Earned Schedule

Presentation to Defence and PMI Canberra Chapter

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Context

“We need to maintain our attention on schedule delivery. Data tells us that since July 2003, real cost increase in projects accounted for less than 3% of the total cost growth. **Therefore, our problem is not cost, it is SCHEDULE.**”

Dr Steve Gumley
CEO DMO
(Defence Materiel Organisation)

Prescription 1st year anniversary
DMO Bulletin, July 06, Issue 61, p3

Outline

- EVM Schedule Indicators
- Introduction to Earned Schedule
  - Concept & Metrics
  - Indicators
  - Predictors
  - Terminology
- Application of Concept
  - Analysis & Verification
  - Prediction Comparisons

Outline

- Status Update
  - Applications
  - PMI-CPM Earned Value Practice Standard
  - Earned Schedule Website
- Summary
- Resources
- Conclusion

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Advanced Topics (not covered)

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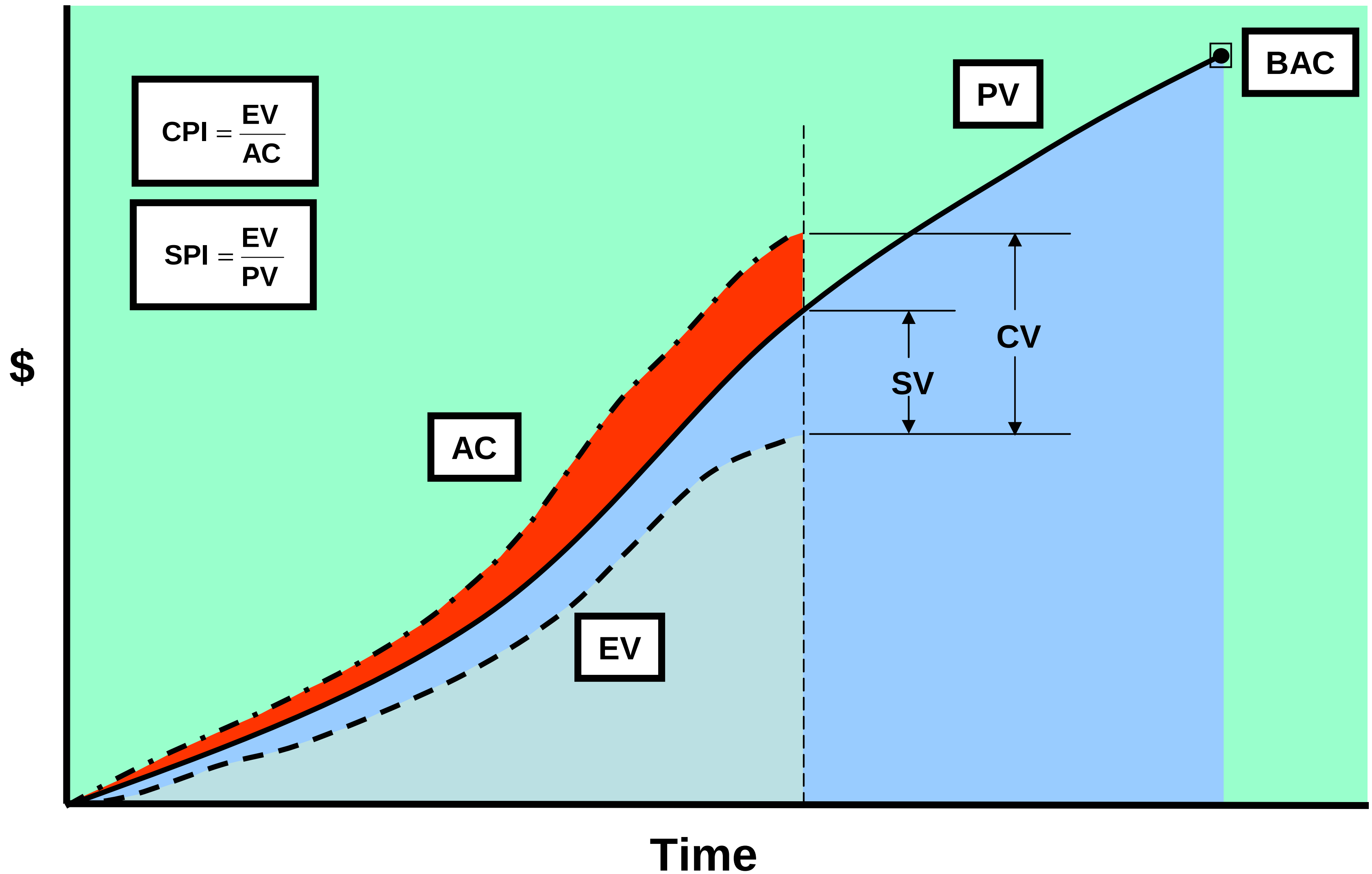
- Interpolation Error
- Network Schedule Analysis
  - Impediments / Constraints
  - Rework
- EV Research
  - Schedule Adherence
- Effective Earned Value
  - Derivation / Indicators / Prediction

EVM Schedule Indicators



EVM Schedule Indicators

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

EVM Schedule Indicators

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

Regardless of lateness !!

