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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**
- **Prediction Study**
- **Network Schedule Analysis**
- **Earned Value Research**
- **Concept of** ***Effective Earned Value***
- **Forecasting with Effective EV**
- **Summary**

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Earned Schedule Concept

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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**

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So, what's the problem?

- Traditional schedule metrics lose predictive ability over the last third of the project
  - Impacts schedule predictions, EAC predictions
- ***Project managers don't understand schedule performance in terms of budget***

…Like most of us!

Earned Schedule Concept

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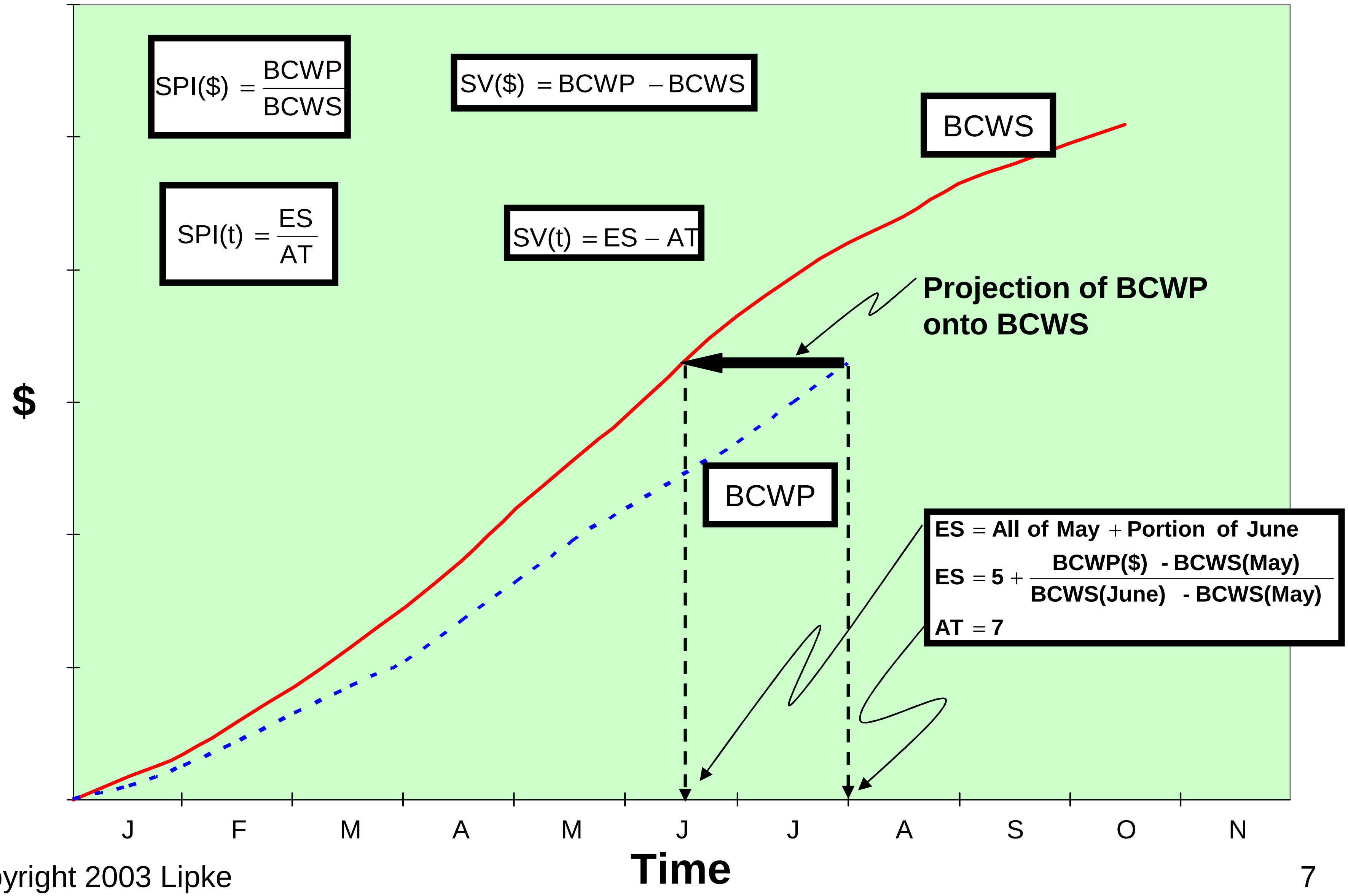

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Earned Schedule:
The Formulae

- **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 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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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

