Weapon Design Tradeoff: Using Life Cycle Costs

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PRICE Systems, L.L.C.
Weapon Design Tradeoff . . .
Using Life Cycle Costs

11/1/2012
LCC: What is it?

**Definition:**
MIL-HDBK-259 (Navy) gives a comprehensive (if long winded) expanded definition:

“LCC is the sum total of the direct, indirect, recurring, non-recurring, and other related costs incurred, or estimated to be incurred in the design, research and development (R&D), investment, operation, maintenance, and support of a product over its life cycle, i.e. its anticipated useful life span. It is the total cost of the R&D, investment, O&S and, where applicable, disposal phases of the life cycle.”

- **More simply:** LCC is the total cost to the customer for a program over its full life.
  - Includes all costs directly and indirectly attributable to the program.

"Cradle to Grave"
The Phases of the Life Cycle

LCC = RDT&E $ + Procurement $ + O&S $ (+ Disposal $)

- Phase 1: Research, Development, Test, Evaluation (RDT&E)
- Phase 2: Procurement (or Acquisition)
- Phase 3: Operations and Support (O&S)
- Phase 4: Disposal (Sometimes a subset of O&S)
LCC: Why do we use it?

By ignoring O&S and disposal costs, what are you missing?

**System**

**Missile ("Wooden Round")**
- RDTE: 11%
- Production/Acquisition: 77%
- O&S: 12%

**Ship (Average)**
- RDTE: 3%
- Production/Acquisition: 37%
- O&S: 60%

**Aircraft (F-16)**
- RDTE: 2%
- Production/Acquisition: 20%
- O&S: 78%

**Ground Vehicle (M-2 Bradley)**
- RDTE: 2%
- Production/Acquisition: 14%
- O&S: 84%

- Early design efforts determine LCC.
- By the time requirements are set over 80% of LCC is committed by design decisions.
- By the time the design is final approximately 90% of LCC is committed!!!!
- Clearly the time to evaluate LCC is EARLY!!

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LCC: How do we use it?

- **Option evaluation**
  - LCC allows the evaluation of competing system proposals on the basis of total ownership cost.

- **Improved Awareness**:
  - LCC allows management and stakeholders a broader and more accurate assessment of cost drivers.
  - May be a first glimpse of the total cost of ownership.
  - Facilitates the appropriate focus of resources to where they are needed.

![Conventional vs. Nuclear Powered Carrier Cost Study](image)

*Source: Analyses by the Naval Sea Systems Command and the Center for Naval Analysis GAO/NSIAD-98-1*
LCC: How do we use it?

• Improved forecasting and budgeting
  – Understanding LCC allows more effective budgeting of future funds such as O&S costs and disposal costs.
  – Helps prevents budgeting surprises

• Cost Strategy Support
  – LCC perspective maximizes the benefit of applying strategies.
    • Cost as an Independent Variable (CAIV)
    • Design to Cost (DTC)
    • Reduced Total Ownership Cost (R-TOC)
LCC – Phasing and Funding
THE DODI 5000 MODEL

051 Funds (DOD TOA)
Military Personnel
O&M
Procurement
RDT&E
Military Construction
Family Housing
R&M Funds
Defense Wide Contingency
Offsetting Receipts
Trust Funds
Inter-fund Transactions
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Total Research, Development, Test & Evaluation
6.1 Basic Research
6.2 Applied Research
6.3 Advanced Technology Development
6.3 Advanced Component Development & Prototypes
6.4 System Development & Demonstration
6.4 RDT&E Management Support Operational Systems Development
Trade Space Window Of Opportunity

Life Cycle Cost Spent (%)

Impact On Life Cycle Cost (%)

Life Cycle Cost

\[ \text{i}^{\text{th}} \text{ year UPC cost } \times \text{Quantity} = \text{i}^{\text{th}} \text{ year Procurement Cost} \]

RDT&E Cost

Disposal

Concept Refinement

Tech. Development

SD&D

Production and Deployment

Operations & Support

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Missile Cost History

DoD Budgets on a Yearly Basis but Plans on a 5 / 6 Year Cycle
“HOW” Design to LCC IS UTILIZED

1. Determine the *customer concerns* and understand those concerns
   - Explicit – States cost goals or operating budgets
   - Implicit – Customer desire to reduce operational staffing
   - Next Phase – Contract contains a limited budget / funding
   - Unit Production – Average unit production cost (AUPC) goals
   - Total Ownership Costs (TOC) – Reduced total ownership costs (RTOC)
   - Life Cycle Costs (LCC) – must be some determine percent (normally 30%) less than the replacement system

2. Determine how the *competition impacts* affordability
   - Marketing determines cost time to WIN the contract
   - Existing inventory items with potential modification costs

