Two Complementary EVM Cost-Risk Models – Part 2

1. Use of EVM Trend Tool (EVMTT) to Forecast Cost Risks with 4 Case Study Examples
2. Integrated Cost-Risk Model (ICRM) Utilizing ACEIT

for

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Outline

- EVMTT Acknowledgements
- Basic Objectives of EVMTT Analysis
- Research Nature of 4 Case Studies
- Dr. Roy Smoker (MCR) 2011 Paper Main Points
- 2 Case Study Results (other 2 are in backup)
- Conclusions
- Integrated Cost-Risk Model Utilizing ACEIT

Use of EVM Trends to Forecast Cost Risks

Original Presentation at
2011 ISPA/SCEA Conference, Albuquerque, NM

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(Other Charts Added by David R. Graham)

*Roy E. Smoker (2011): Use of Earned Value Management Trends to Forecast Cost Risks, Journal of Cost Analysis and Parametrics, 4:1, 31-51

EVM Trend Tool (EVMTT)

- Programmed gratis in Excel by Michael Butterworth, now retired from TASC, for SoCal SCEA/ISPA (now SoCal ICEAA)
  - Based on Dr. Smoker's paper
- Available for use at no charge
- ***MCR has approved its use by any program only requests that they be given credit for the approach and that any program using the EVM Trend Tool asks them for permission to use it***
  - ***Contact MCR CEO Neil Albert*** nalbert@mcri.com

Basic Objectives of EVMTT Analysis

- Utilize rate-of-growth in $BCWS_{CUM}$, $BCWP_{CUM}$, BAC & LRE in monthly linear regression projections
- Utilize the rate of BAC growth on
  - BAC projections at month of analysis & at completion
  - %-Complete based on more conservative estimate of end-of-contract BAC
  - Early projection of completion date
    - Linear regression & Earned Schedule approaches
- Identify a contrast between EVMTT results & contractor positions for further action e.g., apply ACEIT Integrated Cost-Risk Model (ICRM)
- Provide a 25,000 foot view of program performance
  - Needs complementary, WBS-level view e.g., ICRM, to identify lower-level cost-risk impacts that may be getting hidden at program level

Research Nature of 4 Case Studies

- 4 Case Studies had data from beginning to near end of development
- Enables early results to be evaluated in light of results at end of development
- Smoker Case Study had continuous rate of BAC growth
- 3 Case Studies had early BAC growth volatility but BAC growth diminished over time
  - 'Convergence' effects observed
  - Perhaps convergence effects were the result of program management focusing on managing/mitigating risks as a response to early volatility in BAC?
  - Perhaps availability of EVMTT early in effort could have reinforced other sources of risk identification and analysis e.g., Risk Register?

Main Points of EVM Trend Paper

1. EVM data is taken from the PMB's S-curve *at it's most linear section*
2. Regression equation developed to *forecast BAC*
   - Coefficients contain effect of BAC rate of growth ***up to that point***
3. Ending *month* of contract can be forecasted using regression equations
   - $BCWP_{CUM}$ = BAC at contract end so set regression equations equal & solve for months
     - e.g., **BCWP = BAC** ➔ $86.35M*Months = $4,970.56 + $31.76M * Months
     - *Then just solve for months* = 91.06
       - NOTE: Calculation made at month 42 - Coefficients change depending on month selected due to amount of available EVM data increasing over time
4. Plug 91.06 months into BAC & LRE regression equations for end-of-contract forecasts
5. EVMTT also calculates the Earned Schedule end-of-contract month for comparison

Main Points of Paper (cont)

$$\text{Earned Schedule}_{42} = 42 + (\text{BAC}_{\text{CPR }42} - \text{BCWP}_{\text{CUM }42})/\text{WorkRate}_{42}$$

$(\text{WorkRate} = \text{BCWP}_{\text{CUM}}/\text{Months-to-Date (42)})$; so,

$$\text{Earned Schedule}_{42} = 42 + (6269.68 - 3737.55)/88.99 = 70.45 \text{ mos}$$

6. Note: Dr. Smoker's approach does not utilize any performance factors (e.g., CPI, SPI, SCI, Moving Averages, etc.) in making its projections, just BAC growth
7. Conservative %-Complete can be calculated by using the BAC with growth derived at actual month of analysis
   - First, plug end-of-contract months into latest BAC regression equation to solve for $\text{BAC}_{\text{EndMo}}$; then divide $\text{BCWP}_{\text{ActualMo}}$ by $\text{BAC}_{\text{EndMo}}$ result and solve for *adjusted percent complete*
8. ***Variance at Completion (VAC) is a quantification of value of risk that must be paid attention to in order to reduce damaging cost-risk effects***

Full 43 Months of Smoker paper EVM Data (months 25 through 67)

(from the Excel based EVM Trend Tool)

Month	Cumm BCWS	Cumm BCWP	Cumm ACWP	BAC	LRE EAC	CPI	SPI	Raw % Complete	Adjusted % Complete	% Spent	Adjusted % Spent	Cost Var	SV	PC
25	$ 2,034.00	$ 1,988.00	$ 2,017.00	$ 5,750.00	$ 5,750.00	0.98562221	0.97738446	0.34573913	0.258711	0.350783	0.262485	-29.00	-46.00	0.317082
26	$ 2,150.00	$ 2,095.00	$ 2,142.00	$ 5,776.00	$ 5,776.00	0.97805789	0.9744186	0.36270776	0.272636	0.370845	0.278752	-47.00	-55.00	0.334148
27	$ 2,247.00	$ 2,191.00	$ 2,243.00	$ 5,785.00	$ 5,785.00	0.97681676	0.97507788	0.37873812	0.285129	0.387727	0.291896	-52.00	-56.00	0.34946
28	$ 2,357.56	$ 2,294.27	$ 2,352.54	$ 5,822.94	$ 5,823.00	0.97523148	0.97315697	0.39400605	0.298569	0.404013	0.306151	-58.27	-63.28	0.365932
29	$ 2,476.60	$ 2,399.79	$ 2,462.22	$ 5,870.95	$ 5,871.00	0.97464361	0.9689841	0.40875637	0.312300	0.419391	0.320424	-62.43	-76.81	0.382761
30	$ 2,585.78	$ 2,501.16	$ 2,565.08	$ 5,906.54	$ 5,917.00	0.97507917	0.9672756	0.42345579	0.325492	0.434278	0.333811	-63.92	-84.62	0.398929
31	$ 2,704.61	$ 2,616.52	$ 2,693.75	$ 5,961.16	$ 5,972.00	0.97132991	0.96742966	0.43892736	0.340504	0.451883	0.350555	-77.23	-88.09	0.417329
32	$ 2,816.72	$ 2,728.84	$ 2,817.39	$ 6,000.22	$ 6,017.00	0.96857158	0.96879921	0.45478992	0.355121	0.469547	0.366644	-88.55	-87.88	0.435244
33	$ 2,920.87	$ 2,827.75	$ 2,931.70	$ 6,088.19	$ 6,146.00	0.96454204	0.96811804	0.46446406	0.367993	0.481538	0.381520	-103.95	-93.12	0.451019
34	$ 3,038.39	$ 2,938.65	$ 3,051.13	$ 6,160.98	$ 6,350.00	0.9631353	0.96717246	0.47697770	0.382425	0.495234	0.397063	-112.48	-99.74	0.468708
35	$ 3,151.96	$ 3,046.63	$ 3,169.30	$ 6,156.54	$ 6,344.00	0.96129393	0.9665808	0.49485978	0.396477	0.514785	0.412441	-122.67	-105.34	0.48593
36	$ 3,245.29	$ 3,137.93	$ 3,274.30	$ 6,132.15	$ 6,352.00	0.95835289	0.96691883	0.51171791	0.408359	0.533956	0.426105	-136.37	-107.36	0.500493
37	$ 3,369.69	$ 3,258.00	$ 3,407.15	$ 6,211.78	$ 6,401.00	0.95622324	0.96685276	0.52448704	0.423984	0.548499	0.443394	-149.15	-111.70	0.519643
38	$ 3,479.48	$ 3,372.57	$ 3,535.39	$ 6,173.79	$ 6,363.00	0.95394787	0.96927473	0.54627271	0.438894	0.572644	0.460082	-162.81	-106.91	0.537918
39	$ 3,578.85	$ 3,469.61	$ 3,655.92	$ 6,118.34	$ 6,396.00	0.949038	0.9694762	0.56708334	0.451522	0.597535	0.475768	-186.31	-109.24	0.553395
40	$ 3,666.76	$ 3,554.12	$ 3,571.16	$ 6,145.90	$ 6,424.00	0.99522928	0.96927945	0.57829077	0.462520	0.581063	0.464737	-17.04	-112.65	0.566874
41	$ 3,765.17	$ 3,646.86	$ 3,869.45	$ 6,292.16	$ 6,570.00	0.9424745	0.96857724	0.57958792	0.474589	0.614964	0.503556	-222.59	-118.31	0.581666
42	$ 3,865.74	$ 3,737.55	$ 3,978.10	$ 6,269.68	$ 6,548.00	0.93952974	0.96683819	0.59613042	0.486391	0.634499	0.517696	-240.56	-128.20	0.59613
43	$ 4,002.11	$ 3,869.98	$ 4,133.09	$ 6,325.04	$ 6,603.00	0.93595342	0.96677665	0.61185013	0.503625	0.653448	0.537865	-263.11	-132.13	
44	$ 4,109.45	$ 3,980.35	$ 4,271.33	$ 6,325.04	$ 6,603.00	0.93147356	0.9683911	0.62929934	0.517988	0.675305	0.555856	-290.99	-129.11	
45	$ 4,213.25	$ 4,082.74	$ 4,392.25	$ 6,523.65	$ 6,802.00	0.92912819	0.96883922	0.62583605	0.531313	0.673281	0.571592	-309.52	-130.51	
46	$ 4,331.86	$ 4,198.05	$ 4,525.41	$ 6,541.24	$ 7,141.00	0.92726099	0.96893096	0.64178159	0.546319	0.691826	0.588920	-327.36	-133.81	
47	$ 4,427.41	$ 4,292.70	$ 4,647.66	$ 6,541.24	$ 7,141.00	0.92321308	0.96940131	0.65625162	0.558637	0.710517	0.604830	-354.96	-134.71	
48	$ 4,521.69	$ 4,388.90	$ 4,766.00	$ 6,524.30	$ 7,124.00	0.92046	0.97046874	0.67270088	0.571155	0.730500	0.620230	-377.10	-132.79	
49	$ 4,634.99	$ 4,495.84	$ 4,894.03	$ 6,632.65	$ 7,233.00	0.91821925	0.96981596	0.67783415	0.585072	0.737869	0.636892	-398.19	-139.15	
50	$ 4,882.68	$ 4,811.44	$ 5,009.25	$ 6,968.46	$ 7,268.50	0.91219835	0.98533395	0.69045876	0.626143	0.718845	0.651885	-197.81	-71.24	
51	$ 5,130.37	$ 5,127.04	$ 5,124.46	$ 7,304.28	$ 7,304.00	1.00050437	0.99934618	0.70192250	0.667214	0.701570	0.666879	2.57	-3.34	
52	$ 5,231.33	$ 5,217.49	$ 5,214.77	$ 7,231.42	$ 7,231.00	1.00052469	0.99734227	0.72150295	0.678986	0.721126	0.678631	2.72	-13.84	
53	$ 5,338.11	$ 5,315.37	$ 5,311.47	$ 7,231.77	$ 7,232.00	1.00073716	0.99572002	0.73500215	0.691723	0.734463	0.691216	3.90	-22.74	
54	$ 5,427.22	$ 5,401.43	$ 5,409.51	$ 7,322.52	$ 7,323.00	0.99849866	0.99522603	0.73764565	0.702922	0.738750	0.703974	-8.08	-25.79	
55	$ 5,543.33	$ 5,501.06	$ 5,528.29	$ 7,371.96	$ 7,372.00	0.99505187	0.99233935	0.74621400	0.715888	0.749908	0.719431	-27.23	-42.27	
56	$ 5,634.55	$ 5,594.20	$ 5,633.46	$ 7,480.20	$ 7,480.00	0.99300039	0.99280726	0.74786810	0.728009	0.753116	0.733118	-39.26	-40.35	
57	$ 5,721.50	$ 5,674.70	$ 5,722.61	$ 7,516.43	$ 7,516.00	0.99159156	0.99178373	0.75497271	0.738485	0.761346	0.744719	-47.91	-46.80	
58	$ 5,808.10	$ 5,760.12	$ 5,816.40	$ 7,540.40	$ 7,723.00	0.99028317	0.99170462	0.76390142	0.749602	0.771364	0.756925	-56.27	-47.97	
59	$ 5,885.61	$ 5,834.67	$ 5,914.00	$ 7,624.42	$ 7,807.00	0.98653014	0.99130808	0.76526146	0.759303	0.775665	0.769626	-79.32	-50.94	
60	$ 5,963.60	$ 5,911.84	$ 6,004.16	$ 7,646.54	$ 7,830.00	0.98455937	0.99128431	0.77313856	0.769345	0.785212	0.781360	-92.32	-51.76	
61	$ 6,053.34	$ 5,998.67	$ 6,109.34	$ 7,435.05	$ 7,618.00	0.98181083	0.99093001	0.80680902	0.780645	0.821694	0.795047	-110.67	-54.68	
62	$ 6,117.87	$ 6,066.15	$ 6,195.96	$ 7,603.78	$ 7,787.00	0.97896533	0.99151156	0.79778110	0.789427	0.814852	0.806319	-129.80	-51.72	
63	$ 6,190.82	$ 6,137.42	$ 6,276.50	$ 7,587.82	$ 7,771.00	0.97775238	0.99133903	0.80885153	0.798702	0.827181	0.816801	-139.08	-53.40	
64	$ 6,244.15	$ 6,192.58	$ 6,348.50	$ 7,541.59	$ 7,725.00	0.97534339	0.99170787	0.82112419	0.805880	0.841798	0.826171	-155.92	-51.57	
65	$ 6,306.27	$ 6,253.23	$ 6,431.68	$ 7,615.53	$ 7,798.00	0.97214518	0.99155474	0.82111477	0.813772	0.844548	0.836996	-178.46	-53.05	
66	$ 6,369.56	$ 6,315.05	$ 6,513.62	$ 7,644.96	$ 7,828.00	0.9693975	0.99140808	0.82604132	0.821818	0.852015	0.847659	-198.57	-54.51	
67	$ 6,428.81	$ 6,369.99	$ 6,589.25	$ 7,709.25	$ 8,095.00	0.96659773	0.99081516	0.82627964	0.828968	0.854721	0.857502	-219.26	-58.82	

The Main Regression Equations[1]

(1) $BCWS_{18}$ = \$89.12M[1] * Months
(0.7525) T-stat = 118.44 R^2 = 0.9988

(2) $BCWP_{18}$ = \$86.35M * Months
(0.6925) T-stat = 124.68 R^2 = 0.9989

(3) BAC_{18} = \$4,970.56M + \$31.76M * Months
(86.92) (2.56) R^2 = 0.9056
T-stats 57.19 12.39

(4) EAC_{18} = \$4,393.13M + \$52.62M * Months
(106.65) (3.15) R^2 = 0.9459
T-stats 41.19 16.73

- Additional, non-linear regression Earned Schedule Formula

$$IEAC(t) = \text{Actual Time}^{1} + (BAC - BCWP)/\text{WorkRate}^{1}$$

$Workrate_{42}$	\$	88.99
$RawCummBCWP_{42}$	\$	3,737.55
$RawCummBAC_{42}$	\$	6,269.68

[1] 18 months of data used for development of all equations (months 25-42) and above equation coefficients are the result of developing them from data points at month 42

VAC as a Measure of Risk

- Risk is measured in EVM terms as any deviation from the original baseline
  - That is, *risk is anything that results in a variance*
- Therefore, VAC is the basic measure of risk encountered by the end of the contract effort
  - Whether the risk is rooted in opportunity with a positive variance
  - Or, is rooted in issues related to planning of scope, estimating, scheduling, or technical criteria that are identified during testing and generally associated with a negative variance

4 Case Studies

Differences in BAC Growth Per Cases

Smoker Case Study BAC ($M) RANGE	DAU LAR Case Study BAC ($M) RANGE	SMC Case #1 BAC ($M) RANGE	SMC Case #2 BAC ($M) RANGE
$5,750 - $7,709	$63.3 - $70.2		
Growth = $1,959M (43 Mos) 34%	Growth = $6.9M (37 Mos) 11%	Growth over 85 mos = 30%	Growth over 46 mos = 4.3%

- Differences in BAC growth will determine the rate of BAC growth reflected in the coefficients of the linear regression equations for projecting BAC values over the period of analyzed months
  - The greater the range BAC growth from the beginning BAC and ending BAC in the data analyzed, at a steady rate of growth, the greater the linear regression equations will project growth in the BAC
  - The timing of when spurts of growth occurs also affects the BAC projection values
  - If very little growth occurs across the months of BAC data analyzed, the BAC projected by the linear regression equations will be close to the BAC reported on the CPR

