Earned Schedule Leads to Improved Forecasting

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Purpose

To discuss the application of *Earned Schedule* to schedule and cost prediction

Overview

- *Earned Schedule* Review
- Network Schedule Analysis
- Earned Value Research
- Schedule Performance
- Concept of *Effective Earned Value*
- Forecasting with Effective EV
- Summary

Earned Schedule

Why Earned Schedule?

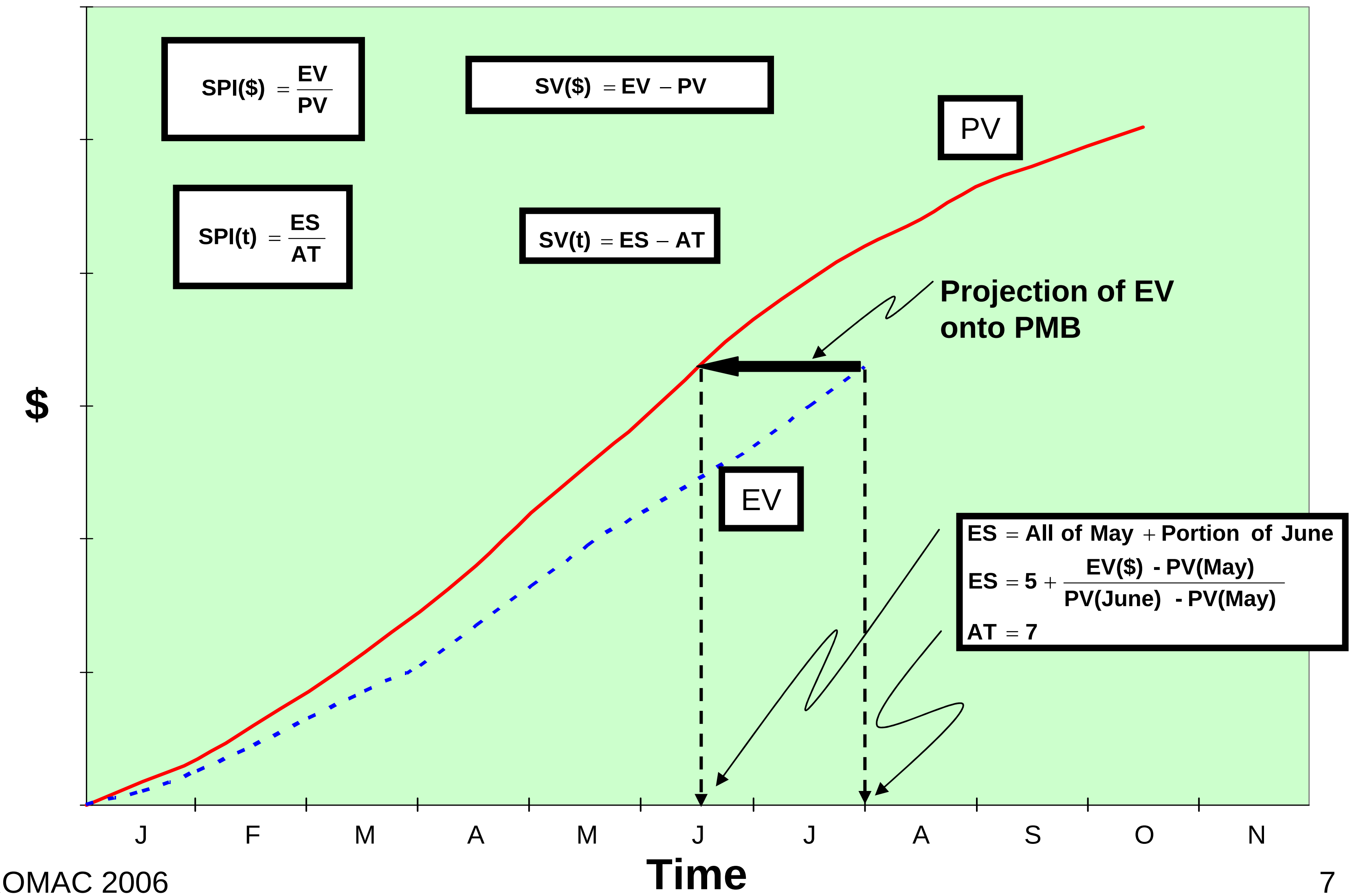
- Traditional schedule EVM metrics are good at beginning of project
  - Show schedule performance trends
- But the metrics don't reflect real schedule performance at end
  - Eventually, all "budget" will be earned as the work is completed, no matter how late you finish
    - SPI improves and equals 1.00 at end of project
    - SV improves and concludes at $0 variance

Why Earned Schedule?

- Traditional EVM schedule metrics lose predictive ability over the last third of the project
  - Impacts both schedule & cost predictions
- *Project managers and customers don't comprehend schedule performance in terms of budget*

…Like most of us!

