

Earned Value Management (EVM)

*Tracking cost and schedule
performance on projects*

"What are my chances?" / "Not good." / "You mean, not good like one out of a hundred?" / "I'd say more like one out of a million." / ... "So you're telling me there's a chance!"

- Jim Carrey as Lloyd Christmas to Lauren Holly as Mary Swanson

Dumb and Dumber, <http://www.imdb.com/title/tt0109686/>

Acknowledgments

- ICEAA is indebted to TASC, Inc., for the development and maintenance of the Cost Estimating Body of Knowledge (CEBoK®)
 - ICEAA is also indebted to Technomics, Inc., for the independent review and maintenance of CEBoK®
- ICEAA is also indebted to the following individuals who have made significant contributions to the development, review, and maintenance of CostPROF and CEBoK®
- Module 15 Earned Value Management (EVM)
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TASC

Technomics
The Center of Professional Cost Estimating

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- Unit II - Cost Analysis Techniques
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- Unit V - Management Applications
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 - 15. Earned Value Management (EVM)**
 - 16. Cost Management

EVM Overview

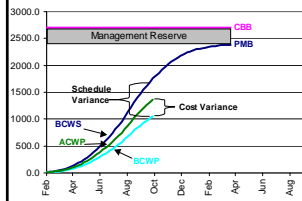
- | | |
|--|--|
| <ul style="list-style-type: none"> • Key Ideas <ul style="list-style-type: none"> - Integrated baseline <ul style="list-style-type: none"> • Resource-loaded schedule - Earned value <ul style="list-style-type: none"> • Objective progressing - Extrapolation from Actuals - Cost and schedule performance | <ul style="list-style-type: none"> • Practical Applications <ul style="list-style-type: none"> - EACs - risk-adjusted rollups - EACs - alternative formulae - Performance measurement <ul style="list-style-type: none"> • Contract vs. technical |
| <ul style="list-style-type: none"> • Analytical Constructs <ul style="list-style-type: none"> - AC (Actual Cost) = actuals to date - EV (Earned Value) = value of work performed - PV (Planned Value) = budget - $EAC = AC + \underbrace{(BAC - EV)}_{BCWR} / PI$ | <ul style="list-style-type: none"> • Related Topics <ul style="list-style-type: none"> - Risk Management - Project Management - Schedule Analysis / Risk |

Tip: This formula, while intuitive, may not be the best predictor of EAC!

EVM within the Cost Estimating Framework

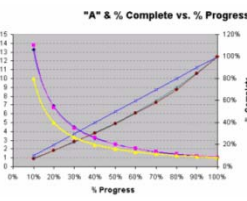
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Past
Understanding your historical data



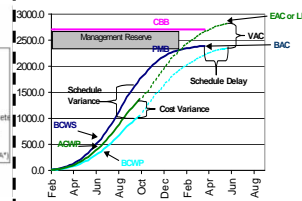
Earned Value data elements

Present
Developing estimating tools



Estimate At Complete (EAC) formulae

Future
Estimating the new system



EAC and Predicted Schedule



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EVM and Cost Estimating

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- How should Cost Estimators be involved in EVM?
- Verify Realistic Baselines
 - 20 - Control Accounts that trace to BOEs
 - Cost Estimator participation in IBRs
- Develop Accurate EACs
 - Statistical and risk-based methods
- Gather Cost Data to Support Estimating
 - IPMR and other EV data serve as data sources for estimating analogous efforts





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What?

EVM Objectives

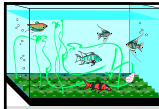
-  Earned Value Management (EVM) integrates Technical Scope, Schedule, and Cost for definitized contract work
-  Earned Value Management System (EVMS)
 - Planning tool
 - Reporting tool
 - Analysis and Decision Making tool
- Provides for integrated management of program planning and execution, which can enable...
 - Accomplishment of Technical Scope within Cost and Schedule parameters
 - Reduced or Eliminated Schedule Delay
 - Reduced or Eliminated Cost Overrun

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Basic EVM Example

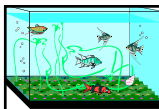
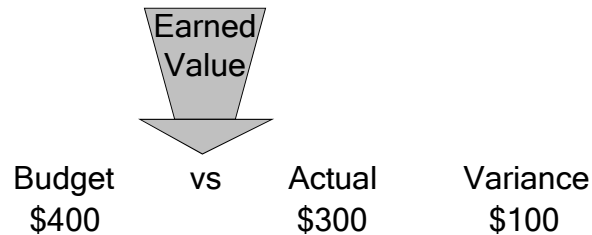
- Managing projects without earned value provides only part of the picture
- Traditional approach:
 - Budget work
 - Record Actual expenses
- Example:
 - Budgeted for 4 Aquaria to be built in November at \$100 each
 - At end of November, spent \$300
 - Great! I am \$100 under budget...or am I?



Basic EVM Example

v1.2

- Example (continued):
 - Did I accomplish \$400 worth of work while spending only \$300?
 - Earned value adds a new dimension - what is the VALUE of work accomplished



Basic EVM Example

v1.2

- Example (continued):
 - At the end of November I spent \$300 but only completed 2 Aquaria

Budget	Earned Value	Actual	Cost Variance
\$400	\$200	\$300	-\$100

- So I am not only overrunning Cost, I am also behind schedule!