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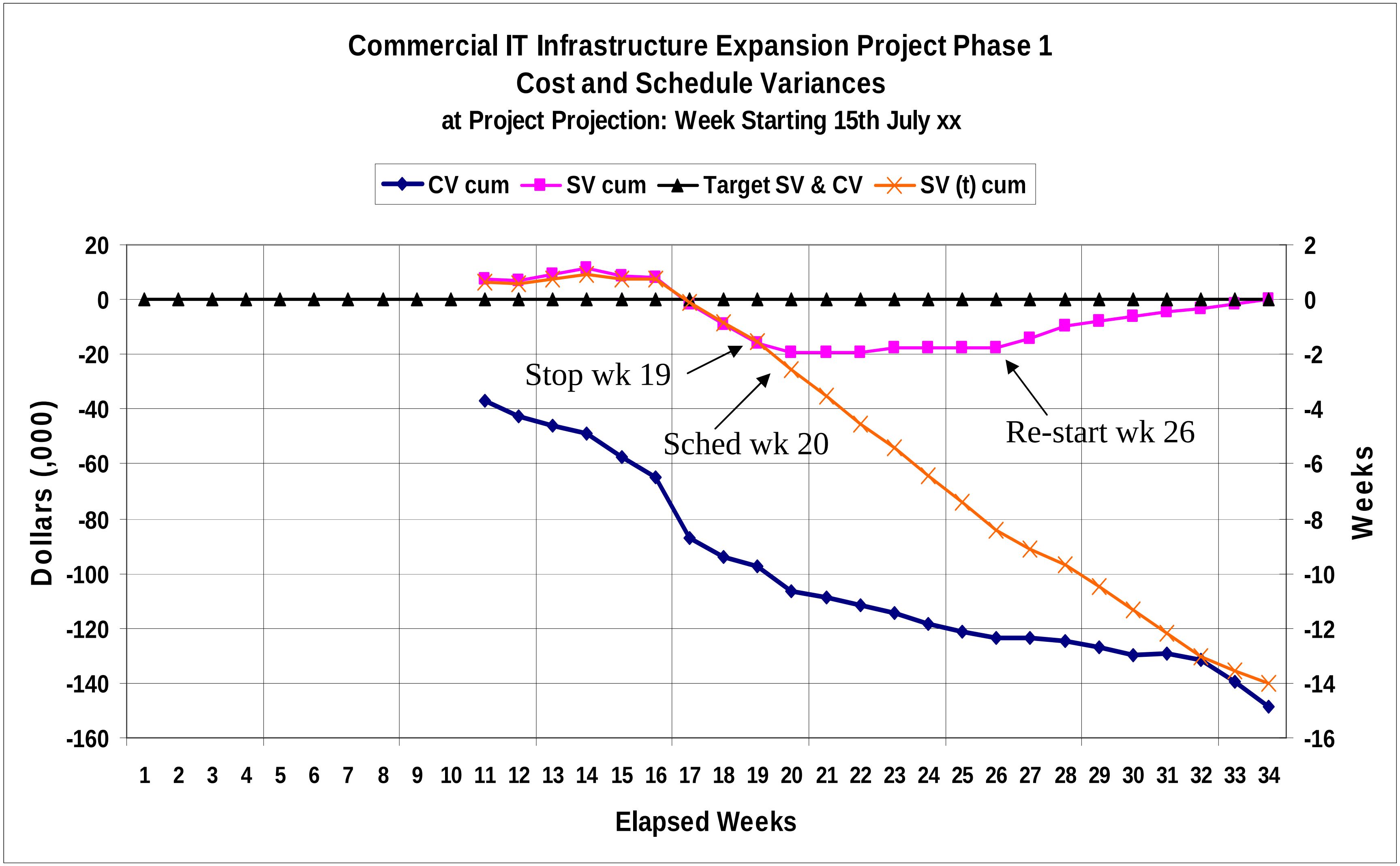
Application Results

ES Applied to Real Project Data:

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



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

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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 ….**