Earned Schedule Concept



Earned Schedule Formulae

- ES_{cum} is the:

  Number of completed PV time increments EV exceeds + the fraction of the incomplete PV increment

- $ES_{cum} = C + I$

  C = number of time increments for EV ≥ PV

  $I = (EV - PV_C) / (PV_{C+1} - PV_C)$

- ESperiod(n) = EScum(n) – EScum(n-1)

  $= \Delta ES_{cum}$

Key Points

- ES indicators are constructed to behave in an analogous manner to the EVM Cost Indicators, CV and CPI
- SV(t) and SPI(t) are <u>not</u> constrained by PV calculation reference (BAC)
- SV(t) and SPI(t) provide <u>duration</u> based measures of schedule performance

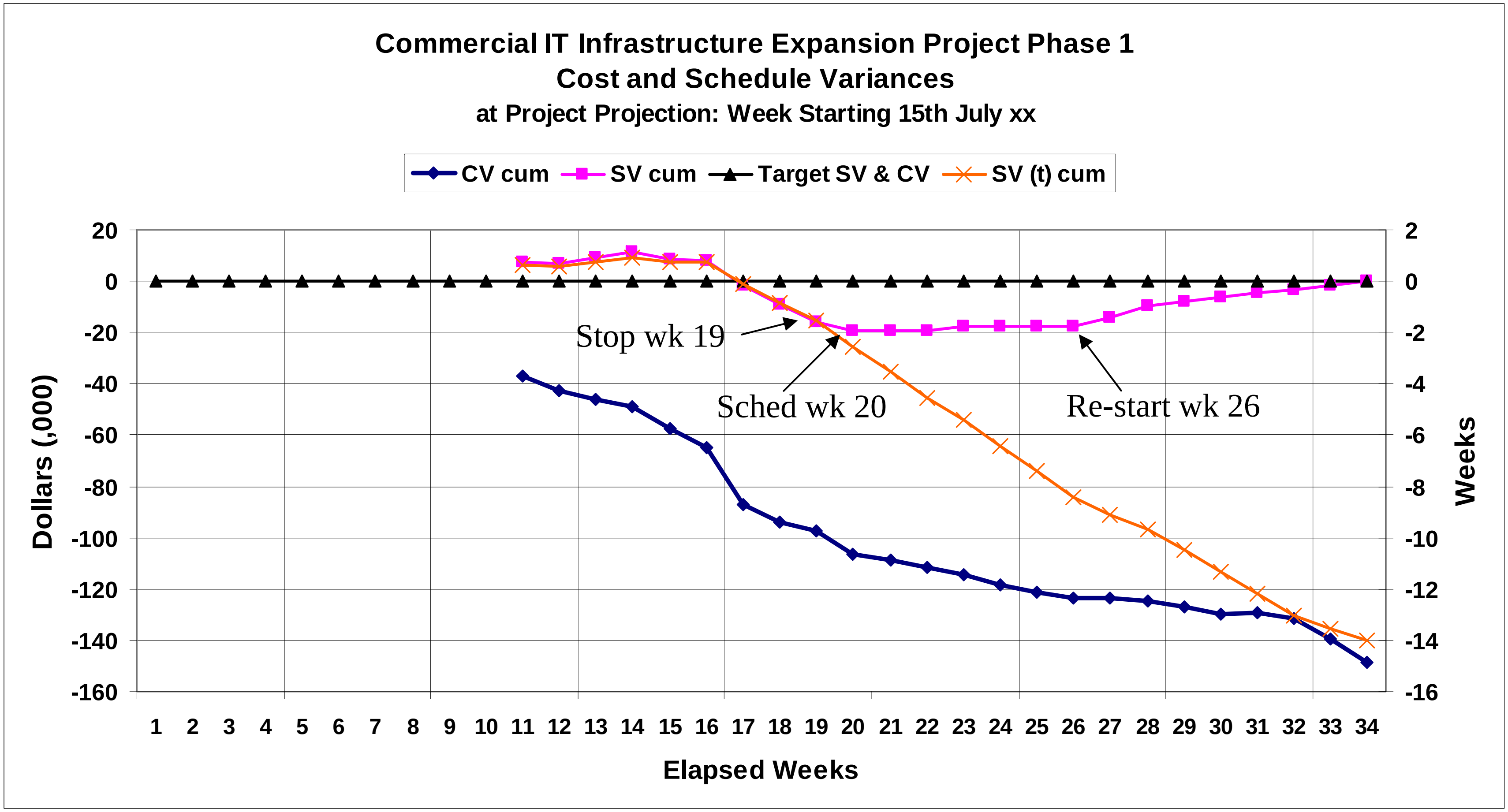
Table of Formulas

Metrics	Earned Schedule	ES_{cum}	ES = C + I number of complete periods (C) plus an incomplete portion (I)
	Actual Time	AT_{cum}	AT = number of periods executed
Indicators	Schedule Variance	SV(t)	SV(t) = ES - AT
	Schedule Performance Index	SPI(t)	SPI(t) = ES / AT
	To Complete Schedule Performance Index	TSPI(t)	TSPI(t) = (PD – ES) / (PD – AT)
			TSPI(t) = (PD – ES) / (ED – AT)
Predictors	Independent Estimate at Completion (time)	IEAC(t)	IEAC(t) = PD / SPI(t)
			IEAC(t) = AT + (PD – ES) / PF

