A METHODOLOGY FOR ASSESSING U. S. DEFENSE SYSTEMS AFFORDABILITY MATURITY

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Agenda

• What Does Affordability Mean to Customer vs. Developer?

• Complexity is Affordability Challenge

• A Method for Assessing Affordability Maturity of Defense Systems Development

• What Does It Take to Meet Cost and Schedule?

• Enablers

• Q&A
The U. S. DoD Defines Affordability as

... the degree to which the life-cycle cost of an acquisition program is in consonance with the long-range investment and force structure plans of the Department of Defense or individual DOD Components. Affordability procedures establish the basis for fostering greater program stability through the assessment of program affordability and the determination of affordability constraints.

- Components shall plan programs consistent with the DOD Strategic Plan, and based on realistic projections of likely funding available in the future years
- **Affordability shall be assessed at each milestone decision point beginning with program initiation-usually-MILESTONE 1.**
- Cost Analysis Improvement Group (CAIG) reviews shall be used to ensure cost data of sufficient accuracy is available to support reasonable judgments on affordability for ACAT 1 programs.
- DOD Component Heads shall consult with the USD (A&T) or the ASD (C3I), as appropriate, on program objective memoranda (POM) and budget estimate submissions (BES) that contain a significant change in funding for, or reflect a significant funding change in, any program subject to review by the DAB or the DOD Chief Information Officer.

How is it being assessed today?
How Is Affordability Being Assessed Today?

**Customer:**
Are we acquiring what we *needed* for the $ we paid within the *time* we agreed?

**Developer:**
Are we delivering the *intended capabilities* within *cost* and *schedule* targets?

**Affordability**

\[
Cost, Schedule, and Technical Performances
\]

\[
(CPI, SPI, and TPM metrics)
\]
The Basis of Affordability

Cost Data *past programs*
Contractor *past performances*
Technology *projection*
Cost of Money *projection*

Estimation *degree of accuracy*

Affordability \( \cong \)
Total Ownership Cost \( t(t) \)

where,

\( t=\text{acquire} \rightarrow \text{operate} \rightarrow \text{retire} \)

✓ Affordability is assessed based on cost projection over a desired time line.
✓ Affordability Performance is influenced by the accuracy of such projection and the organizations’ ability to execute a defense contract.
The Challenges

➢ System of Systems (SoS) is a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. (DoD Defense Acquisition Guidebook (DAG) [2008])

➢ Example:
The Challenges . . .

**SoS Engineering Activities not Integrated with Others**

- SoS systems engineering deals with planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into an SoS capability greater than the sum of the capabilities of the constituent parts [DoD, 2004(1)].
The Challenges . . .

System of Systems’ Acquisition Cycle is too Long

- United States Defense Systems Life Cycle

Primary Goal is to incentivize greater and timely innovation. (Better Buying Power 3.0)
The Challenges . . .

**US DoD Acquisition Budget Continues to Decrease While Threats Increase**

Since the United States implemented the Budget Control Act (BCA) in 2011 and followed by the budget sequestration in 2013, the DoD budget has been reduced about 16% (rounded) from its all-time high in 2010 [51], i.e. the DoD budget in 2015 was $560.40 billion compared to $691.00 billion in 2010, which is $130.6 billion less.

At the same time, threats to the U. S. have been increased since 2010.
How Do Industries Address These Challenges?

**Current Literature and Industrial Practices**

There are numerous processes, tools, best practices, and methodologies created by Systems Engineering community which attempted to *improve* cost and schedule performance. However, an *integrated* and *controlled* methodology for measuring the organizations’ ability to meet cost, schedule, and technical target is still missing. [Dong & Stracener 2016]

Therefore,

there is a critical need for a methodology that enables weapon developers to predicting development program performance in achieving technical requirements within cost and schedule targets.
Part I:

The Introduction of the AMAM
Affordability Maturity Assessment Methodology

➢ Description
The AMAM constitutes a new systems engineering capability for assessing and measuring organizations’ ability to develop and build defense systems within cost and schedule targets

➢ Objective:
*Do more with less* by minimizing cost and schedule incursion and optimizing efficiency through focused systems engineering and program management best practices

