EVM & Project Controls Applied to Manufacturing

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Contents

1) Background ï Business & research context
2) Research ï Fitting EVM & the findings
3) Influence ï Lessons & value
4) Application ï Challenges & further work

1 ï Background

- Research ï snapshot
- Business ï application / scale
- Projects ï details

Background – Research Snapshot

- **Type of research – Industry origin**
  - Investigate EVM in an SME manufacturing case
- **Why was the research done?**
  - Enhance project management knowledge
  - Add value to a traditional product
- **The objectives of the research?**
  - Establish a project mgt. system - ójproject controlô
  - Improve project communication ï ójtime focusedô
- **Thesis Title (ME Res)**
  - ñEVM Applied to an Engineered-to-Order Multiple Project Environmentò (2009-2012)

Background – Business Application

- **What is being manufactured?**
  - Customised pressure equipment (a product)
- **Application focus**
  - Medium size pressure vessels

Units that make up a larger system

Background – Business / Project Scale

- **Project type / scale**
  - High compliance; design & manufacture
  - Average unit value ~$150K
  - Average duration ~ 26 weeks
- **SME Environment**
  - Employees ï 32
  - Project portfolio ~ 30
  - Manufacturing projects ~ 16

A large project for L&A was generally considered a small project in literature terms

Background – Project Activities

Constraints	Activities	Product
specifications	design & QA	
standards	procurement	
space	manufacture	
resources	Testing / QC	pressure vessel

Background – Manufacturing Tasks

cut shell plate

roll shell

make ends

weld together

painting

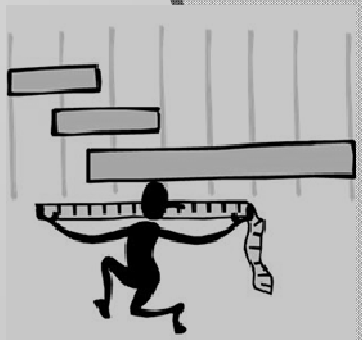
delivery

2 ï Research

- Framework ï getting started
- Configuration ï application details
- Outputs ï EVMôs response

Framework – Starting out

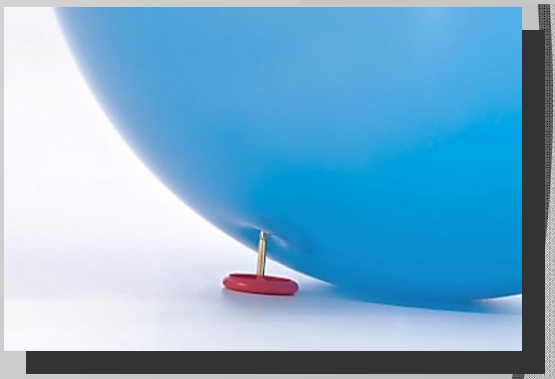
+ EVM =



Estimate Data

Time Records

Cost Records



Application Lesson

Good business systems - key to EVM

Framework – Inputs

Research

EVM theory

project literature

earned schedule

Business

processes

resources

scheduling

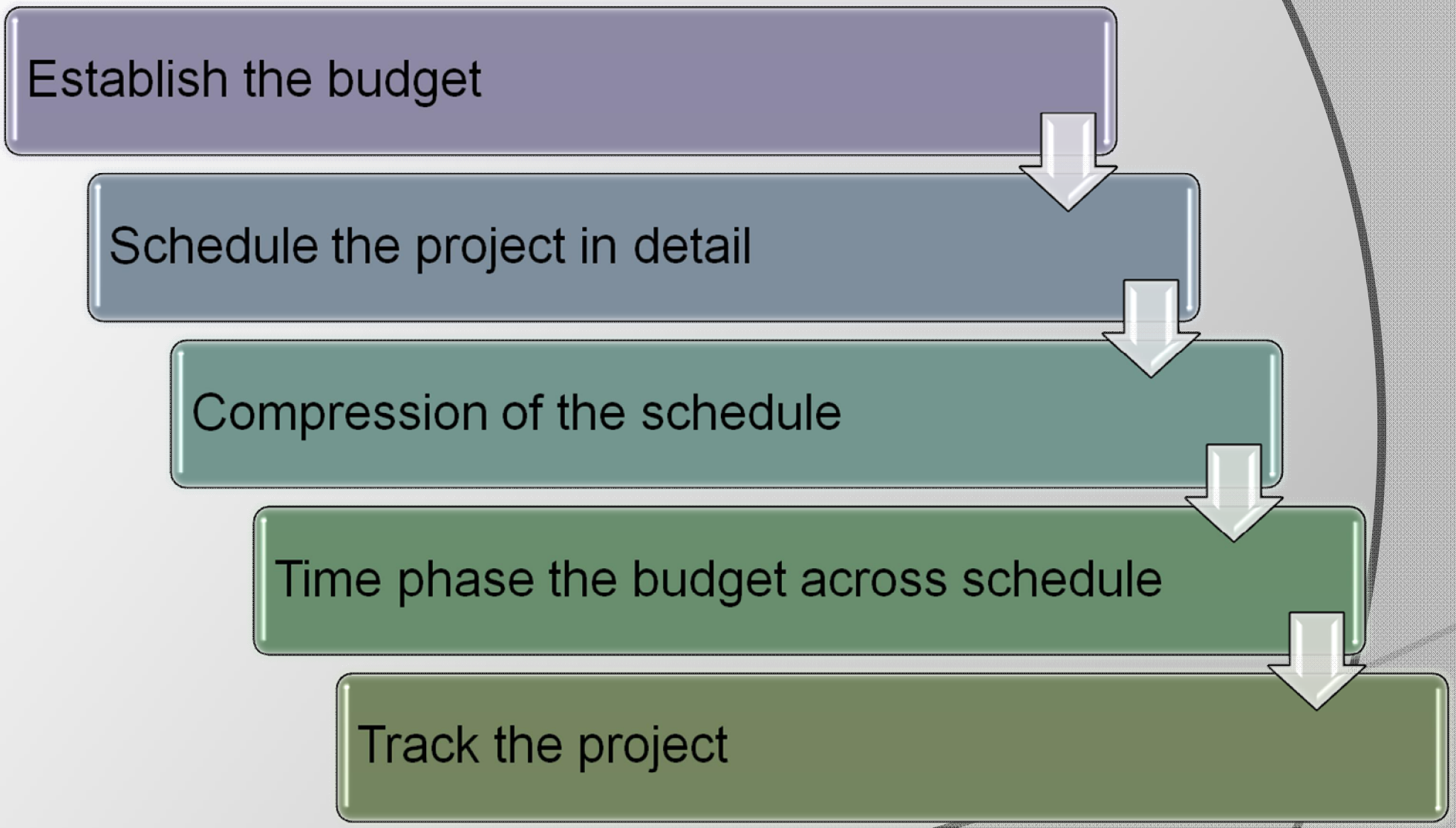
customised spread sheet ϕproject dash boardô

Understand the processes & functions

Framework – Approach taken

- **Adopting a spread sheet method**
  - Tailor EVM inputs for business case
  - Manipulation of EVM calculations
  - Control outputs & their presentation
- **Using EVM outside the scheduling**
  - Preserve the project culture for research
  - Run EVM in background to validate outputs
  - Identify system components that added value

Application – EVM Process



Application – Budget Structure

Elements	Assigned Cost
Materials	$ - net value
Services	$ - net value
Labour	$ - hours x rate
BAC	$ - Sub total
Overhead	$ - indirect costs
Reserve	$ - risk margin
Profit	$ - benefit
Project Budget	$ - Total

Adjust quantity to capture product activities

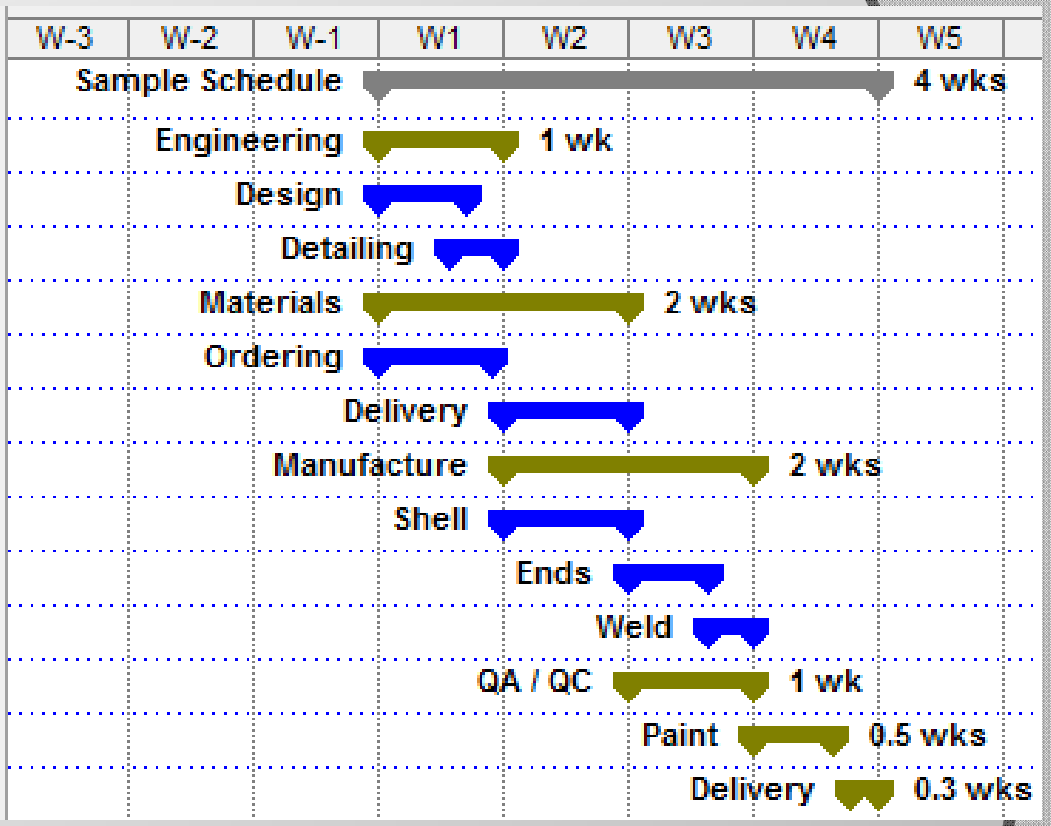
Needs to reflect organisationôs cost structure

