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Earned Schedule Training

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Earned Schedule Training – Part I

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

Earned Schedule Training – Part I

- Prediction Comparisons
- Demonstration of ES Calculator
- Analysis Tool Demonstration
- Interpolation Error

Earned Schedule Training – Part II

- Re-Baseline Effects
- Critical Path Study
- Network Schedule Analysis
  - Impediments / Constraints
  - Rework
  - Schedule Adherence

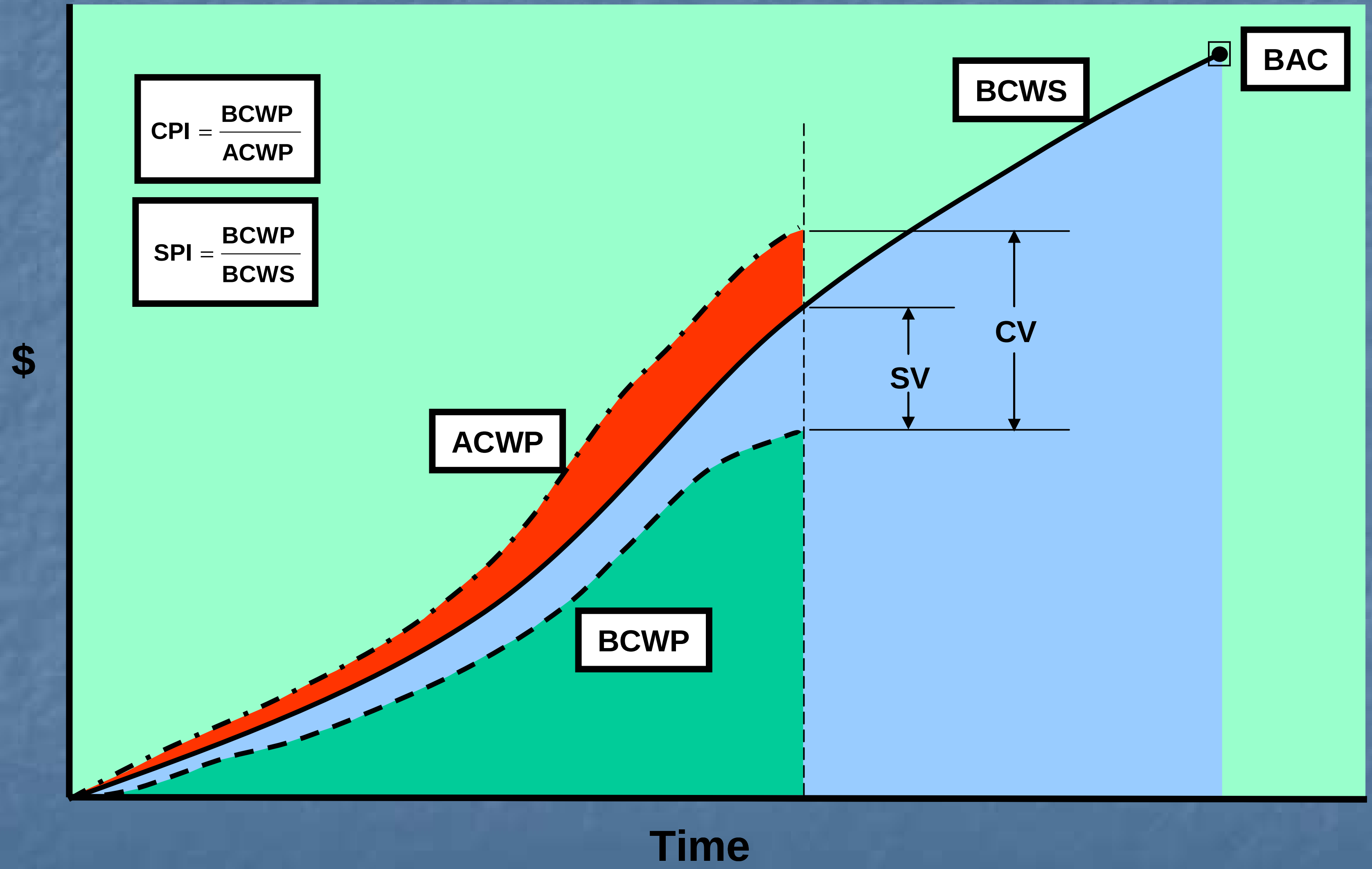
Earned Schedule Training – Part II

- Effective Earned Value
  - Derivation
  - Indicators
  - Prediction
- Available Resources
- Wrap-Up

Earned Schedule Training
Part I

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

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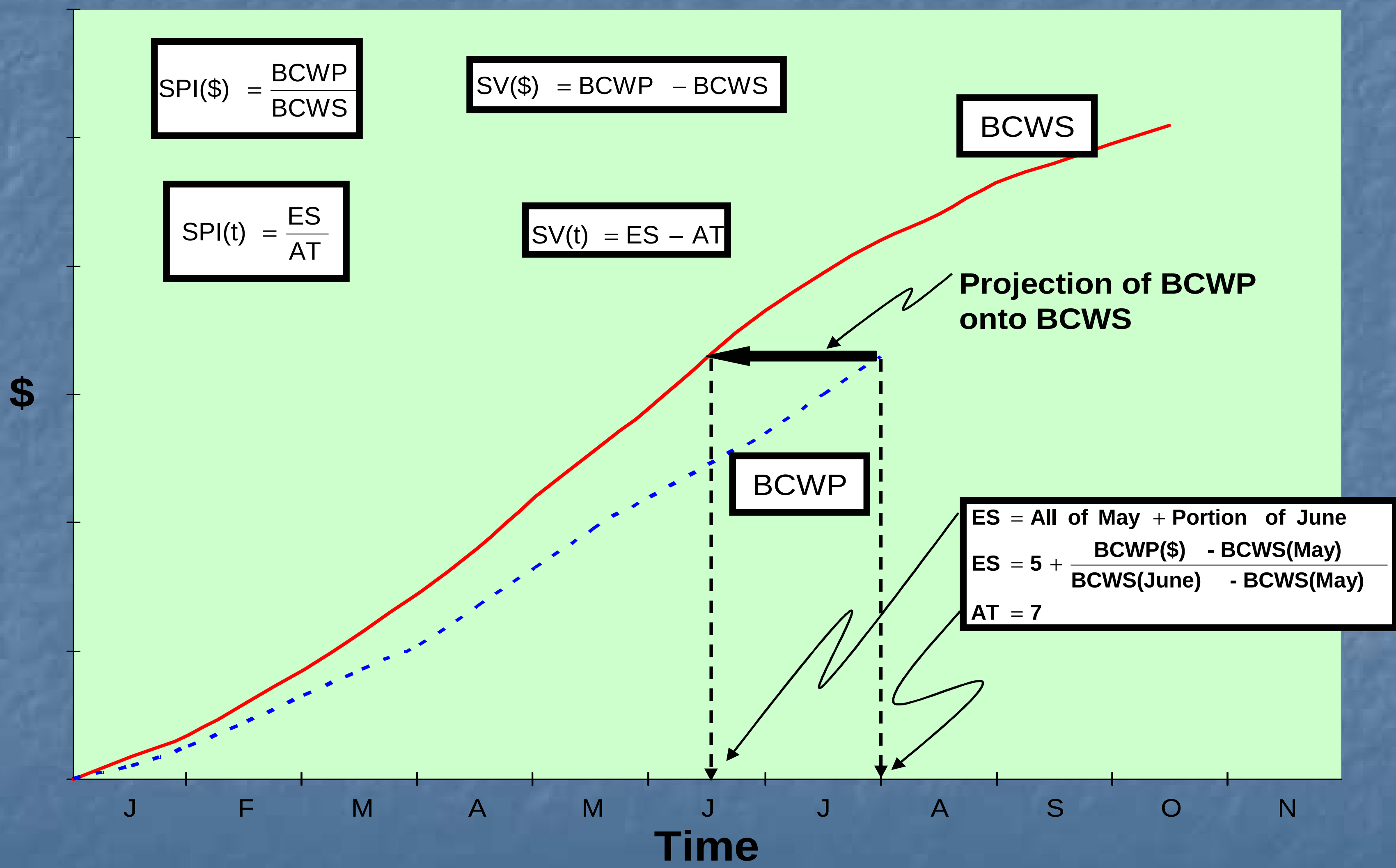
Earned Schedule Concept



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

- EScum 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) = ΔES_{cum}
- ATcum
- ATperiod(n) = ATcum(n) – ATcum(n-1) = ΔAT_{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

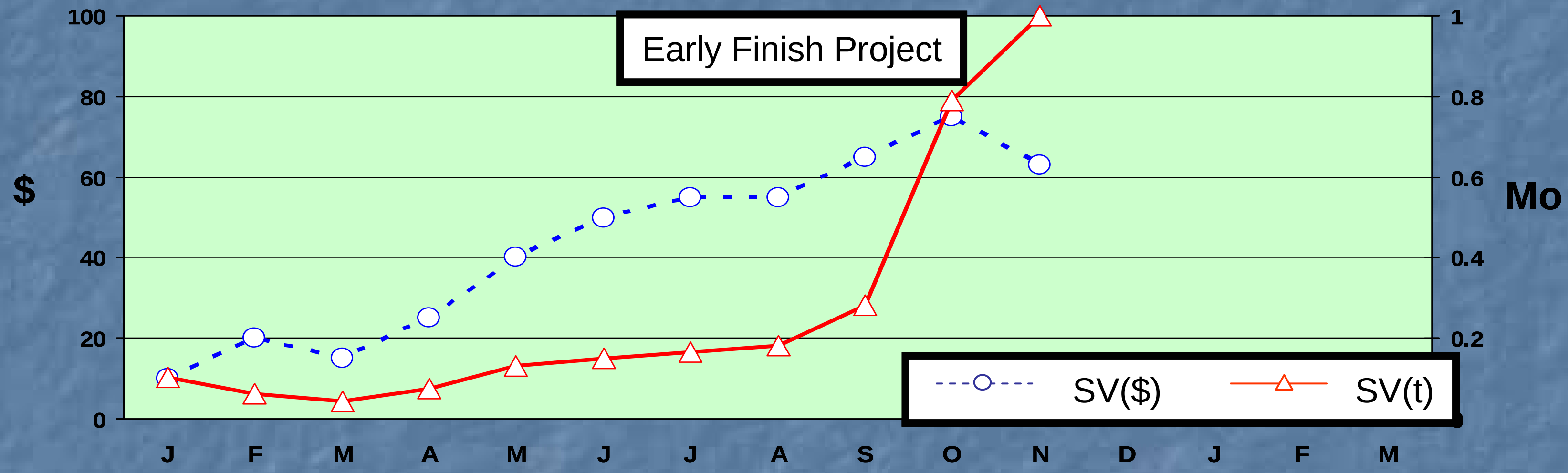
- What happens to the ES indicators, SV(t) & SPI(t), when the planned project duration (PD) is exceeded (BCWS = BAC)?

