



Brief Introduction to Earned Value Management (EVM)

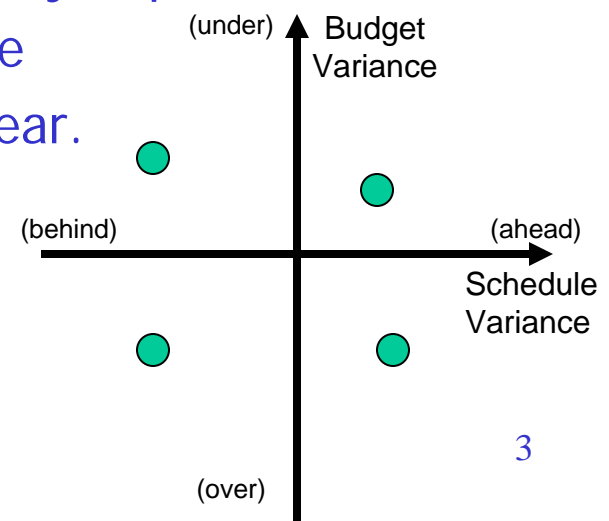
Outline



- Introduction to the basic rationale and elements of EVM
- Issues of actually implementing an EVM tracking scheme
- Background materials

The Problem

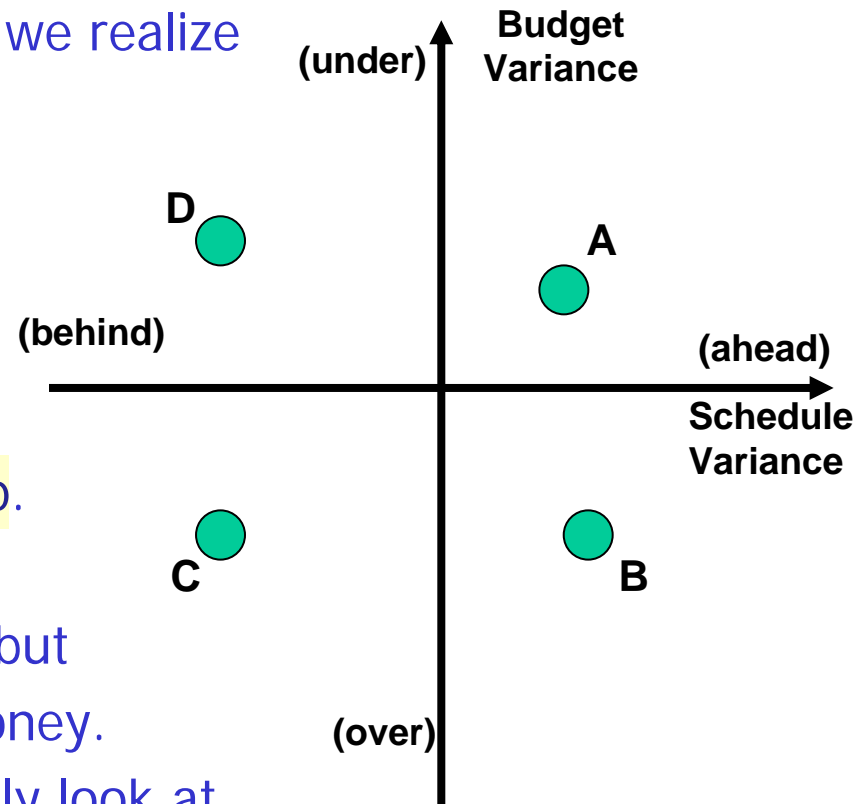
- A successful program manager says: “We completed the project we promised to deliver in the time we promised and with the budget we asked for.”
- The standard source of information about the status of the project is the status of the budget, which only tells you how quickly and how completely you are spending the money you have.
- What you really want to track is how quickly and how completely you are accomplishing the work you promised to do.
- The coupling of money spent to work done or schedule consumed is loose and nonlinear.
- Also, the expenditure track is a one-dimensional projection of a two-dimensional problem.



Why You Need to Know Both Cost and Schedule Variances



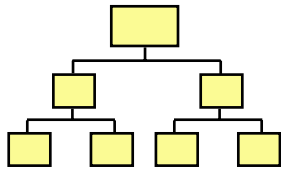
- Project A is in good shape, under budget and ahead of schedule.
- Project B is over budget, but if we realize it is ahead of schedule, we can slow the effort to save money.
- Project D's cost variance looks better than A's, but if we realize it is behind schedule, we can spend more to catch up.
- Project C looks just like B if we only look at the cost variance, but we can't slow down to save money. And it looks just like D if we only look at schedule, but we can't spend more to catch up. It's time to rescope!



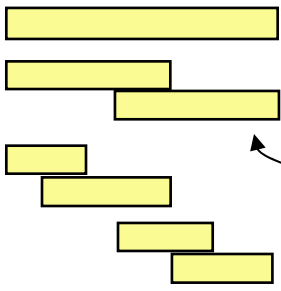
So What Do We Have to Work With?