Map budget with product & estimating

Application – Scheduling in Detail

Sample Schedule	4 wks
1 Engineering	1 wk
1.1 Design	0.6 wks
1.2 Detailing	0.6 wks
2 Materials	2 wks
2.1 Ordering	0.9 wks
2.2 Delivery	1 wk
3 Manufacture	2 wks
3.1 Shell	1 wk
3.2 Ends	0.5 wks
3.3 Weld	0.5 wks
4 QA / QC	1 wk
5 Paint	0.5 wks
6 Delivery	0.3 wks

WBS

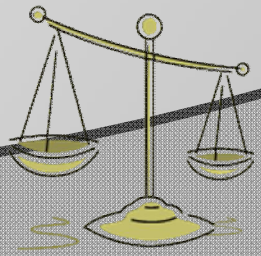


Work **B**reakdown **S**tructure
Plan project around key manufacturing tasks

High level of detail in WBS:
- Improves planning process
- Complicates EVM application

Application – Schedule, Compression

- **Materials & Services**
  - Reflect groups defined by the budget
  - **Material** → plate ($MA), ends ($MB), é
  - **Services** → painting ($SA), transport ($SB), é
- **Labour Break Down**
  - **Engineering deliverables** → drawings ($LA)
  - **Manufacturing milestones** → roll shell ($LB), é
  - **QA / QC milestones** → testing ($LD)



Balance EVM effort vs. benefit

Application – Time Phase the Budget

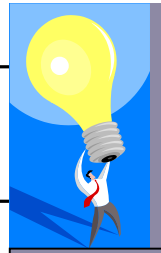
Activities	Week 1	Week 2	Week 3	Week 4
Engineering	labour $LA			
Materials	material $MA	material $MB		
Manufacture		labour $LB	labour $LC	
QA / QC			labour $LD	
Painting				services $SA
Delivery				services $SB

Assign budget values to scheduled time period

Time period to suit the projects duration

Application – Tracking the Project

Activities	Week 1	Week 2	Week 3	Week 4	Week 5
Engineering	labour $LA				
Materials	material $MA	material $MB			
Manufacture		labour $LB	labour $LC		
QA / QC			labour $LD		
Paint				services $SA	
Deliver				services $SB	
Planned Value	$LA + $MA	$MB + $LB	$LC + $LD	$SA + $SB	
Earned Value	$LA	$MA + $MB	$LB + $LC	$LD + $SA	$SB



Apply effort to capture time/progress

See Appendix A for expanded sample

planned values planned time

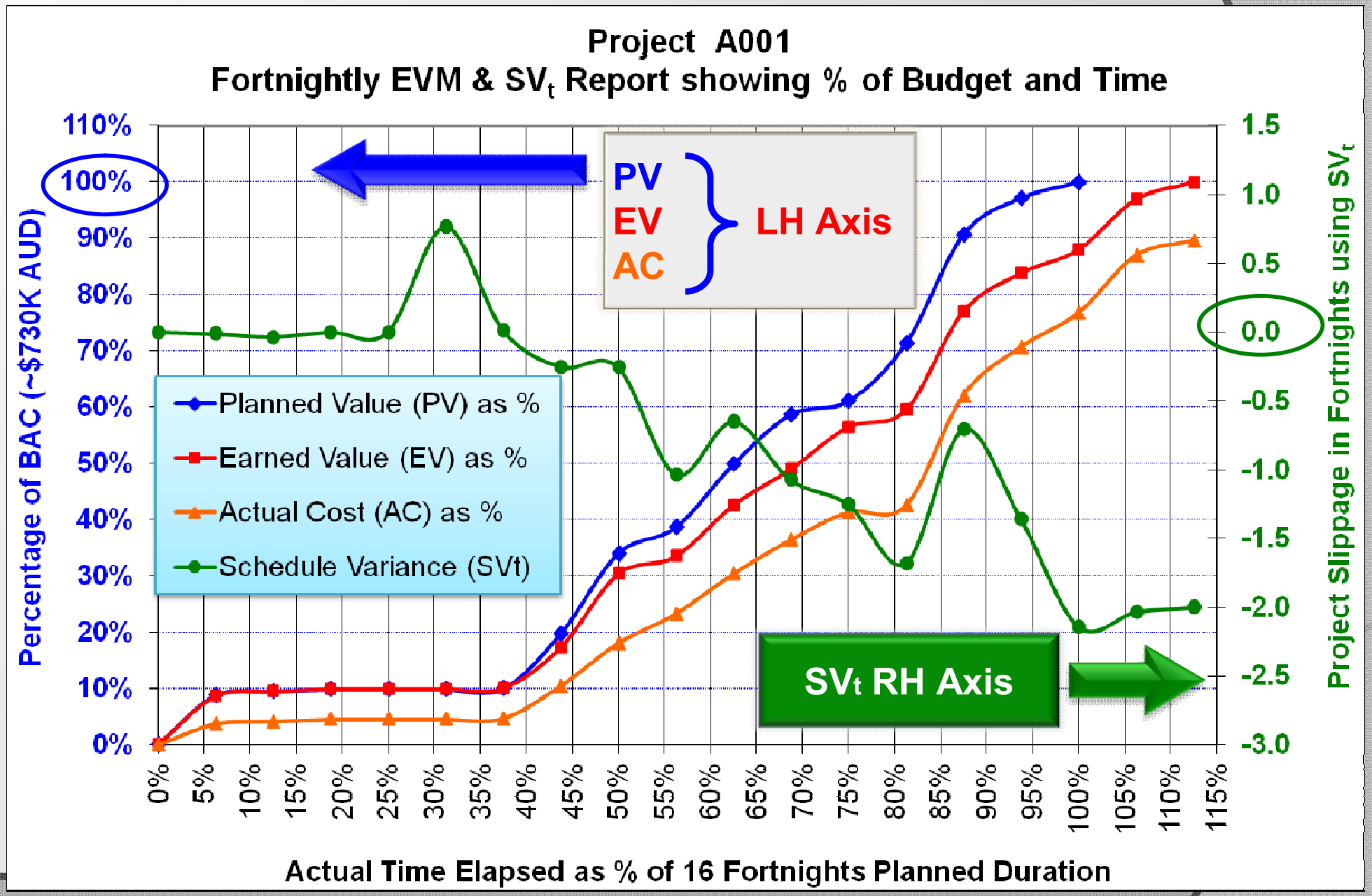
planned values actual time

$SB 1 week late

Outputs – EVM & ES Measures

- **EVM → 'S' Curves**
  - Planned Value ï PV
  - Earned Value ï EV
  - Actual Cost ï AC
- **Earned Schedule (ES) → SV_t Curve**
  - Robust time based measure
  - Can be overlayed on ñSòcurve
  - Used as a visual óprogress statusômeasure

Outputs – EVM & ES Curve

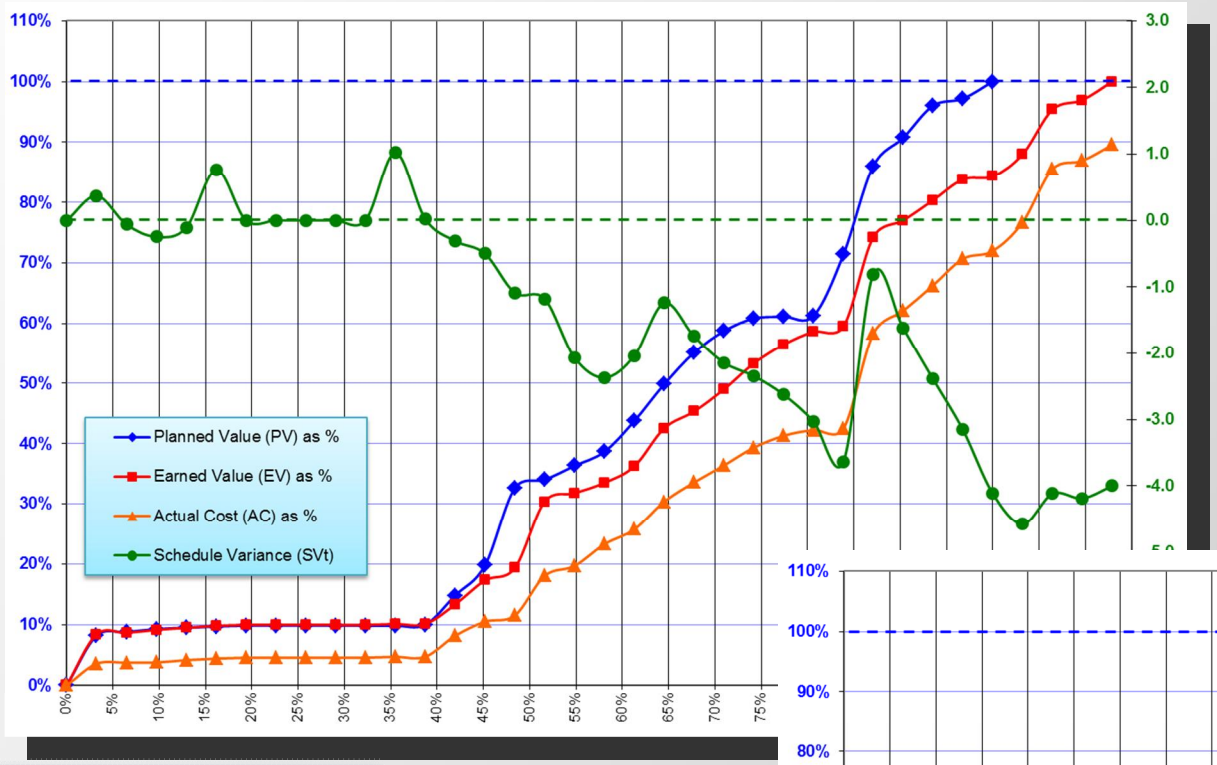


Outputs – Frequency Options

- **Weekly**
  - Noisy but responsive curve
  - Requires high level of effort to maintain
- **Fortnightly**
  - Curve maintains good sensitivity to change
  - Easier to manage updates
- **Monthly**
  - Smooth curve, good visual communicator
  - Time scale did not fit well with short projects