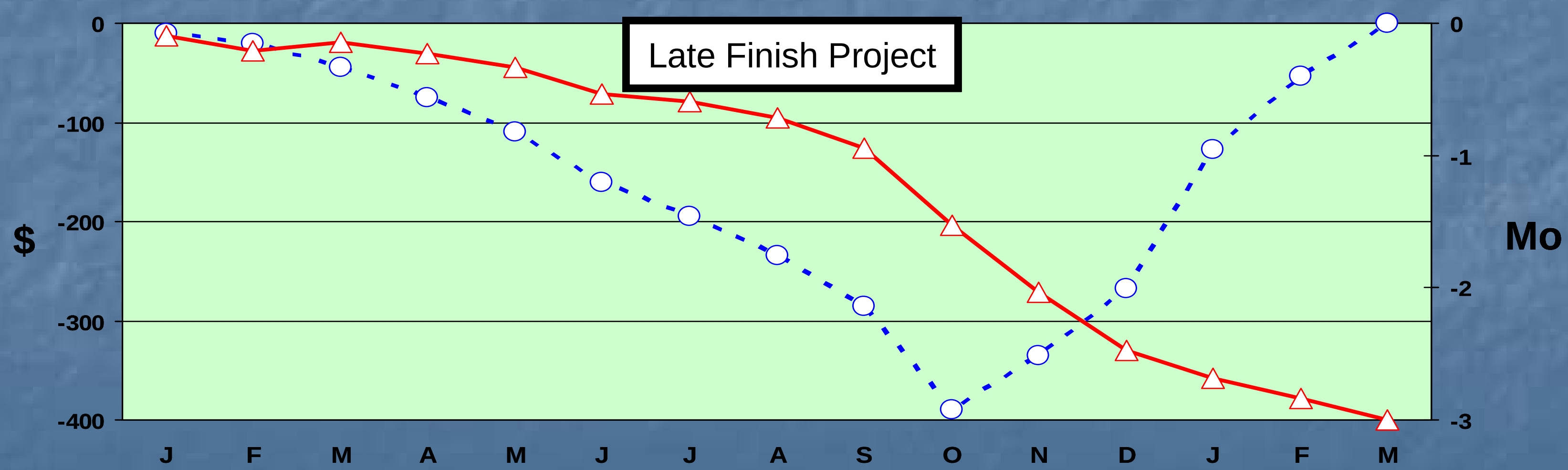
They Still Work …Correctly!!

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

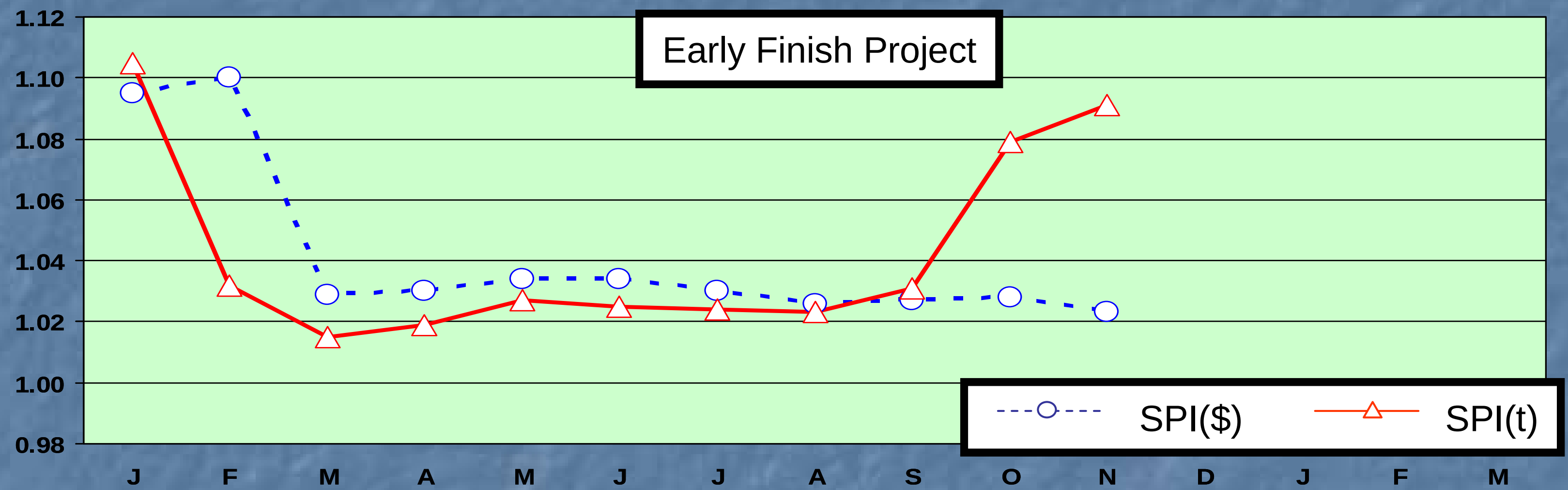
Reliable Values from Start to Finish !!

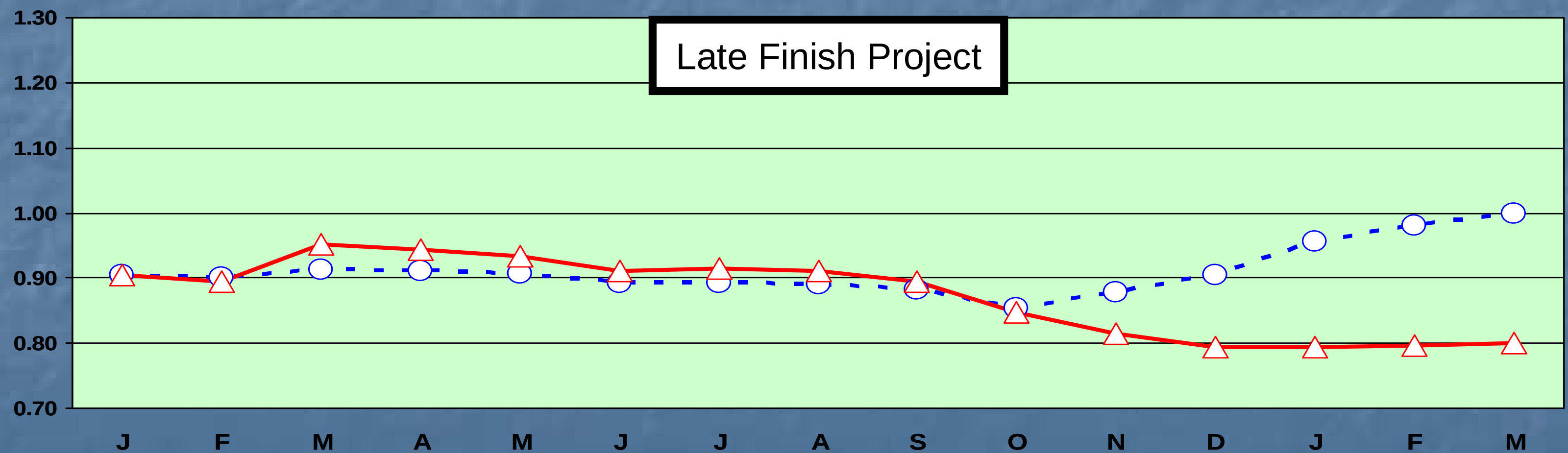
SV Comparison





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
$\leq$ 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)

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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

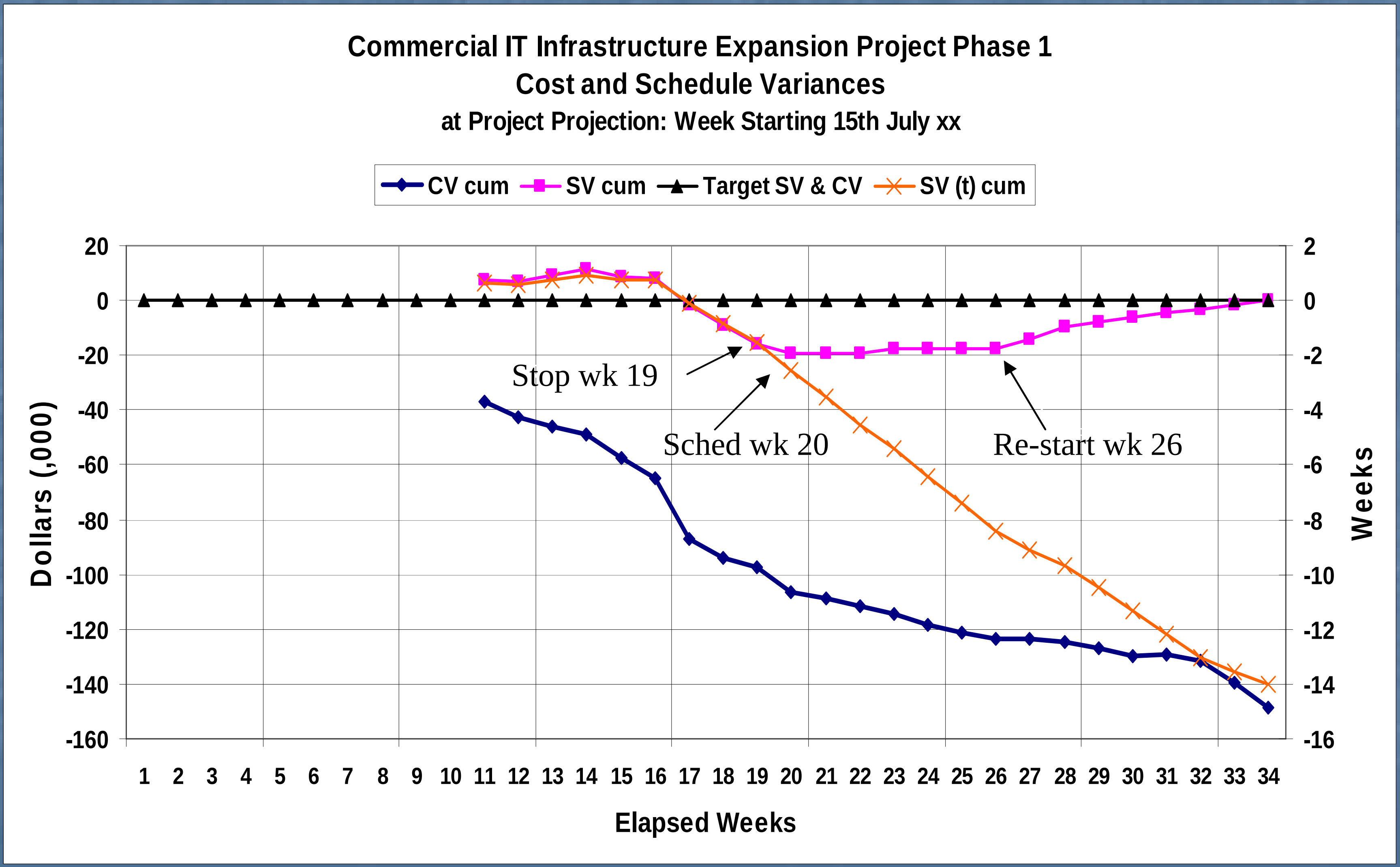
Metrics	Earned Schedule	ES_{cum}	ES = C + I number of complete periods (C) plus an incomplete portion (I)
	Actual Time	AT_{cum}	AT = number of periods executed
Indicators	Schedule Variance	SV(t)	SV(t) = ES - AT
	Schedule Performance Index	SPI(t)	SPI(t) = ES / AT
	To Complete Schedule Performance Index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

