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**Modeling The Life Cycle Cost Of Protecting Us Commercial Aircraft**

**Summit Engineering Group Waldorf, MD 20602**

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Modeling the Life Cycle Cost of Protecting US Commercial Aircraft

Presentation to:
75th MORS Symposium
Annapolis, MD
12-14 June 2007

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Preface

- This briefing focuses on the Life Cycle Cost (LCC) estimate developed by Summit Engineering Group for the Counter-MANPADS (CM) Program managed by the Department of Homeland Security (DHS)
- The completeness and accuracy of the LCC estimate was a key requirement

The Risk of Any Specific Threat is NOT Addressed Here
Acronyms

- A/C = Aircraft
- CM = Counter-MANPADS & Countermeasures
- DHS = Department of Homeland Security
- DIRCM = Directed Infrared Countermeasures
- DT&E = Developmental Test and Evaluation
- ECP = Engineering Change Proposal
- LCC = Life Cycle Cost
- LOE = Level of Effort
- LRU = Line Replicable Unit
- MFHBF = Mean Flight Hours Between Failure
- NB = Narrow Body
- O&S = Operations and Support
- OEM = Original Equipment Manufacturer
- OGC = Other Government Costs
- OT&E = Operational Test and Evaluation
- P^3I = Pre-Planned Product Improvement
- PM = Program Management
- PMP = Prime Mission Product
- RDT&E = Research, Development, Test, and Evaluation
- SE = System Engineering
- ST&E = System Test and Evaluation
- STC = Supplemental Type Certificate
- T_1 = First Unit
- WB = Wide Body

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Discussion Topics

- Background
- LCC Estimate
  - Goals
  - Risks
  - Risk Mitigation
- Key Assumptions
- LCC Estimate
  - Summary
  - RDT&E Phase
  - Production & Deployment Phase
  - Operations & Support (O&S) Phase
  - De-Modification & Disposal Phase
- Risk Insights
- Related Activities
- Questions

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Background

- DHS Science and Technology (S&T) Directorate tasked with demonstrating the technical feasibility, assessing life cycle costs, and evaluating the effectiveness of protecting commercial aircraft against the threat of Man-Portable Air Defense Systems (MANPADS)

- Primarily focused on mature Directed Infrared Countermeasure (DIRCM) systems
  - Self-contained pod
  - Distributed installation

- Complex problem due to
  - Multitude of aircraft types (Wide-body vs. Narrow-body)
  - Varying flight profiles as a function of aircraft type
  - Multiple operating environments (Cargo vs. Passenger)
  - Potentially large lost revenue costs for installations that fall outside normal maintenance cycles

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Aircraft Demographics

- **Wide body (WB)**
  - Multi-aisle
  - Longer flights at altitude
  - More passengers per aircraft
- **Narrow body (NB)**
  - Single-aisle
  - Shorter, more frequent flights
  - Fewer passengers per aircraft, but higher total passenger volume
- **Cargo is ~1,000 of total**

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Type</th>
<th>Fleet Size*</th>
</tr>
</thead>
<tbody>
<tr>
<td>777</td>
<td>WB</td>
<td>122</td>
</tr>
<tr>
<td>767</td>
<td>WB</td>
<td>334</td>
</tr>
<tr>
<td>747</td>
<td>WB</td>
<td>108</td>
</tr>
<tr>
<td>DC/MD10</td>
<td>WB</td>
<td>99</td>
</tr>
<tr>
<td>MD11</td>
<td>WB</td>
<td>74</td>
</tr>
<tr>
<td>A300</td>
<td>WB</td>
<td>140</td>
</tr>
<tr>
<td>A310</td>
<td>WB</td>
<td>64</td>
</tr>
<tr>
<td>A330</td>
<td>WB</td>
<td>29</td>
</tr>
<tr>
<td>A318/19</td>
<td>NB</td>
<td>279</td>
</tr>
<tr>
<td>A320/21</td>
<td>NB</td>
<td>368</td>
</tr>
<tr>
<td>717/727</td>
<td>NB</td>
<td>271</td>
</tr>
<tr>
<td>737</td>
<td>NB</td>
<td>1241</td>
</tr>
<tr>
<td>757</td>
<td>NB</td>
<td>617</td>
</tr>
<tr>
<td>DC8,9/MD80/90</td>
<td>NB</td>
<td>703</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>4,449</strong></td>
</tr>
</tbody>
</table>