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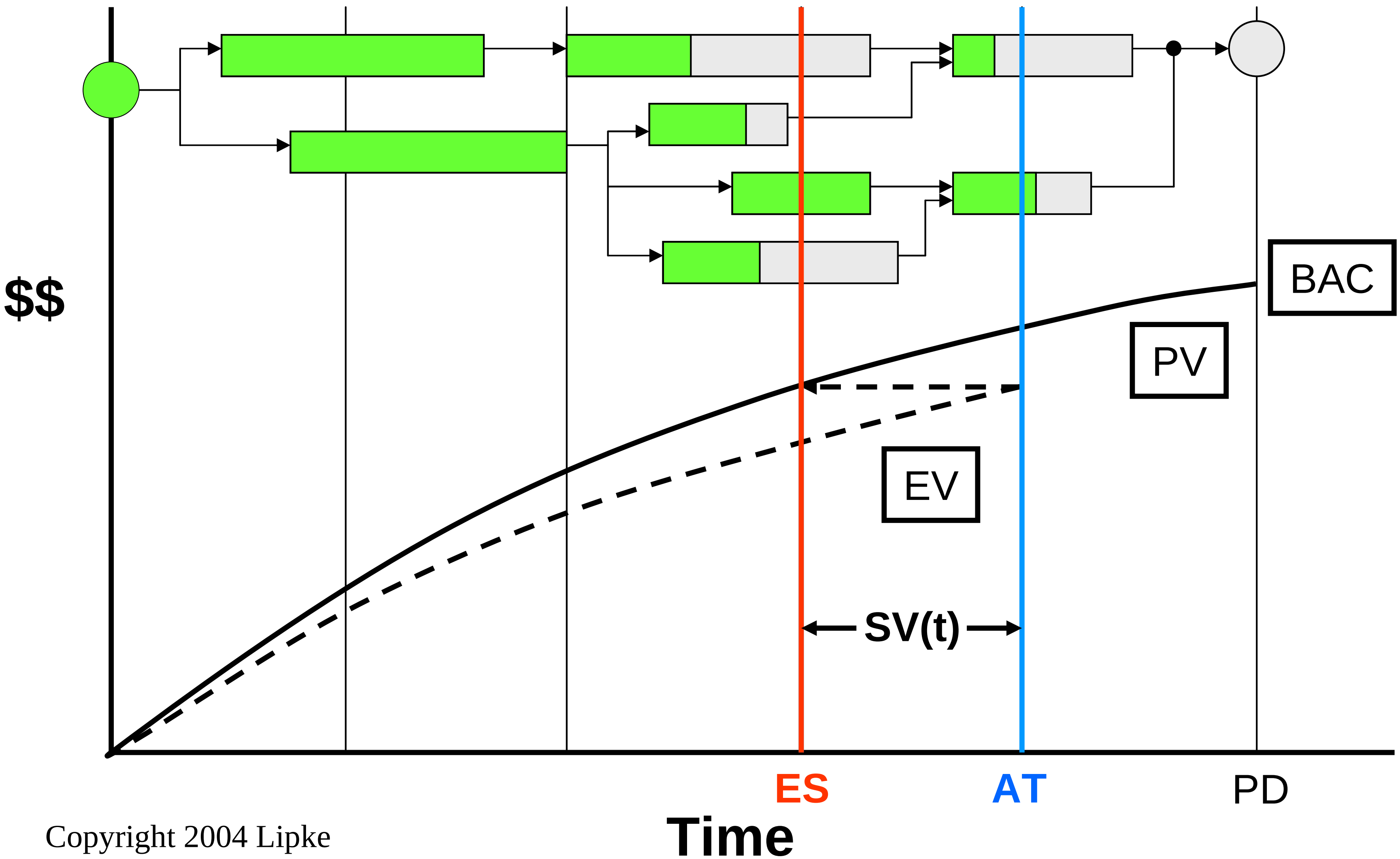
Earned Schedule

Bridges EVM to "Real" Schedule



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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

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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 ⇒ BAC**
  - **|CPI(final) – CPI(20%)| ≤ 0.10**
  - **IEAC = BAC / CPI ≤ Final Cost**

    when Percent Complete is 20% ⇔ 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***

