MORS Introduction to Cost Estimation (Part I)

Module Four – Phase 2: Assessment (Develop Point Estimate)

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Module Four

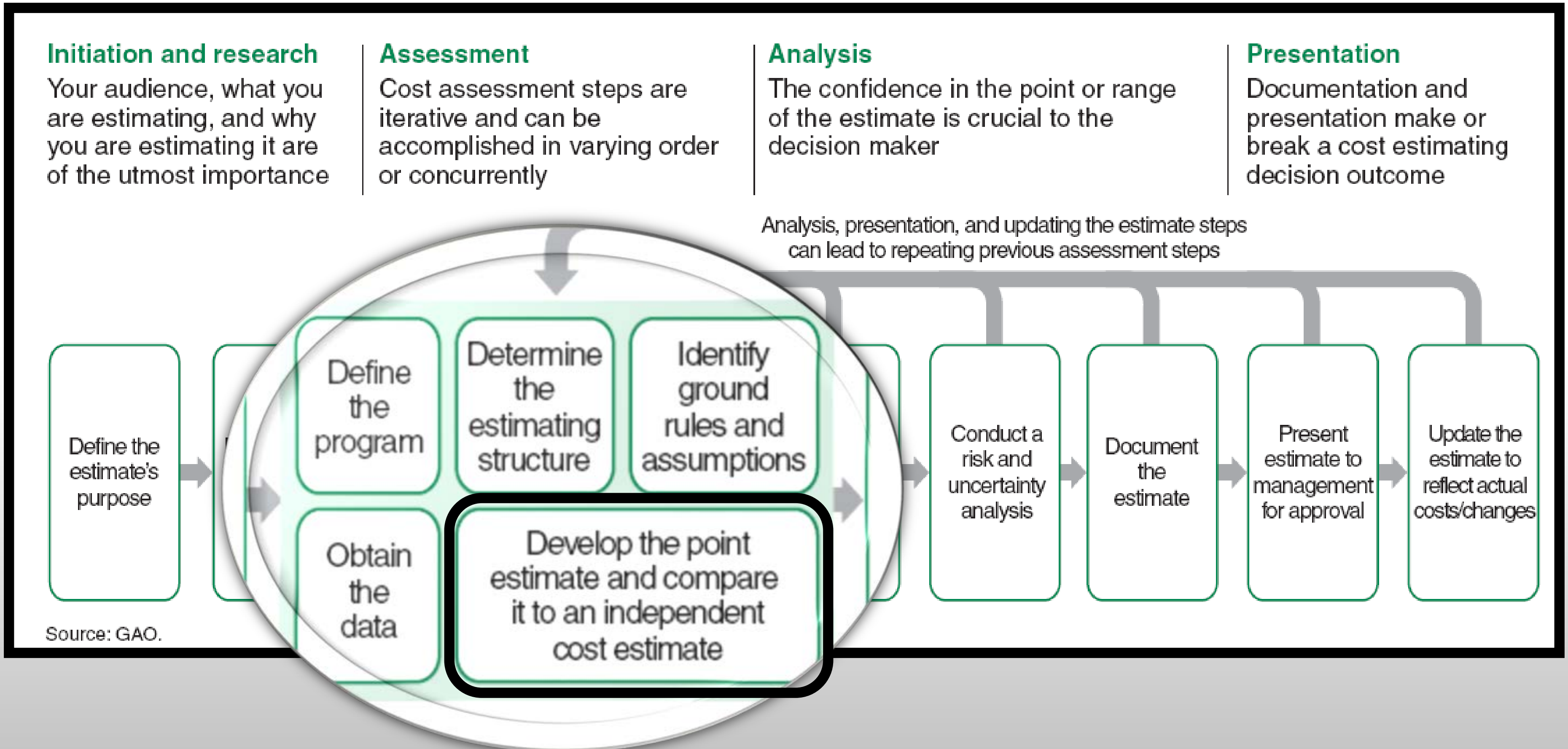
Module #(s)	Items covered	Presenter	Start	Stop
One & Two	(1) Overview and Background (1) Define Estimate's Purpose (1) Develop Estimate Plan -- (2) Define Program (2) Determine Estimate Structure (2) Identify Ground Rules and Assumptions	Huu	13:00	14:30
Break	N/A		14:30	14:45
Three	**Obtain data**	**Huu**	**14:45**	**15:45**
Break	N/A		15:45	16:00
Four	**Develop point estimate**	**Huu**	**16:00**	**17:00**

Learning Objectives of Module Four

1. Understand how to develop a cost model
2. Understand how to output the cost estimate in various formats
3. Understand how to validate the costs
4. Understand how to compare the estimate against an independent cost estimate

Note: Software cost estimating (Chapter 12) only covered in checklist at end

Phase 2: Assessment
Step Seven



Steps to Develop a Point Estimate

1. Develop cost model by estimating each WBS element, using the best methodology from the data collected (**right amount**)
2. Include all estimating ground rules and assumptions in the cost model
3. Time phase the results by spreading costs in the years expected, based on program schedule (**right year**)
4. Add the WBS elements to develop the overall estimate
5. Output the costs in the appropriate format
   - Constant year dollars, then year dollars, discounted dollars as required
   - Average Procurement Unit Cost (APUC) and Program Acquisition Unit Cost (PAUC) for Acquisition Program Baseline (APB)
   - By appropriation (**right color of money**) for the budget charts

Goal: The right amount, of the right color of money, in the right year!