EVMTT Results Table

Dr. Smoker Case Study Data

EVMTT MONTH NUMBER	DATE	REPORTED $BCWS_{CUM}$	EVMTT RESULTS $BCWS_{CUM}$	REPORTED $BCWP_{CUM}$	EVMTT RESULTS $BCWP_{CUM}$	CPR $BAC_{Rpt\ Mo}$	EVMTT $BAC_{Rpt\ Mo}$	CPR $LRE_{Rpt\ Mo}$	EVMTT $LRE_{Rpt\ Mo}$	EVMTT End Month#	EVMTT $BAC_{End\ Mo}$ [1]	EVMTT $LRE_{End\ Mo}$ [1]	MONTHLY PERCENT COMPLETE (CPR DATA)	ADJUSTED PERCENT COMPLETE [2]	CPR $VAC_{Rpt\ Mo}$	EVMTT $VAC_{Rpt\ Mo}$	EVMTT $VAC_{End\ Mo}$	EVMTT VAC (CPR BAC_Rpt Mo - EVMTT LRE_End Mo)	SCI-DERIVED EAC (BCWR = EVMTT BAC End Mo1-REPORTED BCWPCUM)	SCI-DERIVED EAC (BCWR = EVMTT LRE End Mo1-REPORTED BCWPCUM)	Earned Schedule ($IEAC_t$) Using CPR BAC & CPR $BCWP_{CUM}$	Earned Schedule ($IEAC_t$) Using EVMTT $_{End\ Month}$ BAC & EVMTT $BCWP_{CUM}$	Earned Schedule ($IEAC_t$) Using EVMTT $_{End\ Month}$ BAC & CPR $BCWP_{CUM}$
42	Feb-97	$3,866	$3,743	$3,738	$3,627	$6,270	$6,305	$6,548	$6,603	91	$7,863	$9,184	60%	48%	-$278	-$299	-$1,322	-$2,915	$8,519	$9,048	71	91	88
43	Mar-97	$4,002	$3,846	$3,870	$3,726	$6,325	$6,334	$6,603	$6,645	90	$7,830	$9,098	61%	49%	-$278	-$311	-$1,268	-$2,773	$8,510	$8,955	70	90	87
44	Apr-97	$4,109	$3,949	$3,980	$3,826	$6,325	$6,358	$6,603	$6,680	89	$7,761	$8,963	63%	51%	-$278	-$322	-$1,201	-$2,638	$8,463	$8,821	70	89	86
45	May-97	$4,213	$4,053	$4,083	$3,926	$6,524	$6,413	$6,802	$6,743	91	$7,908	$9,088	63%	52%	-$278	-$330	-$1,180	-$2,564	$8,642	$8,945	71	91	87
46	Jun-97	$4,332	$4,157	$4,198	$4,027	$6,541	$6,462	$7,141	$6,853	91	$8,000	$9,372	64%	52%	-$600	-$391	-$1,372	-$2,830	$8,757	$9,224	71	91	88
47	Jul-97	$4,427	$4,260	$4,293	$4,127	$6,541	$6,503	$7,141	$6,947	91	$8,032	$9,526	66%	53%	-$600	-$443	-$1,494	-$2,985	$8,826	$9,377	71	91	88
48	Aug-97	$4,522	$4,362	$4,389	$4,227	$6,524	$6,536	$7,124	$7,023	91	$8,004	$9,563	67%	55%	-$600	-$488	-$1,558	-$3,039	$8,813	$9,416	71	91	88
49	Sep-97	$4,635	$4,466	$4,496	$4,327	$6,633	$6,579	$7,233	$7,105	91	$8,045	$9,656	68%	56%	-$600	-$526	-$1,611	-$3,024	$8,880	$9,502	72	91	88
50	Oct-97	$4,883	$4,578	$4,811	$4,442	$6,968	$6,666	$7,269	$7,181	94	$8,317	$9,862	69%	58%	-$300	-$515	-$1,546	-$2,894	$8,909	$9,519	69	94	86
51	Nov-97	$5,130	$4,699	$5,127	$4,569	$7,304	$6,788	$7,304	$7,251	98	$8,802	$10,179	70%	58%	$0	-$463	-$1,377	-$2,874	$8,800	$10,175	68	98	88
52	Dec-97	$5,231	$4,819	$5,217	$4,693	$7,231	$6,885	$7,231	$7,302	101	$9,121	$10,312	72%	57%	$0	-$417	-$1,191	-$3,081	$9,127	$10,298	69	101	91
53	Jan-98	$5,338	$4,937	$5,315	$4,816	$7,232	$6,970	$7,232	$7,346	103	$9,346	$10,360	74%	57%	$0	-$376	-$1,014	-$3,128	$9,357	$10,337	69	103	93
54	Feb-98	$5,427	$5,054	$5,401	$4,936	$7,323	$7,056	$7,323	$7,396	105	$9,575	$10,436	74%	56%	$0	-$340	-$862	-$3,114	$9,609	$10,410	71	105	96
55	Mar-98	$5,543	$5,171	$5,501	$5,055	$7,372	$7,138	$7,372	$7,445	106	$9,764	$10,489	75%	56%	$0	-$307	-$725	-$3,117	$9,845	$10,446	71	106	98
56	Apr-98	$5,635	$5,286	$5,594	$5,172	$7,480	$7,224	$7,480	$7,502	108	$9,974	$10,583	75%	56%	$0	-$277	-$609	-$3,103	$10,076	$10,542	72	108	100
57	May-98	$5,722	$5,399	$5,675	$5,287	$7,516	$7,305	$7,516	$7,556	109	$10,137	$10,642	75%	56%	$0	-$251	-$505	-$3,125	$10,260	$10,594	73	109	102
58	Jun-98	$5,808	$5,511	$5,760	$5,401	$7,540	$7,380	$7,723	$7,627	110	$10,245	$10,726	76%	56%	-$183	-$248	-$481	-$3,186	$10,384	$10,677	74	110	103
59	Jul-98	$5,886	$5,621	$5,835	$5,512	$7,624	$7,455	$7,807	$7,700	111	$10,362	$10,822	77%	56%	-$183	-$244	-$460	-$3,197	$10,543	$10,770	75	111	105
60	Aug-98	$5,964	$5,729	$5,912	$5,622	$7,647	$7,526	$7,830	$7,767	111	$10,431	$10,871	77%	56%	-$183	-$242	-$440	-$3,225	$10,635	$10,818	76	111	106
61	Sep-98	$6,053	$5,836	$5,999	$5,730	$7,435	$7,567	$7,618	$7,806	109	$10,276	$10,689	81%	57%	-$183	-$239	-$413	-$3,254	$10,506	$10,633	77	109	104
62	Oct-98	$6,118	$5,941	$6,066	$5,836	$7,604	$7,621	$7,787	$7,858	109	$10,231	$10,624	80%	58%	-$183	-$237	-$393	-$3,020	$10,486	$10,570	78	109	105
63	Nov-98	$6,191	$6,045	$6,137	$5,940	$7,588	$7,668	$7,771	$7,903	108	$10,146	$10,520	81%	59%	-$183	-$234	-$374	-$2,932	$10,412	$10,465	79	108	104
64	Dec-98	$6,244	$6,146	$6,193	$6,042	$7,542	$7,706	$7,725	$7,938	106	$10,016	$10,373	82%	60%	-$183	-$232	-$356	-$2,831	$10,302	$10,319	80	106	104
65	Jan-99	$6,306	$6,245	$6,253	$6,142	$7,616	$7,747	$7,798	$7,978	105	$9,923	$10,263	82%	62%	-$182	-$230	-$341	-$2,648	$10,239	$10,208	81	105	103
66	Feb-99	$6,370	$6,342	$6,315	$6,240	$7,645	$7,787	$7,828	$8,016	104	$9,834	$10,161	83%	63%	-$183	-$228	-$327	-$2,516	$10,176	$10,104	81	104	103
67	Mar-99	$6,429	$6,438	$6,370	$6,336	$7,709	$7,829	$8,095	$8,074	103	$9,768	$10,125	83%	64%	-$386	-$245	-$357	-$2,416	$10,138	$10,063	82	103	103

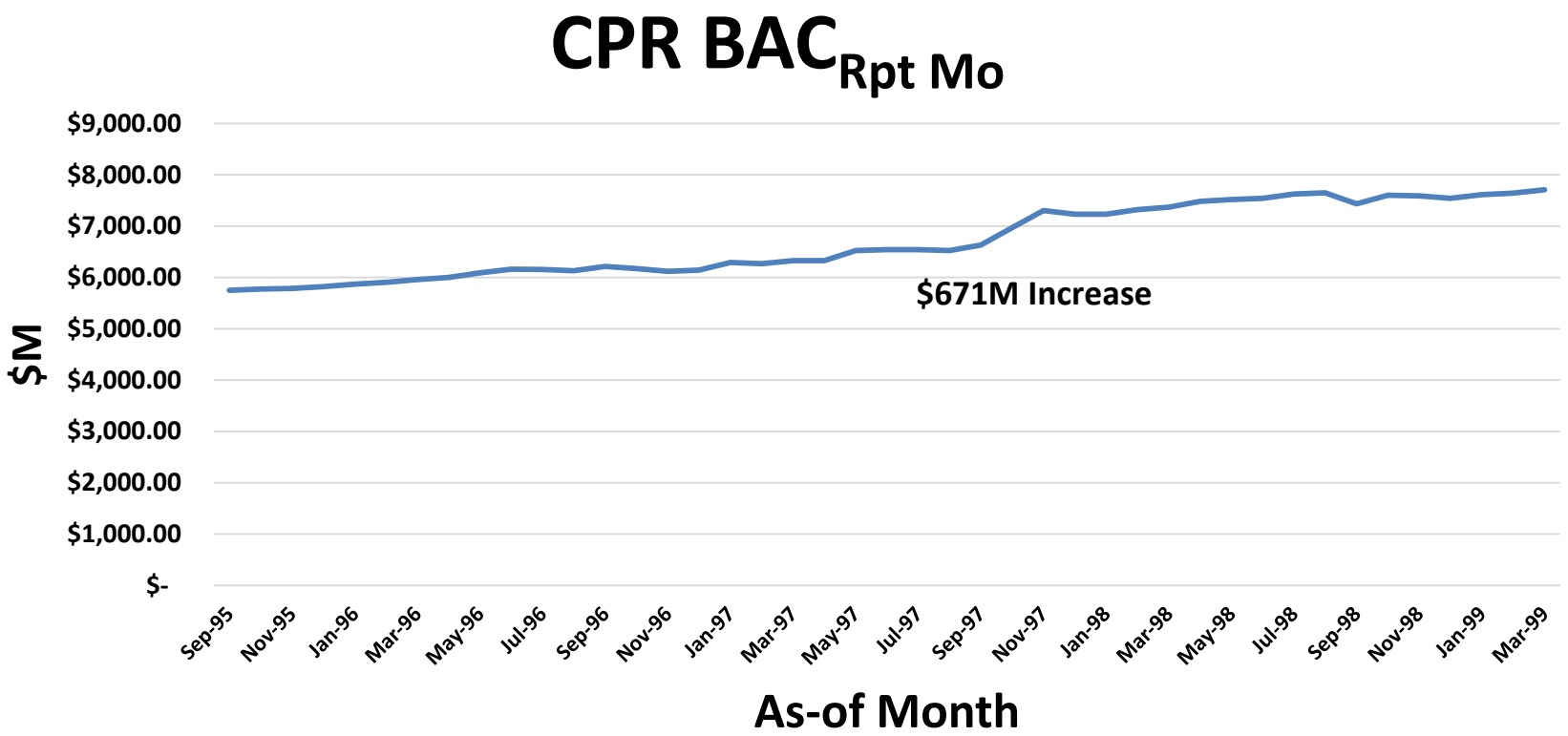
[1] Based on the EVMTT-generated completion month at that month

[2] Based on the EVMTT-generated End-Month BAC

[3] 220th month is not the final end month. It's just the last month of reported BAC in data provided

Dr. Smoker Case Study

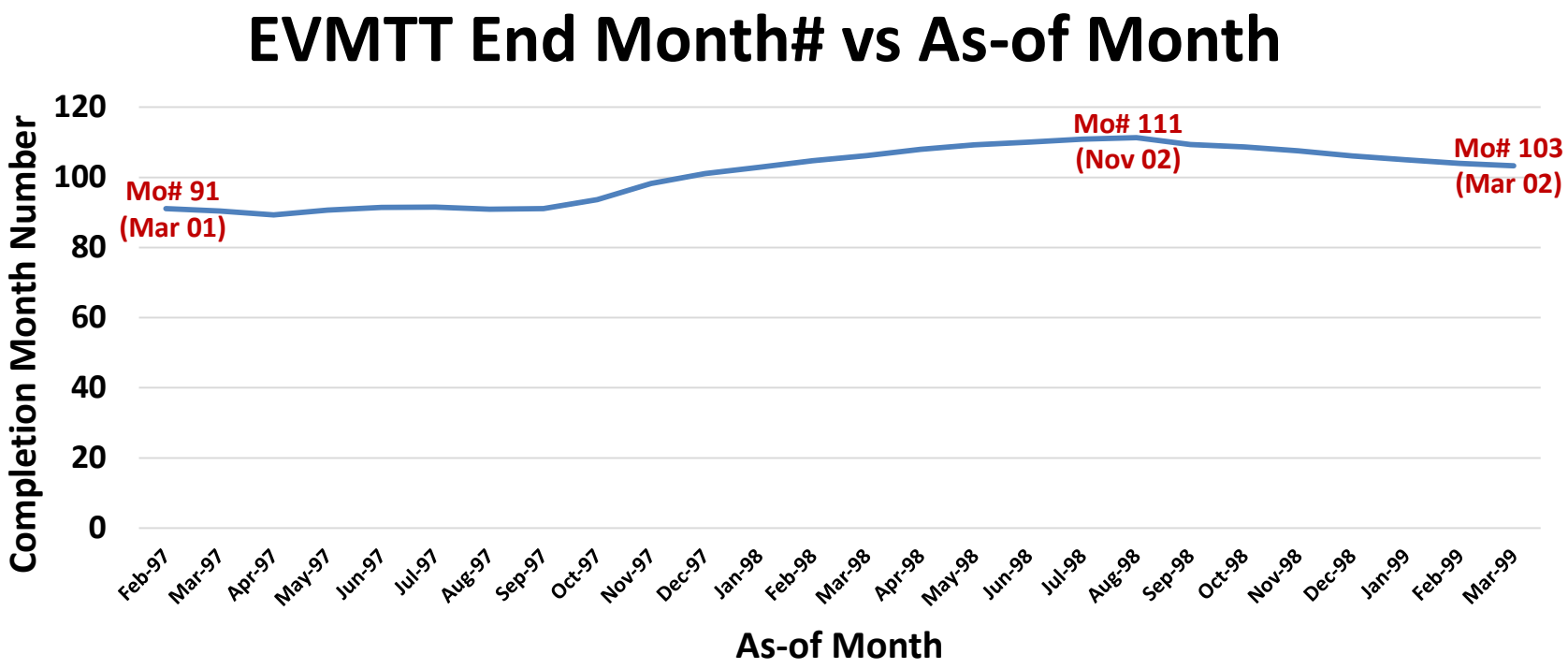
BAC Growth Linearity Trend Over Time



- Dr. Smoker's BAC data was linear
- ***This enabled the linear regression approach***

Dr. Smoker Case Study

EVMTT Completion Month Trend

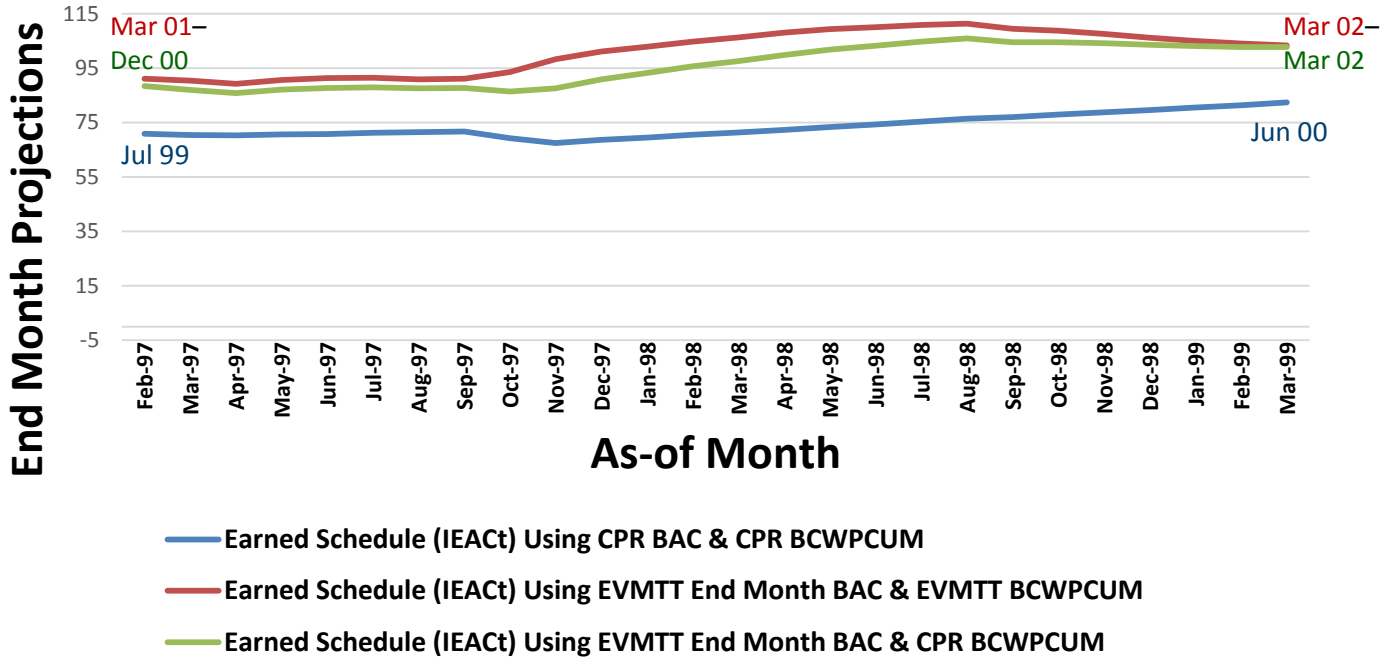


- EVMTT end month projection increased one year from Mar 01 to Mar 02
- ***Comparing the EVMTT initial end month projection (Mar 01) vs the Earned Schedule initial end month projection after the first 18 months of data analyzed (Jul 99) to the EVMTT completion month projection (Mar 02), the increase was a little more than 2.5 years***