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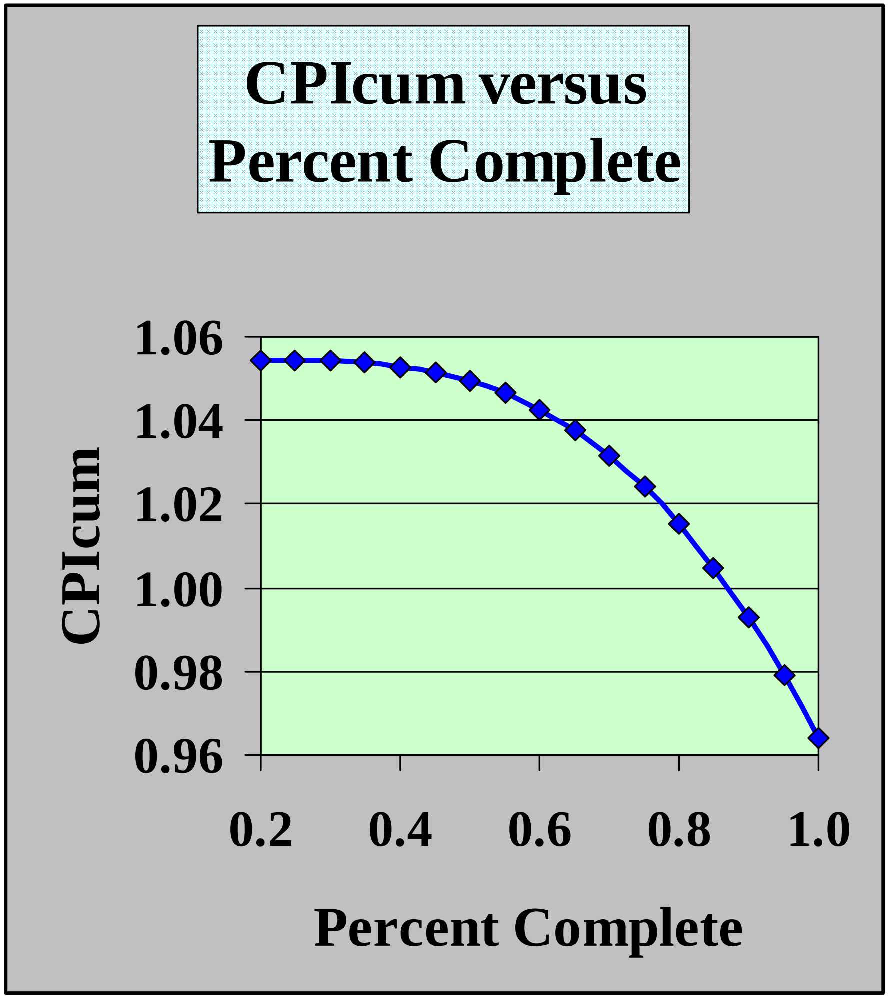
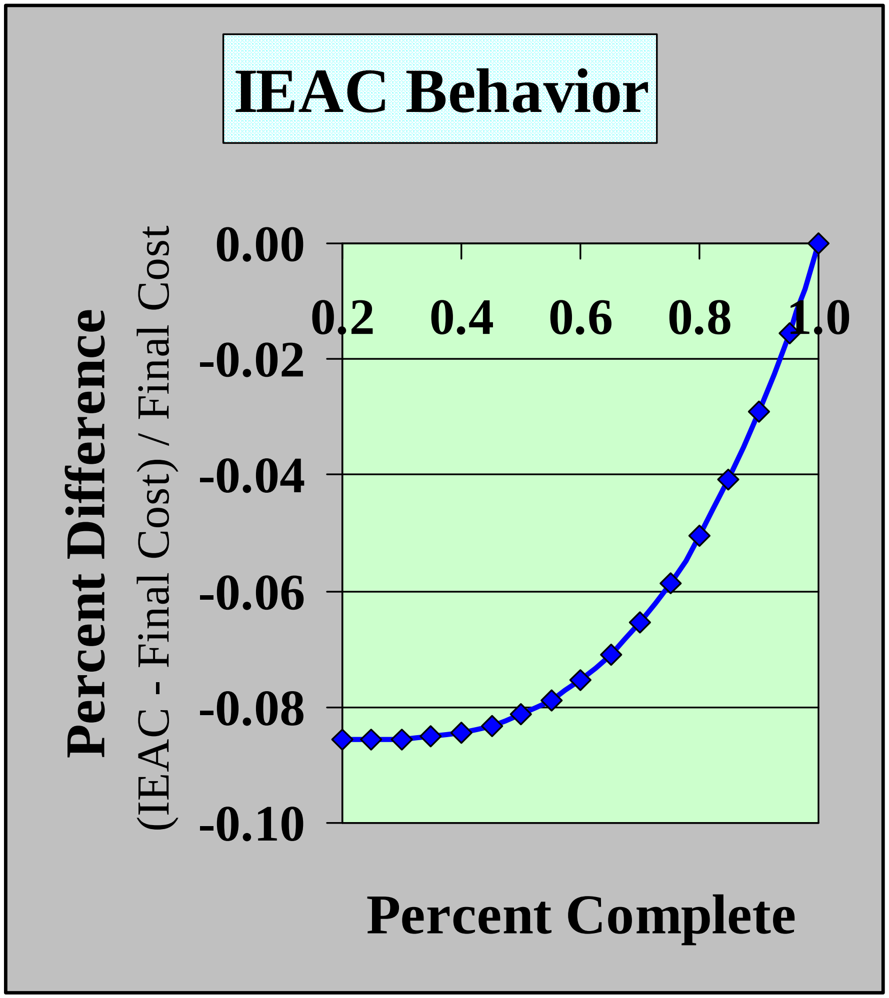
CPI & IEAC Behavior





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Concept:
Effective Earned Value