Estimate Each WBS

Parametric Example

Estimating Method	Explanation
Parametric	A mathematical procedure where product or service descriptors (parameters) and cost algorithms directly yield consistent cost information.

Table 14: An Example of the Parametric Cost Estimating Method

Program attribute	Calculation
A cost estimating relationship (CER) for site activation (SA) is a function of the number of workstations (NW)	SA = $82,800 + ($26,500 x NW)
Data range for the CER	7–47 workstations based on 11 data points
Cost to site activate a program with 40 workstations	$82,800 + ($26,500 x 40) = $1,142,800

Source: © 2003, Society of Cost Estimating and Analysis (SCEA), "Costing Techniques."

- Number of workstations is considered the cost driver
- Always show statistics with the regression
- Keep within range of the data
- Do sanity check on the equation to include zero intercept
- Parametric models always useful for cross-checks

Estimate Each WBS

Analogy Example

Estimating Method	Explanation
Analogy	Under this method, costs for a new item are estimated using comparisons with the cost of completing similar tasks under past or current contracts. Any differences are isolated and cost elements applicable to the differences are deleted from or added to experienced costs. Comparisons may be made at the cost element level or total price level. Adjustments may also be made for possible upward or downward cost trends. Most commonly used when specifications for the item being estimated are similar to other items already produced or currently in production and for which actual cost experience is available.

Table 12: An Example of the Analogy Cost Estimating Method

Parameter	Existing system	New system	Cost of new system (assuming a linear relationship)
Engine	F-100	F-200	
Thrust	12,000 lbs	16,000 lbs	
Cost	$5.2 million	X	(16,000/12,000) x $5.2 million = $6.9 million

Source: © 2003, Society of Cost Estimating and Analysis (SCEA), "Costing Techniques."

- Determined by engineering SMEs that an engine's cost is directly proportional to it's thrust
- This methodology depends on only one data point – strongly consider another cross-check.
- Ensure the new system input is captured in next step – uncertainty

Estimate Each WBS

Engineering Buildup Example

Estimating Method	Explanation
Engineering Buildup	This method is characterized by a thorough review of all components, processes, and assemblies. It requires detailed information to arrive at estimated costs and typically uses cost data derived from the accounting system, adjunct statistical records, and other sources. Most commonly used when the required information is available and future production potential warrants the cost of the detailed analysis required. It is the most accurate of the three methods for estimating direct cost. It is also the most time consuming and expensive.

Table 13: An Example of the Engineering Build-Up Cost Estimating Method

Problem	Similar aircraft	Solution	Result
Estimate sheet metal cost of the inlet nacelle for a new aircraft	F/A-18 inlet nacelle	Apply historical F/A-18 variance for touch labor effort and apply support labor factor to adjust estimated touch labor hours	2,000 hours x 1.2 = 2,400 touch labor hours and 2,400 labor hours x 1.48 = 3,522 labor hours (touch labor plus support labor) estimate for new aircraft **Correct is 3,552 hours**
Standard hours to produce a new nacelle are estimated at 2,000 for touch labor; adjust to reflect experience of similar aircraft and support labor effort	F/A-18 inlet nacelle experienced a 20% variance in touch labor effort above the industrial engineering standard. In addition, F/A-18 support labor was equal to 48% of the touch labor hours		Average labor rates would then be used to convert these total labor hours into costs

Source: © 2003, Society of Cost Estimating and Analysis (SCEA), "Costing Techniques."