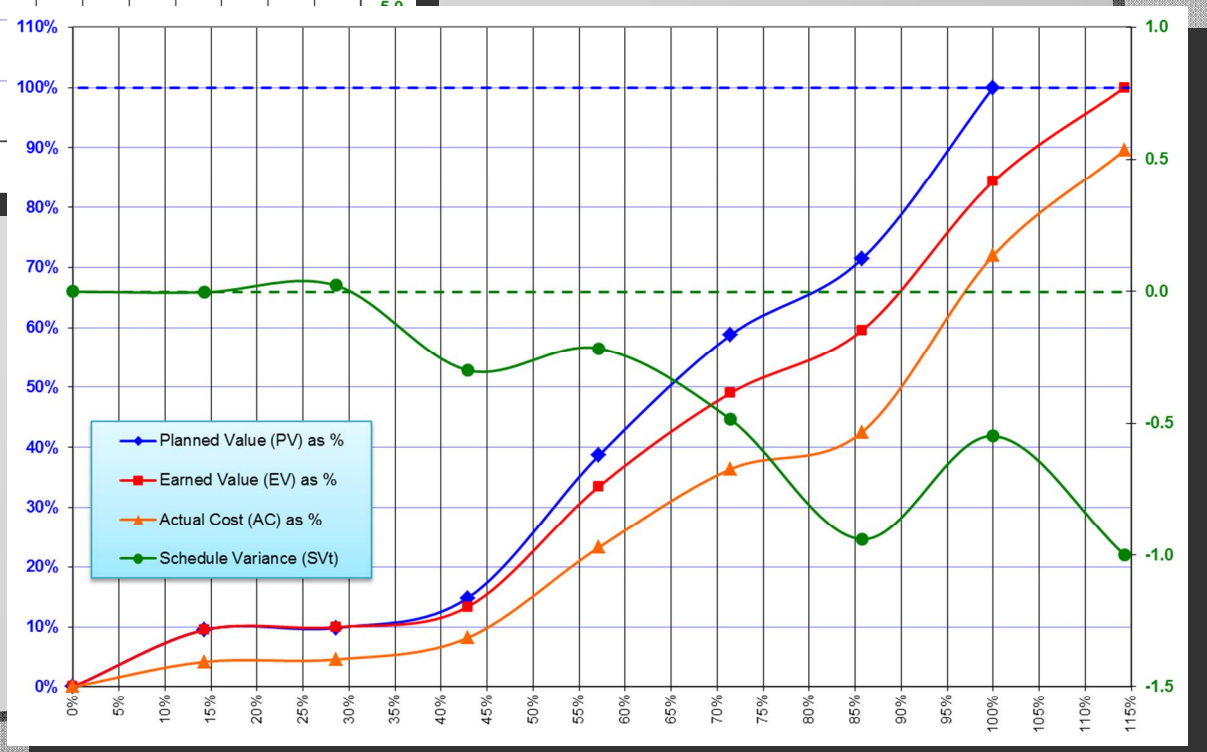
Outputs – EV Frequency Contrast

EVM & ES Curves



Monthly

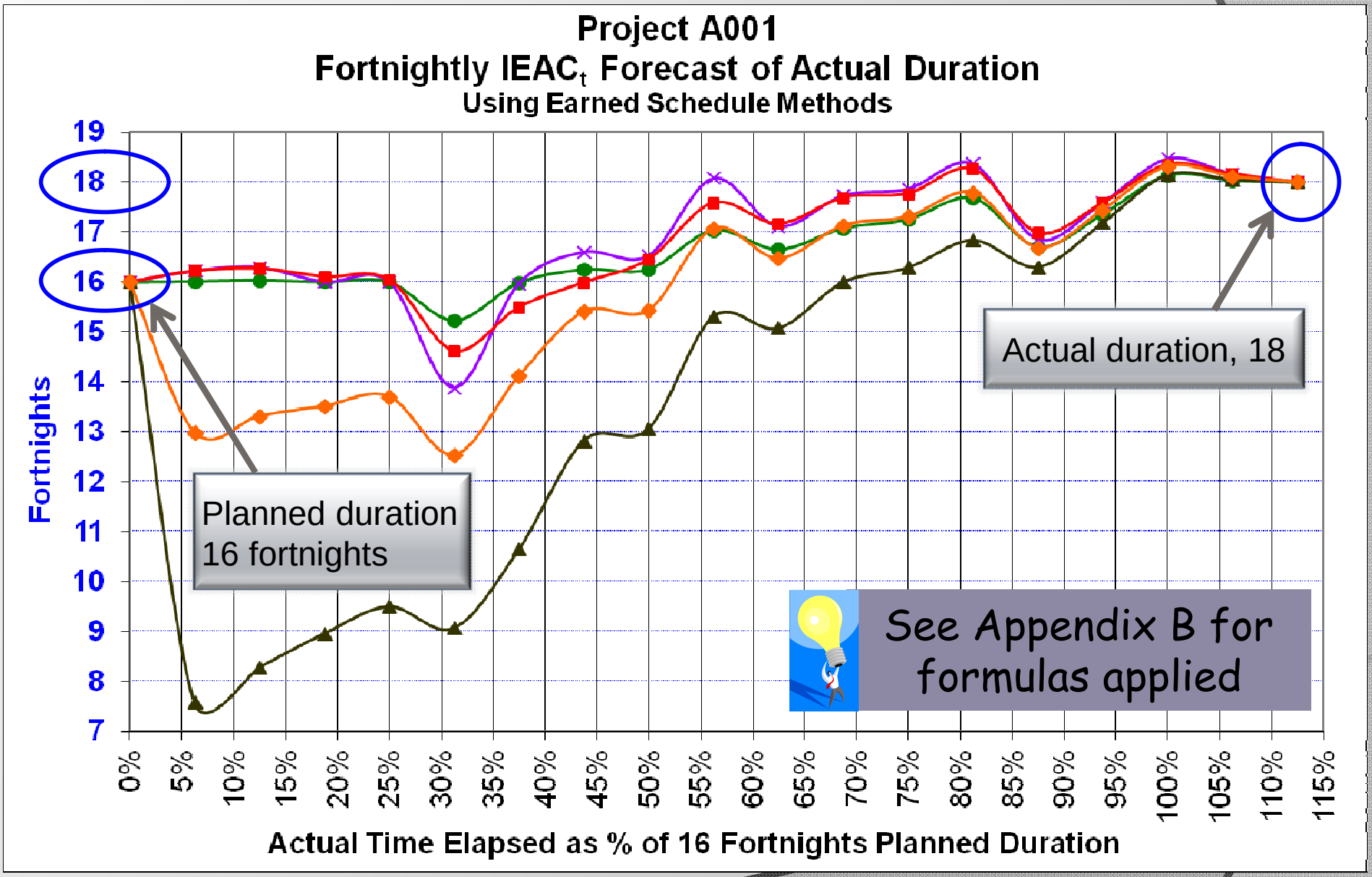
Weekly



Outputs – Forecasting Time

- **Methods**
  - Used earned schedule measures ($IEAC_t$)
  - Formulas - Henderson 2004 | Likpe et al 2009
  - Checked 2011 PMI EVM Standard on release
- **Outcomes**
  - Schedule orientated measures perform better
  - Adding SV_t x -1 to planned duration was effective
  - Weekly frequency very sensitive, monthly better

