Need for Affordability Analysis in Systems Engineering

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Outline

• Problem Statement *(Mark)*

• Affordability Background *(Mike)*
  – Definitions
  – Recent Defense Acquisition Reform
  – Aerospace Industry Affordability Practices

• Affordability Practice Solutions
  – Affordability Analysis Capabilities Summary *(Mark)*
    • Best Value Analysis
    • Cost-performance
  – Best Practice Systems Engineering Practices *(Mike)*
    • Cost As an Independent Variable (CAIV)
    • Target Costing
    • Value Engineering

• Summary
Recent Defense Acquisition Reform and Cost Accountability
Public Law No. 111-23 (May 2009)

- Establishes within the Department of Defense (DOD) a **Director of Cost Assessment and Program Evaluation**.

- Requires the Secretary of the military department concerned to disclose the **confidence level** used in establishing a baseline estimate.

- Requires the rationale for selecting such confidence level, and, if such confidence level is **less than 80 percent**, the justification for selecting a confidence level of less than 80 percent.

- Requires tracking and assessing Major System **operating and support costs**.

**Intent of Law is to Hold DoD Program Managers Accountable for Program Cost-Risk Estimates**
Problem Statement

• Increased pressure to control DoD Program Cost Growth:
  (GAO-09-326SP, March 2009: “Assessments of Selected Weapon Programs”)
  – $300 Billion Growth in FY 08 Acquisition Cost (top 96 programs)
  – 25% increased Acquisition Cost from First Cost Estimate
  – 42% increased R&D Cost from First Cost Estimate
  – “Early system engineering, stable requirements, and disciplined software management on programs…experienced less cost growth”
  – “…Dec ’08 Revised Acquisition policy…places more emphasis on acquiring knowledge about requirements, technology, and design before programs start…recommends holding early system engineering reviews…”

Need “Up-Front” Affordability & Cost-Performance Analyses
Outline

• Problem Statement

• **Affordability Background** *(Mike)*
  – **Definitions**
  – **Recent Defense Acquisition Reform**
  – **Aerospace Industry Affordability practices**

• **Affordability Practice Solutions**
  – Boeing Affordability Analysis Capabilities Summary *(Mark)*
    • Best Value Analysis
    • Cost-performance
  – Best Practice Systems Engineering Practices *(Mike)*
    • Cost As an Independent Variable (CAIV)
    • Target Costing
    • Value Engineering

• **Summary**
Affordability Definitions

“...Affordability is a **Systems Engineering process** used during all phases of the product life cycle where cost is balanced with performance and schedule to define and deliver **best value** solutions to the customer.”

“...Affordability deals with...how much the **marketplace is willing or able to pay** for the program or product.”

*Defense Acquisition University Guidebook:*

“Affordability...the degree to which the Lifecycle cost...is in consonance with the long-range modernization, force structure, and manpower plans...”
Design Influence on Life Cycle Cost

Best Opportunity to Influence System Cost is Early in Design
Selections from ISPA/SCEA Joint Conference 2009, St. Louis

Cost Analysis Impact in Systems Engineering

- **Raytheon**
    - Cost Estimating Methods to Perform CAIV & cost-performance

- **Sikorsky**:
  - “Complex Hardware Models”
    - Integrated Cost Performance with Model Center©
    - Affordability Analysis group for conceptual rotorcraft

- **Air Force Cost Analysis Agency**:
  - “Excessive Project Cost – Where Does it Come From?”
    - Tool that relates program risk mitigation to cost-risk

*Conference highlighted Affordability best-practices*
Outline

- Problem Statement
- Affordability Background

**Affordability Practice Solutions**
- Boeing Affordability Analysis Capabilities Summary *(Mark)*
  - Best Value Analysis
  - Cost-performance
- Best Practice Systems Engineering Practices *(Mike)*
  - Cost As an Independent Variable (CAIV)
  - Target Costing
  - Value Engineering

- Summary
Trade Study Implementation of Affordability
(sample CAIV Analysis Results)

Chart 11

- Cost Threshold
- Cost Objective
- Pareto Front
- Life Cycle Cost
  (Development, Production, Operations & Support)

- Normalized Utility Score
  (Sum of attributes)
- Minimum Threshold
- Maximum Objective

100%
Method to Identify Best Value Engineering Solutions

Customer Attribute Priorities

Customer Desirability (utility score)

Attribute Value
\( i.e., \) speed, payload, noise

Threshold

Objective

Desirability

100%

80% Uncertainty Region

Cost Uncertainty Range

Life Cycle Cost

Best Value

Cost-Risk Analysis

Life Cycle Cost uncertainty

Development

Production

Operations & Support

Chart 12
Design Trade Study Evaluation

*Using Value Analysis Method*

**Attribute Weighting Factors**

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Total</th>
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<tbody>
<tr>
<td>Sonic Boom</td>
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<tr>
<td>Airport Noise</td>
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</tr>
<tr>
<td>Cruise Emissions</td>
<td>2</td>
</tr>
<tr>
<td>Cruise Speed</td>
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</tr>
<tr>
<td>Payload</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>1</td>
</tr>
<tr>
<td>Fuel Efficiency</td>
<td>2</td>
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</table>

