All	Agg	High	Low	CTOL	Static	Deriv
E/A-18G	All	Agg	Low	Low	CTOL	Static	Deriv
F/A-18E	All	NonAgg	Low	High	CTOL	Static	Deriv
JSF STOVL	All	NonAgg	High	High	VTOL	Dynamic	Orig
P-8 MMA	All	NonAgg	High	High	CTOL	Dynamic	Orig
MV-22 BLK A	All	NonAgg	High	High	VTOL	Static	Orig
UH-1Y	All	NonAgg	Low	Low	VTOL	Static	Deriv
VH-71A	All	NonAgg	High	Low	VTOL	Static	Orig
VTUAVN	All	Agg	High	Low	VTOL	Dynamic	Orig

- Various affinitization categories modeled and tested to determine if unique weight vs. program performance relationships existed
- Affinitization categories that exhibited unique characteristics were modeled
- Models that passed all verification tests were used in final tool
- In addition, affinitization categories were evaluated to determine if best practices could be identified

= Model Passed all V&V Tests (Used in Final Tool)

Weight TPM Tripwire Tool – Output Interpretation



Current % Empty Weight Growth (%WG) Status Point –

Read the y-axis to determine the current program %WG based on your inputs. Compare the relative position of the point to the colored threshold backdrop to determine the approximate program performance (cost growth) experienced by similar historical programs (at that point in time). The color of the point tells the user if weight is a driving factor towards overall program performance at this time (see legend).

Program Performance Thresholds (Backdrop) –

The colored backdrop shows the level of program performance (cost growth) expected for any given value of %WG. This relationship is derived based on historical NAVAIR program performance trends.



