SE/IT/PM Factor Development Using Trend Analysis

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Purpose of the Study

- Predict Systems Engineering, Integration & Test, and Program Management (SE/IT/PM) for ongoing programs

- Study examines the SE/IT/PM for Space System, Space Segment, and Ground Segment

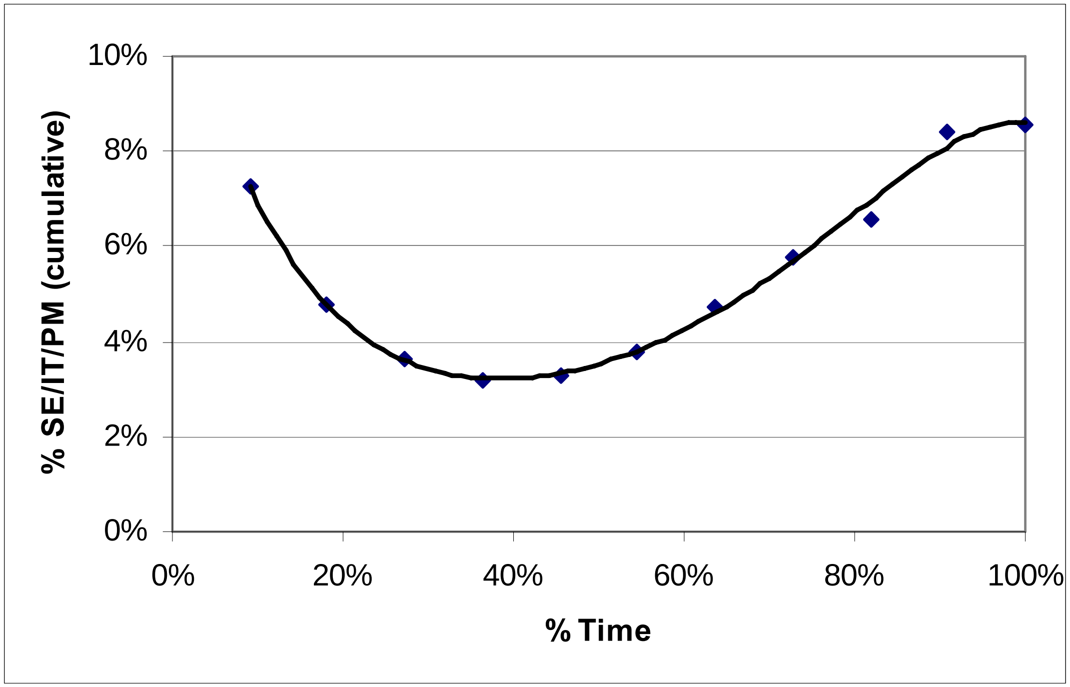
WBS Structure [1]	
1.0	Space System
1.1	SE/IT/PM
1.2	Space Segment (Spacecraft)
1.2.1	SE/IT/PM
1.2.2	Bus
1.2.3	Mission & Comm PL
1.3	Ground
1.3.1	SE/IT/PM

$$\% = \frac{\text{SE/IT/PM \$}}{\text{HW/SW \$}}$$

1. From MIL HDBK 881A

Basic SE/IT/PM Trend Concept

- Trend exists between SE/IT/PM, as a function of the base, and time
- Possible to predict the final cumulative SE/IT/PM % from current % complete and % SE/IT/PM