Earned Schedule Concept

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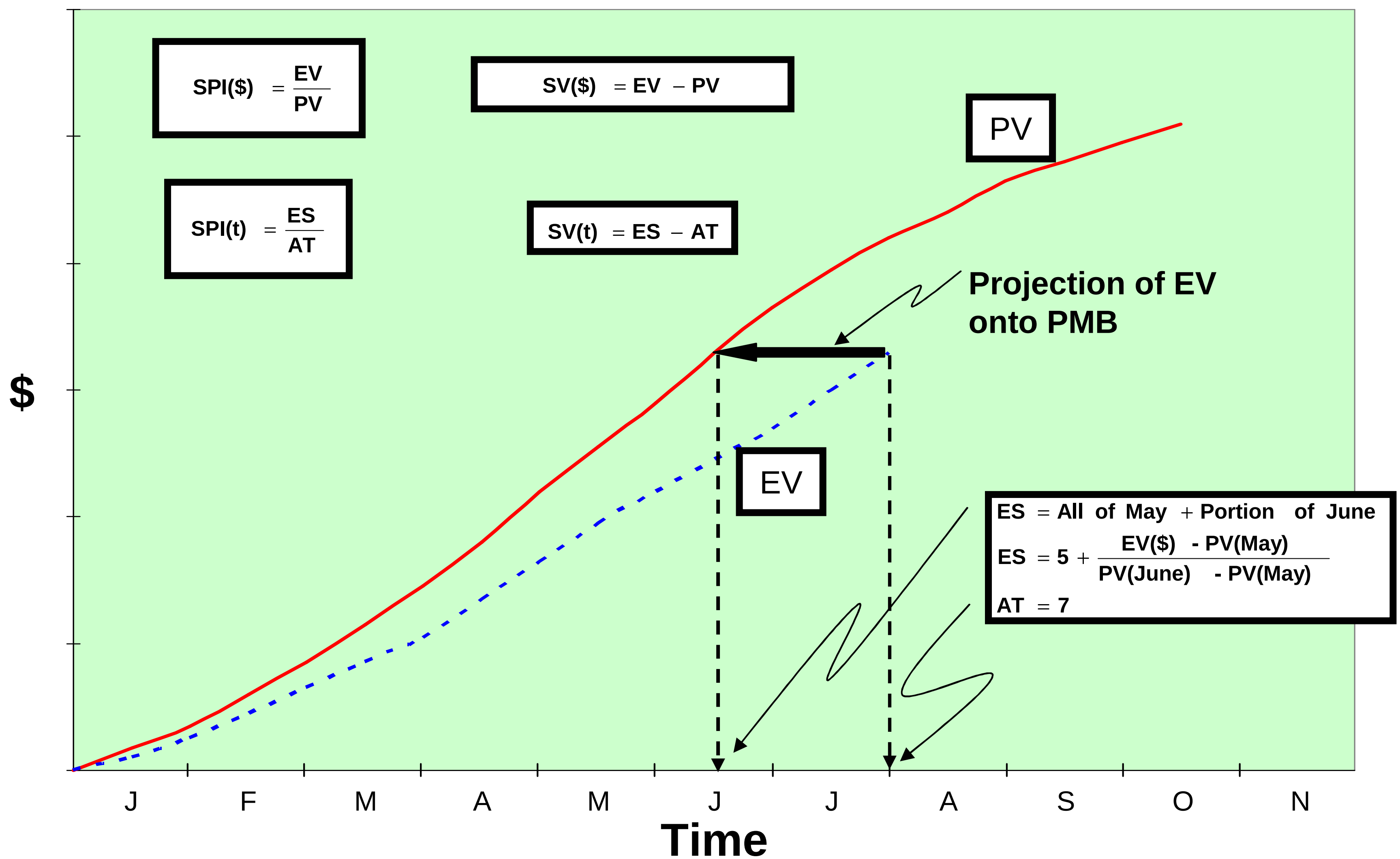

Earned Schedule Metrics

- Required measures
  - Performance Management Baseline (PMB) – the time phased planned values (PV) from project start to completion
  - Earned Value (EV) – 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

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Earned Schedule Metrics

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- ES_{cum} is the:

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

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

  C = number of time increments for $EV \geq PV$

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

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

  ΔAT_{cum} is normally equal to 1

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Earned Schedule Indicators

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- 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

