

Earned Schedule

schedule performance analysis from EVM measures

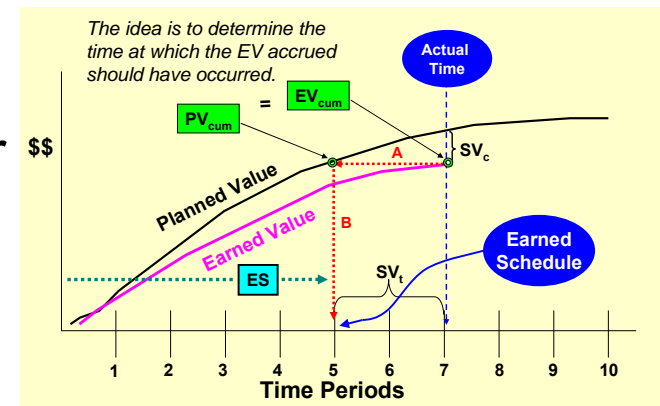
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Importance of Schedule

“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 percent of the total cost growth.

...*Therefore, our problem is not cost, it is SCHEDULE.*”

- Dr. Steve Gumley, CEO

Defence Materiel Organization (Australia)

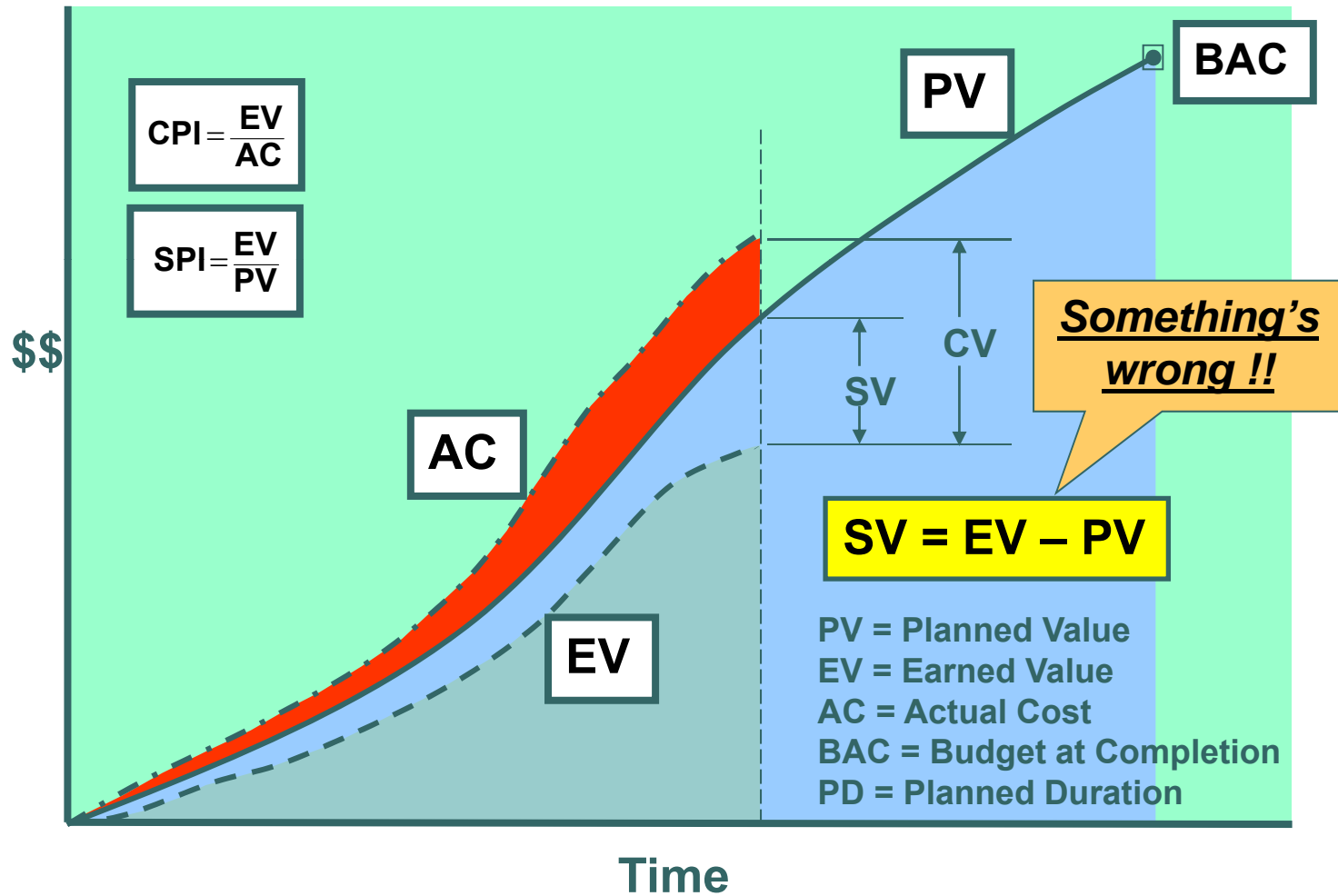
Quote taken from DMO Bulletin, July 2006, Issue 61, page



Overview

- Earned Schedule Concept
- Calculation of Earned Schedule
- Time-Based Schedule Indicators
- Project Duration Prediction & Forecasting
- Critical Path Analysis
- Network Schedule Analysis
- Demonstration of the ES Spreadsheet

