Planet Labs’ Remote Sensing Satellite System

Cubesat Developers Workshop 2013
Logan Utah
A Complete Picture of the Changing Planet

Planet Labs will revolutionize Earth observation by providing universal, low-cost access to information about the Earth, its environment, and its people.
April Tech Demos
# Dove 1 Satellite

<table>
<thead>
<tr>
<th>Function</th>
<th>Subsystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optics</td>
<td>90 mm aperture</td>
</tr>
<tr>
<td>Comms</td>
<td>X-band, UHF</td>
</tr>
<tr>
<td>Attitude Determination</td>
<td>magnetometers, gyros, photo-diodes</td>
</tr>
<tr>
<td>Attitude Control</td>
<td>magnetorquers, reaction wheels,</td>
</tr>
<tr>
<td>Power</td>
<td>Li-ion batteries, fold-out solar arrays</td>
</tr>
</tbody>
</table>
Dove 1 Mission

- Launched April 21, 2013 on Antares
- 241 x 257 km, 51.6 deg
- Re-entered April 27, 2013
- Six Day Mission!

Commissioning
- Manual ops using SRI dish
- Automated telemetry downlink at HMB & UK using mission control system

Operations:
- Downloading of pics at Chilbolton facility
- Routine software updates
Dove 1 Results

Satellite Goals Achieved

- Nominal health status of all key subsystems
- TT&C over UHF radio
- Attitude stabilization using magnetorquers
- On orbit firmware and software upgrades
- 4 Mbps payload downlink
- Fine attitude pointing using reaction wheels

Ground Segment Goals Achieved

- 5 locations deployed and remotely coordinated from Mission HQ in San Francisco
- Operations with 2 satellites in 2 different orbits
- Major progress in mission control software and automated operations
- Mission operations lessons learned
Imagery taken from Dove 1 – First light three days after launch. April 24, 2013
Dove 1 Image Overlaid on Google Earth 20km West of Portland, OR
## Dove 2 Satellite

<table>
<thead>
<tr>
<th>Function</th>
<th>Subsystem</th>
</tr>
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<tbody>
<tr>
<td>Optics</td>
<td>90 mm aperture, 4.40 m GSD at 575 km</td>
</tr>
<tr>
<td>Comms</td>
<td>MHX S-band, UHF</td>
</tr>
<tr>
<td>Attitude Determination</td>
<td>magnetometers, gyrometers, photo-diodes</td>
</tr>
<tr>
<td>Attitude Control</td>
<td>magnetorquers</td>
</tr>
<tr>
<td>Power</td>
<td>Li-ion batteries, body-mounted solar arrays</td>
</tr>
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</table>
Dove 2 Mission

- Launched April 19, 2013 on Soyuz
- 575 x 575 km, 64.9 deg
- Re-entry between ~10 years

Commissioning
- Manual ops using SRI dish
- Automated telemetry downlink at HMB & UK using mission control system

Operations:
- Downloading of pics at Morehead dish
- Routine software updates
Dove 2 Results (on-going)

Satellite Goals Achieved

- Nominal health status of all key subsystems
- TT&C over UHF radio
- Attitude stabilization using magnetorquers
- On orbit firmware and software upgrades
- 30 kbps payload downlink over 2.4 GHz radio

Ground Segment Goals Achieved

- 5 locations deployed and remotely coordinated from Mission HQ in San Francisco
- Operations with 2 satellites in 2 different orbits
- Extremely rapid commissioning phase
- Major progress in mission control software and automated operations
- Mission operations lessons learned
Imagery taken from Dove 2 – Shizuoka, Japan
Imagery taken from Dove 2 – First light three days after launch. April 24, 2013
Tech Demo Mission Results

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Detumbled from $22^\circ$/s to $<0.5^\circ$/s
Bdot needle

- Mimics permanent magnet with hysteresis rods
- Simple and robust controller
  - Easy image geolocation
  - Enables MHx communication
Communications Subsystem
Onboard Radios

● Dove 1
  ○ Entire comms system was developed in house
    ■ CC1110 based UHF transceiver provided lower speed comms for commissioning and ranging
    ■ Software defined, DVB-S2 based high speed x-band radio provided image downlinks

● Dove 2
  ○ Flew a combination of in-house radios and COTS radios
    ■ MHX-2400 provided higher speed comms for image downlinks
    ■ CC1110 based UHF transceiver provided lower speed comms for commissioning and ranging
Communications Subsystem Ground Segment

- **UHF radio**
  - 2 low gain, yagi based homebrew earth stations
  - 2 high gain, parabolic dish based earth stations
  - Geographically diversified for global coverage
  - achieved strong signal links to all ground stations

- **MHX-2400**
  - Used Moorehead 21 meter dish
  - Link quality was poor

- **X-band radio**
  - Used Chilbolton 6 meter dish
  - Link quality was strong
UHF Transceiver

- TI CC1110 (8051 µc + flexible radio peripheral)
  - external 1W power amplifier for transmit
  - external low noise amplifier for receive
- 2.4 kbps to 10 kbps
- Radio firmware updates over RF:
  - work around issues with other parts of satellite
  - add new features
~2 km-accurate ranging with UHF transceiver

- Low cost, low power spacecraft radio and ground station
- No precision pointing needed, no dedicated ranging HW in space or on ground
- Orbit updates approach quality of JSpOC TLEs
- Avoid satellite identification ambiguity during early operations and short missions
Solar Panels - TASC

- TASC used as primary cells for both missions
  - Poor quality control and low packing efficiency
  - 80 cells per panel = high labor cost
Solar Panels - Silicon

- Custom cut silicon cells
  - Commoditized 19% efficient silicon cells, cut to size
  - Higher packing efficiency nearly offsets lower solar efficiency
  - Test panel successfully flown on Dove 1
Solar Panels - Assembly

- Conductive epoxy used to attach cells to PCB
  - Provides mechanical and electrical connection
  - Repeatable with the use of a stencil
  - Cheaper and far less labor intensive than existing methods
  - Flown on Dove 1 and 2
Solar Panels - Encapsulant

- SYLGARD-184 encapsulant used to protect cells
  - Same base resin as DC 93-500 but 50x cheaper
- Only two panels were encapsulated on Dove 2
- 100-day data:
  - Unencapsulated panels degraded by 61%
  - Encapsulated panels degraded by 22%
    - Likely due to UV darkening
Number of telemetry packets