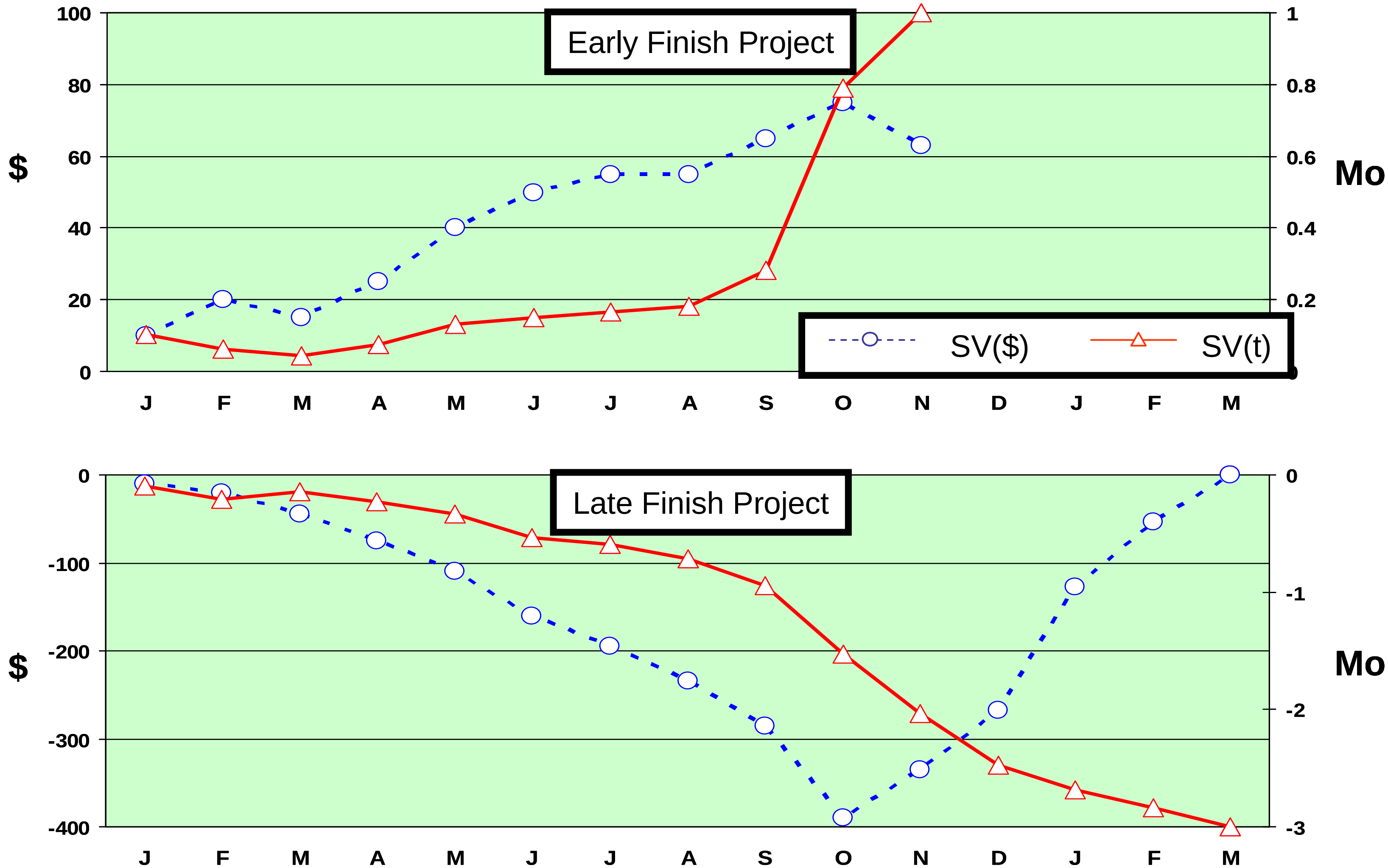
- What happens to the ES indicators, SV(t) & SPI(t), when the planned project duration (PD) is exceeded (PV = BAC)?

They Still Work …Correctly!!