Earned Value Basics





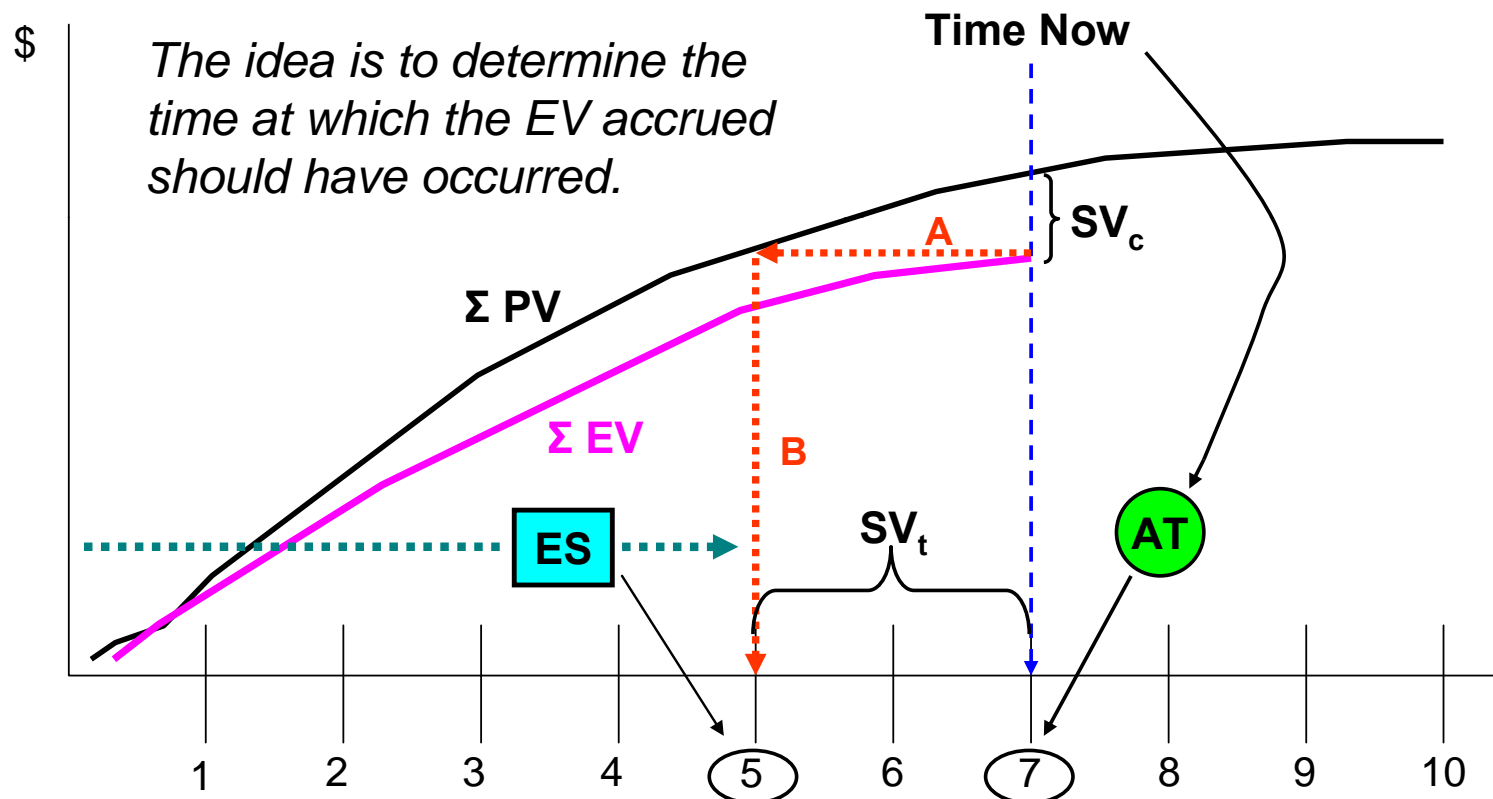
EVM Schedule Indicators

- 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
- Why does this happen?
 - $SV = EV - PV$
 - $SPI = EV / PV$

At planned completion $PV = BAC$
At actual completion $EV = BAC$



Earned Schedule Concept



For the above example, ES = 5 months ...that is the time associated with the PMB at which PV equals the EV accrued at month 7.



Earned Schedule Metric

- Required measures
 - Performance Measurement 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

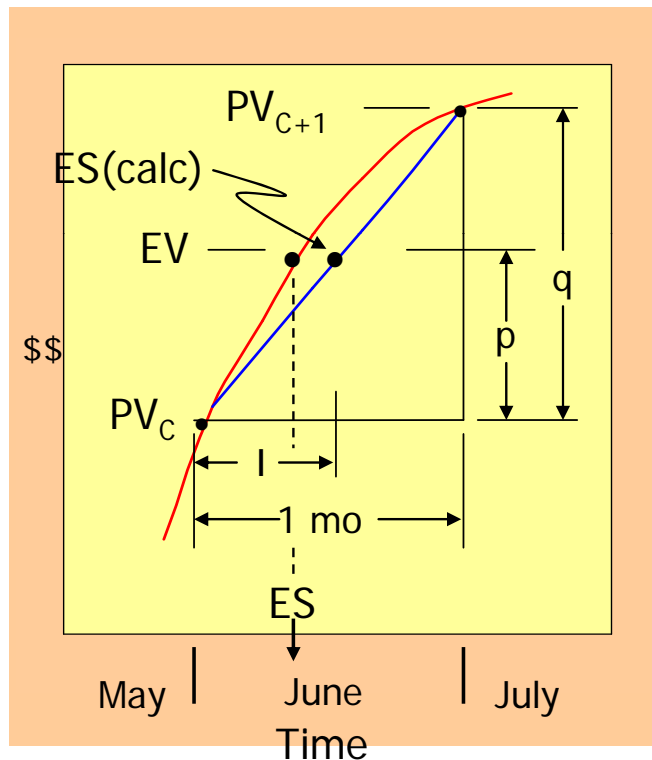


Earned Schedule Calculation



- **ES (cumulative)** is the:
Number of complete PV time increments EV equals or exceeds + the fraction of the incomplete PV increment
- **ES = C + I** where:
C = number of time increments for $EV \geq PV$
 $I = (EV - PV_C) / (PV_{C+1} - PV_C)$

Interpolation Calculation



$$I / 1 \text{ mo} = p / q$$

$$I = (p / q) * 1 \text{ mo}$$

$$p = EV - PV_C$$

$$q = PV_{C+1} - PV_C$$

$$I = \frac{EV - PV_C}{PV_{C+1} - PV_C} * 1 \text{ mo}$$

Subscript C identifies the planned value period at which $EV_{cum} \geq PV_{i,cum}$



Earned Schedule Indicators

- Schedule Variance:

$$SV(t) = ES - AT$$

- Schedule Performance Index:

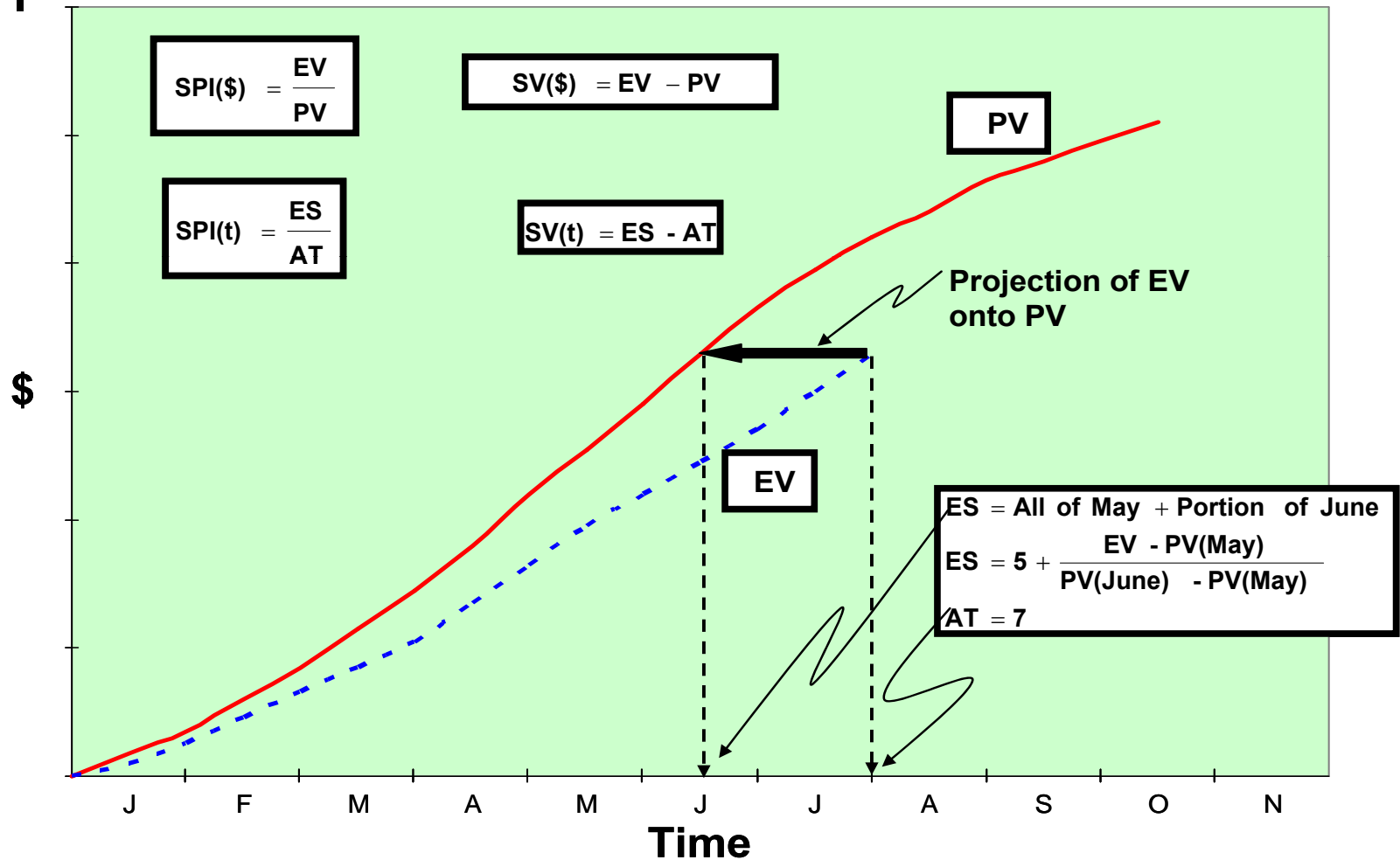
$$SPI(t) = ES / AT$$

where AT is “Actual Time” – the duration from start to time now

- SV(t) and SPI(t) are time-based (months, weeks ...)

