Applying Earned Value to a Manufacturing Environment

David Fox – General / Projects Manager
L&A Pressure Welding Pty Ltd
Email: David@lapressure.com.au
UTS Masters by Research Student
20th May 2010

Content

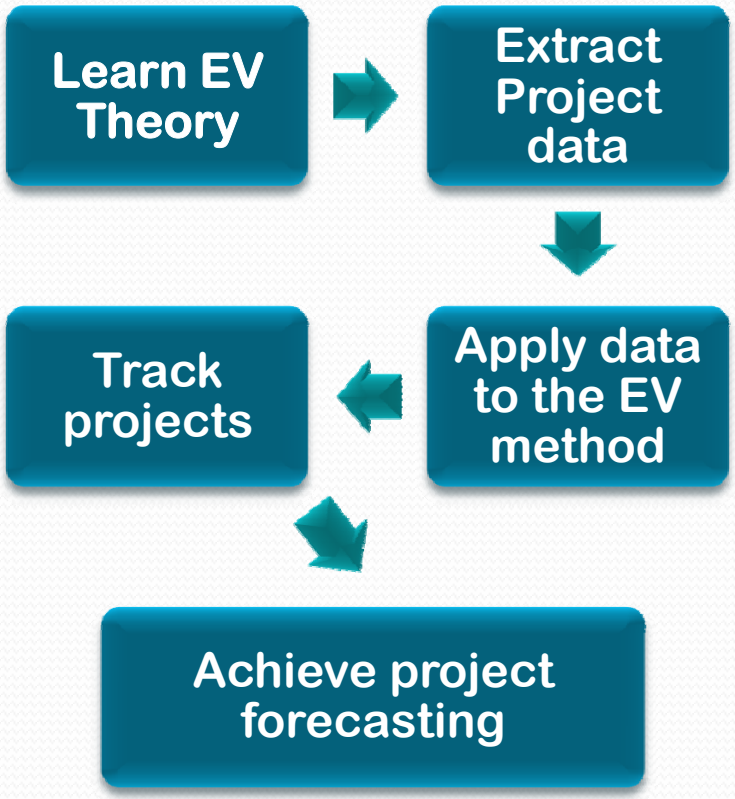
- L&A Project Environment
- Earned Value Management (EVM) - Research
- Earned Value (EV) & Earned Schedule (ES) - Theory
- Applying EV & ES - Sample Project
- Application Lessons

L&A - Project Environment

- **Company**
  - SME (~50 employees)
  - Pressure Equipment
  - Petrochemical
- **Project Scope**
  - 3 to 18 months
  - $20k to $7m
  - Design & Build
  - Testing & Painting
  - Transport

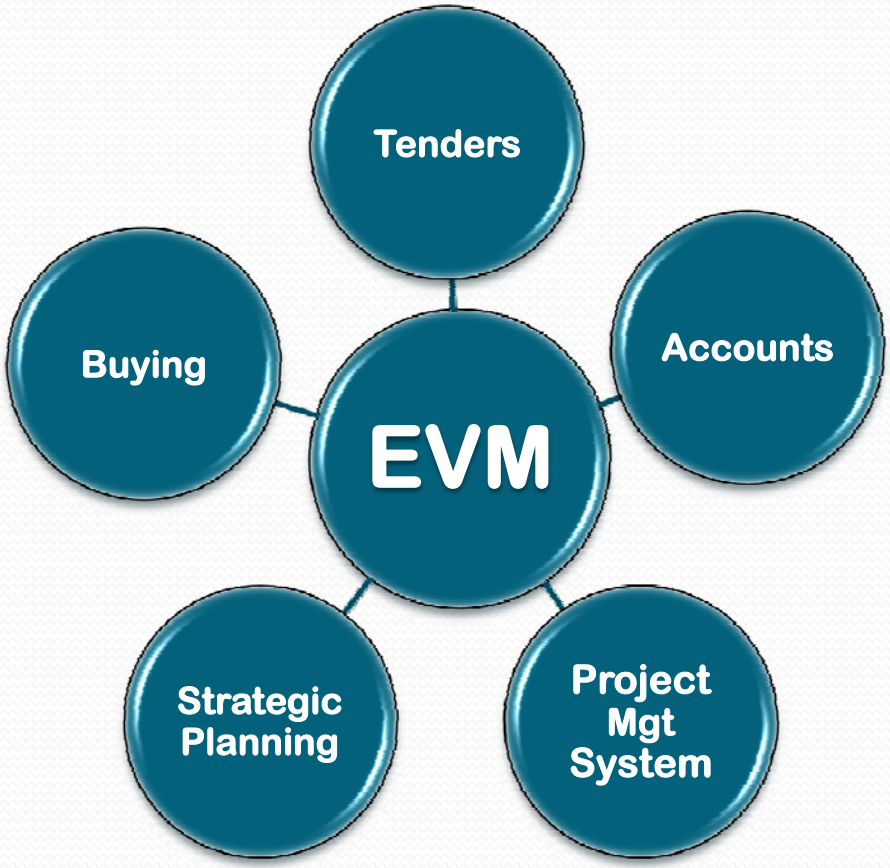
EVM - Research Project

Plan



EVM - Isolated System

Outcome



Centralised System

EVM - Research Project

Benefits

- **Project Mgt System**
  - Project reporting
  - Cost transparency
  - Tool for project decision making
- **Other Business Areas**
  - Project Portfolio mgt
  - Estimating feed back
  - Risk management

Challenges

- **Implementation**
  - Data capture
  - Need for procedures & flexibility in system
- **Research Focus**
  - Curve Interpretation
  - Forecast validation
  - Integration of system with operations