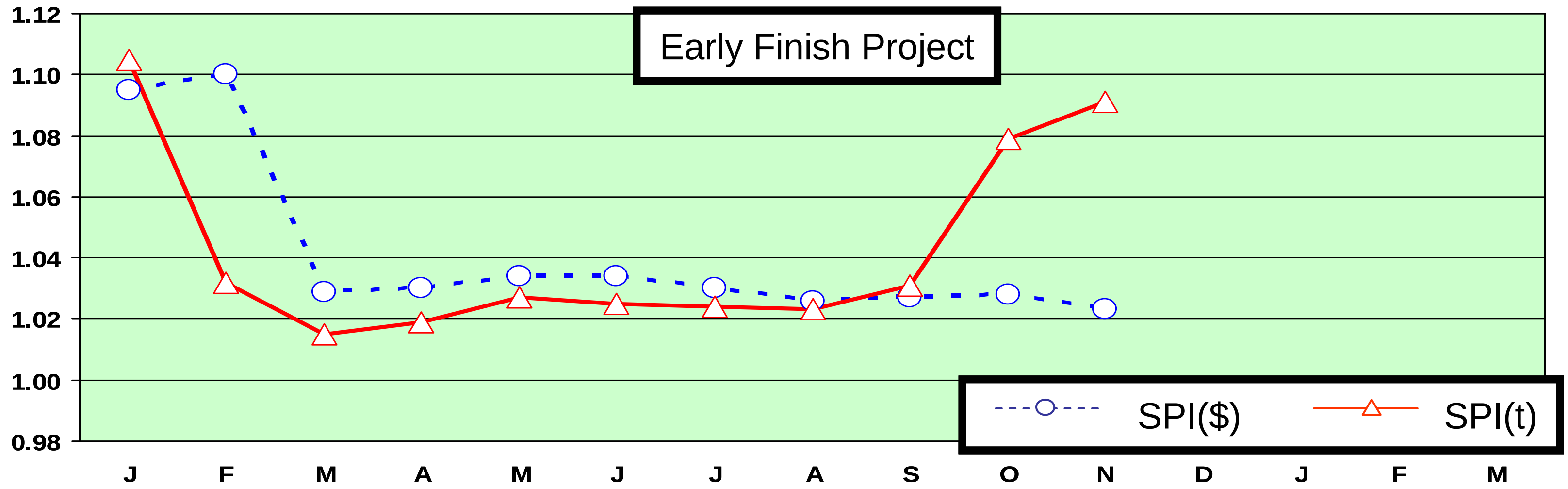
- ES will be ≤ PD, while AT > PD
  - SV(t) will be negative (time behind schedule)
  - SPI(t) will be < 1.00

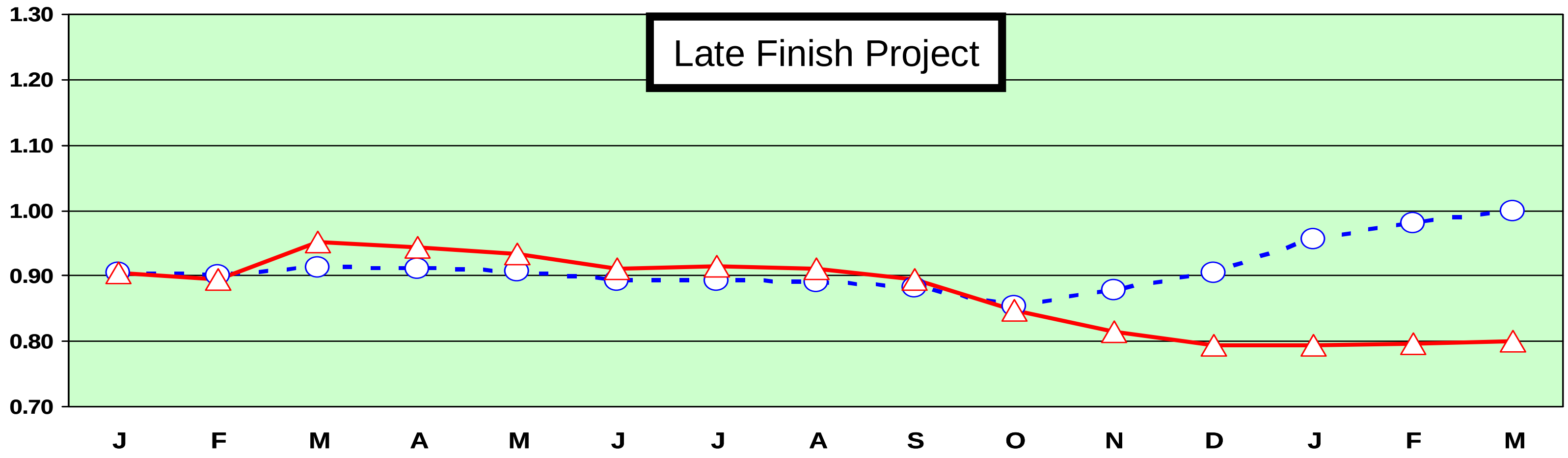
Reliable Values from Start to Finish !!

