Planet Labs' Remote Sensing Satellite System

Cubesat Developers Workshop 2013
Logan Utah

A Complete Picture of the Changing Planet

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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

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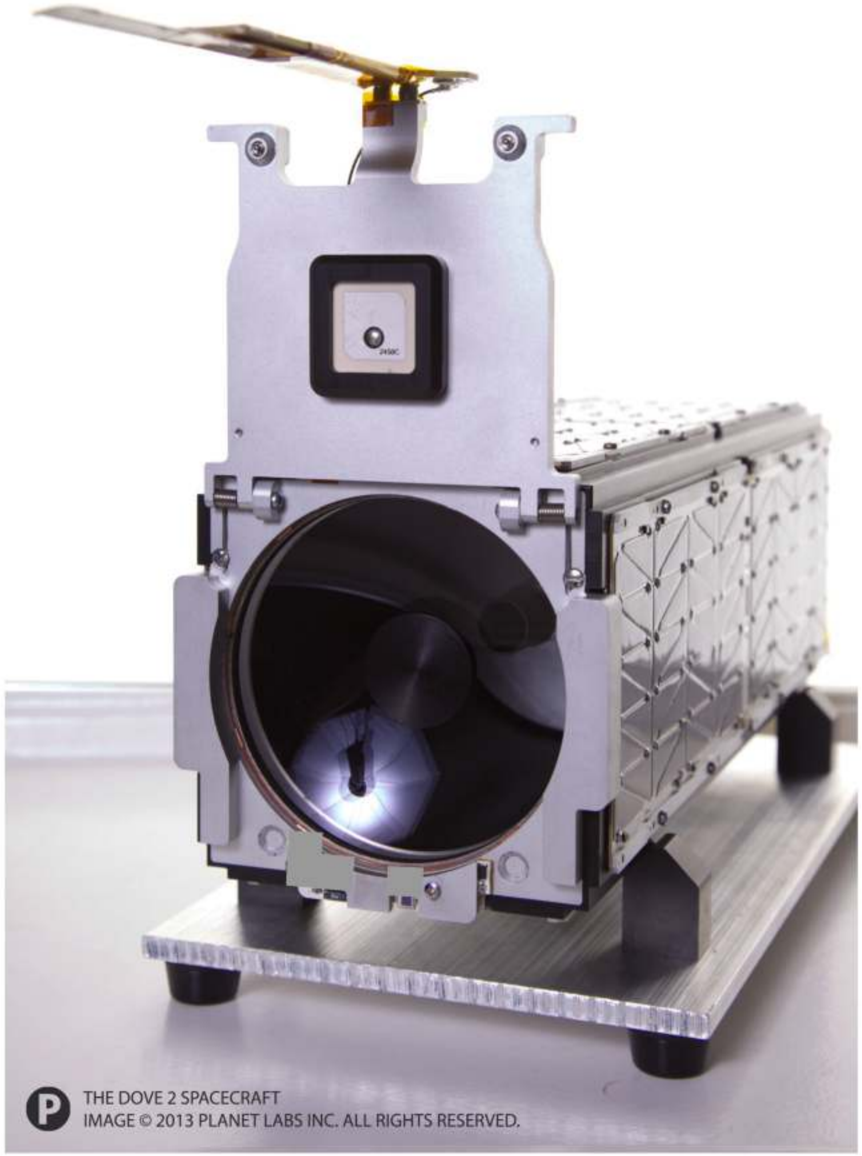
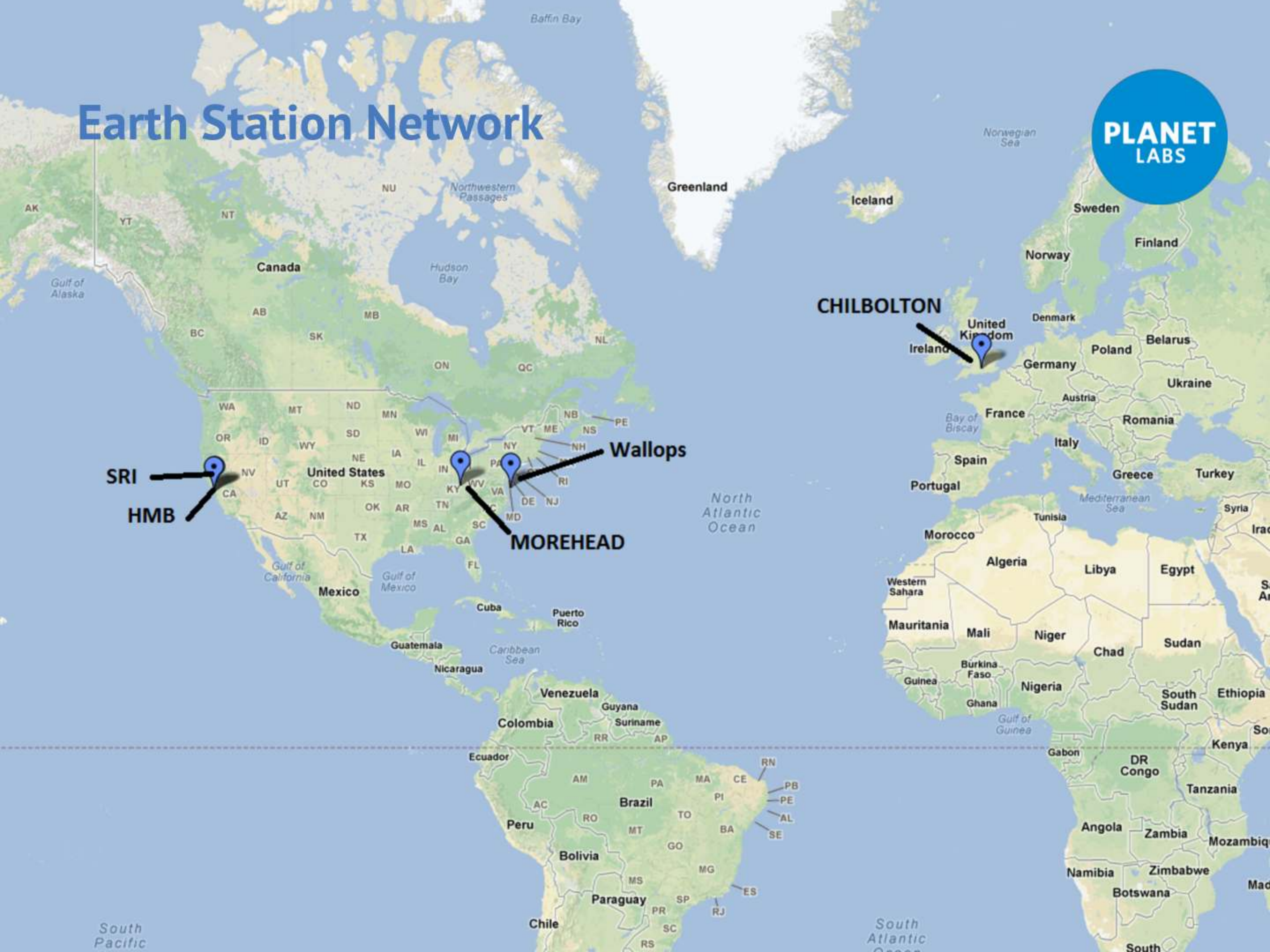


