# Modeling of Life Cycle / Operations & Support Costs

## To what degree is commonality achievable?

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**Prepared by**
**Life Cycle Cost Modeling Subcommittee**
**Modeling and Simulation Committee**
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# Life Cycle Cost Modeling Subcommittee Charter

- **Assess the degree to which Life Cycle Cost (LCC) Models, but more particularly, Operations and Support (O&S) Cost Models, can achieve more commonality**
  - Include both modeling tools and supporting data
  - Consider commonality both within similar system classes (e.g., aircraft), and across different system classes
- **Focus on cost modeling for new systems, and for upgrades to existing systems, early in the acquisition process**
  - Consider factors that affect cost model accuracy at this stage

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## Life Cycle Cost Modeling Subcommittee Membership

- Chris Price (Raytheon), Subcommittee Chair
- Danielle Anderson (Raytheon)
- Rick Cline (Boeing)
- Jim Coolahan (JHU/APL), M&S Committee Chair
- Jerry Cothran (Lockheed Martin)
- Phil Fahringer (Lockheed Martin)
- Charlie Stirk (CostVision)
- Andreas Tolk (Old Dominion University)

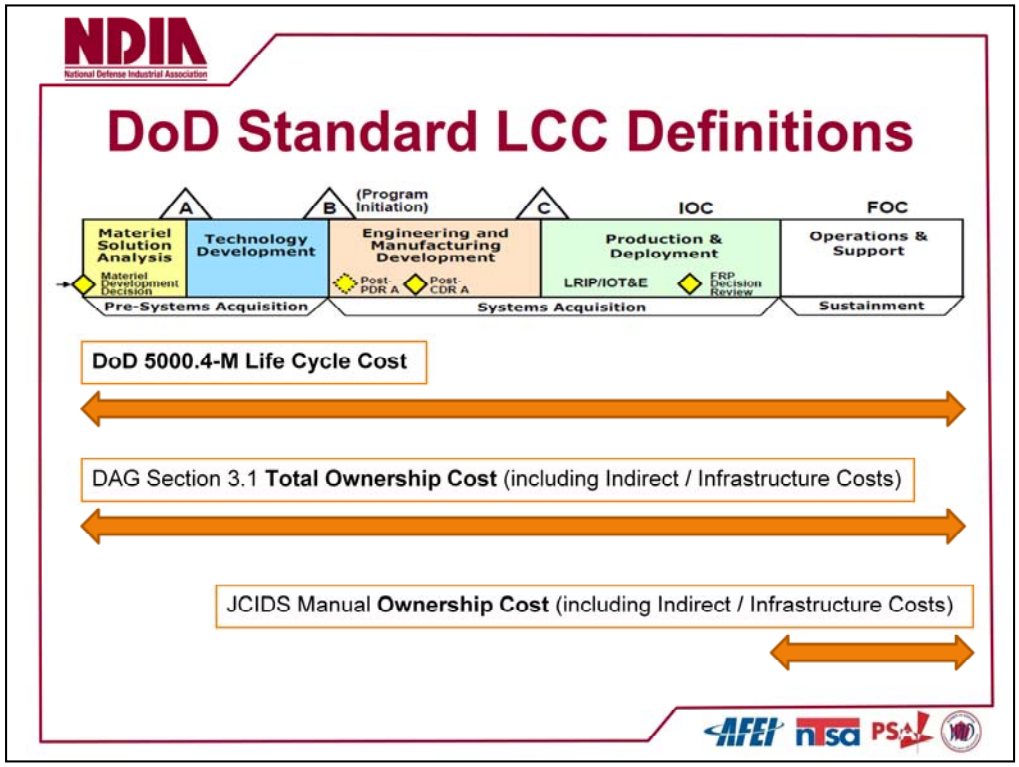
## Presentation Outline

- **Background**
- **Cost Definitions (TOC, LCC, O&S)**
- **How O&S Modeling Is Done Now**
  - Tools, Data
- **Some Data on LCC/O&S Cost Overruns**
- **Why Might Cost Estimates Be "Biased Low"?**
- **Commonalities and Differences in O&S Cost Structures**
  - Within and Across Platform/System Types
- **To What Degree Can LCC/O&S Cost Models Be Common?**

## Background

- **The Department of Defense (DOD) spends billions of dollars each year to sustain its weapon systems. These operating and support (O&S) costs can account for a significant portion of a system's total life-cycle costs …**
- **DOD lacks key information needed to effectively manage and reduce O&S costs for most of the weapon systems GAO reviewed—including life-cycle O&S cost estimates and complete historical data on actual O&S costs. The services did not have life-**

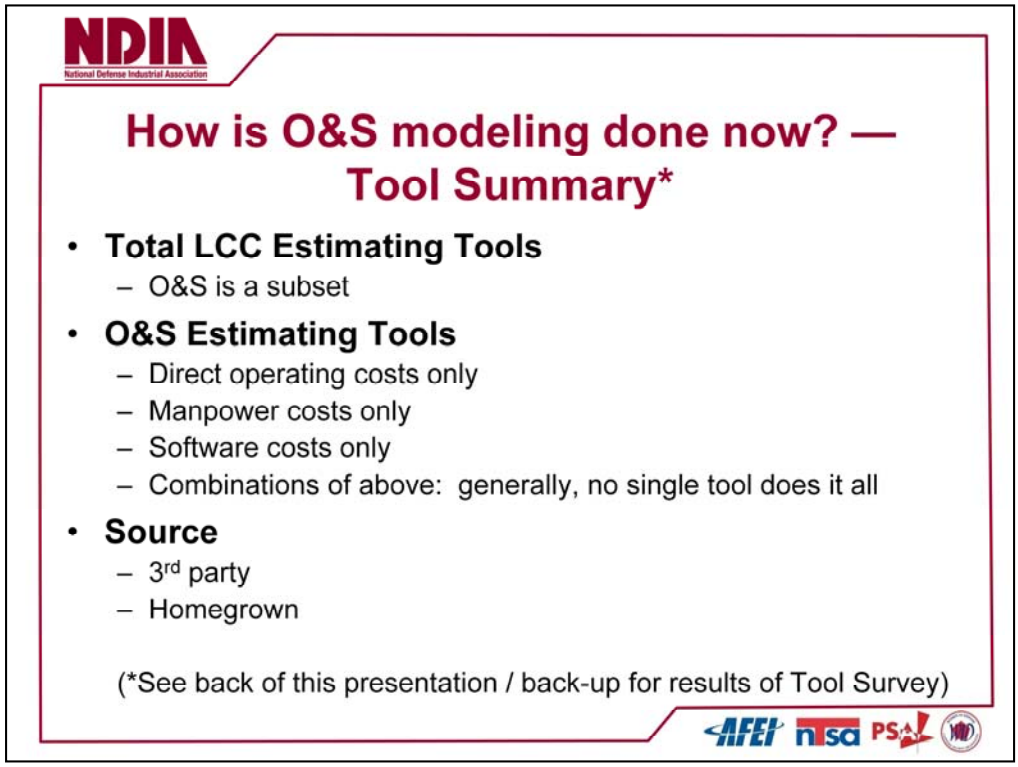
GAO-10-717 'DoD needs better Info. & Guidance to Reduce O&S' July 2010




LCC Definitions:

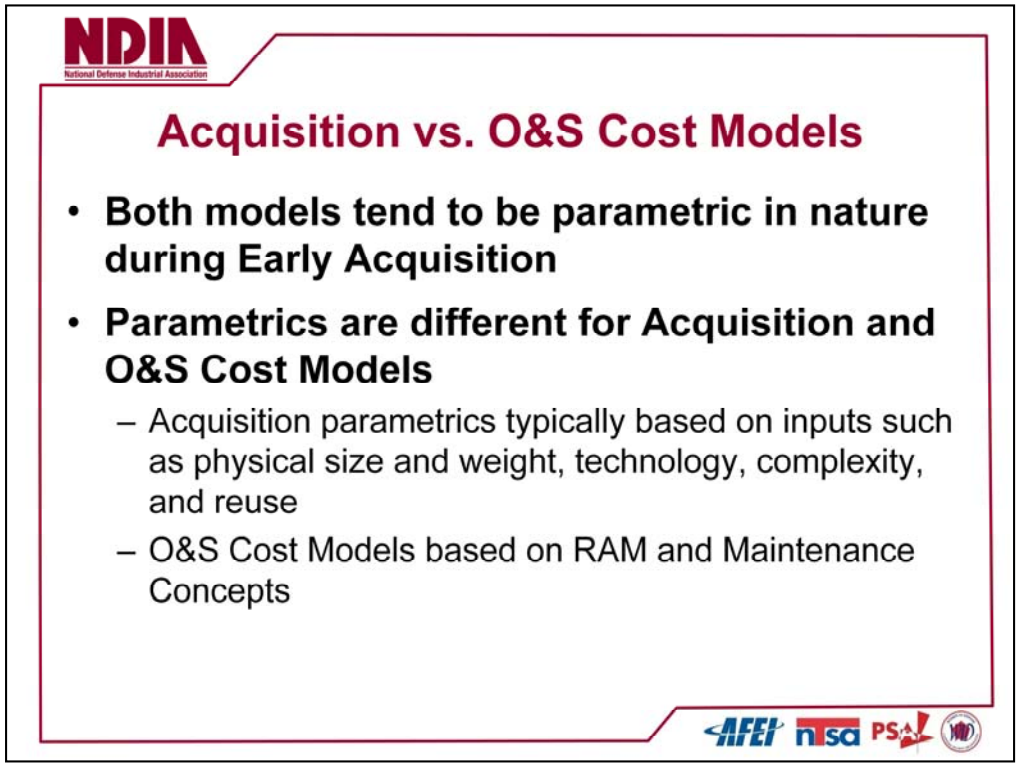
A common understanding of definitions, and their origin is critical to understanding of the problem, and setting the stage forward for process improvement.

This slide portrays the origins for the classical definitions of Life Cycle Cost, Total Ownership Cost, and the most recent Ownership Cost, and portrays what portion of the DoD Acquisition life cycle they consider. Although both the classical Life Cycle Cost and Total Ownership Cost definitions cover the entire DoD Acquisition timeline, Total Ownership Cost and Ownership Cost include Indirect / Infrastructure costs, e.g. fully burden cost of fuel, energy, power, housing and shelters, etc., whereas the classical Life Cycle Cost definition does not.

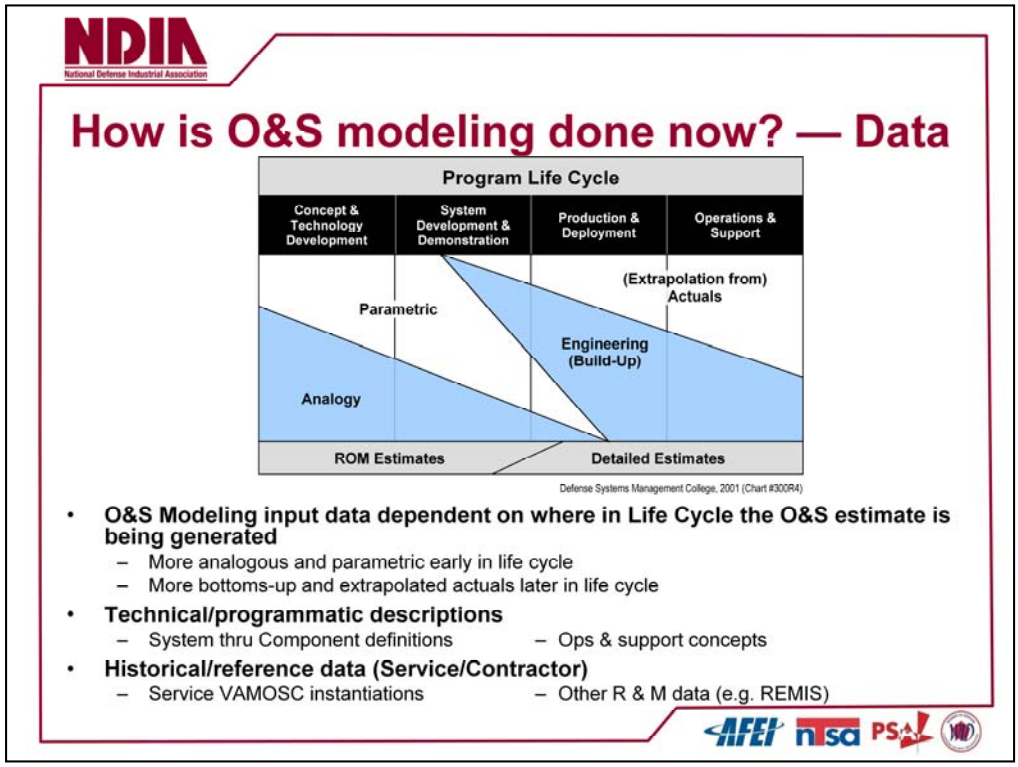



There exist today a large number of both Government and Industry tools that support the estimation of various aspects of LCC, but few to none estimate Total Ownership Costs satisfactorily. Some tools attempt to estimate LCC, including O&S, but most have strengths either in Acquisition Cost Estimation, or O&S, but not both. Others are focused on various aspects of O&S Costs (including most of the Government tools - rightfully so), however few to none adequately cover all aspects of Ownership Cost. Lastly, some large government contractors have, or are in the process of developing their own proprietary Total Ownership Cost tools.

A partial listing of existing Government and Industry LCC tools is provided in the Back-up to this presentation, along with brief descriptions of the specific strengths of these tools.




Most LCC modeling tools are parametric in nature, i.e. they translate various physical parameters to effort or cost. However, to more explicitly define the differences between different types of LCC models and tools, most of the existing Acquisition-oriented tools use parameters such as size, weight, various technology characteristics, complexity and reuse as their inputs, whereas O&S models / tools tend to use Reliability, Maintainability, and Availability, including Fraction of Faults Detected and Isolated as parametric inputs.




What data is needed to complete an O&S cost estimate? It depends on where in the life cycle, a particular weapon system estimate is being generated. This chart depicts the four phases (starting with MS-A at the left of the chart) of weapons systems' life cycles. Additionally, it shows the nature of the cost estimating 'type' (e.g. Analogy, Engineering build-up) that are typically used in a particular life cycle phase. A variation of this chart appears at the bottom of the Defense Acquisition University "Wall Chart".

All O&S models require some programmatic description (e.g. number of operating years) and some technical description. Later in a program, detailed data is generally available down to the component level with explicit characterization of the parts, their respective maintenance and support concepts, as well as geographic distributions. However, at the earliest stages of a weapon system—say Pre-Milestone B—very little data below the subsystem is available to the O&S cost modeler. And generally sparing and maintenance is done at the LRU-level, so models tend to be more abstract the earlier the estimate is generated.