Earned Value Management (EVM) Components

- Integrated Baseline Overview
- Work Breakdown Structure
- Assignment of Work
- Earned Value Data Elements
- Baseline Development
- Performance Measurement

Integrated Baseline Overview

- Key component of EVM is the Resource Loaded Schedule
 - Elements of the Performance Measurement Baseline (PMB) defined early in acquisition process by Government and Contractor
 - WBS Structure
 - Schedule
 - BOEs (justification for time phased costs and effort)
 - Time-Phased Budget / Resource Loaded Schedule initially defined for proposal and refined/baselined post negotiations
- Government review of PMB occurs via Integrated Baseline Review (IBR)



WBS Definition/Overview

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- Work Breakdown Structure (WBS): Product-oriented division of material and work tasks
- Used to organize and define product/work to be accomplished
- Different forms:
 - Program Summary WBS (Government), usually referred to as WBS
 - Contractor WBS, usually referred to as CWBS
 - Cost Element Structure (CES)
 - Level and scope may depend on the underlying data and methodology used in developing the estimate
 - WBS typically several levels higher than CWBS

OSD EVM Website: <http://www.acq.osd.mil/evm/>



WBS Importance to EVM

- WBS provides framework within which all Earned Value planning is accomplished
- WBS must be:
 - Comprehensive
 - Matches program content
 - Hierarchical
 - “Sufficient” level of detail
 - Sufficiency depends on size, complexity, risk, and other factors
 - For EVM, level of detail for *tracking* costs usually lower than level for *reporting* costs



WBS Example

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- WBS Sample layout for the aquaria example
 - 1.0 Aquarium Development Program
 - 1.1 Program Management / Systems Engineering
 - 1.2 Design Aquarium
 - 1.3 Develop/Integrate Aquarium
 - 1.3.1 Material Acquisition
 - 1.3.2 Material Integration
 - 1.3.3 Development Documentation
 - 1.4 Test Aquarium
 - 1.5 Deploy Aquarium
 - 2.0 Aquarium Maintenance Program
 - 2.1 Maintain Environment
 - 2.2 Replace Material
 - 2.3 Maintain/replace Fish Population

NOTE: Example WBS is *not* comprehensive or extensively detailed.

This WBS does not adhere to MIL-STD-881C and therefore needs a comprehensive WBS Dictionary.

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Organizational Breakdown

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Structure (OBS) Definition

- Functional breakdown of Organization
 - Identifies the program's organizational structure
 - Supports the identification of the function responsible for controlling overhead costs
- Typically aligns with Company's Org Chart
- One piece of the framework used for planning resources
- One popular organization technique involved Integrated Product Teams (IPTs)
 - Multi-disciplined
 - Overarching IPT and Working-level IPT(s)

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Defense Acquisition Guidebook,
https://akss.dau.mil/dag/DoD5000.asp?view=document&rf=GuideBookIG_c10.3.asp

Assignment of Work - Control Accounts

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- WBS cross-walked to OBS → Control Accounts
 - Identifies Responsibility
 - Result is Control Account (sometimes called a Cost Account)
- Control Account is the focal point for integration of scope, cost, and schedule
- Control Account Manager (CAM) is person responsible for:
 - Developing plan for Control Account (Technical Scope, Schedule Tasks, Budget/Resources)
 - Work Authorization Document (WAD)
 - Managing Earned Value performance within Control Account
 - Monitoring EVM metrics
 - Analyzing control account performance status
 - Reporting variances
 - Conducting risk management/mitigation as required

Assignment of Work - Work Packages

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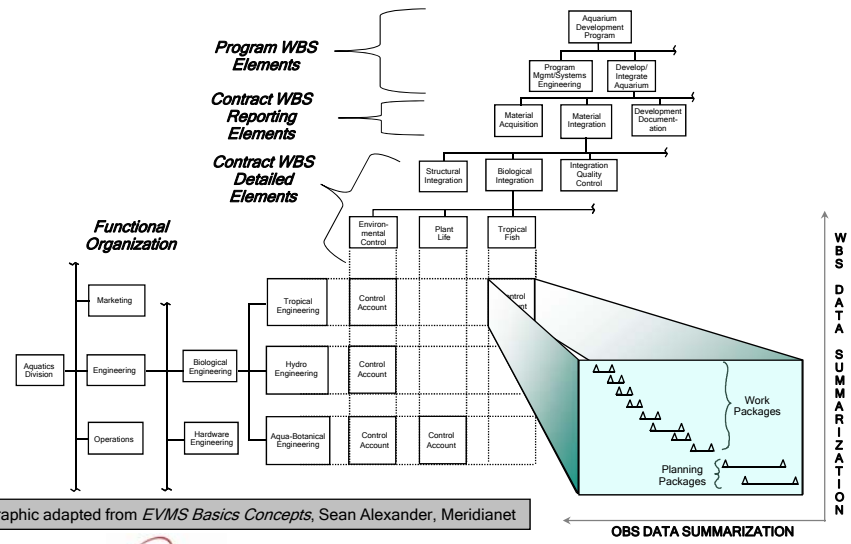
- Work Packages are the lowest level at which resources are allocated
- Within Control Accounts, work and planning packages defined at lowest level of detail
 - Work packages for near-term work
 - Planning packages for far-term work
 - Planning packages become more detailed work packages as time progresses
- Resources allocated to each work/planning package
 - Direct Labor
 - Material
 - Other Direct Charges (ODCs)

Tip: Typically 4-6 weeks long

Tip: Detail plan typically 6 months out

Assignment of Work Illustration

v1.2



Graphic adapted from *EVMS Basics Concepts*, Sean Alexander, Meridianet

Earned Value Data Elements


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- Earned Value has five basic data elements:

Element	Title	Common Terminology
BCWS	Budgeted Cost of Work Scheduled	Planned Value (PV), Performance Measurement Baseline (PMB), plan, baseline
BCWP	Budgeted Cost of Work Performed	Earned Value (EV)
ACWP	Actual Cost of Work Performed	Actual Cost (AC), actuals
BAC	Budget at Complete	Planned Cost
EAC / LRE	Estimate at Complete / Latest Revised Estimate	Forecasted Cost

Tip: EAC generally refers to the Government's independent assessment of the estimate at complete while LRE refers to the Contractor's estimate at complete

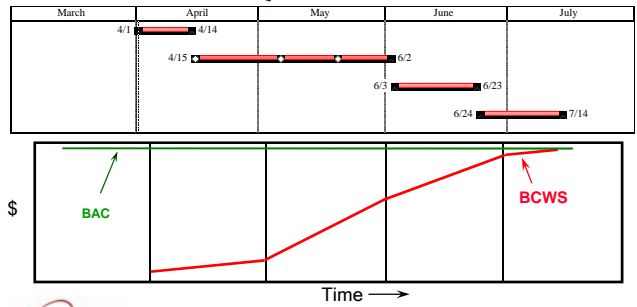
BCWS (The Plan)

 **Budgeted Cost of Work Scheduled (BCWS):** The sum of the budgets for all work packages, planning packages scheduled to be accomplished within a given time period


- The value of the work scheduled
- The baseline used to measure all performance
- The resource-loaded schedule
 - Picture a Gantt chart 

 **AKA Planned Value (PV)**


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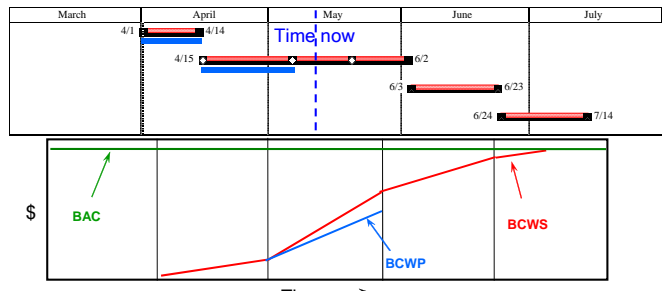


BCWP (What Work Was Performed?)