Dr. Smoker Case Study

Earned Schedule Completion Month Trend Comparisons

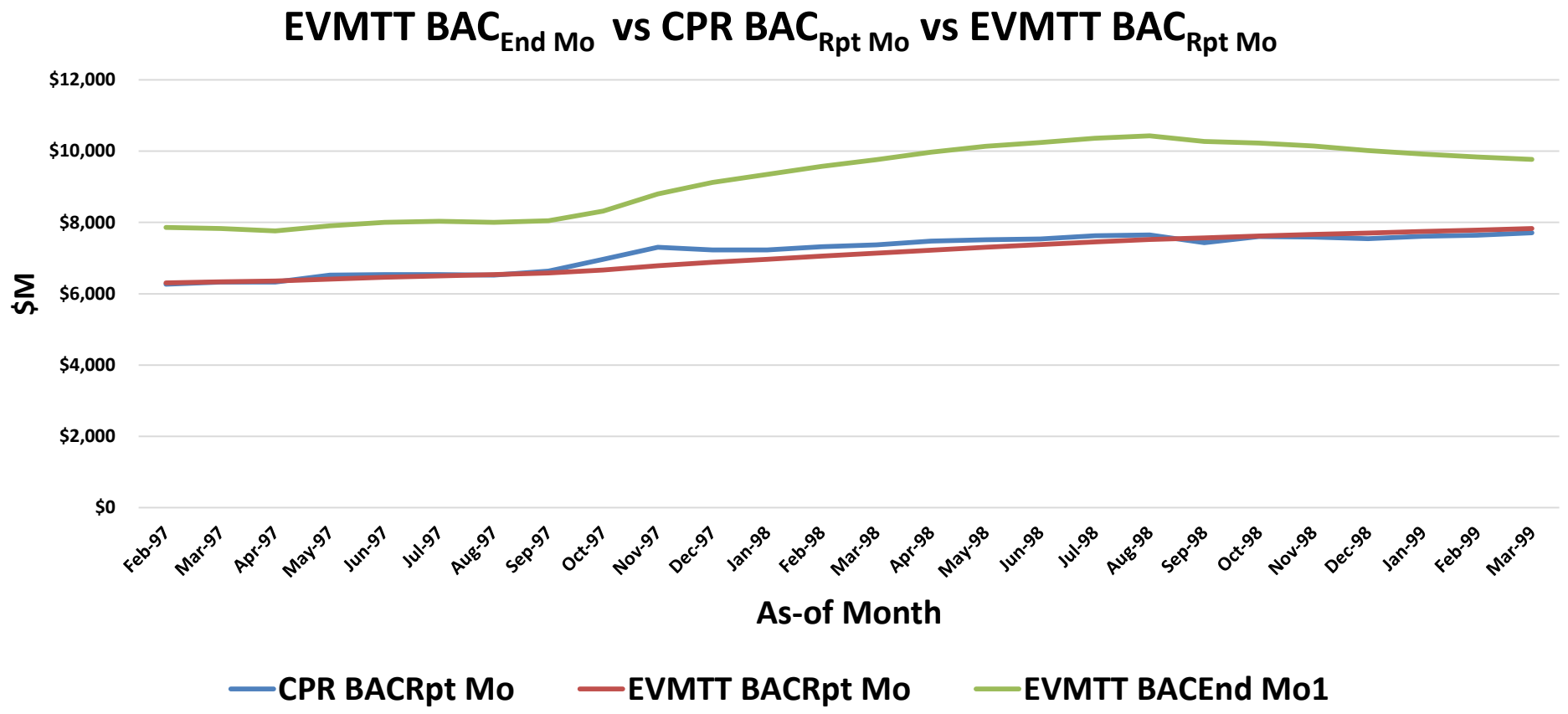
3 Earned Schedule Calculations



- ***Whenever the EVMTT $BAC_{End\ Month}$ was substituted for BAC_{CPR}, Earned Schedule projected a later program end month (red & green lines)***
- ***Not shown is EVMTT's linear regression projection of end month – it was identical to the Earned Schedule projection using EVMTT's end month projection (red line)***

Dr. Smoker Case Study

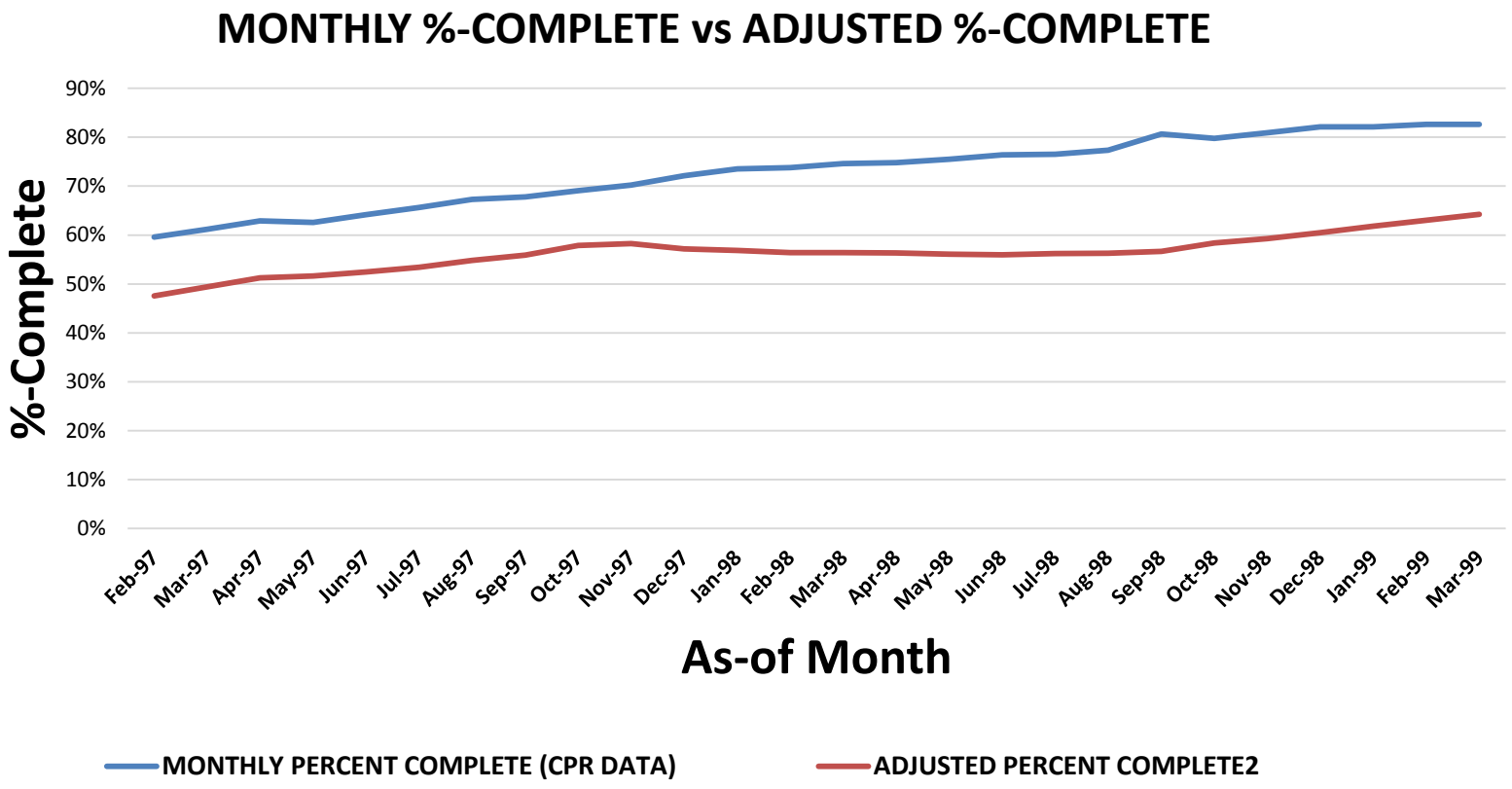
CPR vs EVMTT BAC Projection Trends



- Equal report-month projections due to same incremental BAC growth rate
- ***Higher EVMTT BAC End-Month projections are due to plugging EVMTT End Month estimates into monthly BAC projection equations***

Dr. Smoker Case Study

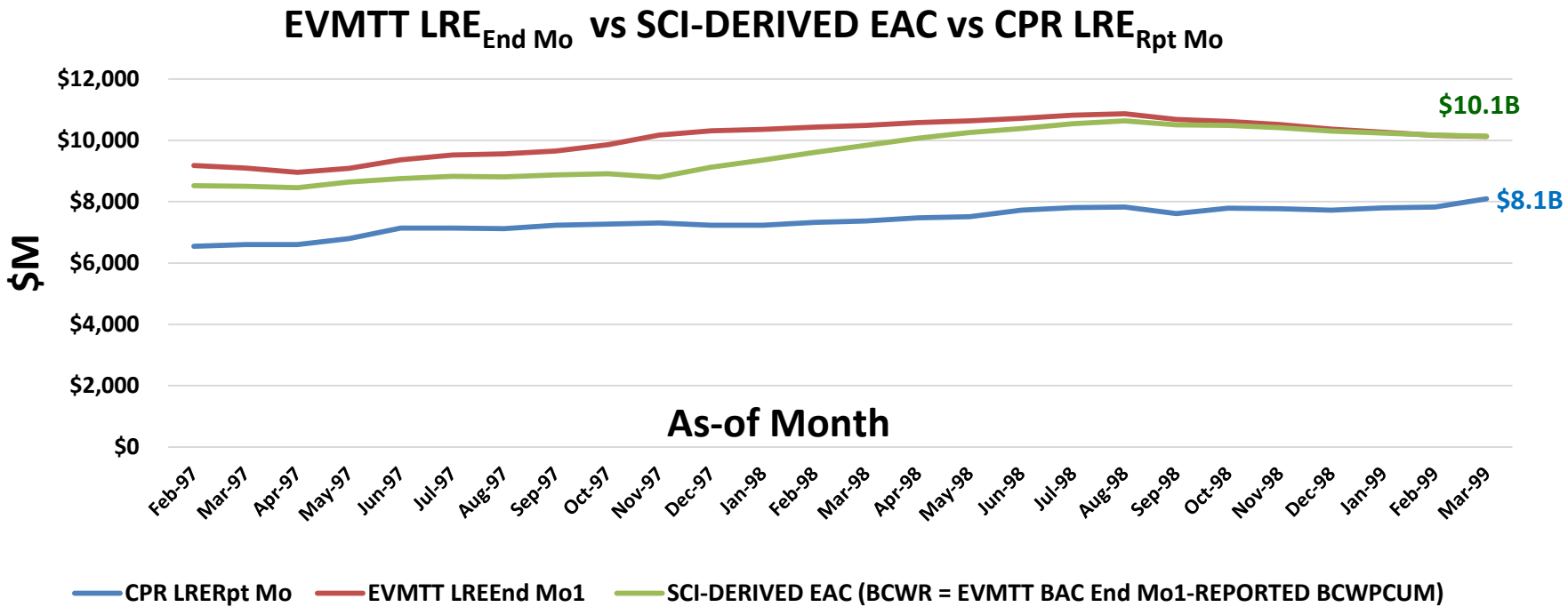
%-Complete Comparisons



- Monthly %-Complete = $BCWP_{CUM}/BAC_{CPR}$ = 83% in Mar 99
- ***Adjusted %-Complete = $BCWP_{CUM}/BAC_{EVMTT\_End\ Month}$ 64% in Mar 99***

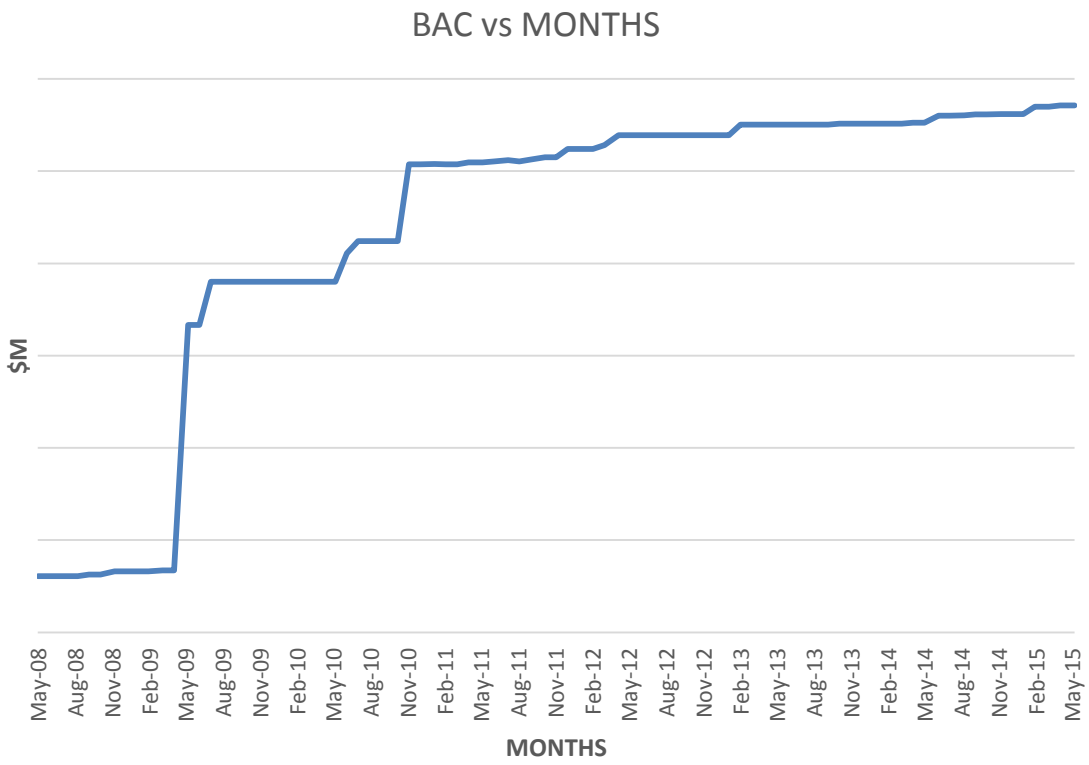
Dr. Smoker Case Study

CPR LRE vs EVMTT LRE vs SCI EAC



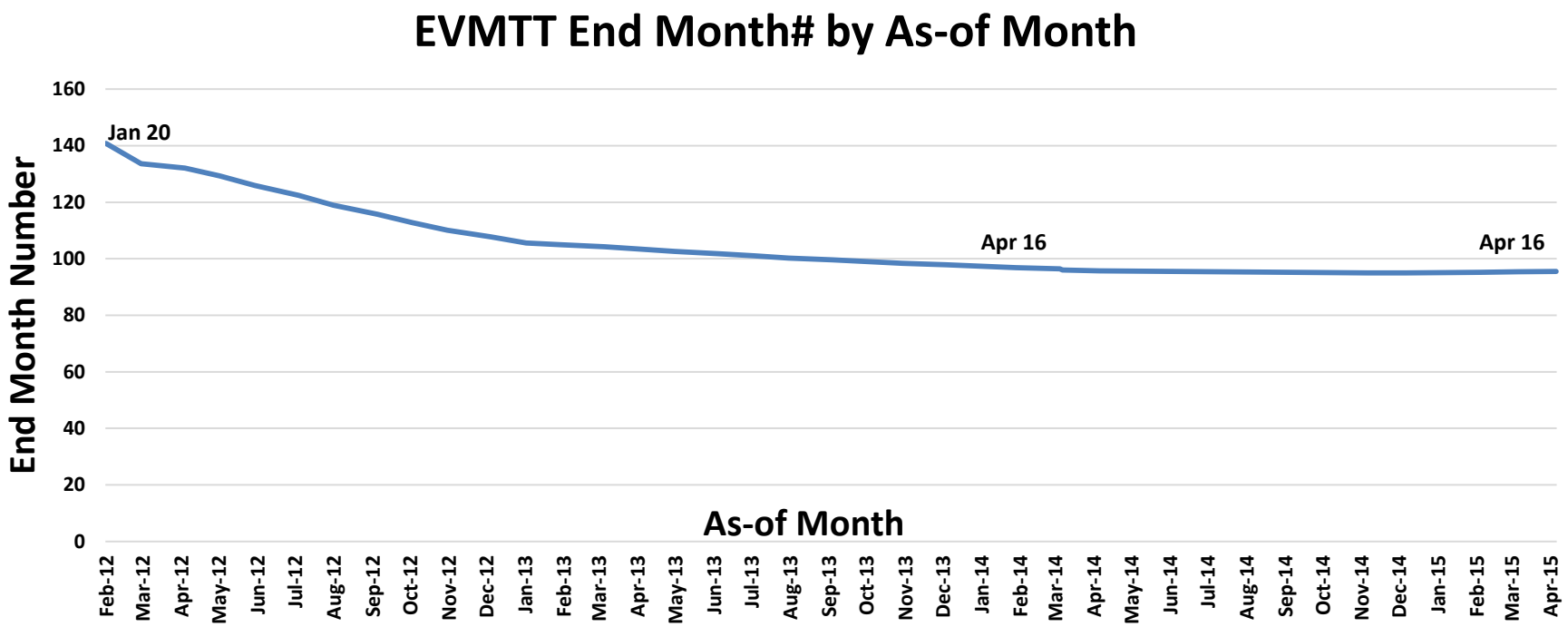
- EVMTT LRE_End Mo & SCI-Derived EAC converge due to increasing BAC rate of growth trend even though EVM performance increased
- ***From the FY05 President's Budget, final program development cost projected to be = $12.8B to occur in MAR 09***