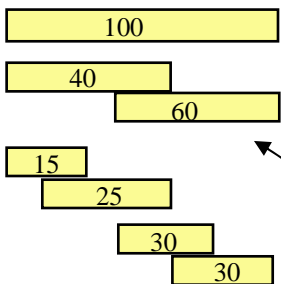
1. DEFINE THE WORK AND ORGANIZE TEAMS



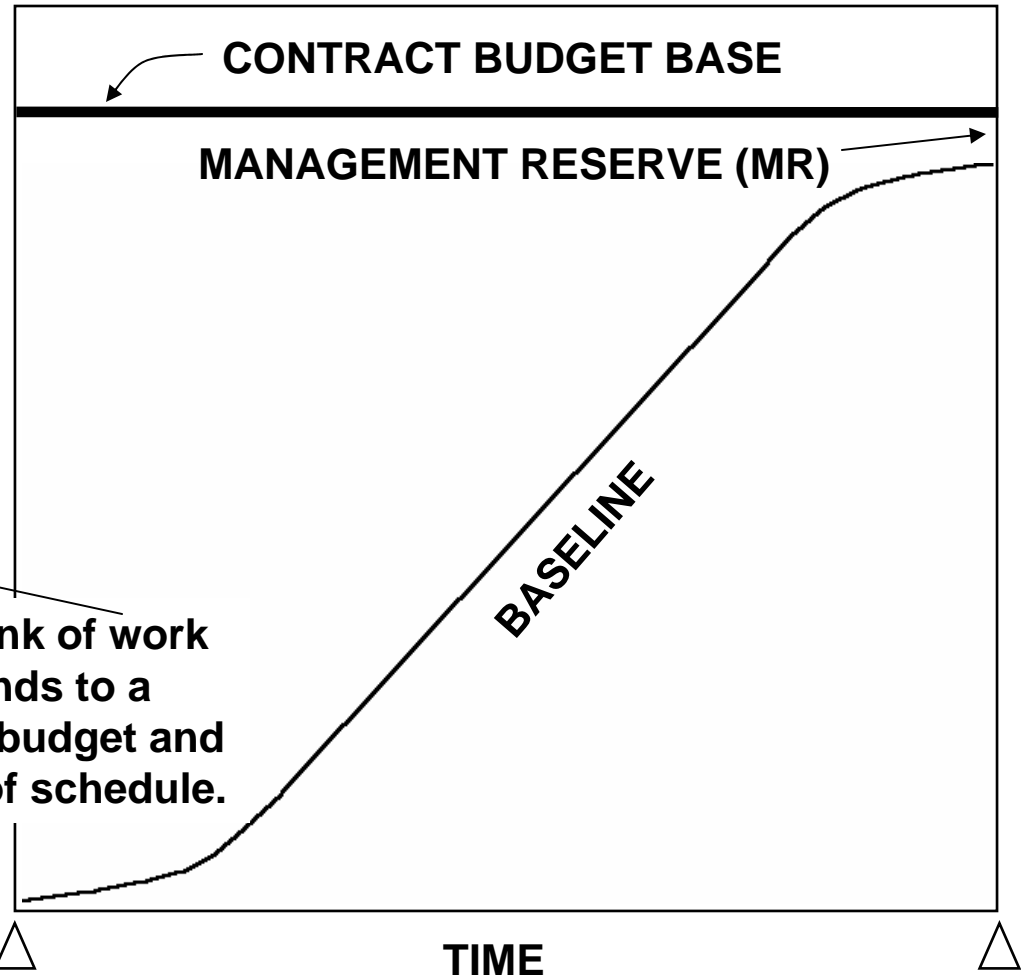
2. SCHEDULE THE WORK



3. ALLOCATE BUDGETS



12/25/06



The Basic Idea

-
- For each chunk of work, define its 'value' as the budget assigned to it.
 - When you complete that chunk of work, you have 'earned' its value.
 - The total earned value to date gives you a point on the (\$,time) graph – the Budgeted Cost of Work Performed (BCWP).
 - You could compare this to the actual amount of work that you were supposed to have completed by this point in the schedule, as measured by its budgeted cost – the Budgeted Cost of Work Scheduled (BCWS), another point on the (\$,time) graph.
 - You could also compare it to the actual amount spent to complete the chunks of work done to date – the Actual Cost of Work Performed (ACWP), a third point on the (\$,time) graph.
 - Look at what information these comparisons give about the status of the project.

Budgeted Cost of Work Scheduled (BCWS)



Month 1
BCWS = \$1,000



Month 2
BCWS = \$1,000



Month 3
BCWS = \$1,000



Month 4
BCWS = \$1,000



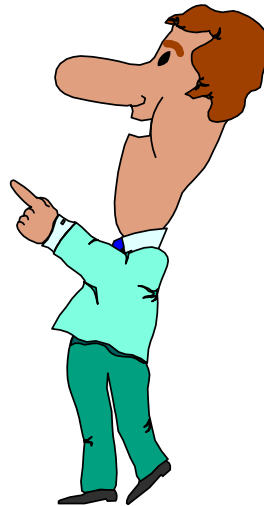
Month 5
BCWS = \$1,000

Total Budget = \$5,000
to be spent over 5 months
We plan to deploy 1 stand
each month at an estimated
cost of \$1,000.
BCWS each month = \$1,000



Each dollar of BCWS represents a specific dollar of work scope. BCWS is aggregated and summed as the performance measurement baseline.

Budgeted Cost of Work Performed (BCWP)



We're at the end of the second month, but only 1 stand is complete.
Value of work performed = \$1,000

You earn value the same way as it was budgeted in the baseline.

Schedule Variance (SV)



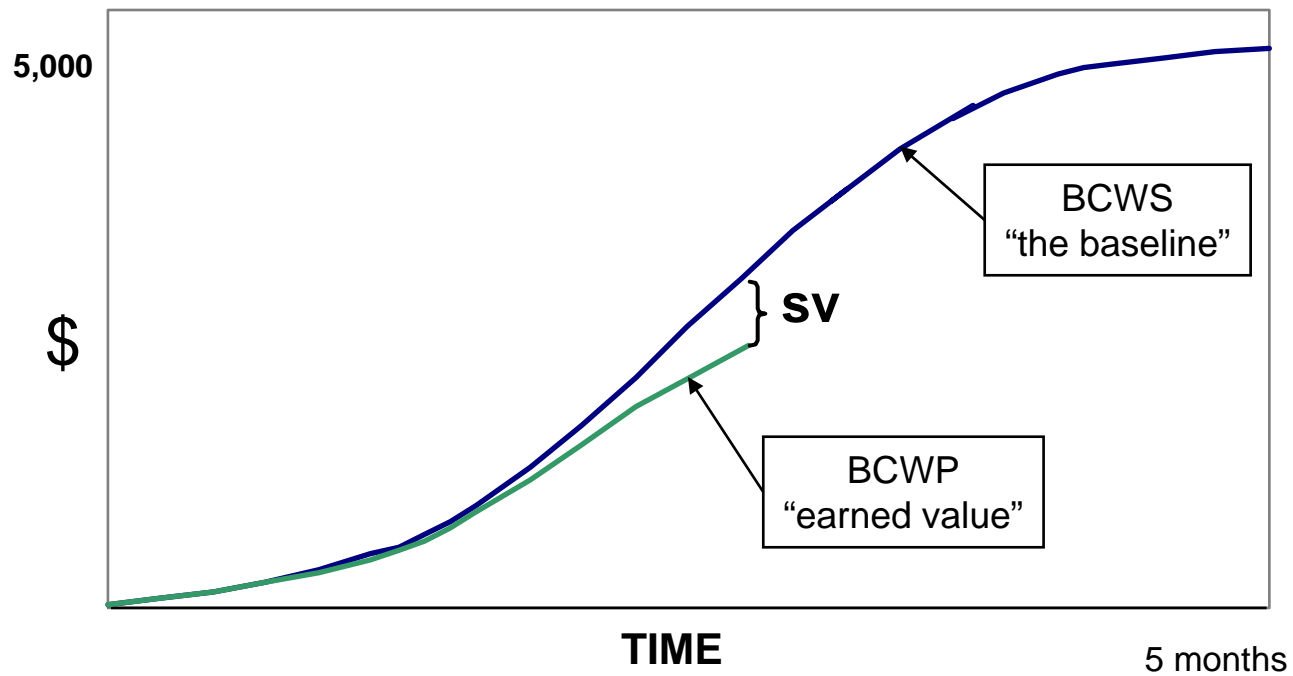
BUDGET BASED	BC	WS	Of the work we <u>scheduled</u> to have done, how much did we budget for it to cost?
	BC	WP	Of the work we actually <u>performed</u> , how much did we budget for it to cost?