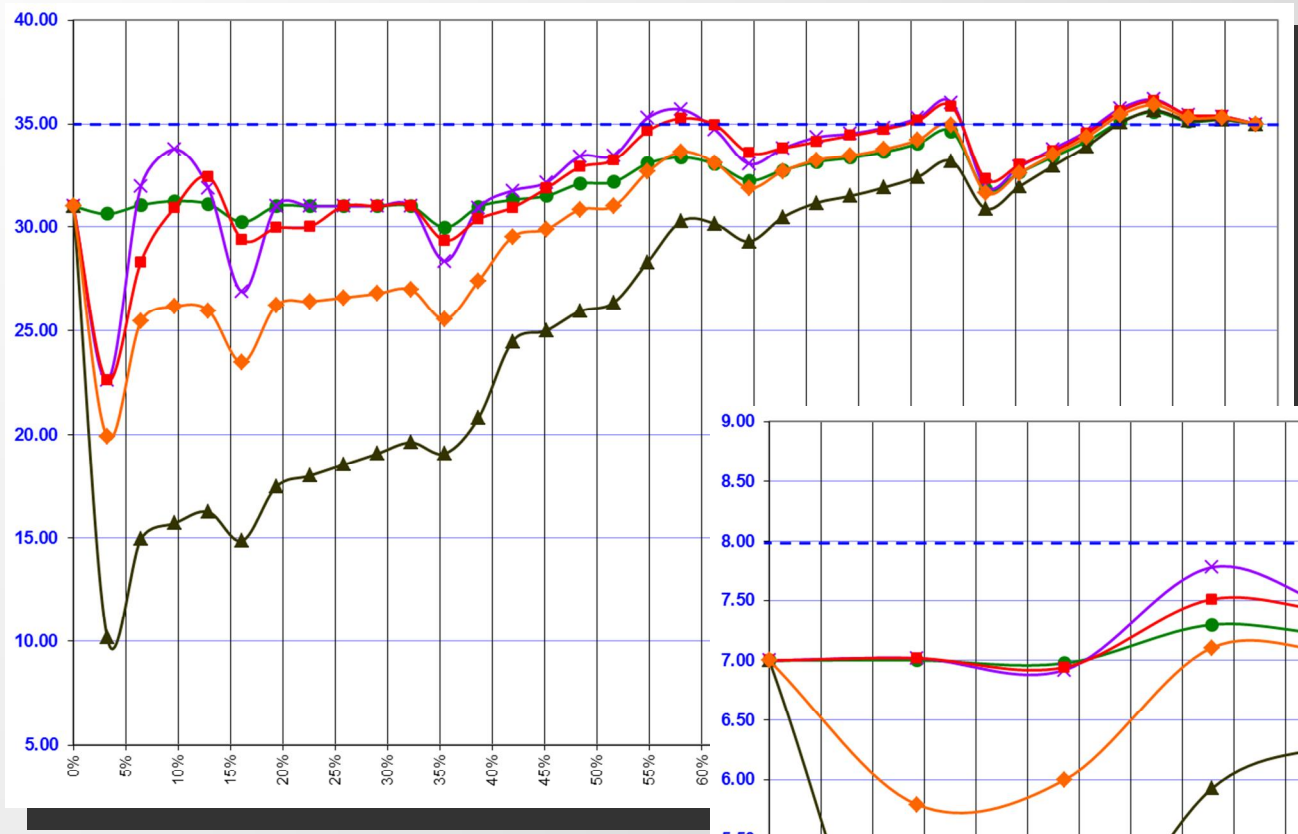
Outputs – Forecasting Time Curves



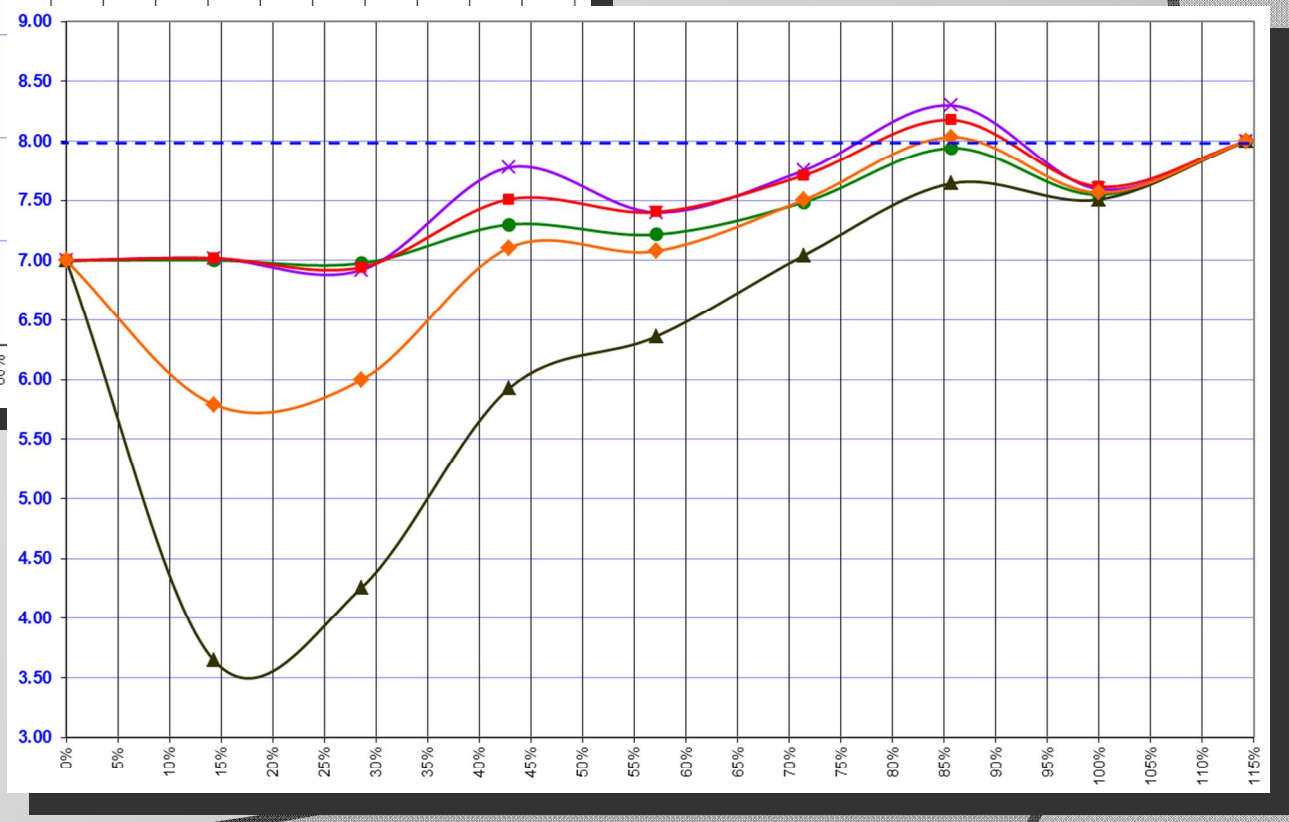
Outputs – IEACt Frequency Contrast

IEACt Curves

Monthly



Weekly



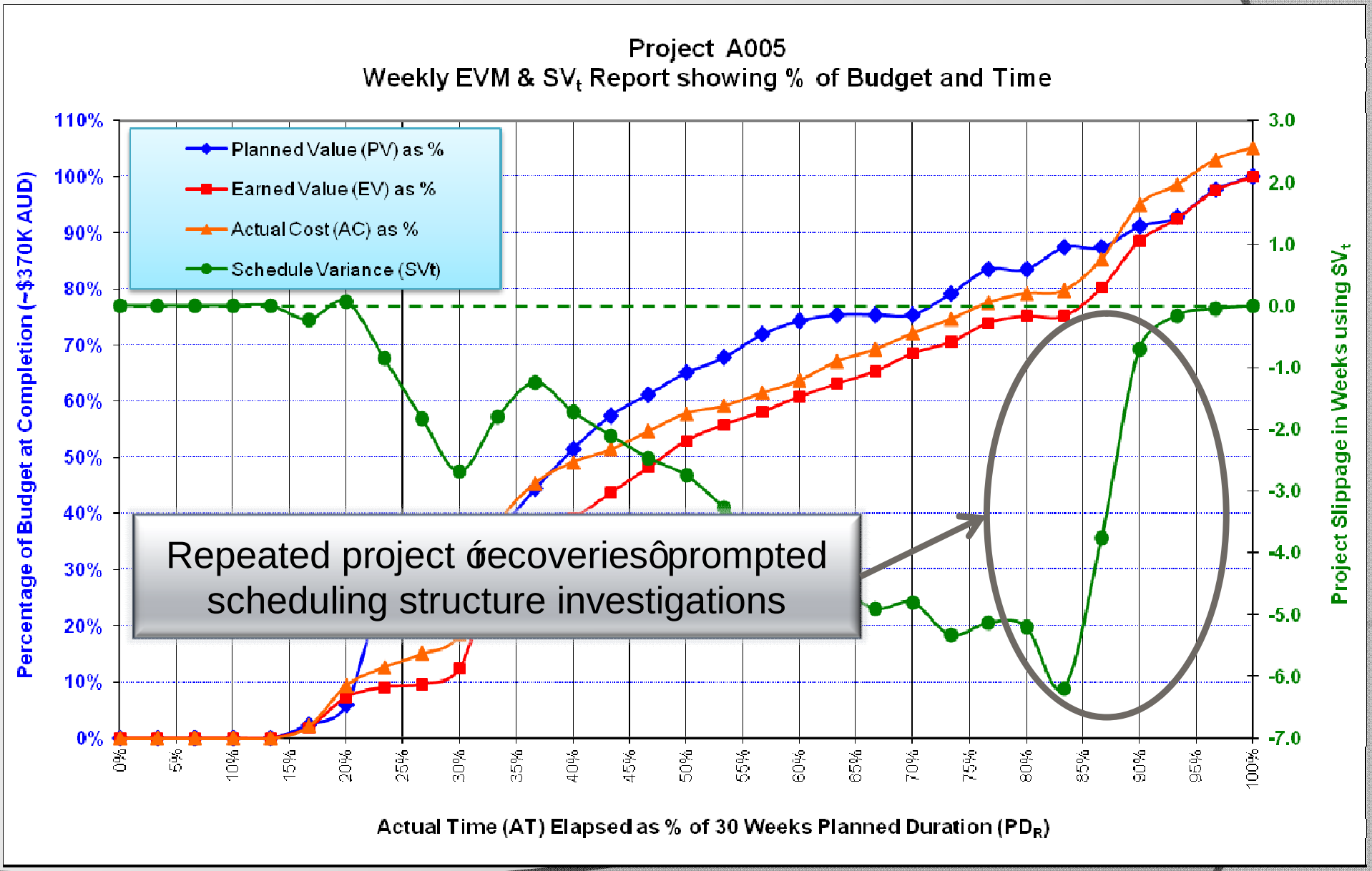
3 ï Influences & Lessons

- Observations ï applying EVM
- Scheduling ï product geometry
- Data streams ï portfolio, capacity & profile

Observations – Applying EVM

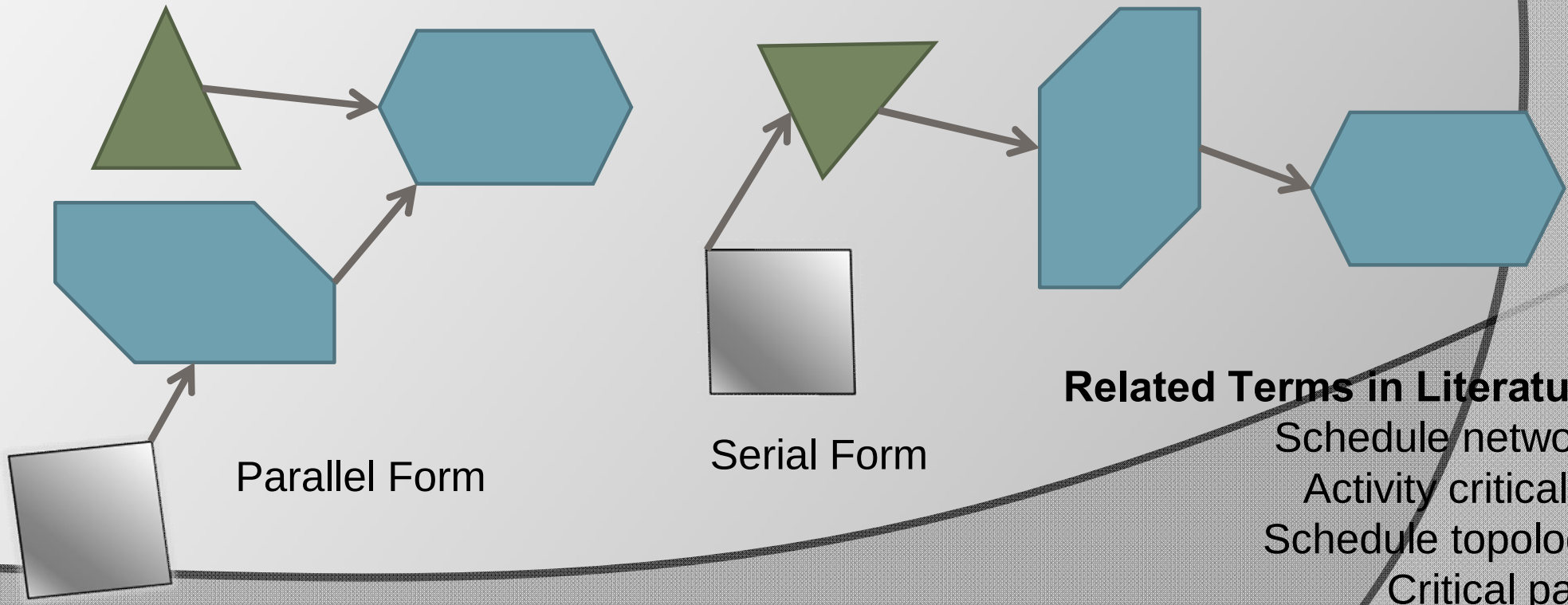
- **Budget**
  - Detail is linked to processes & product content
  - Good alignment helped fit EVM to the project
- **Time Phase Budget (TPB)**
  - Keep it simple → enough detail to get a result
  - Material & services → align the with budget
  - Labour activities → visual milestones
- **Tracking**
  - Capturing progress at time → critical to output
  - Simple labour EV measure → start, middle, end