Example

Edit Program in Database

Add Program to Database

Delete Program From Database

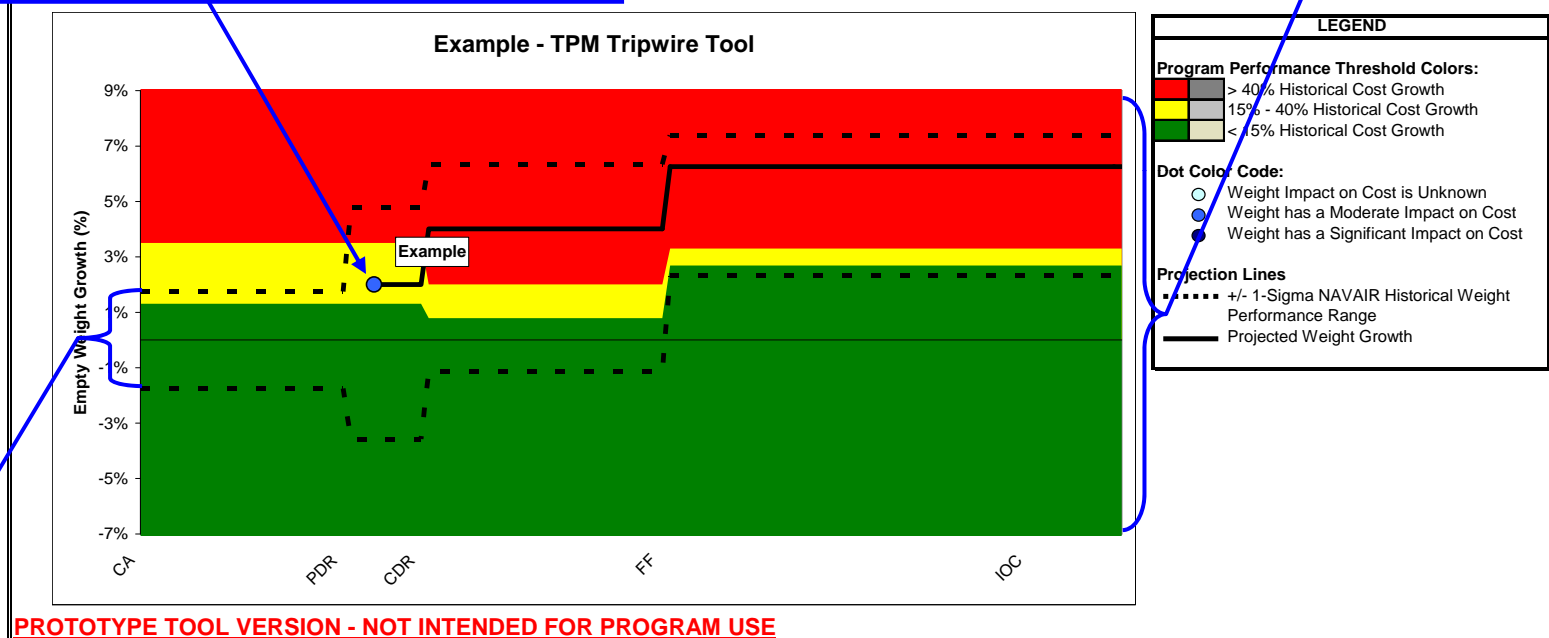
% Cost Growth Threshold Limits

Green/Yellow 15%

Yellow/Red 40%

Apply User Settings

Apply Default Settings



Historical %WG Performance Range –

These dotted lines represent the range of %WG values that similar historical NAVAIR programs have demonstrated in the past. This projected range uses +/- 1-Sigma standard deviation to represent average historical weight performance. Compare the relative position of your program's point to the dotted lines to determine how you are performing compared to past NAVAIR programs.

Weight TPM Tripwire Tool – Output Interpretation



Current % Empty Weight Growth (%WG) Status Point –

The user can compare their program's actual cost to the current projected cost given by the chart to determine if they are performing roughly the same, better, or worse than NAVAIR historical programs. This may indicate to the user if the future program performance projected by the chart will be conservative or not.

%WG Projection Line –

The solid line shows the projected %WG for your program assuming historical average weight growth is demonstrated from this point on. This provides future %WG values at each milestone and allows the user to determine the corresponding level of program performance (cost growth) associated with the projected %WG.