EV Theory - Background

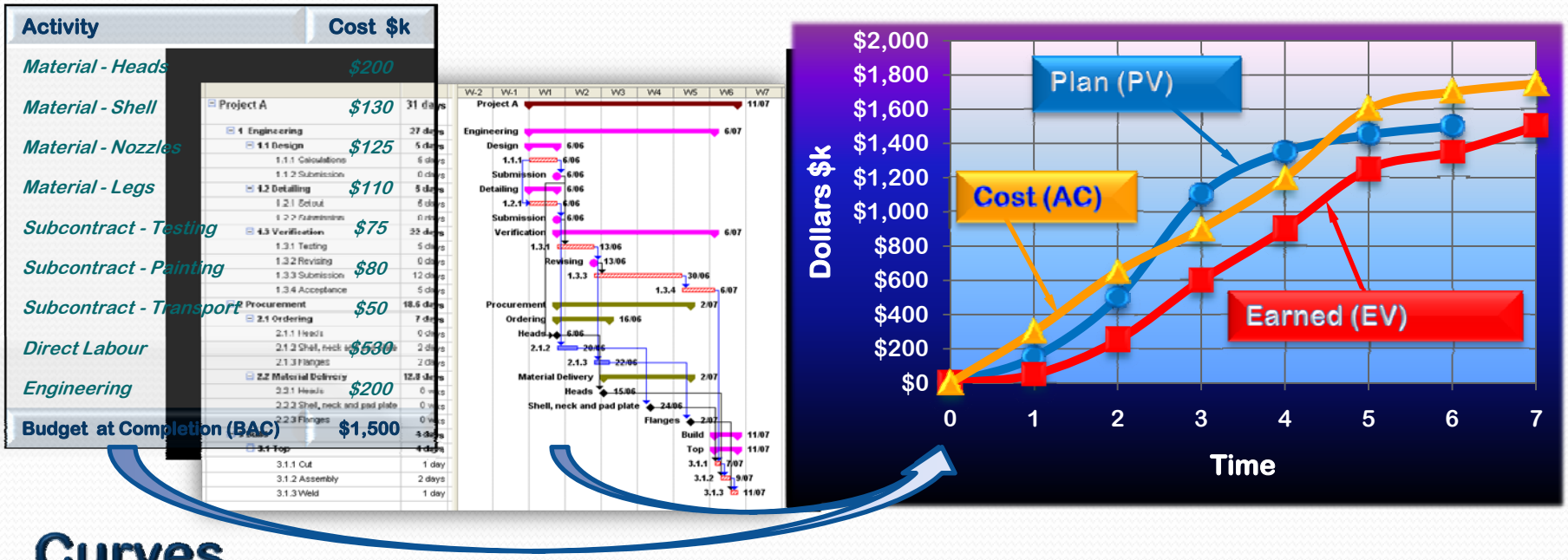
- History
  - Introduced in the 1960 through the US Department of Defence
  - Large projects only - costly & complicated to implement
  - These issues limited early uptake in the private sector, however users agreed on the systems principles
  - 2003
    - Research identifying human factors as the uptake barrier rather than the system its self
    - A viable solution to the EVM schedule performance problem was publicly introduced by Walt Lipke, coined as Earned Schedule© (ES)
    - AS4817 – Project Performance Measurement using EV - Introduced
  - 2004
    - ES Principles cited in the release of PMI Practice Standard for EVM
  - 2006
    - AS4817 revised, however ES principles remain outside its scope

EV Theory - Overview

- **Positives**
  - Converts all activities to $ - simplifies cost reporting
  - Links time & costs in a single cumulative report
  - Project performance indicators, use same data set
- **Negatives**
  - EVM schedule indicators use the planned value (PV)
  - PV remain static when project runs late, causing the indicators to lose their management value
  - Schedule variance measured in $, not weeks / months
  - Schedule performance indicator methods do not match the benefits of the cost indicators

EV Theory - Objective

Graphically Reports Cumulative Progress



Curves

- Planned Value (PV) – Authorised Budget over planned time ‘t’
- Earned value (EV) – Value of the budgeted progress at ‘t’
- Actual Cost (AC) – Cost of the actual progress at ‘t’

EV Theory - Budget Terms

AS4817 – 2006 - Project Performance … using EV

- **Budget at Completion (BAC)**
  - Authorised budget to complete scope of work
  - Sum of allocated budgets plus undistributed budget
- **Undistributed Budget**
  - Budget associated with scope but not yet included in TPB
- **Time Phased Budget (TPB)**
  - Schedule of expenditure for the BAC
  - Performance Measurement Baseline (PMB)
- **Project Budget**
  - Total budget for the project
    - BAC → Authorised Project $
    - Management reserves → Contingencies $
    - Overheads & profit → Organisations $

EV Theory - Measures

Three Measures

- **Planned Value (PV)**
  - Sum of the PV's for each project task, equates to the Budget at Completion (BAC)
  - Planned time, uses periodic intervals – Weeks / Months
  - PV Curve - Cumulative planned value at the planned time →Performance Measurement Baseline (PMB)
- **Earned Value (EV)**
  - EV Curve - Cumulative planned value at the actual time interval accrued
- **Actual Cost (AC)**
  - AC curve - Cumulatively actual cost at the actual time interval accrued

EV Theory - Indicators

(EV) Cost Indicators

- Cost Variance (CV) → CV = EV-AC
- Cost Performance Index (CPI) → CPI = EV/AC

(EV) Schedule Indicators

- Schedule Variance (SV) → SV = EV-PV
- Schedule Performance Index (SPI) → SPI = EV/PV