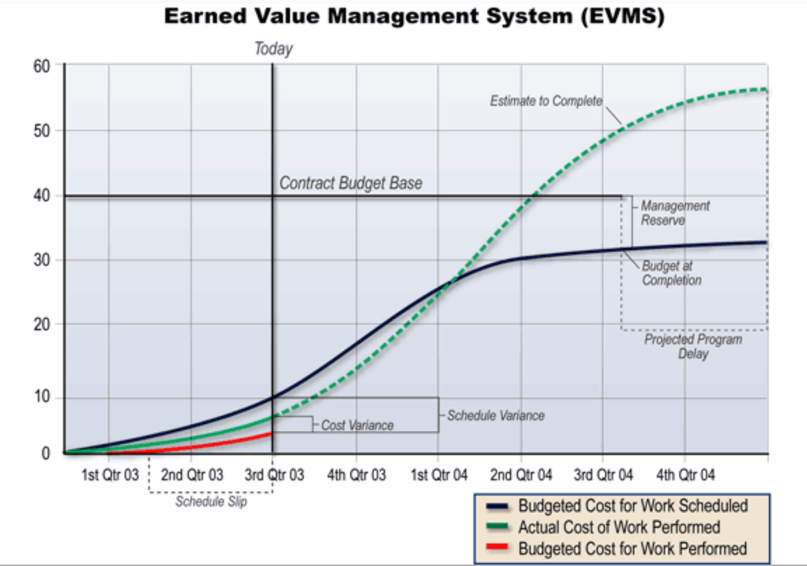
- Normally used during program production phase, when configuration stabilized

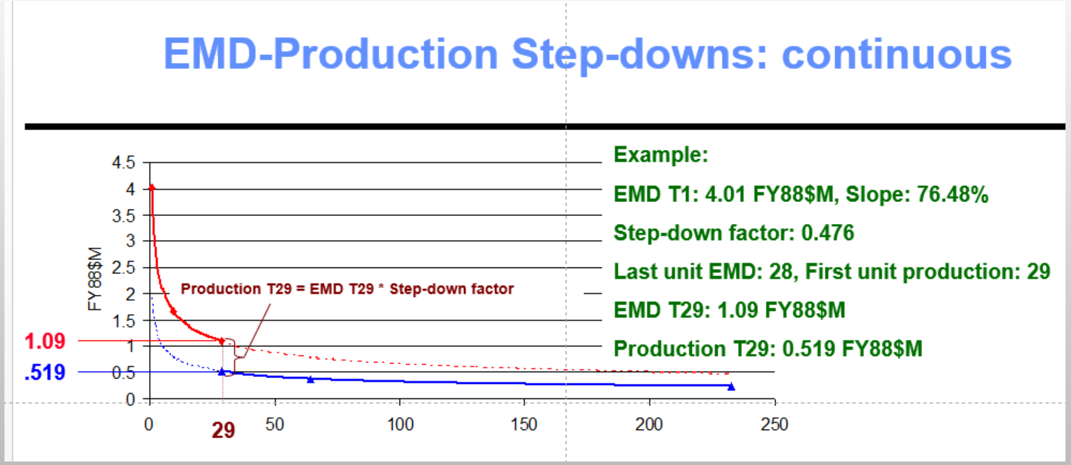
Estimate Each WBS

Extrapolation of Actuals Example

Estimating Method	Explanation
Extrapolation of Actuals	Extrapolation method requires prototype or preproduction actual cost data on the system considered. Primarily used in estimating the production cost of system hardware, and assumes a relationship (technical, performance) between cost of prototypes and production units.

- Normal cases include:
  - Projection for Estimate to Complete using Earned Value Management
  - Actuals from CSDRs from earlier phase of same program





Time Phasing of Results

- Start and stop of each WBS item dependent on program schedule (IMS) and “CARD”
- Ensure the yearly phasing is cross-checked and analyzed across all phases (EMD, Production, Operating & Support)
  - Testing
  - System Engineering / Program Management
  - Other WBSs may be applicable
- Careful analysis given for each appropriation depending on how many years of outlay

Output Costs in Appropriate Format

Aircraft Procurement (Base Year = FY15)

WBS	FY16	FY17	FY18	FY19	Total
Total Costs (**FY15$M**)	**$15.2**	**$31.3**	**$28.5**	**$16.7**	**$91.7**
APN Weighted Index (WI)	1.0489	1.0702	1.0914	1.1132	
Total Costs (**TY$M**) = FY15$M x WI	**$16.0**	**$33.5**	**$31.1**	**$18.6**	**$99.2**
Total Benefits (**TY$M**)	**-$2.2**	**-$3.7**	**-$4.1**	**-$2.3**	**-$12.3**
Total Cost and Benefits (**TY$M**)	**$13.8**	**$29.8**	**$27.0**	**$16.3**	**$86.9**
Nominal Discount Rate = 7% per year $= 1/(1+i)^t$, where i is the interest rate (.07) per t year	.9346 (t=1)	.8734 (t=2)	.8163 (t=3)	.7629 (t=4)	
Net Present Value of Cost and Benefits = Total Cost and Benefits (TY$M) x Nominal Discount Rate	**$12.9**	**$26.0**	**$22.0**	**$12.4**	**$73.3**
Total Procurement Quantities	**12**	**16**	**18**	**15**	**61**
Average Procurement Unit Cost (APUC) = Total Procurement Costs / Total Procurement Quantities	**APUC (FY15$M) = $91.7/61 = $1.5**		**APUC (TY$M) = $99.2/61 = $1.62**		
Budgetary - Aircraft Procurement, Navy (Budget Activity 1) – APN 1 (TY$M)	**$14.7**	**$30.8**	**$28.6**	**$17.1**	**$91.2**
Budgetary - Aircraft Procurement, Navy (Budget Activity 6) – APN 6 (TY$M)	**$1.3**	**$2.7**	**$2.5**	**$1.5**	**$8.0**