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
- …completed as estimated?
  - 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 desire of EVM practitioners…

  Prediction of total project duration

  from EVM data
- 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

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	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

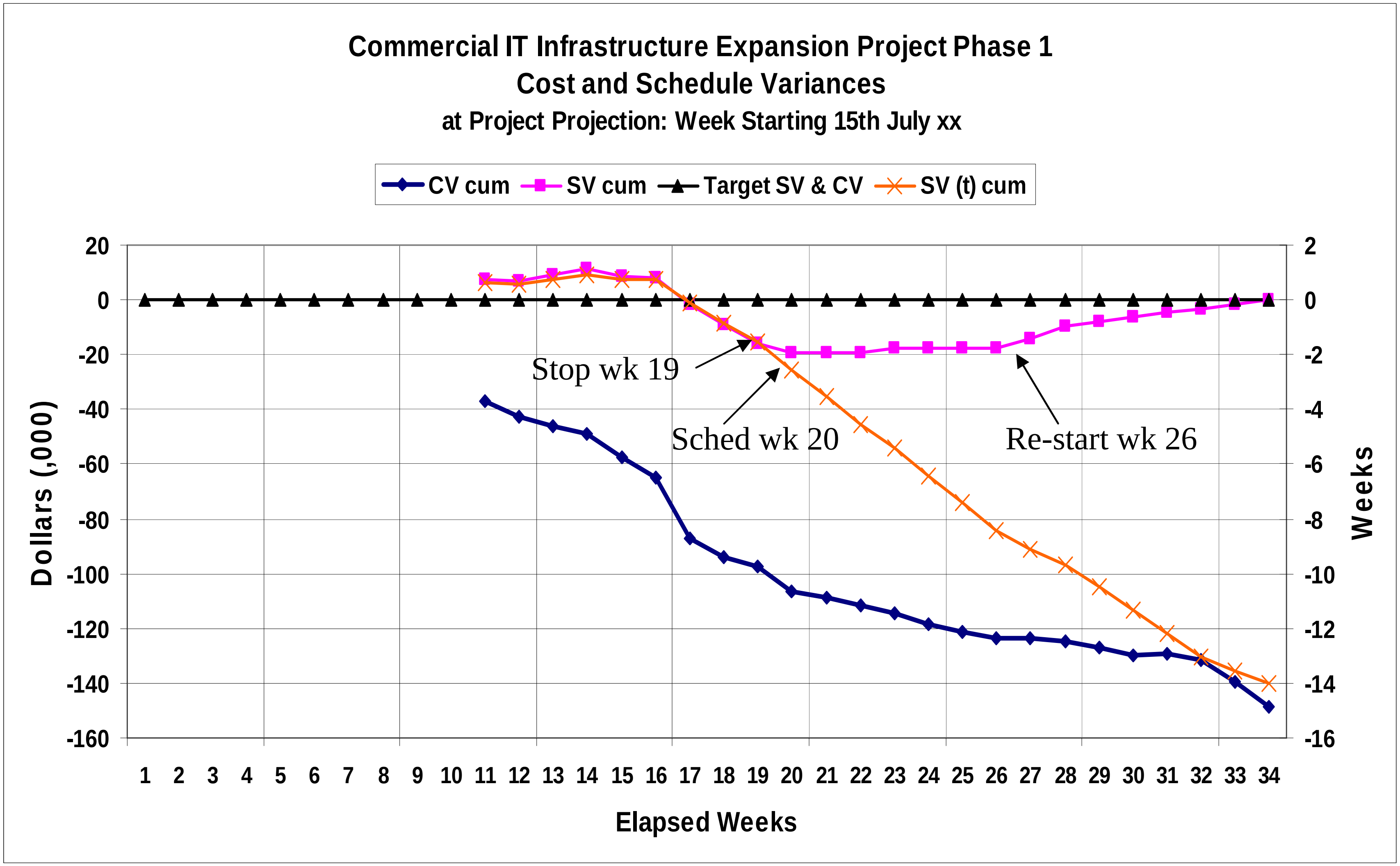
Metrics	Earned Schedule	ES_{cum}	ES = C + I number of complete periods (C) plus an incomplete portion (I)
	Actual Time	AT_{cum}	AT = number of periods executed
Indicators	Schedule Variance	SV(t)	SV(t) = ES - AT
	Schedule Performance Index	SPI(t)	SPI(t) = ES / AT
	To Complete Schedule Performance Index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

