Earned Schedule

Walt Lipke
waltlipke@cox.net
(405) 364-1594

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Earned Schedule Training Basic

- EVM Schedule Indicators
- Introduction to Earned Schedule
  - Concept & Metrics
  - Indicators
  - Predictors
  - Terminology

Earned Schedule Training Basic

- Application of Concept
  - Analysis & Verification
  - Prediction Comparisons
- Demonstration of ES Calculator
  - V1 & V2 Calculators
- Interpolation Error

Earned Schedule Training Basic

- *Exercise – Calculate ES, SV(t), SPI(t)*
- Status Update
  - Applications
  - PMI-CPM Earned Value Practice Standard
  - ES Website

Earned Schedule Training Advanced

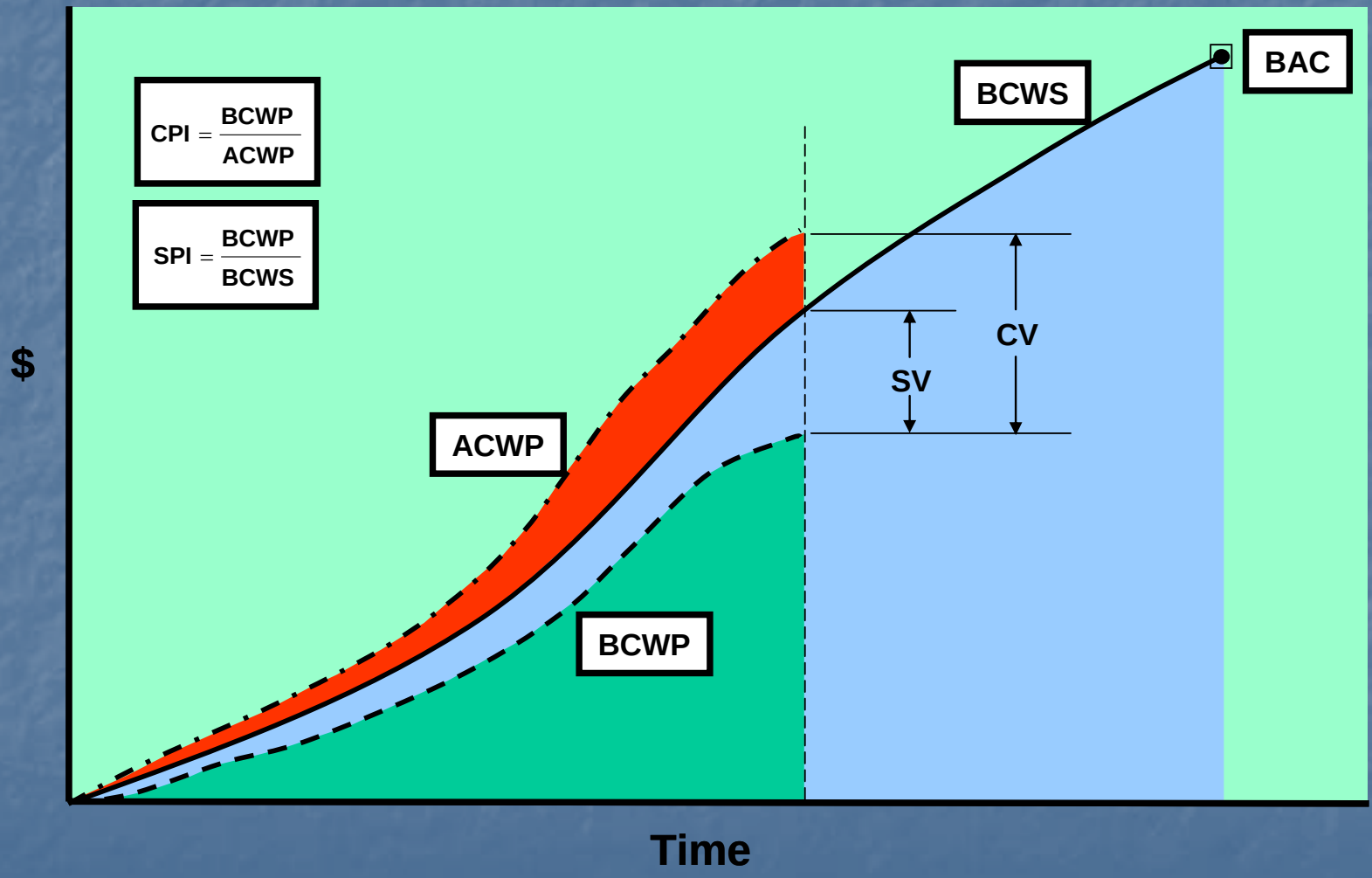
- Network Schedule Analysis
  - Impediments / Constraints
  - Rework
- EV Research
  - Schedule Adherence

Earned Schedule Training Advanced

- Effective Earned Value
  - Derivation / Indicators / Prediction
- Summary
- *Quiz & Discussion* (if time available)
- Wrap Up