Independent Cost Estimate

Validating the Estimate (Step 1)

1. Determine That the Estimate is Well documented

Cost estimate characteristic	Cost estimating step
Well documented	
The estimate is thoroughly documented, including source data and significance, clearly detailed calculations and results, and explanations for choosing a particular method or reference ▪ Data are traced back to the source documentation ▪ Includes a technical baseline description ▪ Documents all steps in developing the estimate so that a cost analyst unfamiliar with the program can recreate it quickly with the same result ▪ Documents all data sources for how the data were normalized ▪ Describes in detail the estimating methodology and rationale used to derive each WBS element's cost	1. Define the estimate's purpose 3. Define the program 5. Identify ground rules and assumptions 6. Obtain the data 10. Document the estimate 11. Present the estimate to management

Independent Cost Estimate

Validating the Estimate (Step 2 and 3)

2. Determine That the Estimate Is Comprehensive

Comprehensive	Cost Estimating Step
The estimate's level of detail ensures that cost elements are neither omitted nor double counted ▪ Details all cost-influencing ground rules and assumptions ▪ Defines the WBS and describes each element in a WBS dictionary ▪ A major automated information system program may have only a cost element structure	2. Develop the estimating plan 4. Determine the estimating approach

3. Determine That the Estimate is Accurate

Accurate	Cost Estimating Step
The estimate is unbiased, not overly conservative or overly optimistic, and based on an assessment of most likely costs ▪ It has few, if any, mathematical mistakes; its mistakes are minor ▪ It has been validated for errors like double counting and omitted costs ▪ Cost drivers have been cross-checked to see if results are similar ▪ It is timely ▪ It is updated to reflect changes in technical or program assumptions and new phases or milestones ▪ Estimates are replaced with EVM EAC and the independent EAC from the integrated EVM system	7. Develop the point estimate and compare it to an independent cost estimate 12. Update the estimate to reflect actual costs and changes

Independent Cost Estimate

Validating the Estimate (Step 2 and 3)

4. Determine That the Estimate Is Credible

Credible	Cost Estimating Step
Discusses any limitations of the analysis from uncertainty or biases surrounding data or assumptions ▪ Major assumptions are varied and other outcomes recomputed to determine their sensitivity to changes in assumptions ▪ Risk and uncertainty analysis is performed to determine the level of risk associated with the estimate ▪ An independent cost estimate is developed to determine if other estimating methods produce similar results	7. Develop the point estimate and compare it to an independent cost estimate 8. Conduct sensitivity analysis 9. Conduct risk and uncertainty analysis

Source: GAO.

Best Practices Checklist #7a

Develop the Point Estimate and Compare it to an Independent Cost Estimate

- The cost estimator considered various cost estimating methods:
  - Analogy is used early in the life cycle when little information is known and data is adjusted for new estimate
  - Expert opinion is used very early on when estimate can be derived no other way
  - The build-up method later, in acquisition, when the scope of work is well defined / WBS complete
  - Parametrics used if a sufficient database exists and data has been normalized correctly
  - Extrapolating from actual cost data at the start of production
  - Before using a CER, the cost estimator
    - Examined the underlying data set to understand anomalies
    - Checked equations to ensure logical relationships
    - Normalized the data
    - Ensured that CER inputs were within the valid dataset range
    - Checked modeling assumptions to ensure they applied to the program

Best Practices Checklist #7b

Develop the Point Estimate and Compare it to an Independent Cost Estimate

- ❑ Learning curve theory was applied if:
  - Much manual labor was required for production
  - Production was continuous or adjustments had to be made
  - Items to be produced required complex processes
  - Technological change was minimal between production lots
  - The contractor’s business process was being continually improved
  - Production rate and breaks in production were considered
- ❑ The point estimate was developed by aggregating the WBS element cost estimates by one of the cost estimating methods
- ❑ Results were checked for accuracy, double-counting, and omissions and were validated with cross-checks and independent cost estimates

Best Practices Checklist #7c

Develop the Point Estimate and Compare it to an Independent Cost Estimate (Estimating Software)

- ❑ Software was sized with detailed knowledge of program scope, complexity, and interactions
- ❑ It was sized with source lines of code, function, object, feature point, or other counts
- ❑ The software sizing method was appropriate:
  - Source lines of code were used if requirements were well defined and if there was a historical database of code counts for similar programs and a standard definition for a line of code
  - Function points were used if detailed requirements and specifications were available, software did not contain a lot of algorithmic functions, and an experienced and certified function point counter was available
  - Feature points were used instead of function points if the software had a high degree of algorithms
  - Object points were used if computer-aided software engineering tools were used to develop the software
  - Use cases were used if system and user interactions were defined
  - Auto-generated and reused source lines of code were identified separately from new and modified code to account for pre-implementation and post-implementation efforts

