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Connecting Earned Value to the Schedule

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Walt Lipke
Tinker AFB
walter.lipke@tinker.af.mil
(405) 736-3341

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Purpose

To discuss the application of ***Earned Schedule*** to schedule analysis and to introduce ***Schedule Adherence*** along with the concept of ***Effective Earned Value***.

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Overview

- **Introduction to *Earned Schedule***
- **Application and Prediction Results**
- **Network Schedule Analysis**
- **Concept of *Effective Earned Value***
- **Summary**

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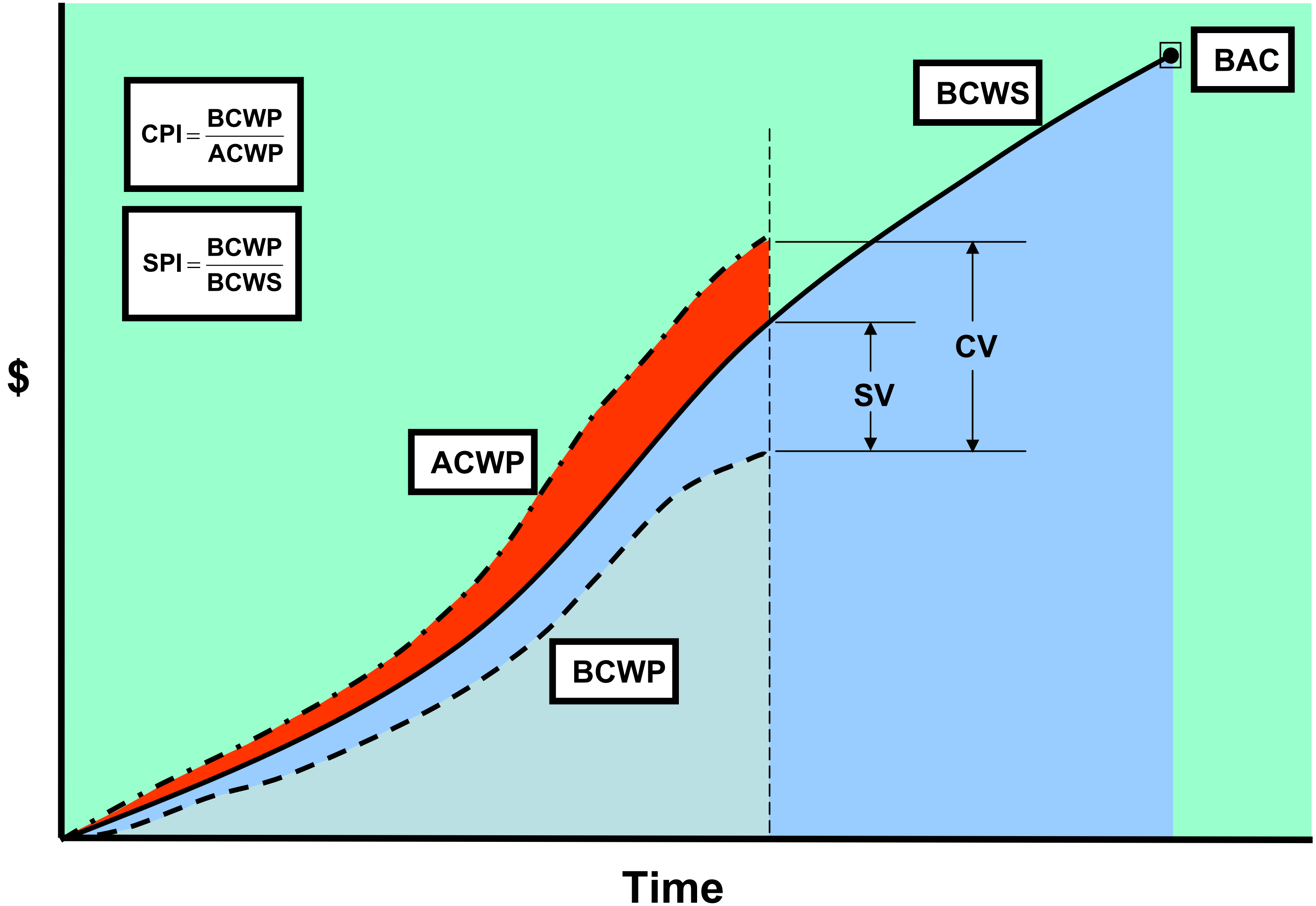
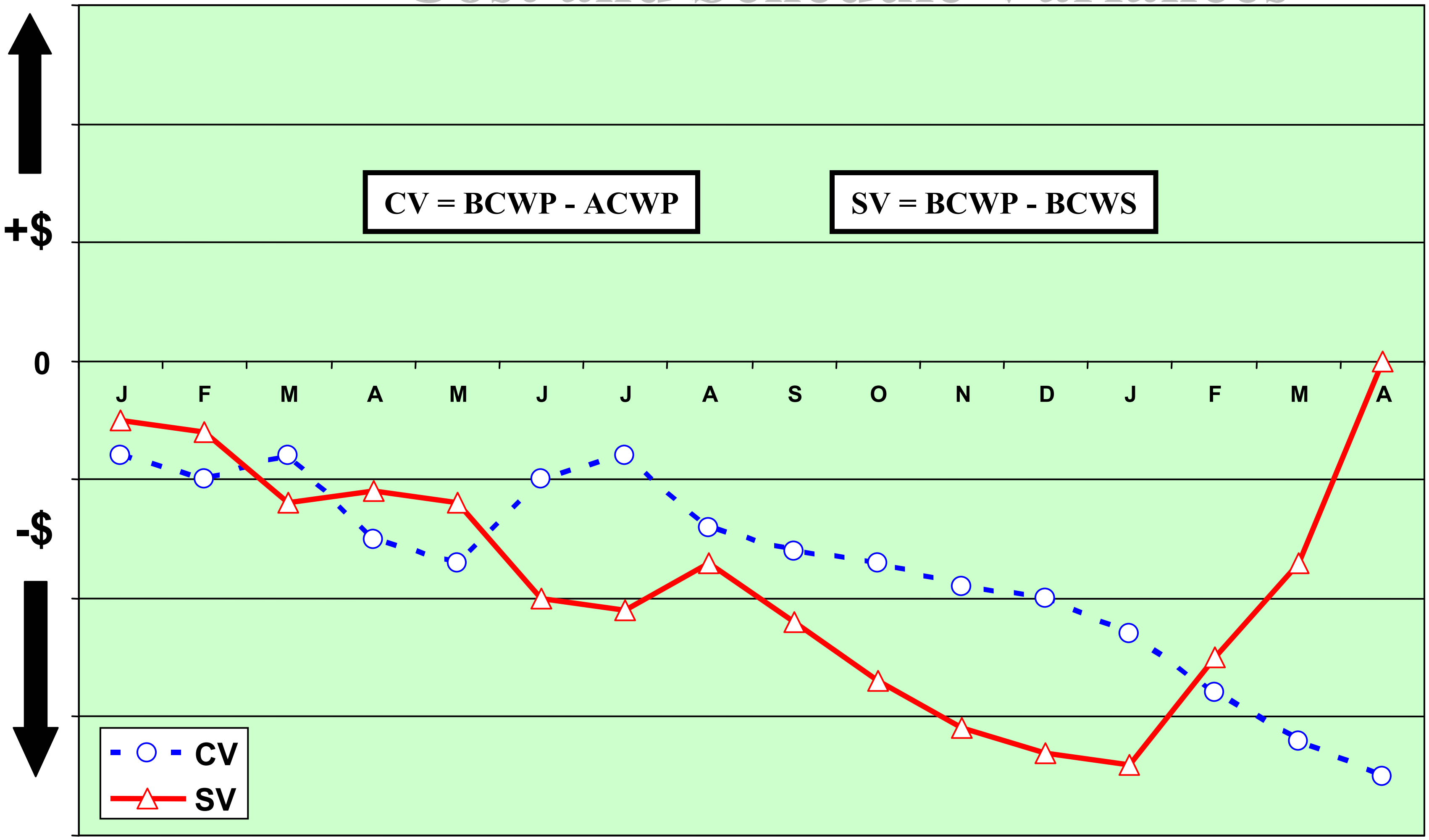
Earned Value Basics



So, what's the problem?