Earned Value Management Schedule Indicators

EVM Schedule Indicators



EVM Schedule Indicators

- SV & SPI behave erratically for projects behind schedule
  - SPI improves and concludes at 1.00 at end of project
  - SV improves and concludes at $0 variance at end of project
- Schedule indicators lose predictive ability over the last third of the project

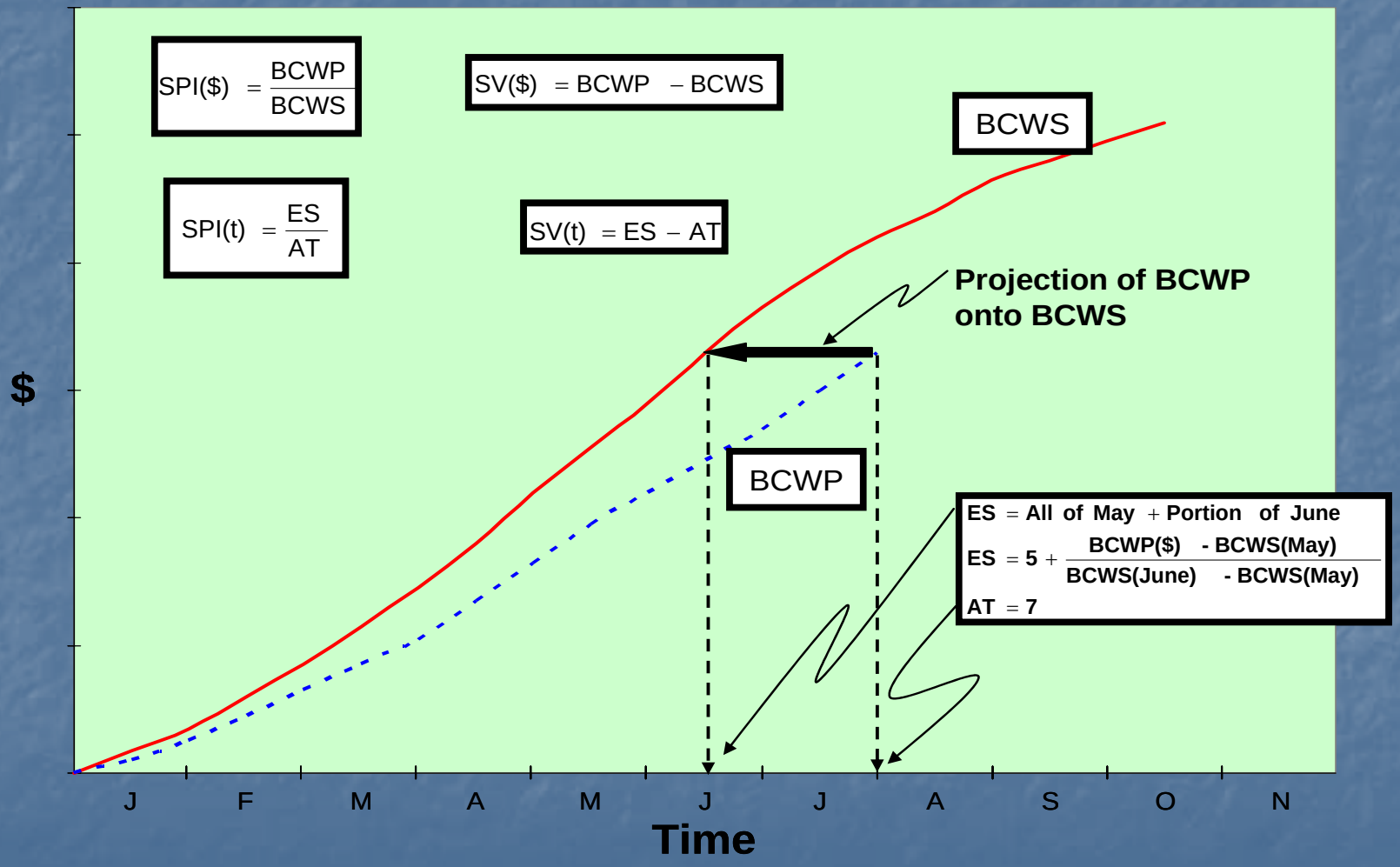
EVM Schedule Indicators

- Why does this happen?
  - SV = BCWP – BCWS
  - SPI = BCWP / BCWS
- At planned completion BCWS = BAC
- At actual completion BCWP = BAC
- When actual > planned completion
  - SV = BAC – BAC = $000
  - SPI = BAC / BAC = 1.00

Regardless of lateness !!

