Satellite Ground System Cost Benefit
Trade-Offs of Commercial Off-The-Shelf
Items Using Parametric Cost Models

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Topics

- Satellite Ground Station Architecture
- Non Developmental Items
- Commercial Off-The-Shelf (COTS) Items
  - COTS Criteria
  - COTS Decision Making
- COTS and Software Development
- Estimating COTS Integration Using Parametric Cost Models
- Cost/Schedule Benefit Trade-Offs
- Summary
Today’s World

- Low life cycle costs mandatory for ground station operations
  - Needed for Classified, DOD, NASA, and commercial satellites
  - Covers all phases: Acquisition, Operations, and Sustainment

Features Desired:

- Multiple missions controlled by a single control center
- Multi-constellation controlled from single workstation
- Automated ground resource management
- Standard Human Computer Interface
- Open, distributed object oriented architecture, COTS
  - Plug’n Play from different vendors
- Database table driven
Ground Station Architecture and Use of Commercial Items

- More and more commercial equipment and software are being mandated by the military for integration into ground station architecture

- Front-end acquisition advantages of lower research and development cost and less time to field than MIL-SPEC designs
  - Benefit from the economies of dealing in a high-volume civilian market

- However, improper handling of COTS can cause long-term problems in mission performance and support that may more than erase initial advantages

- Evaluation criteria can assist in deciding when to use commercial products and when to develop MIL-SPEC items
Non Development Item Hierarchy

NONDEVELOPMENTAL ITEMS (NDI)

GOVERNMENT DESIGN

- MIL-SPEC
  - Military Standards
  - Military Control
  - Techniques & parts civilian market
  Government design for Government use

- BEST COMMERCIAL PRACTICES

NONGOVERNMENT DESIGN

- OLIVE DRAB COMMERCIAL
  - Vendor design & dev.
  - Vendor rights to design
  - Sells exclusively to military
  - Modified comml version
  Nongovernment design for Noncommercial use

- COMMERCIAL-TYPE

- COMMERCIAL OFF-THE SHELF
  - Domestic COTS
  - Foreign COTS
  Commercial design for Commercial use
## The Commercial Spectrum

<table>
<thead>
<tr>
<th>DESIGN FEATURES</th>
<th>MIL-SPEC</th>
<th>BEST COMMERCIAL PRACTICES</th>
<th>OLIVE DRAB COMMERCIAL</th>
<th>COMMERCIAL-TYPE (&quot;Special&quot;)</th>
<th>COTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Govt: Militarized</td>
<td>Govt: Not Militarized</td>
<td>Commercial: Just for Govt</td>
<td>COTS: Mod for Govt</td>
<td>For Civil Market</td>
<td></td>
</tr>
<tr>
<td>EXAMPLES</td>
<td>Fighter Aircraft</td>
<td>Fixed Ground Radio</td>
<td>Tactical Radio</td>
<td>Embedded Computer</td>
<td>Television Monitor</td>
</tr>
<tr>
<td>% OF SALES TO GOVT</td>
<td>100%</td>
<td>100%</td>
<td>Probably 100%</td>
<td>Small (of basic items)</td>
<td>Small</td>
</tr>
<tr>
<td>DESIGN DISCLOSURE</td>
<td>Full (piece part)</td>
<td>Full (piece part)</td>
<td>F3 (Form, Fit and Function) &amp; Full</td>
<td>F3 with some disclosure</td>
<td>F3</td>
</tr>
<tr>
<td>CONFIG. AUTHORITY</td>
<td>Government</td>
<td>Government</td>
<td>Vendor</td>
<td>Vendor</td>
<td>Vendor</td>
</tr>
<tr>
<td>DESIGN STABILITY/ RISK</td>
<td>Low</td>
<td>Low</td>
<td>Moderate to low</td>
<td>Low to High</td>
<td>Low to High</td>
</tr>
<tr>
<td>LONG-TERM SUPPORT/ COST RISK</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Low to High</td>
<td>Low to High</td>
</tr>
</tbody>
</table>
COTS Evaluation Criteria

- Can a commercial item meet ground station performance requirements? (Will it do the job or only partially?)
- Would government furnished equipment (GFE) do the job?
- Must it be modified for military use?
- Can it survive intended military use?
- Is the design relatively stable?
- Good prospect for product longevity, vendor support?
- Is product replacement possible without a major system impact?
- Is a COTS product the lowest-cost alternative?
(1) Can a Commercial Item meet AF’s performance requirements?
Yes
No
Don’t use it

(2) Would Government furnished equipment/software (GFE) do it?
No
Yes
Use GFE if Possible

(3) Can a Commercial Item survive the intended military use?
• Environmental conditions
• Performance demands
• Maintenance/support expectations
Yes
No
Don’t use it

(4) Must it be modified for military use?
No
Yes
Can the AF tolerate the risk?