SCHEDULE VARIANCE is the difference between work scheduled and work performed (expressed in terms of budget dollars)

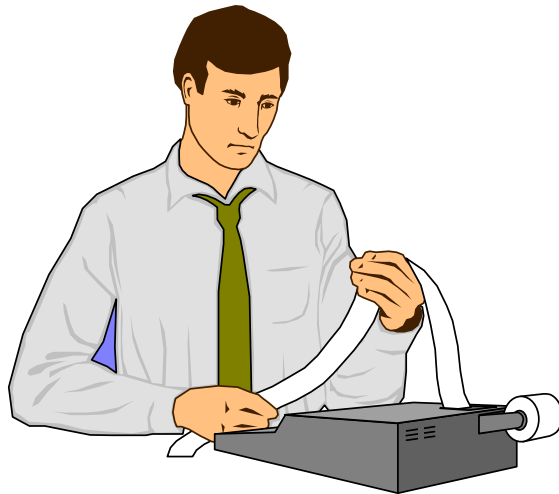
formula: **SV \$ = BCWP - BCWS**

example: SV = BCWP - BCWS = \$1,000 - \$2,000
 SV = -\$1,000 (negative = behind schedule)

Schedule Variance (SV)



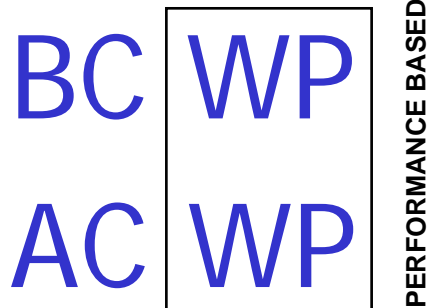
Actual Cost of Work Performed (ACWP)



Labor came to \$1,300, and materials cost \$1,100. That first stand cost \$2,400!

actual expenditures vs. budget

Cost Variance (CV)



Of the work we actually performed, how much did we budget for it to cost?

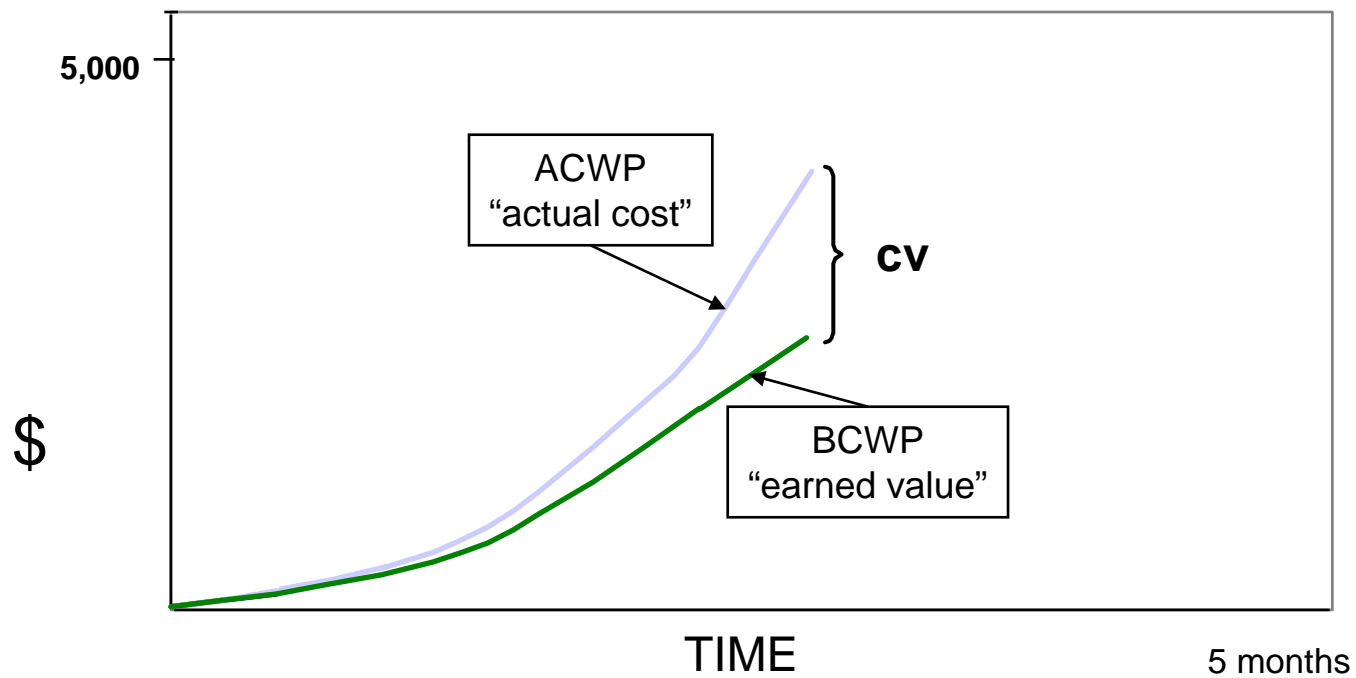
Of the work we actually performed, how much did it actually cost?