 **Budgeted Cost of Work Performed (BCWP):** The sum of all budgets for completed work packages and completed portions of open work packages

- The value of the work performed
- Dependent on BCWS - can only earn as much \$ as is loaded in the completed BCWS tasks

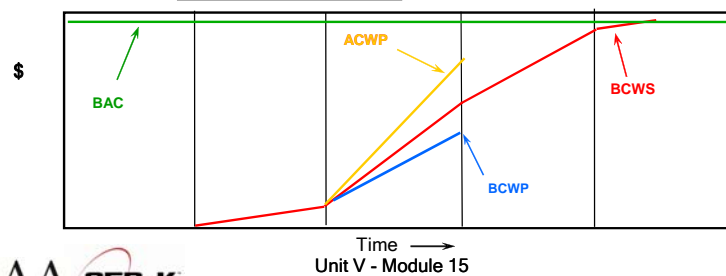
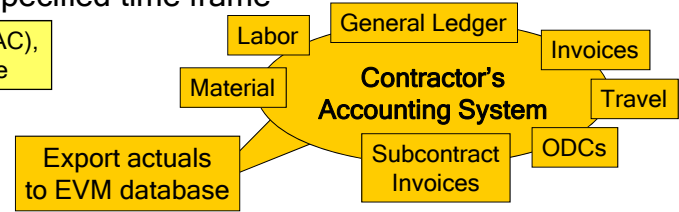
 **AKA Earned Value (EV)**



ACWP (Cost Incurred)

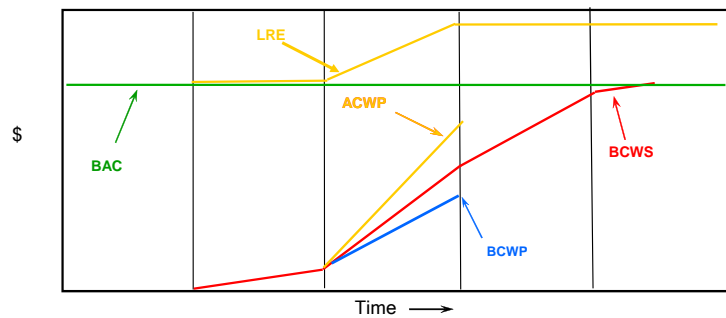
- **Actual Cost of Work Performed (ACWP):** The costs actually incurred to accomplish the work earned within a specified time frame

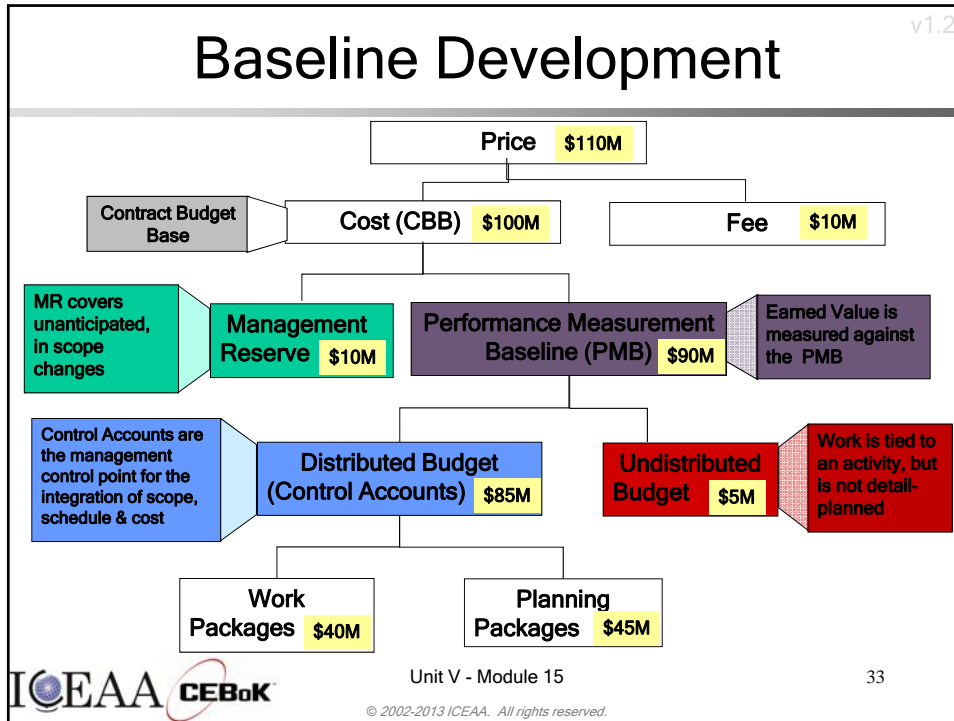
AKA Actuals (AC), Actual Value



BAC and LRE (End of Work)

- **Budget At Complete (BAC):** Cumulative BCWS at the end of the contract
- **Latest Revised Estimate (LRE):** The contractor's best guess at how much the effort will actually cost at the end of the contract





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Baseline Development - PMB

- Performance Measurement Baseline (PMB) developed
 - Sum of all Work/Planning Package Budgets + UB
- Undistributed Budget (UB) is:
 - Work tied to an activity, but not detail-planned
 - Used most often when new work added to contract
- Earned Value is Measured against the PMB
- Work packages and related budget (BCWS) are time phased using logic-driven schedule
 - e.g., PERT chart showing dependencies