Introduction to Earned Schedule

Earned Schedule Concept



Earned Schedule Metrics

- Required measures
  - Performance Management Baseline (PMB) – the time phased planned values (BCWS) from project start to completion
  - Earned Value (BCWP) – the planned value which has been "earned"
  - Actual Time (AT) - the actual time duration from the project beginning to the time at which project status is assessed
- All measures available from EVM

Earned Schedule Metrics

- 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

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

- $ESperiod(n) = EScum(n) - EScum(n-1) = \Delta ES_{cum}$
- ATcum
- $ATperiod(n) = ATcum(n) - ATcum(n-1) = \Delta AT_{cum}$

  ΔAT_{cum} is normally equal to 1

Earned Schedule Indicators

- Schedule Variance: SV(t)
  - Cumulative: $SV(t) = ES_{cum} - AT_{cum}$
  - Period: $\Delta SV(t) = \Delta ES_{cum} - \Delta AT_{cum}$
- Schedule Performance Index: SPI(t)
  - Cumulative: $SPI(t) = ES_{cum} / AT_{cum}$
  - Period: $\Delta SPI(t) = \Delta ES_{cum} / \Delta AT_{cum}$

Earned Schedule Indicators

- What happens to the ES indicators, SV(t) & SPI(t), when the planned project duration (PD) is exceeded (BCWS = BAC)?

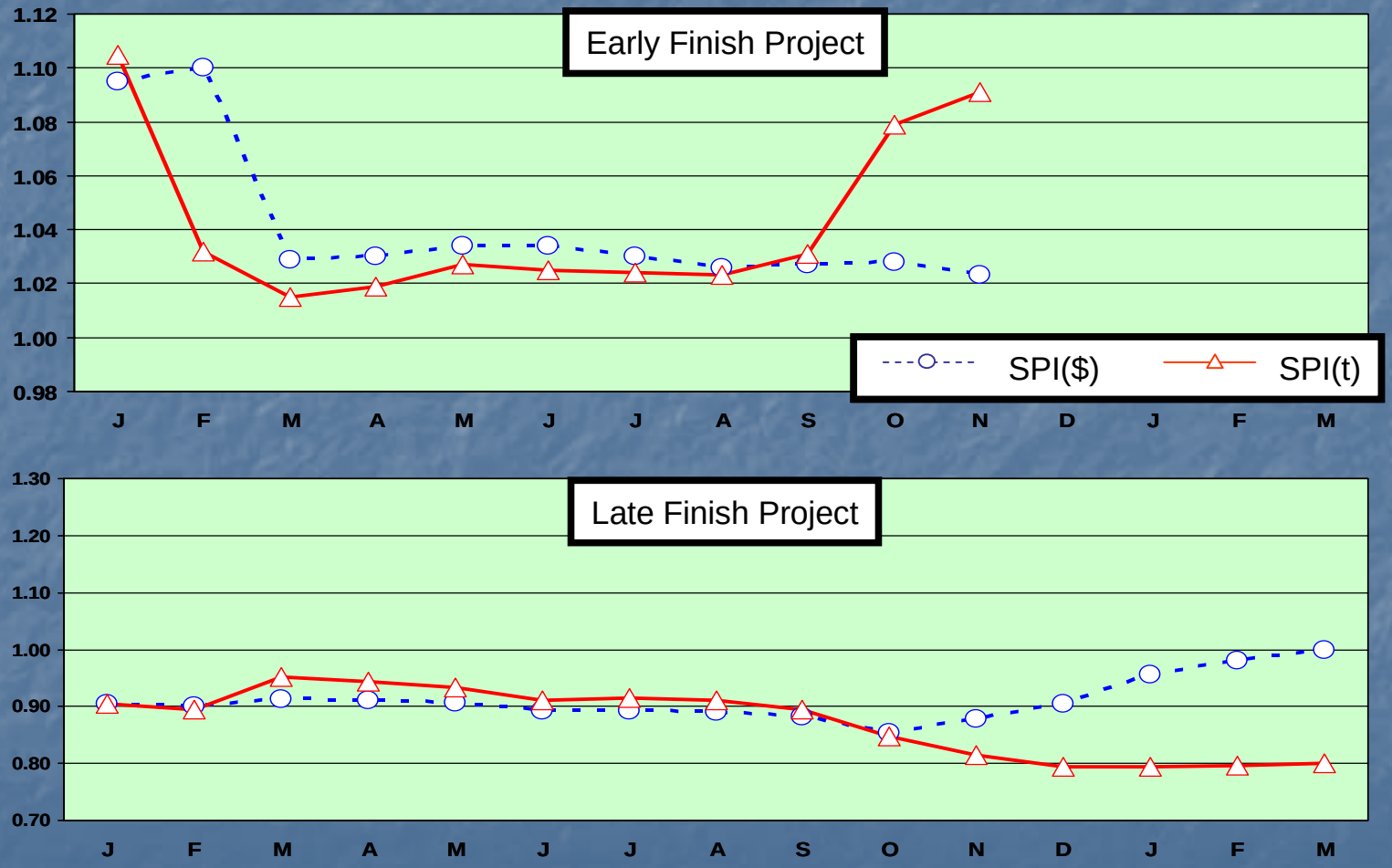
  They Still Work ...Correctly!!

- ES will be ≤ PD, while AT > PD
  - SV(t) will be negative (time behind schedule)
  - SPI(t) will be < 1.00

  Reliable Values from Start to Finish !!