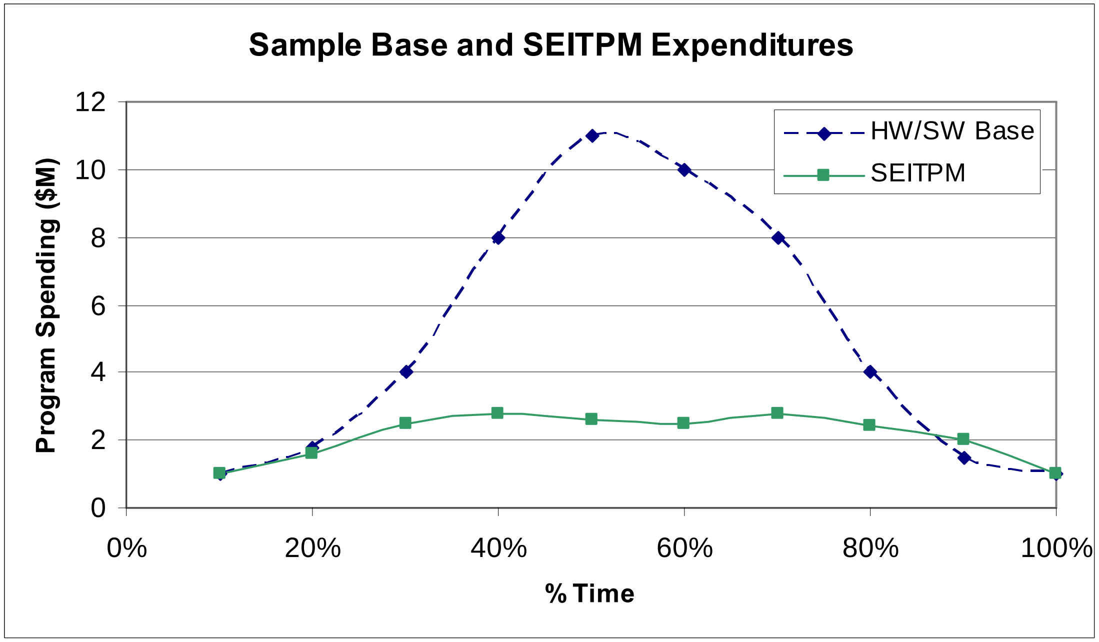


% SE/IT/PM = *ƒ*(time)

Y-axis represents cumulative SE/IT/PM %

X-axis represents the percent time complete
(4 years into a 10-yr schedule is 40 % complete).

Time-Phased SE/IT/PM Analysis

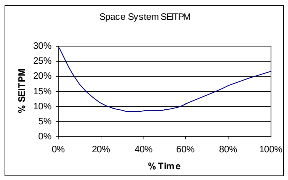


Program Timeline	Beginning	Mid-Program	End of Acquisition
Dominant Components of SE/IT/PM	Primarily PM and SE; high SE/IT/PM percentage	Production levels increase, SE/IT/PM becomes a smaller percentage of the hardware and software cost base	Mostly I&T; cumulative SE/IT/PM ratio increases again.

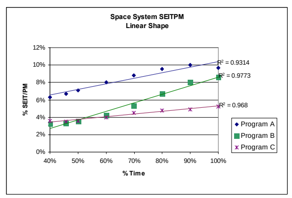
Agenda

% Complete	Cumulative SEIT/PM Ratio	Factor of Complete
10%	6.91%	80%
20%	4.43%	51%
30%	3.42%	40%
40%	3.22%	37%
50%	3.53%	41%
60%	4.24%	49%
70%	5.33%	62%
80%	6.69%	78%
90%	8.00%	93%
100%	8.61%	100%

Factor of Complete (FC)

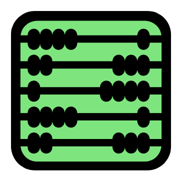


SE/IT/PM Levels



Alternative Approaches

Traditional Methods



Sample Method Application

σ **Estimating Uncertainty**

Factor of Complete Method

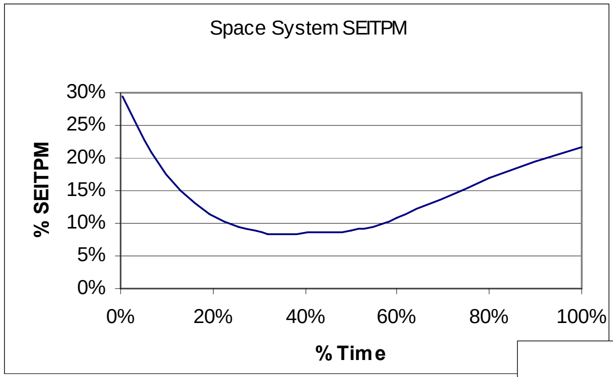
- Factor of Complete (FC) is used as a multiplier to scale SE/IT/PM at a particular point in the program
- FC is the ratio at a given % complete to the predicted final cumulative SE/IT/PM
- For example, a program 4 years into a 10 year schedule would be 40% time complete and could be divided by a factor of 0.37 to reach the program's final cumulative SE/IT/PM percentage

% Complete (by time)	Cumulative SEIT/PM Ratio	Factor of Complete
10%	6.9%	0.80
20%	4.4%	0.51
30%	3.4%	0.40
40%	3.2%	0.37
50%	3.5%	0.41
60%	4.2%	0.49
70%	5.3%	0.62
80%	6.7%	0.78
90%	8.0%	0.93
100%	8.6%	1.00