3. Set *design goals* (including system cost goals and targets)
   - Top level system or architecture
   - Subsystems
   - All phases

4. Understand system *requirements vs. system affordability*
   - Perform economic analysis
   - Establish a cost as an independent variable, design to life cycle costs or design to cost program

5. Review the present estimates against goals often and *react* appropriately and expediently

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Planning the Analysis

• Determine the life cycle
  – System service life: Useful life of the system depends on what the system is.
    (i.e. aircraft – 25 years, ship – 50 years, missile – 20 years, bridge – 100 years, etc.)
  – Planning Horizon: Period of time over which all costs are estimated.
  – May not coincide or may change over time.
Planning the Analysis

- Cost element structure (CES)
  - Estimating LCC requires breaking down the system into its cost elements and time phasing them.
- There is no standard CES for all LCC applications due to the tremendous variation in systems and programs (aircraft, missiles, electronics, ships, infrastructure, etc)
- The CES may be imposed as a requirement
- The level of CES detail will depend on the system as well as the purpose of the analysis. Consider:
  - Estimation methodology
  - Significant cost generating components.
  - Support philosophy
Select / Develop the Model

- Some general guidelines
  - Should be responsive to changes in design and operational scenarios.
  - It should clearly incorporate all major cost drivers.
  - Include clear documentation
  - User friendly and should not require special programming support.
  - Allow for adjustment of inflation, discounting, and learning curve where appropriate.
  - Be able to compare and contrast alternatives
  - Identify areas of uncertainty
  - Support sensitivity analysis

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### HEL Weapon Cost Model - BETA #3 Release Of 5/29/02 - GLS (545-6104)

#### Notes:
- User input Cells are in Blue.
- Red denotes key areas

### SOURCE DATA

#### Acquisition Scenario

<table>
<thead>
<tr>
<th>Platform (HMMWV) and Shelter</th>
<th>Acquisition Distribution Model</th>
<th>SOURCE DATA</th>
<th>HEL Weapon</th>
</tr>
</thead>
<tbody>
<tr>
<td>From VMADS Study</td>
<td>From VMADS Study</td>
<td>HMMWV</td>
<td>97.05</td>
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<td>From VMADS Study</td>
<td>From VMADS Study</td>
<td>Roof/Structure</td>
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<td>From VMADS Study</td>
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<td>From VMADS Study</td>
<td>From VMADS Study</td>
<td>HEL Weapon</td>
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#### HMMWV Laser WS Concept Unit Production Cost

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Terminology</th>
<th>Unit Cost ($ K)</th>
<th>Factors</th>
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<tbody>
<tr>
<td>Laser Diodes</td>
<td></td>
<td>$952.0</td>
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<td>2 Watt Diode Cost $</td>
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<tr>
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<tr>
<td>Laser Cavity</td>
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<td>Missing (in Adaptive Optics?)</td>
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<td>Laser Materials (GGG Heat Capacity M)</td>
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<td>PFM Cards</td>
<td>$10.50</td>
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<td>Inter-Cavity Beam Control</td>
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<tr>
<td>Structure - Laser &amp; associated assembly</td>
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<tr>
<td>Diode Current Regulator</td>
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<td>Beam Control Subsystem</td>
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<td>Power</td>
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<td>75%</td>
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<td>85.98</td>
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<td>Power Processing Unit</td>
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<td>Power Controller Unit</td>
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<td>75% Battery Recharge factor</td>
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<td>31% VMADS % from 100 kW</td>
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<td>Gun Assy</td>
<td>0% VMADS % from 100 kW</td>
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<tr>
<td>Source Supply</td>
<td>31% VMADS % from 100 kW</td>
<td>9.35</td>
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<tr>
<td>Structure</td>
<td>31% VMADS % from 100 kW</td>
<td>6.35</td>
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<tr>
<td>Electronics</td>
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<tr>
<td>Power Conditioning I&amp;A</td>
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<td>6.92</td>
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<tr>
<td>Thermal Subsystem</td>
<td>224.89</td>
<td>100% VMADS Power</td>
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</tr>
</tbody>
</table>

#### Model is built using 2002 dollars

- Used to calculate all non HW direct costs
- Also used in Cost Distribution model to calculate

#### Costs Distribution Model

- Yearly diode buy Quantity: see N4
- Weight Each in LBS
- % ATFLIR Cost
- Unit Cost ($ K)
- VMADS % from 100 KW
- KW Laser Energy Output
- KW Power to Dissipate