Tip: UB usually distributed within 60 days

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Baseline Development - MR

- 
 • Management Reserve (MR) set aside while developing PMB
 - Covers unanticipated, *in scope* changes
 - 
 - MR % tied to level of risk and type of contract
 - 2-4% low risk and/or Cost Plus 
 - 15%+ high risk and/or Firm Fixed Price
 - More discussion on MR and its use is covered under the Analysis of Past Performance section



Tip: MR is most commonly 7-9% of CBB



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Baseline Development - CBB

- 
 • PMB and MR together form the Contract Budget Base (CBB) (“Cost”) 
 - CBB plus fee yields the Total Contract Value (“Price”)
 - A time-phased graphic illustrating PMB and MR forming CBB is on the next slide
 - EVM should be complemented by a disciplined Risk Management (RM) approach to identifying, quantifying, and addressing unknown future events

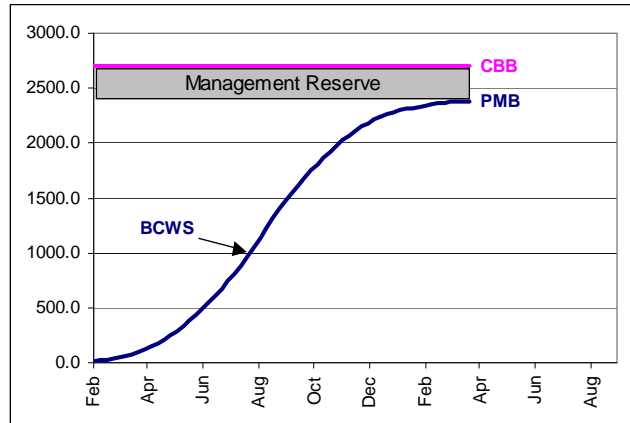
“Integrating EVM and RM: A Statistical Analysis of Survey Results,” Alissa C. Kumley, Northrop Grumman Corporation, ISPA/SCEA Joint International Conference, 2005



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Baseline Development


- Typical Phased Baseline (BCWS)



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Tip: Cum PMB usually follows an S-curve.

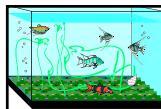
Performance Measurement

- There are different ways to estimate progress of a project
 - Key issue is in-process work packages 
- Value is earned (BCWP) when corresponding work is accomplished
- When value will be earned is determined before beginning work using common performance measurement methods
- Assignment of method should strive to reduce subjectivity
- Table on next slide outlines:
 - Most common methods
 - When methods are typically employed

Performance Measurement - EV Methods

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EV Method	Description	Type of Tasks that Use Method
 Milestone (Weighted)	Take performance as defined Milestones (MS) are accomplished. MSs can be weighted if one or more are considered more important	Tasks that can be planned using interim Milestones <div style="border: 1px solid black; background-color: yellow; padding: 2px; display: inline-block;">Best Method for EVM</div>
Percent Complete	Performance is taken based on Percent of task completed	Work that does not have any reasonable interim measurable MSs
0/100	All performance is taken when task is complete	Short duration tasks - one month or less
50/50 Or X%/Y%	50% (X%) performance taken when task starts; 50% (Y%) performance taken when task is complete	Short duration tasks - two months or less
LOE	Plan based on resource expenditure plan – Performance always equals Plan	Used for tasks that are more time-oriented vice task oriented, such as Program Management



Example - Performance Measurement

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- Determine the best earned value measurement technique:
 - Aquarium System Program Management
 - Aquarium Design
 - Aquarium Deployment to Site ATLANTIC

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Example - Performance Measurement

v1.2

- Valid earned value measurement techniques:
 - Aquarium System Program Management
 - LOE - most common method
 - Milestone
 - Aquarium Design
 - Most likely Design will be divided into smaller work packages and multiple methods will be employed
 - Milestone / Weighted Milestone - most common method
 - Percent Complete
 - Aquarium Deployment to Site ATLANTIC
 - 0/100
 - X%/Y%
 - Milestone

Multiple Answers are Justifiable

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Earned Value Analysis


- Elementary EV Analysis
- Analysis of Past Performance
- Variance Reports
- Projection of Future Performance
- Earned Value Review Process

Elementary EV Analysis

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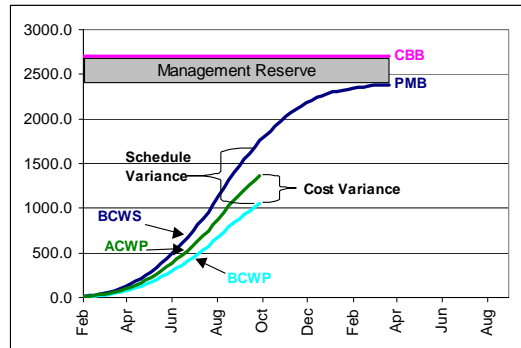
- Common calculated Data Elements:

 - Schedule Variance (SV) = BCWP - BCWS

 - Cost Variance (CV) = BCWP - ACWP



AKA
Accomplishment
Variance



Elementary EV Analysis


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- Common calculated Data Elements:

 - Variance at Complete (VAC) = BAC - LRE

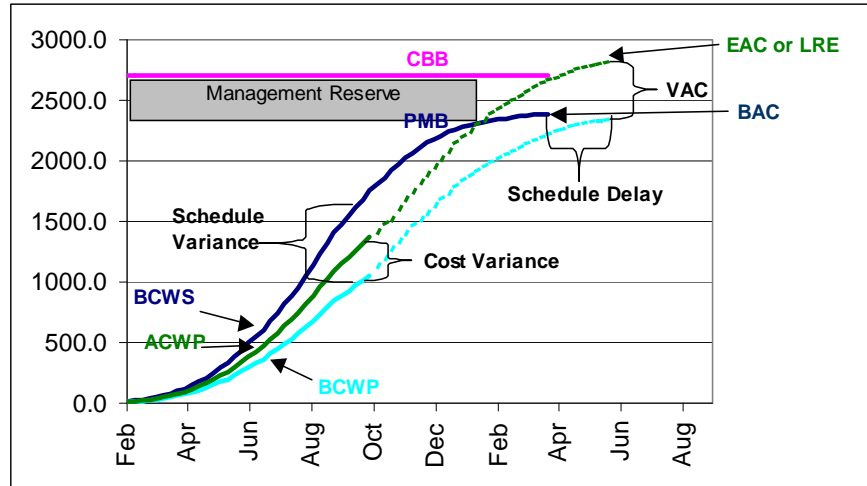
- Estimate at Complete (EAC)