SV Comparison

SPI Comparison



Earned Schedule Predictors

- Can the project be completed as planned?
  - TSPI = Plan Remaining / Time Remaining
    = (PD – ES) / (PD – AT)

    where (PD – ES) = PDWR

    PDWR = Planned Duration for Work Remaining
  - TSPI = (PD – ES) / (ED – AT)

    where ED = Estimated Duration

TSPI Value	Predicted Outcome
≤ 1.00	Achievable
> 1.10	Not Achievable

Earned Schedule Predictors

- Long time goal of EVM ...*Prediction of total project duration from present schedule status*
- Independent Estimate at Completion (time)
  - IEAC(t) = PD / SPI(t)
  - IEAC(t) = AT + (PD – ES) / PF(t)

    where PF(t) is the Performance Factor (time)
  - Analogous to IEAC used to predict final cost
- Independent Estimated Completion Date (IECD)
  - IECD = Start Date + IEAC(t)

Earned Schedule Terminology

	EVM	Earned Schedule
Status	Earned Value (EV)	Earned Schedule (ES)
	Actual Costs (AC)	Actual Time (AT)
	SV	SV(t)
	SPI	SPI(t)
Future Work	Budgeted Cost for Work Remaining (BCWR)	Planned Duration for Work Remaining (PDWR)
	Estimate to Complete (ETC)	Estimate to Complete (time) ETC(t)
Prediction	Variance at Completion (VAC)	Variance at Completion (time) VAC(t)
	Estimate at Completion (EAC) (supplier)	Estimate at Completion (time) EAC(t) (supplier)
	Independent EAC (IEAC) (customer)	Independent EAC (time) IEAC(t) (customer)
	To Complete Performance Index (TCPI)	To Complete Schedule Performance Index (TSPI)

Earned Schedule Terminology

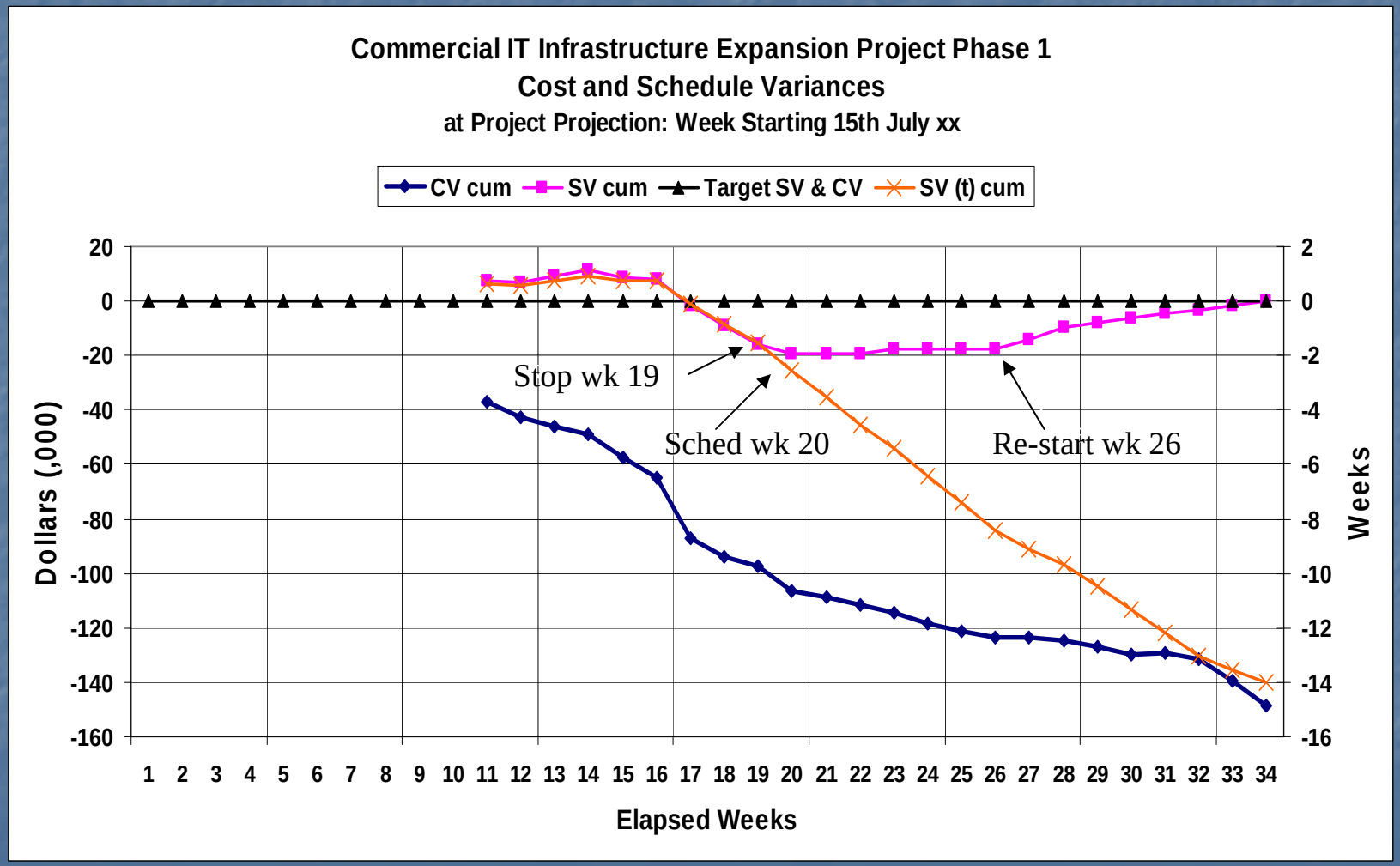
Metrics	**Earned Schedule**	**ES_{cum}**	**ES = C + I number of complete periods (C) plus an incomplete portion (I)**
	Actual Time	**AT_{cum}**	**AT = number of periods executed**
Indicators	**Schedule Variance**	**SV(t)**	**SV(t) = ES - AT**
	Schedule Performance Index	**SPI(t)**	**SPI(t) = ES / AT**
	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(t)