Data is generally drawn from vetted historical reference sources. These include large service-owned VAMOSC data such as the USN VAMOSC system, the USAF AFTOC system, and the USA OSMIS system. These data would also include R&M data that might come from the USAF REMIS system or from a number of sources within the USN, NALDA dbms, for instance. Persons actually working a fielded weapon system can also draw data directly from Program data sources. The more detailed data the better the cost estimate, and also more expensive to generate the cost estimate and more difficult to perform higher-level trade studies.

# O&S Overrun Data, With Sources

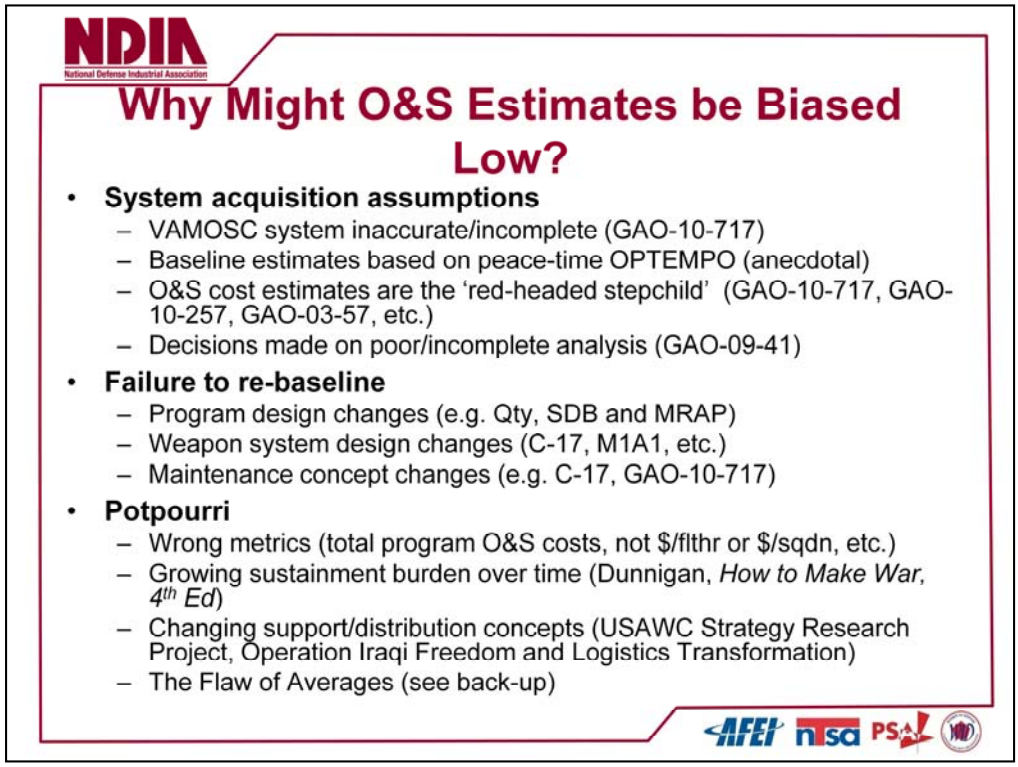
- **Publicly available data, with more than anecdotal references, is very sparse.**
  - We found/relied on only one source from the Center for Naval Analysis (www.ncca.navy.mil/doncas/briefings/2009-Choi.ppt)
    - Reviewed 15 ship programs and 11 Naval aviation programs

| | All programs | Ships | Aircraft |
|---|---|---|---|
| O&S delta | **15%** | 6% | 27% |
| Personnel delta | **17%** | 21% | 13% |
| O&M delta | **19%** | 1% | 42% |

1. *Average is not weighted by size of the program—that causes some distortion when looking at particular O&S component by program type*
2. *All figures are adjusted for inflation, flight hours, and number of aircraft per squadron as appropriate*

- **Major drivers for measureable cost growth include:**
  - Increasing requirements (*"Changes in flyaway costs seem to affect aircraft O&M costs the most"*)
  - Changes in price forecasts (inflation)
  - Moving to new estimation/accounting methods or correcting errors in old methods
  - Cost estimation, per se, did not appear to be a major driver

- **Unquantifiable drivers include**
  - Changes in squadron structure (e.g., difficult to compare a "normal" squadron vs. one with detachments…)
  - Platforms pushed out to fleet too early (implies the process is not yet "optimal," …)
  - Changes in use of performance-based logistics (studies on PBL are inconclusive about its effects on cost)
  - Additional training requirements (related to changes in requirements or utilization…)




We grouped the causes into three distinct categories.

The category "System Acquisition Assumptions" was intended to capture those things that happen around MS-B, when the cost targets are set for a program.

1. As was clearly illuminated in the referenced GAO report, the VAMOSC system is characterized as having inaccurate and incomplete data—the Army being the worst. How then can anyone generate an accurate estimate if the reference data is incorrect?

2. At MS-B, the LCC CDRLs (if requested) are submitted using a projected annual operations tempo based on nominal peace time usage for 20 years. (Anecdotal evidence… some C-17s in Afghanistan are accumulating flight hours at over 2x the original estimate. In Gulf War, tracked vehicles were accumulating upwards of 300 miles per month—CASCOM data for pre-Gulf War tracked vehicles were on the order of 300 miles per year.)

3. Three different GAO reports cite that rarely are O&S cost predictions collected/stored/documented as targets at MS-B.

4. GAO-09-41 references that some programs have entered into contracts for PBL services having not completed business case analyses or basing the decisions on incomplete data.

The category "Failure to re-baseline" was intended to capture those things that happen to a program sometime after the MS-B target is established (sometimes many years later).

1. If the target metric is 'Total Program O&S Cost', then when a program doubles or triples the number of acquired systems over the MS-B target quantity—cost is going to grow (examples cited are SDB and MRAPs)

2. Critical Design Review doesn't happen until before MS-C. The detailed design is not fleshed out before then and many things are subject to change. But the cost target is set at MS-B

3. The referenced GAO report explicitly calls out the C-17 as an example of a program that was originally acquired with organic logistics support and it wasn't until years after deployment that the PMO switched to PBL.