ES Theory - Indicators

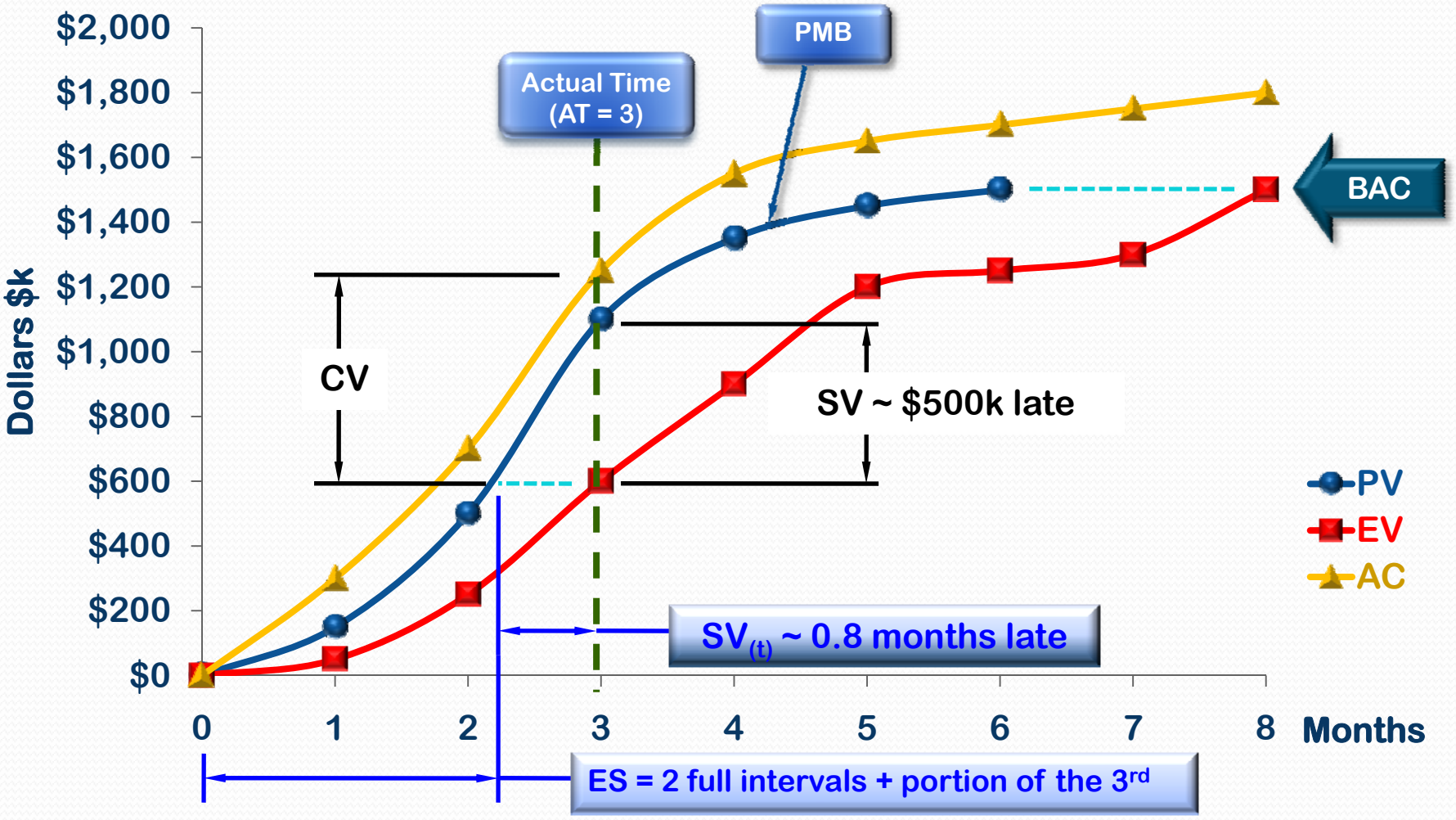
(ES) Schedule Indicators

- Schedule Variance ($SV_{(t)}$) ⟶ $SV_{(t)} = ES - AT$
- Schedule Performance Index ($SPI_{(t)}$) ⟶ $SPI_{(t)} = ES/AT$

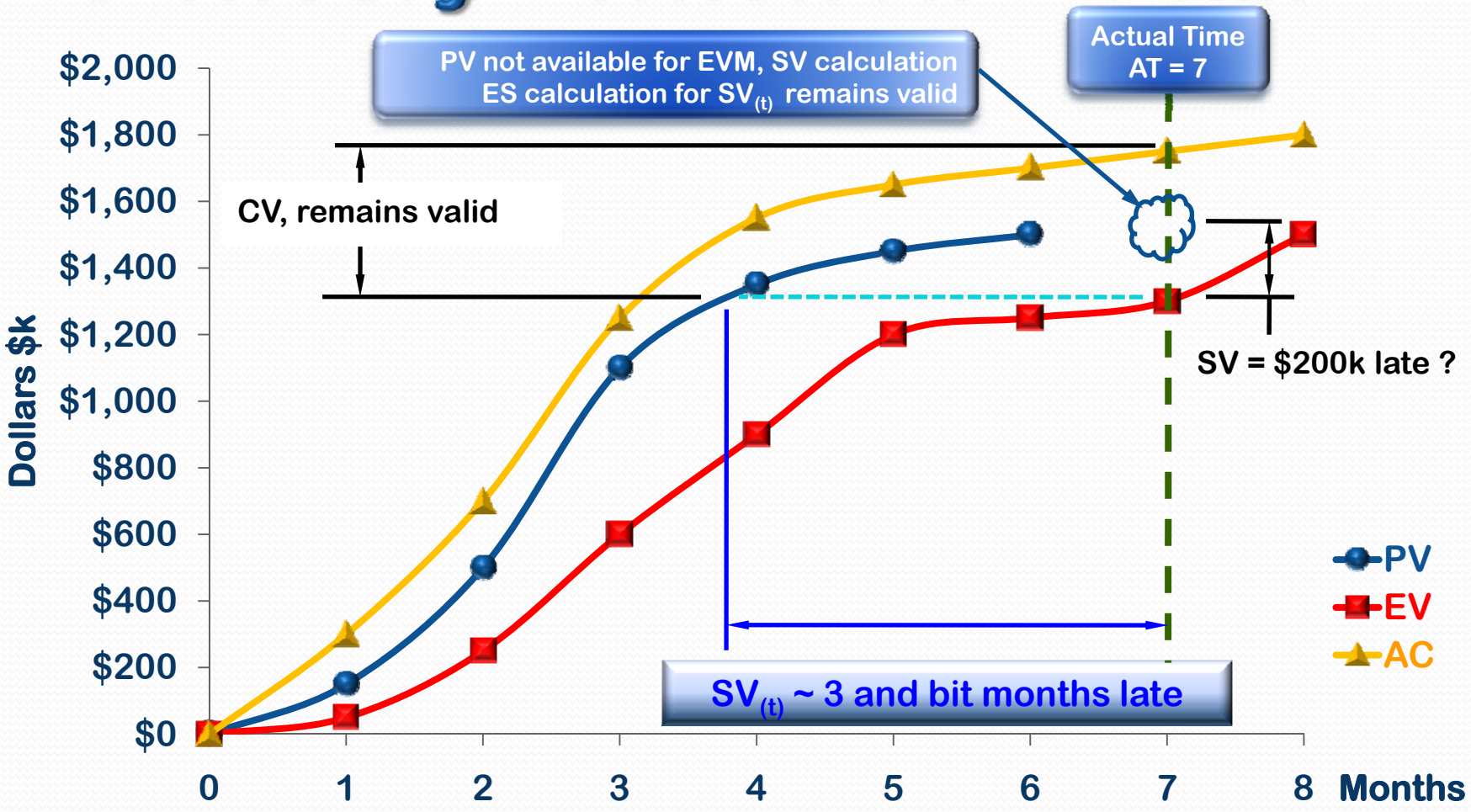
New Terms (using ES method)