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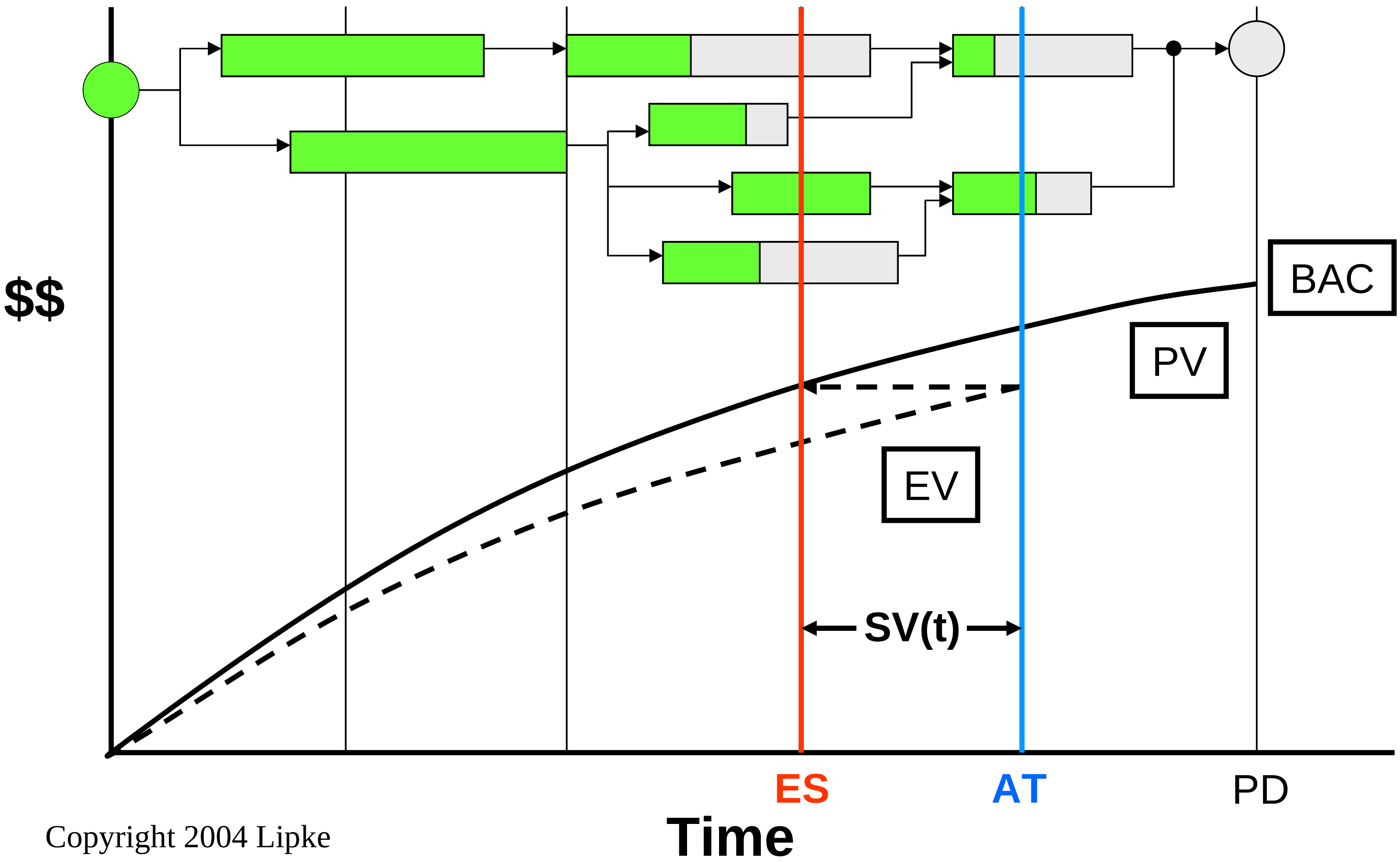
Earned Schedule

Bridges EVM to "Real" Schedule



Effective Earned Value

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- 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 ⇒ BAC**

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Effective Earned Value

- **<u>Schedule Adherence</u> 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:***

$$P = \text{Tasks (perf - corr) / Tasks (plan)}$$
$$= \Sigma EV_j \text{ (corresponding) } / \Sigma PV_j \text{ (plan)}$$
$$\text{where } \Sigma EV_j \leq \Sigma PV_j \;\; \& \;\; \Sigma PV_j = EV$$

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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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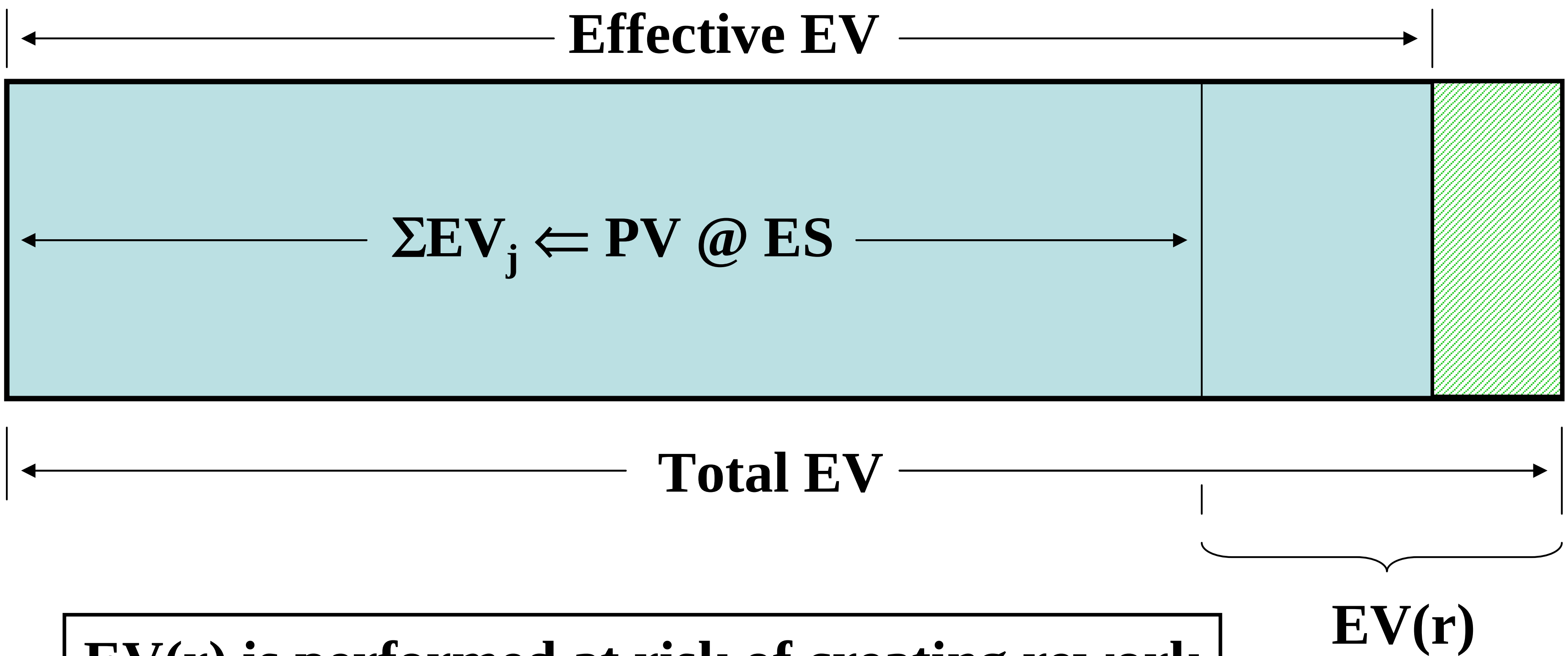
Effective Earned Value