Best Practices Checklist #7d

Develop the Point Estimate and Compare it to an Independent Cost Estimate (Estimating Software)

- ❑ Software cost estimates included:
  - Development labor costs for coding and testing, other labor supporting software development, and non-labor costs like purchasing hardware and licenses.
  - Productivity factors for converting software size into labor effort, based on historical data and calibrated to match program size and development environment
- ❑ If no historical data were available, industry average productivity factors and risk ranges were used
- ❑ Assumptions about productive labor hours in a day and work days in a year
- ❑ Development schedules accounting for staff availability, prior task dependencies, concurrent and critical path activities, number and length of shifts, overtime allowance, down time, and worker locations
- ❑ Costs for help desk support and corrective, adaptive, and preventive maintenance as part of the software's life cycle cost
- ❑ Cost estimators were trained to calibrate parametric tools to match the program
- ❑ Estimators accounted for integrating commercial off-the-shelf software into the system, including developing custom software and glue-code

Review of Learning Objectives of Module Four

1. Understand how to develop a cost model
2. Understand how to output the cost estimate in various formats
3. Understand how to validate the costs
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Practical Example

See Word Handout

- WBS Element and Description
- Ground Rules and Assumptions
- Data and Data Sources
- How we picked methodology based on WBS element and data available and stage of program
- Phasing of Element
- Color of Money
- Constant Dollars, Then Year Dollars, and Discounted Dollars

Note: Sensitivity, uncertainty, and documentation covered in later modules

Course Wrap-Up

- Hand in Course Critique
- Way Ahead for MORS Introduction to Cost Estimation (Part II)
  - Steps 8 though 12
- Instructor Contact Info.
  - Huu M. Hoang, (703) 697 - 1606, huu.m.hoang.civ@mail.mil

Backup

…In the Cost Guide

Step	Description	Cost Guide Chapter	Phase in Process
1	Define estimate's purpose	5	Initiation & Research
2	Define estimate's plan	5, 6	Initiation & Research
3	Define program characteristics	7	Assessment
4	Determine estimating structure	8	Assessment
5	Identify GR&As	9	Assessment
6	Obtain data	10	Assessment
7	Develop point estimate and compare	11, 12, 15	Assessment
8	Conduct sensitivity analysis	13	Analysis
9	Conduct risk & uncertainty analysis	14	Analysis
10	Document the estimate	16	Analysis
11	Present estimate to management	17	Presentation
12	Update the estimate	16, 18, 19, 20	Presentation

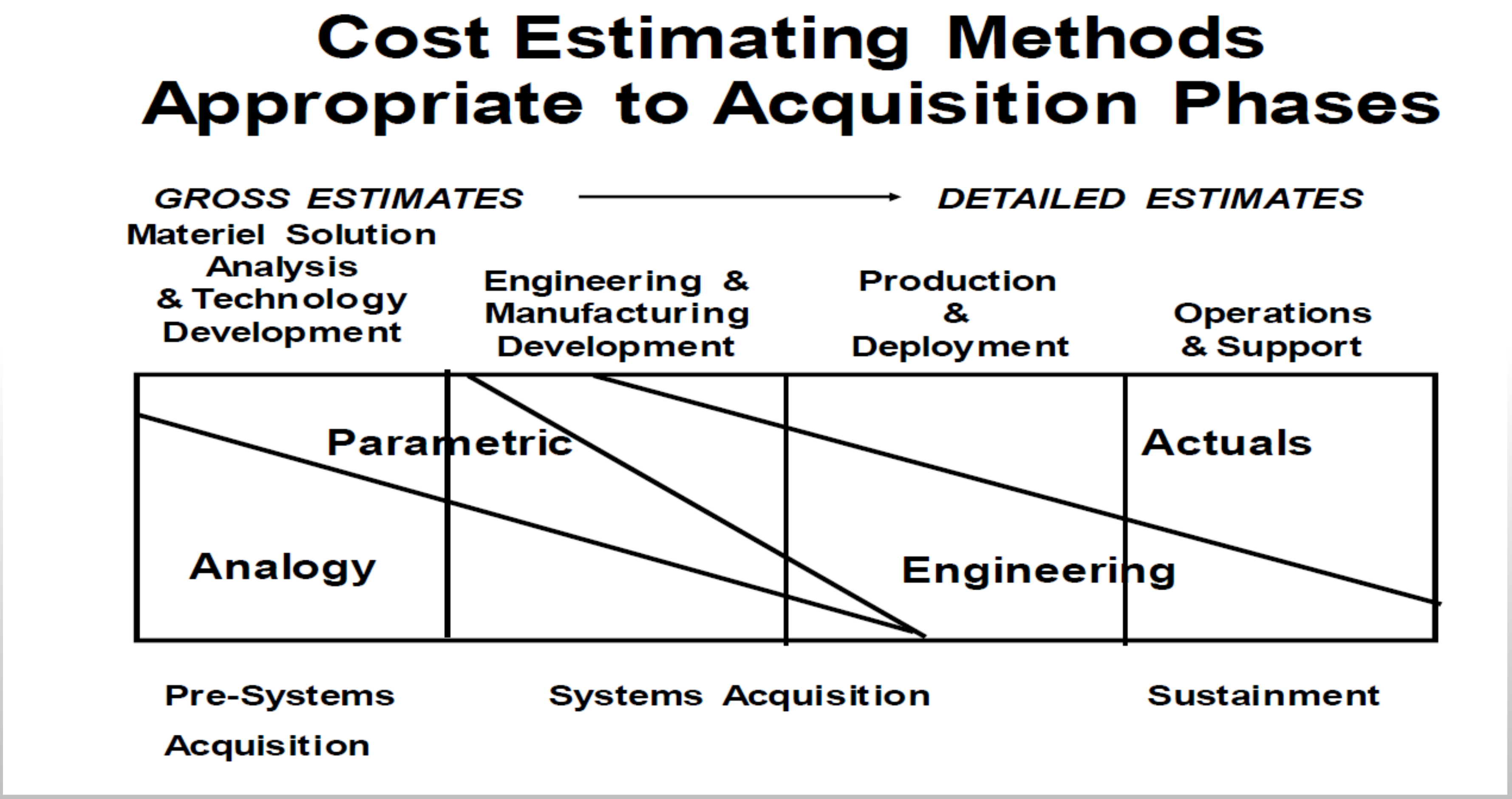
Step 4: Determine the Estimating Approach