- AT – Actual Time, number of time increments corresponding to EV
- C – Number of whole time increments of PMB for condition EV ≥ PV
- ES – Earned Schedule $ES = C + I$
- I – Portion of PMB increment earned $I = \frac{(EV - PV_C)}{(PV_{C+1} - PV_C)}$

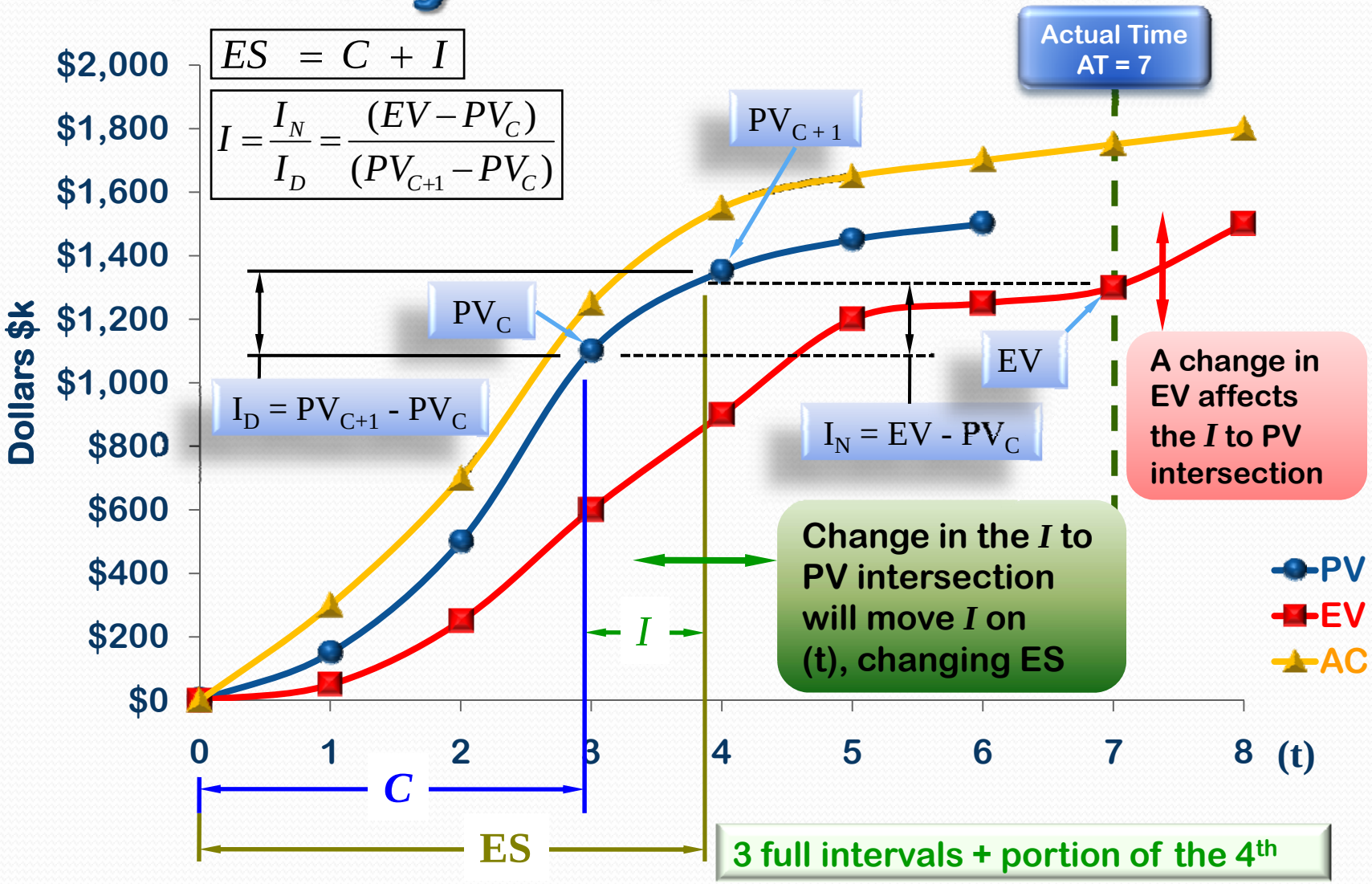
EV Theory - When AT < Plan