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)

Concept Verification

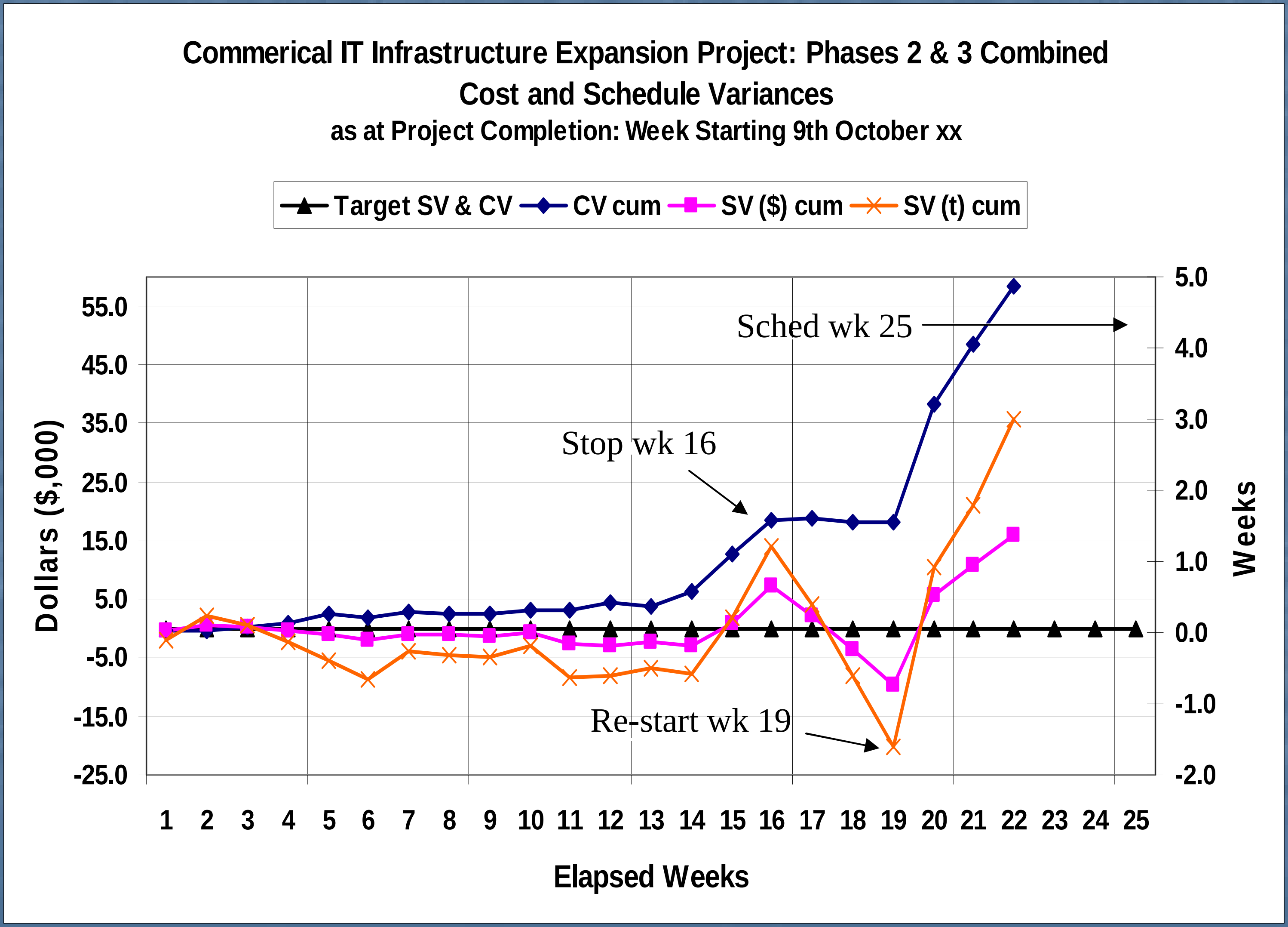
ES Applied to Real Project Data:
Late Finish Project: SV($) and SV(t)



ES Applied to Real Project Data: *Late Finish Project Analysis*

- **No EVM data prior to week 11**
- **SV($) and SV(t) show strong correlation until week 19**
  - Week 20 (The week of the project's scheduled completion) Client delay halted project progress until resolution in Week 26
- **SV($) static at -$17,500 in spite of schedule delay**
  - **Before trending to $0 at project completion**
- **SV(t) correctly calculates and displays**
  - Week on week schedule delay
  - Project -14 week schedule delay at completion
- **Conclusion**
  - **SV(t) provides greater management utility than SV($) for portraying and analyzing schedule performance**

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



Early Finish Project Analysis

- **This project completed 3 weeks ahead of schedule**
  - In spite of externally imposed delay between weeks 16 and 19
- **SV($) and SV(t) show strong correlation over life of project**
  - Including the delay period
  - SV(t)'s advantage is calculating delay as a measure of **duration**
- **With Early Finish projects**
  - ES metrics SV(t) and SPI(t) have behaved consistently with their historic EVM counterparts
- **Conclusion**
  - **SV(t) provides greater management utility than SV($) for portraying and analyzing schedule performance**

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*

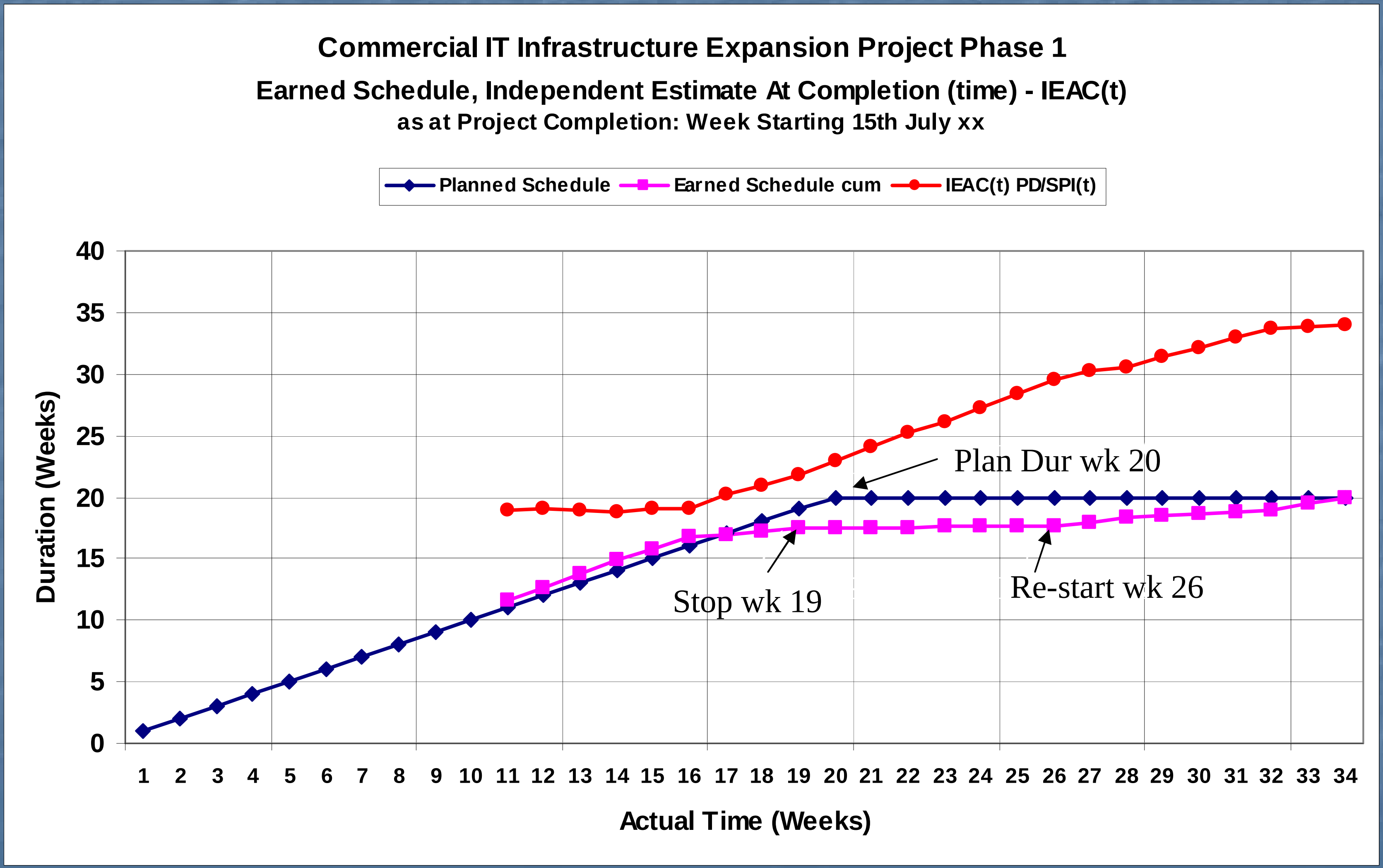
IEAC(t) Metrics at Project Completion Early Finish Project using ES	
Planned Duration (weeks)	25
Actual Time (weeks)	22
Earned Schedule cum	25.0
Planned Duration Work Remaining	0.0
Percentage Complete cum	100%
CPI cum	2.08
SPI(t) cum	1.14
SPI($) cum	1.17
Critical Ratio cum	2.43
Critical Ratio ES cum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

