Key Mission Systems Engineering Trades For Determining Satellite System Architecture

GSAW 98
Paul Nussbaum
Introduction

• Presentation will focus on the common key mission system engineering tradeoffs that must be performed for determining the best space, ground and operations architecture for a satellite system

• Mission system engineering is the single most effective measure a project can undertake to lower the total system cost

• Mission system engineering aims at finding the overall optimum system design solution
Strategies and Techniques For Low Cost Space Mission Operations

*Mission System Engineering*

- Develop a vision for the system
  - Vision lays out the mission system engineering trades in a “perfect world”
- Develop guiding principles for the system that define system constraints and key design/operating rules
  - World is no longer “perfect” but must take into account constraints
- Develop a concept of operations from which requirements can be generated
  - Should be developed prior to the requirements, so can define trades which affect requirements development
- Define the Mission System Engineering architecture trades
  - Satisfying mission objectives for operations, space, and ground at lowest cost
Operations Concept Trade Development

• Determine mission operations functions to be performed (What & Why)
  – Identify options for accomplishing functions (How & Where)
  – Consider the degree of automation or autonomy to be implemented and what organization or teams will be responsible for each function (Who)
  – Identify if functional capability exists or must be developed

• Develop operations scenarios based on options, including timelines (When)
  – Assess candidate operations concepts based on utility, complexity, performance, reliability and cost
  – Select a baseline operations concept

• Identify derived requirements and cost and complexity drivers
  – Negotiate changes to mission concept
Ground Segment Trade Development

- Establish communications architecture
- Establish number and locations of ground stations
  - account for orbital aspects
  - account for treaties e.g., ABM
  - account for geographic conditions i.e., weather, natural disaster, covert communications interference
- Establish space-to-ground data rates
- Determine required antenna G/Ts and EIRPs
- Determine data flow and data handling
- Establish complete or partial use of service provided ground systems
- Determine the development approach include the following; what will be custom, Off-The-Shelf, evolutionary prototyping, SEE tools
Space Segment Trade Development

• Establish communications architecture
  – space-to-space
  – space-to-ground

• Consider on-board autonomy such as;
  – One or more simple and reliable safe modes triggered on-board
  – autonomous telemetry monitoring and alarming
  – autonomous anomaly detection, correction and reporting
  – autonomous orbit management
  – autonomous memory management

• Mission data processing performed on-board as part of the payload or should it be performed on the ground
## Summary Space and Ground Trades

<table>
<thead>
<tr>
<th>Trade</th>
<th>Objective</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/G Links</td>
<td>Determine GS connectivity to satellites</td>
<td>S-band, SHF/EHF, other; also need to determine bandwidth</td>
</tr>
<tr>
<td>Mission Processing</td>
<td>Determine optimal split between space and ground</td>
<td>Space to reports; space to exceedances ground to reports; other</td>
</tr>
<tr>
<td>Ground HW Architecture</td>
<td>Determine network and ADPE architecture</td>
<td>Homogeneous vs. Heterogeneous</td>
</tr>
<tr>
<td>Mission Management (Scheduling)</td>
<td>Determine concept for multi constellation system</td>
<td>Contractor developed or COTS-based augmentation</td>
</tr>
<tr>
<td>Ground Cost Model</td>
<td>Determine cost modeling approach &amp; evaluate CERs</td>
<td>Comparison to like existing systems</td>
</tr>
</tbody>
</table>
## Summary Space and Ground Trades (Cont.)

<table>
<thead>
<tr>
<th>Trade</th>
<th>Objective</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Entry Points</td>
<td>Determine # required and preferred locations</td>
<td>MGSs - Primary /Backup</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GEPs - RGFs, RGSs, Commercial terminals</td>
</tr>
<tr>
<td>Anomaly Resolution</td>
<td>Required capability and S/G partitioning</td>
<td>Level of Sat autonomy vs. Ground autonomy</td>
</tr>
<tr>
<td>Operations and Staffing</td>
<td>Determine preferred concept for ground ops including ops positions and staffing</td>
<td>Integrated vs separated positions and ops</td>
</tr>
<tr>
<td>Transition Plan</td>
<td>Define low cost / risk transition path</td>
<td>Existing MGS, MGSB, or contractor facility 1st transition</td>
</tr>
<tr>
<td>Ground Survivability</td>
<td>Efficient ground survivability/endurability solution</td>
<td>Mobile Component, Facility Harding, Diverse Geographic Location</td>
</tr>
</tbody>
</table>
## Summary Space and Ground Trades (Cont.)

<table>
<thead>
<tr>
<th>Trade</th>
<th>Objective</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4I</td>
<td>Provide efficient ground growth path</td>
<td>Open, distributed COTS-based architectures</td>
</tr>
<tr>
<td>Mobiles</td>
<td>Efficient incorporation of endurable mobile missions</td>
<td>Upgrade of existing, new, or hybrid</td>
</tr>
<tr>
<td>System Activation</td>
<td>Efficient activation of operations (Partial to full constellation)</td>
<td>Contractor support, MGS, or MGSB activation; Specific procedures</td>
</tr>
<tr>
<td>Interfaces (External)</td>
<td>Solid understanding of functional interfaces</td>
<td>Minimal impact except for new products</td>
</tr>
</tbody>
</table>
Mission System Engineering Low Cost Considerations

• Key factors affecting ultimate mission operations cost are:
  – Complexity of the mission being attempted
  – Operability of the S/C performing the mission
  – Operability of the mission operations system
  – Management policies regarding operations (especially risk avoidance)

• General low cost approaches are
  – Eliminating or combining functions
  – Performing functions more efficiently
  – Using lower cost staff
  – Assuming greater risk
Summary

- **Mission System Engineering trades should consider the following cost reduction methods:**
  - Reusing existing facilities which can significantly reduce development and test efforts, and increase system reliability
  - Using COTS components with contractor augmentation where necessary
  - Adhering to standards however, be aware of standards that constrain functionality
  - Leveraging testing and operations commonalities to produce savings due to combined development and reduction in operations training cost