Definitions of Four Major Estimating Methods

Estimating Method	Explanation
Parametric	A mathematical procedure where product or service descriptors (parameters) and cost algorithms directly yield consistent cost information.
Analogy	Under this method, costs for a new item are estimated using comparisons with the cost of completing similar tasks under past or current contracts. Any differences are isolated and cost elements applicable to the differences are deleted from or added to experienced costs. Comparisons may be made at the cost element level or total price level. Adjustments may also be made for possible upward or downward cost trends. Most commonly used when specifications for the item being estimated are similar to other items already produced or currently in production and for which actual cost experience is available.
Engineering Buildup	This method is characterized by a thorough review of all components, processes, and assemblies. It requires detailed information to arrive at estimated costs and typically uses cost data derived from the accounting system, adjunct statistical records, and other sources. Most commonly used when the required information is available and future production potential warrants the cost of the detailed analysis required. It is the most accurate of the three methods for estimating direct cost. It is also the most time consuming and expensive.
Extrapolation of Actuals	Extrapolation method requires prototype or preproduction actual cost data on the system considered. Primarily used in estimating the production cost of system hardware, and assumes a relationship (technical, performance) between cost of prototypes and production units.

Step 4: Determine the Estimating Approach

Choose "Best" Estimating Methodology (When to Use)



DAU Teaching Note of February 2011

Step 4: Determine the Estimating Approach

Choose "Best" Estimating Methodology (Types, Pros/Cons)