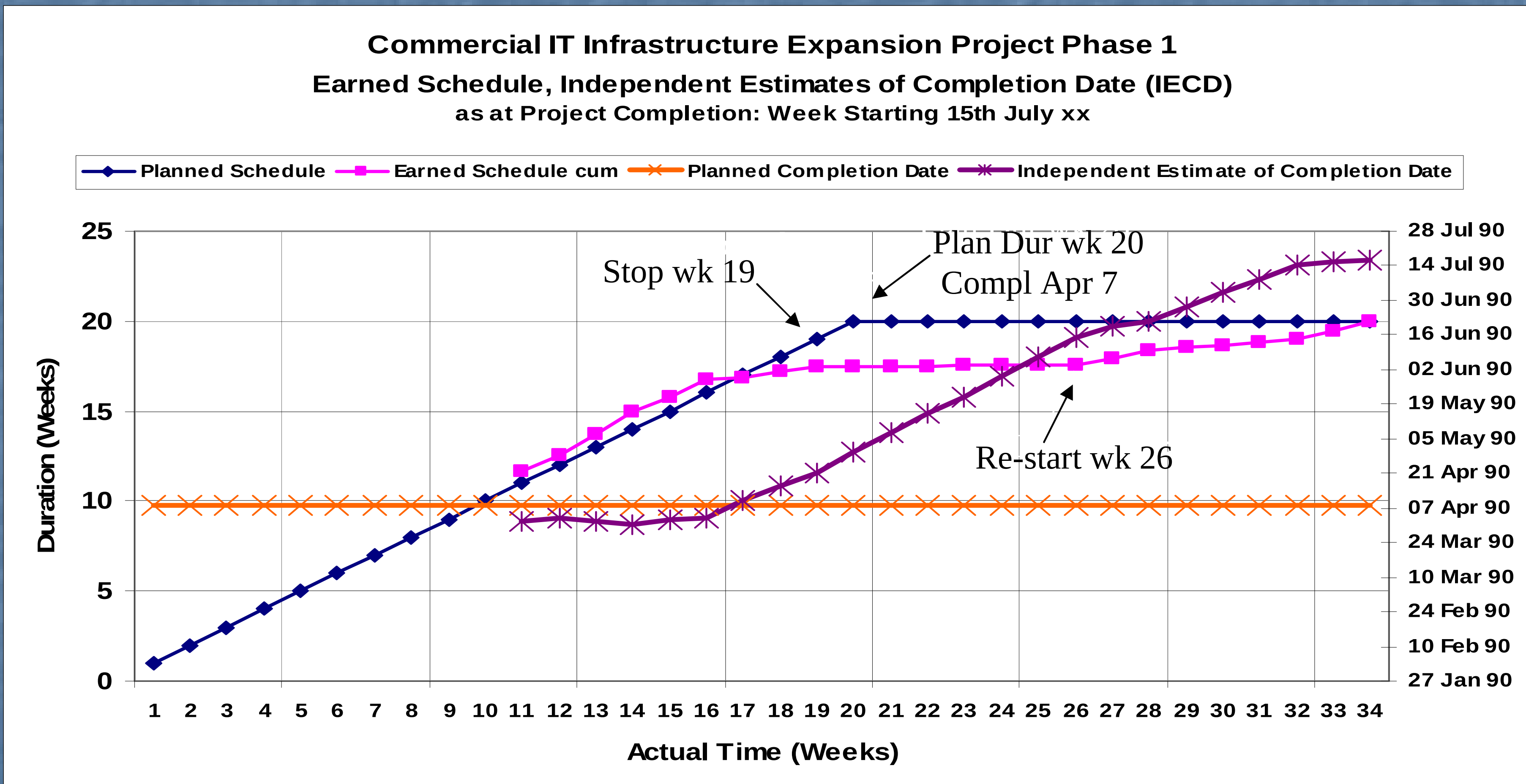
- Use of the ES "long form" IEAC(t) formula, results in **correct** calculation of Actual Duration at Completion

IEAC(t) Predictions using ES Techniques: Weekly Plots of IEAC(t)

Late Finish Project Example



IECD Predictions using ES Techniques: Weekly Plots of *Independent Estimate of Completion Date*



IEAC(t) Predictions using <u>ES</u> Techniques:

- **<u>ES formulae and results are algebraically correct</u>**

"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, <u>Schedule is Different</u>, The Measurable News, Summer 2003

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

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

Demonstration of Earned Schedule Calculator

Earned Schedule Calculator

Earned Schedule Calculator

Analysis Tool Demonstration

Earned Schedule Analysis Tool

Earned Schedule
Analysis Tool

Interpolation Error

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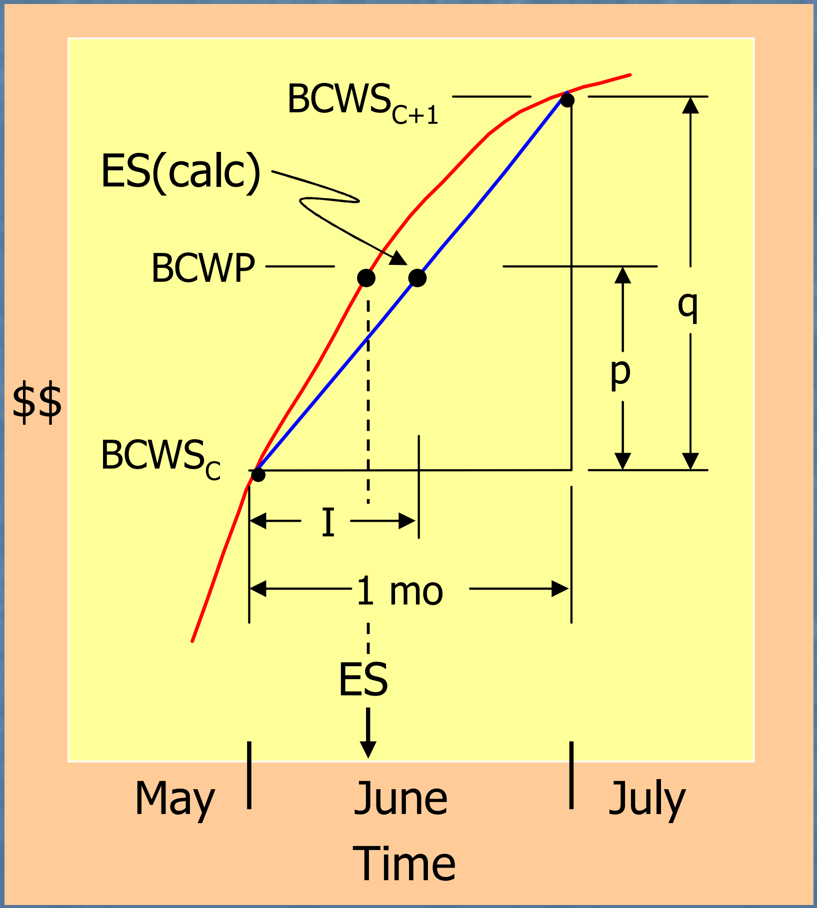
Interpolation Error

- The PMB is an S-Curve. Does the linear interpolation introduce large ES error?
- Is error larger where the S-Curve is steepest?
- What affects the accuracy of the ES calculation?

Interpolation Error



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

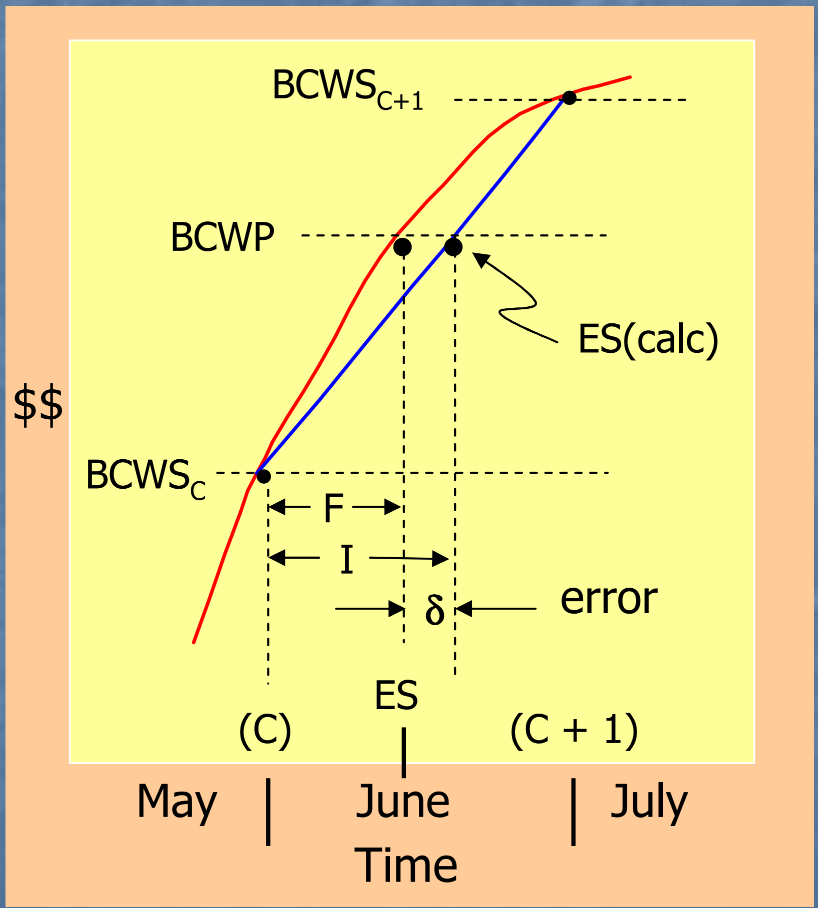
$$I = (p / q) * 1\ \text{mo}$$

$$p = BCWP - BCWS_C$$

$$q = BCWS_{C+1} - BCWS_C$$

$$I = \frac{BCWP - BCWS_C}{BCWS_{C+1} - BCWS_C} * 1\text{mo}$$

Interpolation Error



ES = Number of whole months (C) + Increment on curve (F)

= C + F

ES(calc) = C + calculated increment (I)

Error (δ) = I - F

$$\% \text{ error} = \frac{|\delta|}{C + F}$$

Example = .05 / 8.12 = 0.6%

As C ⇒ larger

- % error ⇒ smaller
- ES(calc) ⇒ more accurate

Weekly EV make ES more accurate

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Interpolation Error

- After a few months of status (C > 4) - **interpolation error is negligible (≤ 3%)**
- What about central portion of PMB, where S-Curve is steepest? Is error greater?
  - Where slope is large, the resolution of the interpolation is maximized
  - Curvature of PMB is minimized
  - **Interpolation error is negligible**

Other Sources of Error

- Partial Month – 1st month
  - Much more significant than interpolation error
  - Error decreases as C becomes larger
  - Correctable – adjust calculator output
- Earned Value recorded
  - By far, the largest source of ES error
  - Low accuracy for EV $\Rightarrow$ inaccurate ES

