Application of Microspacecraft Design Methods to the Development of a Miniature, Low Cost Star Tracker

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Development Strategies Derived from µSpace

- Question all requirements - pare them to the minimum that accomplish the mission
- 80% of missions can be accomplished with much less capability - don’t worry about the other 20%
- Include no features not specifically required
- Achieve reliability via simplicity
- Exploit NRE investments from space and non-space products and components
What are we talking about?

- AeroAstro Miniature Star Tracker
- Engineering Development Unit
- Testbed for algorithms
- Generate customer interest / input
- Flight verification
See a need…

- Need for microsat star tracker “obvious”  
  (after 10 years promoting it)
  - Low size (2” x 2” x 3”)
  - Low weight (< 300g)
  - Low power (~ 2W)
  - Decent performance:
    - 70 arc-seconds (or better) attitude in all 3 axes
    - Lost-In-Space
    - Update rate ~1 Hz
  - $125-150k single unit cost

- Does a market even exist?
  - Best sellers generally have medium/low performance
  - AeroAstro programs believed representative
  - SmallSat attendees think so!
Go after it

Requirements Formulation
- As low as possible!
  - 30 deg FOV
  - Look for bright stars (mag 4.5)
  - Single thre
- Fewer parts = more robust (diesel vs gas)
  - Use CMOS imager
  - Fewer external support parts
- Reliability without $$-parts

<table>
<thead>
<tr>
<th>Star Tracker</th>
<th>Goodrich HD-1003</th>
<th>Ball CT-633 (601)</th>
<th>SODERN SED-16</th>
<th>Galileo AA-STR</th>
<th>AeroAstro MST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (cm)</td>
<td>41 x 16 x 11</td>
<td>34 x 19 x 19</td>
<td>29 x 17 x 16</td>
<td>18 x 12 x 12</td>
<td>5 x 8 x 8</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>3.54</td>
<td>2.85</td>
<td>3.0</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Power (W)</td>
<td>10</td>
<td>10 (12)</td>
<td>12.8</td>
<td>3.8</td>
<td>~ 2.0 W</td>
</tr>
<tr>
<td>Cost ($k)</td>
<td>550</td>
<td>&gt; 600</td>
<td>&gt; 500</td>
<td>~ 300</td>
<td>&lt;150</td>
</tr>
<tr>
<td>Accuracy (arcsec)</td>
<td>5</td>
<td>40 (5)</td>
<td>70</td>
<td>98</td>
<td>~ 70</td>
</tr>
</tbody>
</table>
Go after it ($$)

Funding Streams (Patchwork Quilt)
- SBIRs/STTRs - 2 Ph II - AFRL, MDA
- Commercial Programs (B2B)
  - Sold 3 breadboards
  - Sold 1 flight proto (2/2007)
  - Won another contract:
    - Environmental testing
    - Build an indoor stimulator
- BAA’s
- Cultivate true believers
- Go to conferences (Hello!)
Methods to Minimize Development and Recurring Cost

- **Team**
  - Universities (MIT) - algorithms
  - Govt. funded work as leverage

- **Use existing solutions**
  - COTS Hardware
    - Breadboard uses COTS demo board
    - EDU uses COTS processor board
  - Software
    - Open Source to jump start development
    - Replace over time

- **Emphasis on making software smart**
  - Inexpensive imager with software based FPN correction

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AeroAstro
Minimize Development Cost

- Generate MST Hardware - EARLY!
  - Motivational for team
  - Simulation first then real world-data ASAP
  - Stabilize funding sources
  - Reduces residual risk

- Elicit feedback from customers
  - Example: Command/response

- Test, Test, Test
  - Generate simulator from open source
  - Use night sky in backyard in Blue Ridge Mtns as starfield (700+ star photos)
Typical Imager Data

Vertical Streaks = Noise (FPN)

Cassiopeia

Blotch

Lines not included!
MST EDU Development
(~ 1.8 M$)
Goal!

- Flight Prototype (mockup)
- Microspace market generation
- Penetration of “big space” as low $$$ backup
- Deliveries of breadboard units continue, including one this week to a prime
Conclusion

- Push back on requirements
- Build HW early
- Get customer feedback
- Test early and often
- Use open source to jumpstart sw
- Don’t reinvent the wheel
- For gosh sake, have fun!