- Traditional schedule EVM metrics are good at beginning of project
  - Show schedule performance trends
- But the metrics don't reflect real schedule performance at end
  - Eventually, all "budget" will be earned as the work is completed, no matter how late you finish
    - SPI improves and ends up at 1.00 at end of project
    - SV improves and ends up at $0 variance at end of project
  - Traditional schedule metrics lose their predictive ability over the last third of project
    - Impacts schedule predictions, EAC predictions
- **Project managers don't understand schedule performance in terms of budget**
  - **<u>Like most of us!</u>**

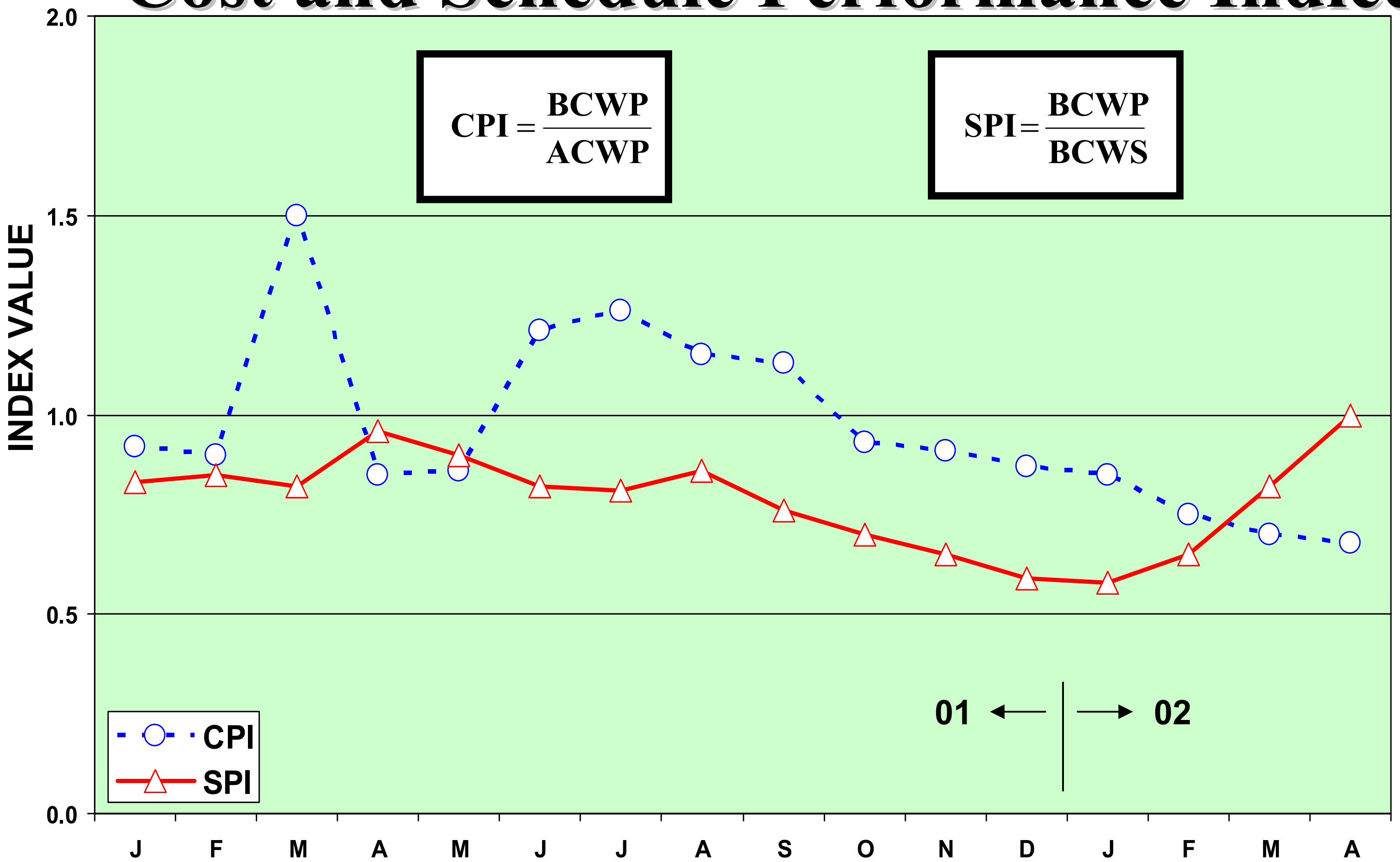
Earned Value
Cost and Schedule Variances



Note: Project completion was scheduled for Jan 02, but completed Apr 02.

Earned Value

Cost and Schedule Performance Indices



Note: Project completion was scheduled for Jan 02, but completed Apr 02.

Earned Schedule Concept

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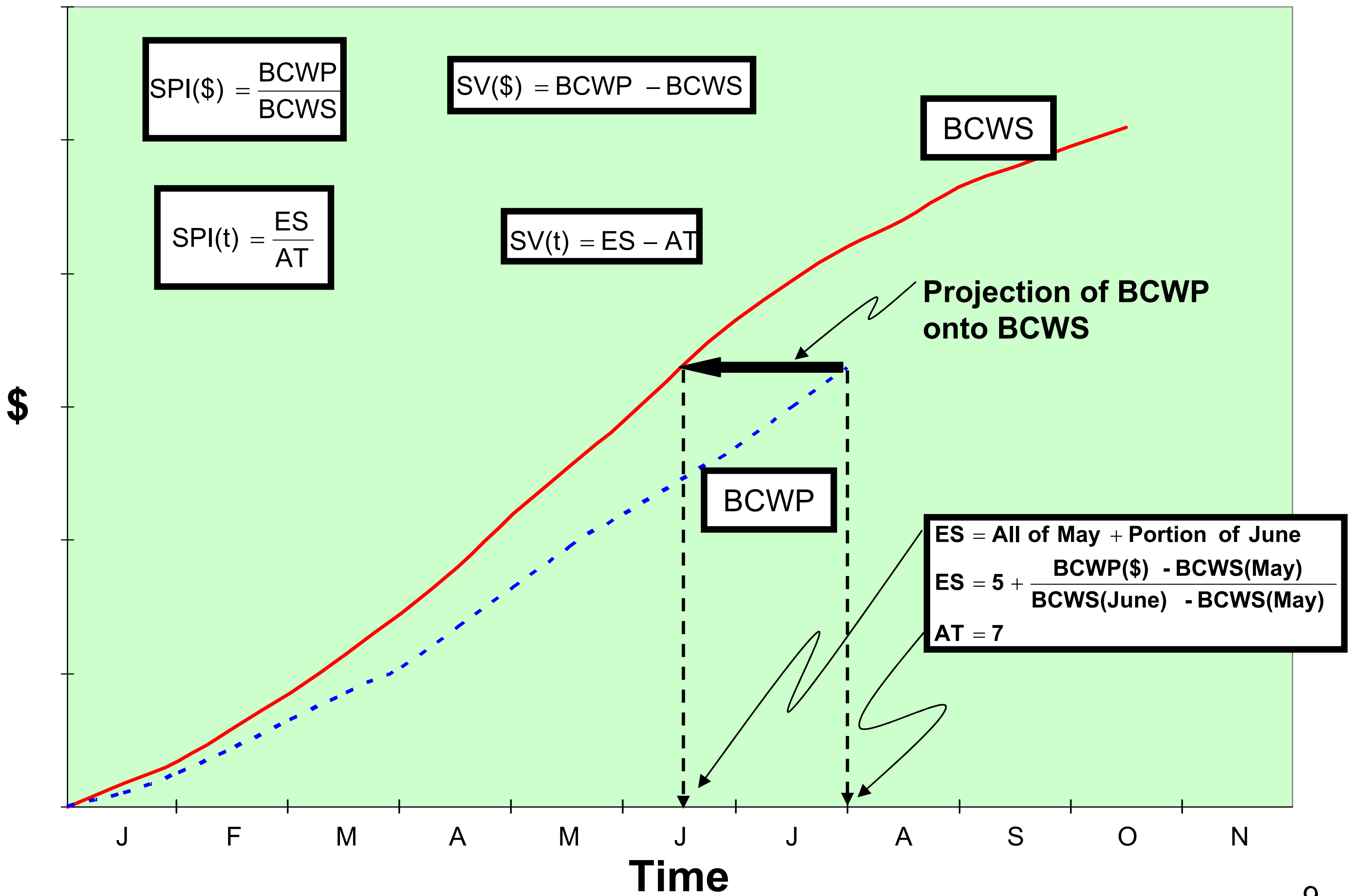
Earned Schedule Concept



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Earned Schedule:
The Formulae

- **ES_{cum} is the:**

  Number of completed BCWS time increments BCWP exceeds + the fraction of the incomplete BCWS increment

- **$ES_{cum} = C + I$ where:**

  C = number of time increments for BCWP ≥ BCWS

  $I = (BCWP - BCWS_C) / (BCWS_{C+1} - BCWS_C)$

- **$ESperiod(n) = EScum(n) - EScum(n-1)$**

  $= \Delta ES_{cum}$

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Earned Schedule:
The Schedule Indicators