#### Key Areas

- Years Operational
- Years from Production to IOC
- Net Years of O&S Costs
- Fielding
- Annual Sustainment (O&S)
- Constant Year Dollars
- Learning Curve
- Labor
- Consumable Items (diodes)
- Material & Purchased Parts
- Production Parts
- Overhead rates (Composite)
- Cost Distribution Model
- Production Parts
- O&S
- Support sensitivity analysis
- include clear documentation
- Be able to compare and contrast alternatives
- Identify areas of uncertainty
- Support sensitivity analysis

#### Notes

- User input Cells are in Blue.
- Yearly diode buy Quantity: see N4
- Model is built using 2002 dollars
- Weight Each in LBS
- Number of Cards (Calculated)
- Average Quantity Built Each Year
- Total Production Quantity
LCC vs. Sunk Cost

LCC = RDT&E $ + Procurement $ + O&S $

Sunk costs are cost already spent

Committed costs are contracted for costs not yet spent (Sunk) - Where in the cost to cancel equals or exceeds the cost to continue the effort.

Therefore, early in SDD, the LCC$_a$ still subject to design trades is:

LCC$_a$ is the LCC still available or subject to be traded

LCC$_a$ = RDT&E $ (Uncommitted SDD $) + Procurement $ + O&S $

where uncommitted SDD $ = RDT&E $ - (Sunk $ + Committed RDT&E $)
Software is included in the “Best Value” Alternative

DECISION POINT

**Missile Alternative**

- Physical and Functional Characteristics
  - Size, Weight, Speed, Range, Payload, etc.
  - FunctionsPerformed (Search, Ballistic Load, etc.)
    - Hardware Resident
      - Seeker Head
      - Propulsion, Warhead, etc.
    - Software Resident
      - Target ID, Tracker, etc.
  - HW/SW Combined
    - Position in Space (IMU and GPS)

**Software Issues**

- Functions Performed
  - Lines of code
  - Interfaces
  - Coding Group Capabilities
  - Environment
- Schedule
- Existing (mod/reuse/etc)
Software Alternatives. . .

Consider the Life Cycle

NEW SW Development
- Requirements (11%)
- Design (14%)
- Code (24%)
- Test (27%)
  - Function / Integ / Sim
  - SW in the Loop
  - HW in the Loop
  - Flight Tests (AD, SD)
- Quality
- Documentation (10%)
- Installation (1%)
- Management (13%)

Enhancement and or Maintenance
Enhancement and or Maintenance
Enhancement and or Maintenance

SW does not age! However, as HW, processes, situations and people change, enhancements (and maintenance) are required. These can either be planned for as a continuous maintenance contract or in separate modification / upgrade contracts. Funding can be through O&S or RDT&E Funds.

SW LCC $s
- RDT&E – Large
- Procurement - ≈ Zero
- O&S – 50-75% of LCC
- Disposal - ≈ Zero
  (avg. Dev to Supt = 47-53%)
Cost Risk and Uncertainty

- Cost risk and uncertainty refer to the fact that because a cost estimate is a forecast, there is always a chance that the actual cost will differ from the estimate.
  - Lack of knowledge about the future
  - The error resulting from historical data inconsistencies, assumptions, cost estimating equations, and factors that were used to develop the estimate
  - Biases get into estimating program costs and developing program schedules.
    - Biases may be cognitive—often based on estimators’ inexperience
    - Or motivational where management intentionally reduces the estimate and/or shortens the schedule to make the project look good to stakeholders.
  - Recognizing the potential for error and deciding how best to quantify it is the purpose of risk and uncertainty analysis.

From GAO Cost Guide, Chapter 14
Document and Review Results

- **Review Results**
  - Ground Rules and Assumptions
  - Modeled System
  - Overall LCC
  - Cost Drivers
  - Spikes
  - Measure of Effectiveness
  - Program Risks and Uncertainties

- **Document**
  - If no one can figure out what you did, how you did it, and why you did it ----- It doesn’t count!!
  *(Hard truth: The program may last longer than you)*

Mirror Cost (www.xs4all.nl/)

<table>
<thead>
<tr>
<th>square side in mm</th>
<th>Single unit cost in $</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
</tr>
<tr>
<td>20</td>
<td>20000</td>
</tr>
<tr>
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<td>80</td>
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<td>100</td>
<td>80000</td>
</tr>
<tr>
<td>120</td>
<td>100000</td>
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</table>
Summary

• LCC is the total cost to the customer for a program over its full life.
  – Cost, including LCC is an engineering design parameter.
    • Total cost impact, not just initial near-term cost, must be considered
    • Each Phase (Color of Money) estimate is important!
  – Early estimates are just estimates! Look at the risks and uncertainty within those estimates. Be prepared for and manage growth.

• More customers (especially government) are emphasizing and requiring an LCC perspective AND POTENTIALLY SEQUESTRATION BEING IMPLEMENTED.
  – Early design efforts determine LCC. Don’t wait!!!!

11/1/2012