Application Results

ES Applied to Real Project Data

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



Duration Prediction

IEAC(t) Prediction Comparison

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

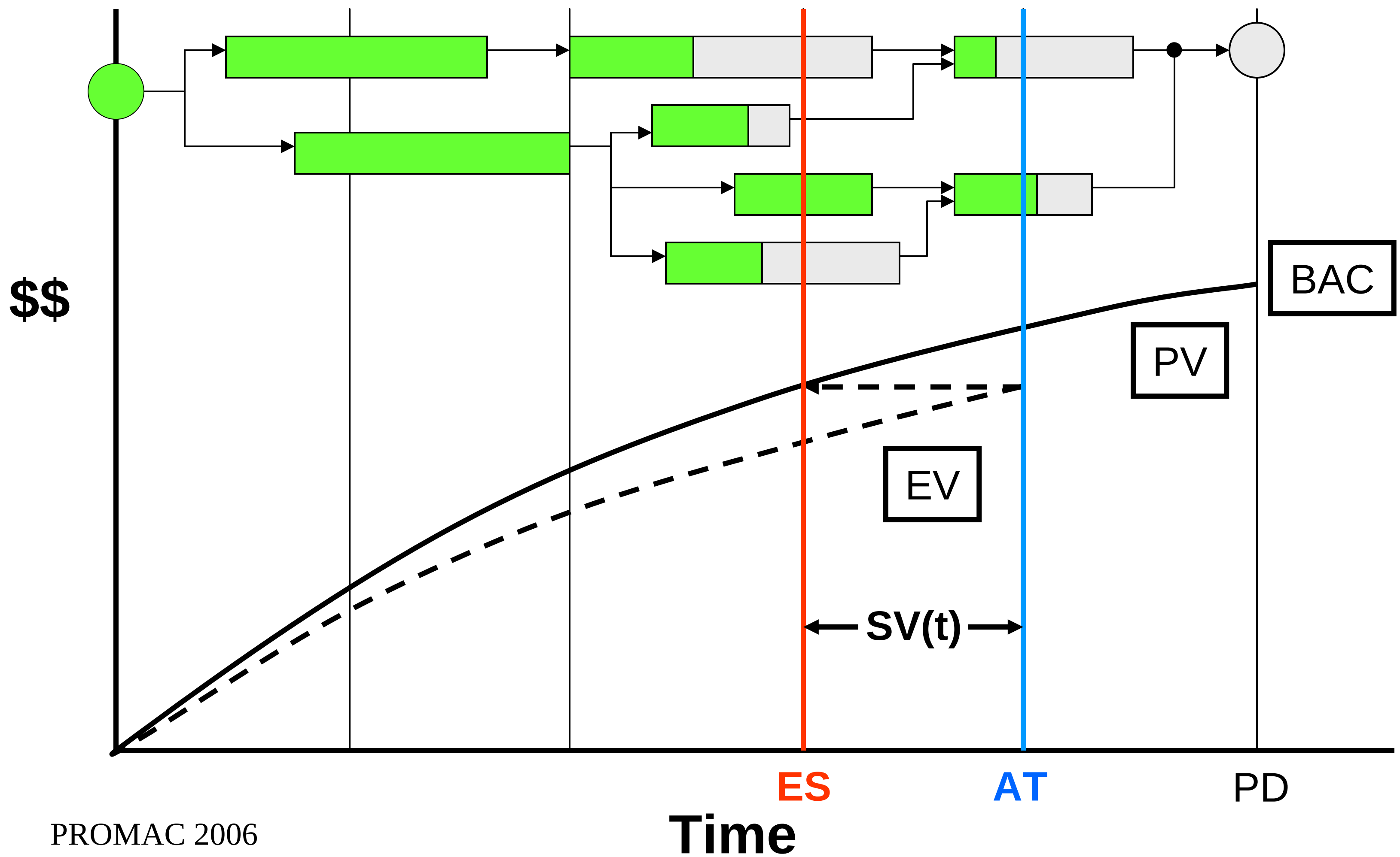
Schedule Analysis

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 Network 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!!**

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

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

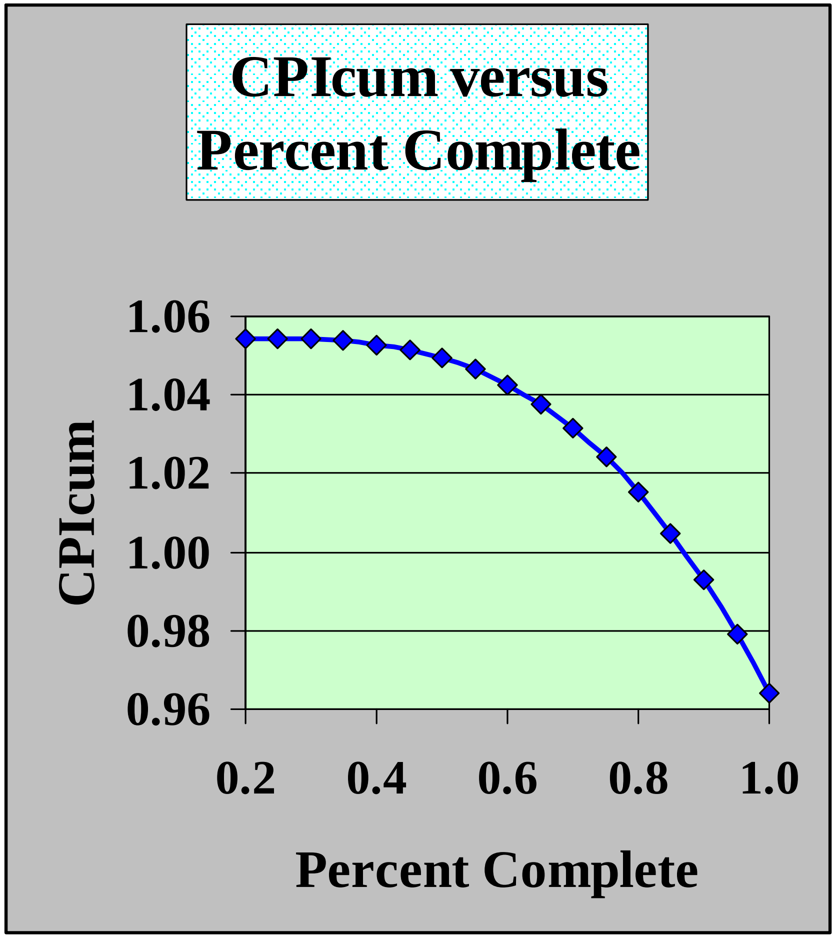
    when Percent Complete is 20% $\Leftrightarrow$ 70%