- Forecasting measure
- Various methods applicable
- Discussed in more detail later

 - Budgeted Cost of Work Remaining (BCWR)
= BAC - BCWP

- Analysis of data, including sample problems, in next section

Elementary EV Analysis



Analysis of Past Performance

- CV, SV, and VAC: Most common and simplest derived earned value data
- Examine current and cumulative data points and trends
 - Cumulative data points good for determining average performance
 - Current data points good for assessing current performance and for highlighting anomalies, errors in data, and error corrections
 - Trend lines good for assessing performance over time - Sudden trend changes should be examined

Analysis of Past Performance

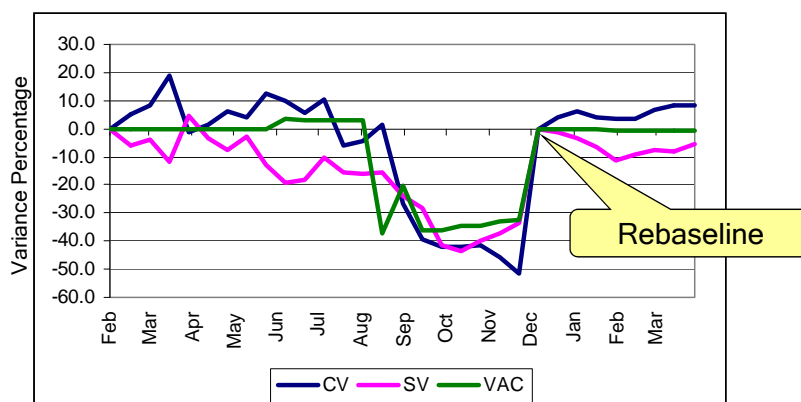
- Any variance over 10% is serious and should be examined
 - $CV\% = CV / BCWP = 1 - 1/CPI$
 - $SV\% = SV / BCWS = SPI - 1$
- Focus on CV and SV (vice VAC)
- Variances are natural
 - Explained and managed, but not eliminated
- Variances, and emerging or present trends, can erase with a rebaseline

Tip: Sudden “healing” spikes in cum CV/SV typically mean a rebaseline has occurred

“Understanding Program Resource Management through Earned Value Analysis.” Falls Church, Va.: Abba Consulting, June 2006.

Analysis of Past Performance

- CV, SV, and VAC:





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Example - Past Performance

- Sample problem:
 - Building 8 Aquaria
 - Budgeted for 4 to be built in Nov and 4 to be built in Dec at \$100 each
 - At the end of Nov, contractor spent \$300 and completed 2
 - Contractor now expects the project to cost a total of \$1000
 - For Month-end (ME) Nov, what is cumulative BCWS? BCWP? ACWP?
 - For ME Nov, what is cumulative CV? SV? VAC?
 - What are those variances telling us?

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v1.2


Example - Past Performance

- Answers:
 - BCWS = \$400 BCWP = \$200 ACWP = \$300
 - CV = **-\$100** SV = **-\$200** VAC = **-\$200**
 - What are those variances telling us?
 1. Overrunning now, accomplished less than planned, expect overrun at complete, if task on critical path then expect a delay at complete - Facts based on data provided
 2. Do not expect to repeat overrun for Aquaria #3-8 because $VAC \neq 4 * CV$. Ask: Is this realistic? Why do they think overrun will not be repeated?
 3. Built 2 in one month, now expect to build 6 in next month - Unlikely - Ask: How do they plan to accomplish this *and* not spend more \$/system than budgeted
 - Begin to plan for how to cover current overrun *and* expected future overrun

Past Performance - Indices

- Cost Performance Index (CPI) and Schedule Performance Index (SPI) display variances on a units-free scale
 - CV of \$100 out of \$2M is nothing
 - CV of \$100 out of \$200 is significant
-  • Cost Performance Index (CPI)
 - Ratio of work performed to actual costs
 - $BCWP / ACWP$
 - Used to determine the *value* of every dollar of work accomplished (bang for the buck)
 - < 1.0 is unfavorable > 1.0 is favorable
-  • Reciprocal of CPI
 - Provides the final cost of dollar's worth of budgeted effort
 - EAC Calculations use reciprocal of CPI to scale budgeted effort up to an expected completion cost

Past Performance - Indices

-  • Schedule Performance Index (SPI)
 - Ratio of value of work performed to value of work planned
 - $BCWP / BCWS$
 - Used to determine the *efficiency* at which scheduled work is being accomplished
 - < 1.0 is unfavorable > 1.0 is favorable
- Analysis using CPI, SPI similar to that using CV, SV
- Table on next slide contains *possible* causes for CV/CPI and SV/SPI

Tip: Examine cost and schedule *together* graphically to assess visually how variances may be impacting one another.

+CV / CPI > 1.0	-CV / CPI < 1.0	+SV / SPI > 1.0	-SV / SPI < 1.0
<p>Work is costing less than planned:</p> <ul style="list-style-type: none"> - More efficient & using fewer hours/mat'l - Using less expensive labor category/mat'l - Achieved a technical breakthrough <p>Delay in payment. Work complete but actuals have not hit ledger yet</p> <p>Incorrect status. Took credit for work not actually completed</p> <p>Improper charging. Took credit for work yet actuals were charged against the wrong account</p>	<p>Work is costing more than planned:</p> <ul style="list-style-type: none"> - Less efficient & using more hours/mat'l - Using a more expensive labor category/mat'l - Additional travel (ODCs)/Rework incurred - Rates (OH, G&A inflation) increased - Encountered Technical problems <p>Incorrect status. Did not take credit for work actually completed</p> <p>Improper charging. Actuals were incorrectly charged against the account</p> <p>Requirements Change. In scope contract requirement changed</p>	<p>Work is being accomplished faster than planned:</p> <ul style="list-style-type: none"> - More efficient & taking less time - Achieved a technical breakthrough <p>Work has been accelerated in the schedule. Due to programmatic events, work has shifted forward</p> <p>Incorrect status. Took credit for work not actually completed</p> <p>Baseline Mistake. Incorrectly set work to occur later than it was supposed to</p>	<p>Work is being accomplished slower than planned:</p> <ul style="list-style-type: none"> - Less efficient & taking more time. - Encountered Technical problems <p>Work has slipped in the schedule:</p> <ul style="list-style-type: none"> - Due to programmatic events (late GFE, GFI, predecessor priorities, etc.), work has shifted right - Due to lack of resources, work has shifted right <p>Incorrect status. Did not take credit for work actually completed</p> <p>Baseline Mistake. Incorrectly set work to occur before it was supposed to</p> <p>Requirements Change. In scope contract requirement changed</p>