➢ Limitations / Constraints
- Pairing the right Skills with the right jobs
- The ability to win a war is our nation’s greatest priority
- Inaccurate Estimation
The AMAM is intended to be applied to any U. S. DoD materiel acquisition program from Milestone A through Milestone C to assess the developer’s ability to develop a new technology or complex system within cost and schedule targets.
Affordability Maturity Assessment Methodology

➢ Cost & Schedule Performance Index (CoSh)

\[
A_{CT} = \prod_{i=1}^{n} \frac{1}{C_i T_i} \{C_i > 0, T_i > 0\}
\]

\(C_i\): Capability Cost Index = \(\frac{C_{i\_actual}}{C_{i\_baseline}}\)

\(T_i\): Capability Schedule Index = \(\frac{T_{i\_actual}}{T_{i\_baseline}}\)

\(A_{CT}\): Program Mgmt. Maturity Index

➢ Technical Performance Risk Index (TecPri)

\[A_R = 1 - TRI_{ALL} \quad (TRI_{ALL} \leq 1)\]

\(TRI_{ALL}\): Technical Performance Risk Index

\(A_R\): Affordability Risk Index

➢ Engineering & Program Management (PM) Capability (OrgCap)

\[\beta_D = \sum_{i=1, j=1}^{n,k} CRI_i.M_j = \max\]

\[\beta_A = \sum_{i=1, j=1}^{n,k} CRI_i.M_j = \text{actual score}\]

\[\beta = \max\left\{1 + \frac{\beta_A - \beta_D}{\beta_D}, 1\right\}\]

\(\beta_D\): Program/organization desired composite score

\(\beta_A\): Program/organization access (actual) composite score

\(\beta\): Normalized Engrng. & PM Maturity Index
Affordability Maturity Assessment Methodology

**OrgCap** model is a component of the AMI that calculates the composite $\beta_0$ and the normalized $\beta$

$$\beta = 1 + \frac{\beta_A - \beta_D}{\beta_D}$$

$$A_R = 1 - TRI_{ALL}$$

**Cosnt** model is a component of the AMI that calculates Cost & Schedule performance indices

$$A_{CT} = \prod_{i=1}^{n} \frac{1}{C_iT_i}$$

**TecPri** model is a component of the AMI that calculates Technical Performance Risk Index, TRI

$$AMI = \beta (1 - TRI_{ALL}) \prod_{i=1}^{n} \frac{1}{C_iT_i} (C_iT_i > 0) = \beta A_R A_{CT}$$
Cost & Schedule Performance Index for PM

Define: "n" as number of capabilities being assessed; $C_i$ is the Cost performance index of an $i^{th}$ capability (where $i = 1 \ldots n$); $C_{actual}^i$ is the actual $\$ spent on developing $i^{th}$ capability and $C_{baseline}^i$ is budgeted $\$ for the same capability; then

$$C_i = \frac{C_{actual}^i}{C_{baseline}^i} = \begin{cases} < 1, & \text{underrun} \\ = 1, & \text{on target} \\ > 1, & \text{overrun} \end{cases}$$

Define: "n" as number of capabilities being assessed; $T_i$ is Schedule performance index of an $i^{th}$ capability (where $i = 1 \ldots n$); $T_{actual}^i$ is the time spent on developing $i^{th}$ capability and $T_{baseline}^i$ is allowed time for developing the $i^{th}$ capability; then

$$T_i = \frac{T_{actual}^i}{T_{baseline}^i} = \begin{cases} < 1, & \text{ahead} \\ = 1, & \text{on track} \\ > 1, & \text{behind} \end{cases}$$

Define: $A_{CT}$ as affordability risk index of based upon cost and schedule performance indices, then $A_{CT}$ is calculated as follow:

$$A_{CT} = \prod_{i=1}^{n} \frac{1}{C_i T_i}, \text{for } C_i > 0 \text{ and } T_i > 0$$
Cost & Schedule Performance Index - Example

Example of cost and schedule performance of a random ten projects. The results show that five projects are considerably desirable and other fives are struggling.