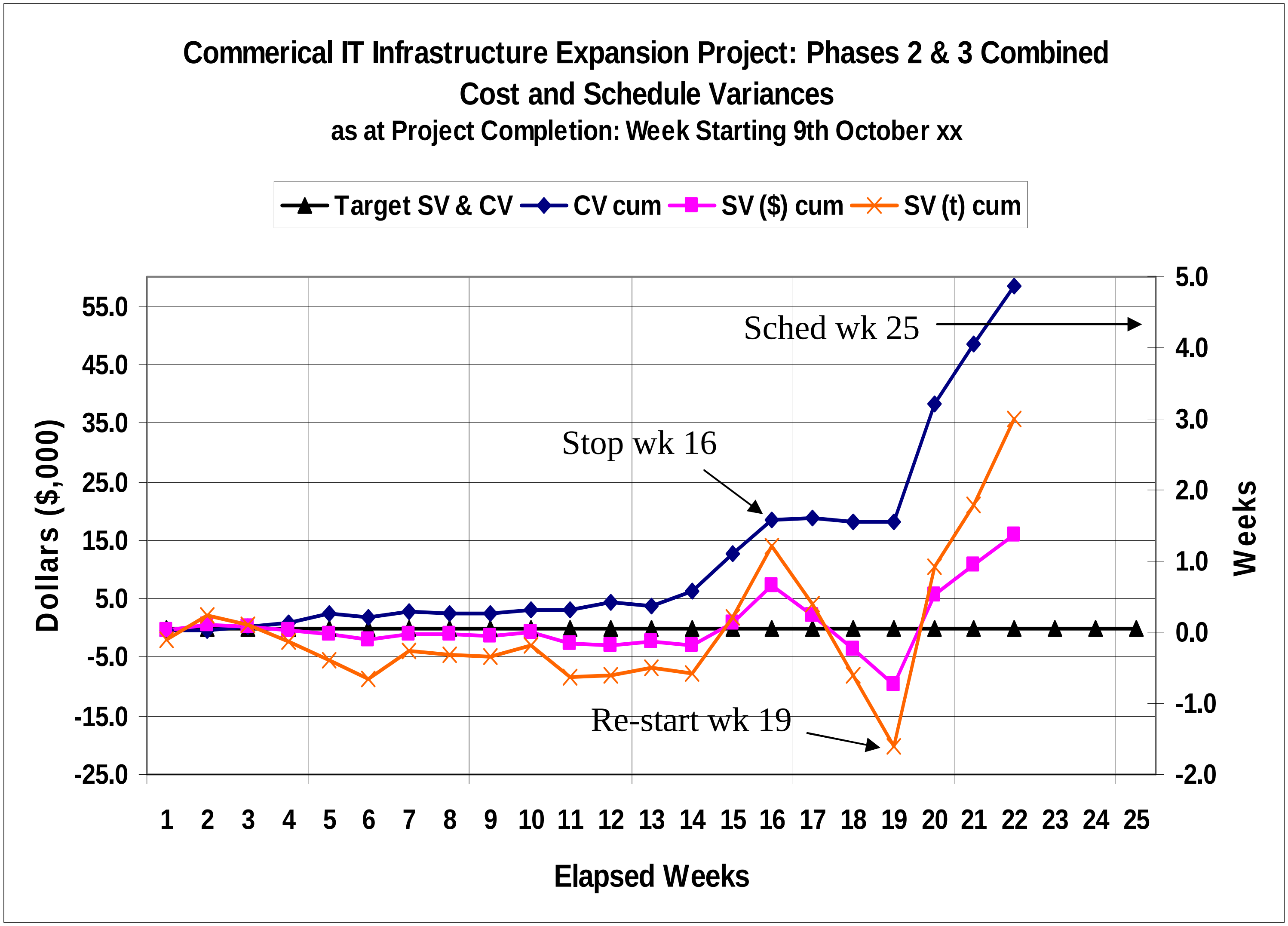
ES Applied to Real Project Data

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



ES Applied to Real Project Data

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



IEAC(t) Prediction Comparison

Short Form - Early and Late Finish 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 Duration Prediction

"Further Developments in Earned Schedule"

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- 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

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IEAC(t) Predictions

Long Form - Early and Late Finish Examples

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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

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IEAC(t) Predictions

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- 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

Early Adopters

- EVM Instructors
  - PMA, Management Technologies …
- Boeing Dreamliner®, Lockheed Martin, US State Department
- Secretary of the US Air Force (SAF/AQX)
- Nimrod, Type 45 Destroyer (UK MoD)
- Several Countries - Australia, Belgium, Sweden, United Kingdom, USA …
- Applications across weapons programs, construction, software development, …
- Range of project size from very small and short to extremely large and long duration

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PMI-CPM EVM Practice Standard

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- 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 = 0.75

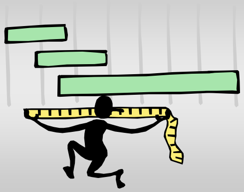
While the work- and time-based methods provide comparable results at the four-month point in Project EZ, look at the difference at project completion after 18 months:

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

Foreseen Uses of Earned Schedule

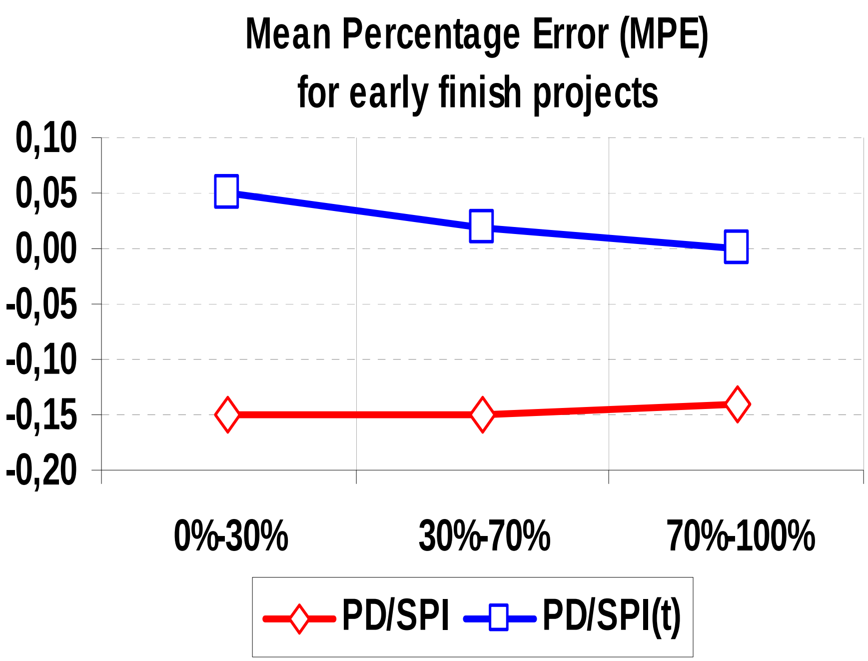
- Enables independent evaluation of schedule estimates: ETC(t), IEAC(t)
  - Client, Contractor, Program and Project Manager ….
- Facilitates insight into network schedule performance
  - Duration based Schedule indicators
  - Identification of impediments/constraints and potential future rework
  - Evaluation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

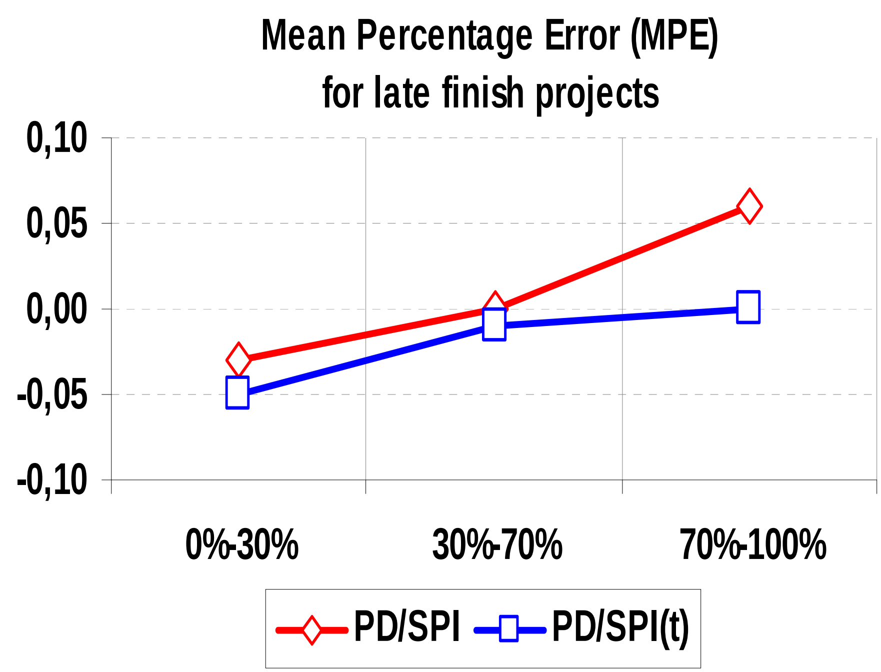


Research Efforts

Forecast Accuracy and the Completion of Work [8]

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





[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

- 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 of the known methods using EVM data
  - 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

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

Available Resources

Papers and Presentations

- PMI-Sydney Chapter

  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*

  – **Identifies Contacts to assist with application**
- Wikipedia references Earned Schedule