COST VARIANCE is the difference between budgeted cost and actual cost

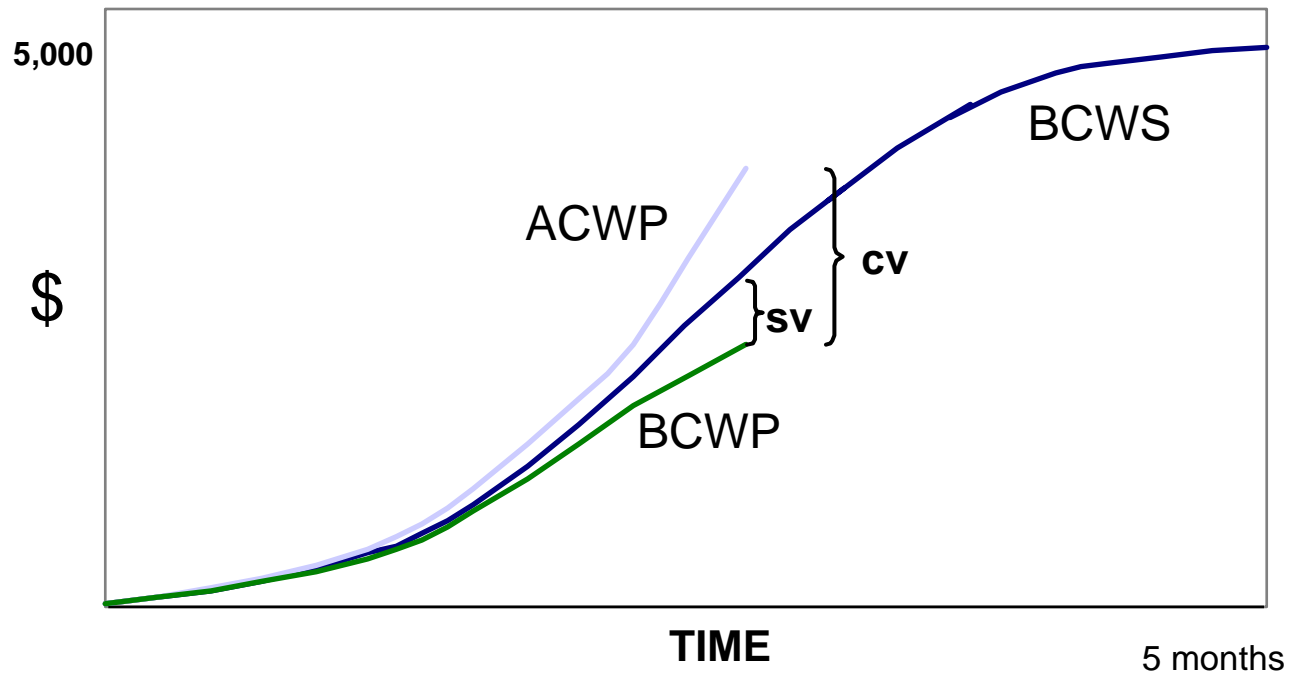
formula: **CV \$ = BCWP - ACWP**

example: CV = BCWP - ACWP = \$1,000 - \$2,400
 CV = -\$1,400 (negative = cost overrun)

Cost Variance (CV)



Note That We Can Isolate Schedule and Cost Variances



schedule variance = BCWP - BCWS = negative number
cost variance = BCWP - ACWP = negative number

**behind schedule,
over cost**

Where are the significant problems?

By tracking and sorting on variances, we can isolate the troublesome WBS elements.

sorted by CV (\$)