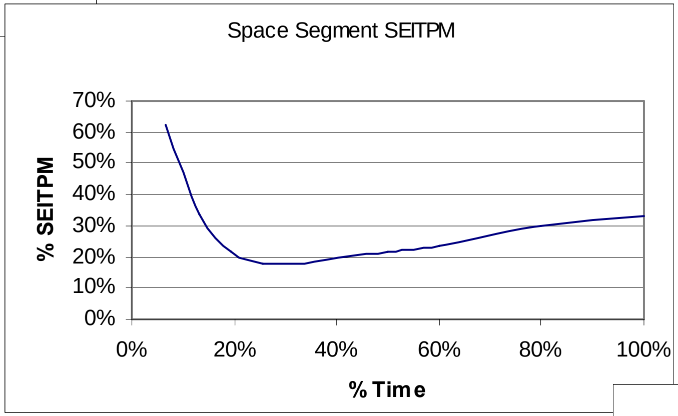
$$FC = \frac{SE/IT/PM_{CURRENT}}{SE/IT/PM_{FINAL}} = \frac{3.2\%}{8.6\%} = 37\%$$

***Note that % complete is based on Schedule Estimating Relationship (SER)**

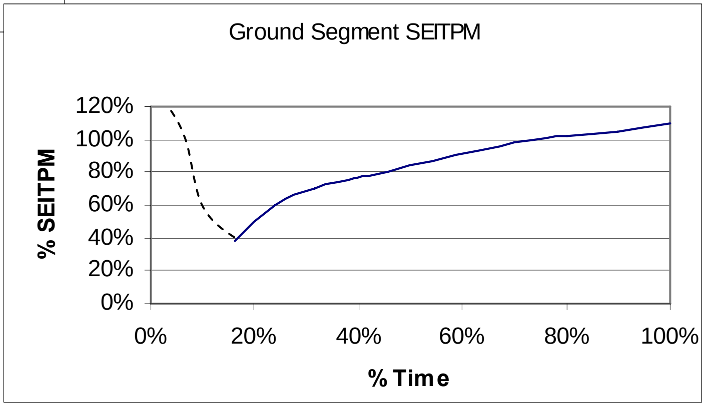
SE/IT/PM at Different WBS Levels



Space System:
Ground, Space, Launch



Space Segment:
Mission and Comm Payloads, Bus



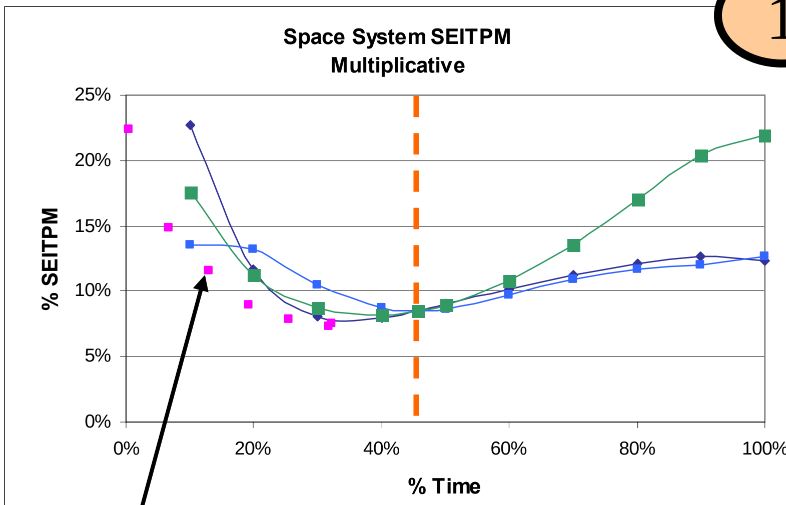
Ground Segment:
Hardware and Software

The study was performed on SE/IT/PM at three WBS levels of

Datasets for each respective WBS item had similar shapes

Alternative Approaches

1

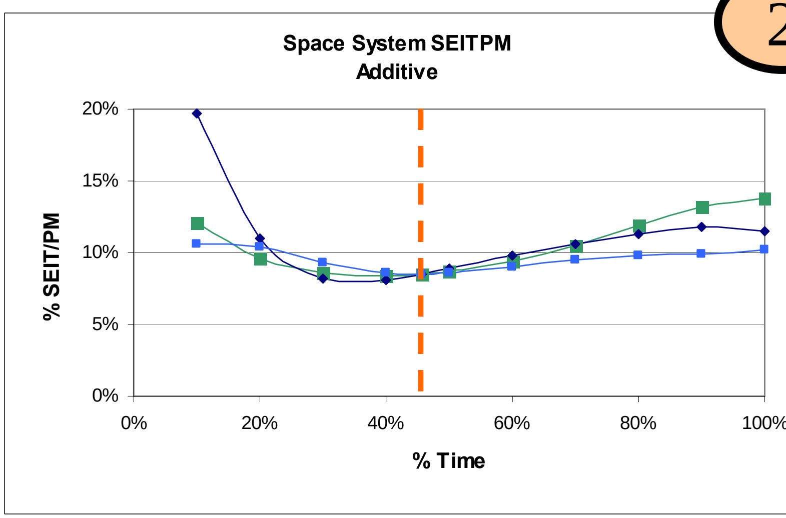


In-process program

Using the same set of data, one could follow these approaches:

	Alternative Approaches	
1	Factor of Complete (Multiplicative)	Trend line is *scaled* to actuals
2	Additive	Trend line is *shifted* to actuals
3	40% Steady-State	Trend line becomes straight line at 40% complete

2



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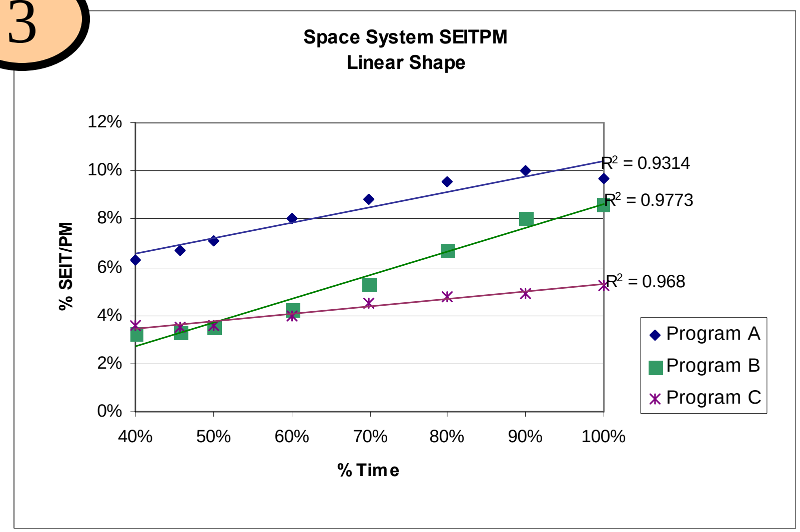


* We discuss the Multiplicative FC method in the rest of the briefing.

Traditional Methods

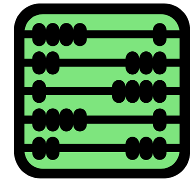
Pre-ATP CER

In-progress CER

- Parametric
  - Factor applied to a base; not helpful for in-process programs
- Staffing Level
  - Predict staffing profile based on historical programs; unpredictable shape
- Earned-Value
  - Adjust predicted value with Schedule/Cost Performance Indices
- Level-of-Effort as a Function of Time
  - Predicting run-out of a program’s established staffing profile; difficult to use historical data
- Fixed-Percentage Extrapolation
  - Current SE/IT/PM percentage is applied to remainder of program

Most traditional methods do not take into account both historical data and current program percentage in predicting SE/IT/PM

Sample Method Application



Problem: Program is 33% complete using schedule estimate

Estimate final SE/IT/PM %, given 8.4% SE/IT/PM at 33% complete

	Factor of Complete (FC)				
% Complete	Program A	Program B	Program C	Mean	Std Dev
10%	1.04	0.80	1.84	1.23	0.543
20%	1.03	0.51	0.95	0.83	0.275
30%	0.83	0.40	0.66	0.63	0.217
33%	*0.77*	*0.38*	*0.63*	0.60	0.198
40%	0.68	0.37	0.65	0.57	0.169
50%	0.67	0.41	0.73	0.60	0.171
60%	0.75	0.49	0.83	0.69	0.176
70%	0.86	0.62	0.91	0.80	0.155
80%	0.92	0.78	0.98	0.89	0.105
90%	0.93	0.93	1.03	0.96	0.060
100%	1.00	1.00	1.00	1.00	0.000

Solution: The mean FC at 33% time is 0.60. Therefore, 8.4% is 60% of the final cumulative system level SE/IT/PM

$$FC = \frac{SE/IT/PM_{CURRENT}}{SE/IT/PM_{FINAL}} \quad \Rightarrow \quad SE/IT/PM_{FINAL} = \frac{SE/IT/PM_{CURRENT}}{FC} = \frac{8.4\%}{0.60} = 14\%$$

→ The expected final SE/IT/PM value is 14% with 0.198 std deviation

Estimate Uncertainty Methods

σ

- Cost uncertainty associated with the trend method is the standard deviation of the historical FC at x% time complete
- Method for applying the cost modeling risk is similar to the application of cost modeling risk in other settings
- Trend of standard deviation shows that as the program progresses, the variance of the FC tends to zero
  - Correctly implies that there is more confidence in the estimate as the program progresses

$$\sigma^2_{\text{SE/IT/PM@y\%}} = \left(\frac{\text{SE/IT/PM current}}{\text{FC current}}\right)^2 * \sigma^2_{\text{FC@y\%}}$$