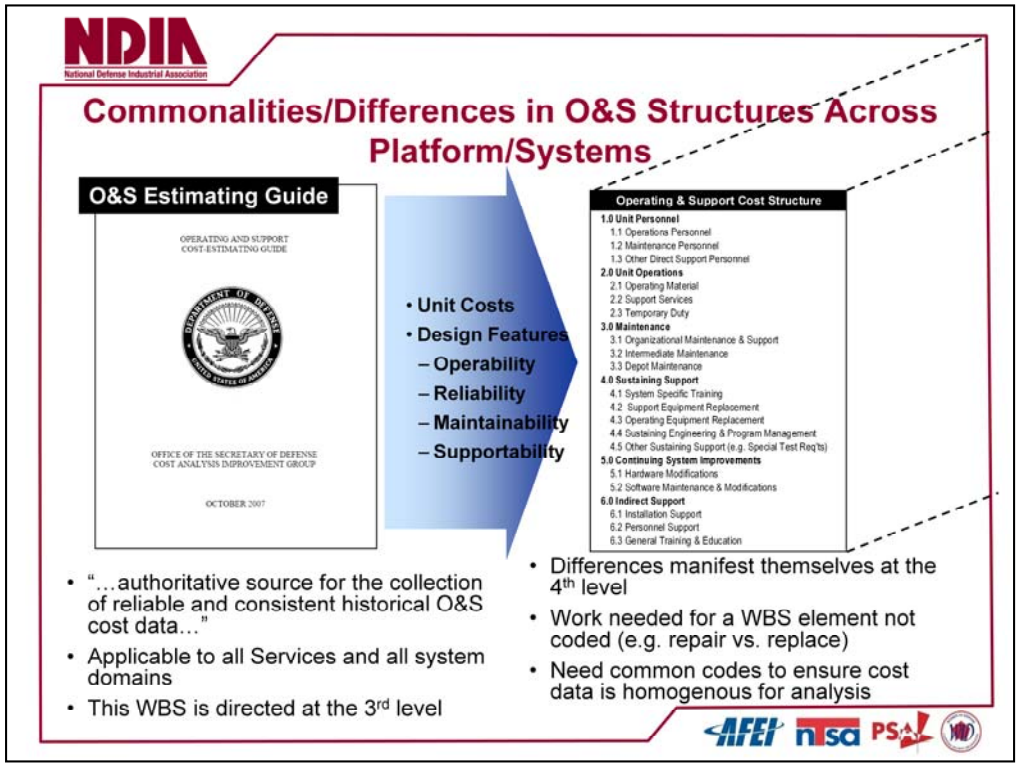
The category "Potpourri" was intended to capture those things that were left over.

1. Presently, the referenced GAO report cited that the metric tracked was Total Program O&S Costs. The problem here is that this BIG number masks a lot of things that are measurable (and therefore designable) in a single weapon system. The total masks things like quantity in use, per unit usage rates, geographic deployments, energy consumption rates, etc.

2. Growing sustainment burden on forces in general over time. (P502 Dunnigan: WWII average US soldier required 55-lbs/day/man. Currently 100-500 lbs/man/day depending on unit) (From the briefing *USMC Initiatives in Energy and Power*, Michael Gallagher, May 2010: In the pre-Operation Iraqi Freedom era the radio density for a typical rifle company was 7 radios per company. Currently, the typical rifle company uses 225 radios. This 30x increase places additional demands for spare parts and replacement batteries.)

3. The final reference refers to a paper published by the Army War College. This paper examined distribution based logistics (DBL). "*DBL is designed to reduce the size of the logistical footprint by providing equal or better capability through better distribution rather than having units carry large stockpiles of supplies. In effect, it swaps warehousing capacity for frequent, reliable flows of supplies.*" However, in the end, during both OEF and OIF DBL suffered and did not fully materialize… problems: comms and costs of a very mobile supply system.)

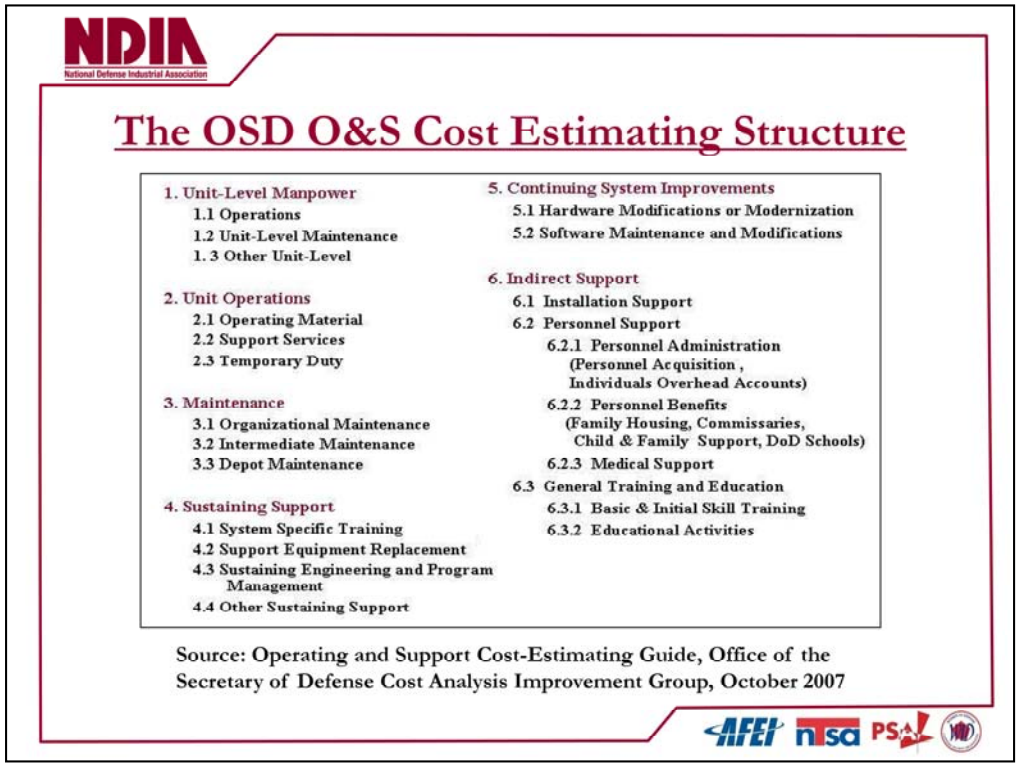
4. The flaw of simply summing a series of most likely estimates in a WBS (The Flaw of Averages), statistically leads to low bias. This phenomena is described in more detail in the back-up to this presentation.




The Cost Analysis Improvement Group, within the OSD, has published a breakdown structure for capturing/reporting all operating and support costs. Versions of this document have remained essentially unchanged for ~20 years. All services use it to varying degrees. So up through the 3rd level the O&S cost structure remains essentially the same for virtually all platform and technology types.

As the chart indicates, the document actually takes the 'user' to a fourth level—but is only directive to the third level.

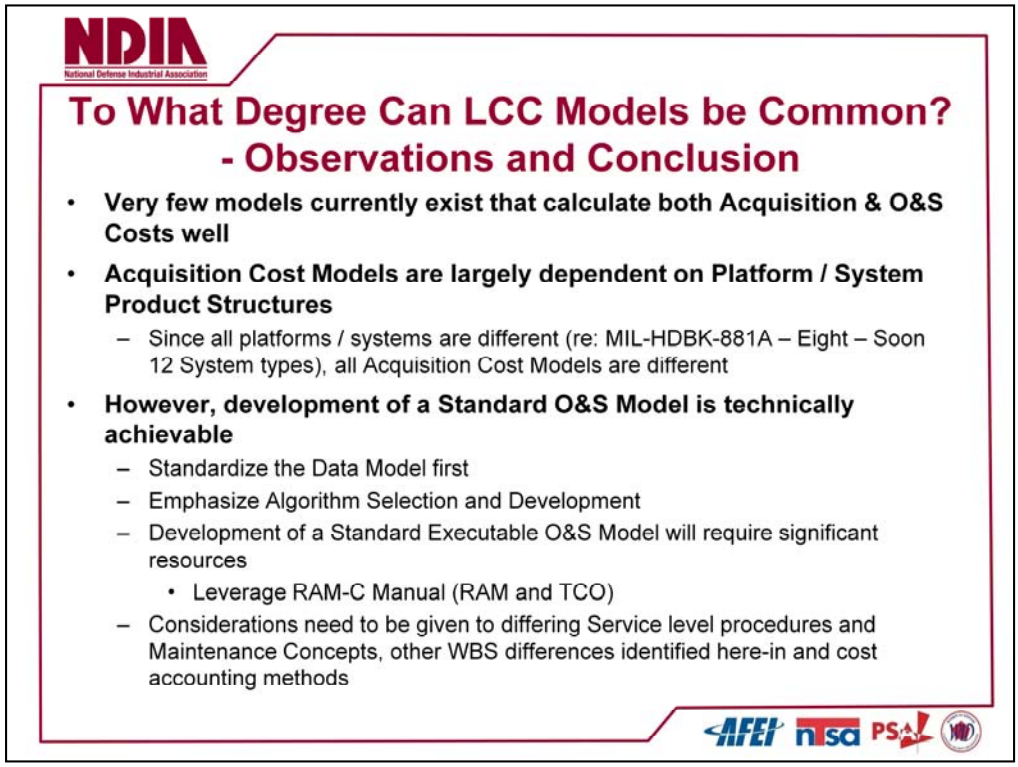
Finally, the blue arrow containing the text is meant to highlight the fact that the O&S costs are DIRECTLY and inextricably related to the system design and system acquisition costs. Any and all changes to the design (& therefore acquisition cost), operations, or maintenance/support concepts will manifest themselves somewhere in the O&S cost structure.