Future Performance - EAC

- Objective, mathematical Estimates At Complete (EACs) can be calculated
- Most common are CPI and CPI * SPI
 - CPI Forecast
 - $ACWP + (BCWR / CPI) = BAC / CPI$
 - Assumes even cost performance across the entire project equal to performance experienced to date
 - Referred to as "best case" EAC
 - CPI * SPI Forecast
 - $ACWP + (BCWR / (CPI * SPI))$
 - Also assumes that past cost and schedule performance are indicative of future performance
 - Adjusts estimate to account for schedule performance experienced to date
 - Referred to as "worst case" EAC

Estimate To Completion (ETC)

Future Performance - TCPI

- What is our (implicit) predicted future performance based on data reported?
- Use the To-complete Cost Performance Index (TCPI)



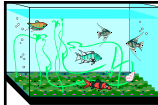
Warning: EVA does *not* typically include cost estimating methodologies (e.g., learning curve)

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- $TCPI_{BAC}$ and $TCPI_{LRE}$
- Ratio of remaining work to complete to remaining \$ available to be spent to achieve the BAC (or LRE)

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- $TCPI_{BAC} = BCWR / (BAC - ACWP)$
- $TCPI_{LRE} = BCWR / (LRE - ACWP)$
- Can also calculate TCPI for EAC forecasts
- “Indicator of the goodness” of the LRE/EAC



Example - Future Performance

- Sample Problem:

BCWS = \$400 BCWP = \$200 ACWP = \$300
 BAC = \$800 LRE = \$1000

- What is the TCPI to achieve the LRE?
- Is the LRE reasonable?
- Using independent forecasts, what is the “best case” EAC? The “worst case” EAC?

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Example - Future Performance

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- Answers:
 - What is the TCPI to achieve the LRE?
 - $TCPI_{LRE} = BCWR / (LRE - ACWP)$
 $= (800 - 200) / (1000 - 300)$
 $= 600 / 700 = 0.86$
 - Is the LRE reasonable?
 - CPI = 0.67; TCPI-LRE = 0.86
 - $TCPI_{LRE}$ is more than 5% higher than CPI
 - LRE may not be reasonable
 - Need to investigate reasoning behind CPI and assess the reasonableness of the plans for improving performance so drastically



Example - Future Performance

v1.2

- Answers (continued):
 - Using independent forecasts, what is the “best case” EAC? The “worst case” EAC?
 - Best Case EAC = CPI Forecast
 $= BAC / CPI$
 $= 800 / 0.67 = 1200$
 - Worst Case EAC = CPI*SPI Forecast
 $= ACWP + BCWR / CPI*SPI$
 $= 300 + (800 - 200) / (0.67)*(0.5)$
 $= 2100$

Cost Management

Managing cost, performance, and value

“If you can bear to hear the truth you’ve spoken
Twisted by knaves to make a trap for fools,....”
-Rudyard Kipling, “If”

Acknowledgments

- ICEAA is indebted to TASC, Inc., for the development and maintenance of the Cost Estimating Body of Knowledge (CEBoK®)
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- Module 16 Cost Management
 - Lead authors: Thomas D. Dauber, Christopher J. Leonetti, Travis C. Manning
 - Senior reviewers: Richard L. Coleman, Fred K. Blackburn
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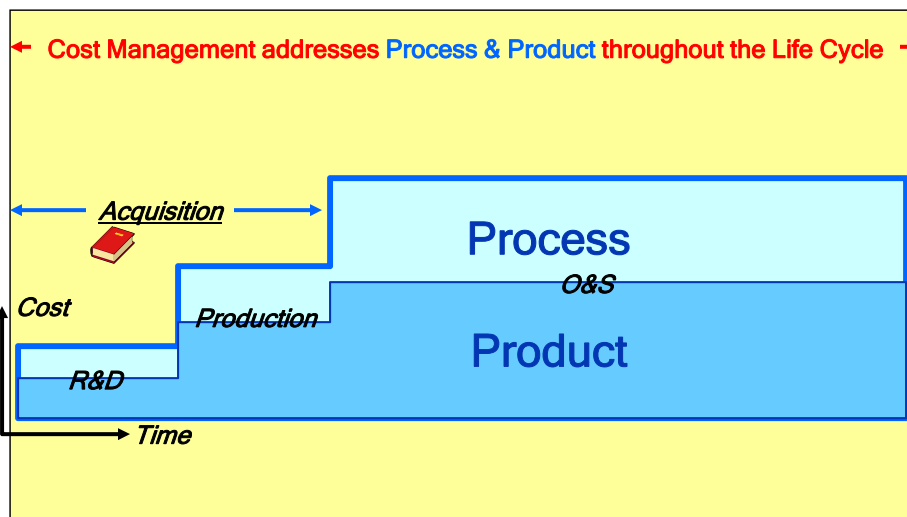



Why Are We Here?