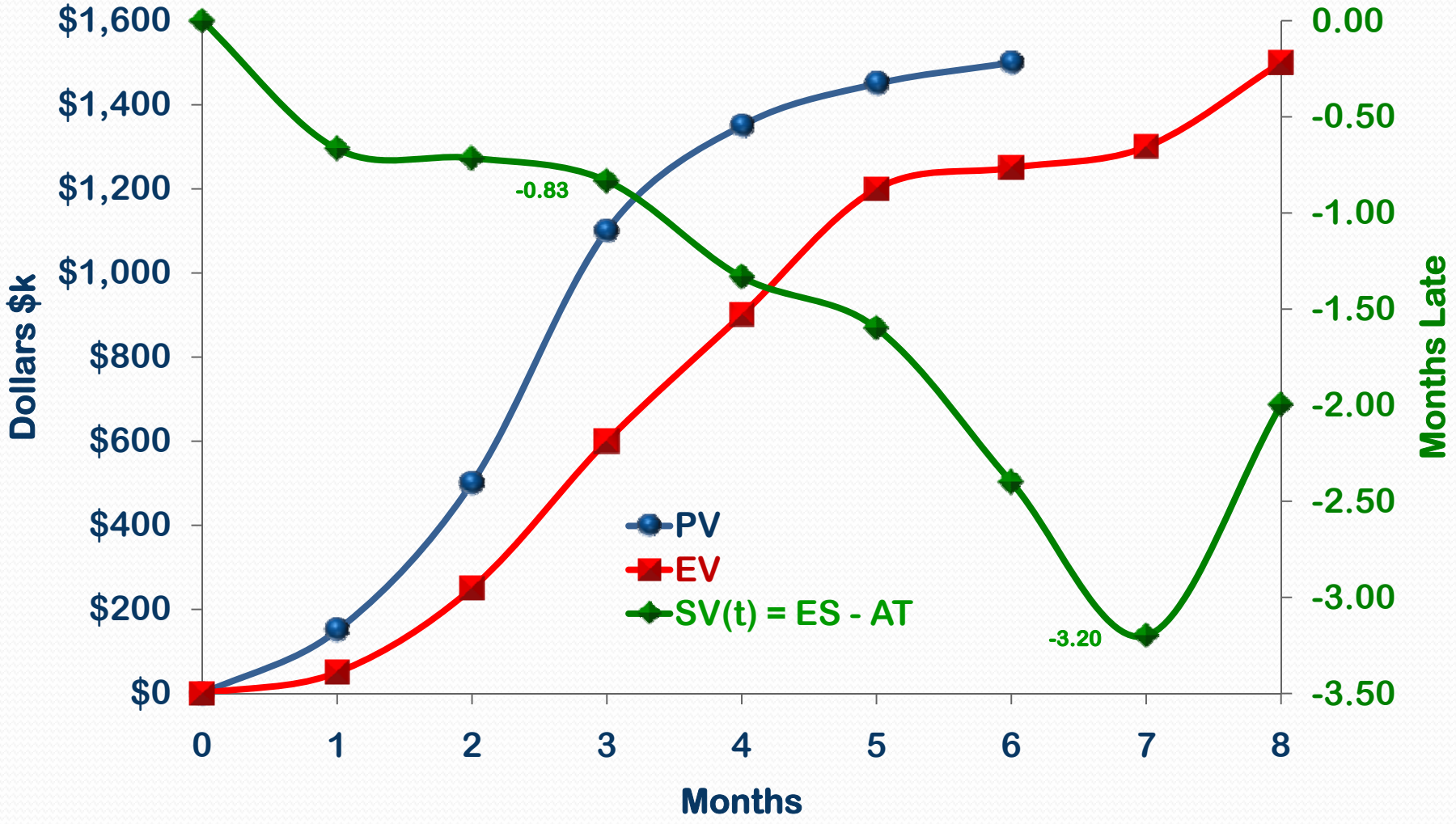
EV Theory - When AT > Plan



ES Theory – ES Calculation



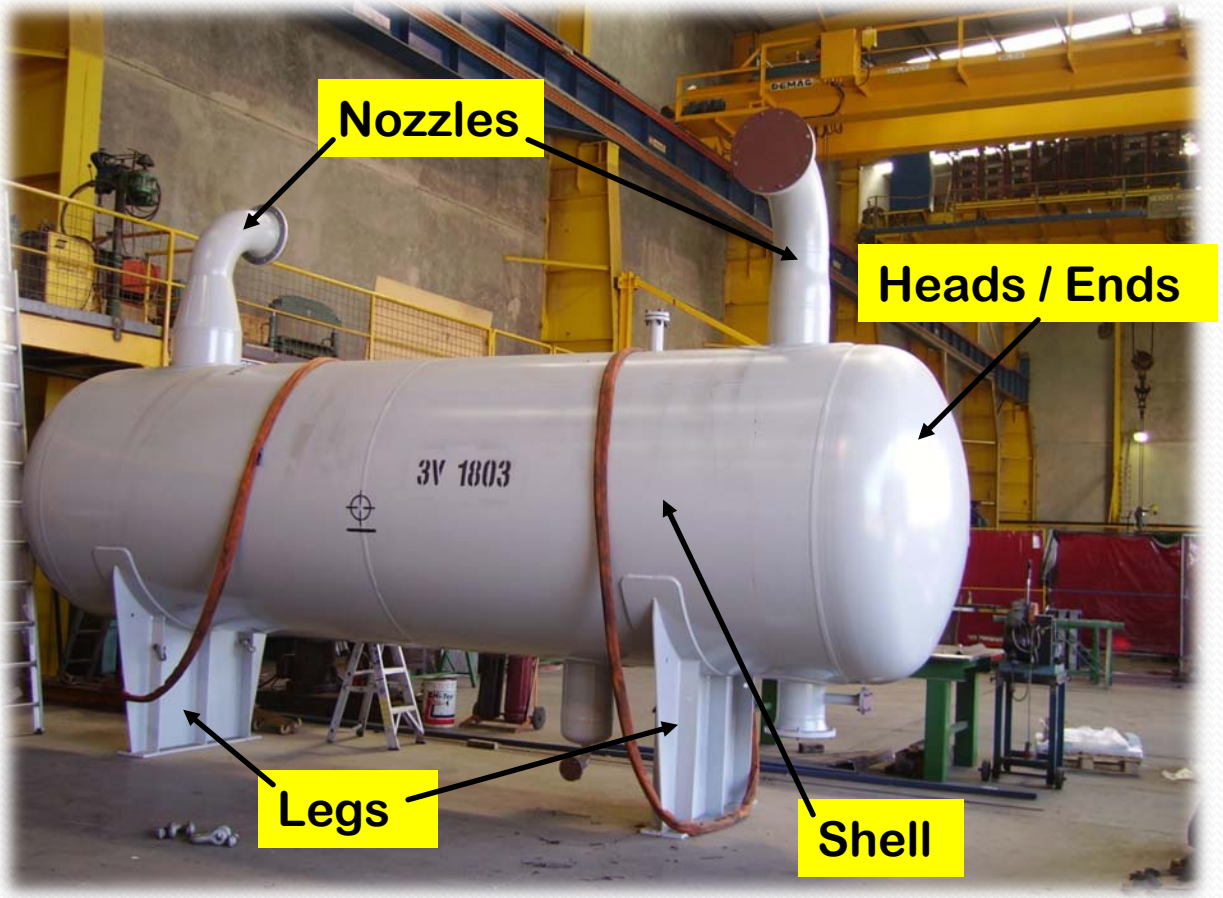
ES Theory - Reporting $SV_{(t)}$



Applying EV - Steps

- Prepare the BAC
- Schedule Baseline
- Time Phased Budget
- Track the Project using Data & Curves