Example

Edit Program in Database

Add Program to Database

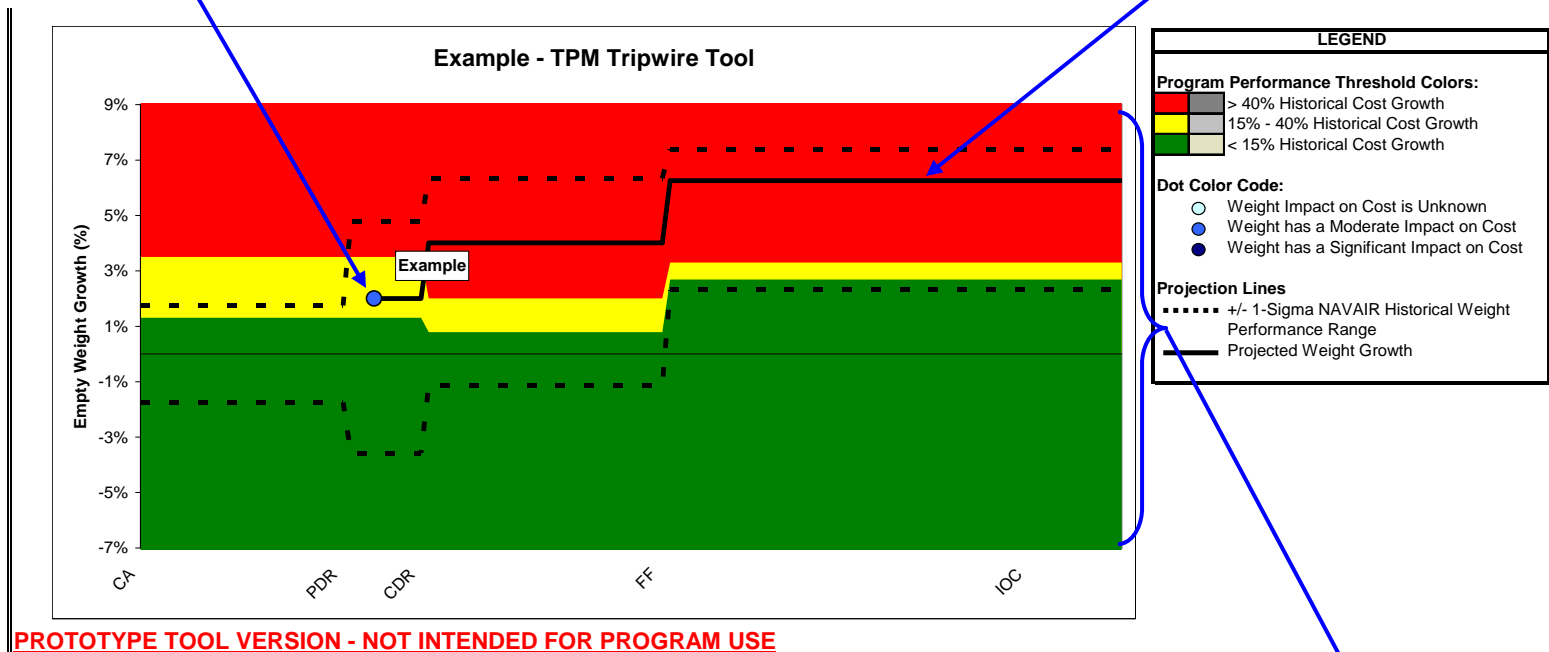
Delete Program From Database

% Cost Growth Threshold Limits

Green/Yellow	15%
Yellow/Red	40%

Apply User Settings

Apply Default Settings



Program Performance Thresholds (Backdrop) –

The shape of these color bands describes how weight affects overall program performance over time. A thin yellow band means small perturbations in weight will likely have a significant impact on overall program performance. A wide yellow band means perturbations in weight will likely have a relatively small impact on overall program performance. For example, the time between CA and CDR represents an opportunity where weight can be greatly reduced/increased with a relatively small affect on overall program performance. Conversely, once you pass through CDR, the impact of changing weight now has significant effects on overall program performance. This effect becomes even more significant after FF. (In other words, get weight under control prior to CDR.)

Weight TPM Tripwire Tool – Output Interpretation



This program is currently in the red and the chart shows it's likely too late to get back into yellow/green. The %WG projection line shows the program is likely to end up well into the red. Furthermore, this program will likely end up with higher %WG than most NAVAIR historical programs (above upper dotted line – will perform worse than ~85% (70% + 30%/2) of all NAVAIR historical programs). Likely too late to save this program.