Earned Schedule Training
Part II

ES and Re-Baselining

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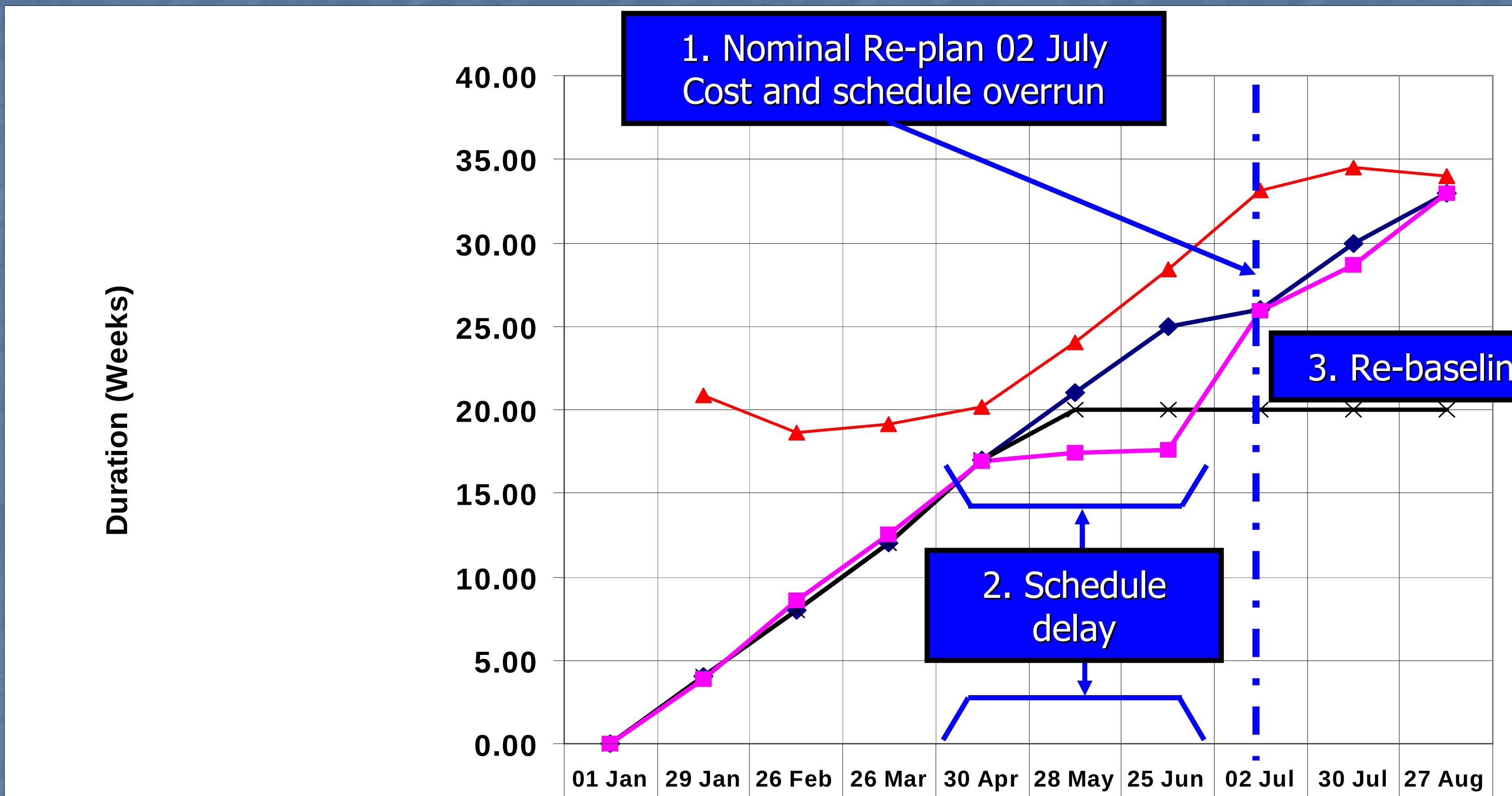
ES and Re-Baselining

- ES indicators are affected by re-baselining
  - Behaviour of SV(t) and SPI(t) is analogous to CV and CPI
    - See examples
- PMB change affects schedule prediction similarly to cost
- **Earned Schedule brings attention to the potential schedule impact of a declared "cost only" change**

Earned Schedule – Re-Baseline Example

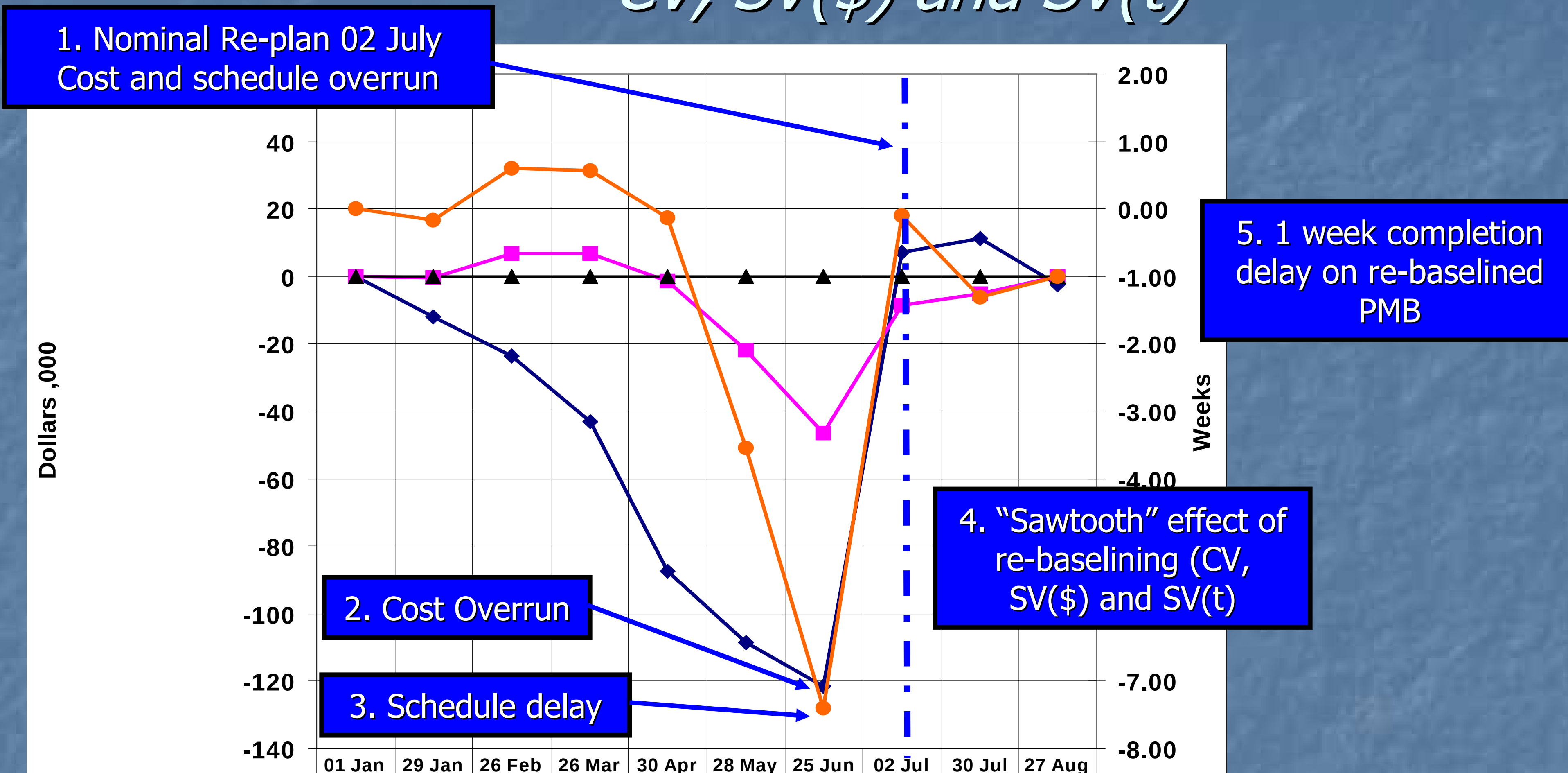
Real project data – nominal re-baseline



	01 Jan	29 Jan	26 Feb	26 Mar	30 Apr	28 May	25 Jun	02 Jul	30 Jul	27 Aug
Actual Time (weeks)	0.00	4.00	8.00	12.00	17.00	21.00	25.00	26.00	30.00	34.00
Planned Schedule ReBline #1	0.00	4.00	8.00	12.00	17.00	21.00	25.00	26.00	30.00	33.00
Planned Schedule cum CBB	0.00	4.00	8.00	12.00	17.00	20.00	20.00	20.00	20.00	20.00
Earned Schedule cum	0.00	3.84	8.60	12.56	16.87	17.45	17.59	25.91	28.70	33.00
IEAC(t) SPI(t)		20.85	18.60	19.11	20.15	24.07	28.42	33.12	34.50	34.00

Earned Schedule – Re-Baseline Example

CV, SV($) and SV(t)



	01 Jan	29 Jan	26 Feb	26 Mar	30 Apr	28 May	25 Jun	02 Jul	30 Jul	27 Aug
Actual Time (weeks)	0.00	4.00	8.00	12.00	17.00	21.00	25.00	26.00	30.00	34.00
CV cum	0.00	(12.14)	(23.70)	(42.92)	(87.31)	(108.61)	(121.43)	6.96	11.09	(2.30)
SV($) cum	0.00	(0.41)	6.65	6.73	(1.42)	(22.07)	(46.48)	(8.60)	(5.22)	0.00
Target CV and SV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SV(t) cum	0.00	(0.16)	0.60	0.56	(0.13)	(3.55)	(7.41)	(0.09)	(1.30)	(1.00)

Critical Path Study

Critical Path Study Outline

- The Scheduling Challenge
- Case Study Project
  - The project
  - The EVM, Earned Schedule and Network Schedule approach
- Earned Schedule vs Critical Path predictors
- Real Schedule Management with Earned Schedule
  - Initial experience and observation

The Scheduling Challenge

- A realistic project schedule is dependent on multiple, often complex factors including accurate:
  - Estimation of the tasks required,
  - Estimates of the task durations
  - Resources required to complete the identified tasks
- Identification and modeling of dependencies impacting the execution of the project
  - Task dependencies (e.g. F-S process flows)
  - "Dependent" Milestones (internal and external)
  - "Other logic"

The Scheduling Challenge

- From small projects into large projects and programs, scheduling requirements becomes exponentially more complex
- Integration
  - Of schedules between "master" and "subordinate" schedules
  - Often across multiple tiers of
    - Activities and
    - Organisations

    contributing to the overall program of work
- Essential for producing a useful integrated master schedule

To further compound schedule complexity

- Once an initial schedule baseline has been established progress monitoring inevitably results in changes
  - Task and activity durations change because "actual performance" does not conform to plan
  - Additional unforeseen activities may need to be added
  - Logic changes as a result of corrective actions to contain slippages; and
  - Improved understanding of the work being undertaken
  - Other "planned changes" (Change Requests) also contribute to schedule modifications over time

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Wouldn't it be nice ….