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

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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***

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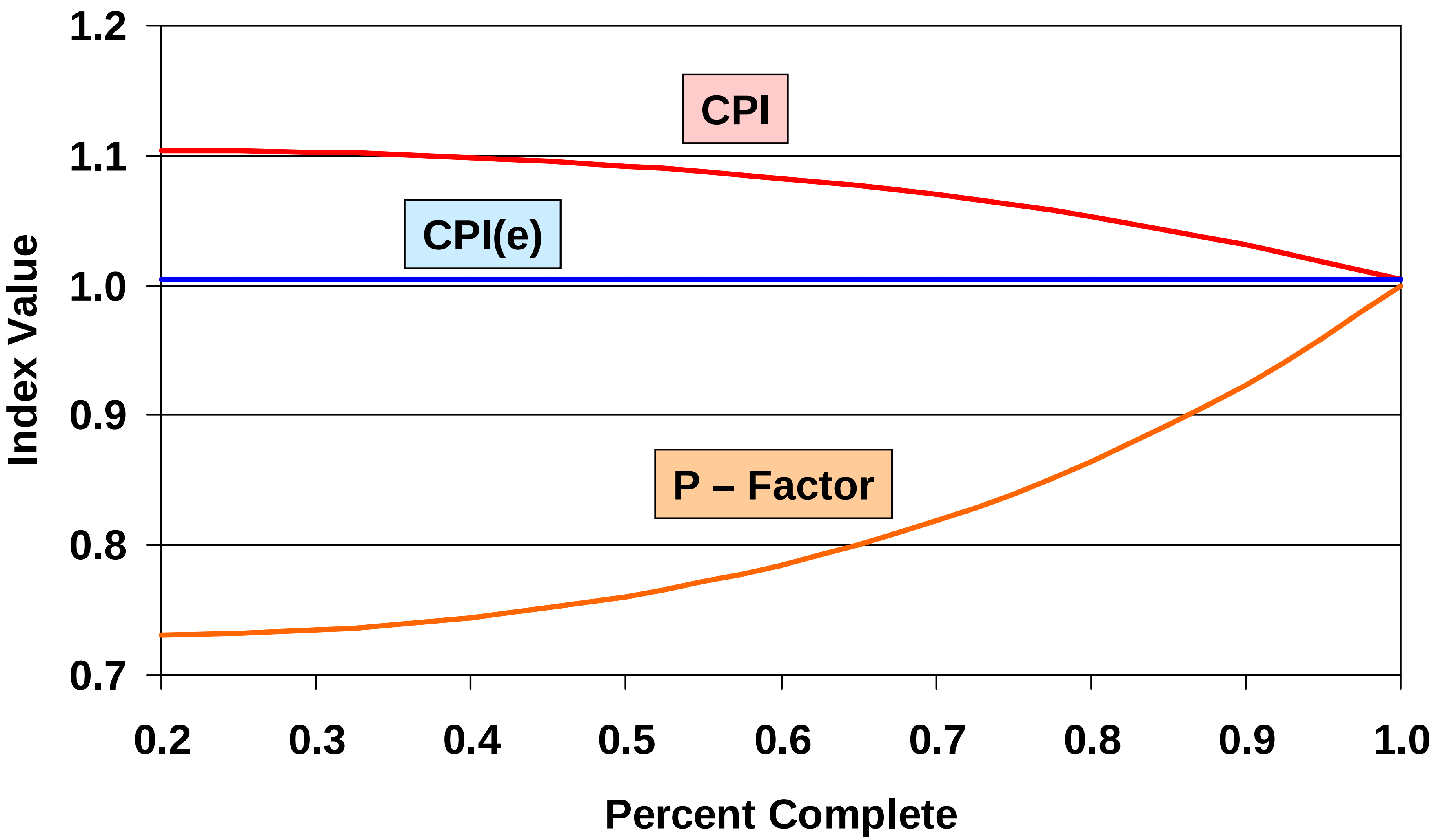
Graphs of CPI, CPI(e) & P - Factor (notional data)