Example

Edit Program in Database

Add Program to Database

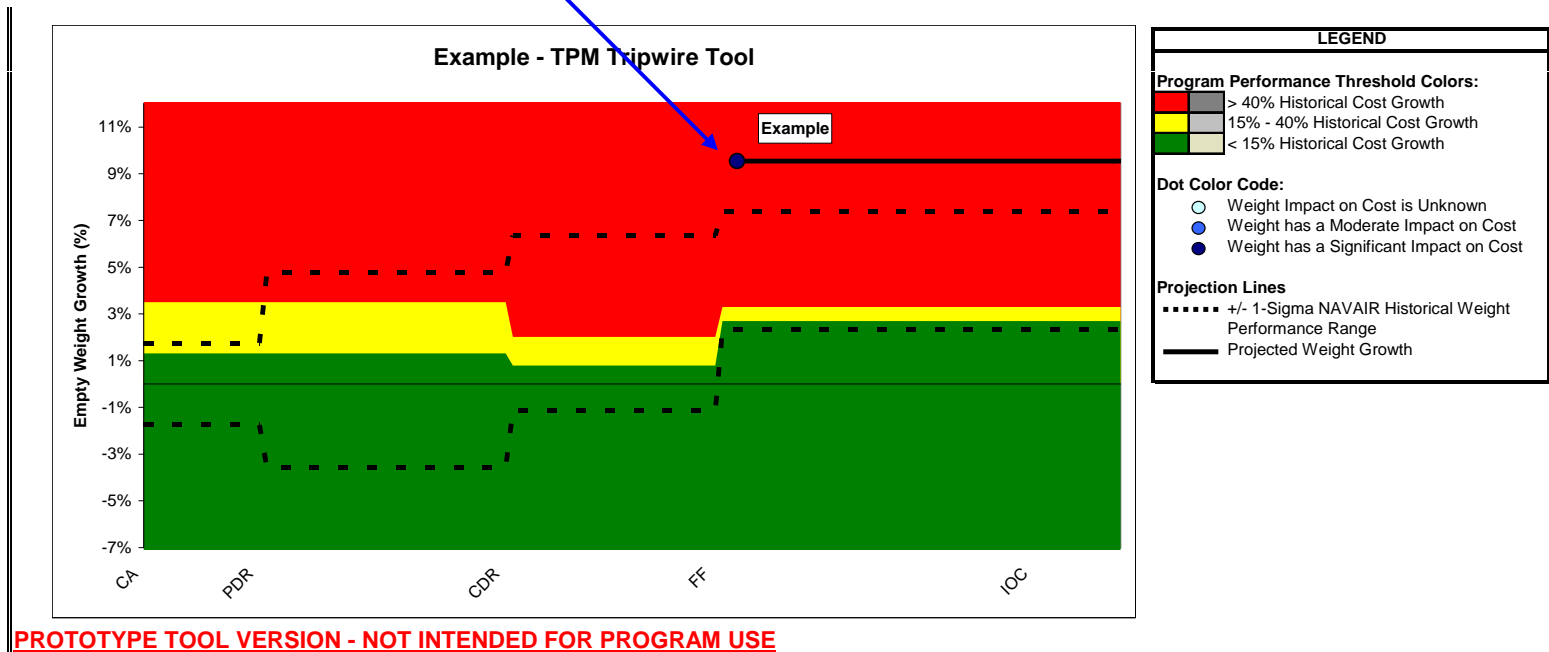
Delete Program From Database

% Cost Growth Threshold Limits

Green/Yellow	15%
Yellow/Red	40%

Apply User Settings

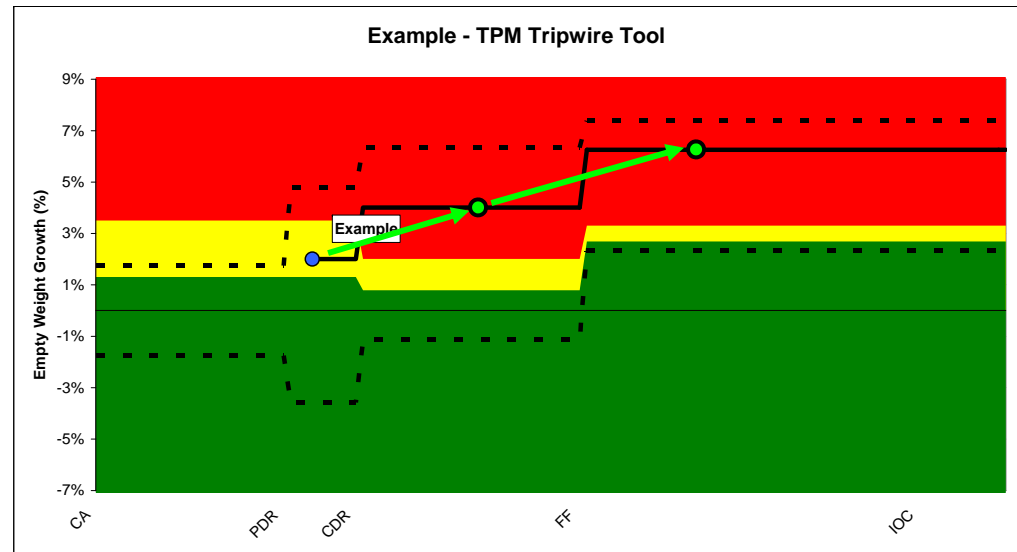
Apply Default Settings



Weight TPM Tripwire Tool – Output Interpretation



This program is currently yellow. They have a chance of attaining green if they act soon. After CDR it will be more difficult to attain green (slight chance based on lower -1-Sigma historical performance line between CDR and FF). If not addressed by FF, there will be an even less chance of achieving green. If the historical rate of weight growth is demonstrated for the remainder of the program, it is likely to end up in the red by IOC.



If the program demonstrates less than average historical weight growth, future %WG projections will show the program will have an increasingly better chance at attaining green by IOC. The projection line is always centered about the most current weight status, and reflects the average historical weight growth rate from that current status value. Therefore, if your program were to reduce weight or maintain it's current weight through first flight, the projection line will move down and possibly be in the green by IOC.