Earth Station Network



Dove 1 Satellite

Function	Subsystem
Optics	90 mm aperture
Comms	X-band, UHF
Attitude Determination	magnetometers, gyros, photo-diodes
Attitude Control	magnetorquers, reaction wheels,
Power	Li-ion batteries, fold-out solar arrays

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

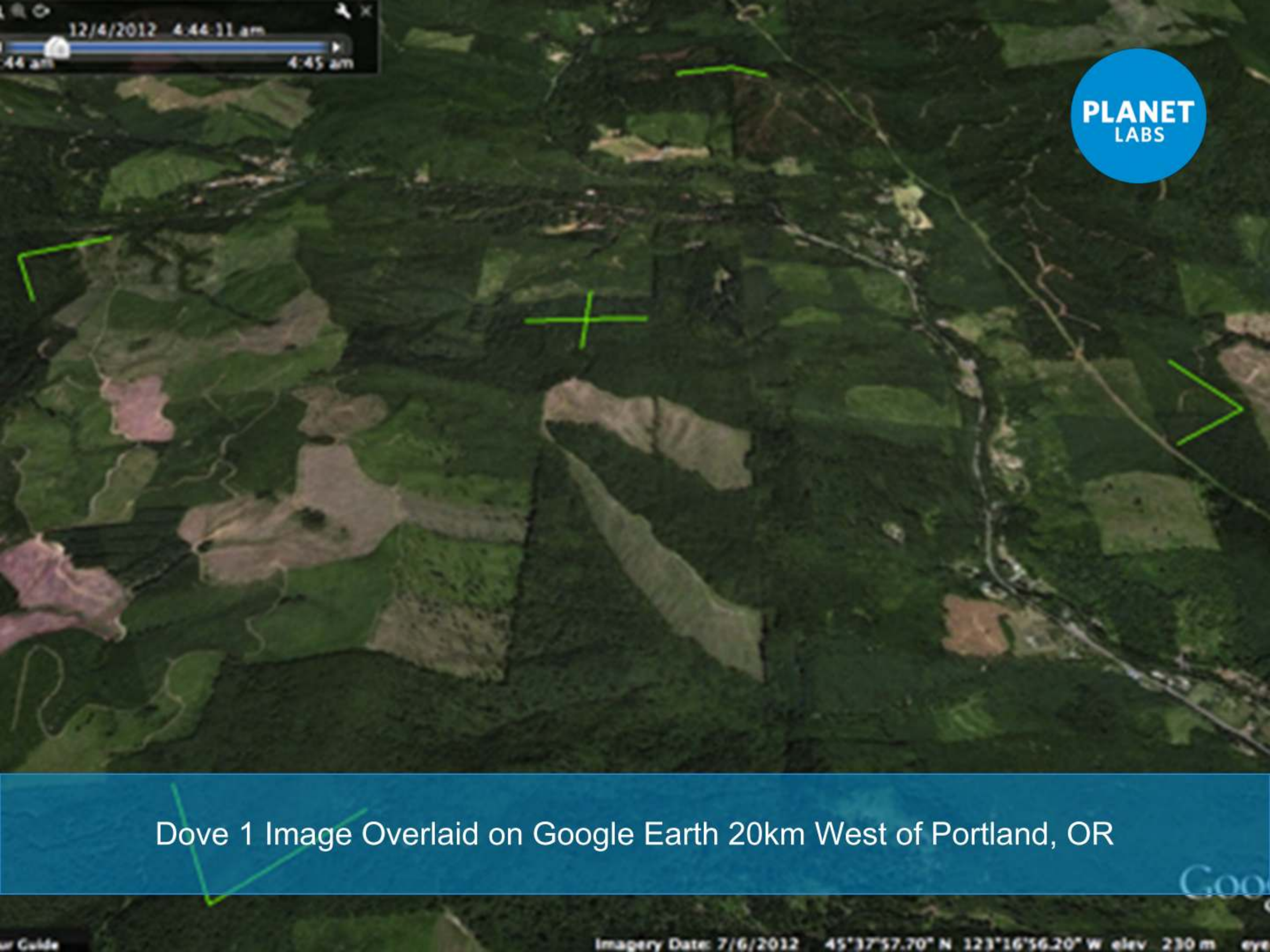
Satellite Goals Achieved

- 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

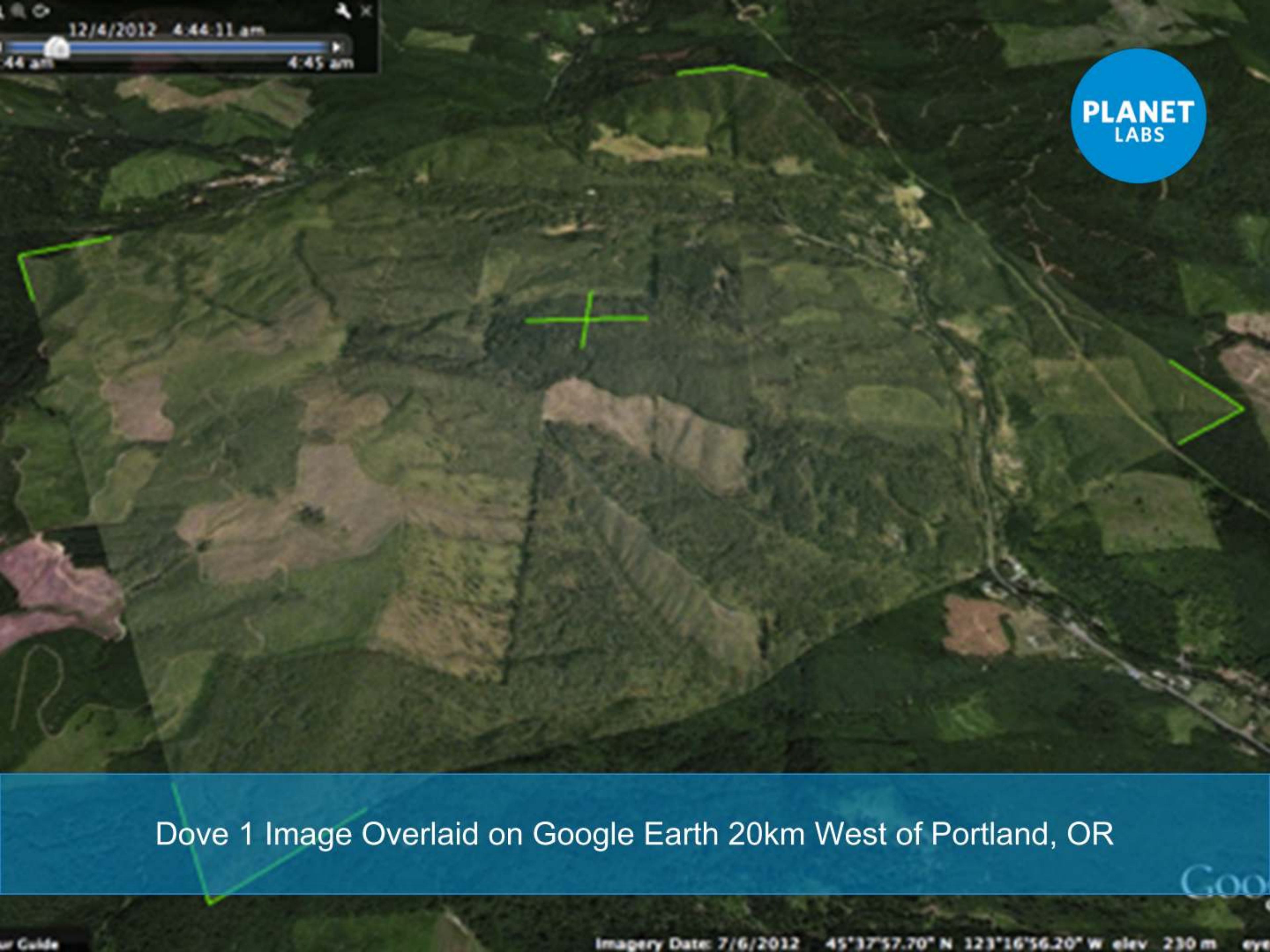
Ground Segment Goals Achieved

- 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 1 Image Overlaid on Google Earth 20km West of Portland, OR

Dove 2 Satellite

Function	Subsystem
Optics	90 mm aperture, 4.40 m GSD at 575 km
Comms	MHX S-band, UHF
Attitude Determination	magnetometers, gyrometers, photo-diodes
Attitude Control	magnetorquers
Power	Li-ion batteries, body-mounted solar arrays

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)