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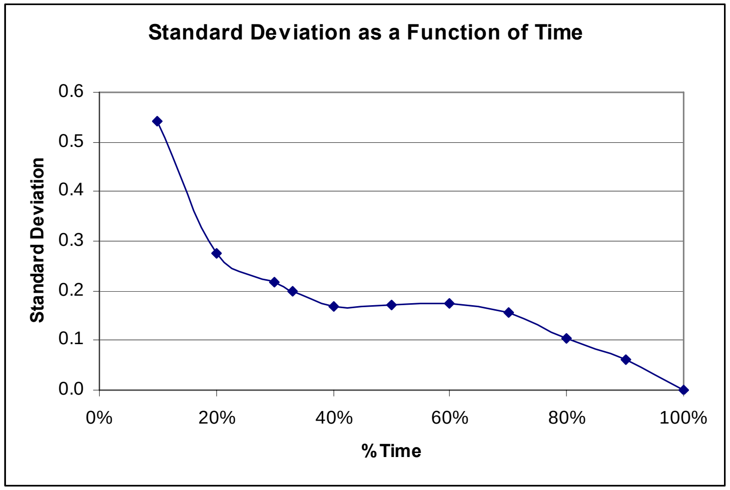

Future Concept Exploration

- Incorporate additional time-phased data with SE/IT/PM/base breakout
- Determine whether alternative methods represent data more accurately
- Schedule risk should be incorporated into the risk distribution
  - Schedule is the only driver used in the methods explored to date
  - Underestimating or omitting schedule error in the estimate will result in a misleadingly narrow risk distribution
- Could examine effect of stratifying data and other drivers on estimate
- Similar methods using trends of cumulative SE/IT/PM dollars (versus percentages) spent over time

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Conclusions and Recommendations

- SE/IT/PM Trend Analysis is a reasonable alternative to traditional methods for in-process programs
  - Traditional methods are limited when predicting in-process programs
  - Takes into account current expenditures of the program
- Trend is intuitively accurate due to the changing relationship of SE/IT/PM and the HW/SW base throughout course of program
- More time-phased data would provide added confidence in the model
- Explore Alternative Approaches to improve Trend Analysis concept

Questions?

Abstract

Systems Engineering (SE), Integration and Test (I&T), and Program Management (PM) costs have traditionally been difficult items to estimate at any point in a program. Cost Estimating Relationships (CERs) are often used in practice to predict the ultimate SE/IT/PM cost. The utility of a CER naturally lessens as a program matures since CERs do not typically account for known performance to date or un-modeled program cost drivers that are not captured in the CER variables. Many people view SE/IT/PM as a level of effort and estimate them as a function of time, which is dependent on predicted schedule, but does not account for program performance to date. Some widely-used methods that do take the actual performance into account include earned-value, staffing-level methods, and fixed-percentage extrapolation. Each of these methods has weaknesses that can be avoided using the presented technique.

This paper presents an alternative to existing methods, using both historical data on similar programs and actual performance on the current program to project final costs. It builds on concepts first applied by an NRO contractor in 2004 for a space system estimate at complete. This method examines the historical trend of cumulative SE/IT/PM versus percentage of time complete. SE/IT/PM, as a function of its base, is typically the prime mission product or the sum of hardware and software. The trend shows a high percentage SE/IT/PM at the beginning, followed by a lower, constant percentage, finally concluding with a graded rise. This is considered the “bathtub effect.” Preliminary analysis demonstrated a consistent shape of the curve confirmed by several historical programs. Variations on this concept are explored, as well as possible applications of risk.

Estimating relationships are shown for multiple levels of SE/IT/PM, including Space System, Space Segment and Ground Segment. It is important to note that while the study was performed using space system data, the method could easily be applied to any Department of Defense or Intelligence Community program cost estimate. Challenges for future research are also identified, most prominently the need for more time-phased data. With the addition of future data, it appears this method can offer the potential for more realistic estimates of SE/IT/PM costs given known information to date.

Acronyms

ATP	Authority to Proceed
CER	Cost Estimating Relationship
EVM	Earned Value Management
FC	Factor of Complete
HW	Hardware
ICE	Independent Cost Estimate
IT	Integration and Testing
I&T	Integration and Testing
NCG	NRO Cost Group
NRO	National Reconnaissance Office
PM	Program Management
SE	Systems Engineering
SER	Schedule Estimating Relationship
SW	Software
WBS	Work Breakdown Structure