SMC Example #1:
BAC Growth Linearity Trend Over Time



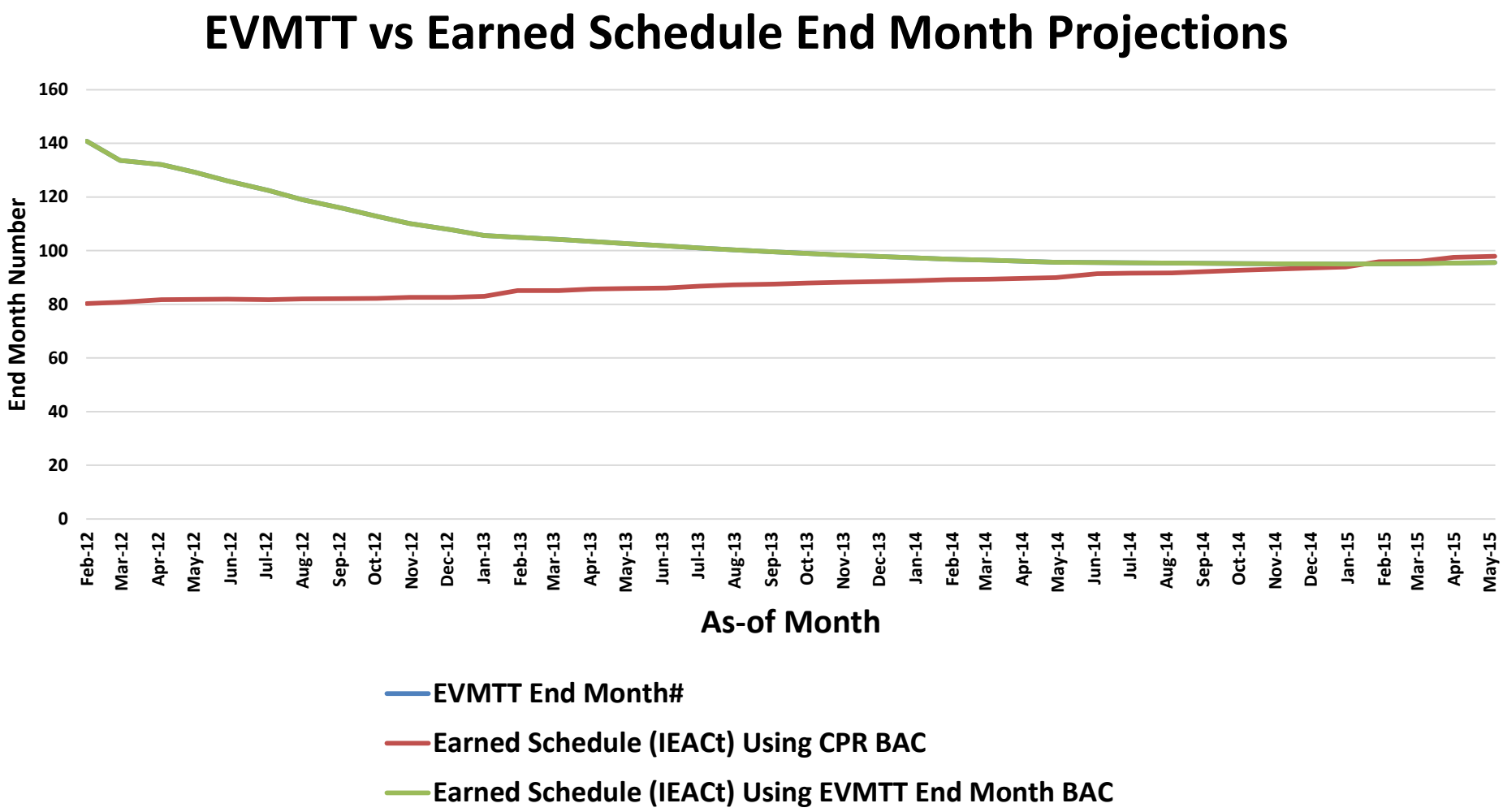
- Graph indicates ***non-linearity in BAC growth*** until about Sep 2010
- Therefore, linear regression analysis ***only appropriate after Sep 2010***
- ***BAC rate-of-growth very modest post-Sep 2010***

SMC #1 EVMTT Completion Month Trend



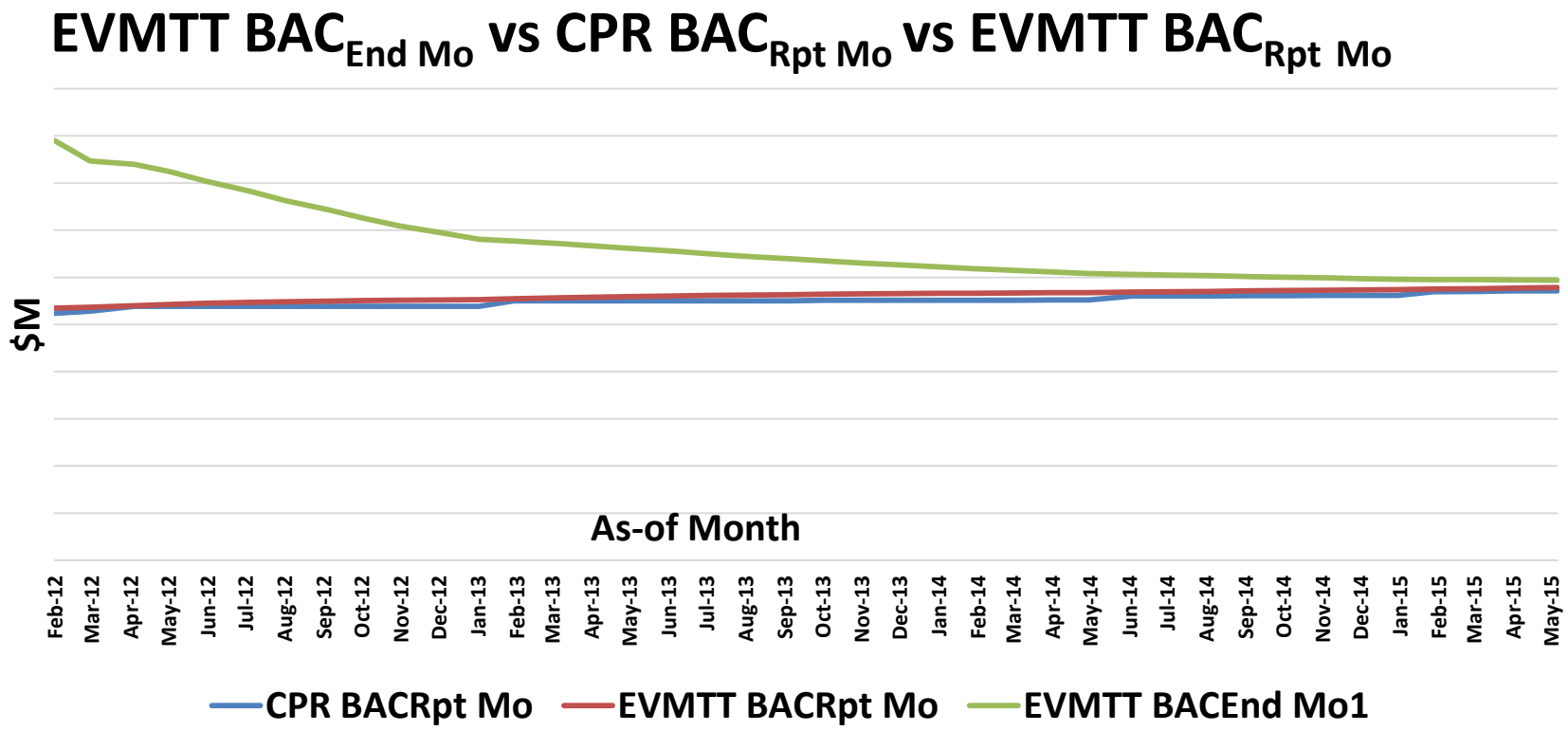
- As the months increase from left to right on the X-axis one month at a time, it represents an additional month's EVM data added to the database upon which the EVMTT's calculations are based
- In Feb 12 the projection for completion was Jan 20; the changes in the BAC stabilized in Mar 14 where the completion month projection became Apr 16 until the last month
- ***If EVMTT had been available in Feb 12, the initial end month projection of Jan 20 would have motivated program management to investigate why; perhaps other indications of risk were available (e.g., Risk Register) and did motivate the PM***
- Contract schedule end of development is ***Mar 16***; ***current contract PoP is through Sep 18 (EVM data does not support that so reconciling difference requires further action - e.g., ICRM)***

SMC #1 EVMTT vs Earned Schedule End Months



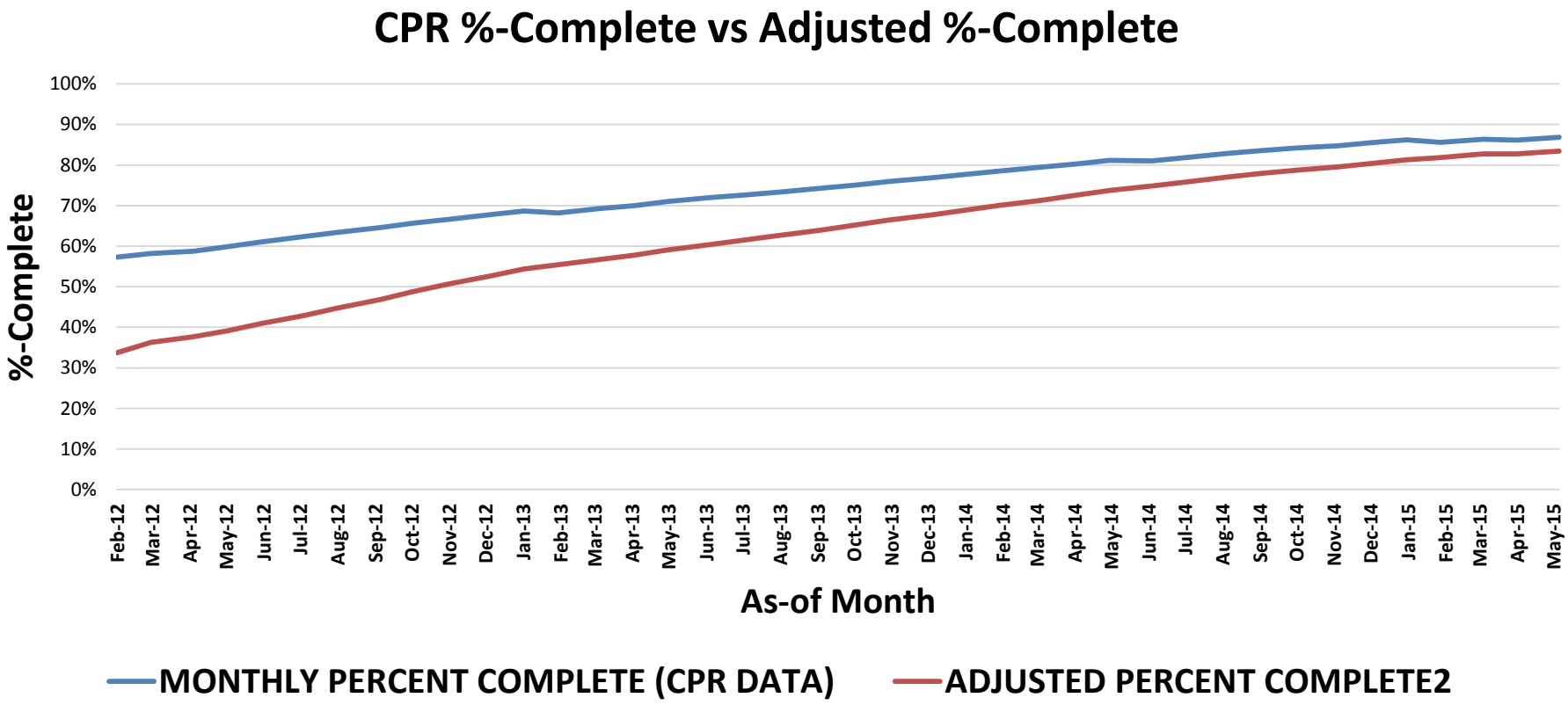
- $EVMTT_{EndMo\#}$ and Earned Schedule using EVMTT BAC_{EndMo} are identical
- ***Diminishing changes in BAC over time reduced the projected end month in EVMTT projections***

SMC #1 EVMTT BAC Comparisons



- Equal report-month projections due to same incremental BAC growth rate
- ***EVMTT BAC$_{End\ Mo}$ decreases over time due to low BAC rate-of-growth essentially converging with report-month projections in May 15***

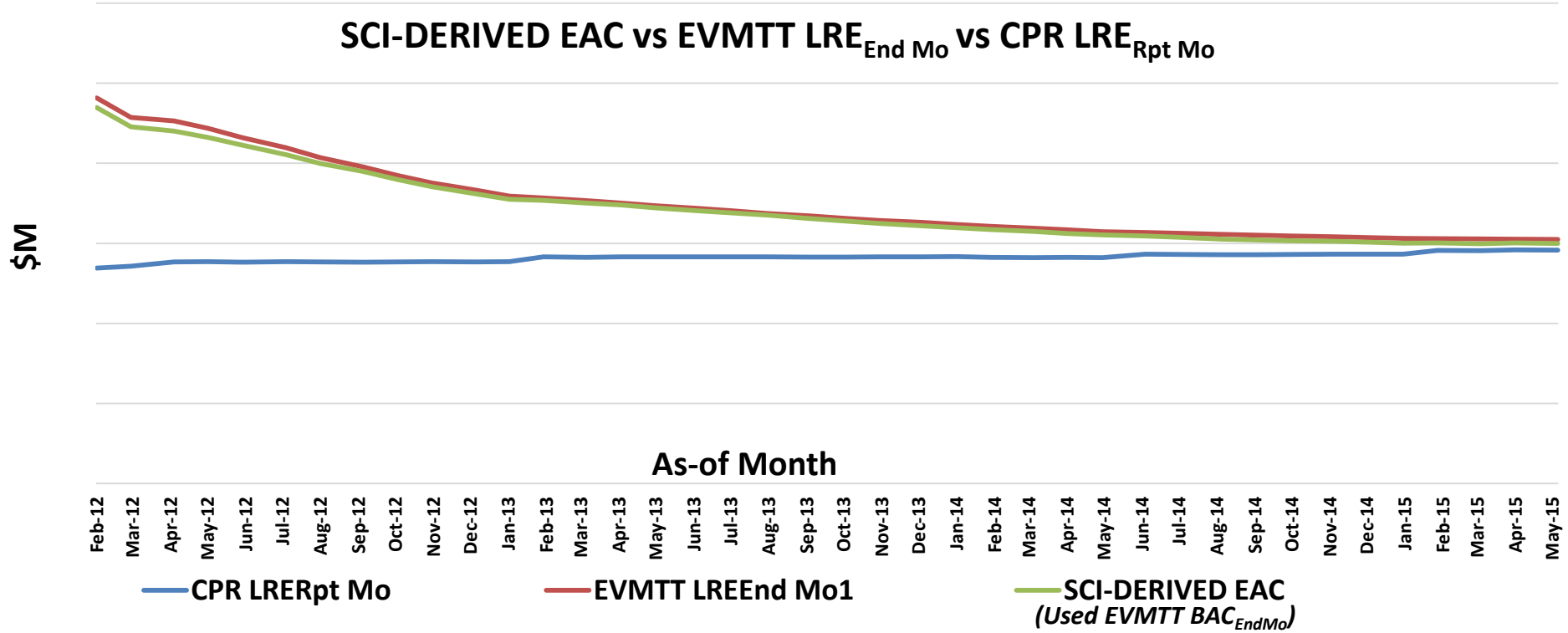
SMC #1 %-Complete Comparisons



- ***Due to diminishing BAC increases over time, a convergence happens between traditionally calculated %-complete and EVMTT-adjusted %-complete***