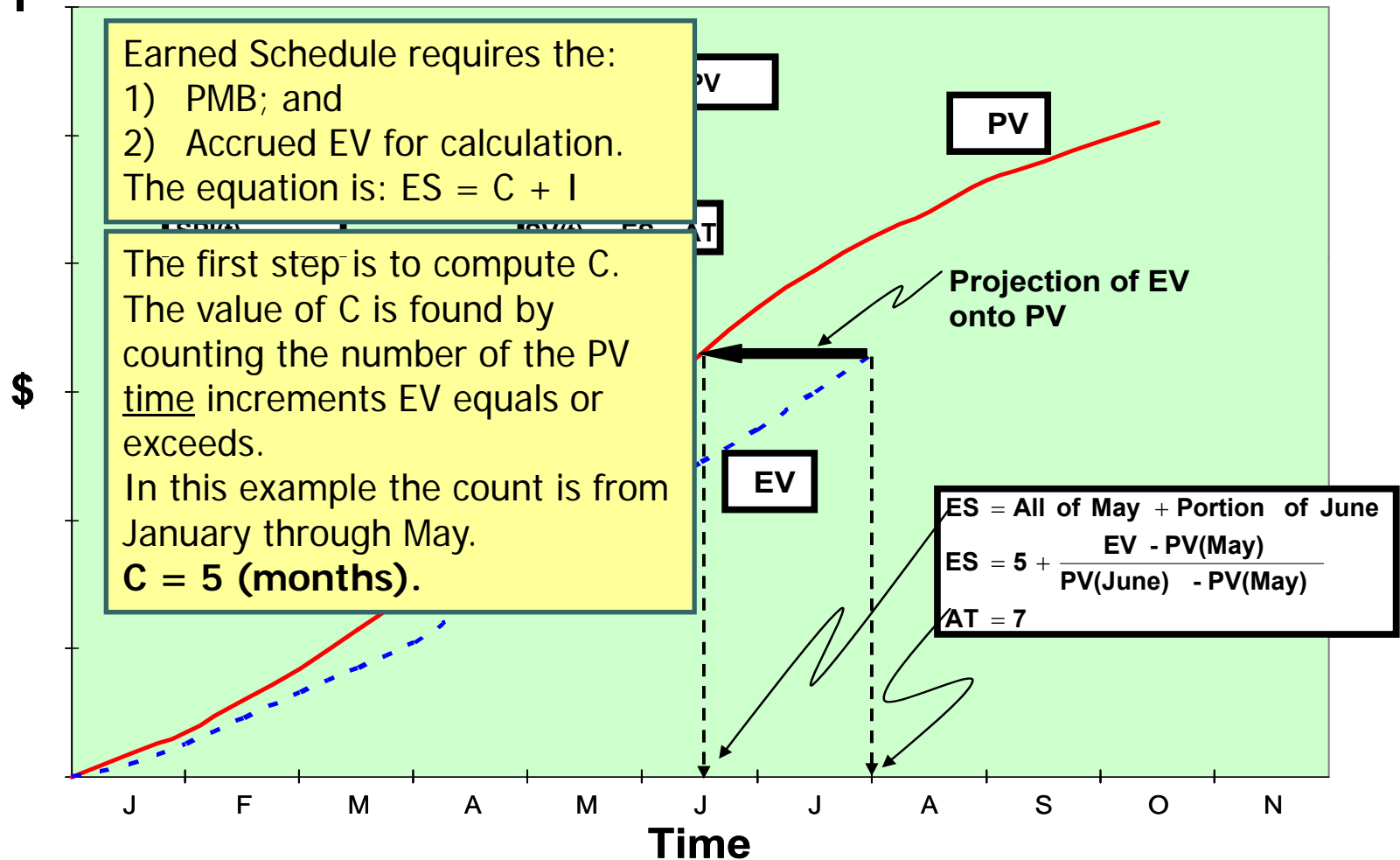


ES Computation Example



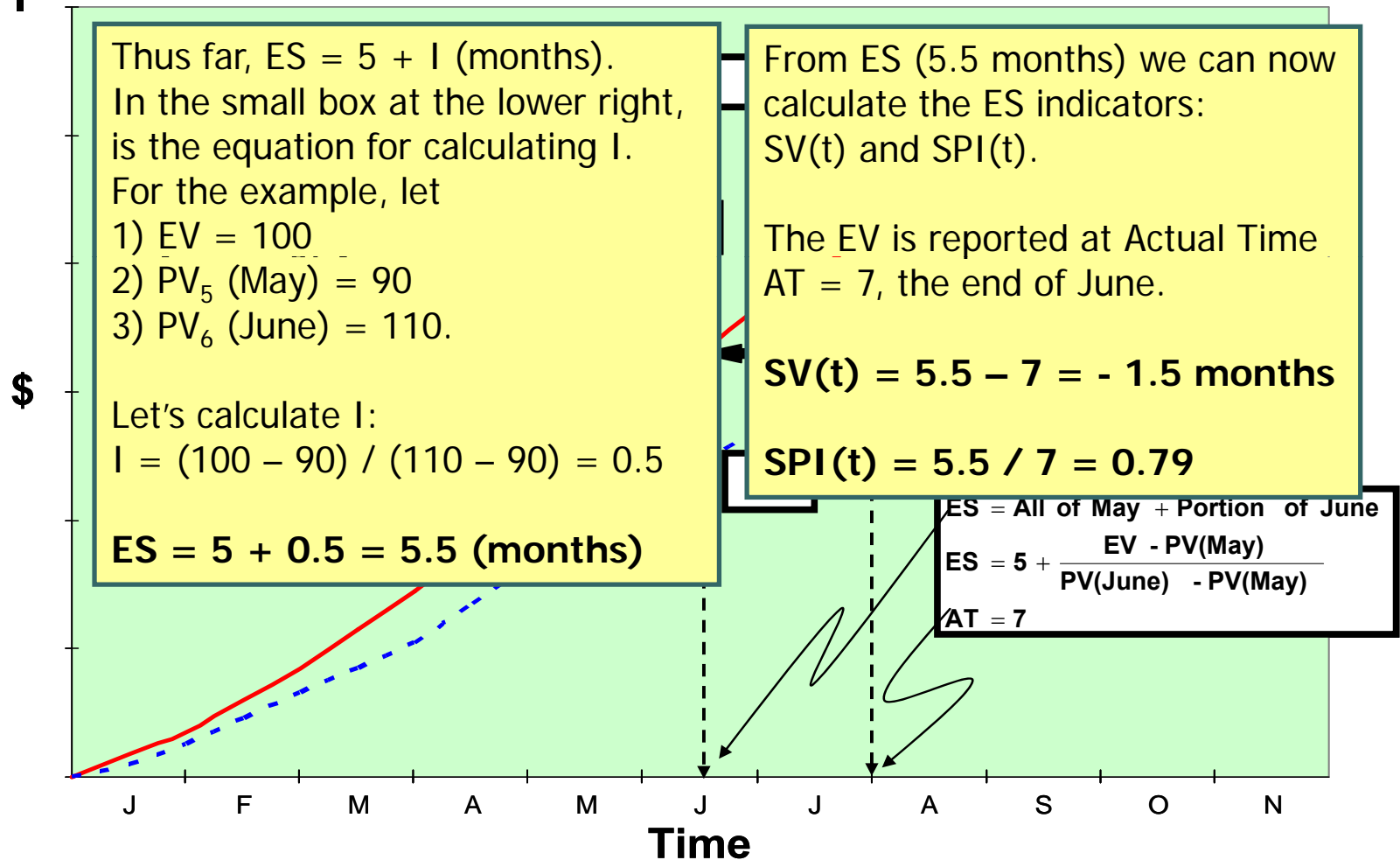


ES Computation Example





ES Computation Example





Earned Schedule Indicators

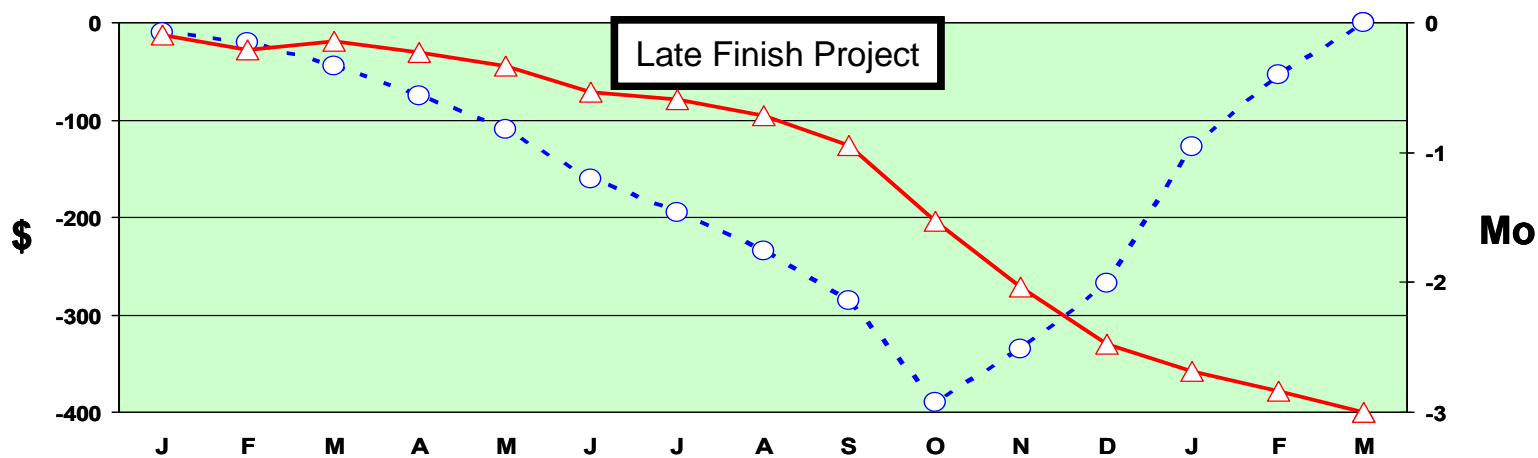
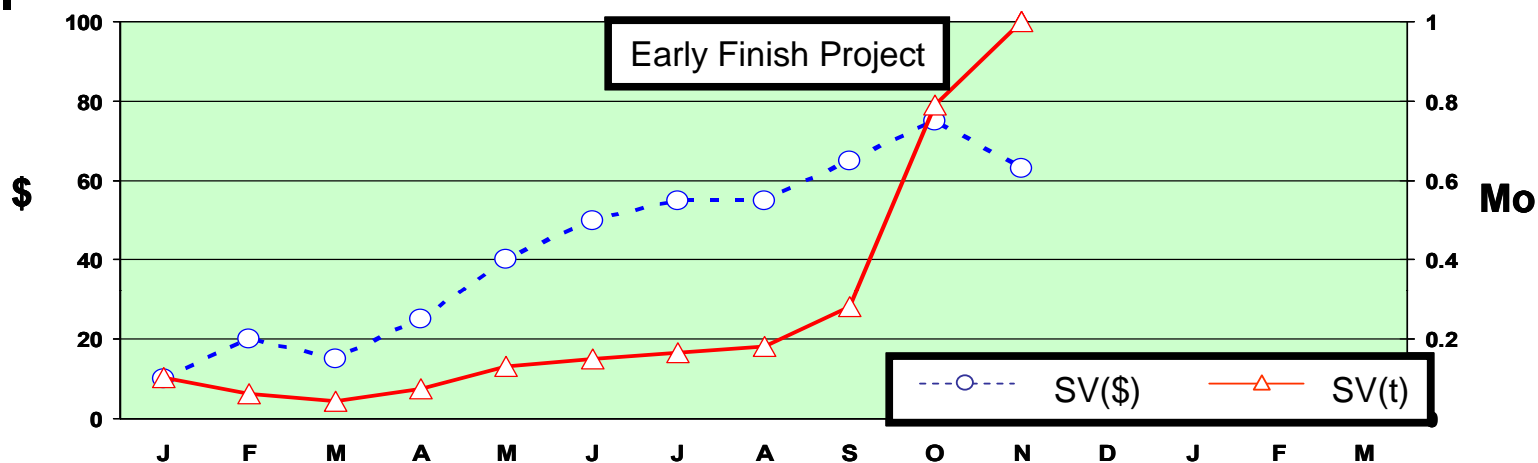
- What happens to the ES indicators, $SV(t)$ & $SPI(t)$, when the planned project duration (PD) is exceeded ($PV = BAC$)?

