Building a Complex Hardware Cost Model for Antennas

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Raytheon Space and Airborne Systems
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Introduction: An Erector Set Analogy
Challenges of Product Level Cost Model Development

A. Government DOD Contractor Challenge (Cost)
   1. Customer expects WBS
   2. Engineering works to PBS
   3. Must **untangle** cost relationship between WBS and PBS

B. Internal Organizational Challenge (Cost)
   1. Matrix organizations make collecting product level costs problematic
   2. Matrix organizations in flux are even more problematic
   3. Must **unmix** organizational data from product data

C. Must Get Agreement on Cost Drivers (Size)
   1. Costs are causal
   2. Key size and scaling factors are causing factors

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Challenge of Bidding Work With Commercial Cost Models

A. Strengths of Commercial Cost Models
   1. Great at getting the bid in the ballpark
   2. Great for tops down, reduced cost, bidding
   3. Great for organizing bid into PBS
   4. Great for remembering the hidden costs that are often forgotten

B. Weaknesses of Commercial Cost Models
   1. Strong matrix organizations argue over allotment
   2. Tend to not have a good grasp on todays technology (maybe a few years old technology)
   3. No flags for items with wide variance in costs tasks such as a performance threshold for ASICs
   4. Jobs are performed bottoms up

C. Observations of Commercial Cost Models
   1. Great for ROMs!
   2. Should be calibrated for actual bids
   3. Possible disconnect between bid and performance
Connecting Tops Down With Bottoms Up

A. Cost Model Connecting Gate 3 (ROM) to Gate 4 (actual bid)
   1. Gate 3 ROM is organizational independent
   2. Gate 4 is organizational and execution dependent
   3. Cost Model must bridge this gap
   4. Cost Model must also provide flags for high cost variance items that can drive architectural and performance trade offs
   5. Cost and size must be based on historical actuals

B. Cost Model Connecting Gate 4 (actual bid) to Gate 5 (plan after win)
   1. Must be detailed enough to provide cost details for execution plan
   2. Must be flexible enough to account for organizational changes

C. Cost Connecting Gate 5 (plan after win) to Execution
   1. Must apply to EACs also!
   2. Must have standardized cost and size collection forms
   3. Must be able to rapidly evolve with technology
Beginning With a Standard Reference Architecture

Radar Functional Block Diagram – Generic and applicable to any Program

Antenna Sub System

Radomes  Radiators  Circulators  TR Product  Distribution Board  RF, Control, Power

Array Power Supply  Beam Controller

Consistent Product Structure

ReX  Power System  Processor
Integrating the early cost estimation process with the final cost estimation process and the execution process.
Getting to a ROM Architecture

Simple set of high level questions answered using rough requirements

<table>
<thead>
<tr>
<th>Requirements</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Bandwidth &amp; Frequency</td>
<td>5 What is the tunable bandwidth</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 What is the instantaneous bandwidth</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Feed/distribution to the back end</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 erp</td>
<td>elemental power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 What is the number of elements</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 swap</td>
<td>input power (input to PCU)</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>cooling</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>weight</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>volume (depth)</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Electrical Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>What is the NF of the Receiver</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>System NF</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 Architecture</td>
<td>Aperture</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>rcs (cross section)</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>steerable apertures</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BSC architecture</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ROM Cost
Answers to questions drive choice of architecture of antenna (panel, tile, etc.) which drives cost.
Specific antenna architecture with specific subproducts related to that architecture with average cost driving parameters.
High level cost trades based on answers to questions and customer needs
Effort results in a ROM cost estimate that is put in context of historical actuals of previous antenna programs in the data base.

<table>
<thead>
<tr>
<th>Antenna</th>
<th>His</th>
<th>Total Drawing SQ FT</th>
<th>Rad. Element Count</th>
<th>Productivity High/ft drawing</th>
<th>Scale Factor</th>
<th>Effective SQ FT Drawings</th>
<th>Effective Productivity High/ft Drawing</th>
<th>Frequency of band</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Moving to the Final Cost Estimate

Each Subproduct Owner reviews ROM for cost driving elements to the performance requirements that will effect execution.
Expert Review of the ROM Cost Estimate

Pre-populated size factors of each subproduct from the ROM is now reviewed in detail for applicability to the final bid.

Cost Model maintains running bid total of updated subproduct cost information.

KSMs (cost trades)

Scaling Factors (architecture trades)
Final Basis Of Estimate is Based on Historical Actuals

Final Cost Totals

Final Architecture With Sizing Parameters

Final Cost Subproduct Allocations
Review Tops Down, Bottoms Up Approach

15 Questions:
High level, Product Requirements

Hardware Impact

Level 3 Cost. Based on Actuals

Rapid Cost Determination

Total Cost. Based on Actuals

Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner

Cost by Sub Assy

Priced To Win?