Applying EV - Sample Project



Applying EV - Budget

Activity	Cost $
Engineering – Calculations, Drafting, Acceptance	*$3,000*
Material Delivery – Heads	*$30,000*
Material Delivery – Shell	*$20,000*
Material Delivery – Nozzles	*$12,000*
Material Delivery – Legs	*$8,000*
Build & Test – Shell, end, nozzles, closing end, legs	*$23,000*
Build & Test – Testing	*$2,500*
Paint & Dispatch – Deliver to Painter & Site	*$3,000*
Paint & Dispatch – Painting	*$6,000*
Budget at Completion (BAC)	**$107,500**
Contingencies & Organisational Allowances	*$20,700*
Project Budget	$128,200

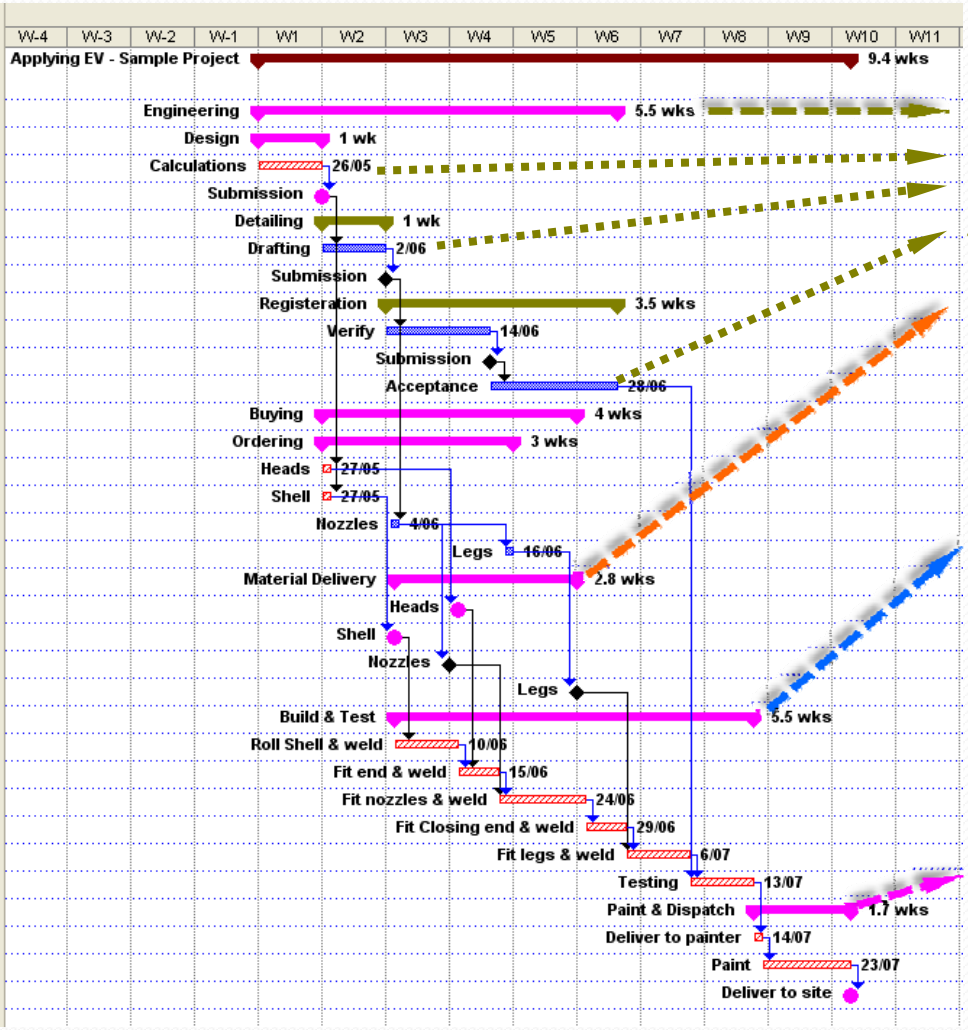
Authorised Project Budget → The BAC

Reserves & Business Costs

Total budget

Applying EV - Schedule

Task Name	Duration
Applying EV - Sample Project	**9.4 wks**
1 Engineering	**5.5 wks**
1.1 Design	**1 wk**
1.1.1 Calculations	1 wk
1.1.2 Submission	0 days
1.2 Detailing	**1 wk**
1.2.1 Drafting	1 wk
1.2.2 Submission	0 days
1.3 Registeration	**3.5 wks**
1.3.1 Verify	1.5 wks
1.3.2 Submission	0 days
1.3.3 Acceptance	2 wks
2 Buying	**4 wks**
2.1 Ordering	**3 wks**
2.1.1 Heads	1 day
2.1.2 Shell	1 day
2.1.3 Nozzles	1 day
2.1.4 Legs	1 day
2.2 Material Delivery	**2.8 wks**
2.2.1 Heads	0 wks
2.2.2 Shell	0 wks
2.2.3 Nozzles	0 wks
2.2.4 Legs	0 days
3 Build & Test	**5.5 wks**
3.1 Roll Shell & weld	1 wk
3.2 Fit end & weld	0.5 wks
3.3 Fit nozzles & weld	1.5 wks
3.4 Fit Closing end & weld	0.5 wks
3.5 Fit legs & weld	1 wk
3.6 Testing	1 wk
4 Paint & Dispatch	**1.7 wks**
4.1 Deliver to painter	1 day
4.2 Paint	1.5 wks
4.3 Deliver to site	0 days



Dates for TPB

Engineering
Calculations – Week 1
Drafting – Week 2
Acceptance – Week 6

Material Delivery
Heads – Week 4
Shell – Week 3
Nozzles -Week 3
Legs – Week 5

Build & Test
(Finish dates)
Shell – Week 4
End – Week 4
Nozzles – Week 6
Closing end – Week 6
Legs – Week 7
Testing – Week 8