Observation – Output Issues



Scheduling – The Geometry Impact

- **Schedule structure**
  - Accuracy is essential for EVM to perform well
  - Need to understand product & build sequence
  - Product geometry ï impacted on application



Related Terms in Literature

Schedule network
Activity criticality
Schedule topology
Critical path

Scheduling – Conversion to EV Curves

- **Curve Data**
  - Sensitivity of curve → allocation & phasing values
  - Assigning & phasing materials → apply caution
  - Frequency → internal / external objectives
- **Curve Response**
  - Performs well during manufacturing cycle
  - Earned schedule method → improved EVM use
  - Projectôs front end → Needed critical path

Data Streams – Extending Time Data

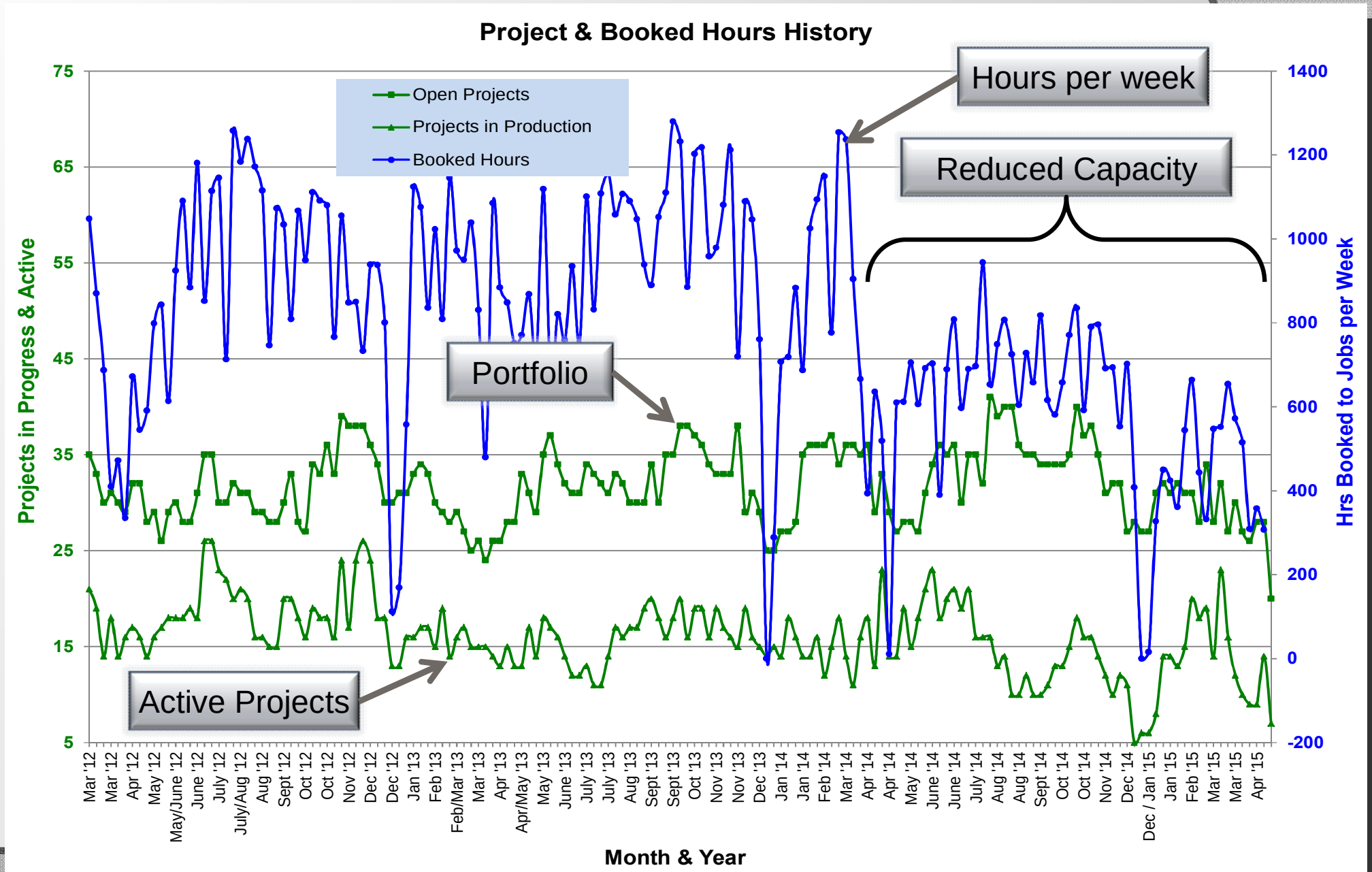
- **Extending EVM Data Feeds**
  - Using hours ón a periodôas an ówperationsôtool
  - Sum the labour effort across the portfolio
  - Project burn rate indicator *(taken from agile mgt.)*

Project	Effort / Week
Project #1	Σ & Δ hours
Project #2	Σ & Δ hours
Project #3	Σ & Δ hours

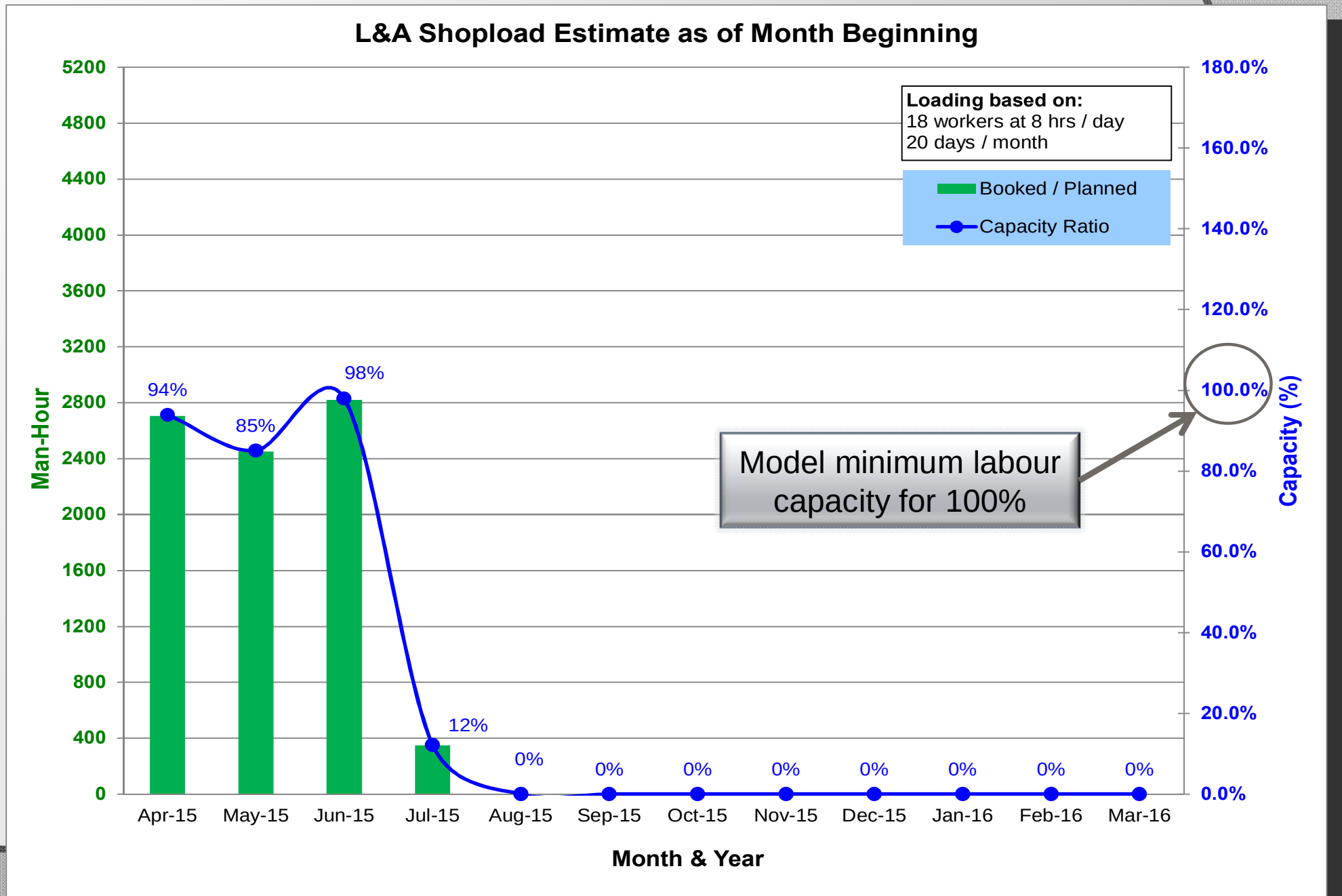
Capture the weekly time effort on every project to deliver portfolio capacity data

- **Dataset outputs**
  - Organisation profile
  - Capacity forecast
  - Product profile