Antenna Sub System

Start

Radomes
Radianers
Circulators
TR Product
Distribution Board
RF, Control, Power
Array Power Supply
Beam Controller

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Cost Models – Tops Down, Model Based bidding

The Cost Model tool is an interactive tool which can rapidly determine cost of hardware based on the Customer’s requirements and integrates with execution team.

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- **15 Questions:** High level, Product Requirements
- **Hardware Impact**
- **Level 3 Cost Based on Actuals**
- **Total Cost. Based on Actuals**
- **Priced To Win?**
- **Design To Cost sensitivity calculations**
- **Top Down Cost Reviewed by Sup Product Owner**
- **Cost by Sub Assy**
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Cost Models – Tops Down, Model Based bidding

Start

15 Questions: High level, Product Requirements

Hardware Impact

Antenna Sub System

Radomes Radiators Circulators TR Product Distribution Board RF, Control, Power Structure Array Power Supply Beam Controller

Priced To Win?

Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner

All Cost Estimates start with the same high-level functional block diagram.

Total Cost. Based on Actuals

Level 3 Cost. Based on Actuals

Hardware Impact

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Cost Models – Tops Down, Model Based bidding

The User answers 15 simple high-level questions regarding Requirements.

Priced To Win?

Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner

Hardware Impact

Level 3 Cost Based on Actuals

Total Cost. Based on Actuals

Rapid Cost Determination

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Cost Models – Tops Down, Model Based bidding

From the answers, the Cost Model tool indicates the impact to the hardware.

Start

Antenna Sub System
- Radomes
- Radiators
- Circulators
- Structure
- Array Power Supply
- Beam Controller

Priced To Win?

Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner

From the answers, the Cost Model tool indicates the impact to the hardware.

Hardware Impact

Level 3 Cost Based on Actuals

Total Cost Based on Actuals

Cost by Sub Assy

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Cost Models – Tops Down, Model Based bidding

Start

15 Questions:
- High level, Product Requirements

Antenna Sub System:
- Radomes
- Radiators
- Circulators
- TR Product
- Array Power Supply
- Structure

Distribution

Sub Assembly costs are calculated

Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner

Priced To Win?

Hardware Impact

Level 3 Cost. Based on Actuals

Total Cost. Based on Actuals

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### Total Antenna costs are calculated

- **Start**: 15 Questions: High level, Product Requirements
- **Antenna Sub System**
  - Radomes
  - Radiators
  - Structure

### Design To Cost sensitivity calculations

### Top Down Cost Reviewed by Sup Product Owner

### Priced To Win?

### Rapid Cost Determination

### Hardware Impact

### Level 3 Cost Based on Actuals

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of Center - AK1 SDC - Total</td>
<td>7180</td>
</tr>
<tr>
<td>Sum of Center - AK3 SWEC - Total</td>
<td>3400</td>
</tr>
<tr>
<td>Sum of Center - AK2 SVC - Total</td>
<td>11284</td>
</tr>
<tr>
<td>Sum of Center - AK5 EC - Total</td>
<td>6</td>
</tr>
<tr>
<td>Count of Center - AK8B MPE - Womble</td>
<td>6</td>
</tr>
<tr>
<td>Count of Center - CMC - Total (this is OPS for Production)</td>
<td>3</td>
</tr>
<tr>
<td>Sum of Center - AK7 MOEC - Total</td>
<td>6</td>
</tr>
<tr>
<td>Count of Center - Adv Mfg/OPS Support - Total (this is now rolled under AK7)</td>
<td>6</td>
</tr>
<tr>
<td>Sum of Center - SCM Support - Total</td>
<td>6</td>
</tr>
<tr>
<td>Count of Center - AK8 PEC - Total</td>
<td>6</td>
</tr>
</tbody>
</table>

### Cost by Sub Assy

- **BSC**: 6,776
- **Radiator**: 5,819
- **Radar**: 2,169
- **Array PS**: 5,400
- **Array**: 6,000
- **Feed**: 3,791
- **Rat**: 1,002
- **Top**: 5,708

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Cost Models – Tops Down, Model Based bidding

15 Questions: High level, Product Requirements

Hardware Impact

We can iterate the requirements until we are Priced To Win

Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner
Concluding Comments

- **Strengths**
  - Integrated ROM/Final Bid/Execution planning
  - Historical Actuals based
  - Organizational roles accounted
  - Quantitative complexity factors
  - Very fast
  - Accuracy

- **Weaknesses**
  - Data collection burdensome
  - What is easy to use is also easy to abuse
Backup and alternative slides