1

- “Capstone” module
 - Coming full circle, revisiting the fundamental motivations for cost estimating and analysis
- Context for cost estimating and analysis
 - Handful of principles and techniques applied in a myriad of different contexts
- Cost and Decision-Making
 - We seek systematic, rational decisions involving cost, though these are all but impossible
- Cost and Efficiency
 - Cost is the ultimate measuring stick for various improvement initiatives
 - Avoid “squeezing the balloon”

Cost Management - Domain of Application

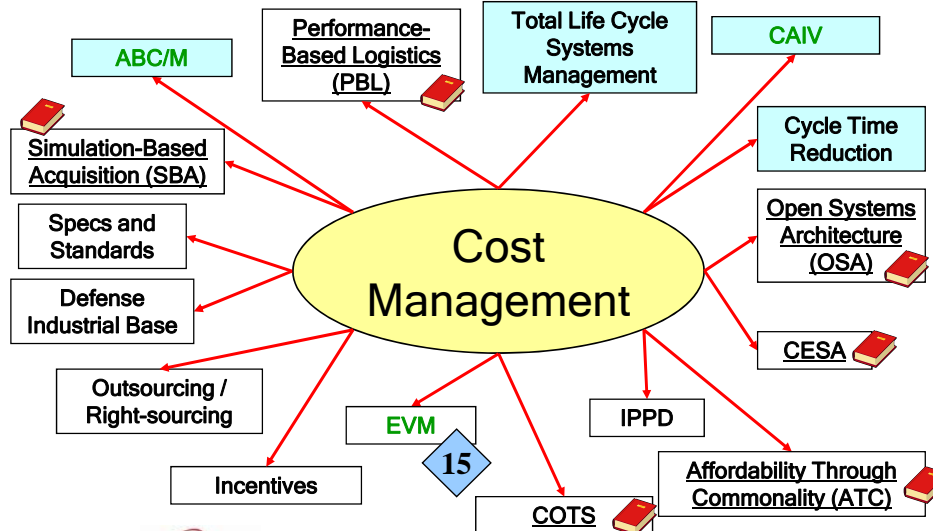


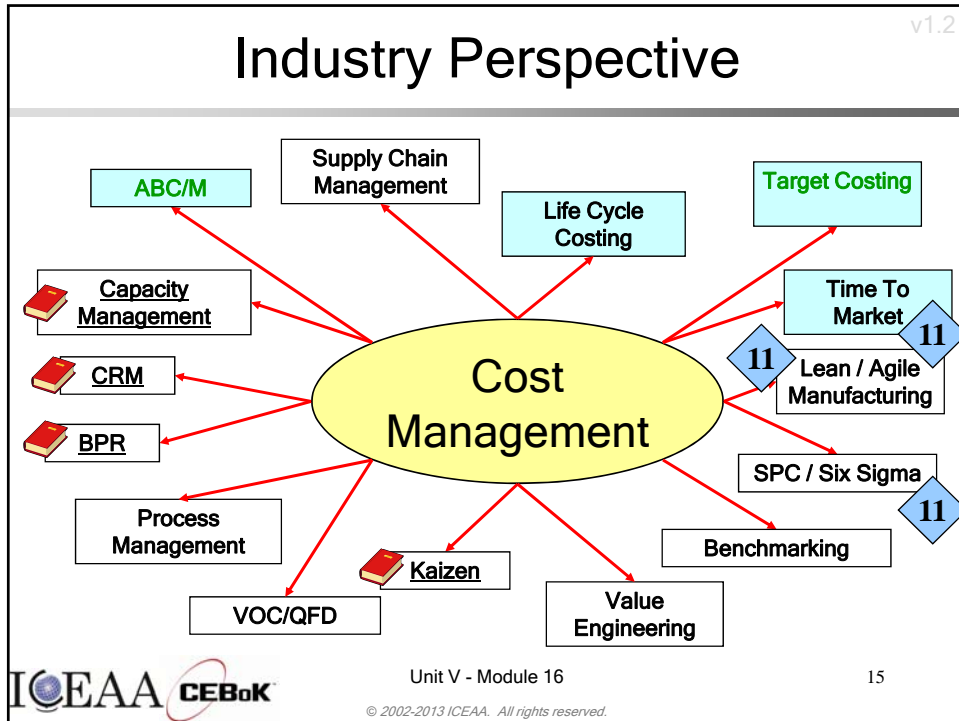
How To Make Things Cheaper

- Do Less
 - No one wants to give up performance
- Do It Better
 - No one will argue with increased efficiency or other improvements
- Do It Differently
 - Everybody's looking for the "silver bullet" that will bring increased performance at reduced cost

"Better, Faster, Cheaper"

Government Perspective





v1.2

Trade Challenges - Bottom Line

- 📖 • **“Linkage”** - To trade, you must be able to show **cost for each alternative**
 - Some alternatives are hard to cost out
 - Costs don't change if CER input variables don't include the parameter you changed
 - Even if possible, the volume and speed of trades can make linkage hard
- 📖 • **“Exchange Rate”** - To trade, you must know the **dollar value of performance** 📖
 - What is one knot of speed worth?
 - What is the dollar value of greater accuracy?