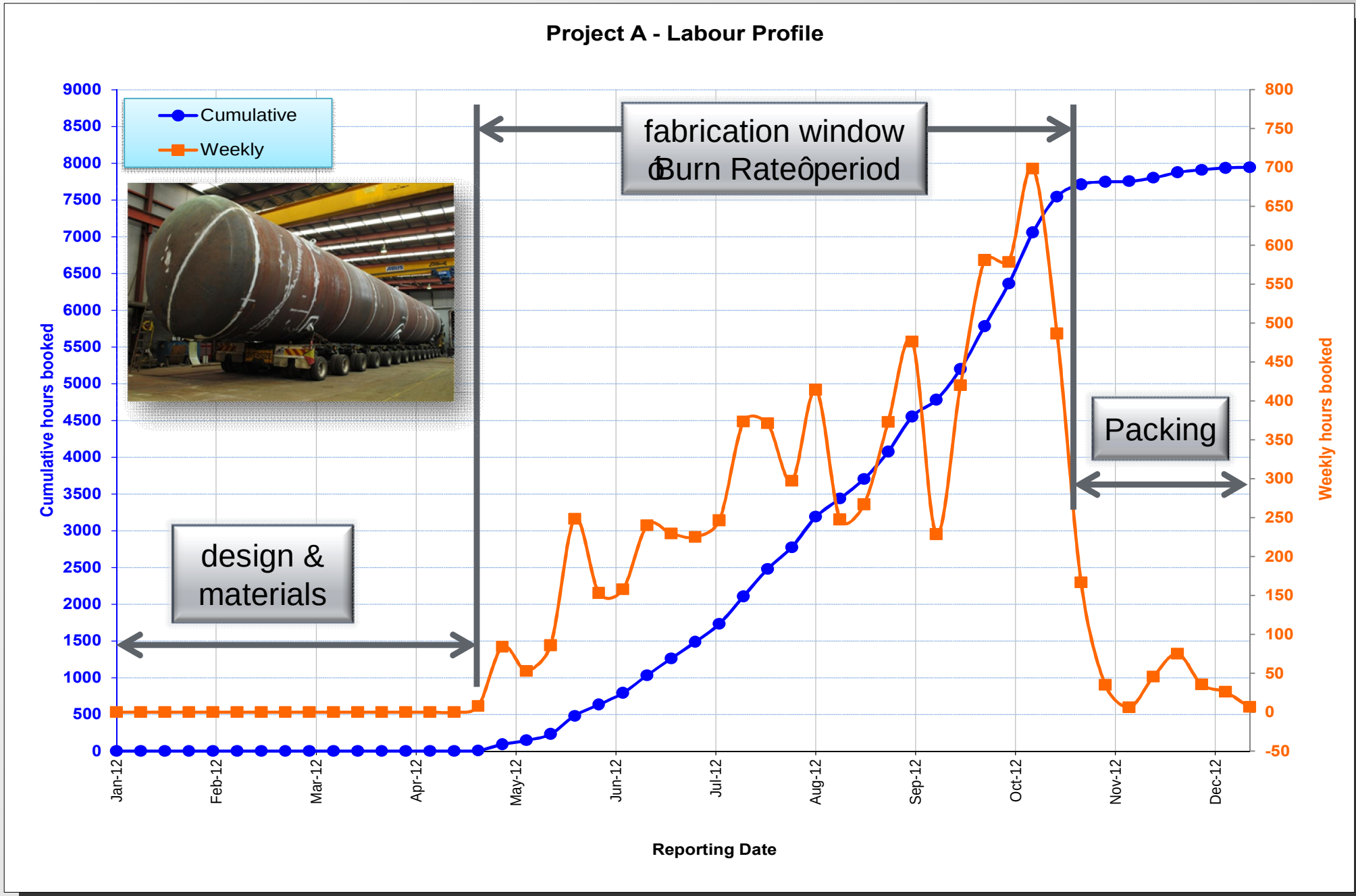
Data Streams – Organisation Profile



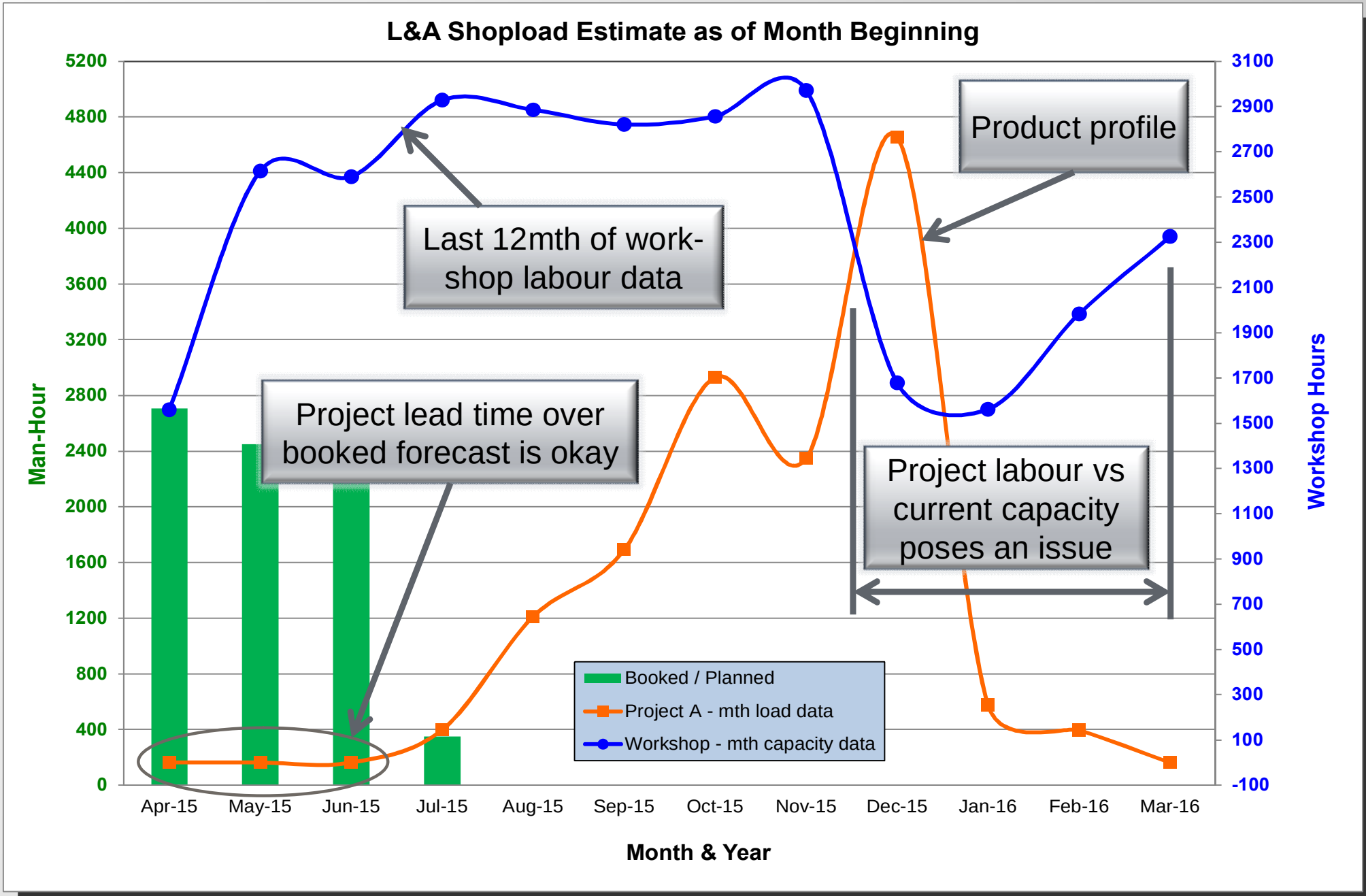
Data Streams – Capacity Forecast



Data Streams – Product / Project Profile



Data Streams – Overlaying Data-Sets

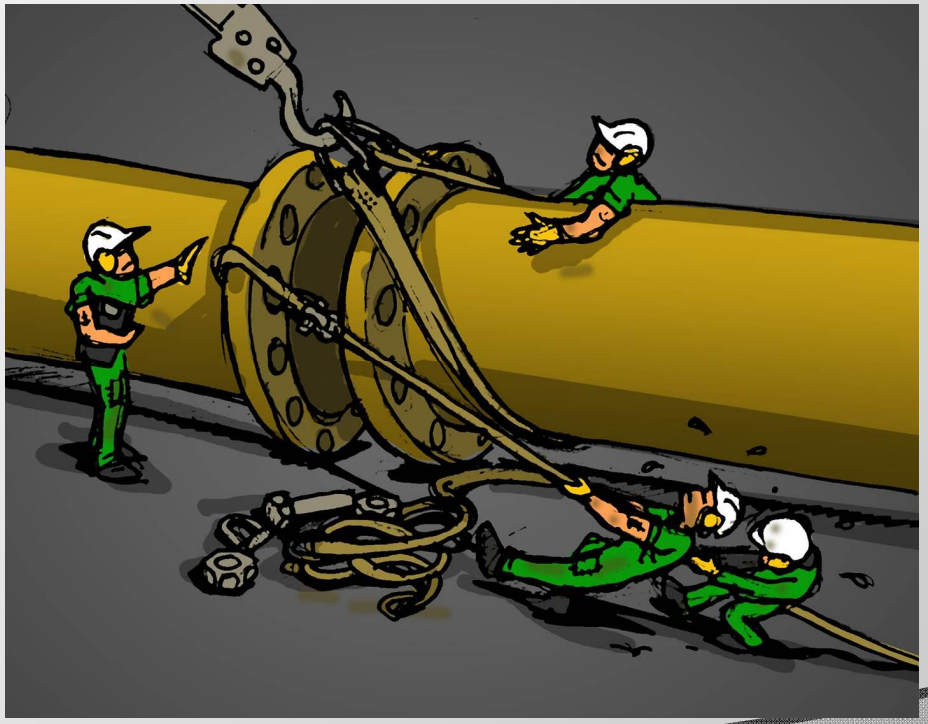


4 ï Application Challenges & Future

- Establishing EVM ï Challenges
- Benefits ï Rigor & dynamics
- EVMôs future at L&A ï Portfolio & risk

Establishing EVM – First Pass

- **Foundation**
  - Data feed systems → project & business cases
  - Implementation platform → integrated or separate
  - Budget & scheduling → rules of measure



Alignment can be really hard to establish

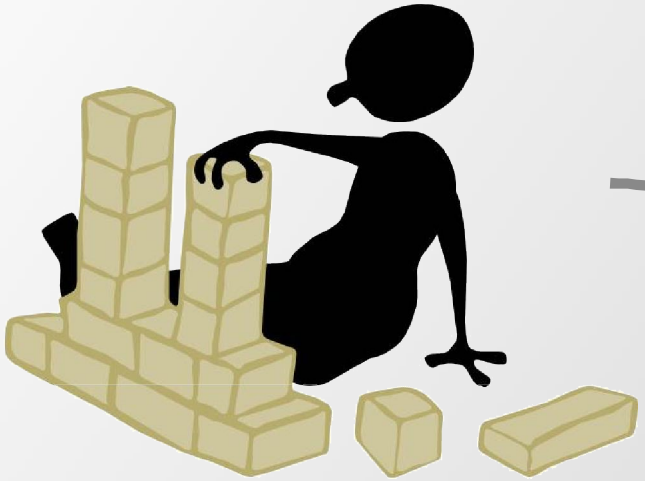
Establishing EVM – Places to disagree

- **Using EVM**
  - System rigidity → dealing with change
  - Ownership → nesting with functions, needs to help
- **Acceptance**
  - Simple in parts → the ensemble is complicated
  - Polarised views → seek benefits then market it

Application can seem locked-up

"the idealistic 'island of order' may suddenly turn into an… 'iron cage'
(Malgrati & Damiani cited in Williams 2003, p.21)