Here is a blow-up of the O&S structure from the preceding chart… showing more detail.

It is easy to see how all types of programs can 'fit' their operating and support costs into this structure. All programs, whether they are satellites, C4 systems, ships, munitions, ground systems have:

1. People supporting them (that can be classified into operations, maintenance, etc.)
2. Operations that consume manpower and material.
3. Maintenance and support to ensure operational readiness
4. Off-line activities, à la software upgrades and or system modernization efforts
5. The entire gamut of indirect support, from base/installation operations to medical/housing, and even amortization of basic skill training & education.




Recommendations (cont.)

3. Standardize Models to the maximum extent possible:

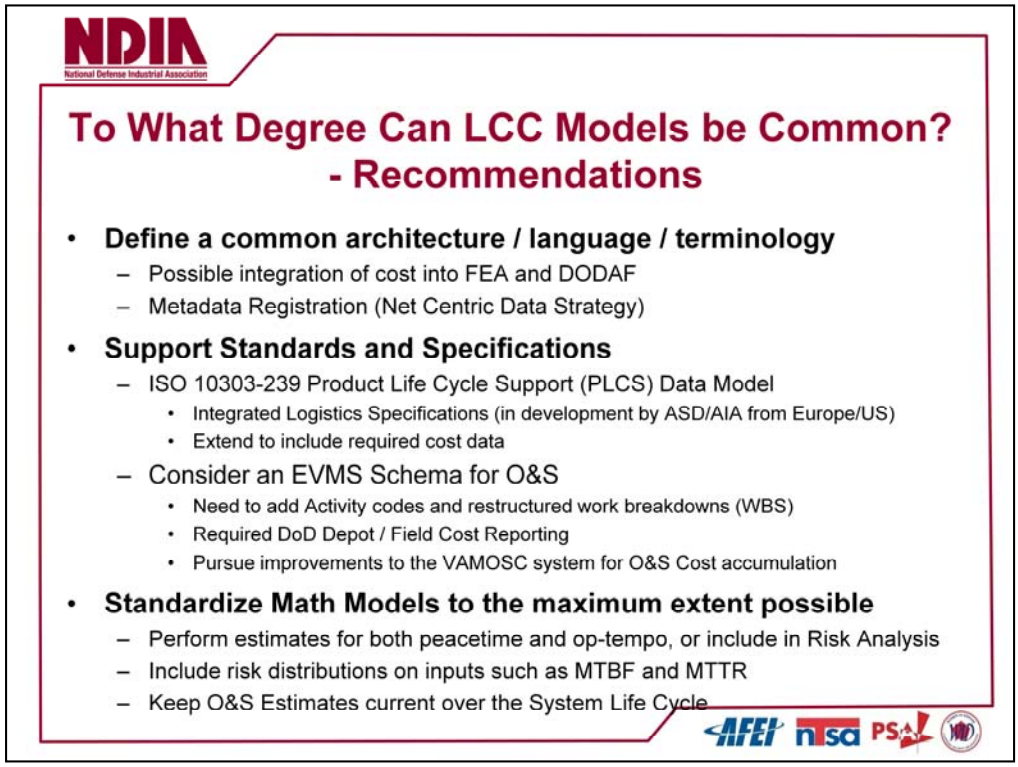
Very few models currently exist that calculate both Acquisition & O&S Costs well.

Acquisition Cost Models are largely dependent on Platform / System Product Structures. Since all platforms / systems are different (re: MIL-HDBK-881A – Eight – Soon 12 System types), all Acquisition Cost Models are different. It is therefore our humble opinion that it is impractical to attempt to develop a standard Acquisition cost model.

However, development of a Standard O&S Model is technically achievable. We specifically recommend the following:

Standardize the Data Model first, as described on the previous slide.

Emphasize Algorithm Selection and development as necessary, opposed to tools. (See back-up for the results of a preliminary analysis of existing tools, and their perceived strengths with respect to algorithms for specific for specific O&S costs.) If/when standard algorithms (or Cost Estimating Relationships) are developed and standardized, tools can be developed as needed to support the calculations. Note however that development of a Standard Executable O&S Model will require significant resources. We recommend that the existing RAM-C Manual be leveraged to the maximum extent practical. Also note that consideration will need to be given to differing Service level procedures and Maintenance Concepts, and other WBS differences identified here-in, as well as cost accounting methods.




Recommendations:

1. Support Government/Industry development of a Common Data Model (Architecture, Language and Terminology):
Advanced research has begun by academic institutions such as Old Dominion University into the possible integration of cost into the Architecture Frameworks of FEA and DODAF. This work centers around assigning costs to activities, and then accumulating the costs via executable architecture models (related research).
Support a Net Centric Data Strategy.

2. Support the continued development of Standards in this area, one of which is ISO 10303-239 - the Product Life Cycle Support (PLCS) Standards currently being developed by NATO with support from Aerospace Industries Association (AIA). The specific ISO 10303-239 Standards that may have applicability to LCC are as follows.

S2000M Material Management
S3000L Logistics Support Analysis
S4000M Scheduled Maintenance Analysis
S5000F Operational and Maintenance Data Feedback

For existing Programs of Record, expand the existing EVMS standard to include Activity codes and restructured work breakdowns to support O&S Field and Data Reporting. Implement EVMS as an O&S cost / schedule tracking tool.