Unit V - Module 16

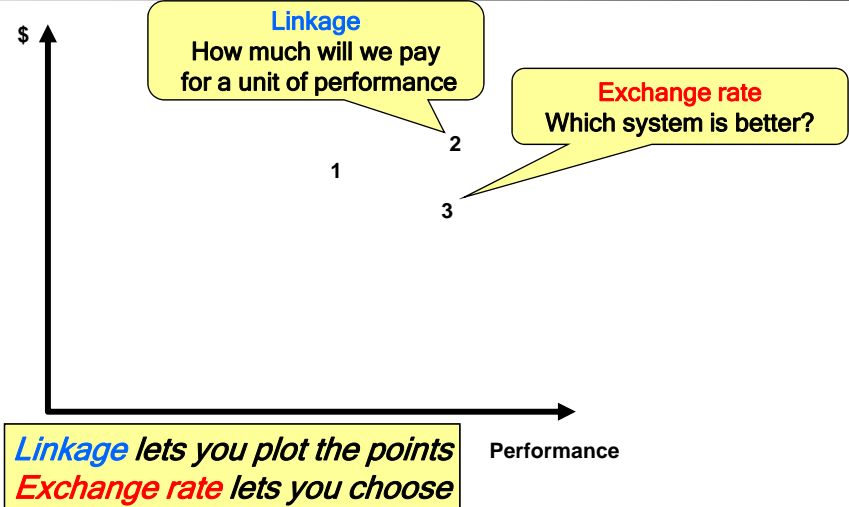
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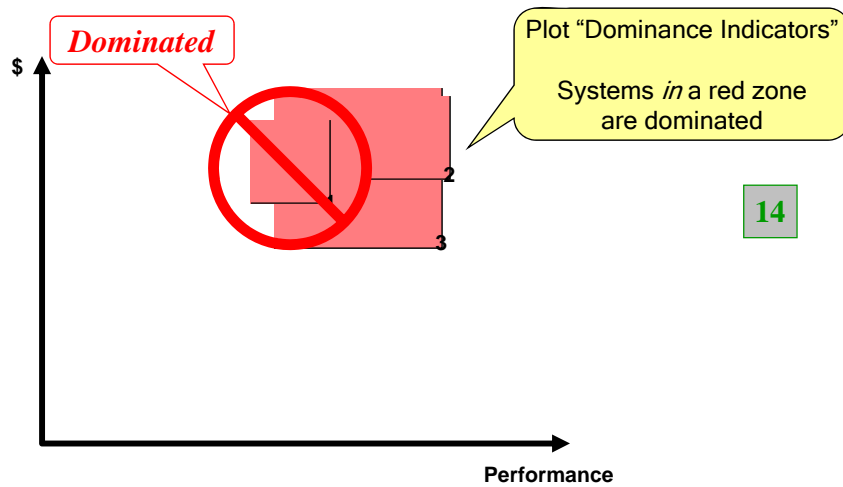
Linkage and Exchange Rate

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Strict Dominance

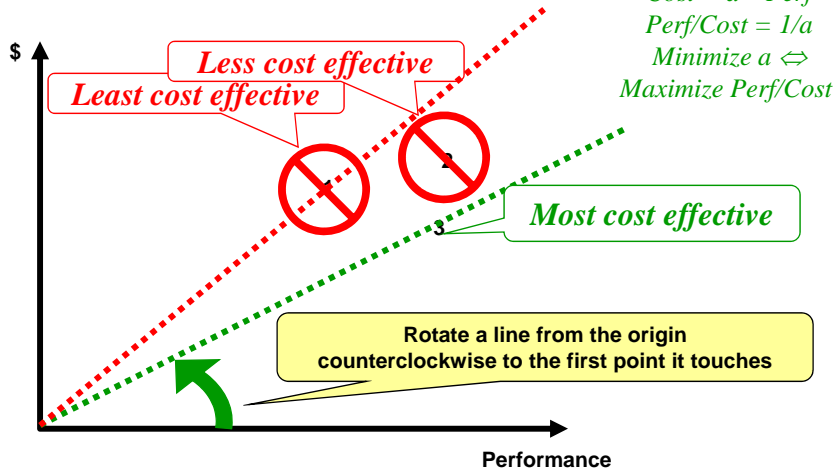
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Best "Bang for the Buck"

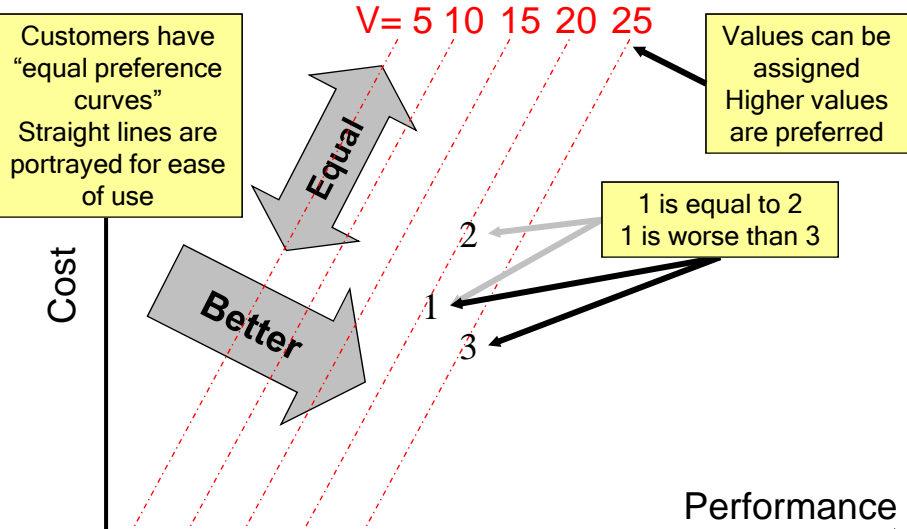
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When unit cost is paramount



Exchange Rate

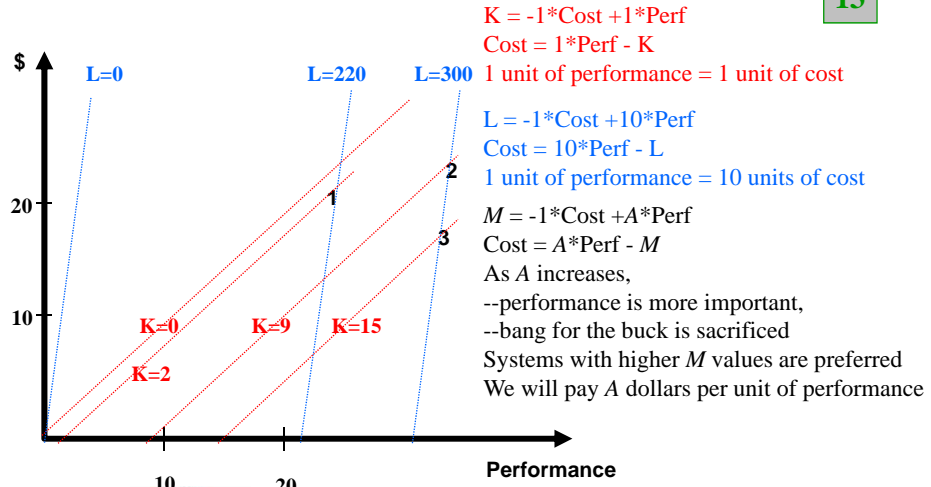
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Exchange Rate

When you know the "Dollar Value" of Performance

13



Trade Space Boundaries - Thresholds and Objectives

This is the crucial corner of the trade space. We must end up below (affordable) and to the right (militarily useful).