- **Schedule Variance (time):**
  - $SV(t) = ES_{cum} - AT_{cum}$

    where AT = actual time
  - $SV(t)_{period} = \Delta ES_{cum} - \Delta AT_{cum}$

    normally $\Delta AT_{cum} = 1$
- **Schedule Performance Index (time):**
  - $SPI(t) = ES_{cum} / AT_{cum}$
  - $SPI(t)_{period} = \Delta ES_{cum} / \Delta AT_{cum}$

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Earned Schedule Indicators

- **Key Points:**
  - ES Indicators constructed to behave in an analogous manner to the EVM Cost Indicators, CV and CPI
  - SV(t) and SPI(t) are not constrained by BCWS calculation reference
  - SV(t) and SPI(t) provide duration based measures of schedule performance

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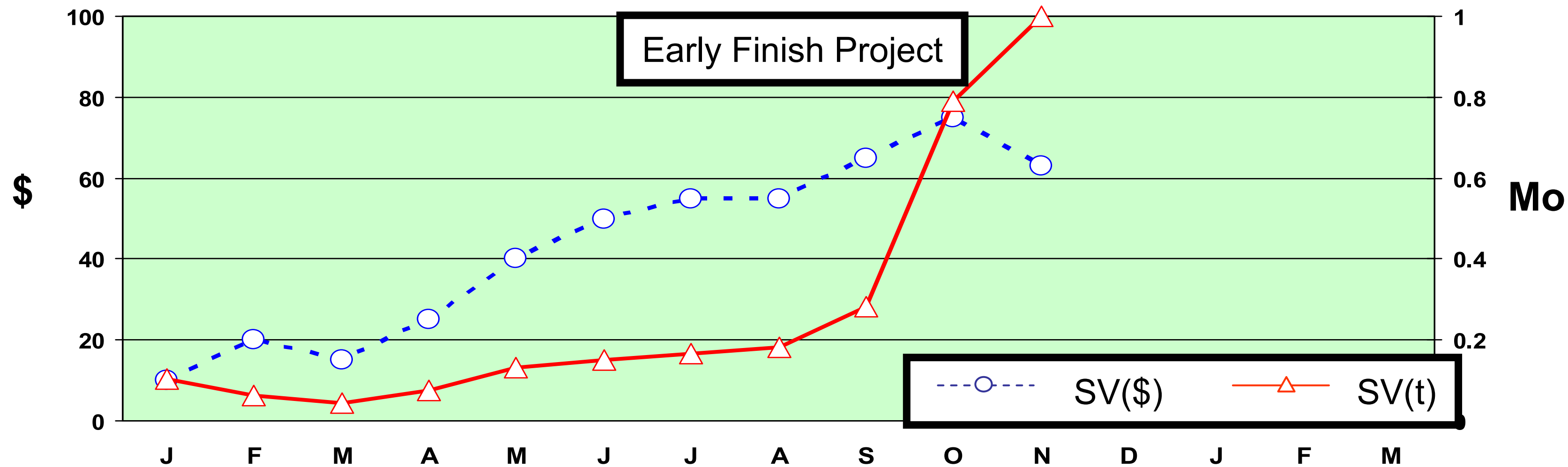
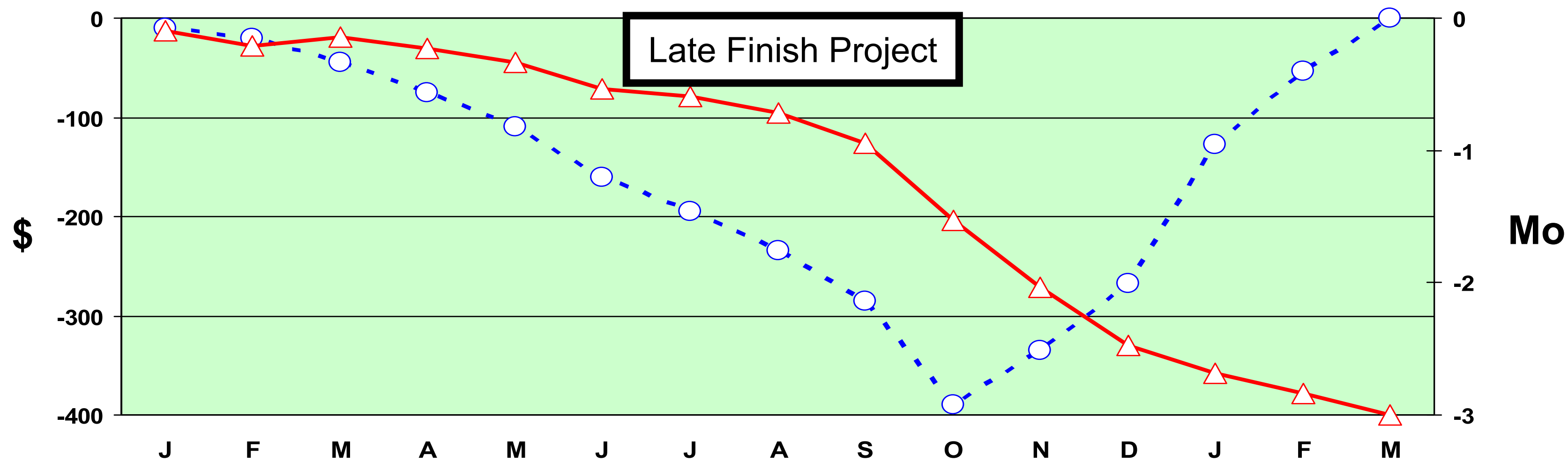
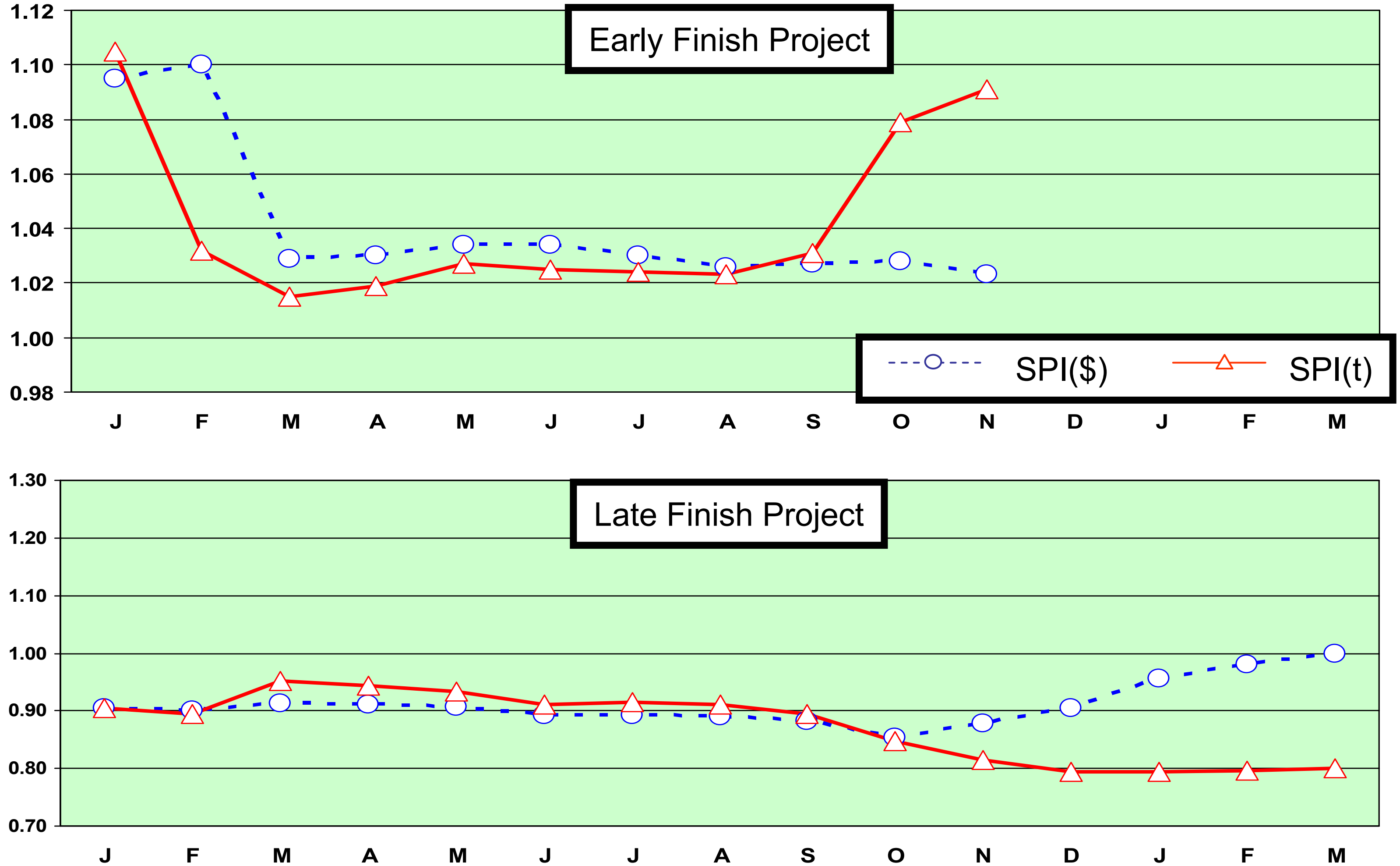
Schedule Variance Comparison