Paint & Dispatch
To painter – Week 8
Paint – Week 10
To site – Week 10

Applying EV - Time Phase Budget

Time Phase Budget - Sample Project

Project Weeks

Activities from WBS	0	1	2	3	4	5	6	7	8	9	10	∑ for Row	∑ for Activities
Engineering													$3,000
Calculations		$1,500										$1,5000	
Drafting			$500									$500	
Acceptance							$1,000					$1,000	
Material Delivery													$70,000
Heads					$30,000							$30,000	
Shell				$20,000								$20,000	
Nozzle				$12,000								$12,000	
Legs						$8,000						$8,000	
Build & Test % of Build & Test - Shell, end, nozzle… $23k BAC allowance													$25,500.00
Roll shell & weld (25%)				$5,000	$750							$5,750	
Fit end & weld (15%)					$3,450							$3,450	
Fit nozzles & weld (30%)						$6,000	$900					$6,900	
Fit closing end & weld (20%)							$4,600					$4,600	
Fit leg & weld (10%)								$2,300				$2,300	
Testing									$2,500			$2,500	
Paint & Dispatch													$9,000
Delivery to Painter									$1,000			$1,000	
Paint										$5,000	$1,000	$6,000	
Delivery to Site											$2,000	$2,000	
Fortnightly Planned Value (PV)	$0	$1,500	$500	$37,000	$34,200	$14,000	$6,500	$2,300	$3,500	$5,000	$3,000	TPB BAC	$107,500
Performance Measurement Baseline (PMB)	$0	$1,500	$2,000	$39,000	$73,200	$87,200	$93,700	$96,000	$99,500	$104,500	$107,500	Project BAC	$107,500
Actual Labour Cost	$0	$0	$0	$3,000	$5,750	$7,525	$4,100	$3,200	$1,100	$0	$0	$24,675	Total Labour
Actual Material Cost	$0	$0	$1,200	$18,500	$36,000	$9,500	$0	$1,200	$3,600	$0	$8,000	$78,000	Total Mat
Earned Value (EV)	$0	$0	$1,500	$23,500	$47,750	$14,450	$3,900	$4,000	$3,400	$1,000	$8,000	$107,500	Total EV
Reporting date for the period	0	1	2	3	4	5	6	7	8	9	10	$102,675	Total Cost

PV's from the BAC are assigned a time interval according to the schedule, e.g.;
- Engineering – Acceptance week 6
- Material Delivery – Heads week 4

PV values are added to EV when they occur

Actual cost and when they occur are added

Applying EV - Curve Data →TPB

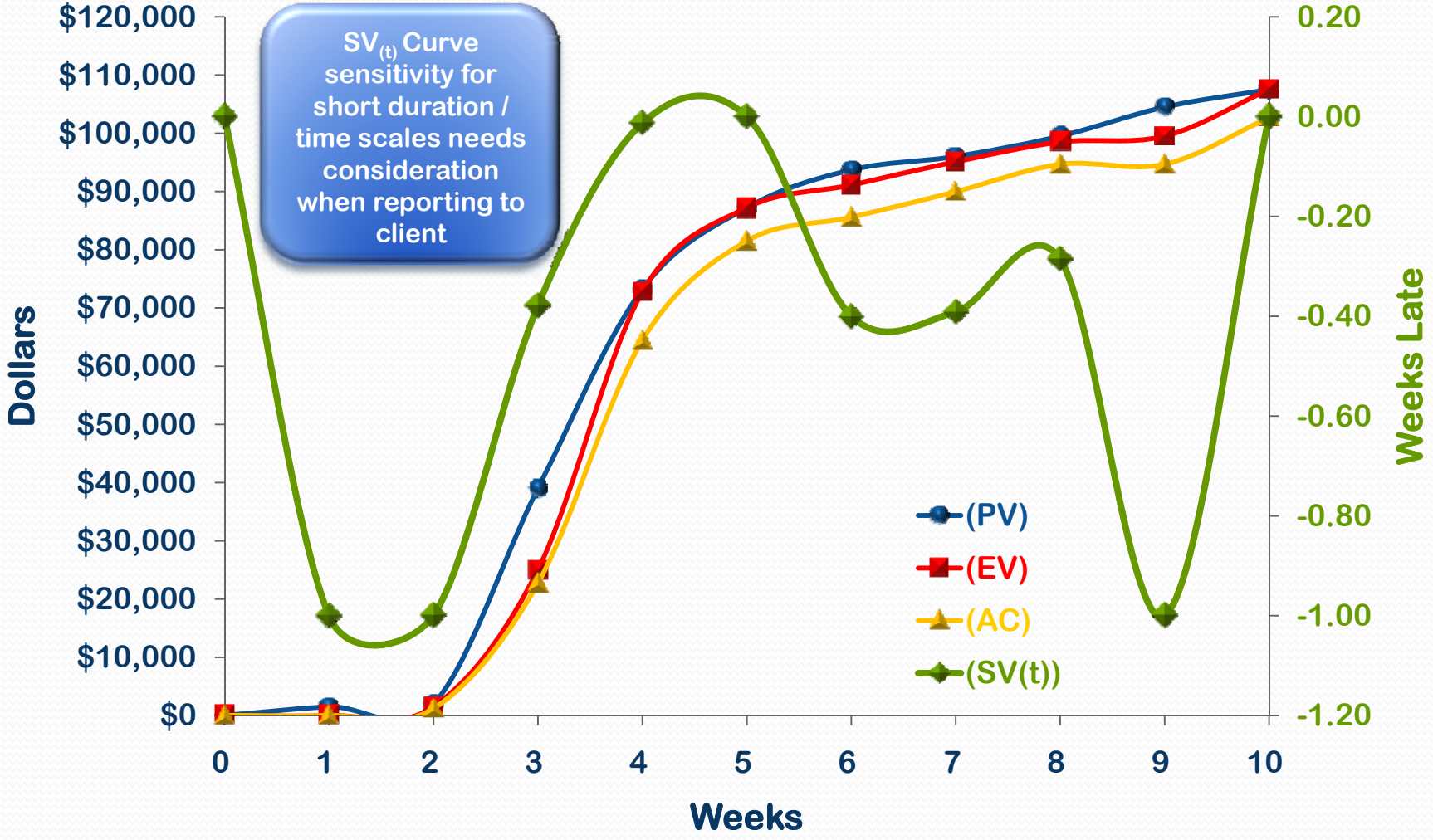
Cumulative Performance

Tracking Tools	Project Weeks										
	0	1	2	3	4	5	6	7	8	9	10
Planned Value (PV)	$0	$1,500	$2,000	$39,000	$73,200	$87,200	$93,700	$96,000	$99,500	$104,500	$107,500
Earned Value (EV)	$0	$0	$1,500	$25,000	$72,750	$87,200	$91,100	$95,100	$98,500	$99,500	$107,500
Actual Value (AC)	$0	$0	$1,200	$22,700	$64,450	$81,475	$85,575	$89,975	$94,675	$94,675	$102,675