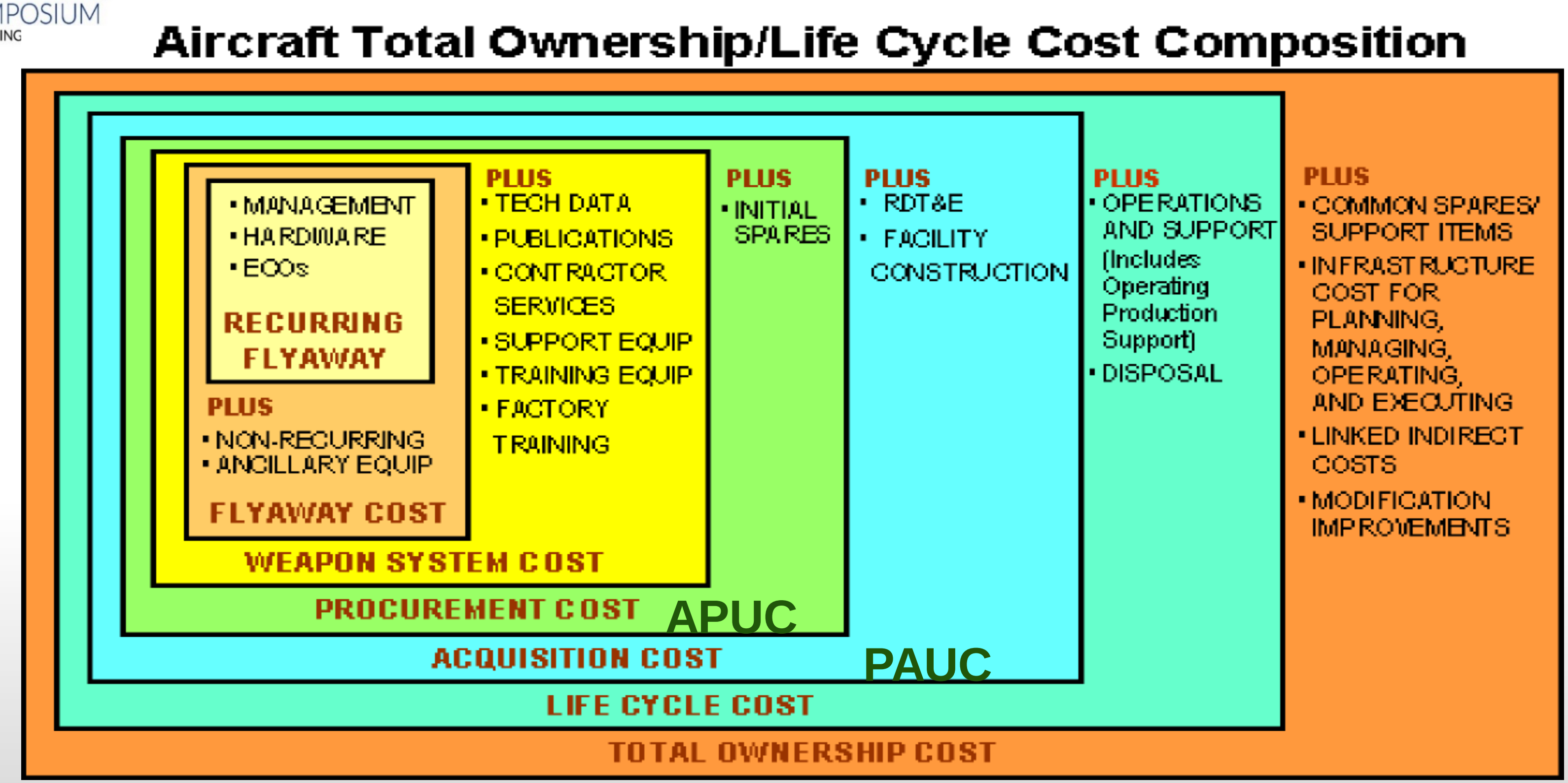
TD Phase . . . . Production Phase

	Estimating Method			
	Parametric	**Analogy**	**Engineering Buildup**	**Extrapolation from Actuals**
Relative Accuracy	**Low** -- because limited data are used	**Moderate/High** --depending on data, technique, and estimator	**High** -- based on engineering principles	**High -** based on actuals
Relative Estimator Consistency	**Low** -- different experts make different judgments	**Moderate/High** --depending on data, technique, and estimator	**High** -- based on uniform principle application	**High -** based on actuals
Relative Development Speed	**Fast** -- little detailed analysis required	**Moderately Fast** -- especially with repetitive use	**Slow** -- requires detailed design and analysis	**Moderately Fast** -- especially with repetitive use
Relative Estimate Development Cost	**Low** -- fast development and limited data requirements allow low development cost	**Moderate** -- depending on the need for data collection and analysis	**High** -- detailed work design and analysis require time and increase cost	**Moderate** -- depending on the need for data collection and analysis
Relative Data Requirements	**Low** -- based on expert judgment	**Moderate** -- only requires historical data	**High** -- requires detailed work design and analysis	**Moderate** -- only requires historical data

No method is more or less correct, depends on data available and WBS element.

Background

Life Cycle Cost Versus Total Ownership Cost



- Average Procurement Unit Cost (APUC) = Total Procurement Cost / Total Procurement Quantities
- Program Acquisition Unit Cost (PAUC) = Total Acquisition Cost / Total Acquisition Quantities (RDT&E + Procurement)

Step 5: Identify Ground Rules and Assumptions
Ground Rules vs. Assumptions

Ground Rules	Assumptions
• Low Rate Initial Production (LRIP) will begin in 2018	• Labor rate for a carpenter is $31/Hr
• The Operating and Support period will be 30 years	• Empty aircraft weight is 42,000 lbs.
• Costs are in Base Year 2014 Dollars	• Non-recurring costs are 2.54 times the amount of recurring costs

Outlay Rates (Outdated)

Appropriation	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	Sum
MPN	91.8%	7.5%	0.7%					100.0%
O&MN	58.6%	32.2%	4.3%	2.2%	1.1%	1.6%		100.0%
RDT&E	51.8%	38.8%	6.2%	1.1%	0.3%	0.2%	1.6%	100.0%
APN	24.9%	37.8%	25.6%	7.1%	2.2%	1.0%	1.4%	100.0%
WPN	26.0%	31.6%	23.4%	11.5%	3.5%	2.0%	2.0%	100.0%
SCN	14.0%	26.0%	20.0%	15.0%	12.5%	8.0%	4.5%	100.0%