Establishing EVM – Finding acceptance



Sit down with it

Seek out an alignment that works for the organisation

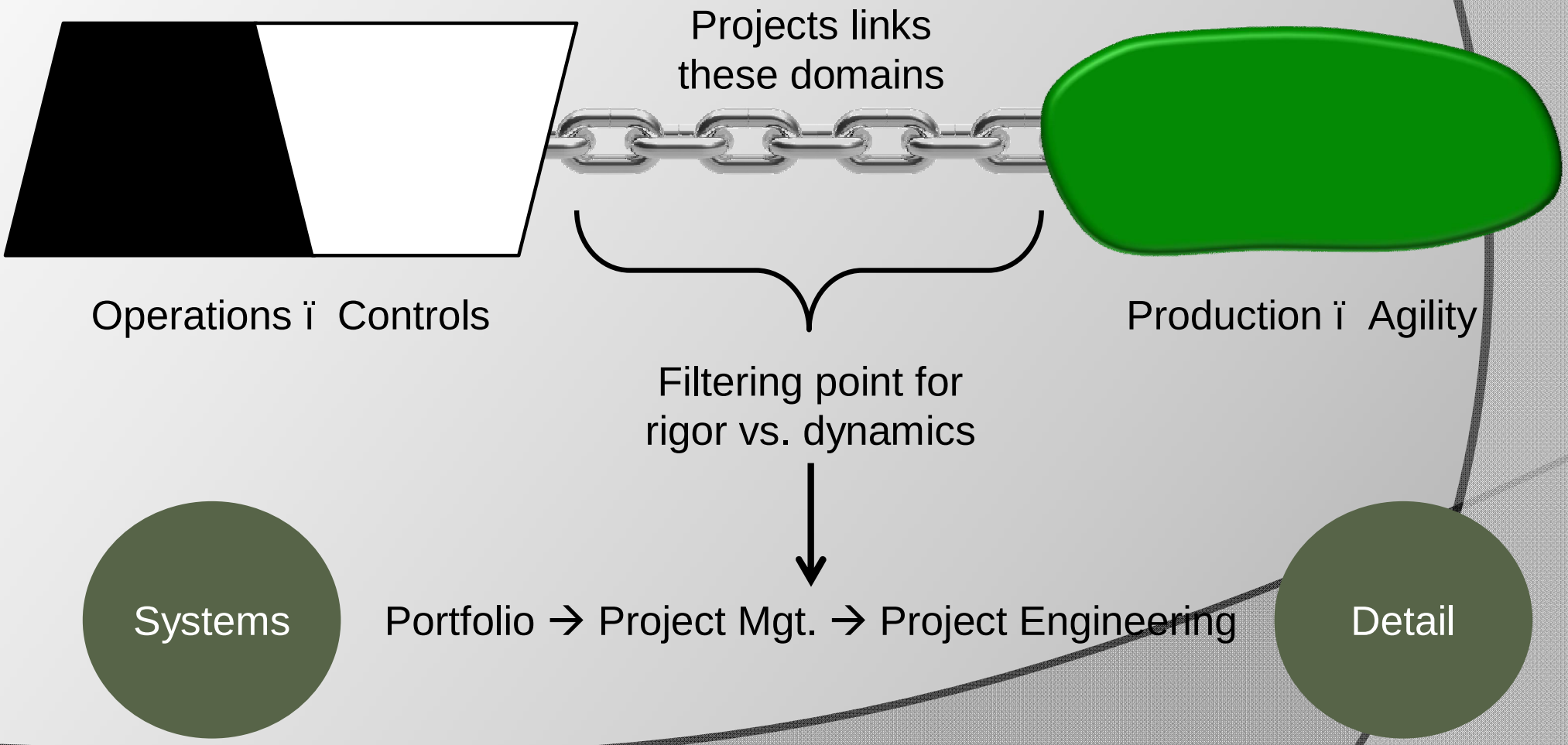
Learn to play - outside the prescription

Benefits – Extracting good from rigor

- **EVM's thirst for data & order**
  - Information → focus on performance
  - Budget → setup audits the estimate
  - Measuring → requires effort early in planning
- **Project Mgt / Operational Systems**
  - Budget & early effort → supports design & buying
  - Incoming data (rigid element) → feeds operations
  - Data history → supports tendering / portfolio mgt

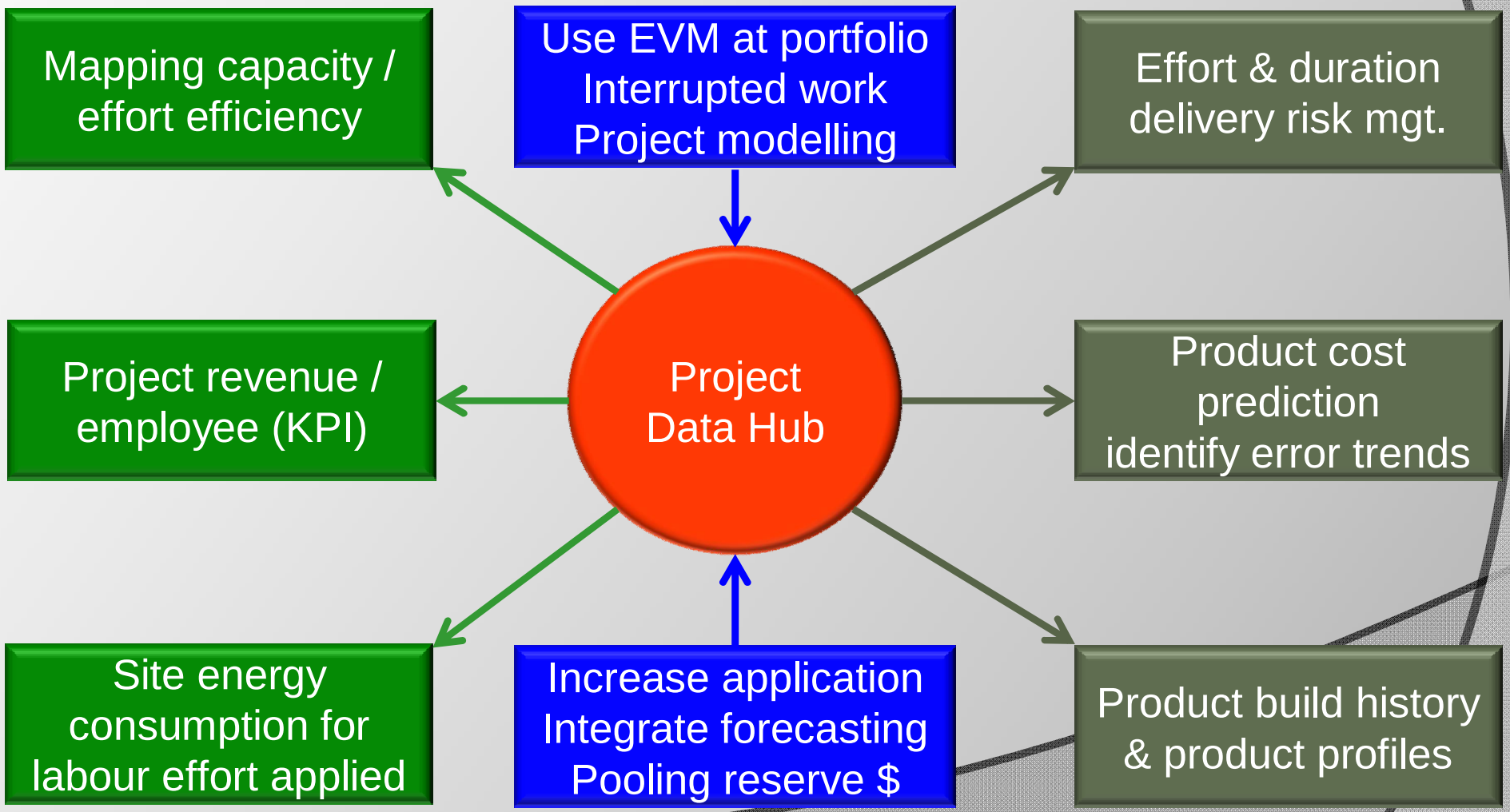
Benefits – Business Dynamics

- **EVM data currently used as support role**



EVM's Future – In L&A's context

- Operations ♭Portfolio mgt. ♭Tenders & Risk



Contact Information

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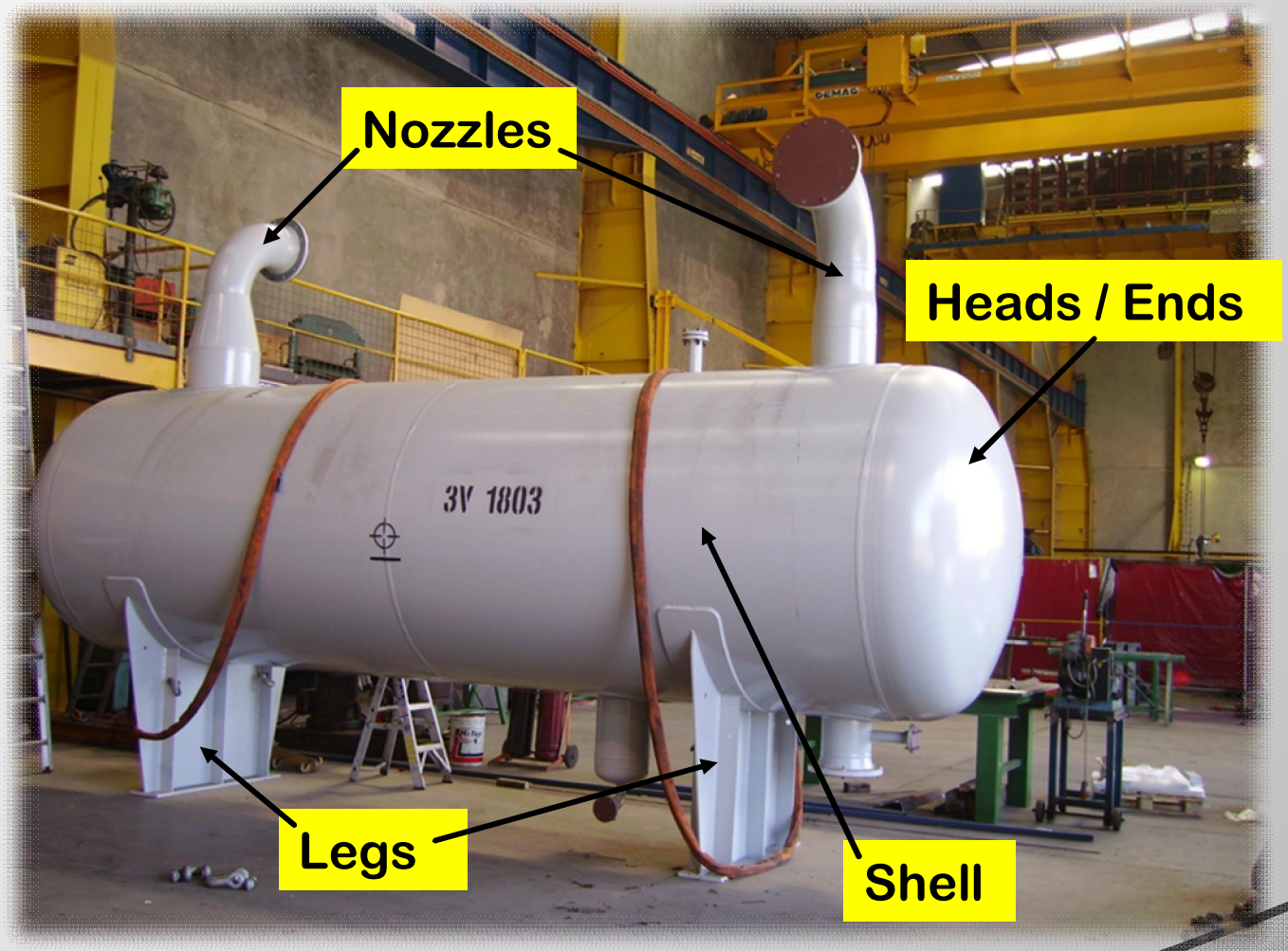
Appendix A - Example EV Application