Schedule Performance Index Comparison



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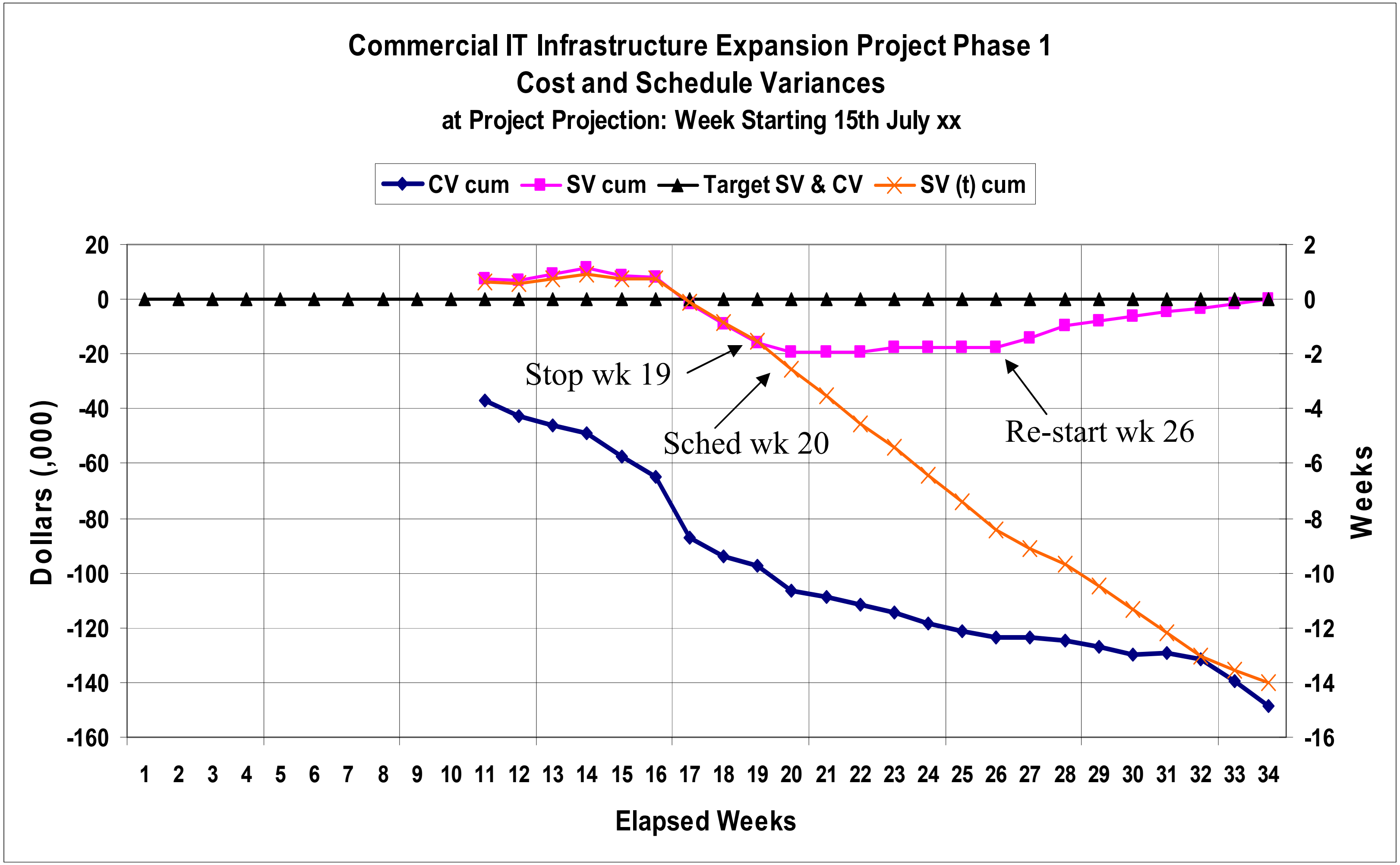
ES vs EVM Schedule Indicators

Earned Schedule	Earned Value
SV(t) and SPI(t) valid for entire project, including early and late finish	SV($) and SPI($) validity limited to early finish projects
Duration based predictive capability analogous to EVM's cost based indicators	Limited prediction capability No predictive capability after planned completion date exceeded
Facilitates Cost – Schedule Management (using EVM and ES)	EVM Management focused to Cost

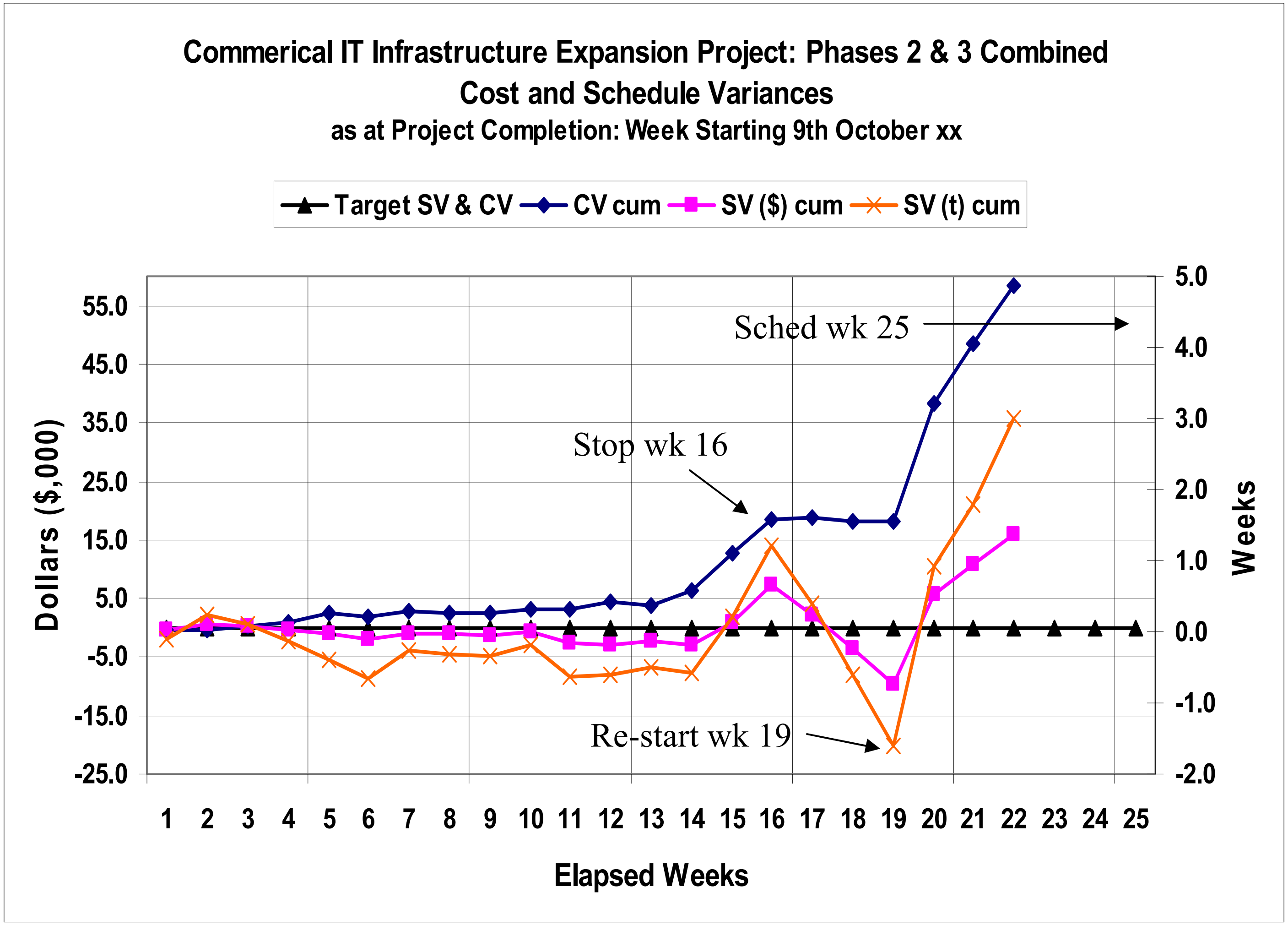
Application Results

ES Applied to Real Project Data:

Late Finish Project: SV($) and SV(t)



Early Finish Project: SV($) and SV(t)



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Duration Prediction

IEAC(t) Predictions using pre ES Techniques:

Early and Late Finish Project Examples

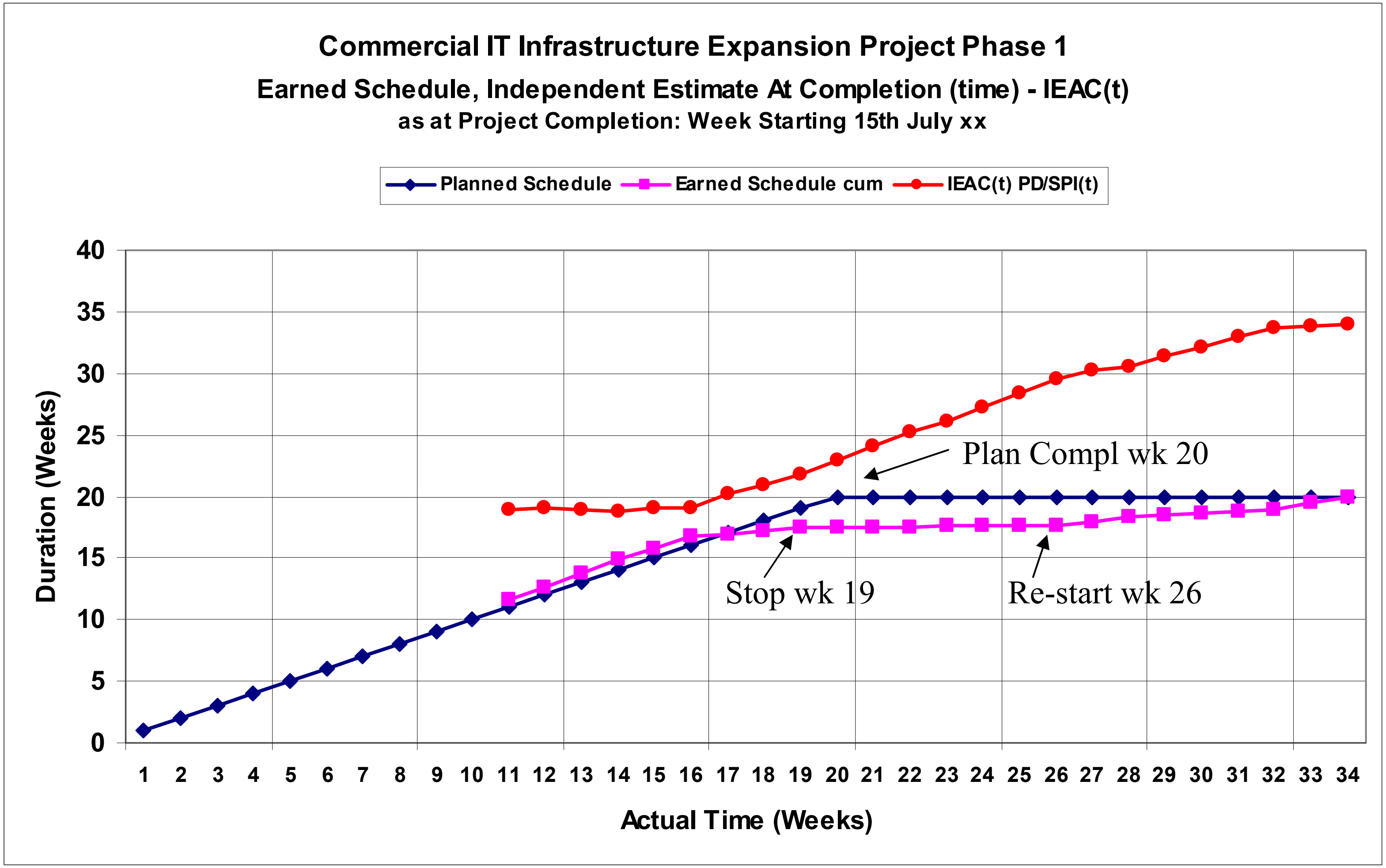
IEAC(t) Metrics at Project Completion Early Finish Project	
Planned Duration (weeks)	25
Actual Time (weeks)	22
Percentage Complete cum	100%
CPI cum	2.08
SPI(t) cum	1.14
SPI($) cum	1.17
Critical Ratio cum	2.43
IEAC(t) PD/SPI(t) cum	22.0
IEAC(t) PD/SPI($) cum	21.4
IEAC(t) PD/CR cum	10.3

IEAC(t) Metrics at Project Completion Late Finish Project - pre ES	
Planned Duration (weeks)	20
Actual Time (weeks)	34
Percentage Complete cum	100%
CPI cum	0.52
SPI(t) cum	0.59
SPI($) cum	1.00
Critical Ratio cum	0.52
IEAC(t) PD/SPI(t) cum	34.0
IEAC(t) PD/SPI($) cum	20.0
IEAC(t) PD/CR cum	38.7

- In both examples, the **pre ES** predictors (in red) **fail** to correctly calculate the Actual Duration at Completion!
- The ES predictor, SPI(t) alone **correctly** calculates the Actual Duration at Completion in both cases

IEAC(t) Predictions using ES Techniques

Weekly Plots of IEAC(t) - Late Finish Project Example



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Schedule Analysis

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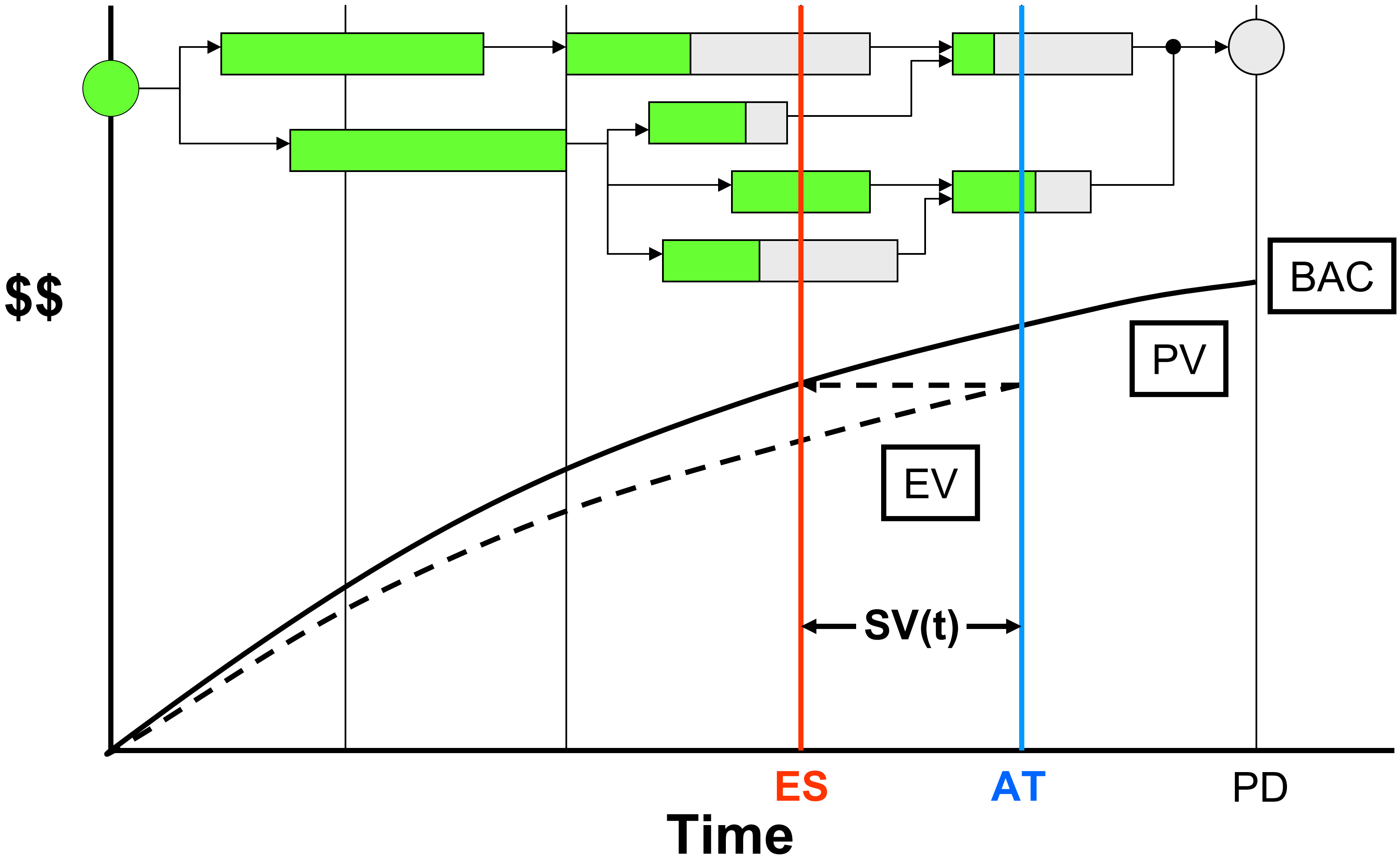
Schedule Analysis with EVM?