3. Standardize Models to the maximum extent possible: (per previous slide)

To recap., the specific tasks that we recommend be accomplished are:

1. Define a Data Model / Dictionary of all elements and inputs.
   A. This should be accomplished for Architecture Cost Data and Relationships
   B. Standards Data and Relationships, and
   C. Computational Model Relationships

2. Define a common set of computational relationships.

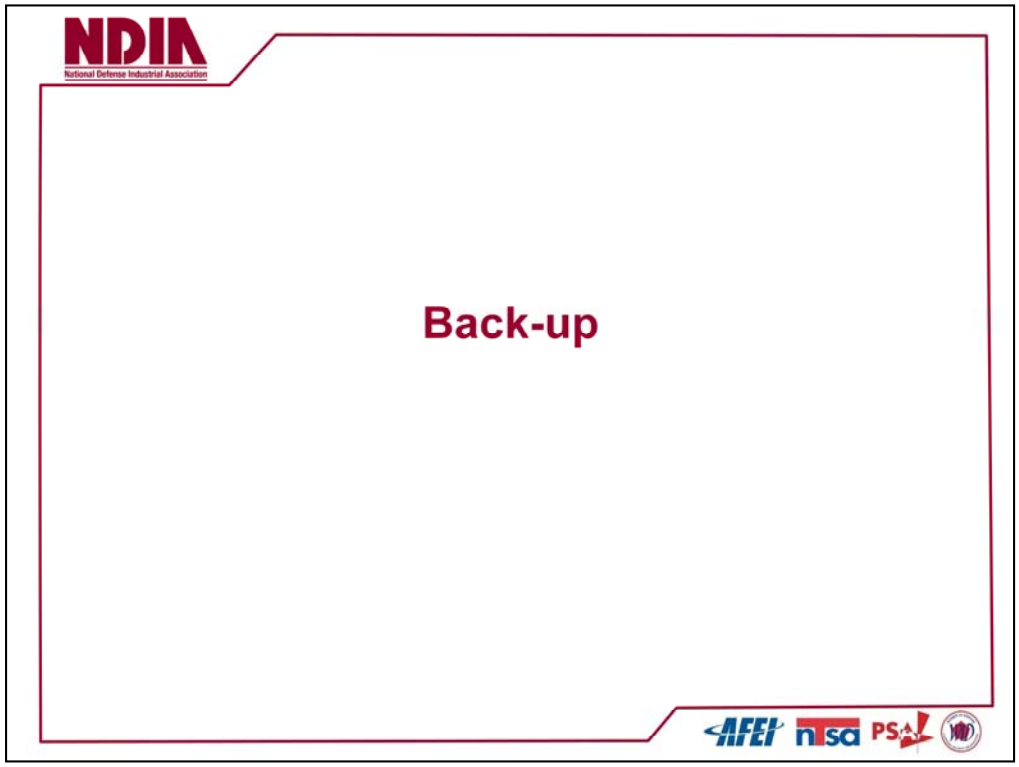
3. Define a standard model user human interface.

Other general recommendations:
Perform estimates for both peacetime and wartime op-tempo, or include in Risk Analysis. The results of the risk analysis should be presented at a specified confidence level.

Include risk distributions on inputs such as MTBF and MTTR. These key O&S Cost drivers can be factored for peacetime and wartime operations respectively.

Keep O&S Estimates current over the System Life Cycle. Start early – Pre-Milestone A, and refine regularly, at a minimum, prior to every subsequent Milestone, as the requirements and associated design mature. Per GAO, archive all estimates.