Earned Schedule Key Points

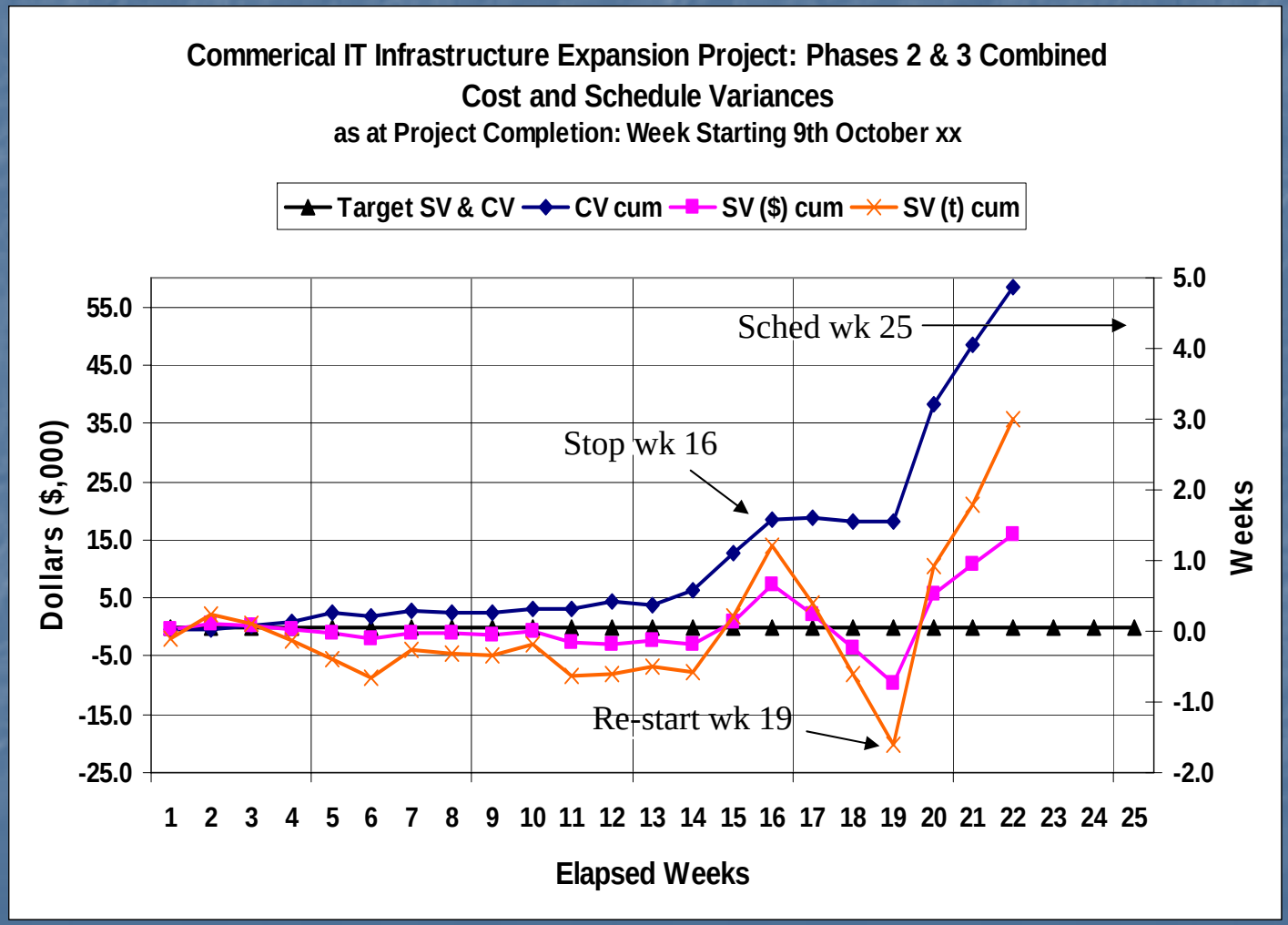
- ES Indicators constructed to behave in an analogous manner to the EVM Cost Indicators, CV and CPI
- SV(t) and SPI(t)
  - Not constrained by BCWS calculation reference
  - Provide duration based measures of schedule performance
  - Valid for entire project, including early and late finish
- Facilitates integrated Cost/Schedule Management (using EVM with ES)

Application of Concept
(Using Real Project Data)

ES Applied to Real Project Data:
Late Finish Project: SV($) and SV(t)