- The general belief is EVM cannot be used to predict schedule duration
- Most practitioners analyze schedule from the bottom up using the networked schedule ….*"It is the only way possible."*
  - Analysis of the Schedule is overwhelming
  - Critical Path is used to shorten analysis

    (CP is longest path of the schedule)
- Duration prediction using Earned Schedule provides a macro-method similar to the method for estimating Cost
  - **a significant advance in practice**
- But, there's more that ES facilitates ….

Earned Schedule

Bridges EVM to "Real" Schedule



How Can This Be Used?

- **Tasks behind** – possibility of impediments or constraints can be identified
- **Tasks ahead** – a likelihood of future rework can be identified
- The identification is independent from schedule efficiency
- The identification can be automated
- **PMs can now have a schedule analysis tool connected to the EVM Data!!**

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Earned Value Research

Earned Value Research

- Most research conducted since 1990
  - Result of cancellation of Navy A-12 Avenger
  - Primary researcher, Dr. David Christensen, Southern Utah University
  - Cost studies using very large DOD projects
- EVM Literature on Dr. Christensen's website http://www.suu.edu/faculty/christensend/ev-bib.html

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Results from EV Research

- Dr. Christensen's & associates' findings
  - CPI stabilizes @ 20% complete
  - CPI tends to worsen as EV $\Rightarrow$ BAC
  - $|CPI(final) - CPI(20\%)| \leq 0.10$
  - IEAC = BAC / CPI $\leq$ Final Cost

    when Percent Complete is 20% $\Leftrightarrow$ 100%

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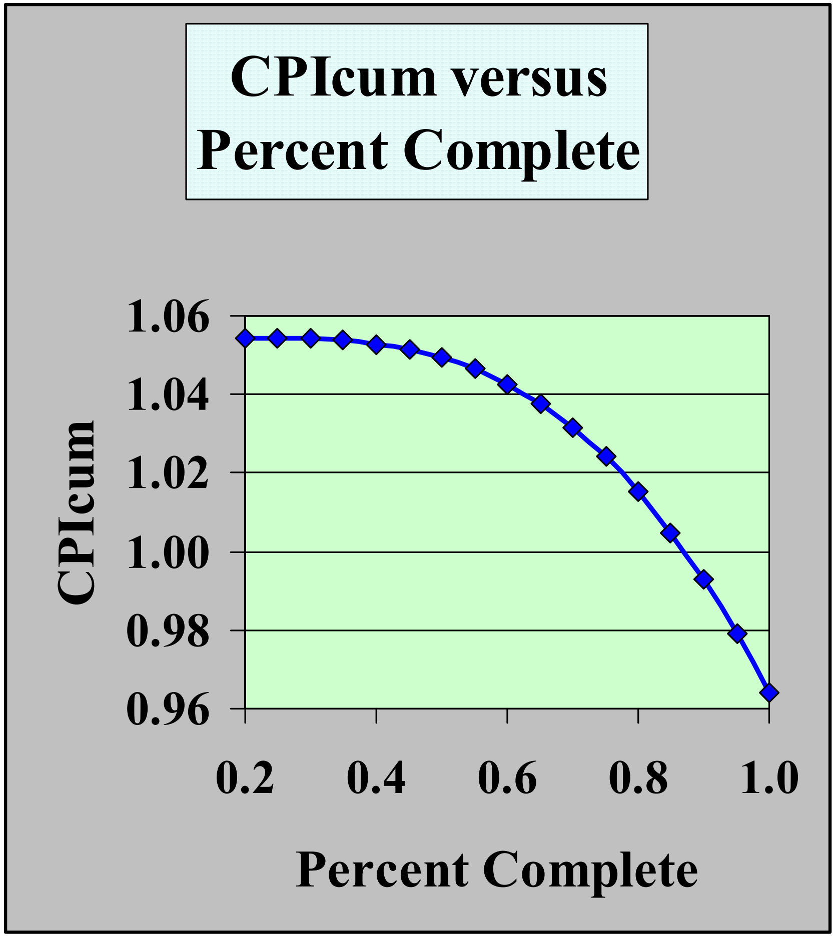
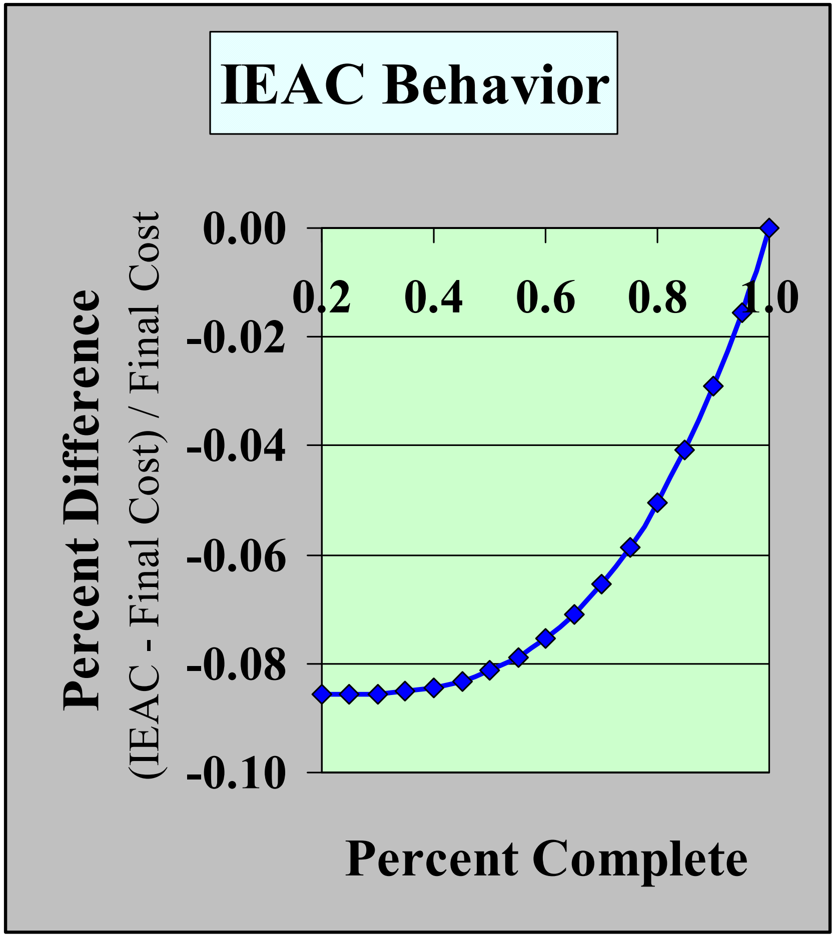
Research Discussion

- **CPI tends to worsen as EV $\Rightarrow$ BAC**
- **IEAC = BAC / CPI $\leq$ Final Cost**
  when Percent Complete is 20% $\Leftrightarrow$ 100%
- **IEAC condition must be true if CPI tendency is true**
- **Rationale supporting CPI tendency**
  - **Rework increasing as EV approaches BAC**
  - **Late occurring impacts from constraints/impediments**
  - **Lack of available EV toward end of project**
- ***My conjecture: SPI(t) & IEAC(t) = PD / SPI(t) behave similarly to CPI & IEAC = BAC / CPI***