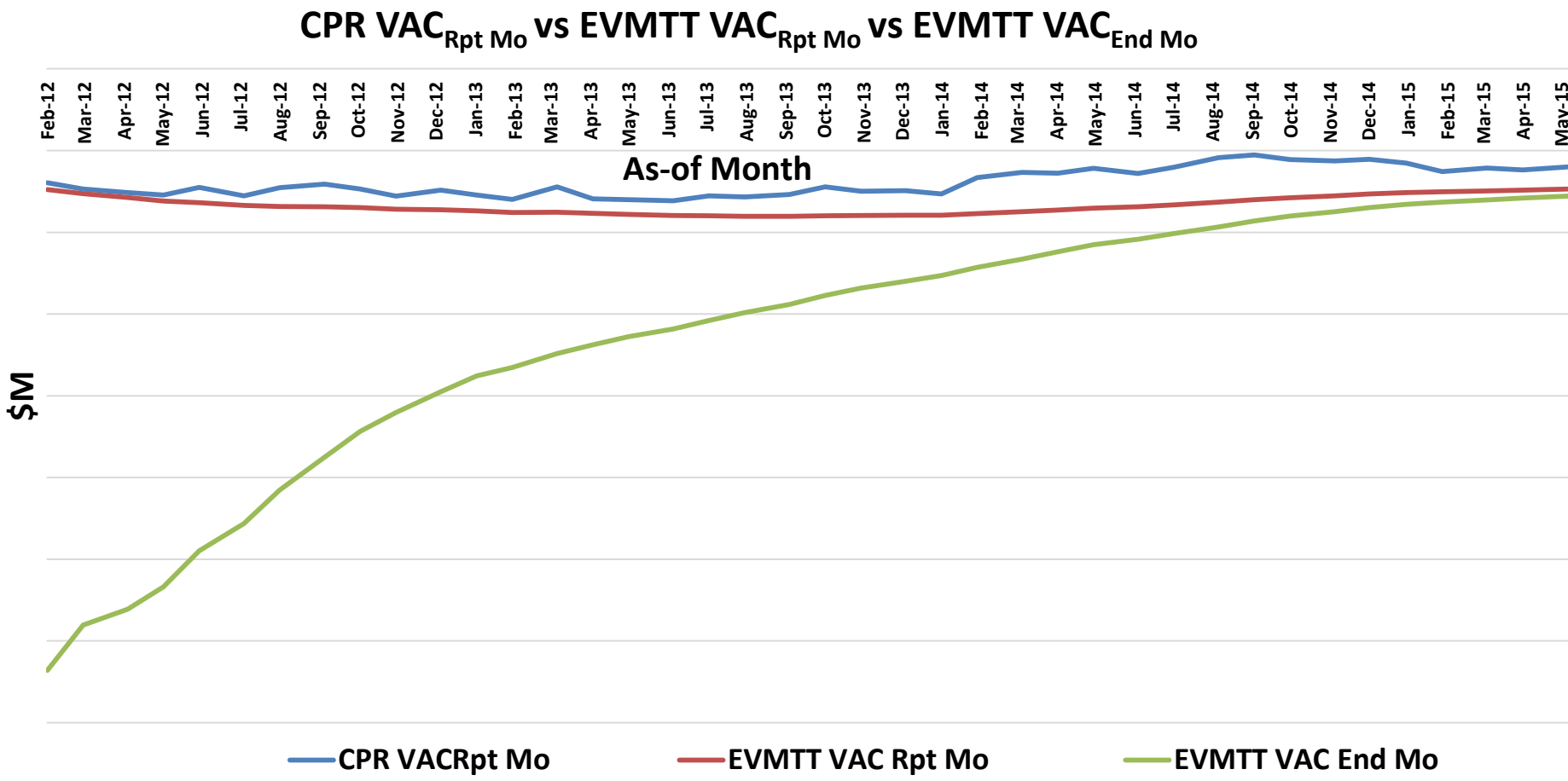
#1 SCI-Derived EAC Trend

($EAC_{SCI} = ACWP_{CUM} + BCWR/SCI$)



- EVMTT LRE_{EndMo} and SCI-Derived EAC using EVMTT BAC_{EndMo} are basically identical and decrease over time due to diminished BAC rate of growth which drove continually decreasing projected End Month
- There has been an ***increase*** in the CPI from 0.97 @ Feb 2012 to 0.99 @ May 15, i.e., better EVM performance
- ***This positive change in EAC trend is consistent with other findings, that is, as the program's growth in BAC subsided along with better cost performance, final cost projections converged closer to plan***

#1 Projected VAC Decrease Over Time



- Relatively large increases in the BAC over Sep-Oct 2010 established a large VAC projection between EVMTT BAC_{EndMo} and EVMTT LRE_{EndMo} initially but decreased over time as the program stabilized
- ***Lack of BAC increases reduced the projected EVMTT VACs***

Conclusions

- Dr. Smoker case study EVMTT results projected steadily increasing end months and increasing EACs due to ever-increasing BAC
  - Actually understated both but would have given PMs early warning to identify risks for mitigation
- SMC Example #1 had minimal BAC increases over time so EVMTT results converged to planned outcomes
  - However, contractor proposed end-month projections conflicted with EVM data performance
  - A further investigation is warranted into what is driving the contractors to propose extended schedules that are unjustified by current EVM data analysis
  - ***Recommend an application of a WBS element-level risk and cost-risk analysis using the ACEIT-based Integrated Cost-Risk Model (ICRM)***

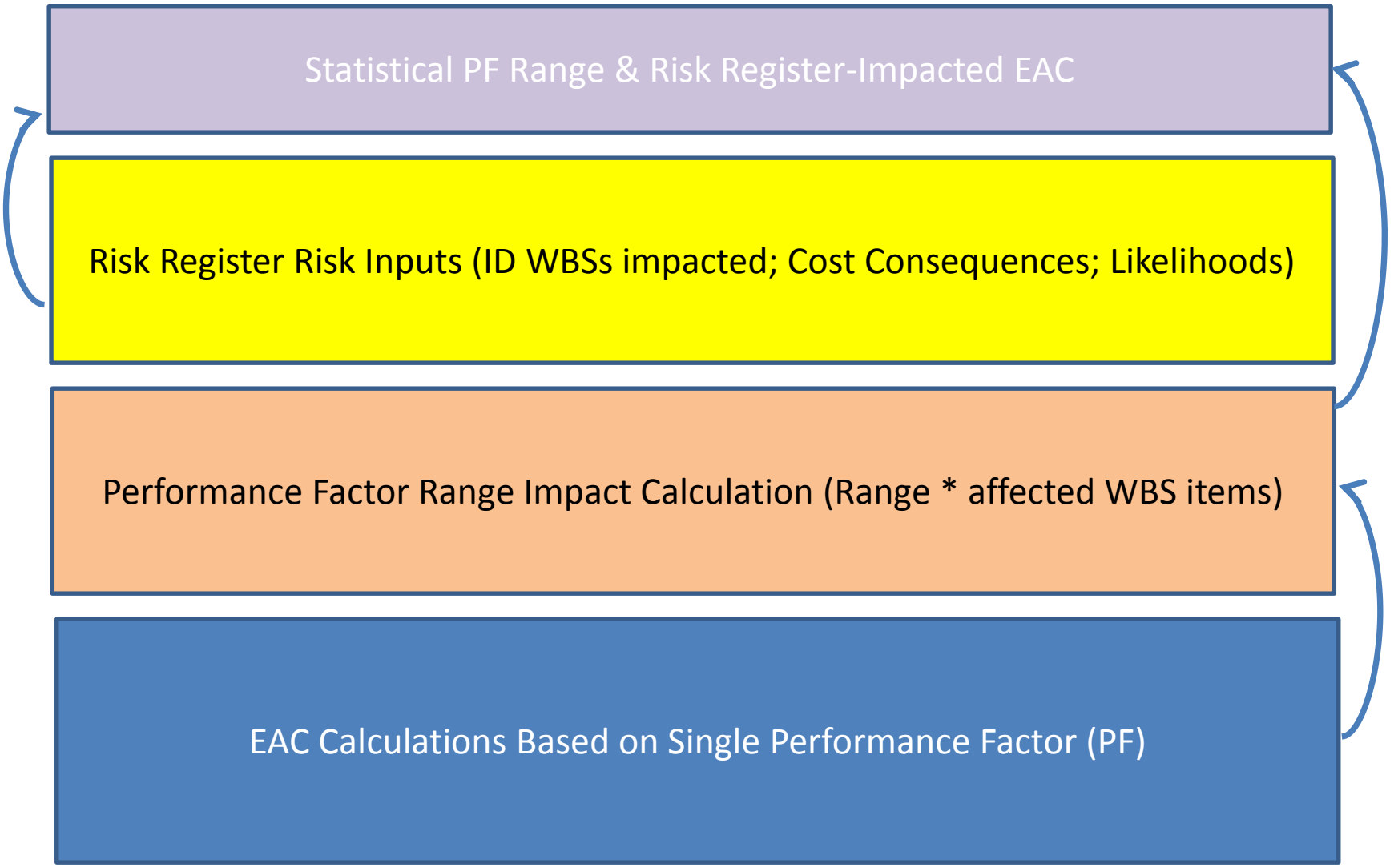
What ICRM in ACEIT Brings

- In latest ACEIT versions ICRM capability is enabled with the new Probability of Occurrence column
- Assume EVM analysts are not proficient ACEIT users but can work with cost estimators proficient in ACEIT in
  - Identifying probabilistic PF-driven WBS-level EACs
  - Producing WBS-level Risk Register-driven cost-risk distributions
- Integration of both probabilistic WBS EVM performance factor-based WBS-level EACs and WBS Risk Register likelihood-based distributions

What ICRM Brings (cont)

- Statistically sums probabilistic WBS EVM performance factor-based WBS-level EACs and WBS Risk Register likelihood-based distributions through monte carlo simulations in ACEIT producing an overall EAC cost-risk distribution
- Enables prioritization
  - By WBS elements most cost-impacted by risks, and
  - By risks causing the most significant cost impacts
- ***These results provide the basis for an ongoing meaningful dialogue that is not happening today between the EVM analysts, technical risk management teams, cost estimators, schedule analysts, project officers and, ultimately, the program managers based on cost impacts caused by risks***

ICRM Model Structure Illustration



DAU EVM 201 LAR Risk Assessment

HIGH:

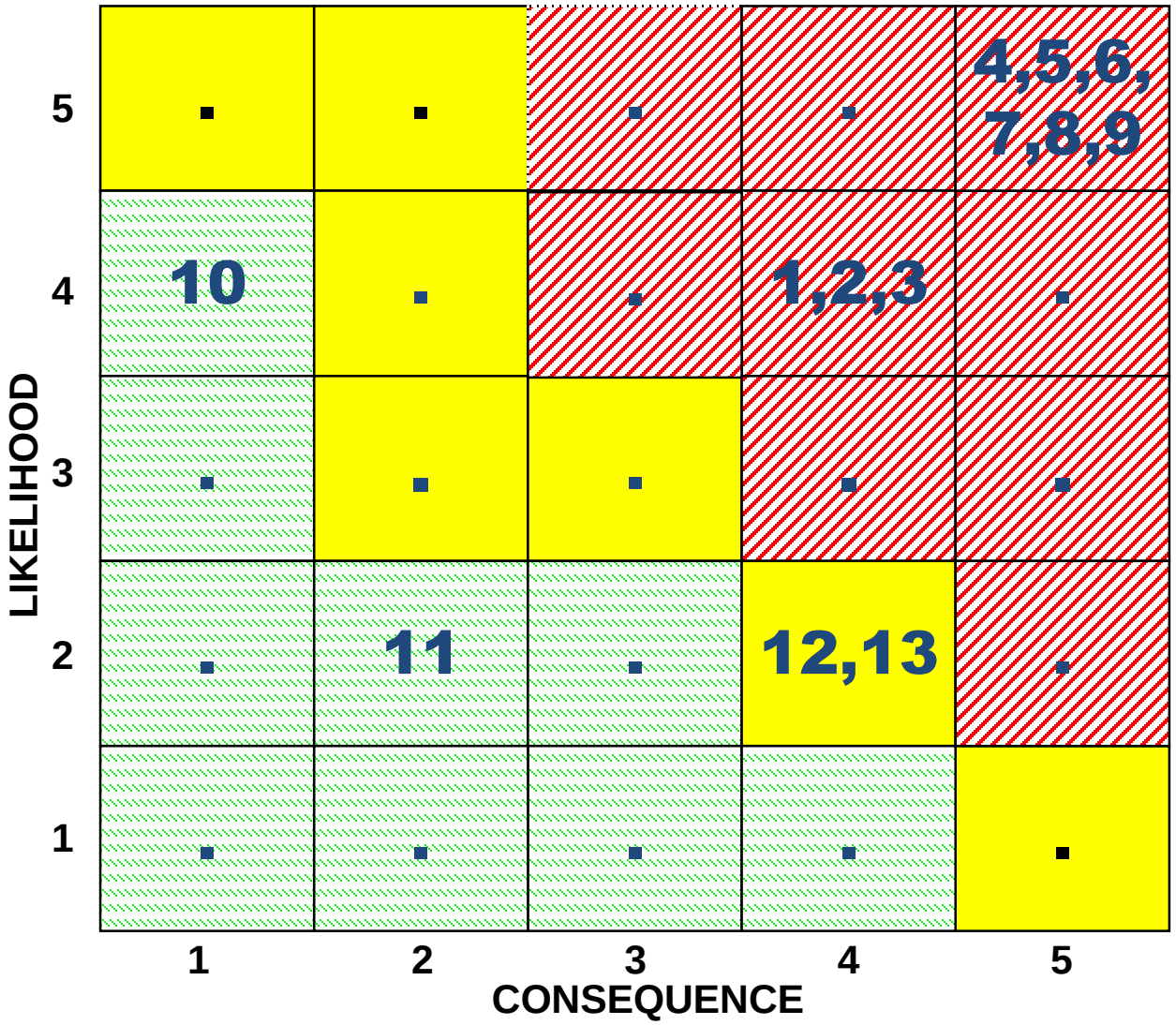
1. Reduce Wheelbase
2. Increase Maneuverability
3. Ruggedize LAR
4. Lower Infrared Profile
5. Reduce LAR Noise
6. Shrink LAR Visible Profile
7. Torque Increase
8. Increase LAR Speed
9. Decrease Pwr Pkg Complexity

MEDIUM:

12. F/U LAR Full Integ Test Failure
13. OTS Parts Failure

LOW:

10. First Unit Integ Test
11. Aux/Auto Sub Sys Function Failures



As of Dec 2003

RISKS ASSOCIATED WITH WBS ELEMENTS ALONG WITH LIKELIHOODS AND IMPACTS

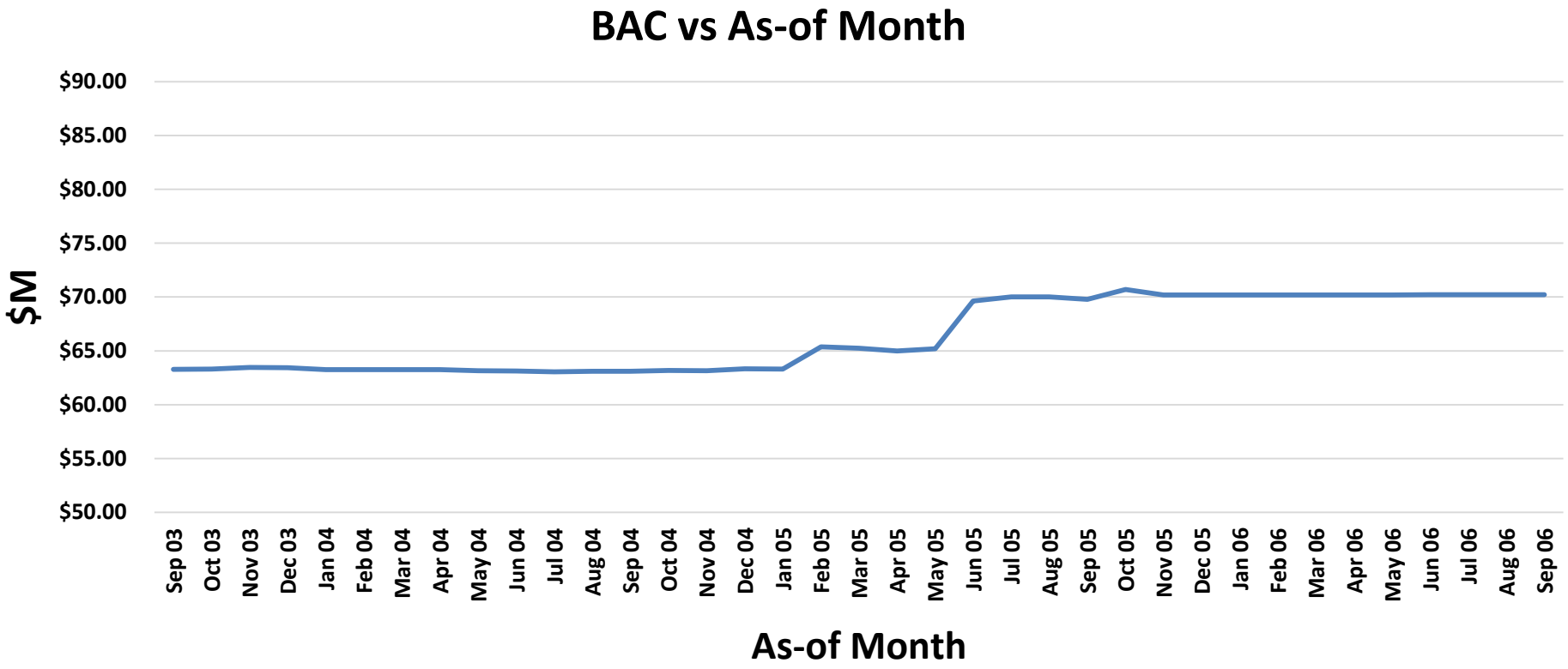
Likelihood	61-80%	61-80%	61-80%	81-99	81-99	81-99	81-99	81-99	81-99	61-80	21-40	21-40	21-40
Impact	15-20%	15-20%`	15-20%`	23-28	23-28	23-28	23-28	23-28	23-28	5-10	5-10	15-20	15-20
	1	2	3	4	5	6	7	8	9	10	11	12	13
WBS/ICES Description	LAR vehicle won't fit into helicopter because wheelbase is too wide (Reduce Wheelbase)	LAR vehicle lacks necessary maneuverability (Increase Maneuverability)	LAR vehicle cannot withstand expected rough enemy terrain (Ruggedize LAR)	LAR vehicle still too visible in infrared spectrum (Shrink LAR Infrared Profile)	LAR vehicle too loud to disguise presence (Reduce LAR Noise)	LAR vehicle's visible profile too high (Shrink LAR Visible Profile)	LAR vehicle cannot generate enough torque for expected performance on hills (Torque Increase)	LAR vehicle's top speed too low (Increase LAR Speed)	LAR engine's, exhaust's and cooling's complexity too high for reliability (Decrease Pwr Pkg Complexity)	LAR vehicle first unit integration test of armament system components (First Unit Integ Test)	(Aux/Auto Sub Sys Function Failures) Changes to surrounding subsystems can cause internal LAR AUX/AUTO electrical and electronic subsystems; on-board diagnostics/prognostics system; fire extinguisher system and controls; chassis mounted	No prototype history of LAR vehicle overall integration testing (F/U LAR Full Integ Test Failure)	Off-the-shelf components not meeting stricter militar standards (OTS Parts Failure)
1.1 - Prime Vehicle													
1.1.1 - Frame	x	x	x	x		x							
1.1.2 - Suspension/Steering	x	x	x										
1.1.3 - Power Package													
1.1.3.1 - Engine				x	x		x	x	x				
1.1.3.10 - Cooling System				x					x				
1.1.3.9 - Exhaust System				x	x				x				
1.1.3.A - Other													
1.1.4 - Auxiliary Auto				x							x		
1.1.5 - Armament										x			
1.1.6 - Body/Cab	x		x			x							
1.1.7 - Communications											x		
1.1.8 - Integ & Assembly	x	x	x							x	x	x	x
1.2 - System Program Mgt													
1.2.1 - Project Management													
1.2.2 - Systems Engineering	x	x	x	x	x	x					x	x	x
1.3 - System Test & Eval													
1.3.1 - Acceptance Test Plan													
1.3.2 - DT & OT Testing													
1.3.3 - Mock-Ups													
1.3.4 - Test & Eval Support	x	x		x	x					x	x	x	x
1.4 - Training											x		
1.5 - Systems Data													
1.5.1 - Engineering Data											x		x
1.5.2 - Management Data													
1.6 - Peculiar Support Equip													
1.6.1 - Test & Measurement											x	x	x

- Affected WBS elements inherit risk likelihoods and cost consequence impact percentages
- EVMTT/ICRM complementarity: EVMTT BAC projection can be apportioned to affected WBS element BACs IAW Risk Register and Risk Management Team's recommendations

BACKUP

DAU Light Assault Reconnaissance (LAR) Vehicle

BAC Linearity Growth Trend Over Time

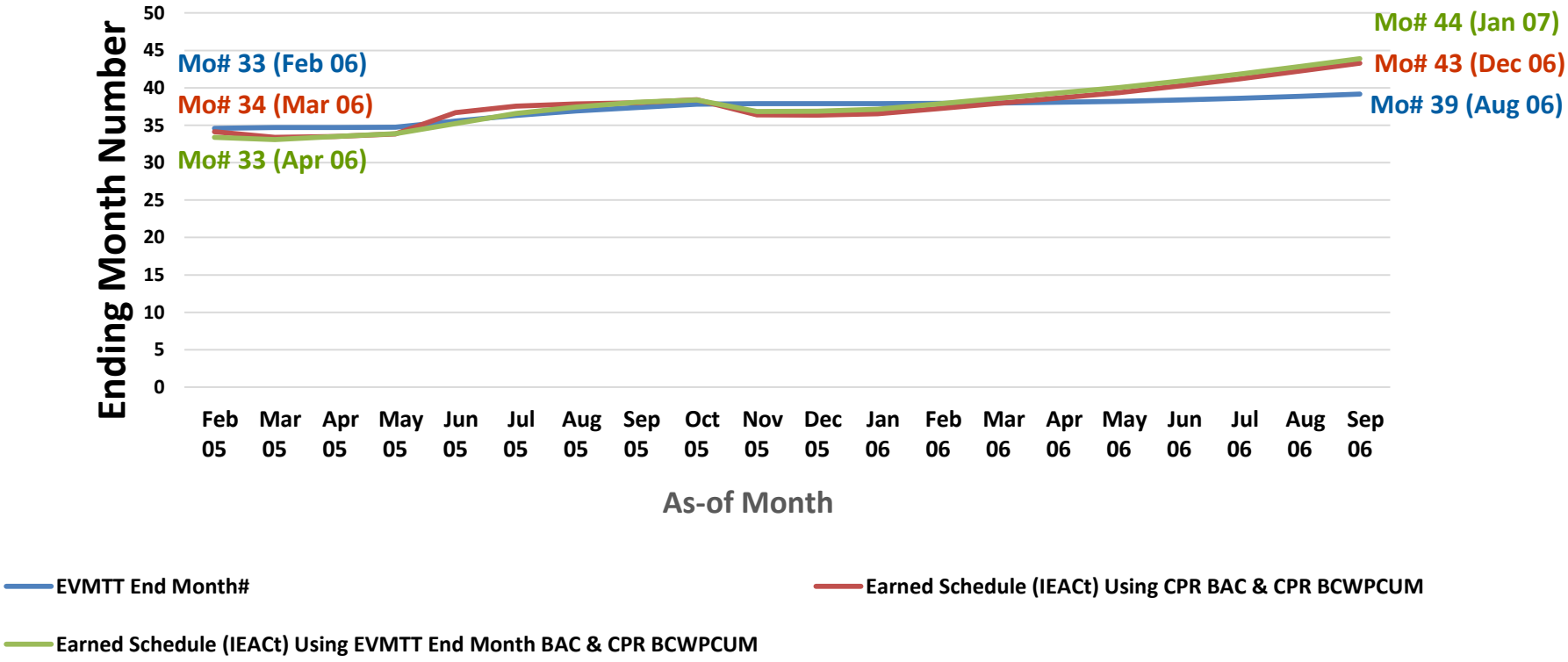


- Graph indicates good linearity over whole span of time of data provided
- ***Applicable for EVMTT linear regression approach***

DAU LAR Vehicle

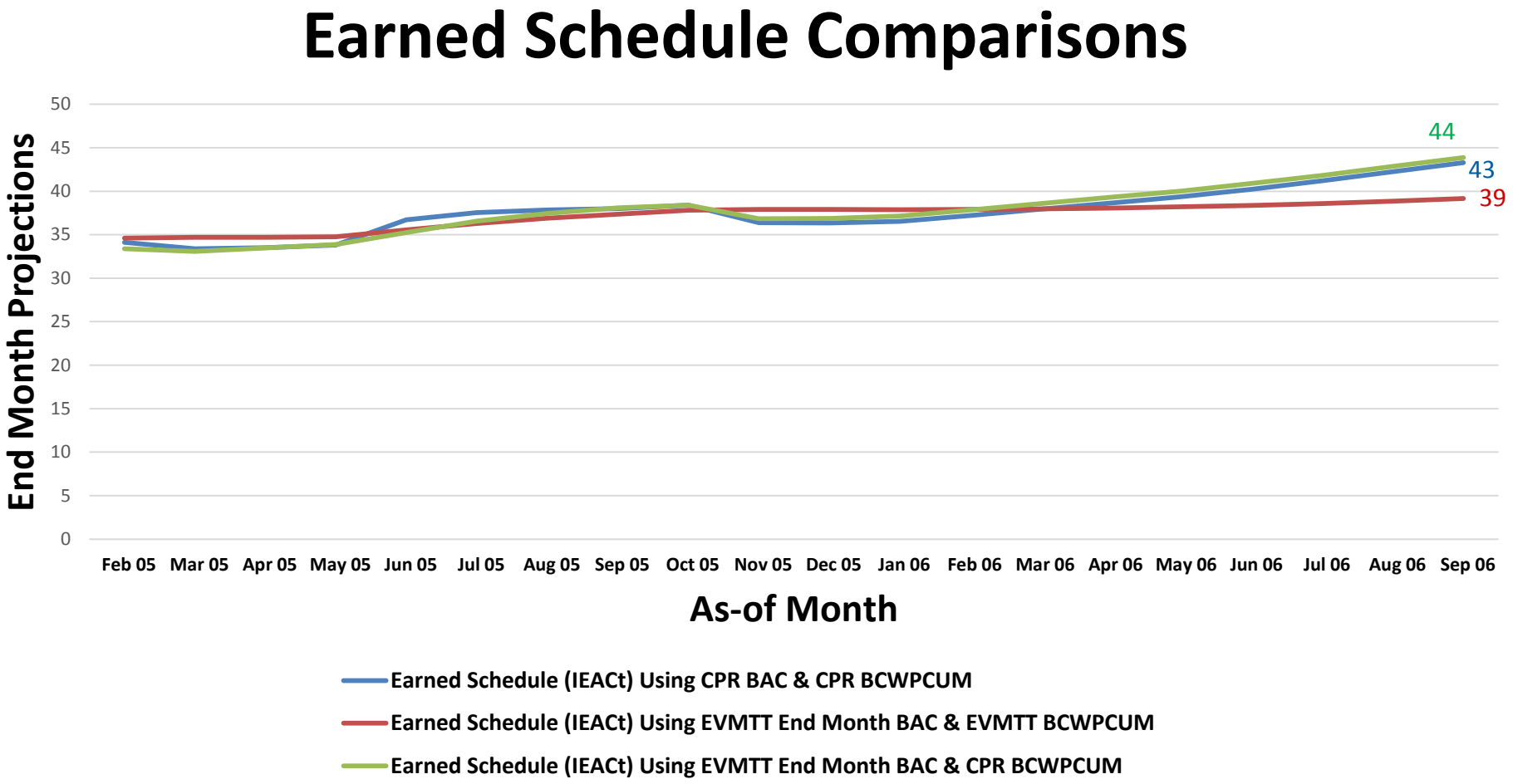
End Month Projection Comparisons

$EVMTT_{EndMo\#}$ vs 2 CPR-Based ES Projections



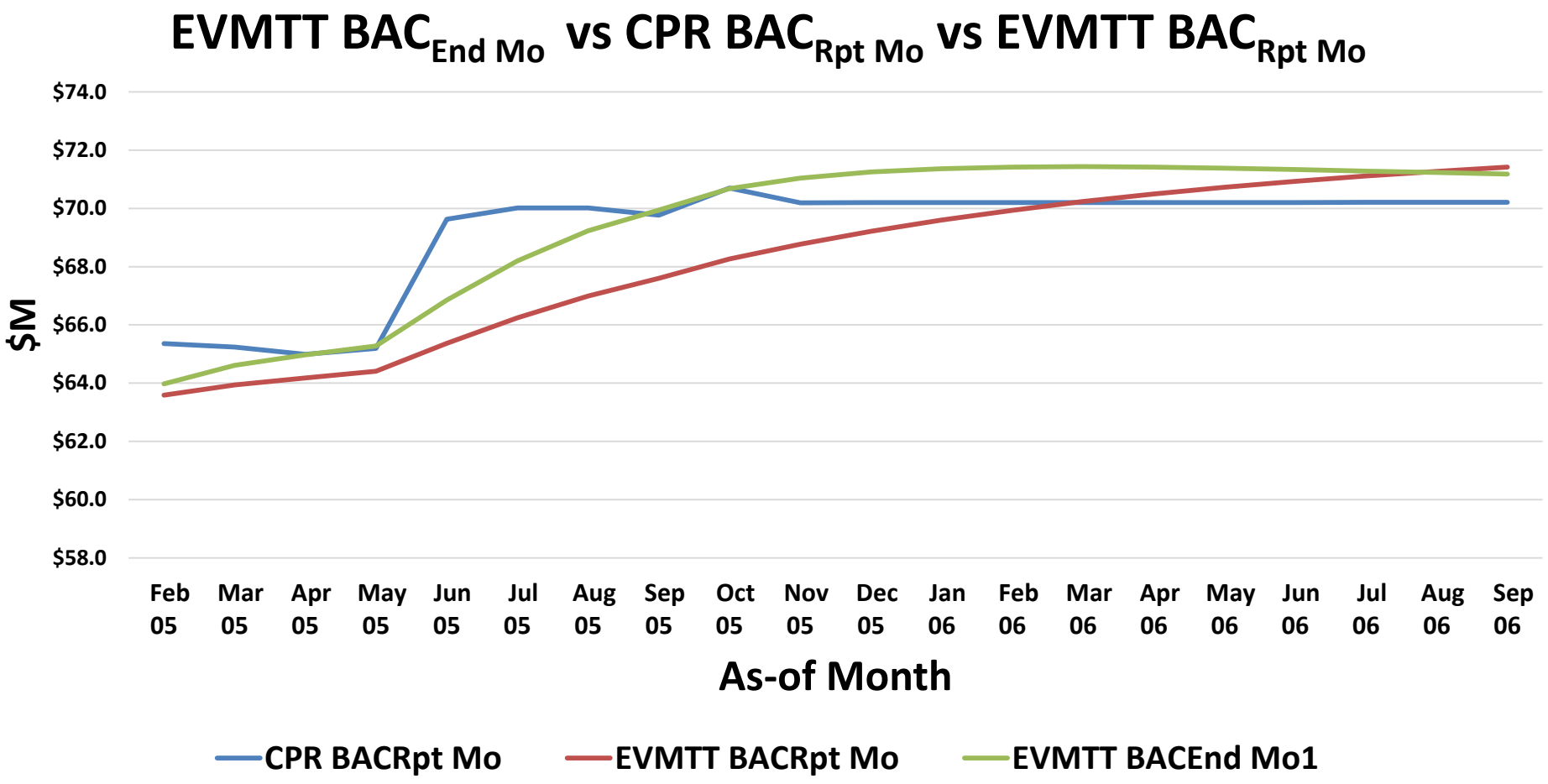
- $EVMTT_{EndMo\#}$ projects a one-month early finish
- Earned Schedule calculations project later finishes, 3-months & 4-months
- ***Reason: ES projections rely on EVM performance and not just BAC changes***

LAR Earned Schedule



- EVMTT-based ES projects lowest end month due to focus on BAC growth rate
- ***Both more CPR-based ES projects higher end months due to incorporating more current EVM performance***