- To be able to explicitly declare "Schedule Reserve" in the project "schedule of record"
  - Protect committed key milestone delivery dates
- To have schedule macro level indicators and predictors
  - Ideally, derived separately from the network schedule!
  - Provides a means for comparison and validation of the measures and predictors provided by the network schedule
  - An independent predictor of project duration would be a particularly useful metric
    - "On time" completion of projects usually considered important
- **Just like EVM practitioners have for cost ….**
  - **The potential offered by Earned Schedule**

Case Study Project

- Commercial sector software development and enhancement project
  - **Small scale**: 10 week Planned Duration
  - **Time critical**: Needed to support launch of revenue generating marketing campaign
  - Cost budget: 100% labour costs
- Mixture of:
  - 3 tier client server development
    - Mainframe, Middleware, Workstation
  - 2 tier client server development
    - Mainframe to Workstation direct

The EVM and ES Approach

- Microsoft Project 2002 schedule
  - Resource loaded for time phased effort and cost estimation
  - Control Account – Work Package views developed in the schedule
  - Actual Costs captured in SAP time recording system
    - Limited (actual) cost – schedule integration
  - Contingency (Management Reserve) managed outside the schedule
  - Top level Planned Values cum "copied and pasted" into Excel EVM and ES template
    - High level of cost – schedule integration achieved

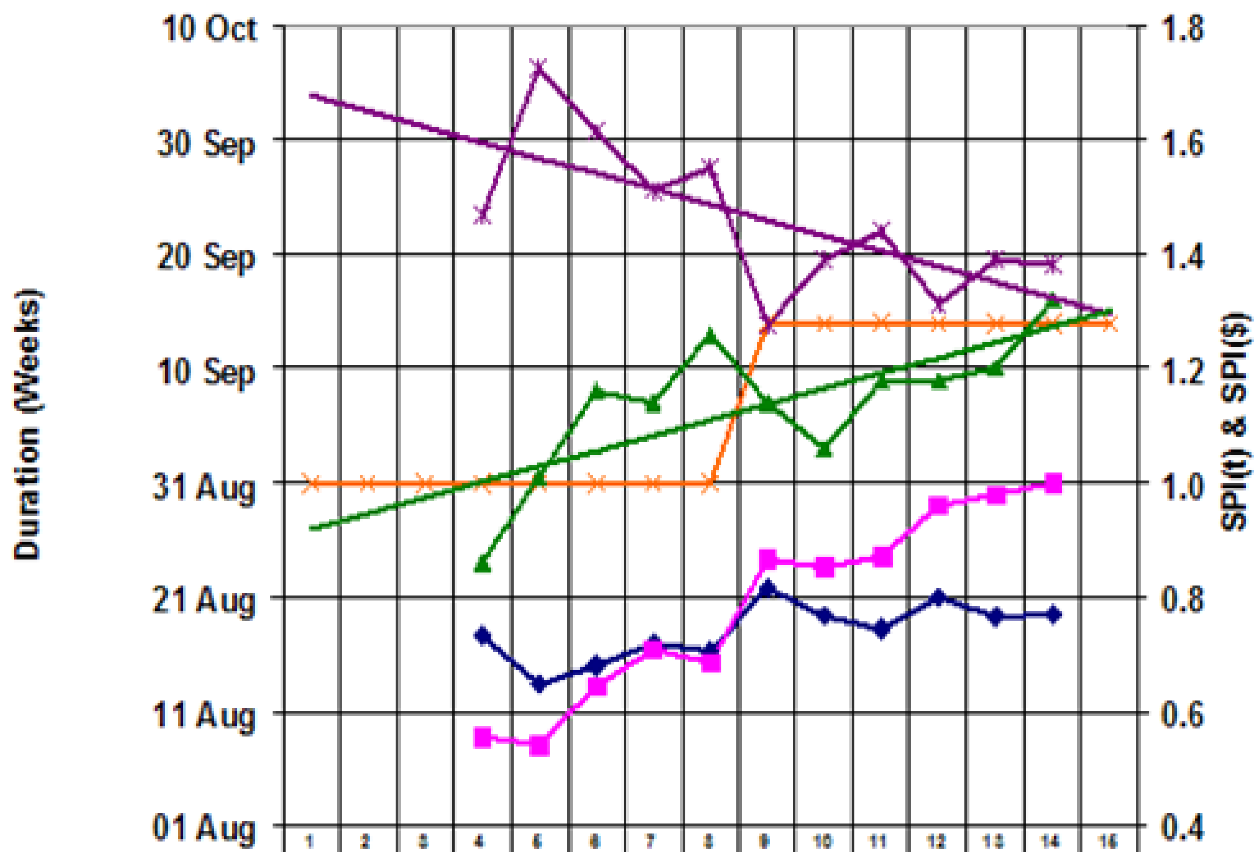
Schedule Management

- Weekly schedule updates from week 3 focusing on:
  - Accurate task level percentage work completion updates
  - The project level percentage work completion (cumulative) calculated by Microsoft Project
    - Percentage work complete transferred to the EVM and ES template to derive the progressive Earned Value (cumulative) measure
- Schedule review focusing on critical path analysis
  - Schedule updates occurred as needed with
  - Revised estimates of task duration and
  - Changes to network schedule logic

  particularly when needed to facilitate schedule based corrective action
- Actual costs entered into the EVM and ES template as they became available (weekly)

An Integrated Schedule Analysis Chart

Critical Path, IECD, SPI(t) and SPI($) on one page



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Planned Completion Date	31	31	31	31	31	31	31	31	14	14	14	14	14	14	14
IECD (PD/SPI(t))				23	08 Oct	30	26	27	13	19	21	15	19	19	
Critical Path Completion				24	31	08	07	13	07	03	09	09	10	16	
SPI(t) cum				0.73	0.65	0.68	0.72	0.70	0.82	0.77	0.74	0.80	0.77	0.77	
SPI($) cum				0.56	0.54	0.64	0.71	0.69	0.87	0.85	0.87	0.96	0.98	1.00	

Schedule Analysis

- Initial expectation
  - The critical path predicted completion date would be more pessimistic than the IECD
- In fact
  - The ES IECD trend line depicted a "late finish" project with improving schedule performance
  - The critical path predicted completion dates showed an "early finish project" with deteriorating schedule performance
- Became the "critical question" in Week 8
  - ES IECD improvement trend reversed
  - Continued deterioration in the critical path predicted completion dates

Schedule Analysis Result

- IECD the more credible predictor in <u>this circumstance</u>
  - Work was not being accomplished at the rate planned
  - No adverse contribution by critical path factors
    - e.g. Externally imposed delays caused by "dependent milestone"
- Two weeks schedule delay communicated to management
  - Very late delay of schedule slippage a very sensitive issue
- Corrective action was immediately implemented
  - Resulted in two weeks progress in one week based on IECD improvement in week 9
  - Project substantively delivered to the revised delivery date

The IECD vs Critical Path Predictors

- Network schedule updates do not usually factor past (critical path) task performance into the future
  - Generally concentrate on the current time window
    - Task updates
    - Corrective action to try and contain slippages
  - Critical path predicted completion date is not usually calibrated by past actual schedule performance
- The ES IECD
  - Cannot directly take into account critical path information
  - BUT does calibrate the prediction based on historic schedule performance as reflected in the SPI(t)

Further Observations

- Much has been written about the consequences of not achieving work at the EVM rate planned
  - At very least, incomplete work needs to be rescheduled …
  - Immediate critical vs non critical path implication requires detailed analysis of the network schedule
  - Sustained improvement in schedule performance is a difficult challenge
    - SPI(t) remained in the .7 to .8 band for the entire project!
    - In spite of the corrective action and recovery effort
  - Any task delayed eventually becomes critical path if not completed
- SPI(t) a very useful indicator of schedule performance
  - Especially later in the project when SPI($) was resolving to 1.0

Questions of Scale

- We know that ES is scalable as is EVM
  - Issues of scale did not arise due to small size of the project
- Detailed analysis of the ES metrics is required
  - The same as EVM for cost
  - The "masking" or "washout" effect of negative and positive ES variances at the detailed level can be an issue
  - The same as EVM for cost
- Apply Earned Schedule to the Control Accounts and Work Packages on the critical path
  - And "near" critical path activities
- **Earned Schedule augments network schedule analysis – it doesn't replace it**
  - Just as EVM doesn't replace a bottom up ETC and EAC

Real Schedule Management with Earned Schedule

- ES is of considerable benefit in analysing and managing schedule performance
- The "time critical" dichotomy of reporting "optimistic" predicted task completions and setting and reporting realistic completion dates was avoided
  - ES metrics provided an independent means of sanity checking the critical path predicted completion date
  - **Prior to communicating overall schedule status to management**
- **ES focused much more attention onto the network schedule than using EVM alone**

Final Thoughts

- ES is expected be of considerable value to the schedule management for large scale projects and programs
  - Exponential increase in the network scheduling complexities
  - Unavoidable and necessary on those programs and so
  - **The need and benefit of an independent means of sanity checking schedules of such complexity is much greater**
- **ES is anticipated to become the "bridge" between EVM and the Network Schedule**

Network Schedule Analysis

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Schedule Analysis with EVM?