  http://en.wikipedia.org/wiki/Earned_Schedule

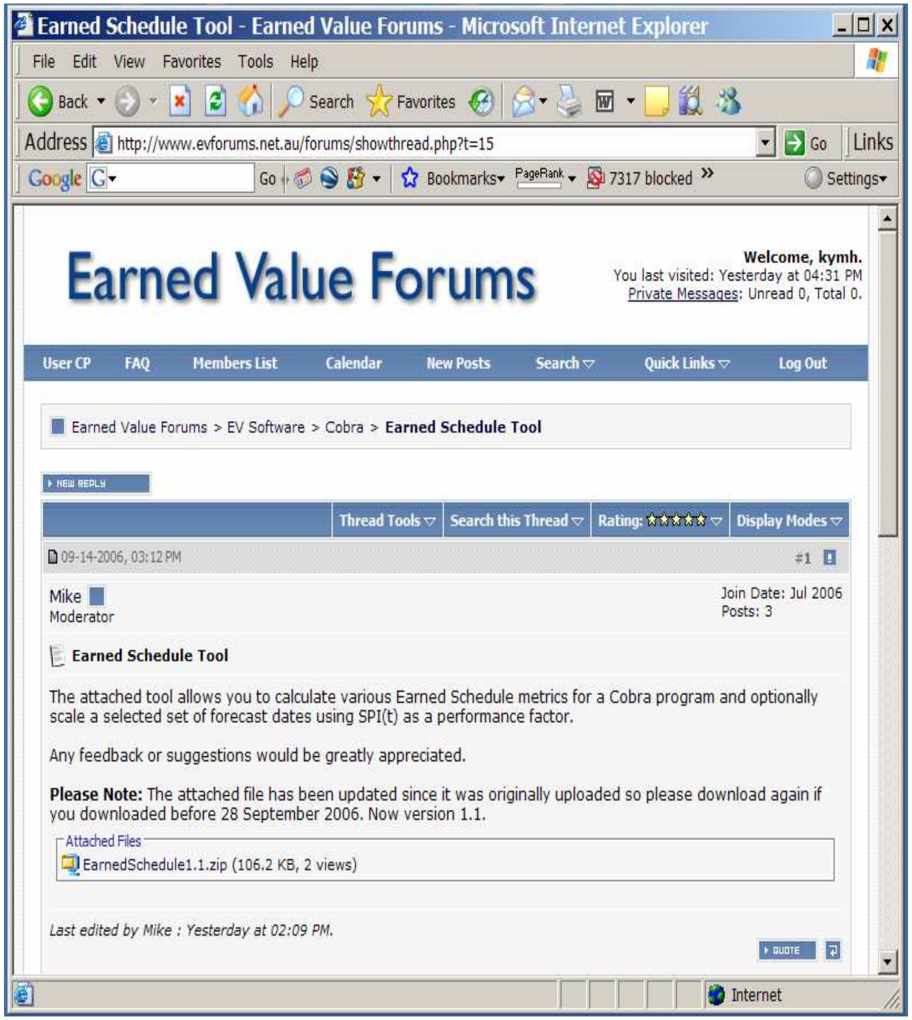
Available Resources

Tools

- Freely available add on tool for the Deltek Cobra product
- Available from:

http://www.evforums.net.au/forums/showthread.php?t=15

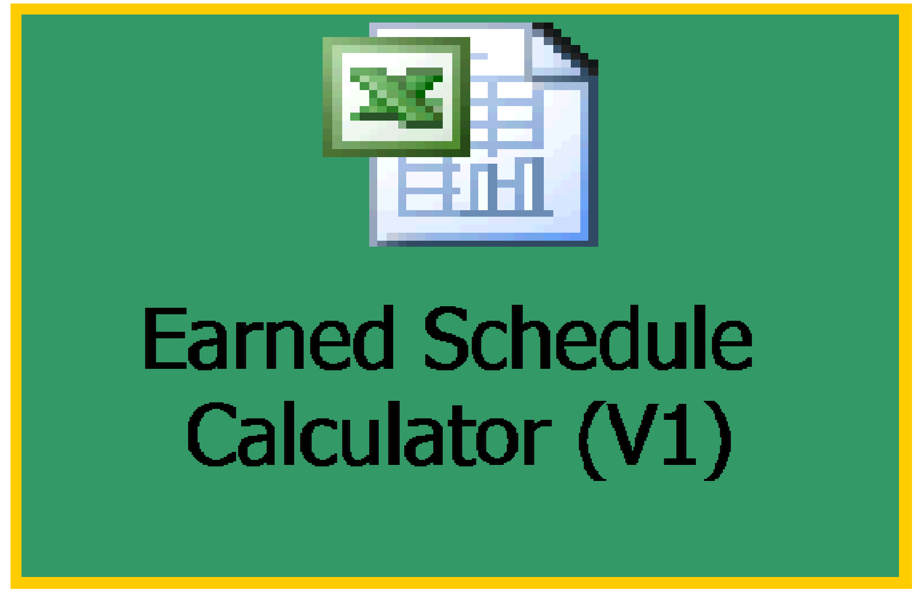
- (Requires registration to Earned Value Forums)
- **Contact:**
  Mike Boulton
  WST Pacific
  mboulton@wstpacific.com.au
  +61 8 8150 5500



Available Resources

Calculators

- Excel based Earned Schedule calculators available from
  http://www.earnedschedule.com



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Conclusion

"EVM has been part of the project control system being used on the Nimrod MRA4 programme for several years and its use is now mandated within the DPA for Category A, B and C programmes during Demonstration. **The advantages offered by Earned Schedule present another tool to improve our project management efforts and to inform the decision-making of the senior management teams. Indeed, it should provide a most useful link between traditional earned value analysis and traditional project schedule analysis - a link that appears to have been missing from traditional EVM theory and practice.**"

Wing Commander Rob Woods

Can you tell the time? - Earned Schedule in the UK

Michael (Mick) Higgins, APM Magazine - Project, Aug/Sep 2006

http://sydney.pmichapters-australia.org.au/programs/customer/v_filedown.asp?P=31&FID=702044831&FRF=n&

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