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



Prediction Comparisons

"Further Developments" in Earned Schedule
Schedule Duration Prediction

- **Calculation of IEAC(t): short form**

  IEAC(t) = Planned Duration / SPI(t)

- **Planned Duration for Work Remaining**

  PDWR = Planned Duration – Earned Schedule cum

  - Analogous to the EVM BCWR

- **Calculation of IEAC(t): long form**

$$\text{IEAC(t)} = \text{Actual Time} + \left(\frac{\text{PDWR}}{\text{Performance Factor}} \right)$$

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

"Further Developments" in Earned Schedule

Schedule Duration Prediction (continued)

- **Pre ES formulae and results algebraically flawed**

"... there is little theoretical justification for EVM practitioners continuing to use the pre ES predictors of schedule performance. Conversion to and use of the ES based techniques is strongly recommended."

- Kym Henderson

IEAC(t) Predictions using ES Techniques:
Same *Early and Late Finish Project Examples*

IEAC(t) Metrics at Project Completion Early Finish Project using ES	
Planned Duration (weeks)	25
Actual Time (weeks)	22
Earned Schedule cum	25.0
Planned Duration Work Remaining	0.0
Percentage Complete cum	100%
CPI cum	2.08
SPI(t) cum	1.14
SPI($) cum	1.17
Critical Ratio cum	2.43
Critical Ratio ES cum	2.37
IEAC(t) PF = SPI(t) cum	22.0
IEAC(t) PF = SPI($) cum	22.0
IEAC(t) PF = CR cum	22.0
IEAC(t) PF = CR ES cum	22.0

IEAC(t) Metrics at Project Completion Late Finish Project using ES	
Planned Duration (weeks)	20
Actual Time (weeks)	34
Earned Schedule cum	20.0
Planned Duration Work Remaining	0.0
Percentage Complete cum	100%
CPI cum	0.53
SPI(t) cum	0.59
SPI($) cum	1.00
Critical Ratio cum	0.52
Critical Ratio ES cum	0.30
IEAC(t) PF = SPI(t) cum	34.0
IEAC(t) PF = SPI($) cum	34.0
IEAC(t) PF = CR cum	34.0
IEAC(t) PF = CR ES cum	34.0

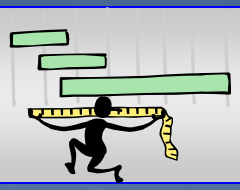
- Use of the ES "long form" IEAC(t) formula, results in **correct** calculation of Actual Duration at Completion

IEAC(t) Predictions using ES Techniques:

- **ES formulae and results are algebraically correct**

"Whilst assessments of the predictive utility of the ES calculated IEAC(t) and the relative merits of using the various performance factors available are matters for further research and empiric validation, the theoretical integrity of ES now seems confirmed."

- Kym Henderson



2 My Experience Summarised

- Schedule Performance Indicators (for early and late finish projects):
  - SPI(t) & SV(t) do portray the real schedule performance in agreement with [1] [2]
- Forecasting Duration (for early and late finish projects):
  - at early & middle project stage: pre-ES & ES forecasts produce similar results
  - at late project stage: ES forecasts outperform all pre-ES forecasts in agreement with [2] [3]
- Assessing Project Duration (for early and late finish projects):
  - the use of the SPI(t) in conjunction with the TCSPI(t) has been demonstrated to be useful to manage the schedule expectations application of [3]

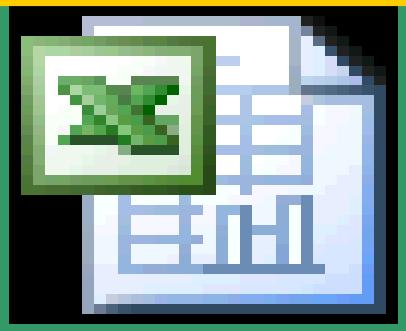
[1] Lipke Walt, Schedule is Different, The Measurable News, Summer 2003

[2] Henderson Kym, Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data,The Measurable News, Summer 2003

[3] Henderson, Kym, Further Development in Earned Schedule,The Measurable News, Spring 2004

Demonstration of Earned Schedule Calculator

Earned Schedule Calculator



Earned Schedule Calculator (V1)