They Still Work ...Correctly!!

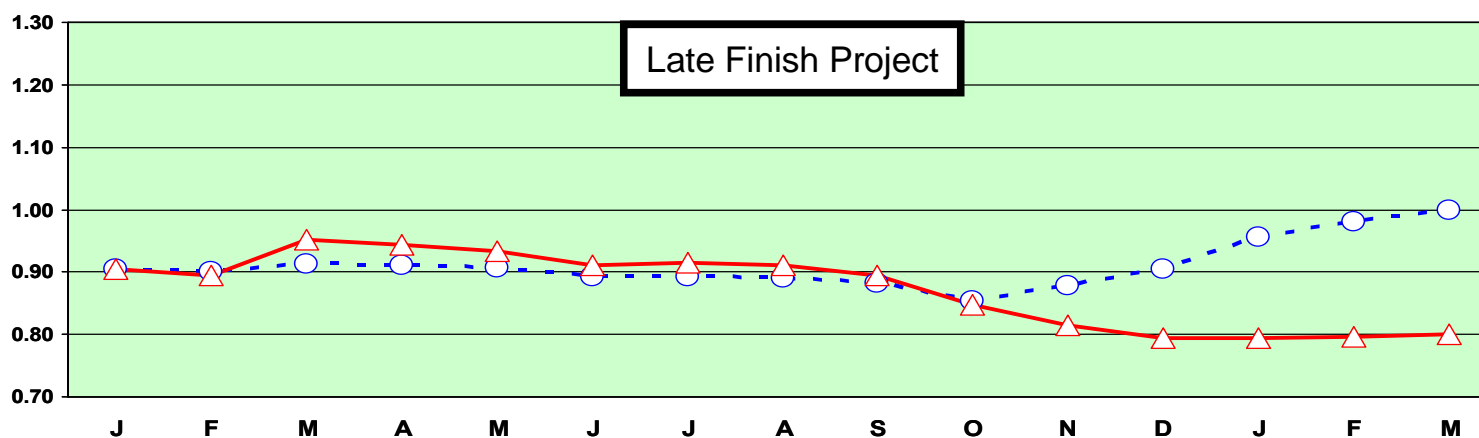
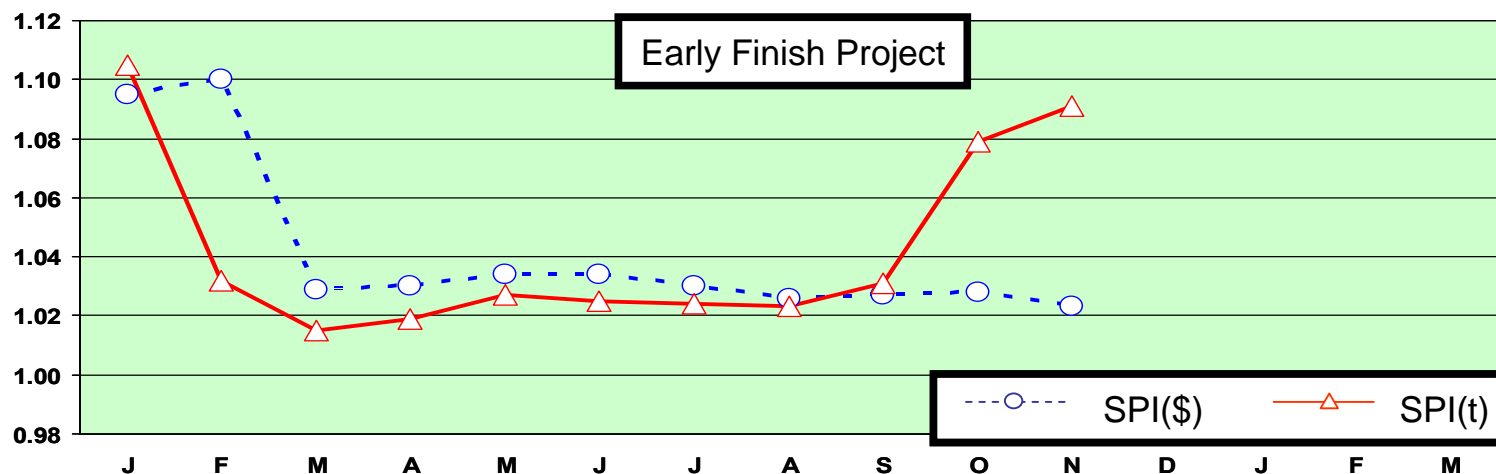
- ES will be $\leq PD$, while $AT > PD$
 - $SV(t)$ will be negative (time behind schedule)
 - $SPI(t)$ will be < 1.00

Reliable Values from Start to Finish !!