(5) Nuclear hardness reqd at component level?
No
Yes
Are you prepared to buy the design?

(6) Is the design relatively stable?
Yes
No
Don’t use it
(6) Is the design relatively stable? No

(7) Will AF later need to modify inside F3 envelope? Yes

(8) Good prospects for product longevity, vendor support? Yes

(9) Substitute possible without major system impact? Yes

(10) Can it meet the AFs support conditions? Yes
(10) Can it meet the AFs support conditions?

Yes

Can you live with that?

Yes

No

Don't use it

No

Accept life-cycle cost?

Yes

Not OK

No

Don't use that item

(11) Competitive base for repair/support?

Yes

(12) Contract repair/support considerations?

Yes

Not OK

Don't use that item

No

Dont use it

(13) Lowest Cost Alternative?

GO For It!
What Happens To Support When COTS Stops Being COTS

WHEN YOU START WITH COTS AND...

Don't need to modify it, and can flow with the vendor's hardware and software upgrades...

It remains true COTS and you support it that way

Need it modified hardware and/or software design

It becomes “Commercial-Type.” If you do nothing, only the vendor will know your “Special” design; he will always be sole source, and he can turn you off at will. Possible but costly remedy: have him bid his design, and fund to buy it.

Must freeze hardware and/or software design

It becomes “commercial-type.” Have the vendor bid an option to sell his design, fund to buy it. If mods needed give vendor contract to do it as incentive.
Types of Development Code

- **Development Code**
  - *New* if no legacy or pre-existing software being used
  - *Pre-existing/Not designed for reuse* if legacy code is being used

- **Glue Code**
  - *New* if no legacy code exists
  - *Pre-existing/Not designed for reuse* if package has been integrated before and code is being reused

- **COTS Cognition**
  - *New* if the COTS package has not been used before
  - *Pre-existing/Designed for reuse* if the package has been integrated before by the same team or organization. Use COTS I&T Kbase to assess rework
Integrating COTS Software

- Commercial Off-The-Shelf (COTS) Software
  - Glue Code
    - Software code that binds COTS software with developmental software
  - Cognition
    - The functionality of the COTS software as it relates to the system software integration. If it has not used before then it is new. If the COTS package has been used before by the same team, then it is pre-existing designed for reuse, and an integration and test knowledge base needs to be addressed and reviewed.
Definitions:

- COTS software are products available in the commercial marketplace that may be used either as stand-alone or may be embedded within some larger application
- Advantages of COTS
  - Predictable license costs
  - Broadly used, mature technology
  - Availability is always “there”
  - Dedicated support organization
  - Frequent upgrades
  - Functionality is great but there are constraints
• Disadvantages of COTS
  – Licensing and property issues
  – No access to source code is available
  – Changes occur within a two year period with feature growth or obsolescence
  – Integrating a COTS software system within a larger application requires “application program interfaces” (API)

• Risk on the use of COTS
  – Due to the growing software product and platform diversity, COTS software integration may become a major performance, cost and quality “set back” that most contractors and organizations must address and resolve in an effective manner.
Identification of Risks in Cost Benefit Trade-Offs

• **Software Size**
  – Inability to size the software product accurately
    • Often caused by unconstrained requirements growth during the software development life cycle
  – Calibration of cost models depend heavily on delivered source lines of code to a historical knowledge base

• **Development Environment**
  – Often incorrectly driven by “quick fixes” or “tweaking” the model to justify an outcome
  – Should be based on the company’s ability and willingness to “bear risk” (e.g., Cost Plus vs. Firm Fixed Price contracts)
Identification of Risks
Continued

• Staffing
  – Highly complex projects have highly complex interdependencies with regard to the order in which engineering problems can be solved and become exceedingly difficult when more people are added.
  – Using a smaller and more capable staff can often result in less effort lost to inefficiencies in communication and team integration, so an actual cost benefit can be achieved, although the schedule length typically increases.
Parametric Model Sensitivity Analysis
Plotting Worksheet