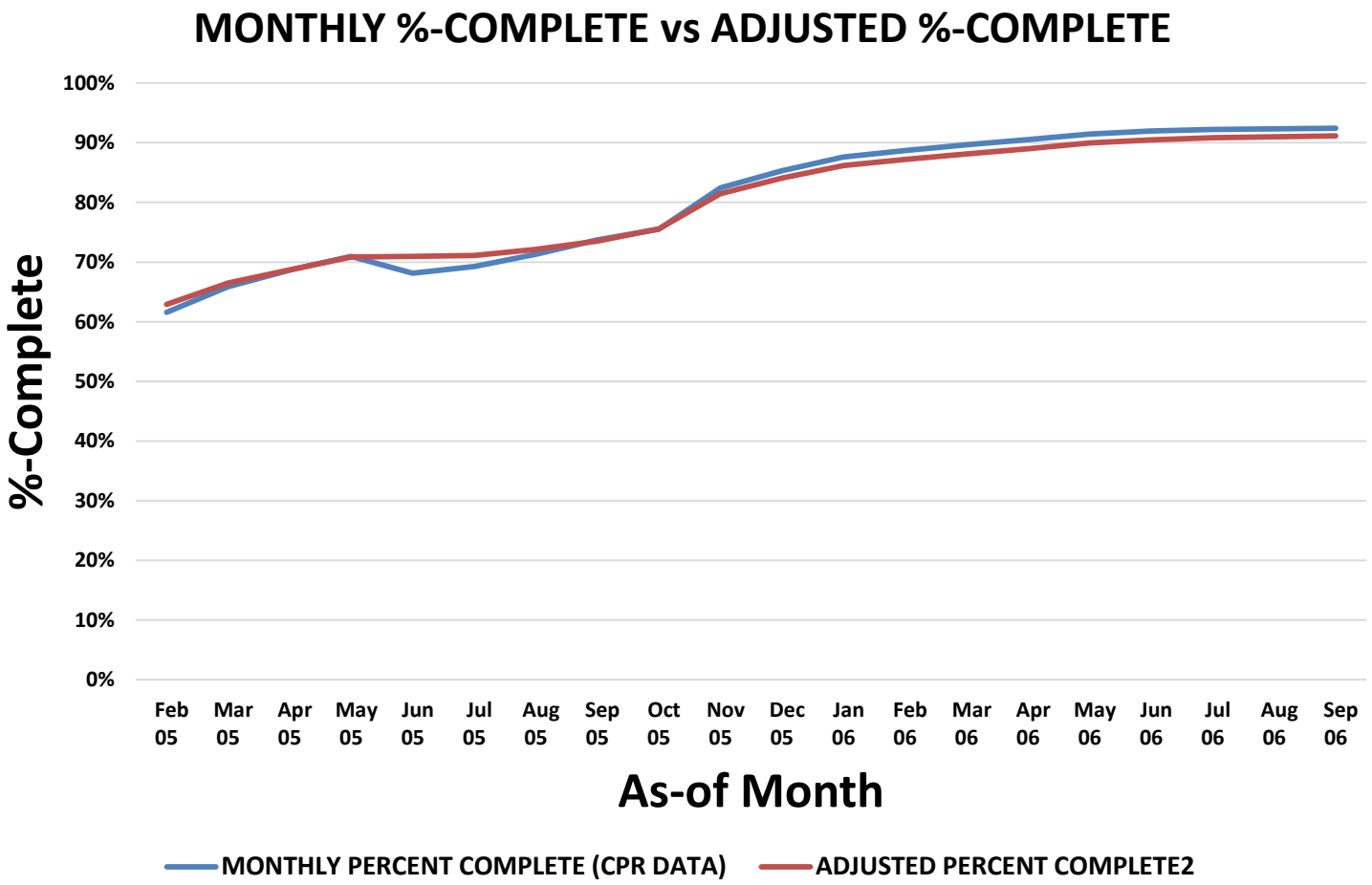
LAR BAC Comparisons



- ***Not much difference between CPR and EVMTT projected ending BACs due to low rate of BAC growth***

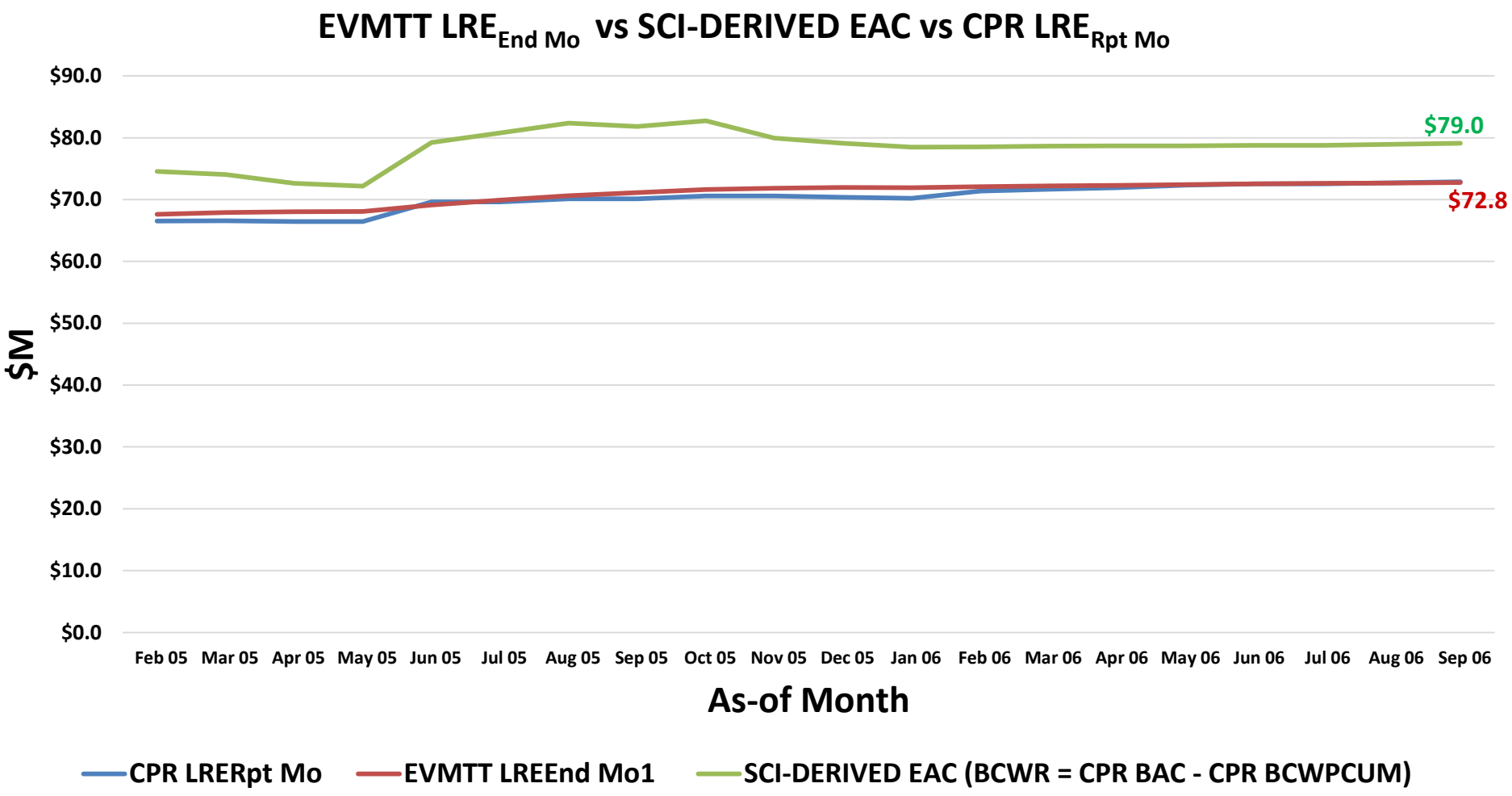
DAU LAR Vehicle

%-Complete Comparisons



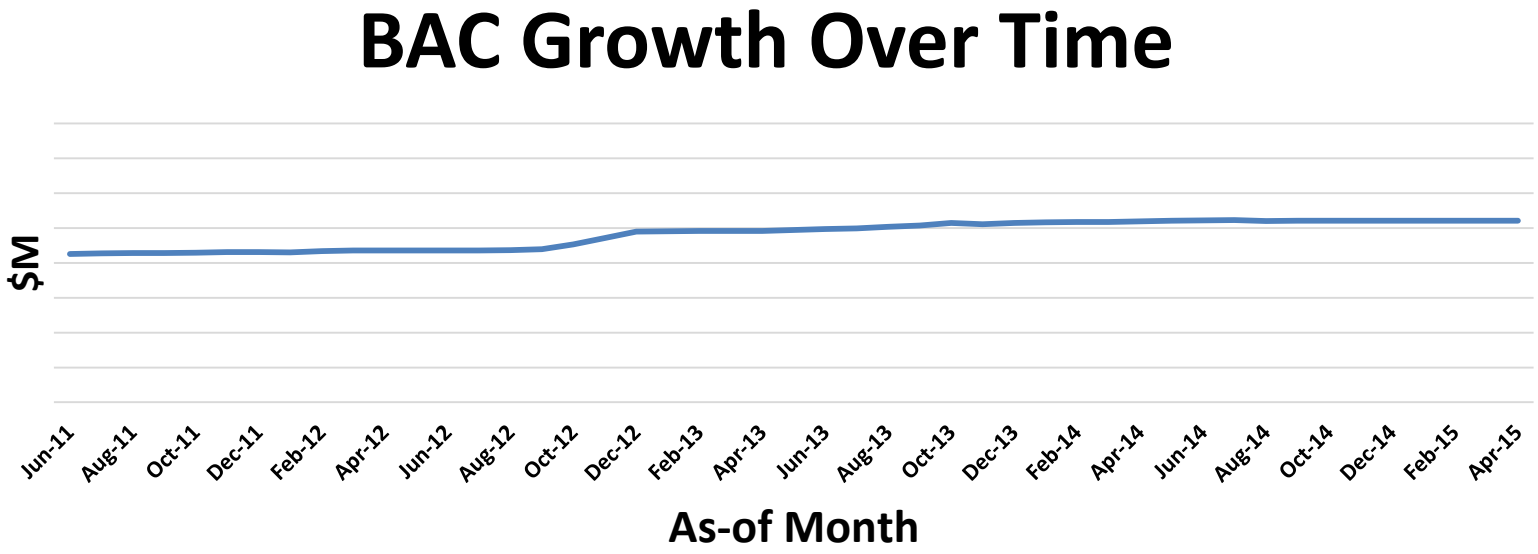
- EVMTT %-Complete calculations are based on CPR BAC vs EVMTT$_{EndMo}$ BAC
- ***Since there were so few BAC increases, the two %-Complete calculations were practically the same over the EVM data provided***

LAR EVMTT, CPR & SCI-Derived LRE/EAC



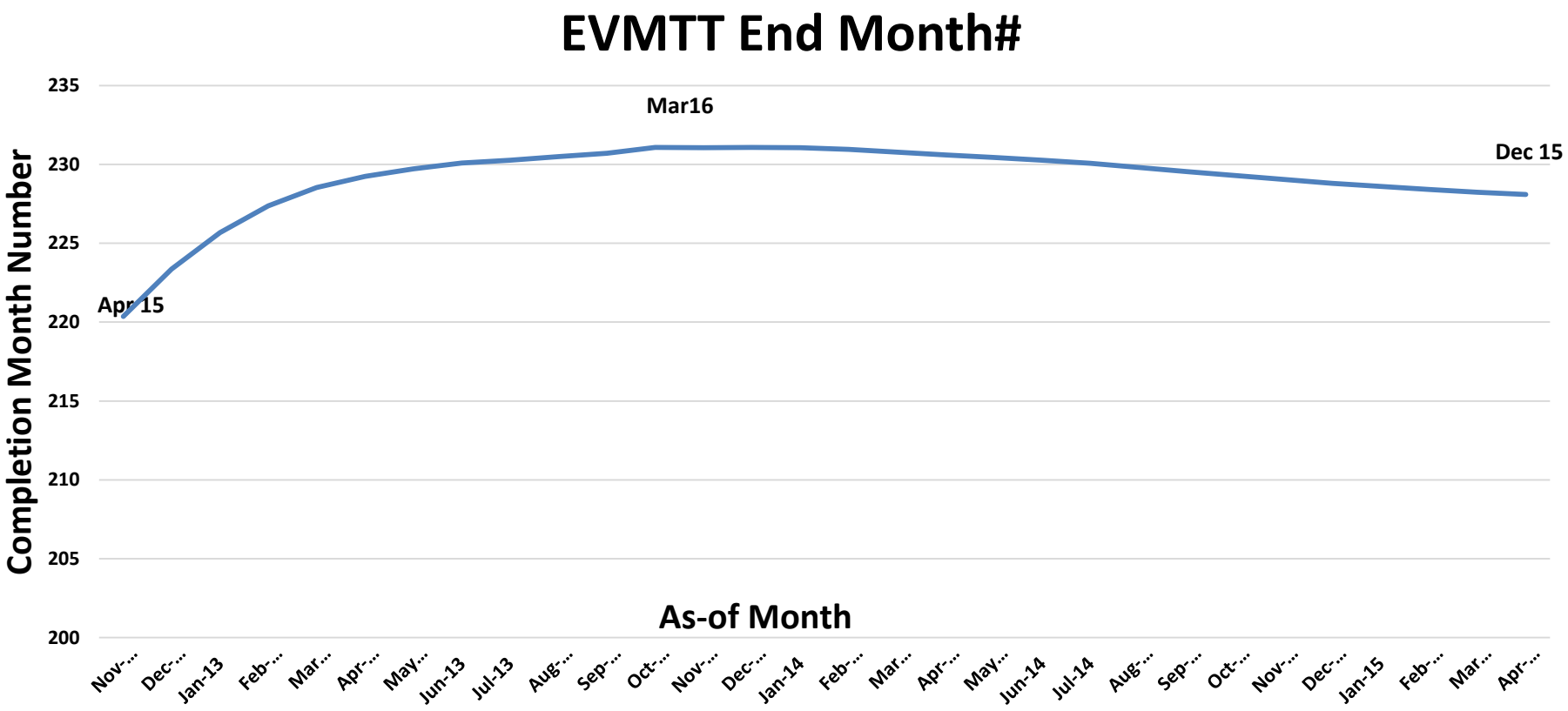
- EVMTT LRE_{EndMo} projects only modest LRE increase since it is based on stable BAC
- ***SCI-Derived EAC projects 8.5% increase over both EVMTT LRE_{EndMo} and CPR LRE due to being based on EVM cost performance vice growing BAC***

SMC Example #2:
BAC Growth Trend Over Time



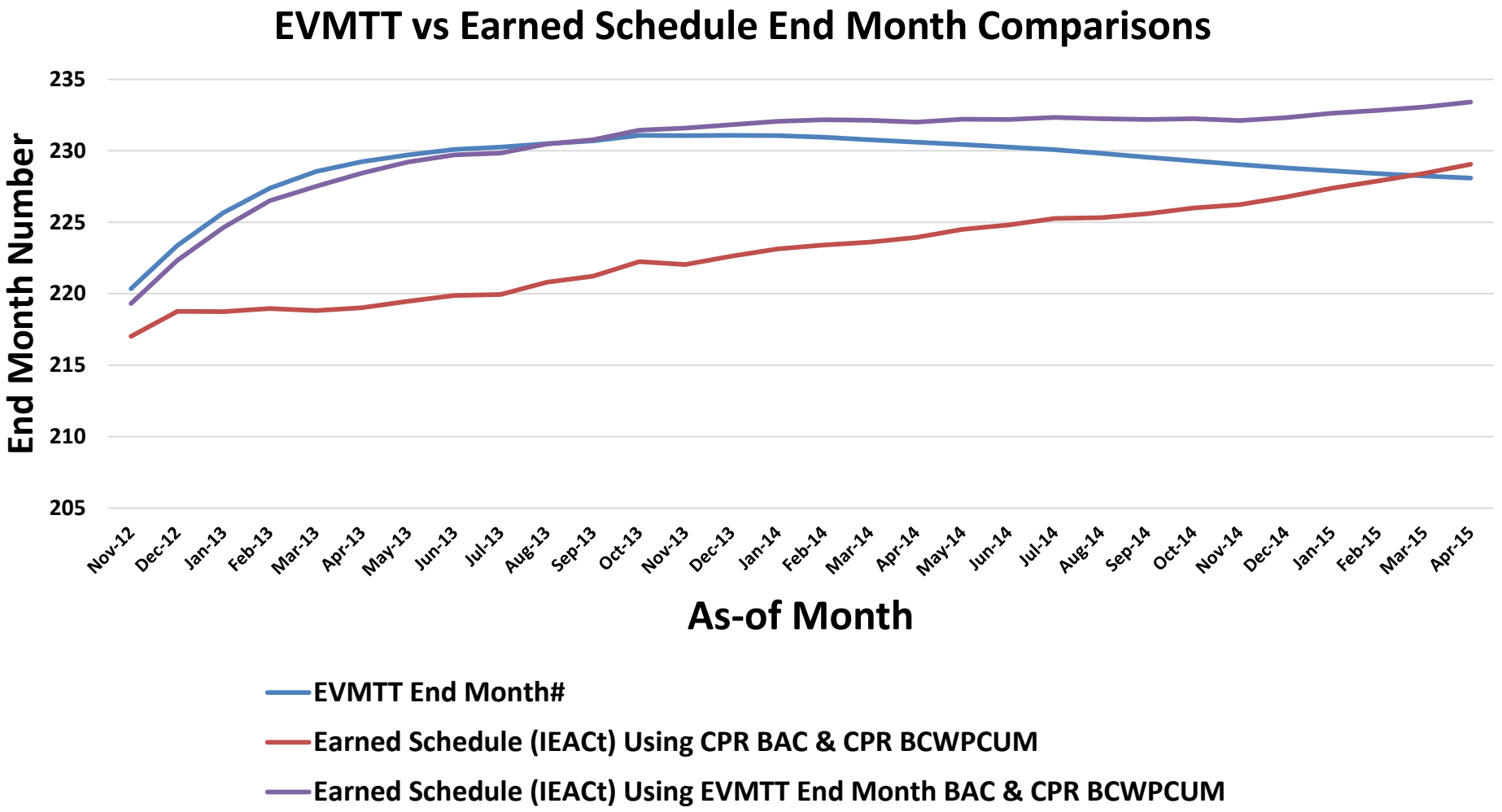
- Span of data used for EVMTT analysis was Jun 11-Apr 15
- ***Graph indicates good linearity over time, magnitude of the increases well within bounds for linearity***