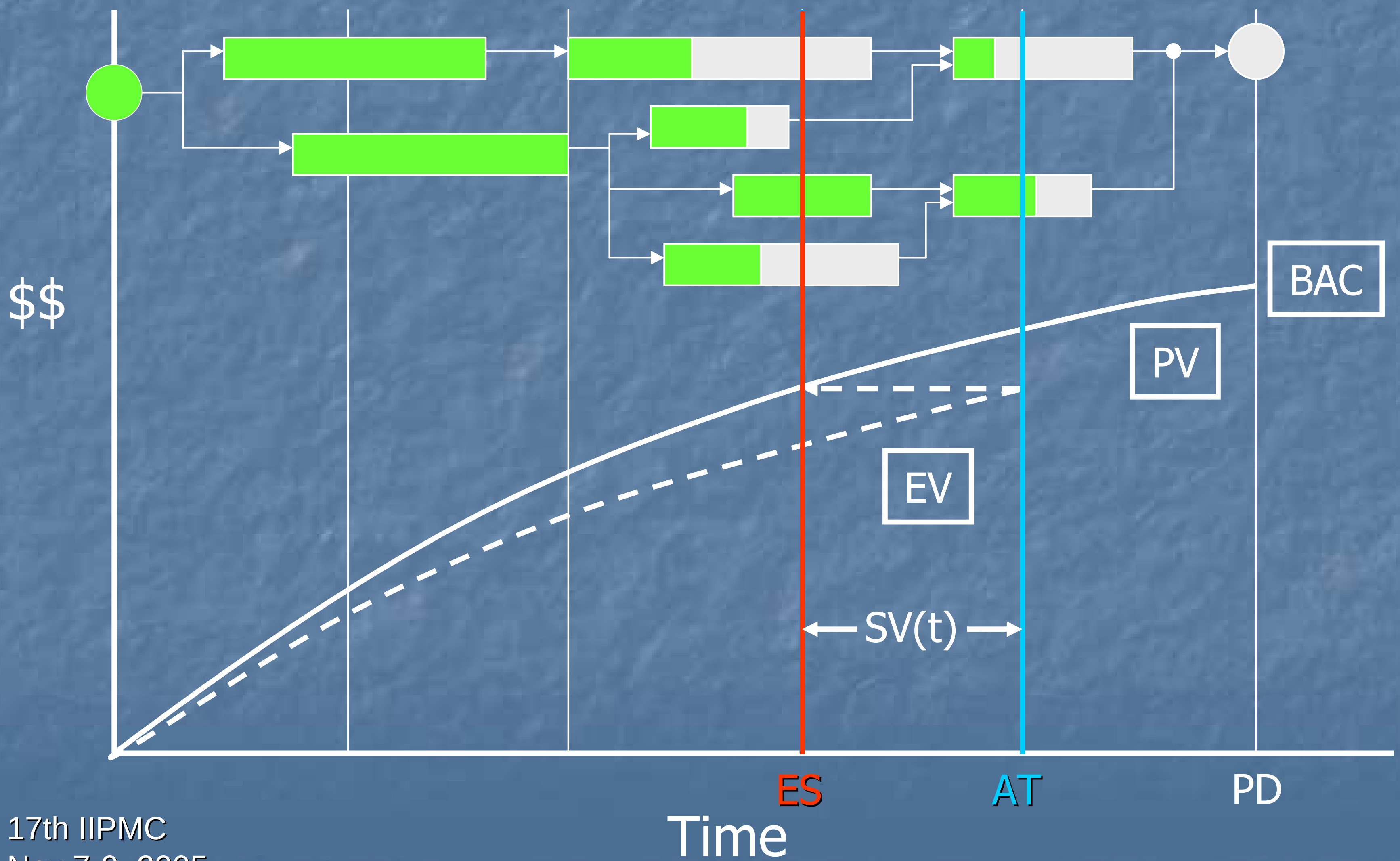
- The general belief is EVM cannot be used to predict schedule duration
- Most practitioners analyze schedule from the bottom up using the networked schedule ….“It is the only way possible.”
  - Analysis of the Schedule is overwhelming
  - Critical Path is used to shorten analysis
    (CP is longest path of the schedule)

Schedule Analysis with EVM?

- 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 "Real" 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 Adherence

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Schedule Adherence

- 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 Adherence

- 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

- Schedule Adherence 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:*

$$P = \text{Tasks (perf - corr)} / \text{Tasks (plan)}$$

$$= \Sigma\, EVj\ (\text{corresponding}) / \Sigma\, PVj\ (\text{plan})$$

where $\Sigma\, EVj \leq \Sigma\, PVj$ & $\Sigma\, PVj = EV$

Schedule Adherence

- 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}
- *The behavior of P may explain Dr. Christensen's findings for CPI & IEAC*
- P used to compute effective earned value {EV(e)}

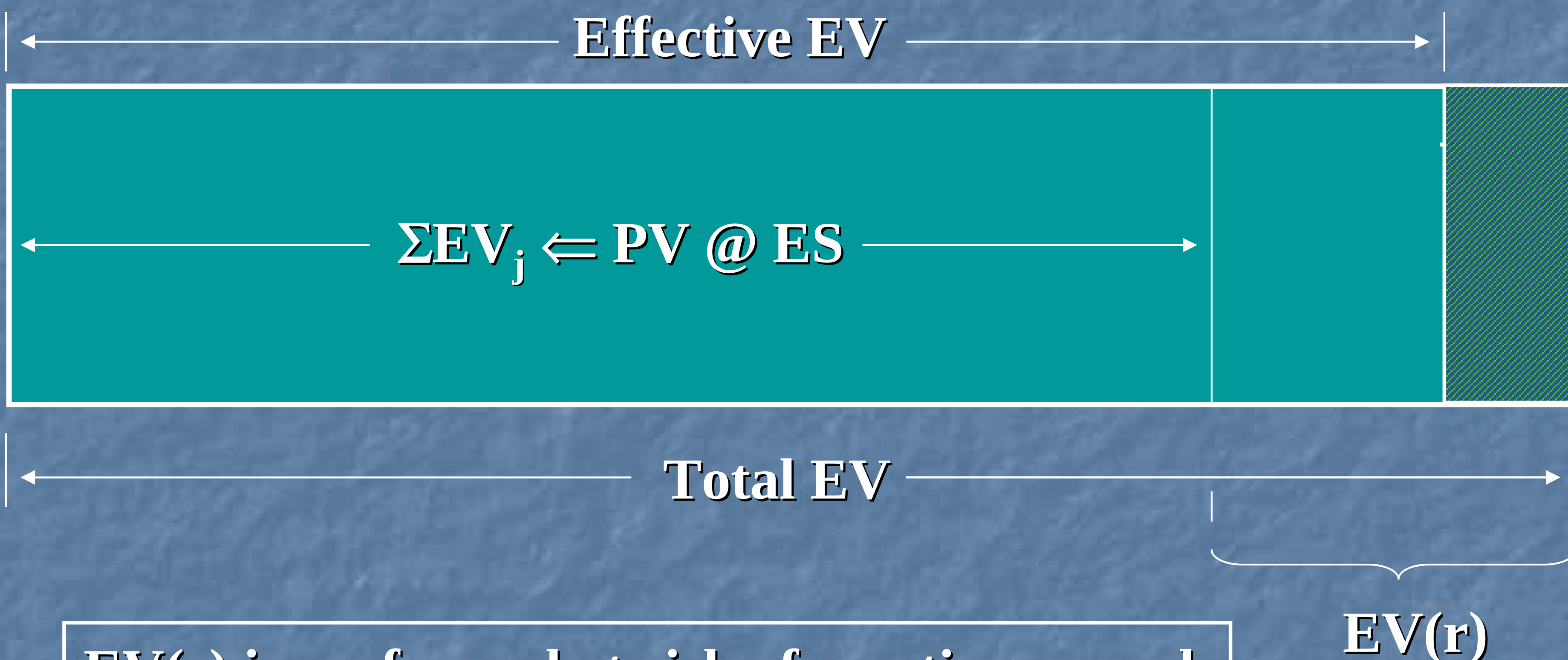
Effective Earned Value

Discussion of EV Research

- CPI tends to worsen as EV ⇒ BAC
- IEAC = BAC / CPI ≤ Final Cost

  when Percent Complete is ≥ 20%
- 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*

Effective Earned Value



EV(r) is performed at risk of creating rework
Portion colored [teal] is usable
Portion colored [hatched] is unusable

Effective EV Relationships

- P-Factor (or P) = ΣEVj / ΣPVj = ΣEVj / EV

  ΣEVj = P ∗ EV

- EV(p) is portion of EV consistent with the plan

  EV(p) = ΣEVj = P ∗ EV

- EV(r) is portion of EV with anticipated rework

  EV(r) = EV – EV(p) = EV – P ∗ EV

  EV(r) = (1 – P) ∗ EV

Effective EV Relationships

- Rework proportion (R%) = f(r) / f(p)
  - f(r) = fraction of EV(r) unusable
  - f(p) = fraction of EV(r) usable
  - f(r) + f(p) = 1
- Portion of EV(r) usable
  - f(p) * R% + f(p) = 1
  - **f(p) = 1 / (1 + R%)**

Effective Earned Value

- Effective earned value is a function of EV, P, and Rework: EV(e) = f (EV, P, Rework)

  $EV(e) = EV(p) + (\text{fraction usable}) * EV(r)$

  $= P * EV + (1 / 1 + R\%) * [(1 – P) * EV]$
- General equation for Effective Earned Value

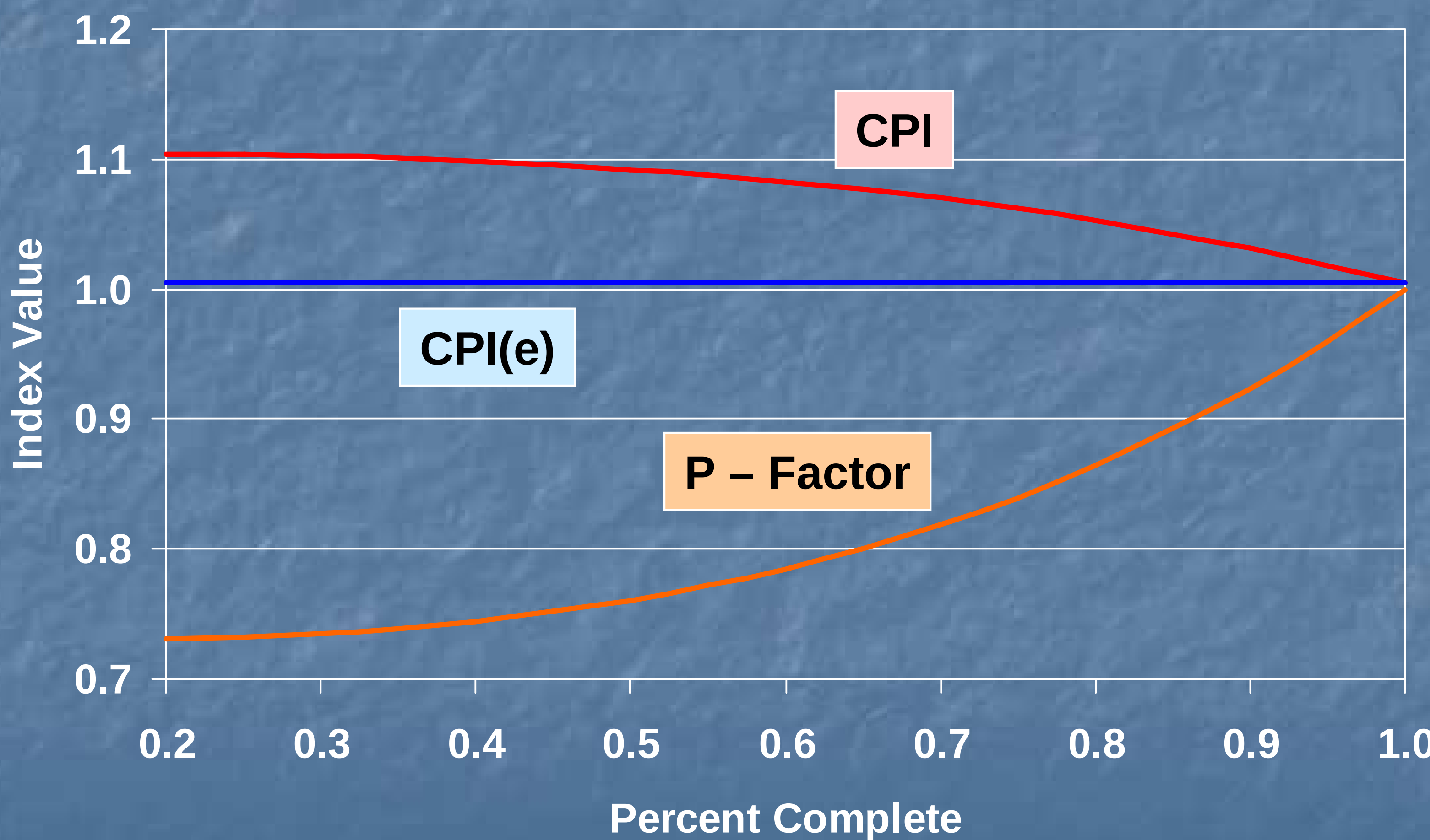
  $$EV(e) = [(1 + P * R\%) / (1 + R\%)] * EV$$
- Special case, when R% = 50%