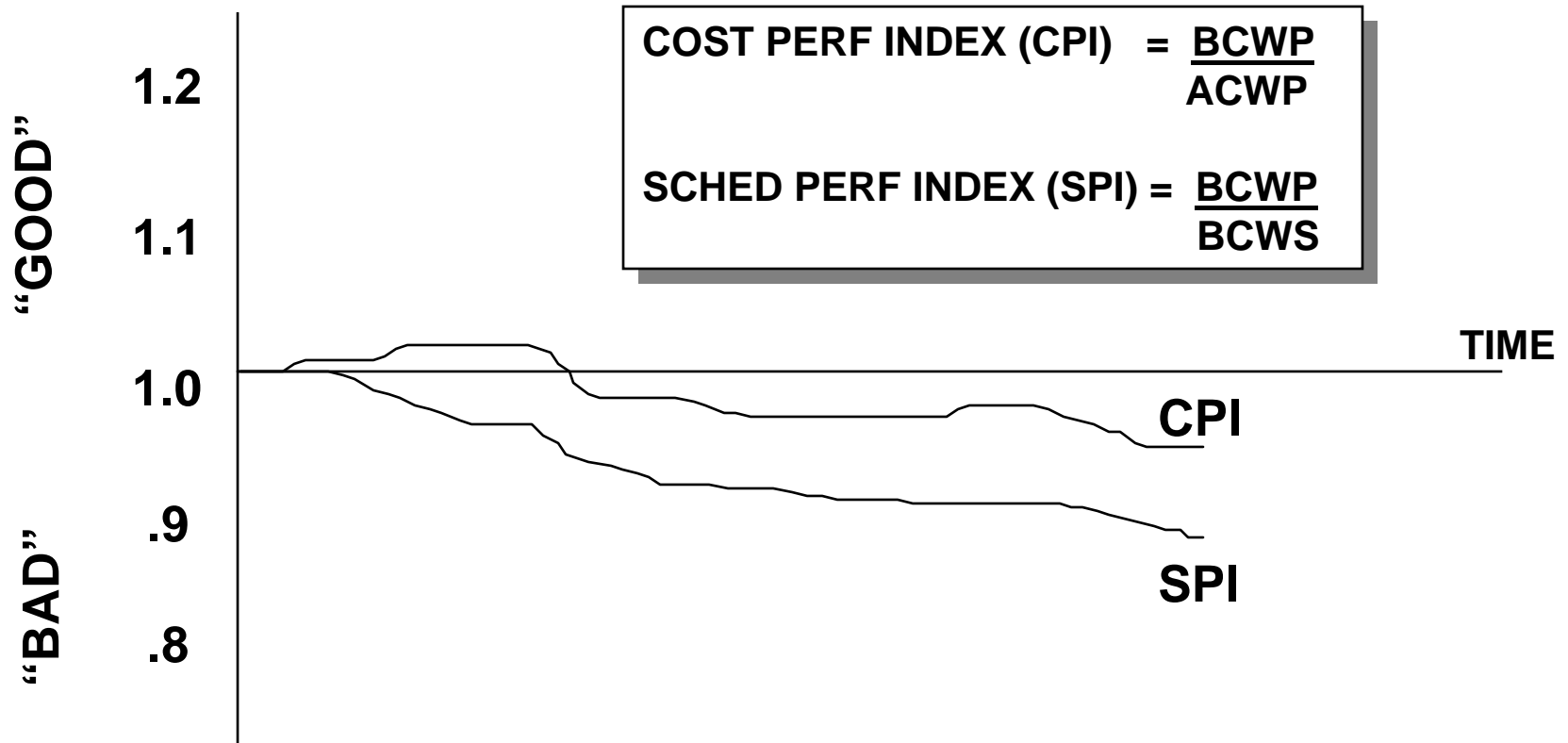


	WBS	DESCRIPTION	Proj Ofcr	%Comp	%Spent	CPI	CV	CV	CV %	VAC	VAC
1	3600	PCC	Zepka	28.99	34.09	0.850	↑	-296.2	-17.62	↔	-187.2
2	3200	COMMUNICATIONS	Tideman	34.63	41.03	0.844	↓	-130.8	-18.49	↔	-87.0
3	G&A	GEN & ADMIN		33.67	36.11	0.932	↓	-45.2	-7.26	↔	-36.8
4	2200	SYS ENGINEERING	Price	85.04	94.35	0.901	↓	-26.4	-10.95	↔	0.0
5	3800	I & A	Troop	35.40	37.08	0.955	↓	-24.2	-4.75	↔	-24.8
6	2100	PROJ MANAGEMENT	Brown	45.70	48.51	0.942	↔	-17.4	-6.16	↔	-3.2
7	2300	FUNC INTEGRA	Price	71.62	75.23	0.952	↓	-17.4	-5.03	↔	-30.8
8	5200	MANAGEMENT DATA	Simmons	84.18	98.10	0.858	↓	-13.2	-16.54	↑	-16.0
9	3100	SENSORS	Smith	20.87	21.49	0.971	↓	-10.6	-2.94	↔	-21.6
10	4000	SPARES	Blair	17.87	18.90	0.945	↑	-7.8	-5.78	↔	-6.2
11	6200	SYSTEM TEST	Hall	60.82	61.66	0.986	↑	-5.6	-1.38	↔	-2.0
12	5100	ENG DATA	Novak	38.51	52.80	0.729	↓	-4.6	-37.10	↔	0.0
13	MR	MGT RESERVE		0.00	0.00			0.0		↔	439.2
14	UB	UNDIST BUDGET						0.0			0.0
15	COM	COST OF MONEY						0.0			0.0
16	3700	DATA DISPLAY	Troop	41.13	41.13	1.000	↔	0.0	0.00	↔	0.0
17	OV	OVERHEAD						0.0			0.0
18	6100	TEST FACILITIES	Smart	100.00	98.02	1.020	↔	2.0	1.98	↔	0.0
19	3500	COMP PROGRAMS	Pino	46.46	44.66	1.040	↓	3.4	3.87	↔	-1.4
20	6300	PCC TEST	Bond	23.13	22.64	1.021	↓	4.2	2.10	↔	0.0
21	3400	ADPE	Zepka	41.89	39.79	1.053	↓	12.6	5.02	↔	4.6
22	3300	AUX EQUIP	Tideman	27.57	24.33	1.133	↓	78.2	11.73	↓	8.4

Performance Indices



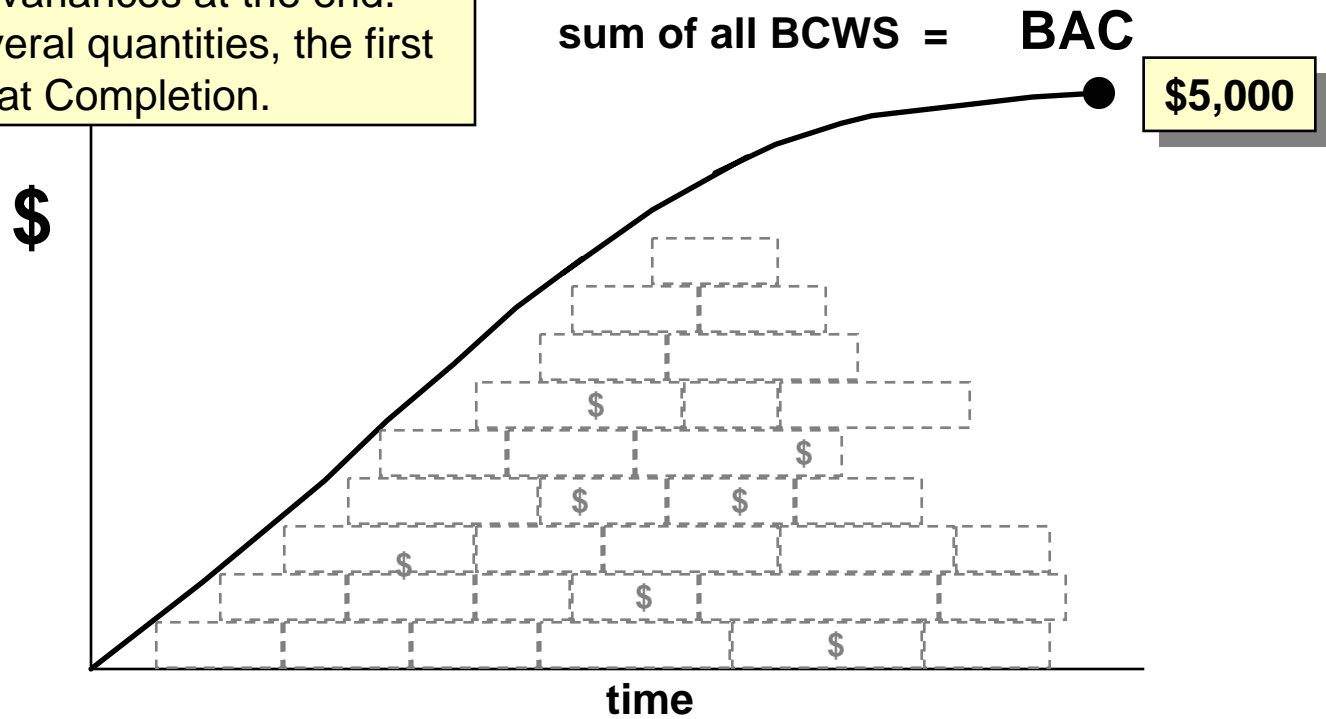
We can also get a sense of the overall performance of the project by tracking performance indices.



Budget at Completion (BAC)



The most important markers of the overall performance of the project look at predictions of the variances at the end. These require several quantities, the first being the Budget at Completion.



When all work has been phased, the cumulative BCWS = BAC
e.g., \$5,000 = \$5,000

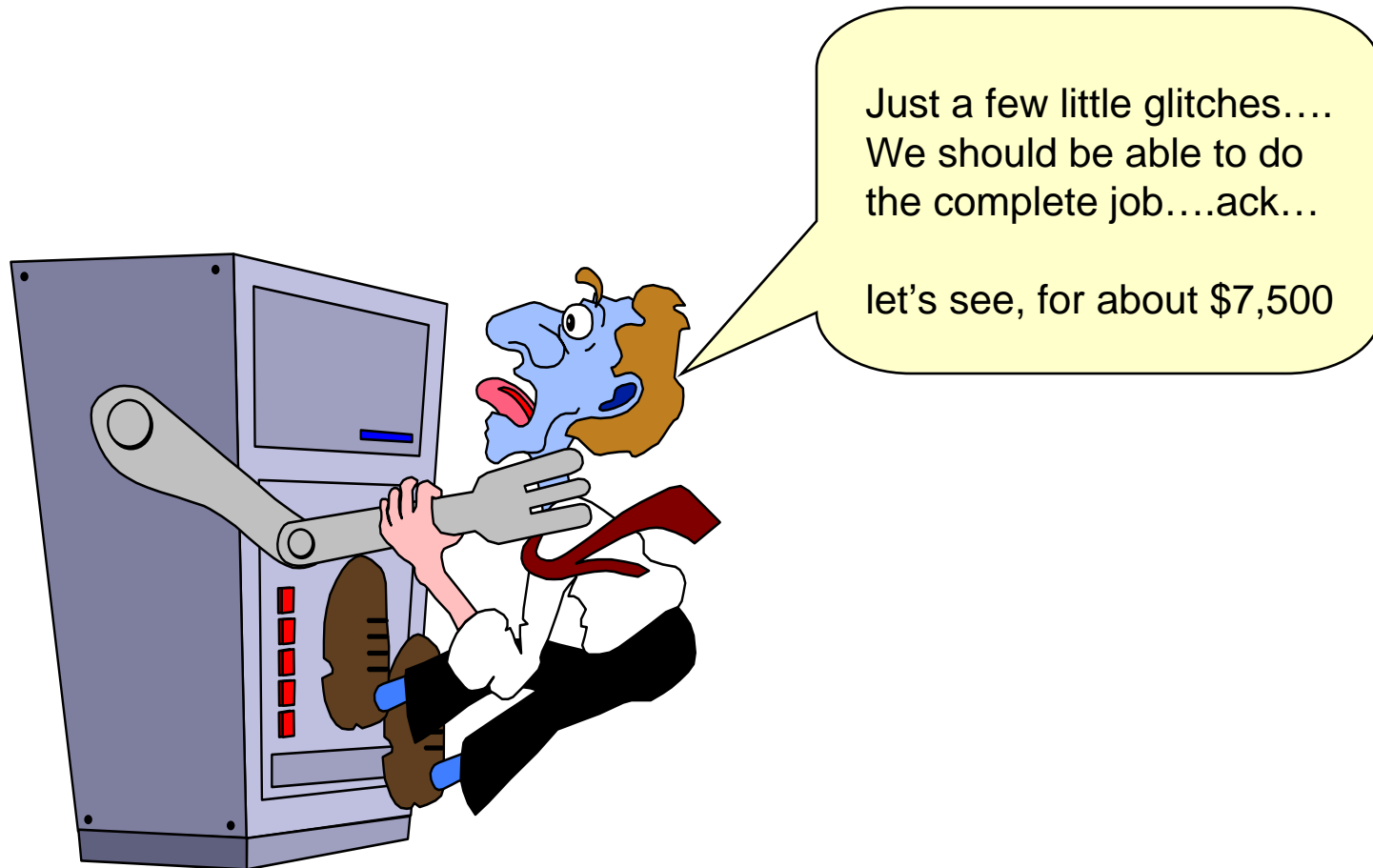
What will be the final cost?