CPI & IEAC Behavior

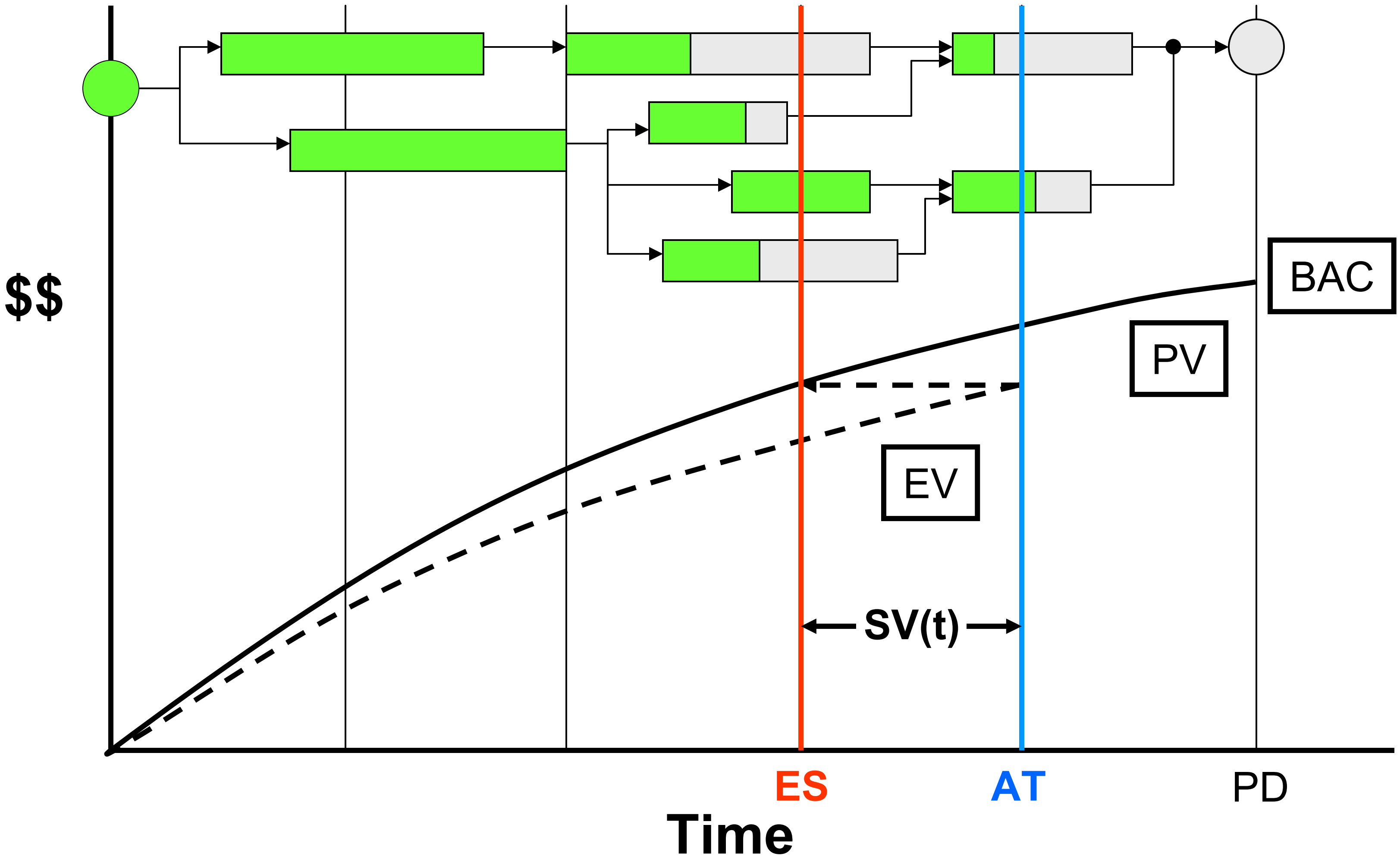




Concept:
Effective Earned Value

Earned Schedule

Bridges EVM to "Real" Schedule



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Effective Earned Value

- EV isn't connected to task sequence
  - Hypothesis: Completion sequence of tasks affects performance efficiency
- Incorrect task sequencing occurs when there is …
  - Impediment or constraint
  - Poor process discipline
- Improper performance sequence may cause …
  - Overloading of constraint
  - Performance of tasks w/o complete inputs

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Effective Earned Value

- Result from improper performance sequence …
  - Constraint limited output
    - Schedule lengthens
    - Cost increases while waiting (*when other EV available is severely limited)*
  - Rework occurs *(~ 50%)*
    - Schedule lengthens
    - Cost escalates
- Constraint problem & Rework appear late causing …
  - CPI & *SPI(t)* to decrease as EV $\Rightarrow$ BAC

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Effective Earned Value

- **Schedule Adherence** measure is used to enhance the EVM measures
  - Early warning for later cost and schedule problems
  - Proposed Measure: *In accordance with the project plan, determine the tasks which should be completed or started for the duration associated with ES. Compare the associated PV with the EV of the tasks which directly correspond. Calculate the ratio:*

$$P = \text{Tasks (perf - corr)} / \text{Tasks (plan)}$$

$$= \Sigma EV_j \text{ (corresponding)} / \Sigma PV_j \text{ (plan)}$$

$$\text{where } \Sigma EV_j \leq \Sigma PV_j \;\;\&\;\; \Sigma PV_j = EV$$

Effective Earned Value

- Characteristics of the P measure
  - P measure cannot exceed 1.0

$$0 \leq P \leq 1.0$$

  - At project completion P = 1.0
  - P is likely unstable until project is 20% complete *{similar to the behavior of CPI}*
- P used to compute effective earned value {EV(e)}

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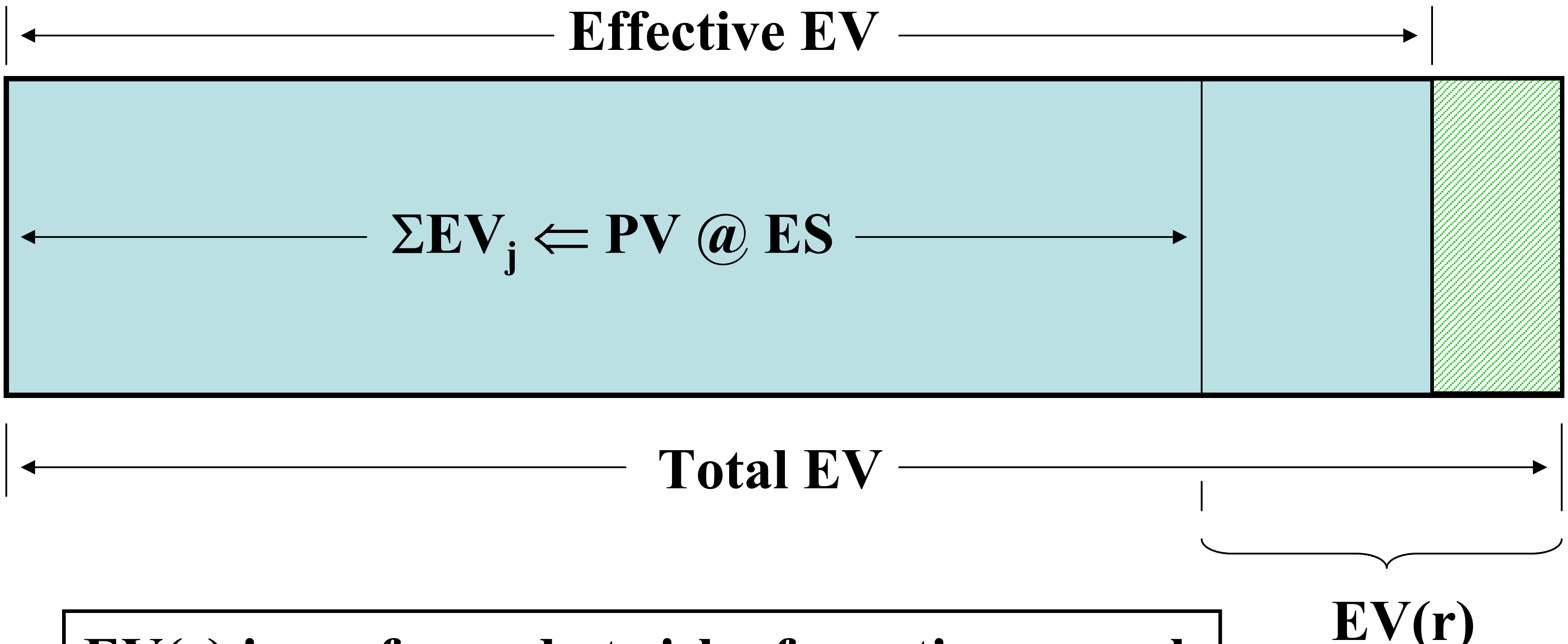
Effective Earned Value



EV(r) is performed at risk of creating rework
Portion colored [blue] is usable
Portion colored [green hatched] is unusable

Effective Earned Value

- Effective earned value is a function of EV, P, and Rework

  $EV(e) = f\ (EV, P, Rework)$

- $EV(e) = [\ (1 + P * R\%) / (1 + R\%)\ ] * EV$

  where R% (Rework Percent) = fraction of EV(r) unusable / fraction of EV(r) usable $\{\ EV(r) = \Sigma PV_j - \Sigma EV_j\ \}$