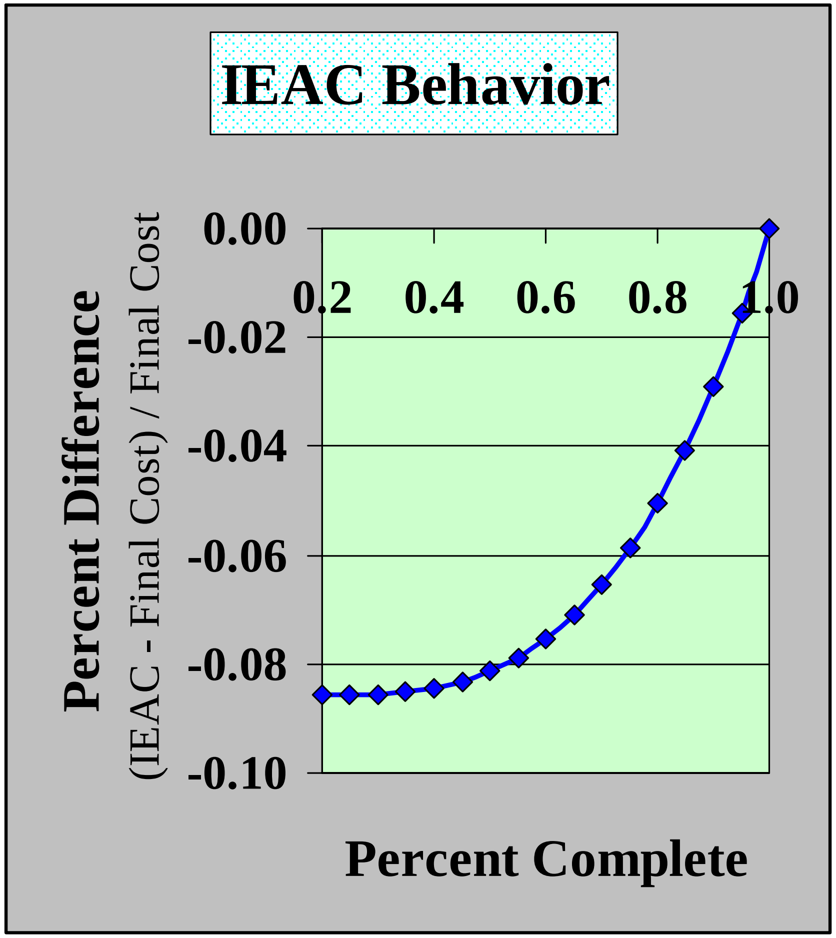
Research Discussion

- CPI tends to worsen as EV $\Rightarrow$ BAC
- IEAC = BAC / CPI $\leq$ Final Cost

  when Percent Complete is 20% $\Leftrightarrow$ 70%
- 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