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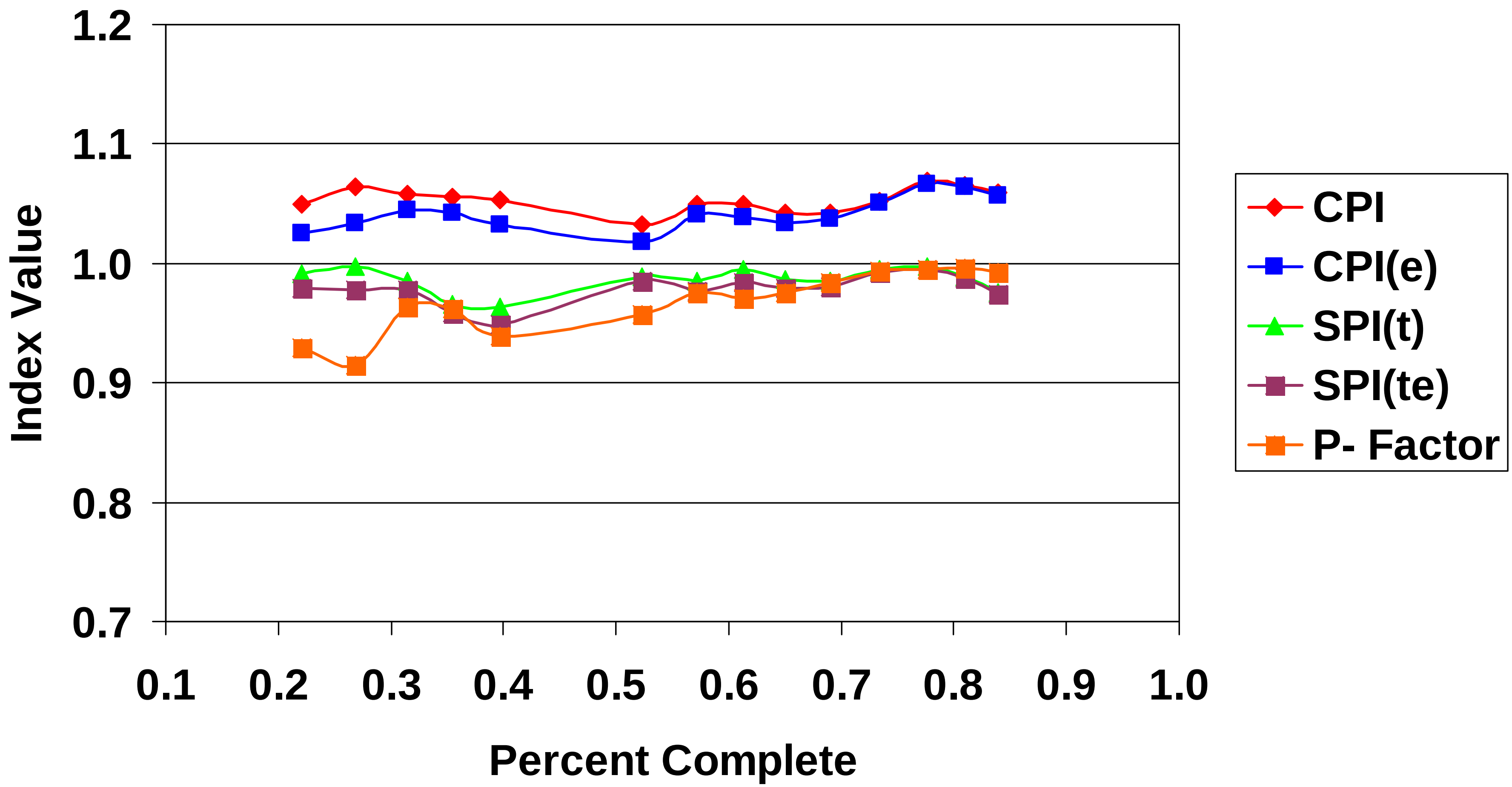
Graphs of CPI & SPI(t) with the P - Factor



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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***

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Forecasting with Effective Earned Value

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Forecasting with Effective Earned Value