- Estimate at Completion (EAC)

- defined as actual cost to date + estimated cost of work remaining
- usually develop comprehensive EAC at least annually
 - reported by WBS in cost performance report
- should examine on monthly basis
- consider the following in EAC generation:
 - performance to date
 - impact of approved corrective action plans
 - known/anticipated downstream problems
 - best estimate of the cost to complete remaining work
- also called latest revised estimate (LRE), indicated final cost, etc.

$$\text{ACWP} + \text{ETC} = \text{EAC}$$

Getting the Estimate at Completion





- Common EAC Formulae:

$$EAC = BAC/CPI$$

$$= ACWP_{cum} + \frac{\text{Budgeted Cost of Work Remaining}}{CPI_3}$$

$$= ACWP_{cum} + \frac{\text{Budgeted Cost of Work Remaining}}{.8(CPI) + .2(SPI)}$$

$$= ACWP_{cum} + \frac{\text{Budgeted Cost of Work Remaining}}{CPI * SPI}$$



- “Grass Roots” or formal EAC
 - detailed build-up from the lowest level detail
 - hours, rates, bill of material, etc.
- Average of statistical formulae
- Show range of EACs (optimistic, most probable, pessimistic)
- Complete schedule risk analysis for remaining work, estimate work remaining

Variance at Completion (VAC)



B	AC	what the total job is <u>supposed</u> to cost
E	AC	what the total job is <u>expected</u> to cost

VARIANCE AT COMPLETION is the difference between what the total job is supposed to cost and what the total job is now expected to cost.

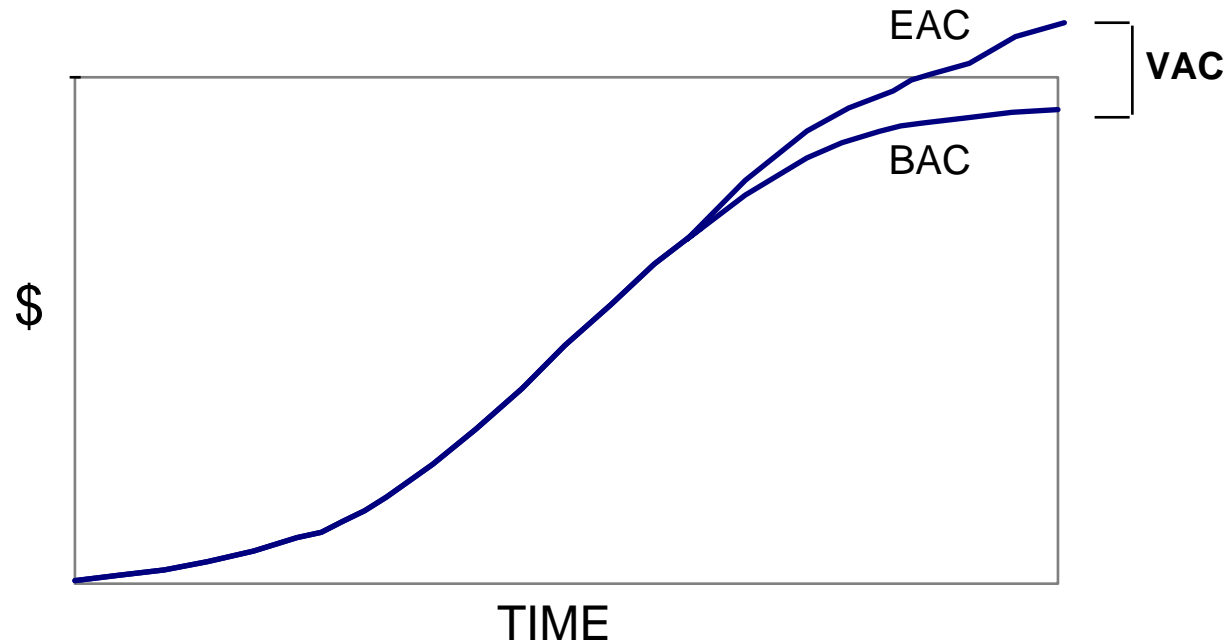
FORMULA: **VAC = BAC - EAC**

Example: VAC = \$5,000 - \$7,500
 VAC = - \$2,500 (negative = overrun)

Variance at Completion (VAC)



$$\begin{aligned} \text{VAC} &= \text{Budget at Completion} - \text{Estimate at Completion} \\ &= \text{BAC} - \text{EAC} \end{aligned}$$



VAC is Particularly Important for Government Contracts



- Variance at Completion vs. Contractor Loss
 - Positive VAC:
 - $EAC < BAC$ underrun contractor gain
 - Negative VAC:
 - $EAC > BAC$ share area contractor partial loss
 - $EAC > ceiling$ overrun contractor loss (100%)
- Government develops top level EAC for comparison
 - Government will limit progress payments if EAC is greater than ceiling
 - Government needs forecast of fund requirements
- May still have time to change the final outcome

Probably the Biggest Selling Point for EVM



- A survey of over 800 military programs showed that **no** program ever improved performance better than the following EAC calculation:

$$EAC = BAC/CPI,$$

at the **15%**-complete point in the program.