Status Update

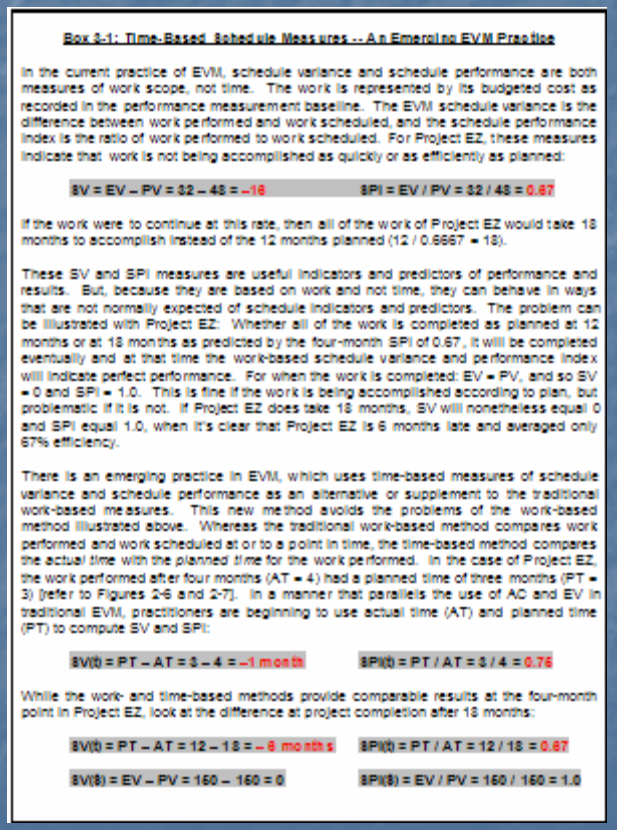
Early Adopters

- EVM Instructors
  - PMA, Management Technologies ...
- Boeing Dreamliner®, Lockheed Martin, US State Department, Secretary of the Air Force
- Several Countries - Australia, Belgium, Sweden, USA ...
- Applications across weapons programs, construction, software development, ...
- Range of project size from very small and short to extremely large and long duration

www.earnedschedule.com

PMI-CPM EVM Practice Standard

- Inclusion of Emerging Practice Insert into PMI - EVM Practice Standard
  - Dr. John Singley, VP of CPM
- Included in Box 3-1 of EVM Practice Standard
  - Describes basic principles of "Earned Schedule"
  - Provides foundation for acceptance as a valid extension to EVM
- EVM Practice Standard released at 2004 IPMC Conference



Box 3-1: Time-Based Schedule Measures -- An Emerging EVM Practice

In the current practice of EVM, schedule variance and schedule performance are both measures of work scope, not time. The work is represented by its budgeted cost as recorded in the performance measurement baseline. The EVM schedule variance is the difference between work performed and work scheduled, and the schedule performance index is the ratio of work performed to work scheduled. For Project EZ, these measures indicate that work is not being accomplished as quickly or as efficiently as planned:

SV = EV – PV = 32 – 48 = –16 SPI = EV / PV = 32 / 48 = 0.67

If the work were to continue at this rate, then all of the work of Project EZ would take 18 months to accomplish instead of the 12 months planned (12 / 0.6667 = 18).

These SV and SPI measures are useful indicators and predictors of performance and results. But, because they are based on work and not time, they can behave in ways that are not normally expected of schedule indicators and predictors. The problem can be illustrated with Project EZ: Whether all of the work is completed as planned at 12 months or at 18 months as predicted by the four-month SPI of 0.67, it will be completed eventually and at that time the work-based schedule variance and performance index will indicate perfect performance. For when the work is completed: EV = PV, and so SV = 0 and SPI = 1.0. This is fine if the work is being accomplished according to plan, but problematic if it is not. If Project EZ does take 18 months, SV will nonetheless equal 0 and SPI equal 1.0, when it's clear that Project EZ is 6 months late and averaged only 67% efficiency.

There is an emerging practice in EVM, which uses time-based measures of schedule variance and schedule performance as an alternative or supplement to the traditional work-based measures. This new method avoids the problems of the work-based method illustrated above. Whereas the traditional work-based method compares work performed and work scheduled at or to a point in time, the time-based method compares the actual time with the planned time for the work performed. In the case of Project EZ, the work performed after four months (AT = 4) had a planned time of three months (PT = 3) [refer to Figures 2-6 and 2-7]. In a manner that parallels the use of AC and EV in traditional EVM, practitioners are beginning to use actual time (AT) and planned time (PT) to compute SV and SPI:

SV(t) = PT – AT = 3 – 4 = –1 month SPI(t) = PT / AT = 3 / 4 = 0.76

While the work- and time-based methods provide comparable results at the four-month point in Project EZ, look at the difference at project completion after 18 months:

SV(t) = PT – AT = 12 – 18 = – 6 months SPI(t) = PT / AT = 12 / 18 = 0.67

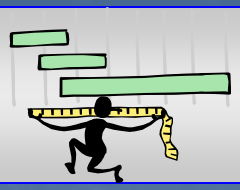
SV($) = EV – PV = 160 – 160 = 0 SPI($) = EV / PV = 160 / 160 = 1.0

Available Resources

- PMI-Sydney http://sydney.pmichapters-australia.org.au/
  - Repository for ES Papers and Presentations
- Earned Schedule Website
  http://www.earnedschedule.com/
  - Established February 2006
  - Contains *News, Papers, Presentations, ES Terminology, ES Calculators*
  - Identifies Contacts to assist with application
- Wikipedia now references Earned Schedule
  http://en.wikipedia.org/wiki/Earned_Schedule