PARAMETER ANALYSIS

Set the SEER-SEM parameter settings for analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACAP</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
</tr>
<tr>
<td>AEXP</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
</tr>
<tr>
<td>PCAP</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
</tr>
<tr>
<td>LEXP</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
</tr>
<tr>
<td>HEXP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEXP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMEXP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODP</td>
<td>Lo</td>
<td>Hi</td>
<td>Hi</td>
</tr>
<tr>
<td>TOOL</td>
<td>VL</td>
<td>Hi</td>
<td>Hi</td>
</tr>
<tr>
<td>TURN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDED</td>
<td></td>
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<td></td>
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<tr>
<td>PVOL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RQVT*</td>
<td>Lo</td>
<td>Nom</td>
<td>VH</td>
</tr>
<tr>
<td>RELY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEST</td>
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<td></td>
</tr>
<tr>
<td>QA</td>
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<td></td>
<td></td>
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<tr>
<td>RDEV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
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</table>

INPUTS FROM SEER-SEM RUN

Fill in from SEER-SEM risk display (nominal schedule)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Low</th>
<th>Nominal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFFORT</td>
<td>636.87</td>
<td>722.70</td>
<td>810.27</td>
</tr>
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</table>

% change from nominal if the factor is:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Lower</th>
<th>Higher</th>
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</thead>
<tbody>
<tr>
<td>ACAP</td>
<td>38.4%</td>
<td></td>
</tr>
<tr>
<td>AEXP</td>
<td>31.3%</td>
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<tr>
<td>PCAP</td>
<td>36.1%</td>
<td></td>
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<tr>
<td>LEXP</td>
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<tr>
<td>HEXP</td>
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<tr>
<td>TEXP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMEXP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MODP</td>
<td>20.9%</td>
<td></td>
</tr>
<tr>
<td>TOOL</td>
<td>36.3%</td>
<td></td>
</tr>
<tr>
<td>TURN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME</td>
<td></td>
<td></td>
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<tr>
<td>SITE</td>
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<td>RDED</td>
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<td>RLOC</td>
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<tr>
<td>PVOL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RQVT*</td>
<td>-8.3%</td>
<td>35.7%</td>
</tr>
<tr>
<td>RELY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDEV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SENI TIVIT Y ANALYSIS SOLUTION

Nominal Schedule/Worst Factors = [w]

<table>
<thead>
<tr>
<th>EFFORT (Manmonths)</th>
<th>-3 σ</th>
<th>Nominal</th>
<th>+3 σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.122.1</td>
<td></td>
<td>3.542.9</td>
<td>3.972.2</td>
</tr>
<tr>
<td>636.9</td>
<td></td>
<td>722.70</td>
<td>810.3</td>
</tr>
<tr>
<td>583.8</td>
<td></td>
<td>662.4</td>
<td>742.7</td>
</tr>
</tbody>
</table>

TOTAL POTENTIAL INCREASE IN PROGRAM EFFORT = 198.6%

TOTAL POTENTIAL DECREASE IN PROGRAM EFFORT = -8.3%

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Cost/Schedule Benefit Sensitivity

Effort (Cost) vs. Size

-3σ  Nominal  +3σ

LOC Uncertainty

Environment Uncertainty

Minimum Schedule/ Worst Factors

Nominal Schedule/ Best Factors

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COTS for Schedule and Staff

The following questions need to be addressed:

ï Does integration costs increase with COTS?
ï Does the use of COTS cause a delay in the schedule?
ï What is the cost impact if COTS is not tested properly to fit the entire system?
Risk Chart Example

![Diagram showing the relationship between effort (in millions) and size (standard deviation from nominal).]
The Cost/Performance Tradeoff

Find the \( \text{iKnee(s)\text{î of the Curve} \)

- Region for marginal performance improvement
- Region for \( \text{ìbest bang for the buckî} \)
- Consider this \( \text{i\text{thresholdî if meets true need} \)

Cost

Performance

KPP Objective

KPP Threshold

Prohibitive Cost

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Ground station architecture development must consider equally HW, SW and commercial items throughout all design and implementation phases.

Conduct early market investigation of available commercial items that can support mission needs:

- Design several preliminary architectures which could be acceptable.
- Based upon preliminary architectures prototype and evaluate hardware, software and commercial items together.
- During implementation of selected architecture continue to evaluate new and improved commercial items.

Failure to consider commercial items early can lead to an architecture which is inferior.
Summary
Page 2 of 2

- Size uncertainty while contributing to overruns is a component of risk
- Environmental differences specified during trade-offs
  - Analyst experience exemplified by the project team accounts for a large percentage of uncertainty
- COTS can play a major role in cost overruns, or maybe underruns in some cases
  - Cognition software using function points plays a major role in this uncertainty