SV Comparison

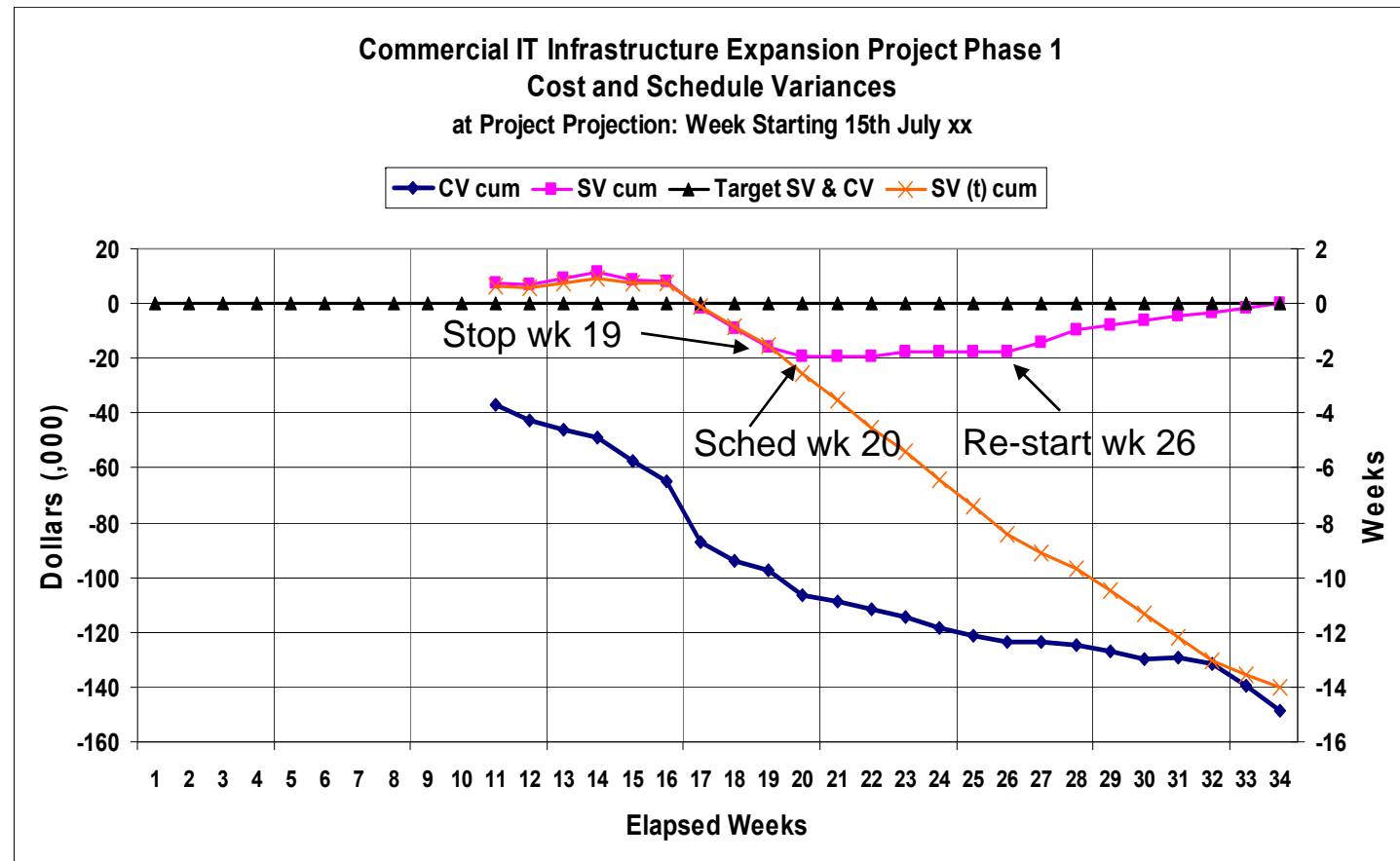


SPI Comparison





Late Finish Project



Schedule Prediction

- Can the project be completed as planned?

- $$\text{TSPI} = \text{Plan Remaining} / \text{Time Remaining}$$

$$= (\text{PD} - \text{ES}) / (\text{PD} - \text{AT})$$

where PD is the planned duration (time at BAC)

$$(\text{PD} - \text{ES}) = \text{PDWR}$$

PDWR = Planned Duration for Work Remaining

- ...completed as estimated?

- $$\text{TSPI} = (\text{PD} - \text{ES}) / (\text{ED} - \text{AT})$$

where ED = Estimated Duration

TSPI Value	Predicted Outcome
≤ 1.00	Achievable
> 1.10	Not Achievable



Schedule Forecasting

- 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 forecast final cost
- Independent Estimated Completion Date (IECD)
 - $IECD = \text{Start Date} + IEAC(t)$



Performance Confirmation



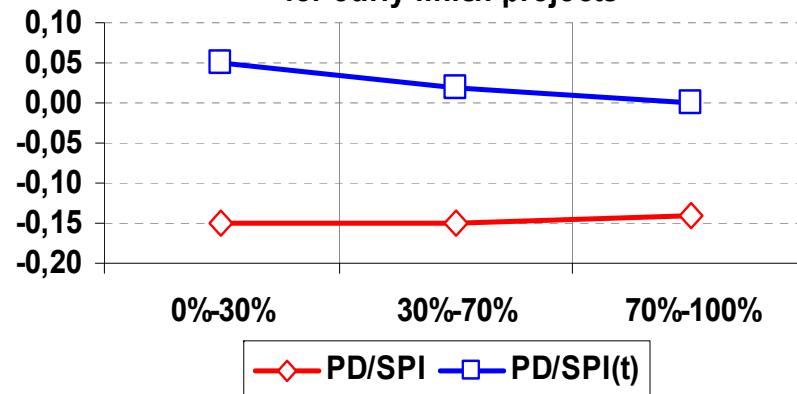
- SPI(t) & SV(t) do portray the real schedule performance
- At early & middle project stages pre-ES & ES forecasts of project duration produce similar results
- At late project stage ES forecasts outperform all pre-ES forecasts
- “The use of the SPI(t) in conjunction with the TSPI has been demonstrated to be useful for managing the schedule.” *Stephan Vandevoorde – Fabricom Airport Systems, Belgium*
- “The results reveal that the earned schedule method outperforms, on the average, all other forecasting methods.” *Dr. Mario Vanhoucke & Stephan Vandevoorde*

Research Results

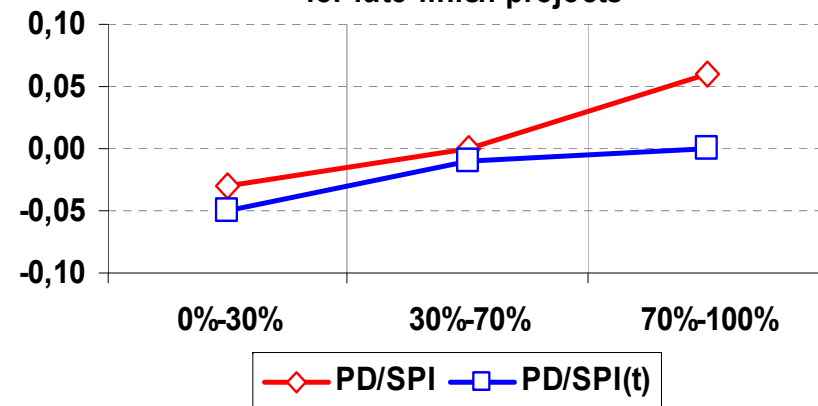
Forecast Accuracy and the Completion of Work

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

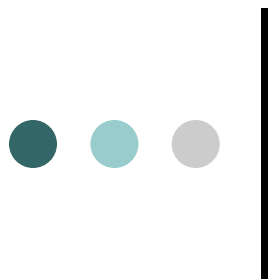
Mean Percentage Error (MPE)
for early finish projects



Mean Percentage Error (MPE)
for late finish projects



Vanhoucke M., S. Vandevoorde, "A simulation and evaluation of earned value metrics to forecast the project duration," Journal Of Operations Research Society September 2006



Research Results



Hypothesis Test Results - EVM vs ES Time Forecast								
Significance α = 0.05		***** Percent Complete Test Bands *****						
		10% - 40%	40% - 70%	70% - 100%	10% - 100%	25% - 100%	50% - 100%	75% - 100%
Test Statistic Sign Test		0.0000	0.0267	0.0000	0.0000	0.0000	0.0002	0.0000
		Ha	Ha	Ha	Ha	Ha	Ha	Ha
Count #1s	ES	11	7	12	11	11	10	12
	EVM	5	9	4	5	5	6	4

Hypothesis Test: Sign Test at 0.05 level of significance.