Appendix A – Sample Budget

Activity	Cost $
Engineering – Calculations, Drafting, Acceptance	*$3,000*
Materials Delivery – Heads	*$30,000*
Materials Delivery – Shell	*$20,000*
Materials Delivery – Nozzles	*$12,000*
Materials Delivery – Legs	*$8,000*
Build & Test – Shell, end, nozzles, closing, 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**
Overheads	*$15,000*
Management Reserve	*$3,800*
Profit	*$1,900*
Project Budget	**$128,200**

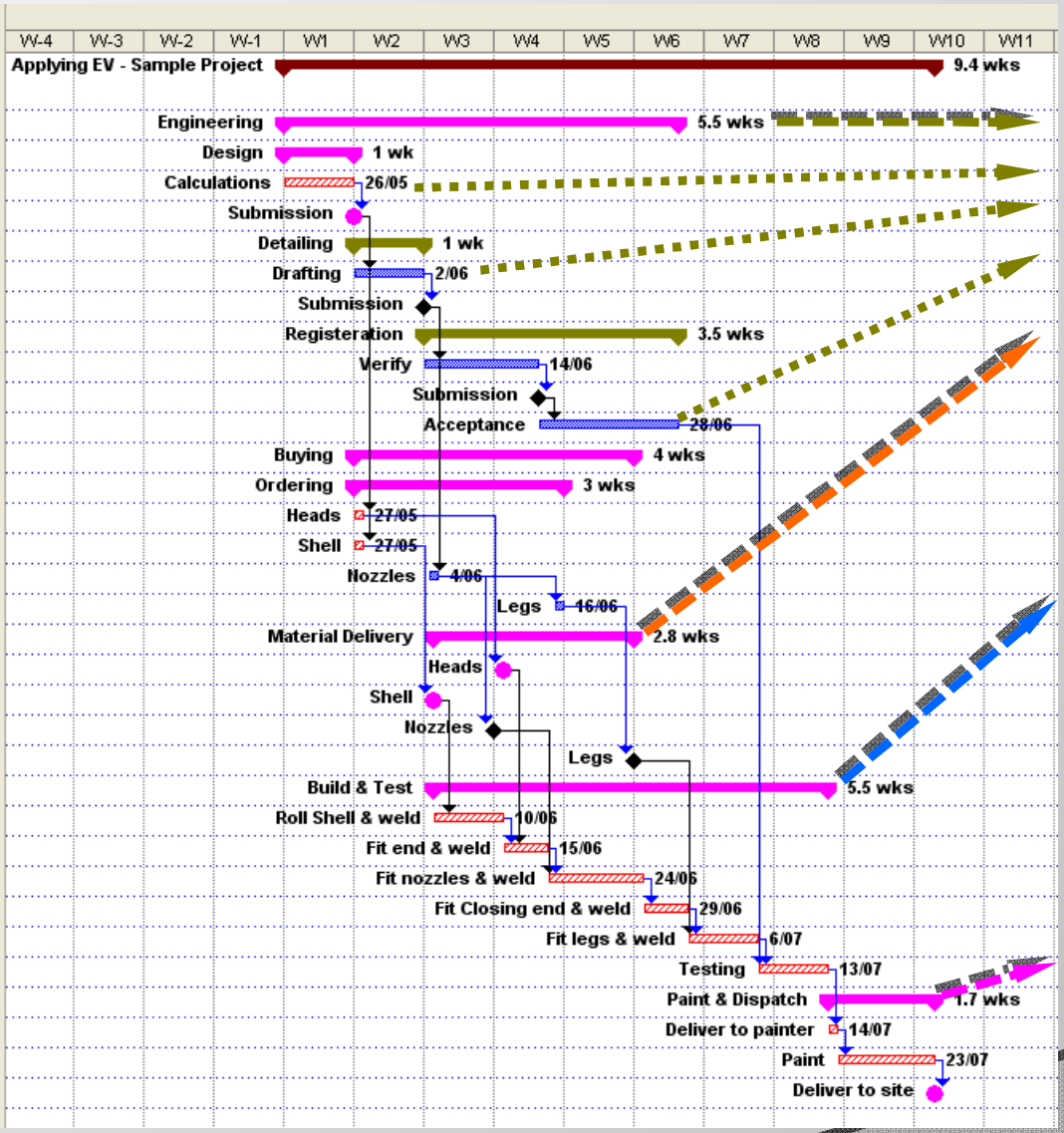
Authorised Project Budget

Reserves & Business Cost

Total budget

Appendix A – Sample 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

Appendix A - 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… $23,000 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 values are added to EV when they occur

Actual values; cost and when they occur are added

PVûs from authorised budget are assigned a time interval according to the schedule:

ÅEngineering ï Acceptance Week 6

ÅMaterial Delivery ï Heads Week 4

Appendix A – Curve Data, Reference

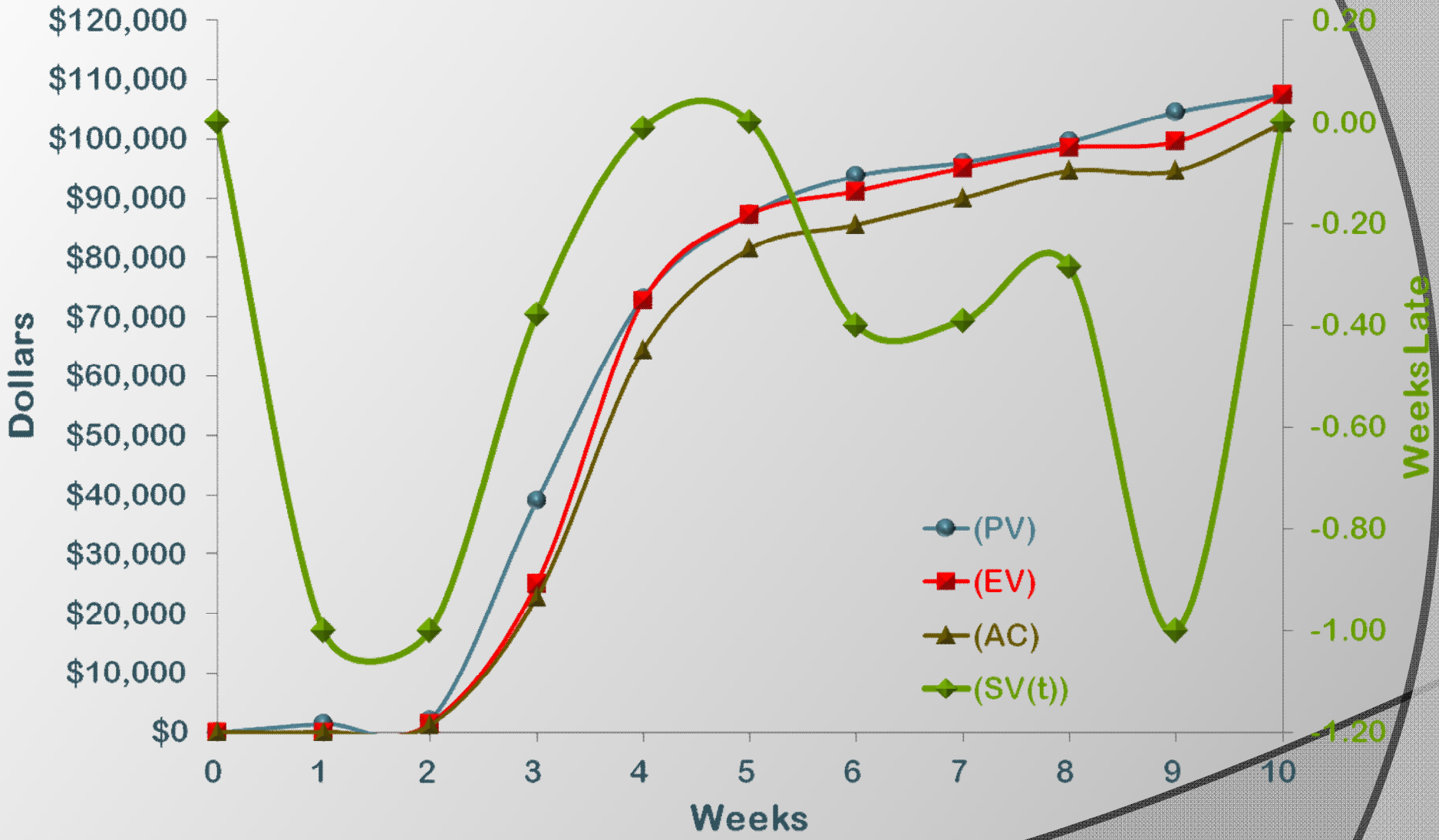
Cumulative Performance

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

Appendix A – **Curve Sample**



Appendix B – IEACt, Curve formula

- Forecast of AD (fortnights) Simple Form
  IEACSVt = PDR + (SVt x -1)

- Forecast of AD (fortnights) Short Form equ
  IEACt = PDR / SPIt

- Forecast of AD (fortnights) Long Form PF = i,j,k (BM)
  IEACt,i,j,k = AT + [(PDR - ES) / ((ESi + ESj + ESk) / (ATi + ATj + ATk))]

- Forecast of AD (fortnights) Long Form PF = product of CPI & SPIt
  IEACt,IP = AT + [(PDR - ES) / (CPI x SPIt)]

- Forecast of AD (fortnights) Long Form PF = sum of CPI & SPIt factored (variable)
  IEACt,IF = AT + [(PDR - ES) / (CPIf*CPI + SPIf*SPIt)]