Dnepr 2 Satellite Identification and the Mk.III P-POD

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CubeSat Developers’ Workshop
Dnepr Launch 2

- April 17, 2007, 6:46:35 UTC
- 7 CubeSats in 3 P-PODds
  - P-POD A: CSTB1, AeroCube2, CP4
  - P-POD B: MAST
  - P-POD C: Libertad-1, CAPE1, CP3
- CP4, Libertad-1, and CAPE1 had beacons
Integration Timeline

- 2 months: CubeSats delivered to Cal Poly for integration and acceptance
- 6 weeks: Ship P-PODs to launch site
- 3 weeks: Arrive at launch site, inspect P-PODs, integrate with LV
- Launch!
Integration Timeline

- Early Dec. – CubeSats shipped to Cal Poly
  - P-POD A integrated and accepted
- Mid Dec. – Launch delay
- Early Mar. – Libertad-1 arrives at Cal Poly
- Mid Mar. – P-PODs hand-carried to Baikonur
- End Mar. – Launch delay
- Mid Apr. – Launch (finally!)
Tracking Data

- Preliminary TLEs were used to track first passes; heard all CubeSats with beacons
- First TLEs on Space Track available within 12 hours of launch
- All CubeSats independently identified after one week, most within 2 days
- Four weeks before data became consistent
P-POD C

Days after Launch

Semimajor Axis [km]

CP3, CAPE1, Libertad-1

0 10 20 30 40 50 60 70

7097.9
7097.85
7097.8
7097.75
7097.7
7097.65
7097.6
7097.55
7097.5
7097.45
Separation Rates

- Analytical separation rates ~5 cm/s between CubeSats
- Reasons for discrepancies:
  - Friction
  - Different strength springs on CubeSats
  - Separation springs in P-POD A likely not fully compressed

<table>
<thead>
<tr>
<th>Between CubeSats</th>
<th>Observed Relative Speed [cm/s]</th>
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<tbody>
<tr>
<td>CP4/ AeroCube2</td>
<td>0.3</td>
</tr>
<tr>
<td>AeroCube2/CSTB1</td>
<td>1.5</td>
</tr>
<tr>
<td>CP3/ CAPE1</td>
<td>4.9</td>
</tr>
<tr>
<td>CAPE1/ Libertad-1</td>
<td>2.2</td>
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</tbody>
</table>
Satellite Misidentification

- Order of CubeSats in cluster was still unclear after a month
- First and last CubeSats in each P-POD were interchanged when names were assigned to objects
- Problem not discovered for two months, when CP3 was contacted for the first time
Recommendations for Improvement

- Stronger separation springs to disperse CubeSats faster
- P-POD redesign allows for visual confirmation of total spring compression
- Beacons!
Poly Picosatellite Orbital Deployer

- Standard deployment system
  - Tubular frame
  - Spring assisted ejection
  - Payload of 3 single CubeSats

- P-POD mission objectives
  - Protect LV and primary payload
  - Safe/reliable deployment
  - Compatibility with many LV
P-POD Mark III Structure

- **Mark III P-POD**
  - Increased Side Panel Access to facilitate CubeSat integration process
  - The Mk III can accommodate both the Qwknut and NEA 9102G release mechanisms to meet different launch vehicle requirements.
  - Release door modified to account for shear relief from NEA
The CubeSat Standard

- Shape and size (10 cm cube)
- Mass (up to 1 kg)
- Interface to P-POD
  - Rails
  - Access ports
- Materials and tolerances
- Operations
  - Deployables
  - Communication
- Different configurations possible
6-Pack Concept

- Larger form factor
- Fully enclosed deployer
- One NEA
- One satellite
6-Pack

- Mass: +6kg
- Size: +6U
Major Domestic Launch Vehicles
<table>
<thead>
<tr>
<th>Launch</th>
<th>Number of P-PODS</th>
<th>CubeSat Missions</th>
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</thead>
<tbody>
<tr>
<td>Eurokot</td>
<td>2</td>
<td>P-POD A: CanX-1, DTUsat, AAU CubeSat</td>
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<tr>
<td></td>
<td></td>
<td>P-POD B: QuakeSat</td>
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<tr>
<td>SSETI Express</td>
<td>1</td>
<td>CubeSat XI-V, NCUBE-2, UWE-1</td>
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<tr>
<td>Belka: Dnepr</td>
<td>5</td>
<td>P-POD A: ION, Sacred</td>
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<tr>
<td></td>
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<td>P-POD B: KUTESat Pathfinder</td>
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<td></td>
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<td>P-POD C: SEEDS, HAUSAT 1, Ncube 1</td>
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<td>P-POD D: MEROPE, AeroCube-1, CP2</td>
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<td>P-POD E: CP1, Ice Cube 2, Mea Huaka (Voyager)</td>
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<tr>
<td>TacSat-2: Minotaur</td>
<td>1</td>
<td>Modified P-POD: GeneSat-1</td>
</tr>
<tr>
<td>EgyptSat: Dnepr</td>
<td>3</td>
<td>P-POD A: CP4, AeroCube 2, CSTB 1</td>
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<tr>
<td></td>
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<td>P-POD B: MAST</td>
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<td>P-POD C: CP3, CAPE 1, Libertad-1</td>
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Upcoming Launches

- **Falcon-1 3rd flight**
  - 2 P-PODs
    - NASA Ames 3U
    - NASA Marshall 3U
- **Falcon-1 RazakSat**
  - 2 P-PODs
- **Minotaur-I TacSat 3**
  - 2 P-PODs