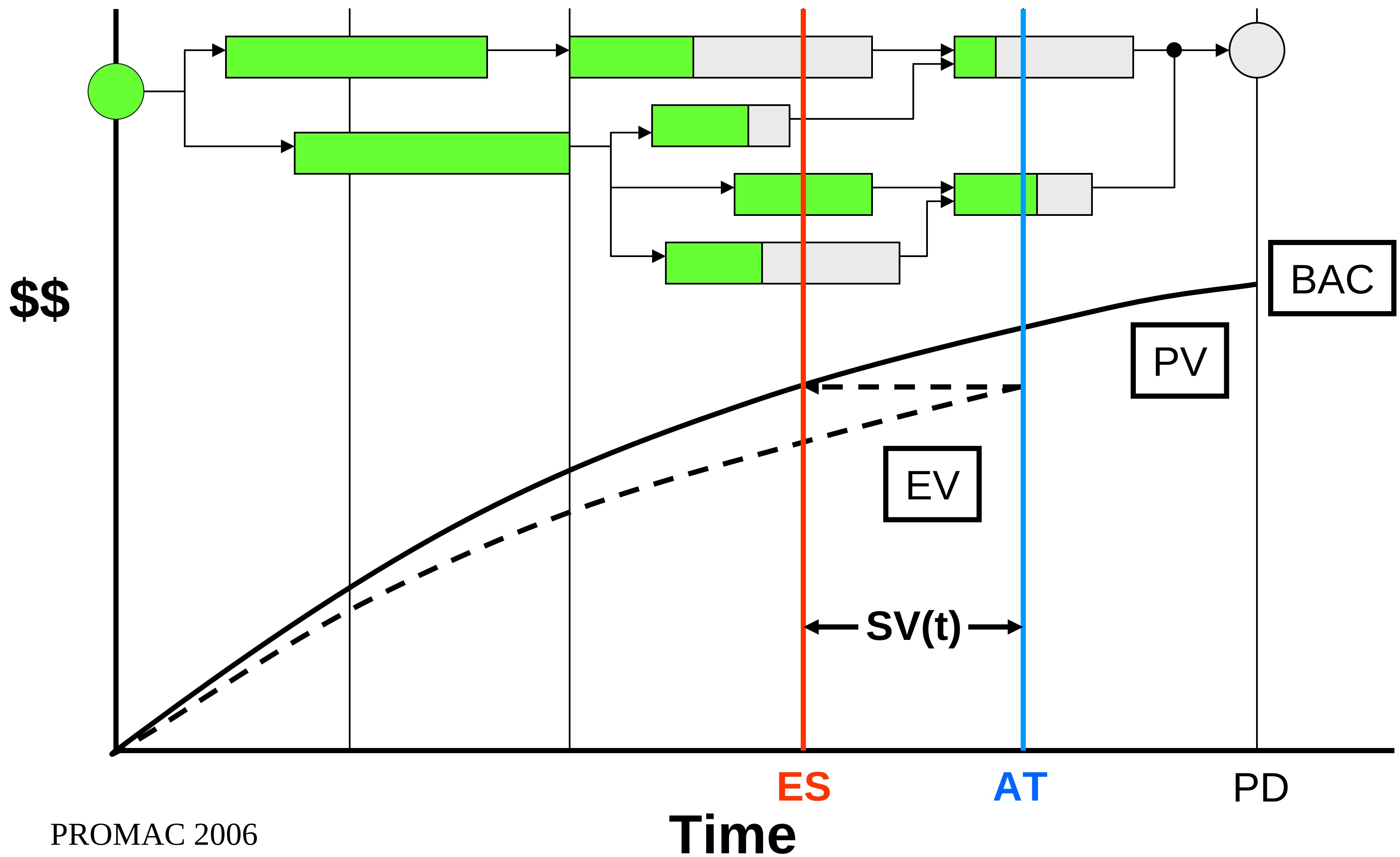




Schedule Performance

Earned Schedule

Bridges EVM to Network Schedule



Schedule Performance

- 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

Schedule Performance

- 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 ⇒ BAC

Schedule Adherence Measure

- Schedule Adherence measure is proposed 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:*

$$P = Tasks_{(correspond)} / Tasks_{(plan)}$$

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

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

Schedule Adherence Measure

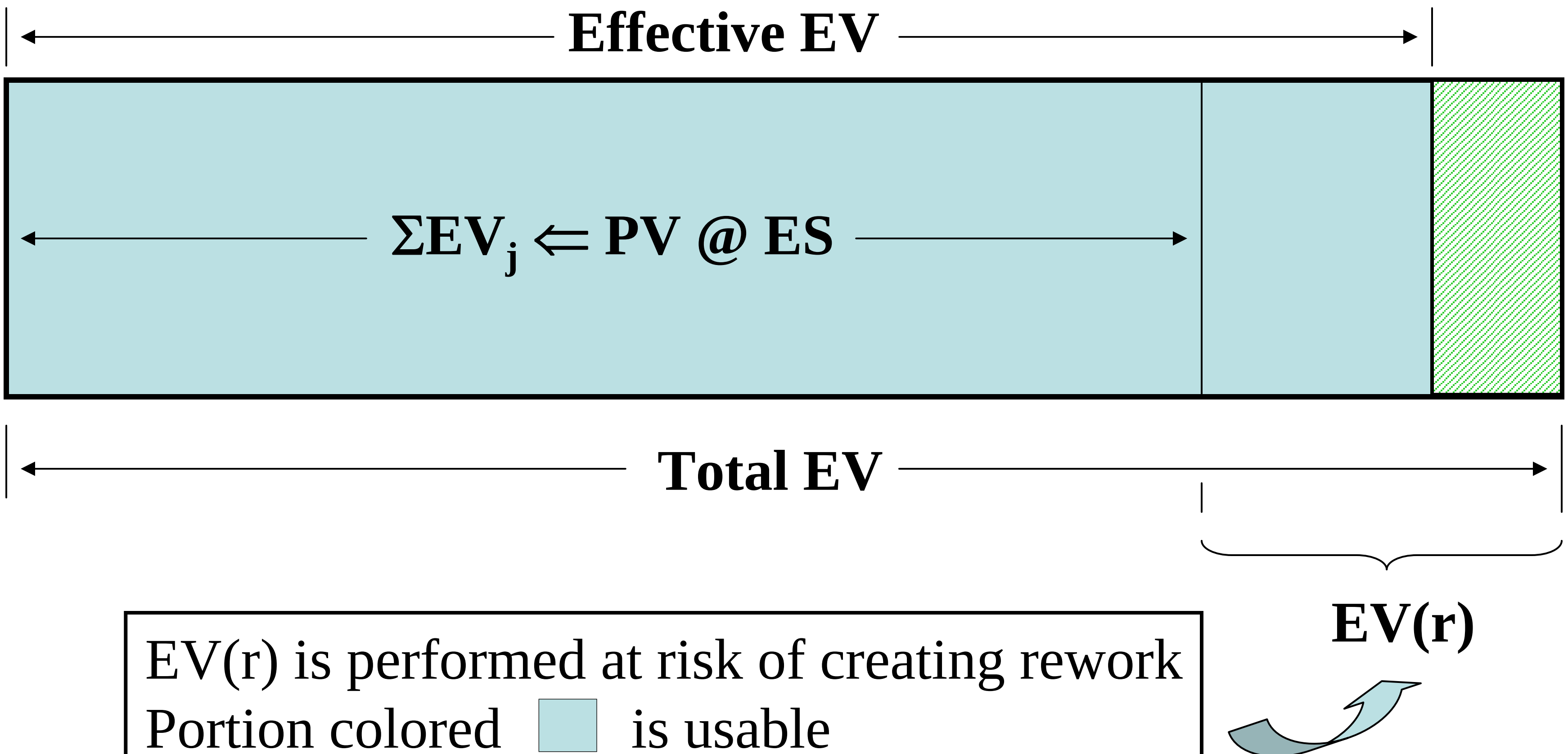
- Characteristics of the P measure
  - P measure cannot exceed 1.0