Ho: The aggregate of EVM forecasts is better / the null hypothesis

Ha: ES forecast is better / the alternate hypothesis



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
		SV(t)%	SV(t)% = (ES – AT) / ES
	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



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*)



Schedule Analysis with EVM?



- Most practitioners analyze schedule from the bottom up using the network schedule, independent from EVM

....“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 forecasting 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*

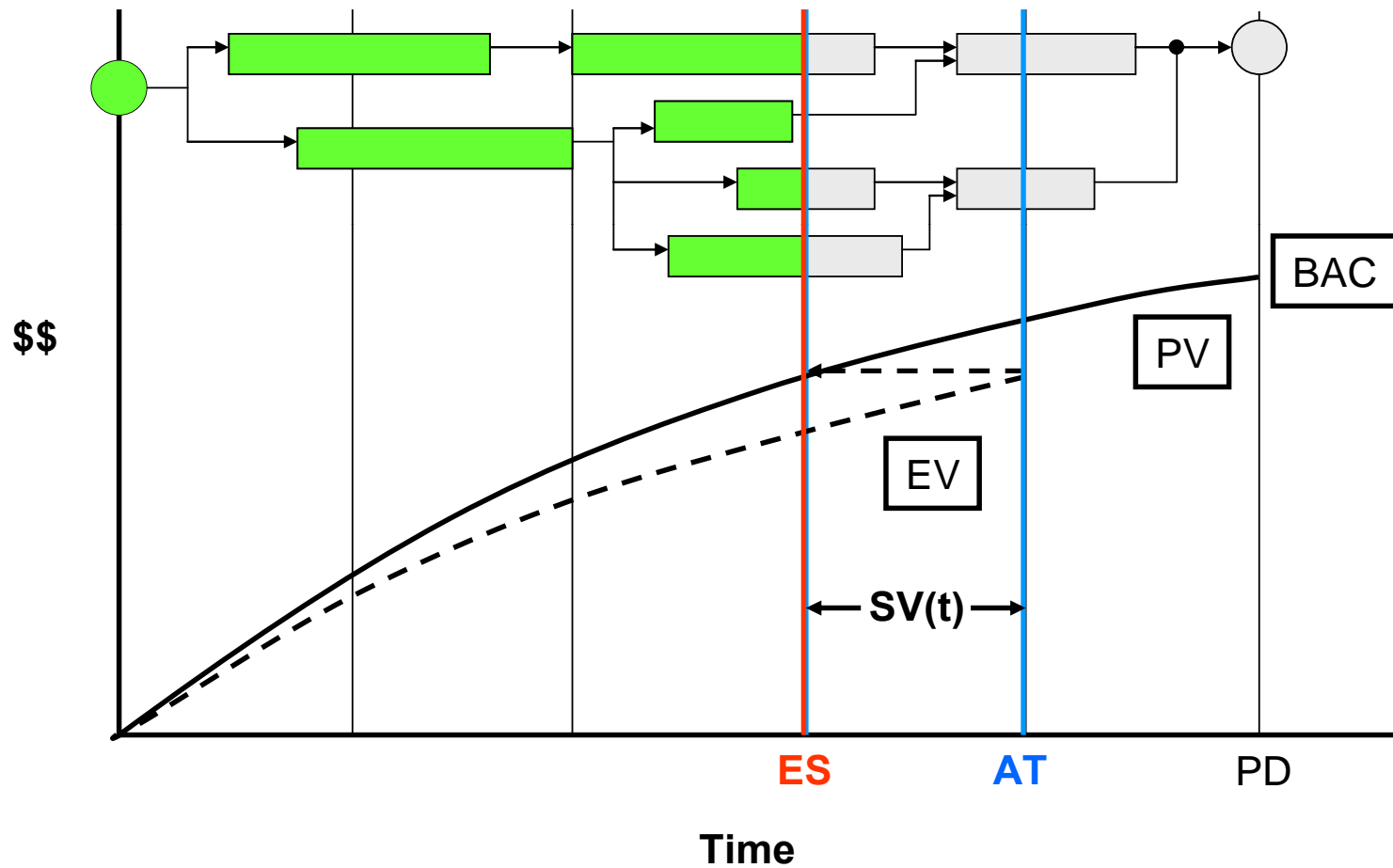


Facilitates Drill-Down Analysis

- ES can be applied to any level of the WBS, to include task groupings such as the Critical Path
 - Requires creating PMB for the area of interest
 - EV for the area of interest is used to determine its ES
- Enables comparison of forecasts, total project (TP) to Critical Path (CP)
 - Desired result: forecasts are equal
 - When TP forecast > CP forecast, CP has changed
 - When CP > TP, possibility of future problems