Each of the above represents specific actionable tasks that can be accomplished, that will directly contribute to a Common O&S Cost Model.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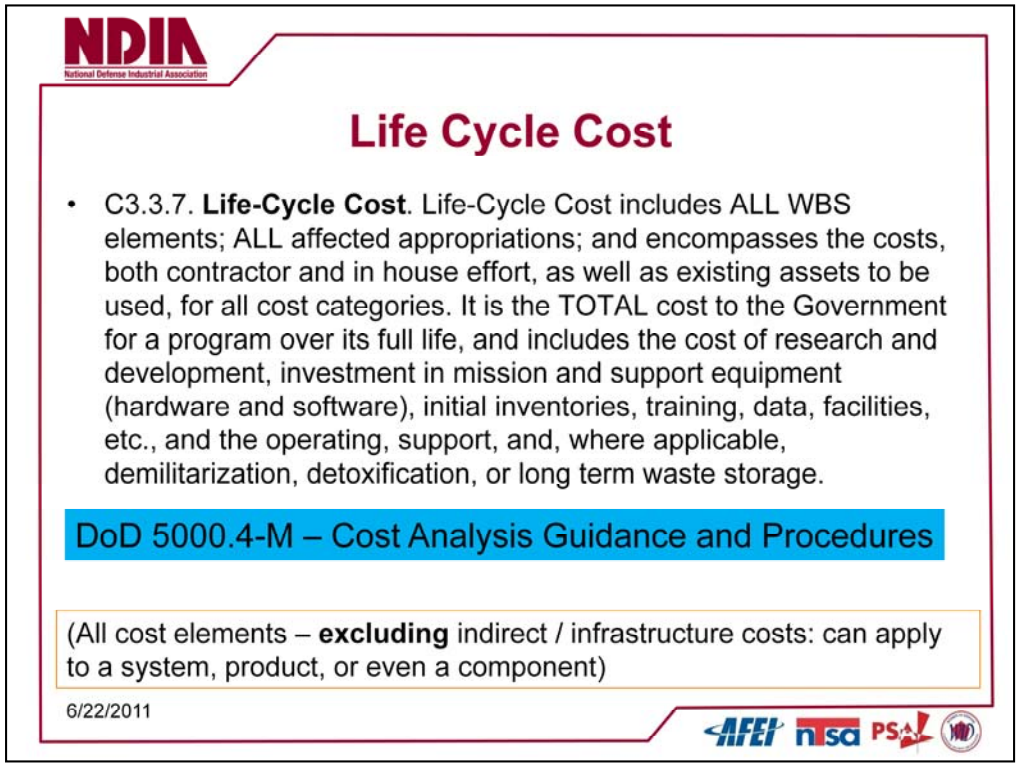
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Life Cycle Cost
• C3.3.7. Life-Cycle Cost. Life-Cycle Cost includes ALL WBS elements; ALL affected appropriations; and encompasses the costs, both contractor and in house effort, as well as existing assets to be used, for all cost categories. It is the TOTAL cost to the Government for a program over its full life, and includes the cost of research and development, investment in mission and support equipment (hardware and software), initial inventories, training, data, facilities, etc., and the operating, support, and, where applicable, demilitarization, detoxification, or long term waste storage.
DoD 5000.4-M – Cost Analysis Guidance and Procedures
(All cost elements – excluding indirect / infrastructure costs: can apply to a system, product, or even a component)
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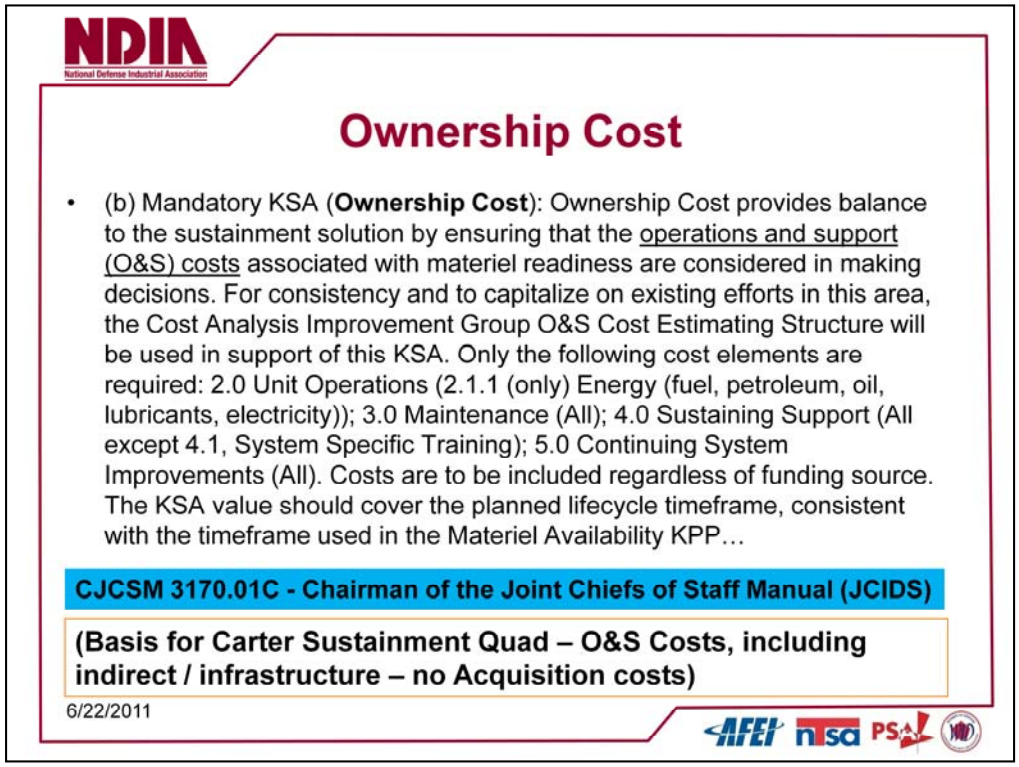
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Ownership Cost
• (b) Mandatory KSA (**Ownership Cost**): Ownership Cost provides balance to the sustainment solution by ensuring that the operations and support (O&S) costs associated with materiel readiness are considered in making decisions. For consistency and to capitalize on existing efforts in this area, the Cost Analysis Improvement Group O&S Cost Estimating Structure will be used in support of this KSA. Only the following cost elements are required: 2.0 Unit Operations (2.1.1 (only) Energy (fuel, petroleum, oil, lubricants, electricity)); 3.0 Maintenance (All); 4.0 Sustaining Support (All except 4.1, System Specific Training); 5.0 Continuing System Improvements (All). Costs are to be included regardless of funding source. The KSA value should cover the planned lifecycle timeframe, consistent with the timeframe used in the Materiel Availability KPP…
CJCSM 3170.01C - Chairman of the Joint Chiefs of Staff Manual (JCIDS)
(Basis for Carter Sustainment Quad – O&S Costs, including indirect / infrastructure – no Acquisition costs)
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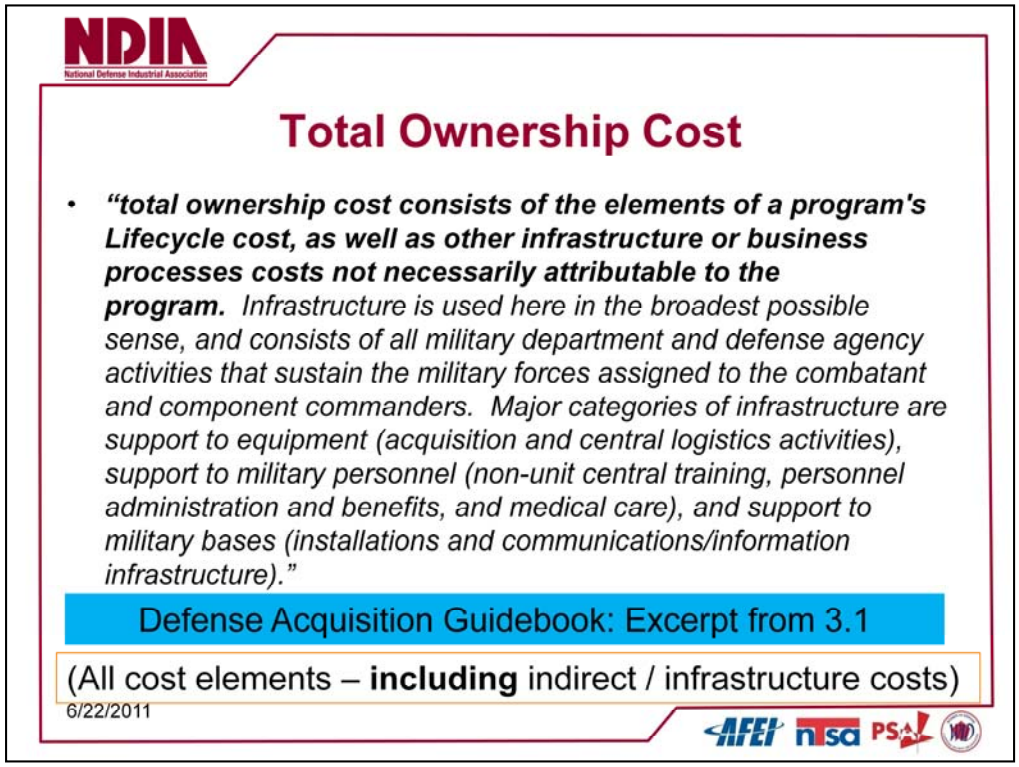
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Total Ownership Cost
• "total ownership cost consists of the elements of a program's Lifecycle cost, as well as other infrastructure or business processes costs not necessarily attributable to the program. Infrastructure is used here in the broadest possible sense, and consists of all military department and defense agency activities that sustain the military forces assigned to the combatant and component commanders. Major categories of infrastructure are support to equipment (acquisition and central logistics activities), support to military personnel (non-unit central training, personnel administration and benefits, and medical care), and support to military bases (installations and communications/information infrastructure)."
Defense Acquisition Guidebook: Excerpt from 3.1
(All cost elements – including indirect / infrastructure costs)
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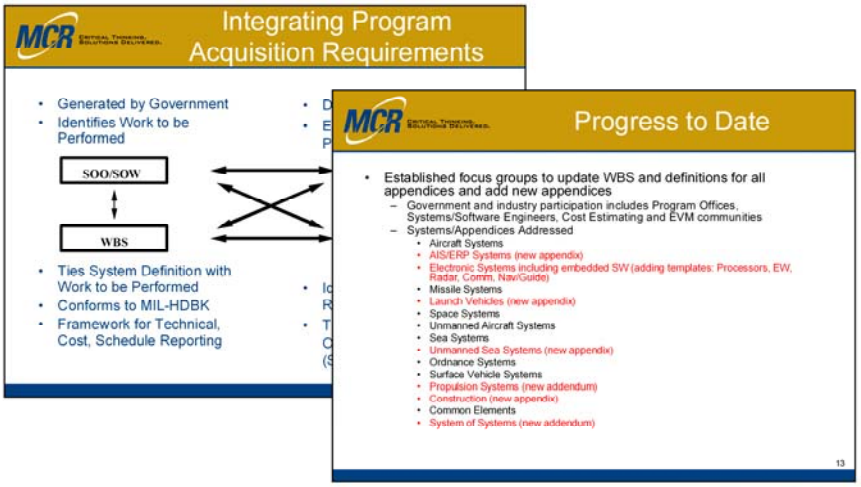
# Commonalities/Differences in O&S Structures Across Platform/Systems Cont.



# Flaw of Averages in Cost Estimation

Consider a simple project that has four tasks completed in parallel, where the total cost of the project is determined by the total number of days required to complete all the tasks. Specifically, let us assume all four tasks will take 15 days and the project cost is $1/day. Therefore, the total cost for the project will be $15 (15 days * $1/day, remember the tasks are completed in parallel).

Well, now let us assume that each task actually has some uncertainty around it, such that each one will actually get completed in 15 days +/- 5 days distributed uniformly. How much is the total estimated cost now? If we use the average value for each task, which still equates to our original estimate of 15 days, we will incorrectly estimate that our overall project will take 15 days on average and therefore cost $15 on average.