* Circa 2005  ** Excludes ~1,600 regional jets

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LCC Estimate Goals

- Comprehensive accounting of all foreseeable costs
- Explicitly address key LCC parameters
  - STCs and follow-on P3I/testing
  - Production rate tooling/test equipment (& for depot)
  - Investments to achieve reliability growth
  - CM system weight/drag impacts to fuel consumption
- Consistent approaches among vendors’ LCC estimates so individual results could be leveraged
- Exercise LCC across various quantity profiles

The goal was an independent, vendor-neutral Cost Estimate at about the 70% confidence level
Civil Counter-MANPADS Cost Elements

- Hardware (Production)
  - Aircraft Mod/Install (Airframe, Power, Display, etc.)
  - Counter-MANPADS (Sensors, Processing, Negation H/W & S/W)
- Other Cost Elements
  - I&A/T
  - SE/PM
  - Non-Recurring “Start up”
  - Gov’t Furnished Equipment (GFE)
  - First Destination Transportation
  - Allowances for Change
  - Warranties

PLUS
- RDT&E
  - Design
  - Engineering
  - Software
  - Prototypes
  - System Test & Evaluation
  - SE/PM
  - Other
  - OGCs
- FAA Certification
- Facility Construction
- Disposal

FLYAWAY COST
SYSTEM COST
PROCUREMENT COST
PROGRAM ACQUISITION COST
LIFE CYCLE COST (LCC)
TOTAL OWNERSHIP COST (TOC)

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LCC Estimate Risks

- Inaccurate assumptions
- Vendor optimism
  - Initial system reliability and reliability growth
  - Learning curves
  - Flight duration across various aircraft types
- Uncertain policies
  - Export controls
  - Ground notification requirements
  - Alarm response
- Deployment timeframe

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LCC Estimate Risk Mitigation

Summit Engineering Group role was to …

- Develop comprehensive Cost Ground Rules and Assumptions
  - Promulgated and updated at each major program milestone
- Interface with major air carriers to discuss and socialize program assumptions
- Conduct intensive research into US commercial flight demographics
- Interface with vendors on developing detailed Manufacturing Rate Assessments
Key Assumptions

- Quantity of CM Systems and Aircraft Modified
- Production start & initial deployment in FY08
- 20-year service life
- 2-level maintenance (Airport and OEM/Depot)
- Flights demographics
  - 350 Days per Year
  - Narrow body (NB), ~5 flights/ day, ~2.3 hours/ flight
  - Wide body (WB), ~2 flights/ day, ~6.8 hours/ flight
- $2.00/gallon (BY03) applied to CM system induced fuel consumption
- >525 A-kit installs/ year could a ‘special visit’ penalty
LCC Estimate – Summary

<table>
<thead>
<tr>
<th>LCC Phase</th>
<th>% of Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. RDT&amp;E</td>
<td>1.5%</td>
</tr>
<tr>
<td>2. Production &amp; Deployment</td>
<td>23.4%</td>
</tr>
<tr>
<td>3. O&amp;S</td>
<td>73.9%</td>
</tr>
<tr>
<td>4. De-Mod &amp; Disposal</td>
<td>1.1%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

- RDT&E – FY08 to FY18
- Production & Deployment – FY08 to FY17
- O&S – FY08 to FY34
- De-mod & Disposal – FY27 to FY35
## LCC Estimate – RDT&E Phase

<table>
<thead>
<tr>
<th>WBS Element</th>
<th>Phase%</th>
<th>LCC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 PMP</td>
<td>17.4%</td>
<td>0.3%</td>
</tr>
<tr>
<td>1.2 A/C Integr</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>1.3 Grd Sys Imp</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>1.4 ST&amp;E</td>
<td>56.2%</td>
<td>0.8%</td>
</tr>
<tr>
<td>1.5 SE/PM</td>
<td>14.9%</td>
<td>0.2%</td>
</tr>
<tr>
<td>1.6 Support</td>
<td>1.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>1.7 Data</td>
<td>1.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>1.8 ECP</td>
<td>4.5%</td>
<td>0.1%</td>
</tr>
<tr>
<td>1.9 OGC</td>
<td>4.8%</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0%</strong></td>
<td><strong>1.5%</strong></td>
</tr>
</tbody>
</table>