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

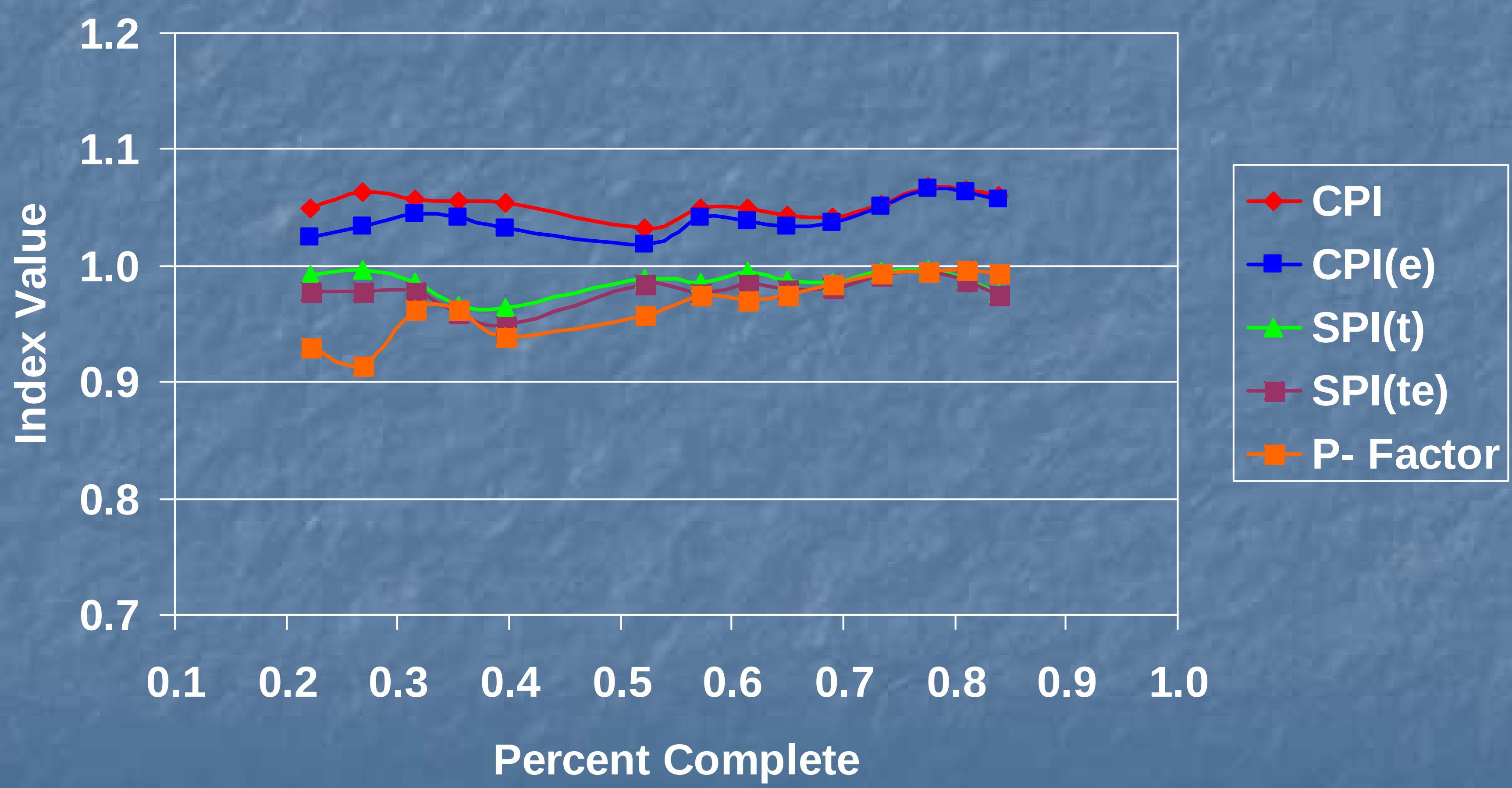
Effective Earned Value

- Effective ES is computed using EV(e) *{i.e., ES(e)}*
- Effective EV and ES indicators are …
  - CV(e) = EV(e) – AC
  - CPI(e) = EV(e) / AC
  - SV(te) = ES(e) – AT
  - SPI(te) = ES(e) / AT

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



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*

Available Resources

Publications

1. "Schedule is Different," _The Measurable News_, March & Summer 2003 [Walt Lipke]
2. "Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data," _The Measurable News_, Summer 2003 [Kym Henderson]
3. "Further Developments in Earned Schedule," _The Measurable News_, Spring 2004 [Kym Henderson]
4. "Connecting Earned Value to the Schedule," _The Measurable News_, Winter 2004 [Walt Lipke]
5. "Earned Schedule in Action," _The Measurable News_, Spring 2005 [Kym Henderson]
6. "Not Your Father's Earned Value," _Projects A Work_, February 2005 [Ray Stratton]

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Presentations

1. Earned Schedule – An Emerging Practice, 16th IIPM Conference, November 2004 [Walt Lipke, Kym Henderson]
2. Schedule Analysis and Predictive Techniques Using Earned Schedule, 16th IIPM Conference, November 2004 [Walt Lipke, Kym Henderson, Eleanor Haupt]
3. Earned Schedule – an Extension to EVM Theory, EVA-10 Conference (London), May 2005 [Walt Lipke, Kym Henderson]
4. Forecasting Project Schedule Completion by Using Earned Value Metrics, EVM Training at Ghent University (Belgium), January 2005 [Stephan Vandevoorde]

http://sydney.pmichapters-australia.org.au/
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Presentations

5. New Concept in Earned Value – *Earned Schedule*, PMI Southeast Regional Conference, June 2005 [Robert Handshuh]
6. Forecasting Project Schedule Completion by Using Earned Value Metrics, Early Warning Signals Congress (Belgium), June 2005 [Stephan Vandevoorde, Dr. Mario Vanhoucke]

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Calculator & Analysis Tools

- Freely provided upon email request
  - Application assistance if needed
- Please respect Copyright
- Feedback requested
  - Improvement / Enhancement suggestions
  - Your assessment of value to Project Managers
  - Disclosure of application and results (with organization permission)

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Wrap-Up

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

Leads to improved
Schedule & Cost Forecasting

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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

Appendix –
ES Calculation Exercise

ES Exercise - Worksheet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BSWS($)	105	200	515	845	1175	1475	1805	2135	2435	2665	2760	2823
BCWP($)	115	220	530	870	1215	1525	1860	2190	2500	2740	2823	------
SV($)	10	20	15	25	40	50	55	55	65	75	63	------
SPI($)	1.095	1.100	1.029	1.030	1.034	1.034	1.030	1.026	1.027	1.028	1.023	------

Month Count	1	2	3	4	5	6	7	8	9	10	11	12
ES(cum)												
SV(t)												
SPI(t)												

Early Finish Project (Cumulative Values)

ES Exercise - Worksheet

	Year 01												Year 02		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
BSWS($)	105	200	515	845	1175	1475	1805	2135	2435	2665	2760	2823	------	------	------
BCWP($)	95	180	470	770	1065	1315	1610	1900	2150	2275	2425	2555	2695	2770	2823
SV($)	-10	-20	-45	-75	-110	-160	-195	-235	-285	-390	-335	-268	-128	-53	0
SPI($)	0.905	0.900	0.913	0.911	0.906	0.892	0.892	0.890	0.883	0.854	0.879	0.905	0.955	0.981	1.000

Month Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ES(cum)															
SV(t)															
SPI(t)															

Late Finish Project (Cumulative Values)

ES Exercise - Answers

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BSWS($)	105	200	515	845	1175	1475	1805	2135	2435	2665	2760	2823
BCWP($)	115	220	530	870	1215	1525	1860	2190	2500	2740	2823	------
SV($)	10	20	15	25	40	50	55	55	65	75	63	------
SPI($)	1.095	1.100	1.029	1.030	1.034	1.034	1.030	1.026	1.027	1.028	1.023	------

Month Count	1	2	3	4	5	6	7	8	9	10	11	12
ES(mo)	1.105	2.063	3.045	4.076	5.133	6.152	7.167	8.183	9.283	10.789	12.000	------
SV(t)	0.105	0.063	0.045	0.076	0.133	0.152	0.167	0.183	0.283	0.789	1.000	------
SPI(t)	1.105	1.032	1.015	1.019	1.027	1.025	1.024	1.023	1.031	1.079	1.091	------

Early Finish Project (Cumulative Values)

ES Exercise - Answers

	Year 01												Year 02		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
BSWS($)	105	200	515	845	1175	1475	1805	2135	2435	2665	2760	2823	------	------	------
BCWP($)	95	180	470	770	1065	1315	1610	1900	2150	2275	2425	2555	2695	2770	2823
SV($)	-10	-20	-45	-75	-110	-160	-195	-235	-285	-390	-335	-268	-128	-53	0
SPI($)	0.905	0.900	0.913	0.911	0.906	0.892	0.892	0.890	0.883	0.854	0.879	0.905	0.955	0.981	1.000

Month Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ES(mo)	0.905	1.789	2.857	3.772	4.667	5.547	6.409	7.288	8.050	8.467	8.967	9.522	10.316	11.159	12.000
SV(t)	-0.095	-0.211	-0.143	-0.228	-0.333	-0.533	-0.591	-0.712	-0.950	-1.533	-2.033	-2.478	-2.684	-2.841	-3.000
SPI(t)	0.905	0.894	0.952	0.943	0.933	0.911	0.916	0.911	0.894	0.847	0.815	0.794	0.794	0.797	0.800

Late Finish Project (Cumulative Values)