- Thus, there is strong empirical evidence that EVM translates early information into essential guidance for program re-baselining.

There are a wide variety of indicators to play with in EVM.

Term	Symbol	Formula	Checklist Actions
Percent Complete	% Done	$\frac{BCWP}{BAC}$	Ratio of work accomplished in terms of the total amount of work to do.
Cost Performance Index or Performance Factor	CPI or PF	$\frac{BCWP}{ACWP}$	Ratio of work accomplished against money spent (an efficiency rating: Work Done for Resources Expended)
To Complete Performance Index or Verification Factor	TCPI or VF	$\frac{BAC - BCWP}{EAC - ACWP}$	Ratio of work remaining against money remaining (Efficiency which must be achieved to complete the remaining work with the expected remaining money)
Schedule Performance Index	SPI	$\frac{BCWP}{BCWS}$	Ratio of work accomplished against what should have been done (Efficiency Rating: Work done as compared to what should have been done)
Schedule Correlation	SC or S/C	$\frac{\bar{P}_{CUM}}{SV}$	Ratio of Schedule Variance (SV) in terms of average amount of work accomplished (in weeks or months). It indicates a correlation to program true schedule condition
Independent Estimate At Completion	IEAC	1) $\frac{BAC}{PF}$ 2) $ACWP + \frac{BAC - BCWP}{.8CPI + .2SPI}$	Calculation of a projected Estimate At Completion to compare with the CAM's Estimate At Completion: 1) Ratio of total work to be done against experienced cost efficiency 2) Sunk costs added to a ratio of remaining work against weighted cost and schedule efficiencies
Average Performance	\bar{P}_{CUM}	$\frac{BCWP_{cum}}{\text{Duration (wks or mos) Since ACWP Began}}$	Average rate at which work has been accomplished since work began
Average Expected Performance To Finish	$\bar{P}_{TO GO}$	$\frac{BCWP_{cum}}{\text{Duration (wks or mos) From Time Now to Manager's Stated Completion Date}}$	Average rate at which work must be accomplished in the future to finish on the date the CAM has forecasted for completion of the work.

EVM Analyses

There are a wide variety of analytic techniques to play with in EVM.

- Sort on significant variances
 - eliminate almost complete, just starting, etc.
- Graph and analyze trends
- Look at comparative data
 - e.g. cumulative performance vs. projected performance
- Examine written analysis by contractor
 - does it answer why?
 - adequacy of corrective action plans
- Analysis of schedule trends, critical path
- Analysis of EAC realism

what are the drivers?
what can we do about them?



Will the contractor come in on budget?

COST PERFORMANCE INDEX:

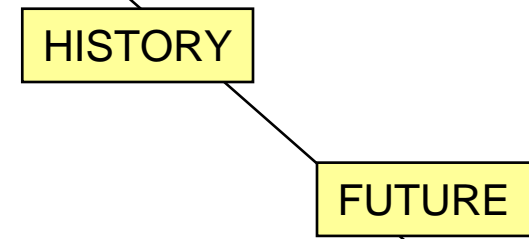
**CPI = cost efficiency for work performed to date
(The value of work accomplished for each dollar spent)**

$$= \frac{\text{BCWP}}{\text{ACWP}} = \frac{\text{WORK ACCOMPLISHED}}{\text{ACTUALS}} = \frac{\$1000}{\$2400} = .42$$

Compare the CPI to the TCPI-BAC:

TCPI(BAC) = Efficiency necessary to complete on budget

$$= \frac{\text{BAC-BCWP}}{\text{BAC-ACWP}} = \frac{\text{WORK REMAINING BUDGET REMAINING}}{\text{BUDGET REMAINING}} = \frac{\$5000 - \$1000}{\$5000 - \$2400} = \frac{\$4000}{\$2600} = 1.54$$





SCHEDULE PERFORMANCE INDEX:

**SPI = schedule efficiency with which work has been accomplished
(The rate at which work is being accomplished)**

$$= \frac{\text{BCWP}}{\text{BCWS}} = \frac{\text{WORK ACCOMPLISHED}}{\text{WORK SCHEDULED}} = \frac{\$1000}{\$2000} = .50$$

Example: Using Performance Efficiencies (3)



IS THE CONTRACTOR'S EAC (LRE) REASONABLE?

Compare the CPI to the TCPI-LRE

TCPI(LRE) = Efficiency necessary to complete at the contractor's estimate

$$= \frac{\text{BAC-BCWP}}{\text{LRE-ACWP}} = \frac{\text{WORK REMAINING}}{\text{ESTIMATE REMAINING}} = \frac{\$5000 - \$1000}{\$6400 - \$2400} = \frac{\$4000}{\$4000} = 1.00$$

reasonable?

Cumulative performance to date (CPI) = .42

Contractor has been performing at 42% efficiency, but expects to complete remaining work at 100% efficiency!

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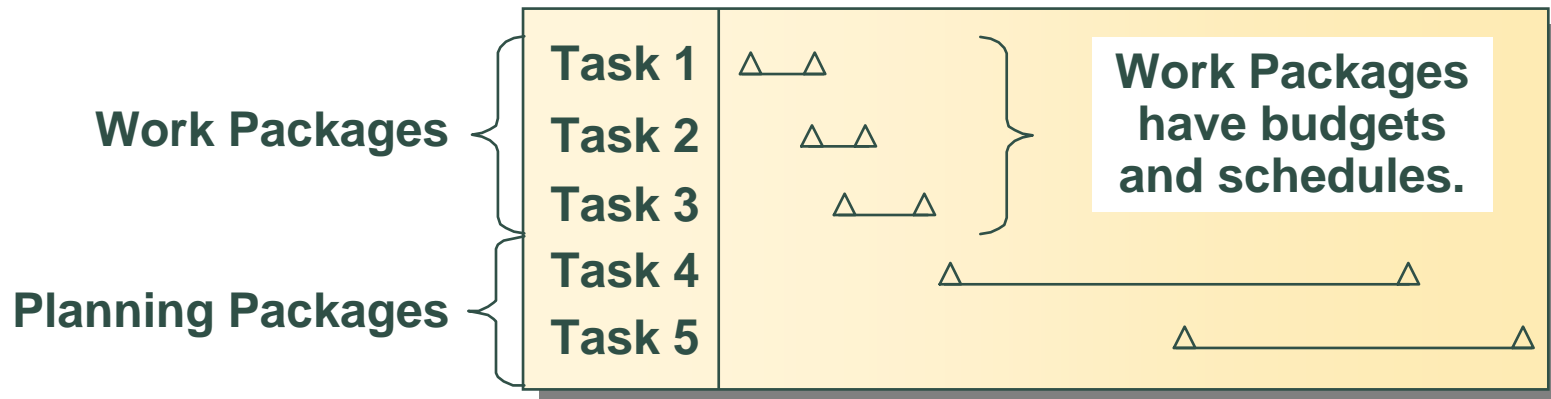


Work Packages

Detailed, short-span tasks, or material items, required to accomplish the CA objectives, typically in the near term

Planning Packages

Future work that has not been detail planned as work packages. They are always scheduled to occur in the future.