Earned Value & Earned Schedule Performance Measurements

Measurement Tools	Project Weeks										
	0	1	2	3	4	5	6	7	8	9	10
Cost Variance (CV = EV - AC)	$0	$0	$300	$2,300	$8,300	$5,725	$5,525	$5,125	$3,825	$4,825	$4,825
Schedule Variance (SV = EV - PV)	$0	-$1,500	-$500	-$14,000	-$450	$0	-$2,600	-$900	-$1,000	-$5,000	$0
Earned Schedule Actual Time (AT)	0	1	2	3	4	5	6	7	8	9	10
Whole Time Increment of PMB (C = AT for EV >= PV)	0	0	1	2	3	5	5	6	7	8	10
Numerator portion of PMB increment earned ($I_N = (EV_{AT} - PV_C)$)	$0	$0	$0	$23,000	$33,750	$0	$3,900	$1,400	$2,500	$0	$0
Denominator portion of PMB increment earned $I_D = (PV_{C+1} - PV_C)$	$1,500	$1,500	$500	$37,000	$34,200	$6,500	$6,500	$2,300	$3,500	$5,000	-$107,500
Earned Schedule ($ES = C + I_N/I_D$)	0.00	0.00	1.00	2.62	3.99	5.00	5.60	6.61	7.71	8.00	10.00
Schedule Variance (time) ($SV_{(t)} = ES - AT$)	0.00	-1.00	-1.00	-0.38	-0.01	0.00	-0.40	-0.39	-0.29	-1.00	0.00
Schedule Performance Index (time), ($SPI_{(t)} = ES/AT$)	1.00	0.00	0.50	0.87	1.00	1.00	0.93	0.94	0.96	0.89	1.00

Applying EV - Curve Output



Applying EV - Lessons

- Baseline scheduling & TPB need accuracy
- Errors in these drivers will be displayed as delays or early finish dates by the indicators
- Balance between effort & the benefits
- For small projects (where scope is tangible) a gut feeling needs to be applied until the systems response is understood
- When is the curve showing a trend – Statistical analysis / filtering curve response over time?

References

- Kim, E., Wells, W.G. & Duffey, M.R. 2003, 'A model for effective implementation of Earned Value Management methodology', *International Journal of Project Management, vol. 21, no. 5, pp. 375-382.*
- Lipke, W., Zwikael, O., Henderson, K. & Anbari, F. 2009, 'Prediction of project outcome: The application of statistical methods to earned value management and earned schedule performance indexes', *International Journal of Project Management, vol. 27, no. 4, pp. 400-407.*
- Lipke, W. & Henderson, K. 2006, Earned Schedule: An Emerging Enhancement to Earned Value Management', *Cross Talk the Journal of US Defence Software Engineering, Issue. Nov*
- Standards Australia 2006, *Project performance measurement using Earned Value AS 4817-2006, Standards Australia, Sydney.*

Supp 1 - Earned Schedule Notes

- **Earned Schedule – Background**
  - Official Earned Schedule (ES) web site is found at; *www.earnedschedule.com*
  - ES concept was conceived during the summer of 2002
  - Publicly introduced it in March 2003 with '*The Measurable News*' article, '*Schedule is Different*'
  - Interest has grown in the method which has seen it expand into areas of:
    - Application of statistical methods to improve forecasting
    - Schedule adherence measures relating to EVM's connection to the network schedule

Supp 2 - Earned Schedule Origin

- **Walt Lipke**
  - Developed the Earned Schedule© method
  - Professional engineer with a Master' degree in Physics & Graduate of the US Department of Defense course for Program Managers
  - Recently retired deputy chief of the Software Division at the Oklahoma City Air Logistics Centre
  - Recently published a book tilted '*Earned Schedule*'
- **Kim Henderson**
  - Actively involved with Walt Lipke in the testing and promotion of ES
  - He is Sydney based IT professional
  - Provided some initial information for the research project noted in slides 4 & 5
  - Master of Science in computing from UTS

Supp 3 - Data for Theory Curves

Working for Earned Value & Earned Schedule Sample - Slides 13 to 16

Curves	EV Curve Data ($k)								
Planned Value (PV)	$0	$150	$500	$1,100	$1,350	$1,450	$1,500		
Earned Value (EV)	$0	$50	$250	$600	$900	$1,200	$1,250	$1,300	$1,500
Actual Cost (AC)	$0	$300	$700	$1,250	$1,550	$1,650	$1,700	$1,750	$1,800
Time Increments	0	1	2	3	4	5	6	7	8
ES Inputs	**Calculation for ES**								
Actual Time (AT)	0	1	2	3	4	5	6	7	8
C = Whole time increment of PMB for condition EV>=PV	0	0	1	2	2	3	3	3	6
$I_N = (EV_{AT} - PV_C)$ Numerator portion of PMB	0	50	100	100	400	100	150	200	0
$I_D = (PV_{C+1} - PV_C)$ Denominator portion of PMB	150	150	350	600	600	250	250	250	-1,500
$ES = C + I_N/I_D$ Earned Schedule	0.00	0.33	1.29	2.17	2.67	3.40	3.60	3.80	6.00
$SV_{(t)} = ES - AT$ Schedule Variance (time)	0.00	-0.67	-0.71	-0.83	-1.33	-1.60	-2.40	-3.20	-2.00
$SPI_{(t)} = ES/AT$ Schedule Performance Index (time)	0	0.33	0.64	0.72	0.67	0.68	0.60	0.54	0.75
Sum $ES + SV_{(t)} = AT$ Check of ES & SV(t) Calculation	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00

Thankyou for your Attention

L&A Pressure Welding Pty Ltd