- $EV(e) = [\ (P + 2) / 3\ ] * EV$

  when $R\% = 50\%$

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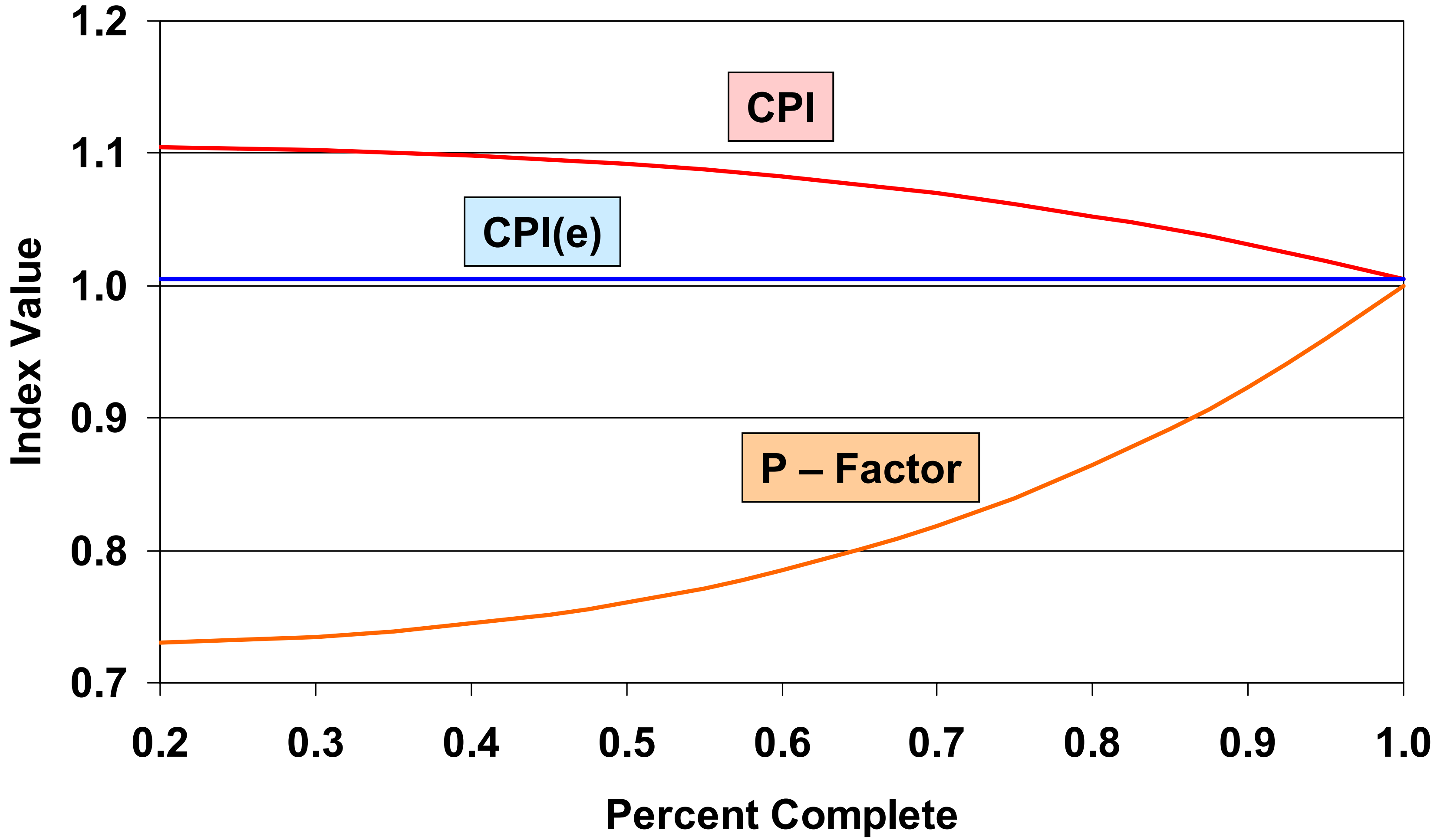
Effective Earned Value

- **Effective ES is computed using EV(e) {i.e., ES(e)}**
- **Effective EV indicators are …**
  - **CV(e) = EV(e) – AC**
  - **CPI(e) = EV(e) / AC**
  - **SV(te) = ES(e) – AT**
  - **SPI(te) = ES(e) / AT**
- ***The behavior of P may explain Dr. Christensen's findings for CPI & IEAC***

Graphs of CPI, CPI(e) & P - Factor (notional data)



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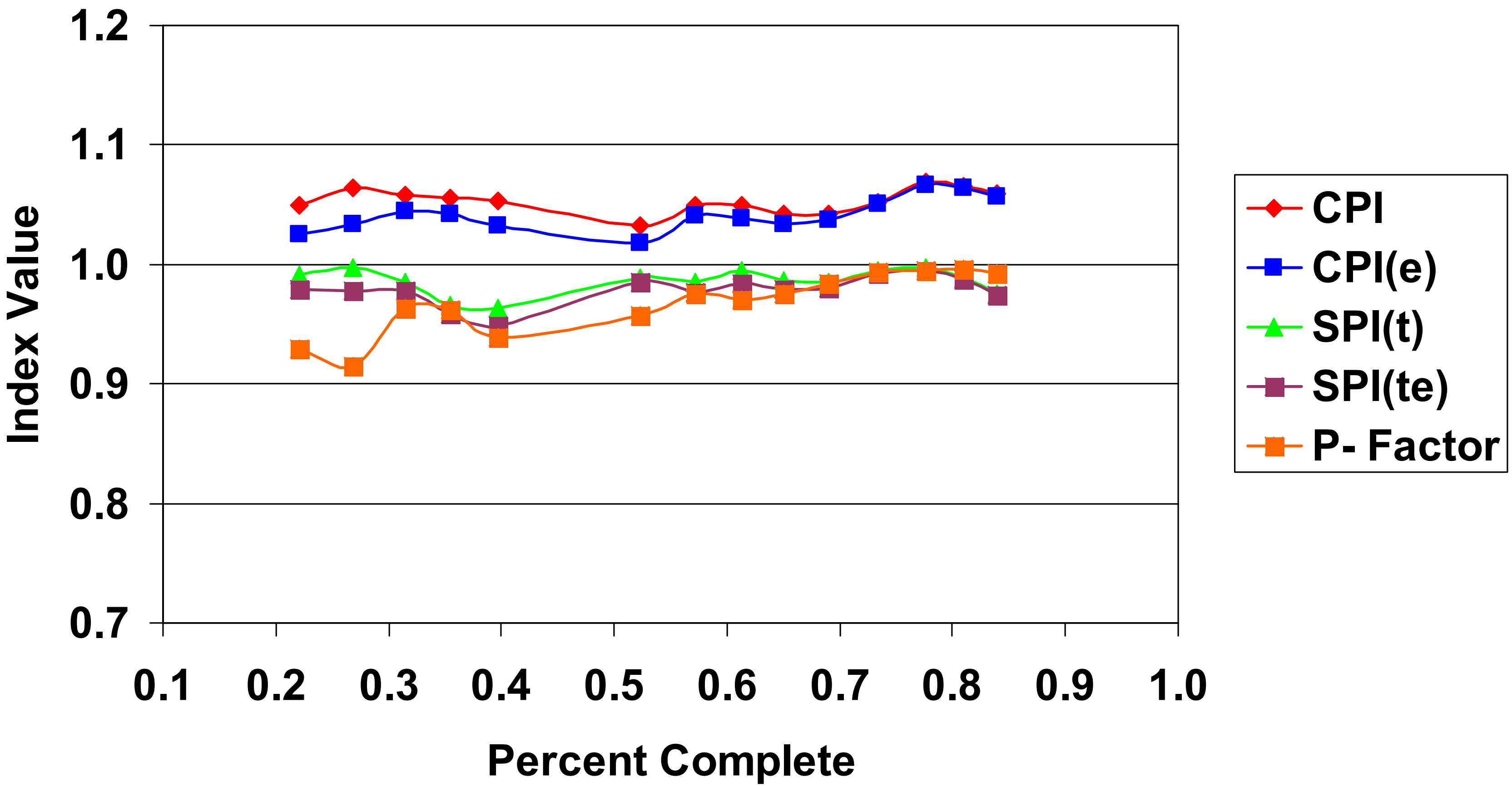
Graphs of CPI & SPI(t) with the P - Factor



Summary: Effective Earned Value

- **Lack of adherence to the schedule causes EV to misrepresent project progress**
- **P indicator introduced to measure schedule adherence**
- **Effective EV calculable from P, R% and EV reported**
- **Prediction for both final cost and project duration hypothesized to be improved with *Effective Earned Value***

Summary

Summary

- ES derived from EVM data … only
- Indicators do not fail for late finish projects
- Schedule prediction is better than any other EVM method presently used
- Application is scalable up/down, just as is EVM
- **Facilitates bridging EVM to the schedule**
- Schedule Adherence Indicator
- Concept of Effective Earned Value

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- "Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data," ***The Measurable News***, Summer 2003 [Kym Henderson]
- "Further Developments in Earned Schedule," ***The Measurable News***, Spring 2004 [Kym Henderson]
- "Connecting Earned Value to the Schedule," ***The Measurable News***, Pending [Walt Lipke]

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Contact Information

Name: *Walt Lipke*

Organization: *Software Division*

Address: *OCALC/MS*
8745 Entrance Rd
Bldg 3333 Room 140
Tinker AFB, OK 73145-3312

Phone: *(405) 736-3341*

Fax: *(405) 736-3345*

Email: *walter.lipke@tinker.af.mil*