$$0 \le P \le 1.0$$

  - At project completion P = 1.0
  - P is likely unstable until project has accumulated a sufficient amount of data *{similar to the behavior of CPI}*
- P used to compute effective earned value {EV(e)}

Effective Earned Value

Effective Earned Value



EV(r) is performed at risk of creating rework
Portion colored (light 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

  R% = Rework Percent

  R% = fraction of EV(r) unusable ÷ by fraction of EV(r) usable
  { $EV(r) = \Sigma PV_j - \Sigma EV_j$ }

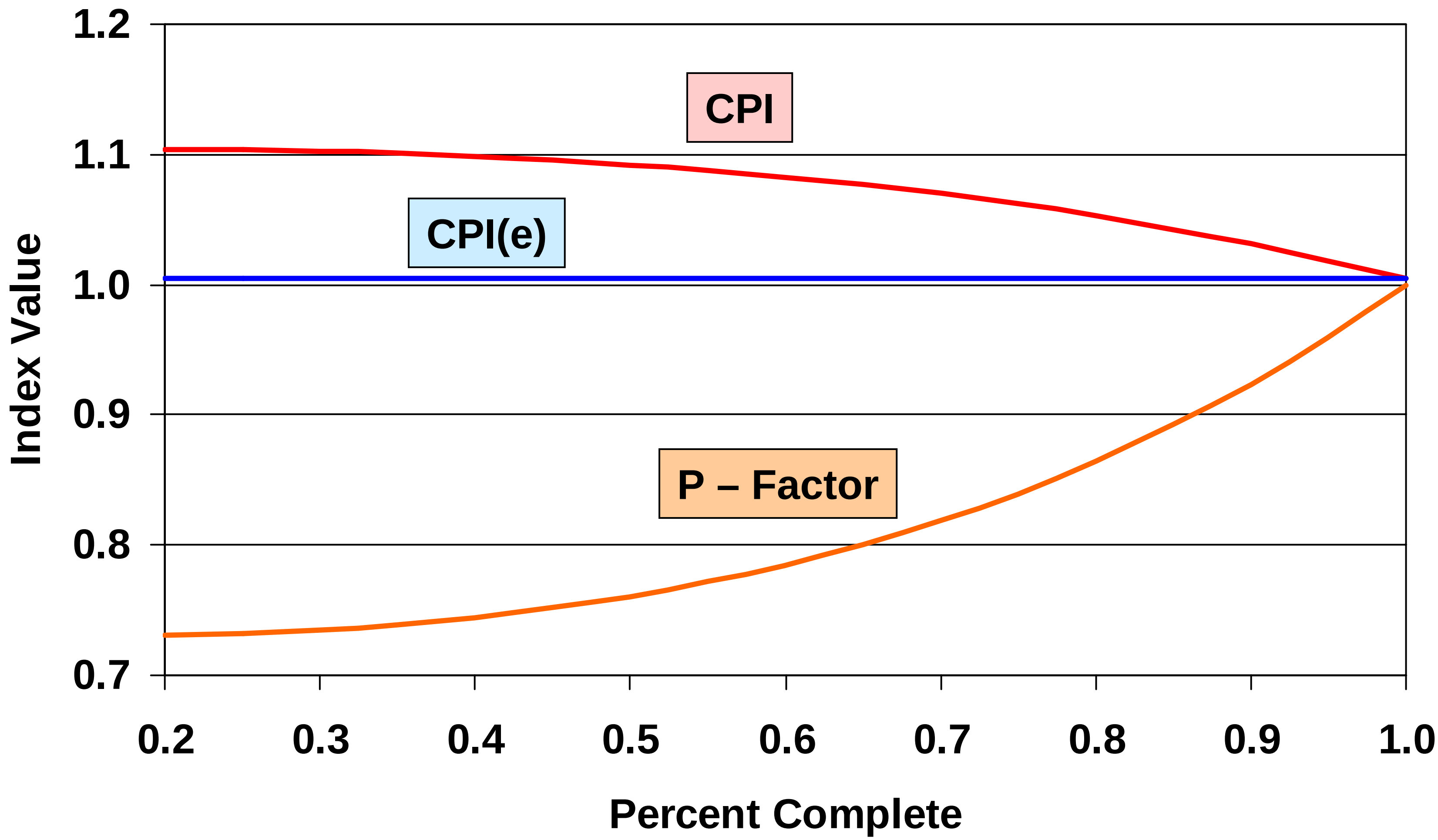
- EV(e) = [(P + 2) / 3] $*$ EV

  when R% = 50%

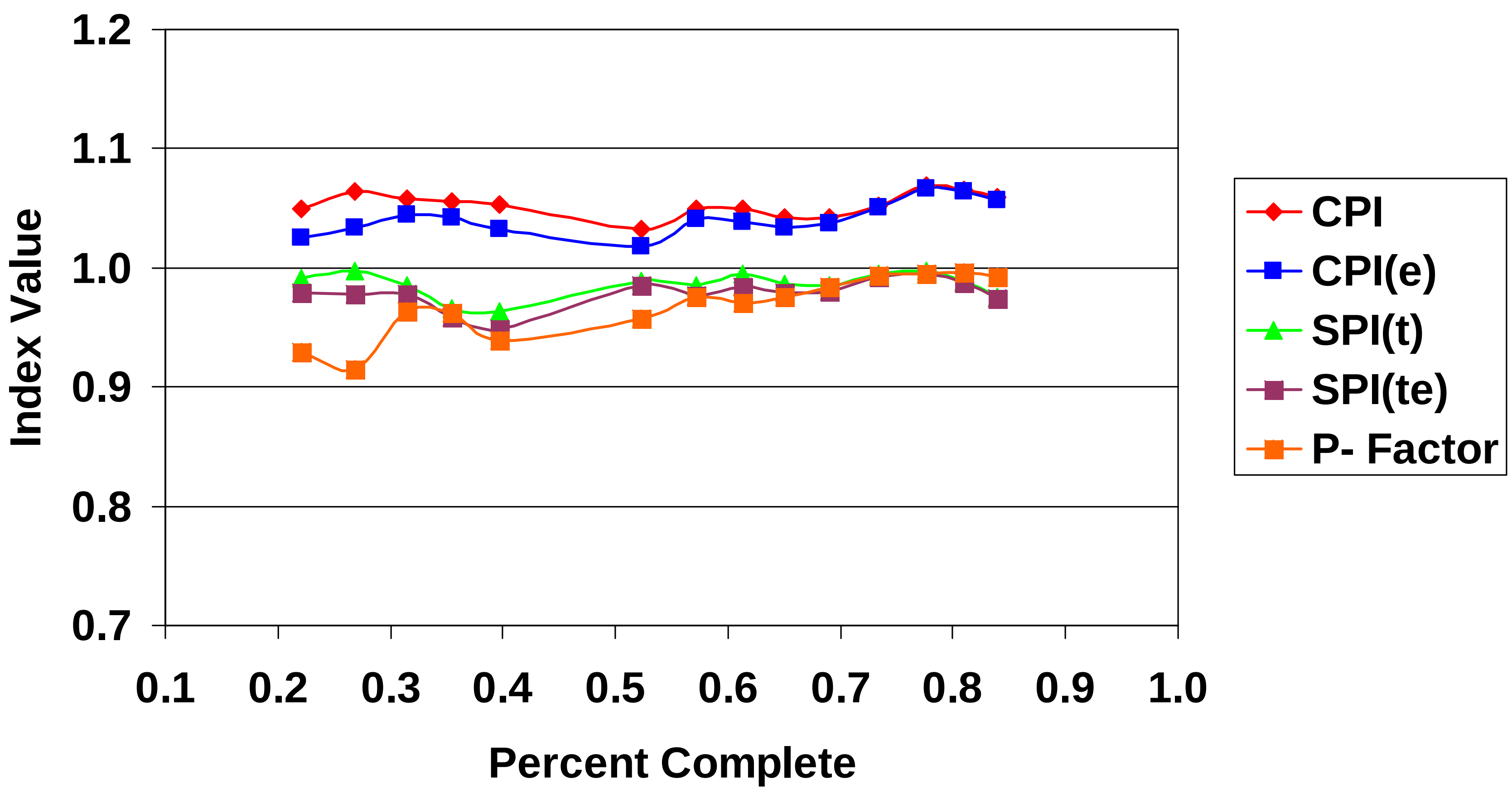
Effective Earned Value

- 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)