SMC #2 Completion Month Trend



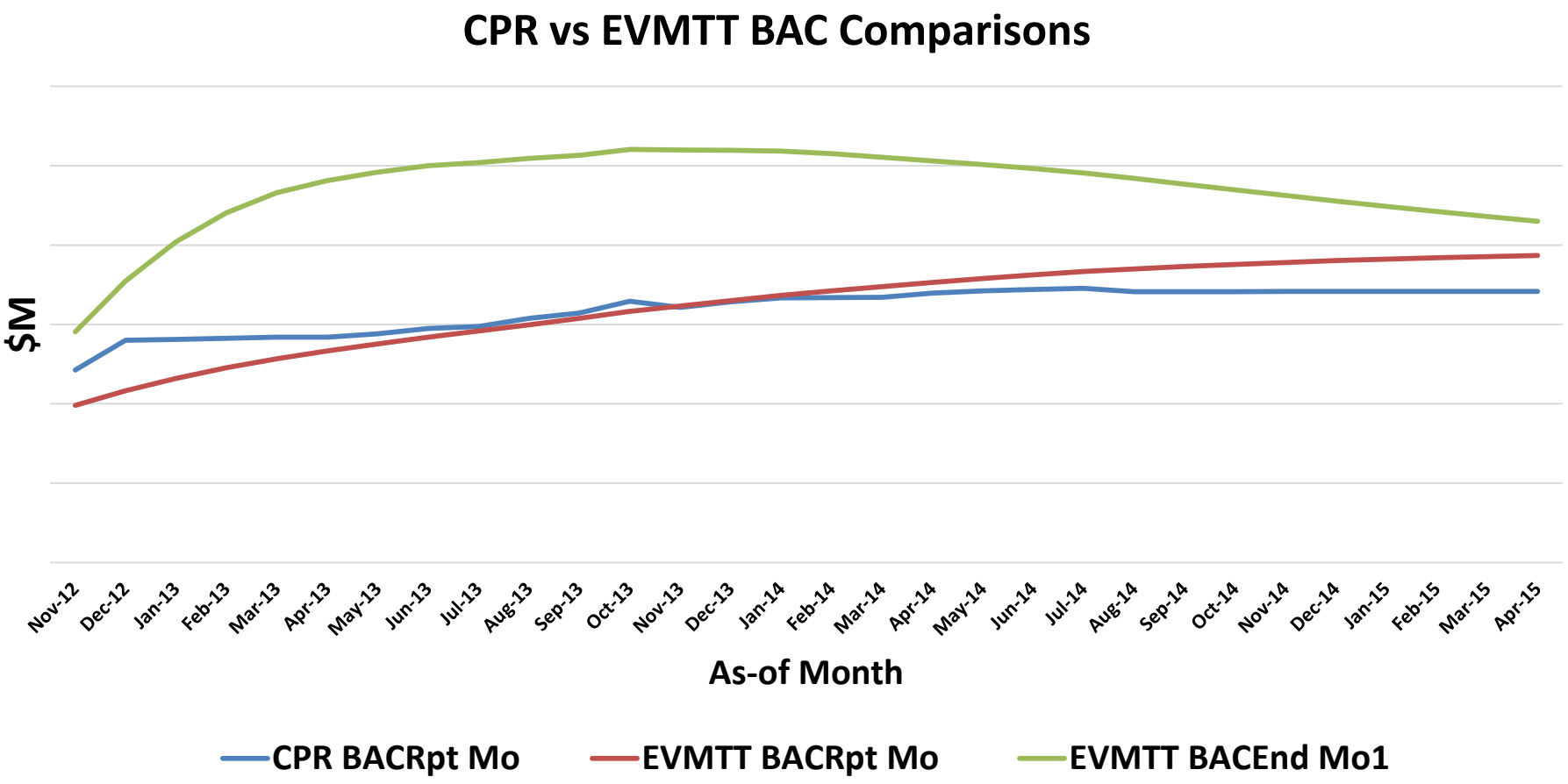
- The initial Completion Month projection in Nov 12 was month #220 (April 15), peaked in Oct 13's projection at month #231 (Mar 16) and decreased in Apr 15's projection to month #228 (Dec 15)
- ***In contrast, the contractor's end month is now Apr 17 which is not supported by EVM data***

SMC #2 Earned Schedule Comparisons



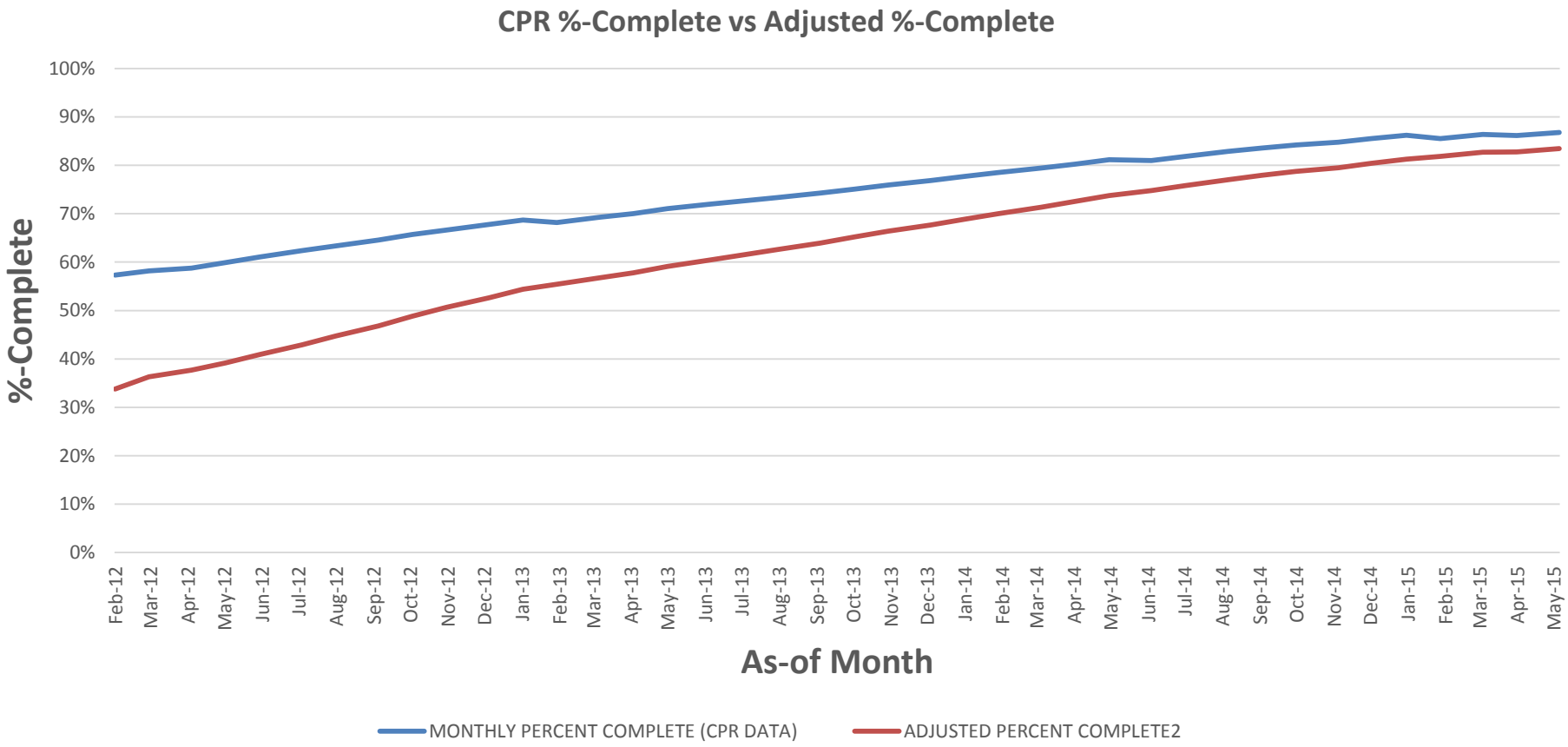
- $EVMTT_{EndMo\#}$ projections spanned Apr 15 – Dec 15
- ES using only CPR BAC & CPR $BCWP_{CUM}$ projections spanned Jan 15 – Jan 16
- ***ES using EVMTT BAC $_{End\ Mo}$ & CPR $BCWP_{CUM}$ projected the highest end month spanning Mar 15 – May 16***

SMC #2 BAC Comparisons



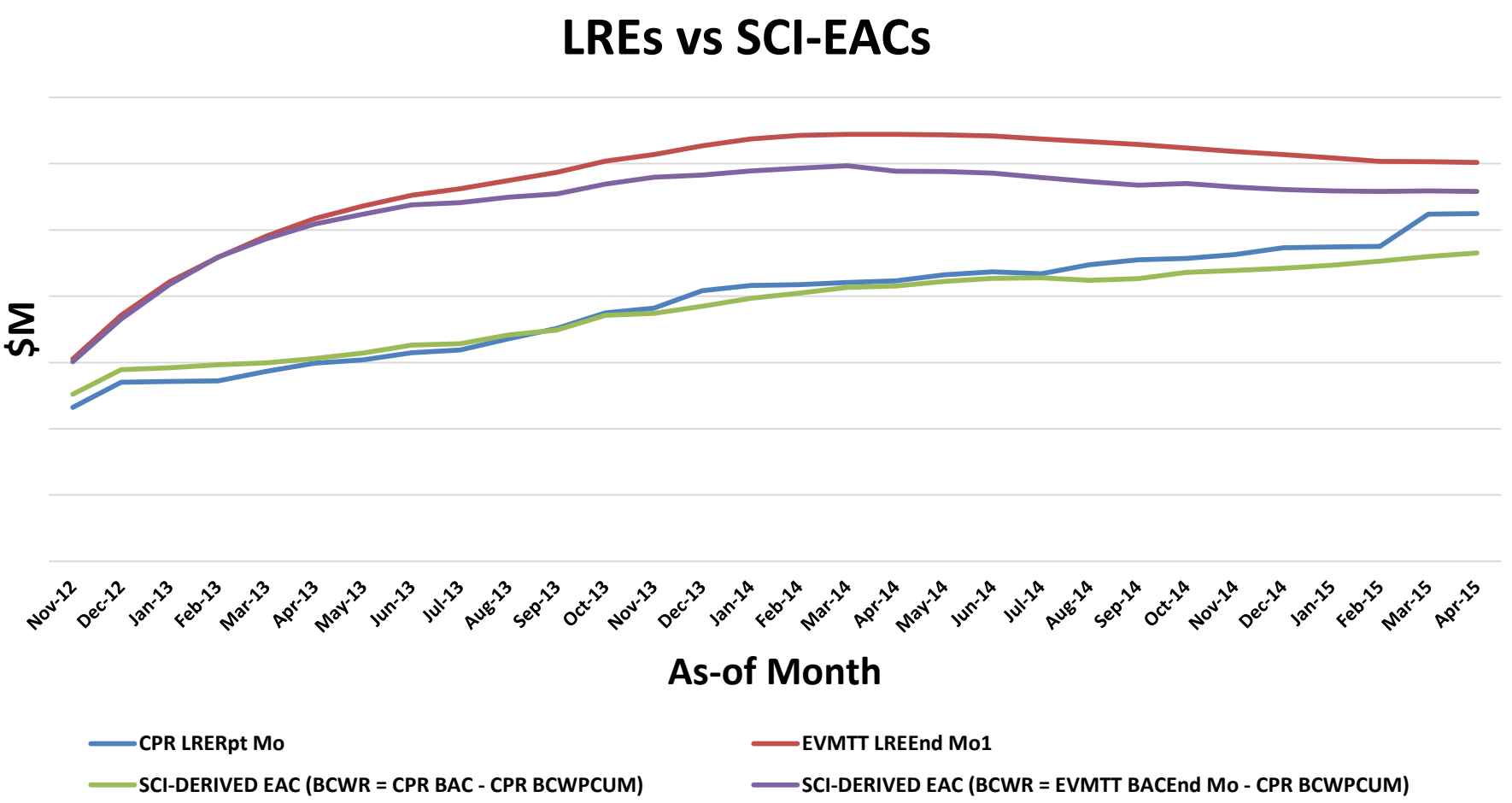
- ***Despite initial jump in BAC in EVMTT End Month BAC, over time a lack of BAC growth allowed the EVMTT projection to converge near the level of CPR reported BAC***

SMC #2 %-Complete Comparisons



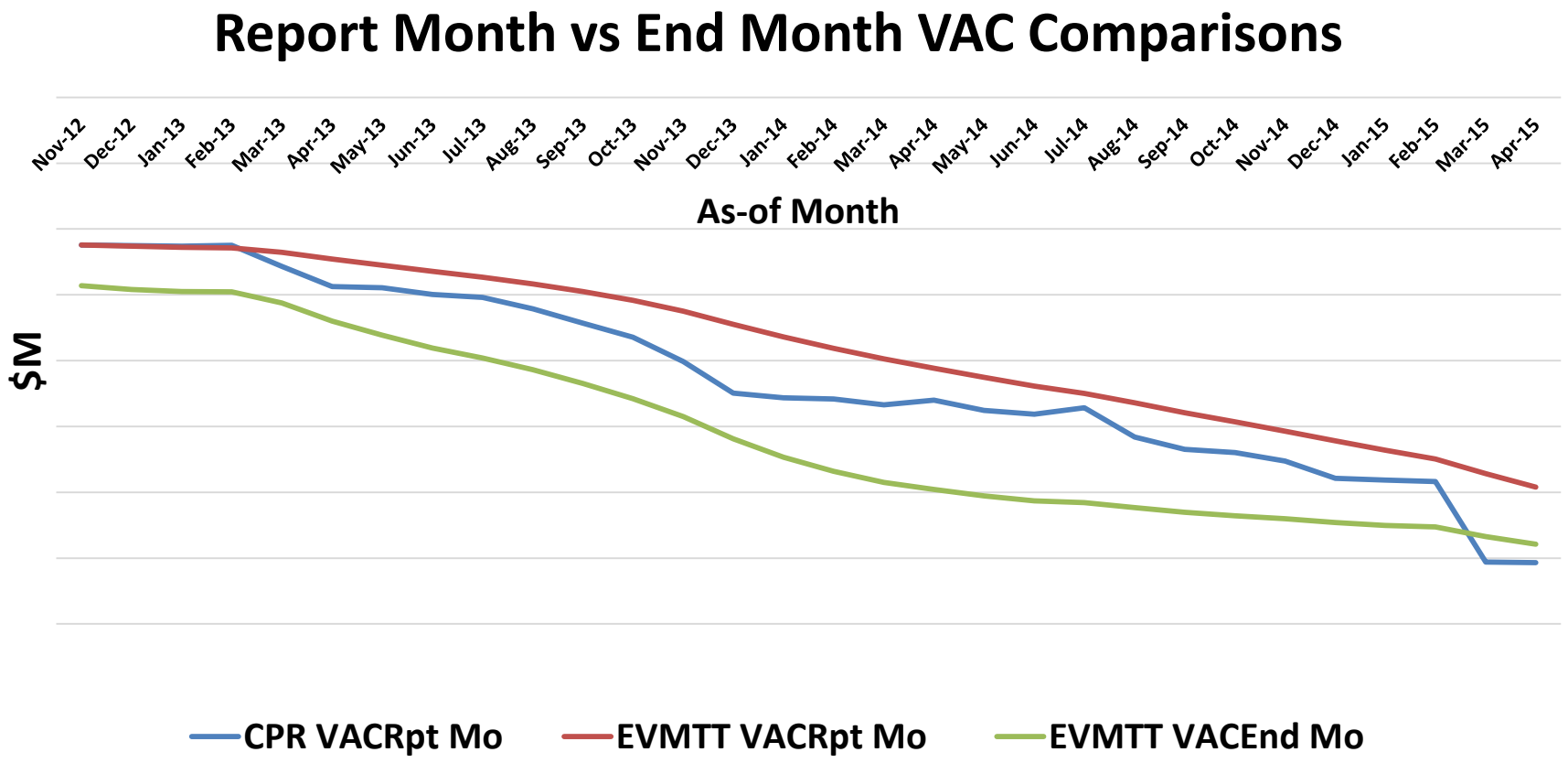
- ***Early BAC increase volatility which gave way to convergence over time***

SMC #2 SCI-Derived EAC Trend



- There has been a ***decrease*** in the CPI from 0.98 @ Nov 12 to 0.95 @ Apr 15
- ***EVMTT LRE_{EndMo} and SCI-Derived EAC using EVMTT BAC_{EndMo} as well as the CPR LRE and SCI-Derived EAC have increased over time thus indicating potential problems***

SMC #2 Projected VAC Decrease Over Time



- There has been a negative trend observed in the CPR monthly Variance at Completion (VAC) along with a corresponding EVMTT VAC projections
- ***This is direct EVMTT evidence of some growing problems and is consistent with the contractor's latest completion month estimate***

Conclusions DAU LAR & SMC Case Study #2

- DAU LAR case study data had minimal BAC increases so EVMTT-based results showed minimal differences with CPR-based reports
  - However, when EVM performance-based methods were used, end month and EAC projections were higher
- SMC Example #2 also had minimal BAC increases over time but decreasing cost performance trends showed up in ever increasingly negative VACs
  - Plus, the contractor is proposing end month projections beyond what would be expected