The true average is actually 18 days and therefore the cost is actually $18 on average – this can be easily verified with a simple Monte Carlo simulation as outlined on the next slide. Some knowledge of Monte Carlo Simulation and Uncertainty Distributions are required.

# Flaw of Averages in Cost Estimation

| | Estimated Time |
|---|---|
| Task 1 | 15 |
| Task 2 | 15 |
| Task 3 | 15 |
| Task 4 | 15 |
| Total Estimated Time | 15 |
| Total Estimated Cost | $15 |

Model the four task times with point estimate values – therefore the total time equals the estimated maximum time for any of the four tasks, since they are completed in parallel; and the total cost is equal to this value multiplied by $1 – in this case, using point estimates for each task time, this equals $15.

| | Estimated Time |
|---|---|
| Task 1 | Uniform (10,20) |
| Task 2 | Uniform (10,20) |
| Task 3 | Uniform (10,20) |
| Task 4 | Uniform (10,20) |
| Total Estimated Time | Average MAX (Task 1 - 4) |
| Total Estimated Cost | Average MAX (Task 1-4) * $1 |

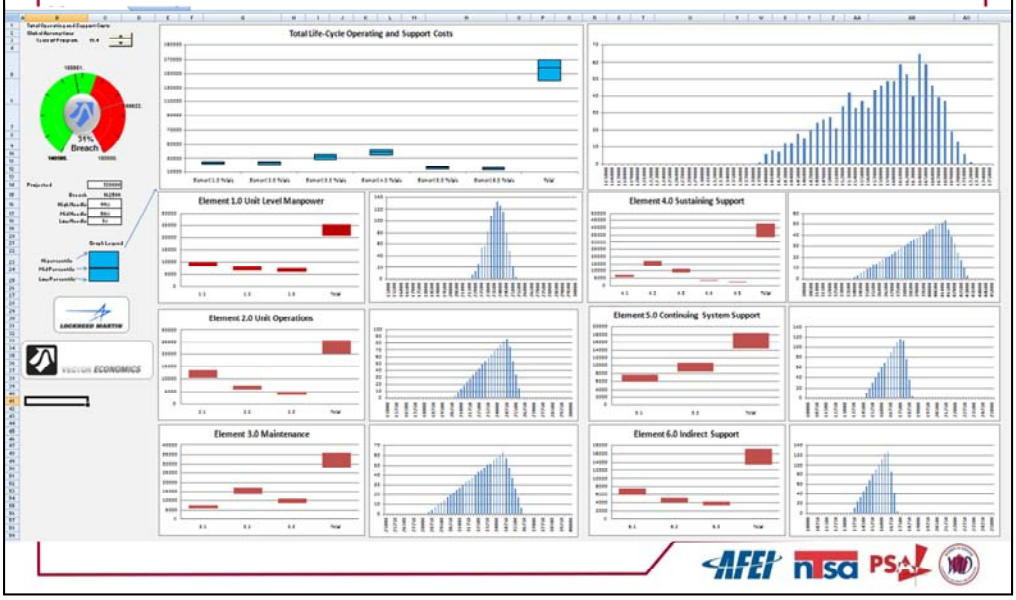
| | Estimated Time |
|---|---|
| Task 1 | 15 |
| Task 2 | 15 |
| Task 3 | 15 |
| Task 4 | 15 |
| Total Estimated Time | 18 |
| Total Estimated Cost | $18 |

Results from a Monte Carlo simulation of 100,000 trials

Replace the four task times with uniform distributions between 10 and 20; and also replace the Total Estimated Time cell with the formula for the Average of the Maximum value for any of the four tasks. Because again, since each task is completed in parallel, the total project time depends on the Maximum time of Any of the projects, so the true average project time is the Average value of the Maximum value for any one of the tasks – in this case that value is 18, and again therefore our true total average cost is $18 – not $15. (Also, the probability of the actual cost equaling $15 or less, is less than 7%.)

Note, additionally however, that actual results for a single execution of the project will vary and may be better or worse than $18. ALSO – if your uncertainty associated with each task is different, this will impact both the true average expected cost and the variance around this average.

# A Notional Ownership Cost Dashboard



# How is O&S Modeling Done Now? – Selected Tools

## O&S Cost Estimation Tools*

- MOSS
- Cost 2 Own
- VAMOSC
- OSCAM
- AceIt
- FEMP
- Blanchard
- METEOR
- AMCOS
- AFTOC
- COCOMO
- Company Specific
- COMPASS
- D-LCC
- LCCA
- Relex
- EDCAS
- CASA
- PRICE
- SEER
- DISA
- MAAP

*Sample of tools surveyed

## OSD O&S Cost Estimating Structure

1. Unit-Level Manpower
   - 1.1 Operations
   - 1.2 Unit-Level Maintenance
   - 1. 3 Other Unit-Level
2. Unit Operations
   - 2.1 Operating Material
   - 2.2 Support Services
   - 2.3 Temporary Duty
3. Maintenance
   - 3.1 Organizational Maintenance
   - 3.2 Intermediate Maintenance
   - 3.3 Depot Maintenance
4. Sustaining Support
   - 4.1 System Specific Training
   - 4.2 Support Equipment Replacement
   - 4.3 Sustaining Engineering and Program Management
   - 4.4 Other Sustaining Support
5. Continuing System Improvements
   - 5.1 Hardware Modifications or Modernization
   - 5.2 Software Maintenance and Modifications
6. Indirect Support
   - 6.1 Installation Support
   - 6.2 Personnel Support
     - 6.2.1 Personnel Administration (Personnel Acquisition , Individuals Overhead Accounts)
     - 6.2.2 Personnel Benefits (Family Housing, Commissaries, Child & Family Support, DoD Schools)
     - 6.2.3 Medical Support
   - 6.3 General Training and Education
     - 6.3.1 Basic & Initial Skill Training
     - 6.3.2 Educational Activities

Source: Operating and Support Cost-Estimating Guide, Office of the Secretary of Defense Cost Analysis Improvement Group, October 2007

**The OSD O&S WBS provides a good standard for O&S Cost Estimation, but effectively none of the tools surveyed estimate to this WBS**

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## Super O&S Model Basis

**Based on preliminary analyses of current / existing cost models / tools, we believe that the models shown here can be used as a basis for construction of a 'Best of Breed' Super O&S Cost Model**

**Raytheon LCC Tool Study, Dec, 2010**

| Source Model / Tool | Cost Output / Algorithm |
|---|---|
| CASA | - repair labor and material<br>- support equipment maintenance<br>- training<br>- SW mod and maintenance |
| VAMOSC | - repair labor and material<br>- government labor<br>- operations manpower<br>- SW mod and maintenance<br>- support services |
| MAAP | - operations manpower |
| PRICE | - repair labor |
| Blanchard | - other unit-level manpower |
| MOSS | - other unit-level manpower<br>- training munitions and expendable stores |
| FEMP | - electricity cost |
| METEOR | - government labor<br>- indirect ownership |
| AMCOS | - indirect ownership |
| AFTOC | - operator training<br>- other operational material<br>- Hardware modification and modernization |
| OSCAM | - training<br>- repair material<br>- other operational material<br>- hardware modification and modernization |
| LCCA | - support and operating equipment maintenance<br>- other sustaining support |
| SEER IT | - other sustaining support |
| DISA | - other sustaining support |
| SEER SEM | - SW mod and maintenance |
| COCOMO | - SW mod and maintenance |