<table>
<thead>
<tr>
<th>Project</th>
<th>$C_i$</th>
<th>$T_i$</th>
<th>$C_iT_i$</th>
<th>$1/C_iT_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.99</td>
<td>1.30</td>
<td>1.2870</td>
<td>0.7770</td>
</tr>
<tr>
<td>2</td>
<td>0.76</td>
<td>0.74</td>
<td>0.5624</td>
<td>1.7781</td>
</tr>
<tr>
<td>3</td>
<td>1.20</td>
<td>0.89</td>
<td>1.0680</td>
<td>0.9363</td>
</tr>
<tr>
<td>4</td>
<td>1.10</td>
<td>0.99</td>
<td>1.0890</td>
<td>0.9183</td>
</tr>
<tr>
<td>5</td>
<td>1.07</td>
<td>1.04</td>
<td>1.1128</td>
<td>0.8986</td>
</tr>
<tr>
<td>6</td>
<td>0.89</td>
<td>1.00</td>
<td>0.8900</td>
<td>1.1236</td>
</tr>
<tr>
<td>7</td>
<td>1.48</td>
<td>1.52</td>
<td>2.2496</td>
<td>0.4445</td>
</tr>
<tr>
<td>8</td>
<td>0.82</td>
<td>1.12</td>
<td>0.9184</td>
<td>1.0889</td>
</tr>
<tr>
<td>9</td>
<td>0.95</td>
<td>0.88</td>
<td>0.8360</td>
<td>1.1962</td>
</tr>
<tr>
<td>10</td>
<td>0.98</td>
<td>0.87</td>
<td>0.8526</td>
<td>1.1729</td>
</tr>
</tbody>
</table>

Ground Rules & Assumptions:
An organization’s ability to design and performance work packages within each major Work Breakdown Schedule (WBS) and the decomposed WBSs is assessed and predicted in $\beta$. The mathematical model defined herein is for assessing a recent performance risk index and the result to be integrated with $\beta$ to predict future performance of the remaining works cope.
**Affordability Maturity Assessment Methodology**

➢ **Technical Performance Risk Index**

\[ TRI_{CAT_A} = 1 - \left[ \frac{\sum_{i=1}^{n} Wt_i}{\sum_{i=1}^{n} NAV_i} \right] \]

<table>
<thead>
<tr>
<th>Category A: Payload (lbs)</th>
<th>T</th>
<th>A</th>
<th>NAV</th>
<th>1/NA</th>
<th>Wt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25000</td>
<td>35000</td>
<td>1.400</td>
<td>0.714</td>
<td>1</td>
</tr>
<tr>
<td>Sortie (mins)</td>
<td>50</td>
<td>100</td>
<td>2.000</td>
<td>0.500</td>
<td>2</td>
</tr>
<tr>
<td>MTBR (mins)</td>
<td>120</td>
<td>240</td>
<td>2.000</td>
<td>0.500</td>
<td>1</td>
</tr>
<tr>
<td>Sig.Range (nm)</td>
<td>8</td>
<td>16</td>
<td>2.000</td>
<td>0.500</td>
<td>3</td>
</tr>
</tbody>
</table>

Calculated TRI: 0.469

\[ TRI_{CAT_B} = 1 - \left[ \frac{\sum_{i=1}^{n} Wt_i NAV_i}{\sum_{i=1}^{n} Wt_i} \right] \]

<table>
<thead>
<tr>
<th>Category B: Speed (nmph)</th>
<th>T</th>
<th>A</th>
<th>NAV</th>
<th>Wt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400</td>
<td>320</td>
<td>0.800</td>
<td>1</td>
</tr>
<tr>
<td>Range (nm)</td>
<td>950</td>
<td>680</td>
<td>0.716</td>
<td>2</td>
</tr>
<tr>
<td>Altitude (ft)</td>
<td>45000</td>
<td>38000</td>
<td>0.844</td>
<td>1</td>
</tr>
<tr>
<td>MTBF (Hrs)</td>
<td>1800</td>
<td>950</td>
<td>0.528</td>
<td>1</td>
</tr>
</tbody>
</table>

Calculated TRI: 0.279

\[ TRI_{ALL} = \frac{Wt \cdot TRI_{CAT_A} + Wt \cdot TRI_{CAT_B}}{Wt \cdot CAT_A + Wt \cdot CAT_B} \]

<table>
<thead>
<tr>
<th>Summary</th>
<th>TRI</th>
<th>Wt*</th>
<th>Overall TRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT A TPMs</td>
<td>0.469</td>
<td>7</td>
<td>0.390</td>
</tr>
<tr>
<td>CAT B TPMs</td>
<td>0.279</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

\[ (A_R = 1 - TRI_{ALL} = 0.610) \]