**Chart Description**

- **80% Uncertainty Region**
- **Cost Uncertainty Range**
- **Notional Data**
- Concepts: A, B, C, D, E, F
Life Cycle Phase of Program Determines Cost Estimating Methods

<table>
<thead>
<tr>
<th>System Life Cycle</th>
<th>Conceptual</th>
<th>Dem/Val - Risk Reduct</th>
<th>Engr &amp; Mfg Development</th>
<th>Production</th>
<th>Deployment</th>
<th>O&amp;S</th>
</tr>
</thead>
</table>

- **Analogy**
- **Expert Opinion**
- **Engineering ~ Bottoms-Up**
- **Parametric**

**Affordability Cost Analysis**

**Estimating Cost Analysis**

**Affordability Cost Analysis is Involved in early & O&S phases**
NASA “Process Based Economic Analysis Tool” (P-BEAT)
Cost Estimating Tool for Design Trade Studies (Boeing Developed for NASA)

Benefits of Analogy Cost Estimating:
• Facilitates cost estimate “buy-in” from IPT members
• Allows “early” cost impact during conceptual design

P-BEAT Features:
• Free use and training to contractors
• Cost estimated using few or many cost-driver inputs
• Built-in regression for cost vs. performance analysis
Impact of Technology Maturity on Development Cost

_P-BEAT Cost Analysis_

R&D Planners Need Cost Estimates Based on Technology Maturity

Chart 16
Example Cost Analysis with P-BEAT

**NASA Study of Aircraft Technologies**

**Engineering Tools**
- Sub-system characteristics
  - Mass
  - Size

**P-BEAT Tool**
- Sub-system costs
  - Development
  - Unit production

**P-BEAT analysis results:**
- Cost-performance relationships
- Cost to achieve Technology maturity

**Cost-Performance Relationships**

\[
\text{AUPC} = -3.02E+08 + 2.68E+06 \times (2.02E+04 + 7.81E-09 \times \text{FUEL}^{2.81E+00} + 1.29E+02 \times \text{NITROGEN OXIDES EMISSIONS}^{9.87E-01} + 9.80E+20 \times \text{Emissions}^{3.00E+01 \times 3.96E-01} + 1.81E-06 \times \text{FUEL}^{2.85E+00} + 1.74E+00 - 2.93E+01 \times \text{Noise}^{4.29E+01} + 2.11E-24 \times \text{Block Time}^{3.00E+01 \times 3.99E+00})
\]

**Matrix of technology attributes**

<table>
<thead>
<tr>
<th>Technology Category</th>
<th>Benefit in Terms of Metrics</th>
<th>Cost to Achieve TRL 6</th>
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<tr>
<td></td>
<td>Sonic Boom</td>
<td>Noise</td>
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<td><strong>Aero</strong></td>
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<td><strong>Structures &amp; Materials</strong></td>
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<tr>
<td>Technology #4</td>
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**Chart 17**
Cost As an Independent Variable (CAIV)

- DoD Affordability Process
- Used to develop an acquisition strategy for acquiring and operating affordable DoD systems by setting aggressive, achievable cost objectives and managing achievement of these objectives
- Helps arrive at cost objectives (including life-cycle costs) and helps the requirements community set performance objectives
Target Costing

- **Commercial Affordability Process**
- **Sponsored by the Consortium for Advanced Management – International (CAM-I) [www.cam-i.org](http://www.cam-i.org)**

- **Focused on setting and achieving aggressive cost targets**
  - Assigning Cost Targets
  - Designing products & processes to meet those targets
Value Engineering

\[
\text{Value} = \frac{\text{Function}}{(\text{To the Customer})} \quad \text{Cost}
\]

- “We buy functions; what things do.”
  - Larry Miles, inventor of Value Analysis
- Functional Analysis Systems Technique (FAST)
  - Logically diagrammed functional relationship
Functional Analysis Systems Technique (FAST)
Personal Applications of Affordability

• Mike’s story
Summary

Systems Engineering Capability Needs:

- **CAIV approach** to Systems Engineering used by industry
- **Target Cost** Analyses and Cost Control Practices
- **Value Engineering** to enhance Systems Engineering functional analysis

Affordability Analysis Capability Needs:

- **Cost-estimating and cost-performance** methods & tools
- **Best Value Analyses** for early design trade studies
- **Collaboration** with Affordability experts to learn best tools and methods used in industry & government (eg. NASA and ISPA Cost Conference experts).