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

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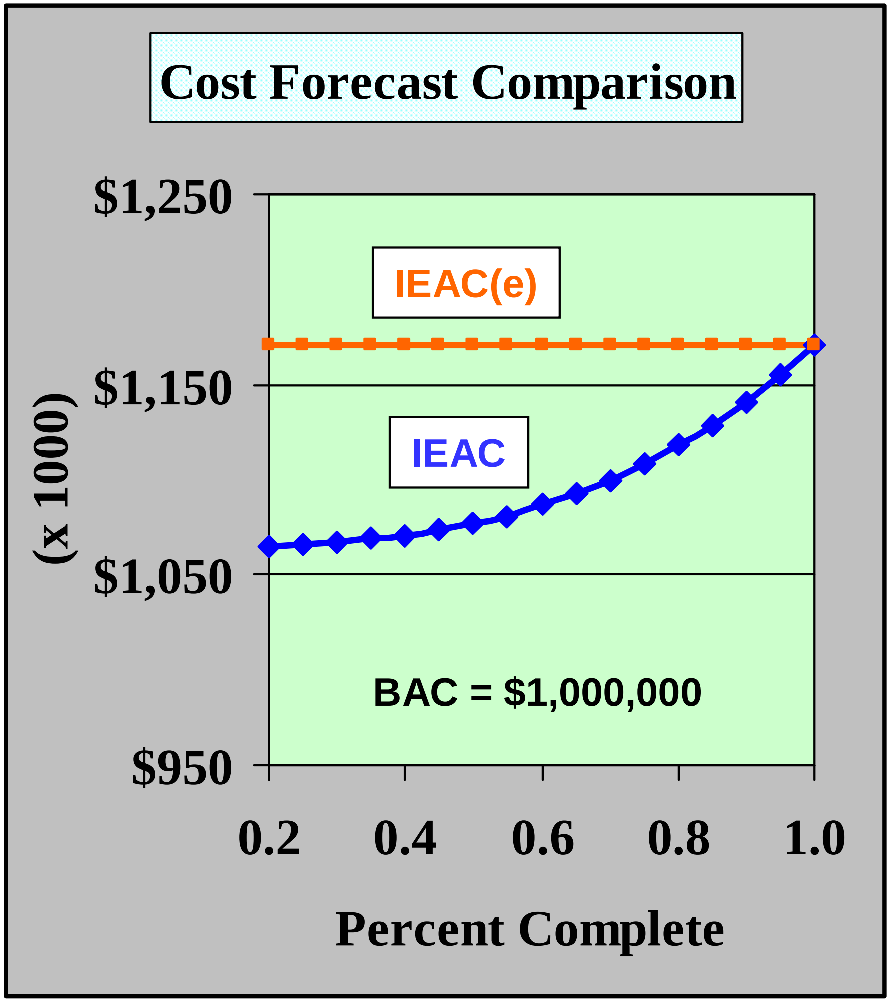
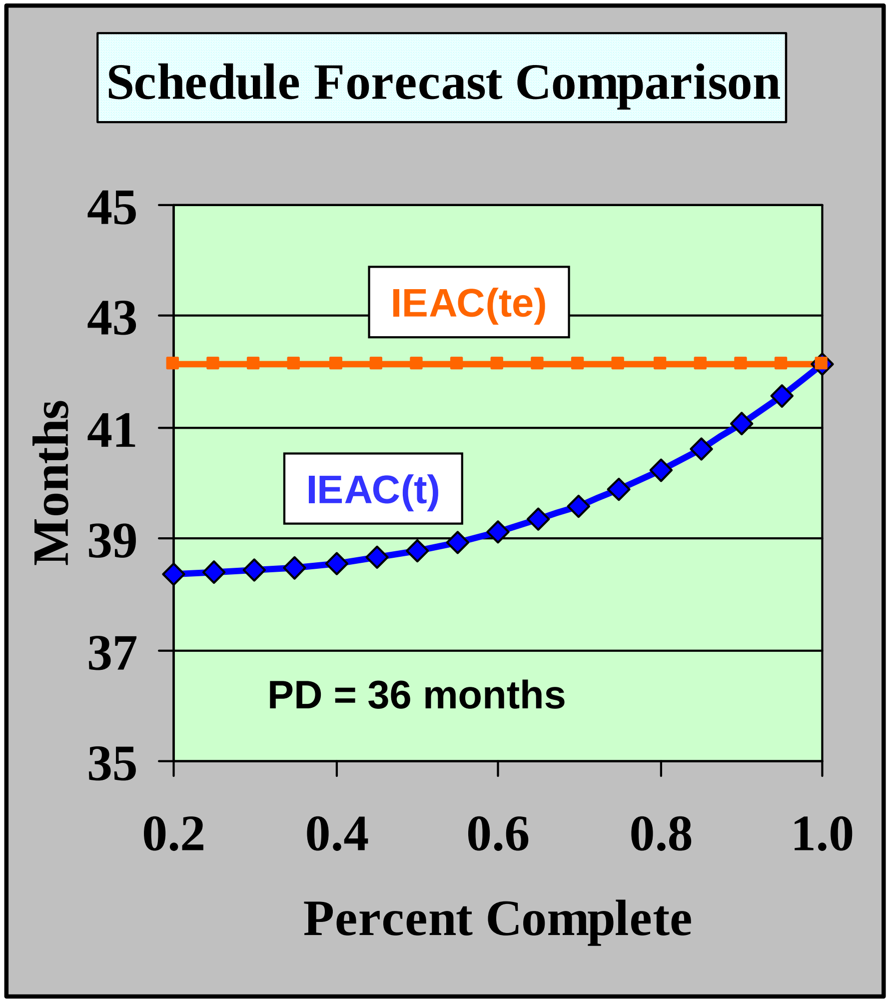
Schedule & Cost Prediction





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**

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