Cumulative Outlays

	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	Obligation Period (yrs)
MPN	**91.8%**	99.4%	100.0%					1
O&MN	58.6%	**90.8%**	95.1%	97.3%	98.4%	100.0%		1
RDT&E	51.8%	**90.6%**	96.8%	97.9%	98.2%	98.5%	100.0%	2
APN	24.9%	62.7%	88.3%	**95.4%**	97.6%	98.6%	100.0%	3
WPN	26.0%	57.6%	81.0%	**92.5%**	96.0%	98.0%	100.0%	3
SCN	14.0%	40.0%	60.0%	75.0%	87.5%	**95.5%**	100.0%	5

Practical Problem Answer Slide 1 of 3

Hours Calculation		Factor	Total	
Touch =	2,000	1.2	**2,400**	Factor from analogy F/A-18
Support =		0.48	**1,152**	Support factor of touch from engineering judgment (SME)
Fee =			0.12	
Aircraft Quantities	FY16	FY17	FY18	
	5	6	8	

Direct Rates 2014 BY14$

Labor Category	KTR A	KTR B	KTR C
Touch labor III	$30.42	$35.67	$32.45
Engineering Support II	$38.74	$37.95	$36.29

Direct Rates BY15$ from BY14$

Raw Index from 2014$ to 2015$ = 1.0140

Labor Category	KTR A	KTR B	KTR C	Average	Median	
Touch labor III	$30.85	$36.17	$32.90	**$33.31**	$32.90	**Used Average Rates for each category**
Engineering Support II	$39.28	$38.48	$36.80	**$38.19**	$38.48	

Indirect rates — Used Average of all three averages of the KTRs

Prime	2014	2015	2016	2017	2018	**Average**	**Stand. Dev.**	CV= SD/Average
A	2.76	2.76	2.77	2.78	2.75	**2.764**	0.010	0.4%
B	2.87	2.88	2.87	2.86	2.88	**2.872**	0.007	0.3%
C	3.05	3.06	3.05	3.05	3.06	**3.054**	0.005	0.2%

Average of all three averages = 2.8967

Practical Problem Answer Slide 2 of 3

MORS SYMPOSIUM
FIFTY YEARS SECURING THE NATION

Total Rate for each category equals average rate across three KTRs times average Wrap Rate for all three KTRs				
	No Fee	With Fee		
Touch labor III	$ 96.48	$ 108.06		
Engineering Support II	$ 110.62	$ 123.89		
Total Labor for each category equals number of aircraft times hours per aircraft times total rate per hour.				
BY15$	FY16	FY17	FY18	Total
Touch labor III	$ 1,296,663	$ 1,555,995	$ 2,074,660	$ 4,927,319
Engineering Support II	$ 713,604	$ 856,325	$ 1,141,766	$ 2,711,695
Total Touch and Support	$ 2,010,267	$ 2,412,320	$ 3,216,427	$ 7,639,014
But they asked for this in BY15$M				
BY15$M	FY16	FY17	FY18	Total
Touch labor III	$ 1.30	$ 1.56	$ 2.07	$ 4.93
Engineering Support II	$ 0.71	$ 0.86	$ 1.14	$ 2.71
Total Touch and Support	$ 2.01	$ 2.41	$ 3.22	$ 7.64
Output in TY$M	FY16	FY17	FY18	
Weighted from BY$15 to TY$				
(Aircraft Procurement, Navy)	**1.049856396**	**1.07017605**	**1.09141888**	
TY$M	FY16	FY17	FY18	Total
Touch labor III	$ 1.36	$ 1.67	$ 2.26	$ 5.29
Engineering Support II	$ 0.75	$ 0.92	$ 1.25	$ 2.91
Total Touch and Support	$ 2.11	$ 2.58	$ 3.51	$ 8.20

Practical Problem Answer Slide 3 of 3

Discounted stream for Economic Analysis, Nominal Discount Rate = 7% per year				
	FY16	FY17	FY18	
Discount Stream	**0.9346**	**0.8734**	**0.8163**	
Net Present Value of Cost Only (No Benefits)	FY16	FY17	FY18	Total
Touch labor III	$ 1.27	$ 1.45	$ 1.85	$ 4.58
Engineering Support II	$ 0.70	$ 0.80	$ 1.02	$ 2.52
Total Touch and Support	$ 1.97	$ 2.25	$ 2.87	$ 7.09

- So how do we feel about this point estimate (not final answer)?
  - Strengths
  - Weaknesses
- Looking ahead at next steps, what can we do?
  - Sensitivity
  - Uncertainty
  - Documentation
  - Updating the estimate