The Evolution of Nano-Satellite Proximity Operations

02-01-2017

In-Space Inspection Workshop 2017
Tyvak Introduction

- We develop miniaturized custom spacecraft, launch solutions, and aerospace technologies for defense, intelligence, and scientific programs.

- We provide cost-effective solutions by utilizing agile aerospace processes and leveraging advanced commercial-off-the-shelf (COTS) electronic components.

- We design and manufacture sophisticated embedded software electronic devices such as avionics systems.

- Currently have ~58 employees and growing
Tyvak: Satellite Solutions for Multiple Organizations

• Facts and Figures
  – Tyvak Nanosatellite Systems founded in 2011
  – Holding Terran Orbital Corp. founded in 2014
  – Tyvak International founded in 2015
    • Fully independent European establishment

• 3 locations, > 40 employees
  – Irvine, CA
  – San Luis Obispo, CA
  – Torino, Italy
Deployment Configurations and Vehicle Checkout

3 Connected “6U” Configuration

4a First Panel Deploy Initial SOH Checkout

4b-c Vehicle Separation Second Panel Deploy Complete Checkout
CPOD Space Segment

- RPO Module
  - 2 Visible Cameras
  - 2 Infrared Cameras
  - 2 Processors for RPO
  - GPS
  - Inter-Satellite Link
  - Docking Module and Gripper

- Cold Gas Propulsion Tank
  - \(\sim 27\text{m/s} \cdot \text{d-v}\)

- Satellite Bus
  - CDH and ADCS Computers
  - EPS & 60W-hr Batter Pack
  - UHF and S-Band radios
  - 3-axis Attitude Control System
  - Distributed MPPT inputs
Test as you Fly – Hardware in the Loop (HITL) and Ground Software. Will the current system configuration (HW and SW) complete the mission?

- AIT vehicle level testing uses ground operations software during all functional checkouts
- Flight Software verifications through HITL simulations.
  - Below is an example of V-Bar hops from 20m, to 7m, to 0.5m with station-keeping between hops.
  - During the run, the navigation filter diverged, and the Fault Detection system issued (correctly) an abort command.
  - The same models can be deployed for Monte-Carlo analysis

A config file parameter was changed over a UHF command from the ground station

Truth Models Include:
- Gravity, and Gravity Gradient
- Solar Pressure
- Atmospheric drag and torques
- Magnetic Field
- Earth Rotation, Nutation, and Precession

The simulation was re-run and the system held at 0.5m for several hours

A combination of HITL, Monte-Carlo analysis, and Day in the Life Testing on Flight Units and Engineering Units are primary means of final software verification
CPOD Hardware Description – An Evolution of Capabilities

- Some things scale nicely
  - Size, weight, power
  - Advances in micro-electronics and processes have allowed us to stuff more hardware functionality into smaller volumes

- Some things don’t scale nicely…
  - Software
    - The team heavily leveraged open source and terrestrial software to make great advances in rapid development, scalability, and configurability of software
  - Interfaces and connections
    - Tyvak designed highly integrated multipurpose boards to minimize interconnections
Algorithm Simulations

Two Solutions

<table>
<thead>
<tr>
<th>Calculated Range1</th>
<th>20.52 m</th>
<th>Range 1 Error</th>
<th>0.05%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculated Range 2</td>
<td>19.38 m</td>
<td>Range 2 Error</td>
<td>5.93%</td>
</tr>
</tbody>
</table>

Range 1 Error: 0.05%
Range 2 Error: 5.93%
## CPOD Performance Summary

<table>
<thead>
<tr>
<th>Capability</th>
<th>Specification</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Power Generated</td>
<td>~17W to 30W OAP</td>
<td>Polar Sun-Sync</td>
</tr>
<tr>
<td>Average Load</td>
<td>~15W</td>
<td>Fully Active</td>
</tr>
<tr>
<td>Pointing Accuracy</td>
<td>&lt;0.15 degrees</td>
<td>Star Trackers available under all mission scenarios</td>
</tr>
<tr>
<td>Mission Data Downlink</td>
<td>~60MB / day</td>
<td>UHF and S-Band</td>
</tr>
<tr>
<td>Delta-V</td>
<td>~25 m/s</td>
<td>Cold Gas</td>
</tr>
<tr>
<td>Total Mass</td>
<td>5.990kg</td>
<td>Wet Mass (13% Margin)</td>
</tr>
</tbody>
</table>
CPOD – Areas of Improvement

- Phase Differential GPS – Not currently used, and was never baselined due to the intent of the missions demonstration. However, use of this technique would improve system robustness.
- Better control over thruster configuration - That’s the challenge of propulsion procurement in the nano-satellite space, very little customization is possible.
- Improved IMU – Required use of a MEMS IMU with a Size and Power that fits the CPOD form-factor, which places greater emphasis on star tracker availability.
- Use of in-space communications network for commanding. Critical phases of the missions may be performed in the blind.
- Moving to a larger platform would allow many of these changes.
Questions?