- 73.6% of Total RDT&E $ is for PMP and ST&E (shaded areas)
- Prime Mission Product (PMP)
  - ~LOE/Yr for Block Design Upgrades
- System Test & Evaluation (ST&E)
  - Periodic DT&E/OT&E to Support PMP block upgrades
    - LOE/Test Cycle & Test Materials
    - New/Amendment STCs each vendor
      - X quantity New STC
      - Y quantity Amendment STC

### Strongest Influences or Highest Risk
- **PMP** – Extent of future design updates
- **ST&E** – # and Extent of STCs

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### LCC Estimate – Production/Deployment Phase

<table>
<thead>
<tr>
<th>WBS Element</th>
<th>Phase%</th>
<th>LCC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 PMP</td>
<td>61.8%</td>
<td>14.5%</td>
</tr>
<tr>
<td>2.2 A/C Integr</td>
<td>3.6%</td>
<td>0.8%</td>
</tr>
<tr>
<td>2.3 Grd Sys Imp</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2.4 ST&amp;E</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>2.5 SE/PM</td>
<td>8.3%</td>
<td>2.0%</td>
</tr>
<tr>
<td>2.6 Supportability</td>
<td>20.3%</td>
<td>4.7%</td>
</tr>
<tr>
<td>2.7 Data</td>
<td>1.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>2.8 ECP</td>
<td>1.9%</td>
<td>0.4%</td>
</tr>
<tr>
<td>2.9 OGC</td>
<td>2.9%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>23.4%</td>
</tr>
</tbody>
</table>

- **85.7% of Production/Deployment $** is for PMP, A/C Integration and Supportability (shaded areas)
- **Prime Mission Product (PMP)**
  - Detailed T₁ (Labor/Mat’l) and Learning Curve across Each LRU
- **Aircraft (A/C) Integration**
  - Assumed no Learning for Modification/Install Labor based on numerous organizations performing them across time
- **Supportability**
  - Manufacturing Rate Assessment: Special Tooling/Prod Rate SE/Repair Station SE
  - Annual Quantity drives demand

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**Strongest Influences or Highest Risk**
- PMP – Assumed learning curve
- A/C Integration & Supportability – System deployment qty/rate

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LCC Estimate – Operations & Support Phase

<table>
<thead>
<tr>
<th>WBS Element</th>
<th>Phase%</th>
<th>LCC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Mission Per</td>
<td>3.2%</td>
<td>2.4%</td>
</tr>
<tr>
<td>3.2 UL Conspmp</td>
<td>56.1%</td>
<td>41.4%</td>
</tr>
<tr>
<td>3.3 I/M Maint</td>
<td>16.1%</td>
<td>11.9%</td>
</tr>
<tr>
<td>3.4 Depot Maint</td>
<td>8.9%</td>
<td>6.6%</td>
</tr>
<tr>
<td>3.5 Ktr Support</td>
<td>3.5%</td>
<td>2.6%</td>
</tr>
<tr>
<td>3.6 Sustain Spt</td>
<td>8.8%</td>
<td>6.5%</td>
</tr>
<tr>
<td>3.7 Indirect Spt</td>
<td>1.4%</td>
<td>1.0%</td>
</tr>
<tr>
<td>3.8 ECP</td>
<td>0.5%</td>
<td>0.4%</td>
</tr>
<tr>
<td>3.9 OGC</td>
<td>1.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>73.9%</td>
</tr>
</tbody>
</table>

- 81.1% of Total O&S $ is for Unit Level Consumption, Inter. Maint. and Depot Maint. (shaded areas)
- Unit Level (UL) Consumption
  - CM System induced Weight/Drag Impacts on Fuel Use across Aircraft Types (done for every discrete aircraft type) *Ex of how risk/uncertainty reduced*
- Intermediate Maintenance (I/M)
  - Unscheduled Repairs—due to MFHBF/year across each LRU—times $/Repair
- Depot Maintenance
  - Periodic CM System Tech Refresh