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



Recap - 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*

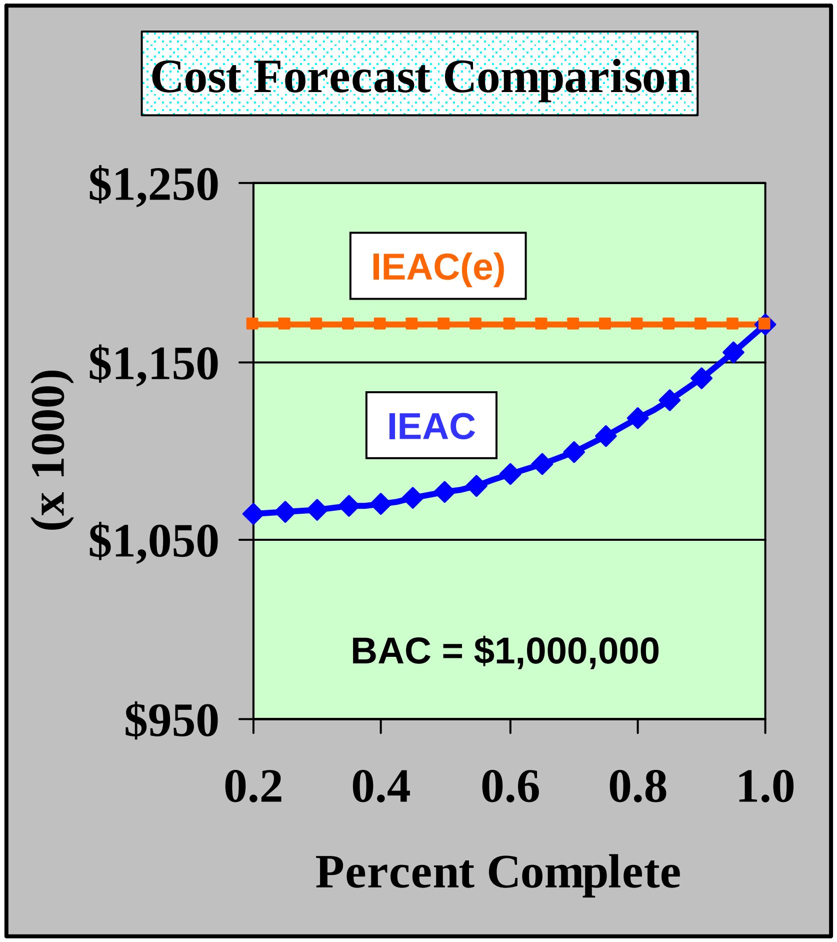
Forecasting with Effective Earned Value

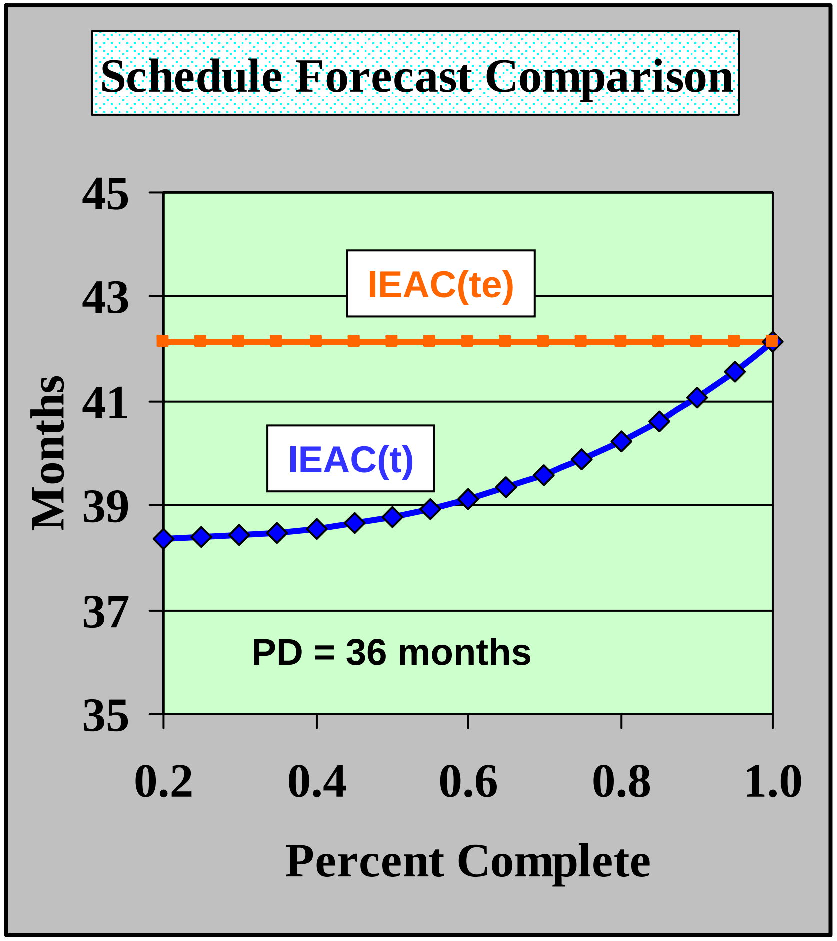
Forecasting using Effective Earned Value

Schedule Prediction	**IEAC(te) = PD / SPI(te)**
Cost Prediction	**IEAC(e) = BAC / CPI(e)**

Schedule & Cost Prediction

(notional data)





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
- Leads to Schedule Adherence & Effective Earned Value, and …
- Improved Cost & Schedule Forecasting

References

- "Schedule is Different," *The Measurable News*, March & Summer 2003 [Walt Lipke]
- "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*, Winter 2004 [Walt Lipke]

Earned Schedule Website: www.earnedschedule.com
PMI-Sydney Website: http://sydney.pmichapters-australia.org.au/
Click "Education," then "Presentations and Papers"