**Ground Rules & Assumptions:**

An organization’s ability to perform all required technical performance measures (TPMs) and manage technical risks is assessed and predicted in \( \beta \). The mathematical model defined herein is for assessing a recent Technical Performance Measures Risk Index (TRI) and the result to be integrated with \( \beta \) to predict future performance of the remaining works cope.
## Engineering & Program Management Capability - Example

Let $\beta_A$ be the organization capability (or maturity) assessed score, $\beta_D$ be the organization desired maturity score, then the normalized maturity index, $\beta$, is calculated as follows:

\[
\beta = \max \left\{ 1 + \frac{\beta_A - \beta_D}{\beta_D}, 1 \right\}
\]

**Simulated Composite Value of $\beta_A$**

<table>
<thead>
<tr>
<th>$M_{j=1...k}$</th>
<th>$j_1$</th>
<th>$j_2$</th>
<th>$j_3$</th>
<th>$j_4$</th>
<th>Desired $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lo</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CRI$_{i=1...n}$</th>
<th>$i_1$</th>
<th>$i_2$</th>
<th>$i_3$</th>
<th>$i_4$</th>
<th>$i_5$</th>
<th>$i_6$</th>
<th>$i_7$</th>
<th>$i_8$</th>
<th>$i_9$</th>
<th>$i_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tools</td>
<td>2</td>
<td>0</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience</td>
<td>4</td>
<td>0</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Funding</td>
<td>5</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>3</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>42</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assessed $\beta_A = 132$ Pick: 150

$\beta_A = \sum_{i=1,j=1}^{n,k} (CRI_i \times M_j)$

$\rightarrow \beta_A = (2) \times (7) + (1) \times (10) + (4) \times (7) + (5) \times (10) + (3) \times (10) = 132$

$\beta_D = (M_{j=k}) \times \sum_{i=1}^{n} CRI_i$

$\rightarrow \beta_D = (10) \times (2 + 1 + 4 + 5 + 3) = 150$

$\beta = \max \left\{ 1 + \frac{\beta_A - \beta_D}{\beta_D}, 1 \right\}$

$\rightarrow \beta = \left\{ 1 + \frac{132 - 150}{150} \right\} = 0.880$
The AMI Mathematical Model:

\[ \beta = \max \left\{ 1 + \frac{\beta_A - \beta_D}{\beta_D}, 1 \right\} \]

\[ A_C T = \prod_{i=1}^{n} \frac{1}{C_i T_i} \left( C_i > 0, T_i > 0 \right) \]

\[ A_R = 1 - T R I_{ALL} (A_R \leq 1) \]
Publication: (Google Keywords: A Methodology for Affordability Maturity Assessment)

What Does It Take To Be Affordable?

- Accurate Estimation: Contract Proposals
  - Requirements
  - Complexity
  - Risks
  - Assumptions

- Perform:
  - Design, Implementation, Test/Ver./Val.:
    - Concurrency Design Changes Implementation
  - Procurement, Mfg. Processes, Mfg. Tools, Build, Tests, and Delivery
  - Quality

- Manage the Unknowns:
  - Cost = c(r)
  - Schedule = t(r)

- Manage the Enablers
Enablers . . .

• Engineering Processes, Tools, and Skills
• Program Management Processes, Tools, and Skills
• Production Processes, Tools, and Skills
• Procurement Processes, Tools, and Skills
• Sustainment Processes, Tools, and Skills
Summary

• Affordability Means differently to Customer and Developer:
  ➢ Continue Performing Affordability Assessment
  ➢ Constitute Affordability as a Systems Engineering Role

• Complexity is Affordability Challenge:
  ➢ Devil is in the details
  ➢ Understand total effort

• What Does It Take to Meet Cost and Schedule?
  ➢ Accurate Estimation, Perform, and Manage the Unknowns & Enablers
Part II:

How to Apply the AMAM

Next Chapter Meeting
Lockheed Martin Corporation

MISSILES & FIRE CONTROL
- Air and missile defense
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- Nuclear systems and solutions

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- Advanced Development

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- Training and logistics solutions
- Simulation technologies
- Sikorsky

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- Surveillance & navigation
- Global communications
- Human space flight
- Strategic and defensive systems

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