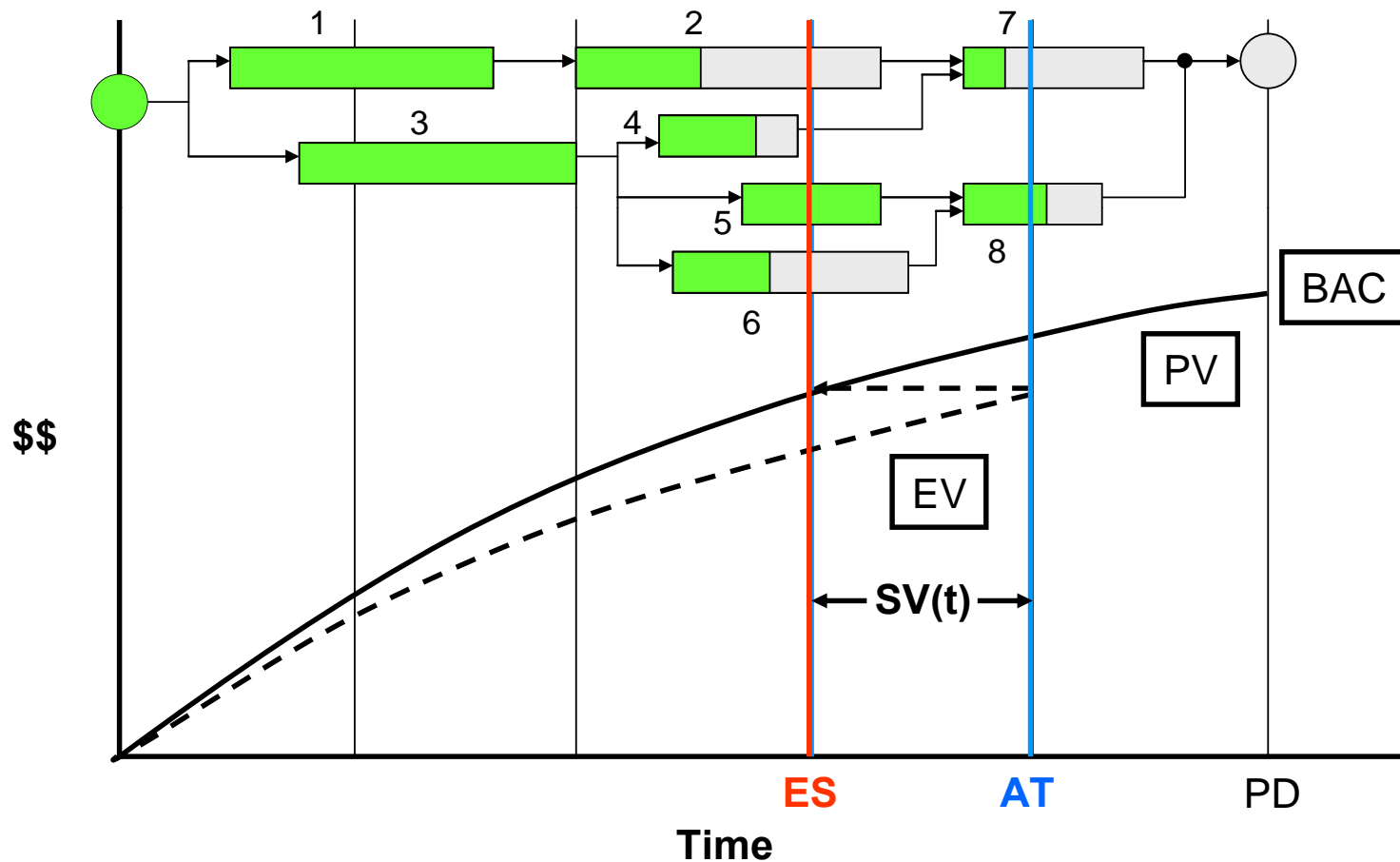


ES Bridges EVM to the Schedule





ES Bridges EVM to the 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!!



Schedule Analysis Example



Task	PV	PV@ES	EV@AT	EV - PV	I/C or R
1	10	10	10	0	
2	12	9	5	-4	I/C
3	10	10	10	0	
4	5	5	3	-2	I/C
5	5	2	5	+3	R
6	8	4	3	-1	I/C
7	7	0	1	+1	R
8	5	0	3	+3	R
Total	62	40	40	0	

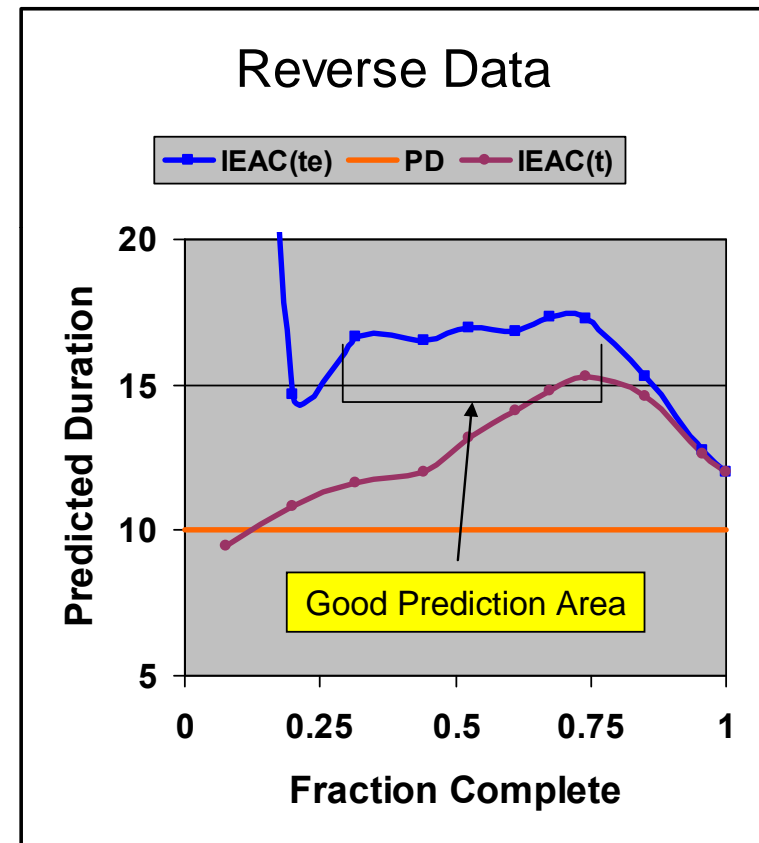
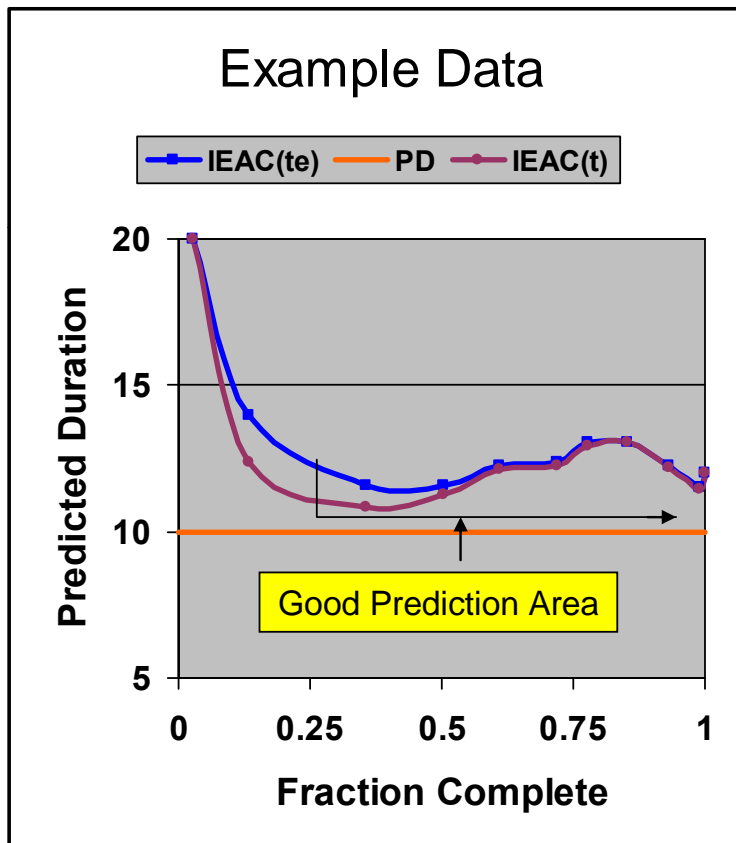


Leads to ...

- Concept of Schedule Adherence
 - Most efficient project execution follows the plan
 - ES provides a way to measure how closely execution is to the plan
- Schedule Adherence provides a means to refine predictions and forecasts
 - Research underway
 - Application has begun



Enhanced Forecasting Example





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 other EVM method presently used
- Facilitates bridging EVM analysis to include the Schedule
- Provides capability to understand source of rework and refine forecasts & predictions



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 references Earned Schedule
http://en.wikipedia.org/wiki/Earned_Schedule



ES Spreadsheet



Earned Schedule Calculator (v1)