Foreseen Uses of Earned Schedule

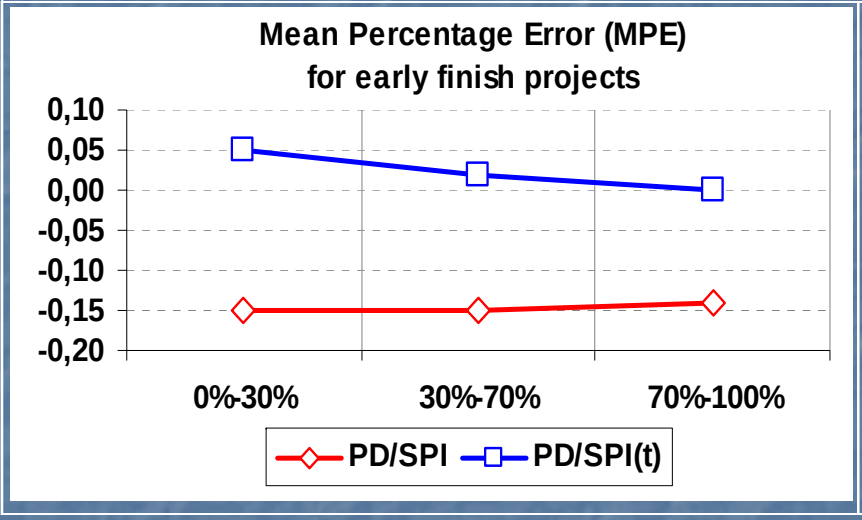
- Enables independent evaluation of schedule estimates: ETC(t), EAC(t)
  - Client, Contractor, Program and Project Manager ….
- Facilitates insight into network schedule performance
  - Duration based Schedule indicators
  - Identification of impediments/constraints and potential future rework
  - Evaluation of adherence to plan
- Improvement to Schedule and Cost prediction
  - Client, Contractor, Program and Project Manager ….
- Application of direct statistical analysis of schedule performance

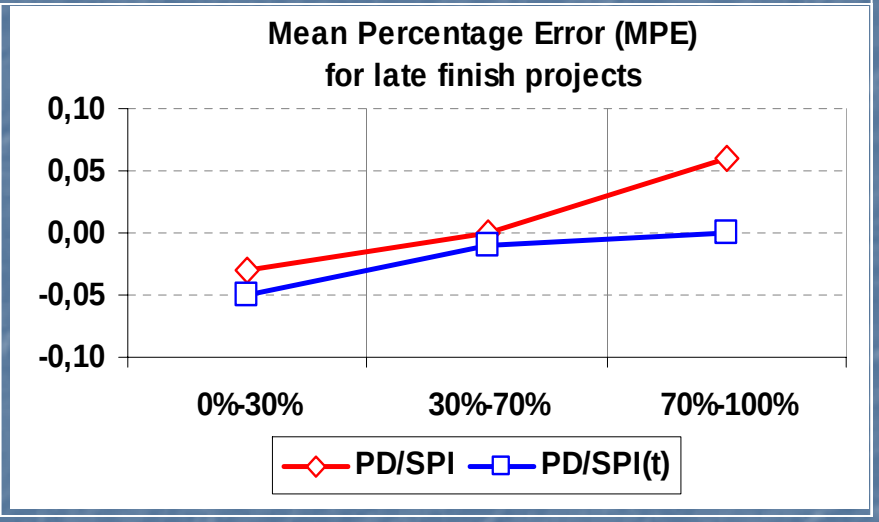


3 Research Efforts (2/3)

Extracted results from [8]: Forecast Accuracy and the Completion of Work

Simulation runs performed: 1 run project finish ahead of schedule, 1 run projects finish behind





Plans are made to present the research report *"A simulation and evaluation of earned value metrics to forecast the project duration"* at the 22nd PMI-CPM Spring Conference 2006.

[8] Vanhoucke Mario, Vandevoorde Stephan, A simulation and evaluation of earned value metrics to forecast the project duration , Working Paper 2005/317, July 2005, Ghent University

Summary

Summary - Basic

- Derived from EVM data ... only
- Provides time-based schedule indicators
- Indicators do not fail for late finish projects
- Application is scalable up/down, just as is EVM
- Schedule prediction is better than any other EVM method presently used
  - SPI(t) behaves similarly to CPI
  - IEAC(t) = PD / SPI(t) behaves similarly to IEAC = BAC / CPI

Summary

- Schedule prediction – much easier and possibly better than “bottoms-up” schedule analysis
- Application is growing in both small and large projects
- Practice recognized as “Emerging Practice”
- Resource availability enhanced with ES website and Wikipedia
- Research indicates ES superior to other methods

Summary

- Facilitates bridging EVM to schedule analysis
  - Identification of Constraints / Impediments and Rework
  - Calculation of Schedule Adherence
  - Creation of Effective Earned Value

Leads to improved
Schedule & Cost Forecasting

Wrap-Up

Conclusion

- "Whatever can be done using EVM for Cost Analysis can also be done using Earned Schedule for Schedule Analysis"
- Earned Schedule
  - A powerful new dimension to Integrated Project Performance Management (IPPM)
  - A breakthrough in theory and application

the first scheduling system

Contact Information

Walt Lipke		Kym Henderson
waltlipke@cox.net	Email	kym.henderson@froggy.com.au
(405) 364-1594	Phone	61 414 428 537