Work Packages




- Development of Control Account Plans
 - MAY break down the control account budget into smaller work packages

- Work Package
 - subset of control account
 - reasonably short in duration
 - single element of cost (e.g., labor)
 - single technique for earning value
 - consistent with detail schedules
 - has same characteristics as control account
 - scope of work
 - milestone completion criteria
 - single performing organization
 - start and end dates

<u>CONTROL ACCOUNT PLAN</u>				
Work Pkg #1	↑ \$	\$	↑ \$	
Work Pkg #2		↑ \$	\$	↑ \$
Work Pkg #3			↑ \$	\$

Work Package Characteristics

- 
- Work packages are discrete and measurable.
 - Work packages yield products or accomplishments, such as
 - design drawing package
 - conduct design review
 - install stand
 - Often done in rolling wave
 - detailed plans made for near term work packages
 - planning packages are for future work and are not detailed
 - CAMs periodically plan another increment of work packages

Ways of Earning Value



- Should be a quantitative and discrete way to measure the work
 - Discrete
 - physical, tangible end product
 - Apportioned
 - discrete, dependent on another discrete work package
 - example: quality assurance
 - planned as historical estimating factor (e.g., 7%)
 - Level of Effort
 - no tangible end product
 - basis of measurement: time
 - when clock starts ticking, you automatically accumulate earned value
 - no schedule variance
 - example: management personnel
- May tie in with success criteria or technical measure
 - e.g., successful completion of a specific test, reliability growth curve

Methods for Assigning Earned Value



<u>Method</u>	<u>How Value is Earned</u>
0/100	no EV at opening, 100% EV at close of WP
50/50	50% EV at opening, 50% EV at close of WP
Units Completed	same budget value for identical units
Equivalent Units	planned unit standards, allows partial credit
Weighted Milestone	each milestone weighted based on planned resources ideal to have a milestone each month
Percent Complete	subjective (least desirable)

Suggested for LWA



- 0/50/100 measurement
- Typical work package length is 80 hours.
- Work package status is reported at status meetings, held every two weeks.
 - May just be that 50% of work packages are reported at weekly status meetings.
- EV is 0% (of budget for work package) if it has not yet been started, or is only now starting.
- EV is 50% if work is underway.
- EV is 100% if work is complete.
- If work package is at 50% two status meetings in a row, it is flagged as a potential issue.
- Avoids subjectivity of “% done”; compromises on granularity of tracking, frequency of reporting
- **Puts the onus on doing the WPs right, up front.**

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A Spectrum of Implementation



Where	Commercial or Defense		Government Organic	Major Defense Contractors
	Small Companies	Larger Companies		Foreign Countries
When	as desired	corporate policy, "enterprise wide"	FFP contracts?	DoD Non-Major Contracts (>12 months) <\$6M* >\$6M
				DoD Major Contracts >\$70M RDT&E >\$300M Prod
Reports	streamlined, no paper?	tailored to needs	C/SSR	CPR
	Core EV Principles		Tailored Applications	
			ANSI/EIA-748-1998 (32 criteria)	

*with judgment

Earned Value Management: History

- 1959 PERT and PERT/Cost
 - Milestone Charts And Rate-of-Expenditure Curves
 - Dollars Spent Vs Estimates Of Percent Complete (DD 1097)
- 1963 Earned Value Concept (MINUTEMAN)
- 1964 Cost Accomplishment Concept (TITAN III)
- 1966 AF—Cost/schedule Planning And Control Specification (C/SPCS)
- 1967 DOD—Cost/Schedule Control Systems Criteria (C/SCSC) (DODI 7000.2)
- 1972 DOD—Revised DODI 7000.2 and Issued the Joint Implementation Guide (JIG)
- 1972 NASA Marshall Space Flight Center—C/SPC
- 1975 DOE—Performance Measurement System (PMS)
- 1976 DOD—Revised the C/SCSC JIG
- 1980 DOD—Revised the C/SCSC JIG
- 1982 National Security Agency—Earned Value
- 1983 NASA—Goddard Space Flight Center—PMS
- 1984 FAA & NASA Lewis Research Center—PMS
- 1985 NASA Johnson Space Flight Center—PMS
- 1987 DOD—Revised DOD C/SCSC JIG
- 1988 NASA Marshall SFC—Revised PMS (MMI 8020.7C, 44 Criteria)
- 1989 Australian DOD—DODI 7000.2
- 1990 Canadian DOD—PMS
- 1991 DODI 5000.2 replaces DODI 7000.2
- 1992 National Oceanic And Atmospheric Administration (NOAA)—PMS
- 1993 Swedish FMV—C/SCSC
- 1994 Internal Revenue Service (IRS)—C/SCSC
- 1994 Federal Bureau Of Investigation (FBI)—C/SCSC
- 1996 DODR 5000.2-R replaces DODI 5000.2 C/SCSC revised from 35 to 32 criteria
- 1996 Revised JIG—Renamed Earned Value Management Implementation Guide (EVMIG)
- 1997 EVMIG Revised
- 1998 MIL-STD 881B replaced by MIL HDBK 881

- Books
 - ☑ *Earned Value*
Quentin W. Fleming & Joel M. Koppleman
 - ☑ *Cost/Schedule Control Systems Criteria*
Quentin W. Fleming
 - ☑ *Project Performance Measurement*
Robert R. Kempes
 - ☑ *Visualizing Project Management*
Kevin Forsberg, Ph.D., Hal Mooz and Howard Cotterman
- Software
 - ☑ *Artemis Views*
Artemis Management Systems
Contact: Patrick Perugini (303) 581-3102
Web: <http://www.artemisp.com>
 - ☑ *Cobra*
Welcom Software
Contact: Diana Melton (281) 558-0514
Web: <http://www.wst.com>
- Software [continued]
 - ☑ *Dekker TRAKKER*
Dekker Ltd.
Contact: Ron Barry (909) 384-9000
Web: <http://www.dtrakker.com>
 - ☑ *MicroFrame Project Manager (MPM)*
MicroFrame Technologies, Inc.
Contact: Carl Amacker (415) 616-4000
Web: <http://www.microframe.com>
- Internet
 - ☑ Project Management Institute
<http://www.pmi.org>
 - ☑ US DoD Earned Value
<http://www.acq.osd.mil/pm>
 - ☑ Earned Value Bibliography
<http://www.uwf.edu/~dchrste/ev-bib.html>