**Strongest Influences or Highest Risk**
- Unit Level Consumption – Assumed fuel cost, induced drag
- Maintenance – System reliability
### LCC Estimate – De-Mod/Disposal Phase

<table>
<thead>
<tr>
<th>WBS Element</th>
<th>Phase%</th>
<th>LCC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 De-Mod</td>
<td>72.2%</td>
<td>0.8%</td>
</tr>
<tr>
<td>4.2 Disposal</td>
<td>27.8%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

- **De-Modification**
  - Final removal of the Aircraft Modifications (e.g., A-kit)
    - 100% of original install time
  - Final removal of CM Equipment (e.g., B-kit)
    - 50% of original install time

- **Disposal**
  - All disposal costs of A-kit and B-kit material

**Strongest Influences or Highest Risk**
- De-Modification – % of labor effort from original installation

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LCC Estimate – Sensitivities

<table>
<thead>
<tr>
<th>Attribute</th>
<th>+ / - %</th>
<th>Low</th>
<th>LCC</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/STC (New/Amend)</td>
<td>20</td>
<td>0.998</td>
<td>1.000</td>
<td>1.002</td>
</tr>
<tr>
<td>CM System T₁</td>
<td>15</td>
<td>0.952</td>
<td>1.000</td>
<td>1.048</td>
</tr>
<tr>
<td>CM System Learning Curve</td>
<td>5</td>
<td>0.852</td>
<td>1.000</td>
<td>1.255</td>
</tr>
<tr>
<td>Fuel ($/gal)</td>
<td>25</td>
<td>0.903</td>
<td>1.000</td>
<td>1.097</td>
</tr>
<tr>
<td>Fleet Drag (%)</td>
<td>20</td>
<td>0.941</td>
<td>1.000</td>
<td>1.059</td>
</tr>
<tr>
<td>Installed Weight (lbs)</td>
<td>10</td>
<td>0.991</td>
<td>1.000</td>
<td>1.009</td>
</tr>
<tr>
<td>Initial Reliability (MFHBF, WB/NB)</td>
<td>25</td>
<td>0.970</td>
<td>1.000</td>
<td>1.050</td>
</tr>
<tr>
<td>Order Quantity (For Illustrative Case)</td>
<td>5</td>
<td>0.958</td>
<td>1.000</td>
<td>1.040</td>
</tr>
</tbody>
</table>

- Costs normalized to ‘Base Case’
- Sensitivities are shown as being independent of each other
  - Correlations could result in significantly different impacts (e.g., an increase in fuel cost coupled with higher than projected drag effects)
Risk Insights

- Highest Estimating Risk
  - System Deployment Quantity and Rate
  - Fuel Cost
  - System Reliability
  - Learning Curves

- Other ‘Influences’
  - NRE Cost for Each Aircraft Type
  - Technology Refresh Costs
  - Installation Weight (unless talking Regional Jets)
  - First Unit Cost (e.g., T₁)
Related Activities

- Deployment decision influenced by probability of threat and applicable cost/benefit analyses
- USC CREATE has done groundbreaking work on the economic impacts of a MANPADS attack
  - Avoiding the economic impact is a benefit
- Ongoing threat assessments are crucial to evaluating the likelihood of a MANPADS attack
- Metrics for quantifying the level of protection afforded by a given deployment alternative
  - More than just number of planes, number of flights, and/or number of passengers

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Questions?
Presenter Biographies

- **Mr. Kurt Willstatter**
  - Sr. Principal at Summit Engineering Group
  - Certified Cost Estimator/Cost Analyst (SCEA)
  - BA Biology (Texas A&M)
  - MS Operations Research (Naval Post Graduate School)
  - 15+ years of systems engineering, modeling & simulation, cost estimation experience
  - 20 years of Navy operations and systems engineering

- **Mr. Richard “Andy” Campbell**
  - Associate at Summit Engineering Group
  - Certified Cost Estimator/Cost Analyst (SCEA)
  - BS Mathematics, BA Economics (Rhodes College)
  - 4+ years of cost estimation, program analysis/management, and effectiveness modeling experience