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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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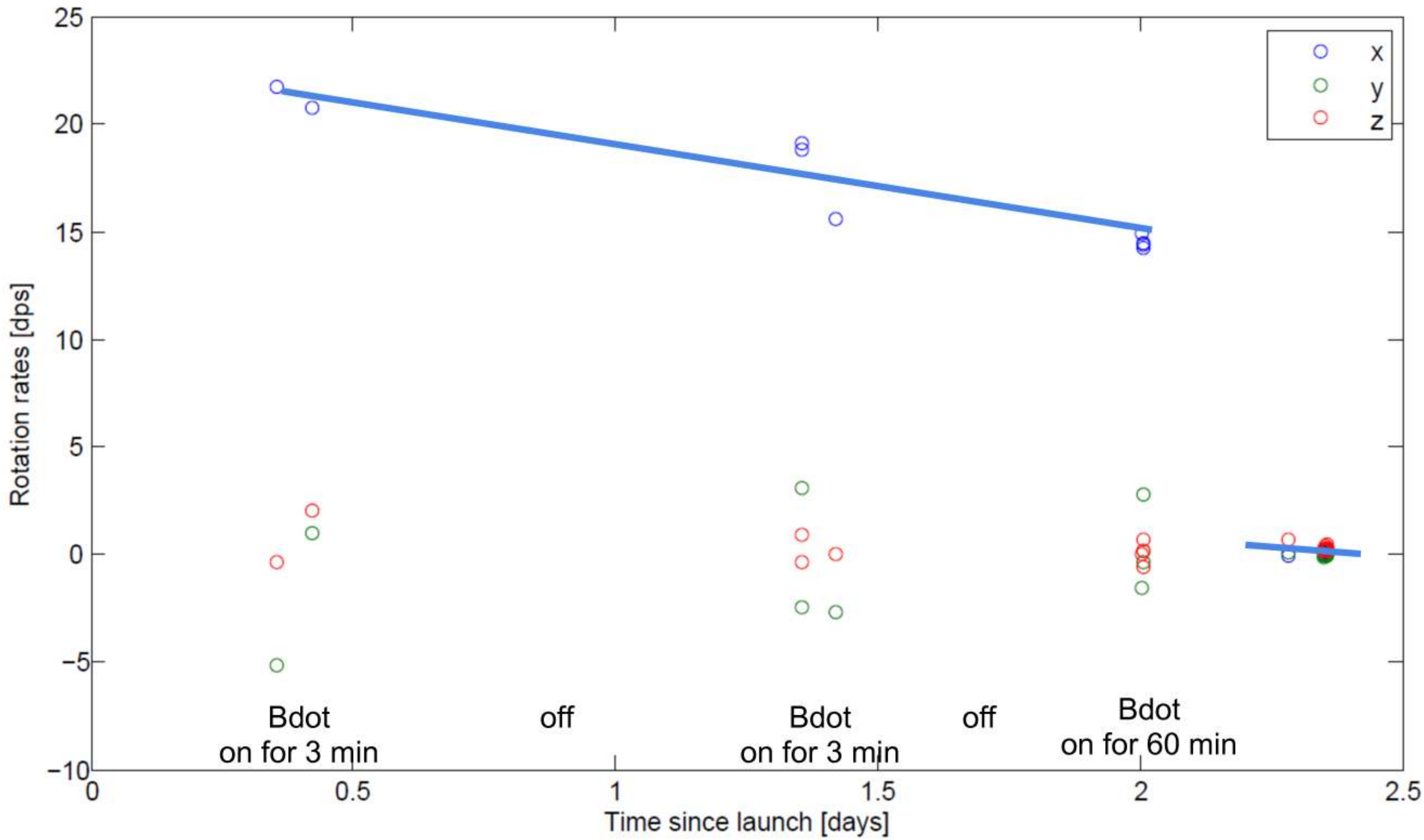
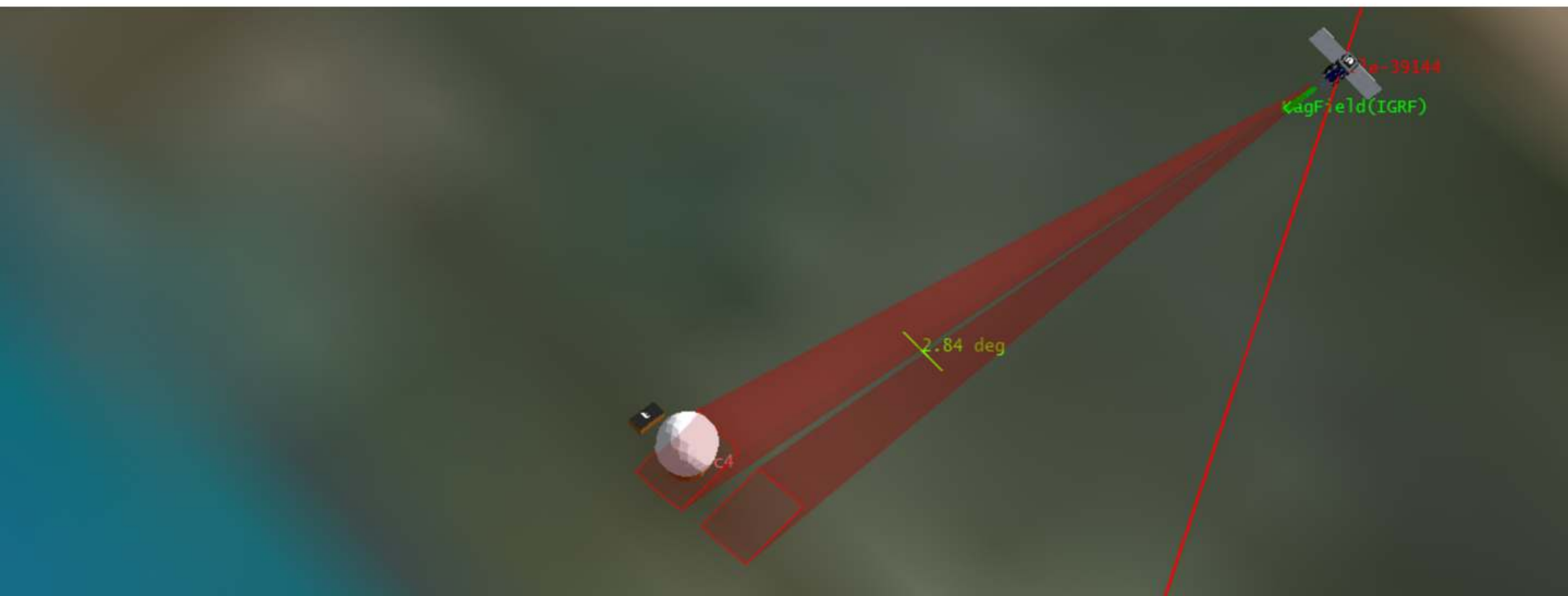
Detumbled from 22°/s to <0.5°/s



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

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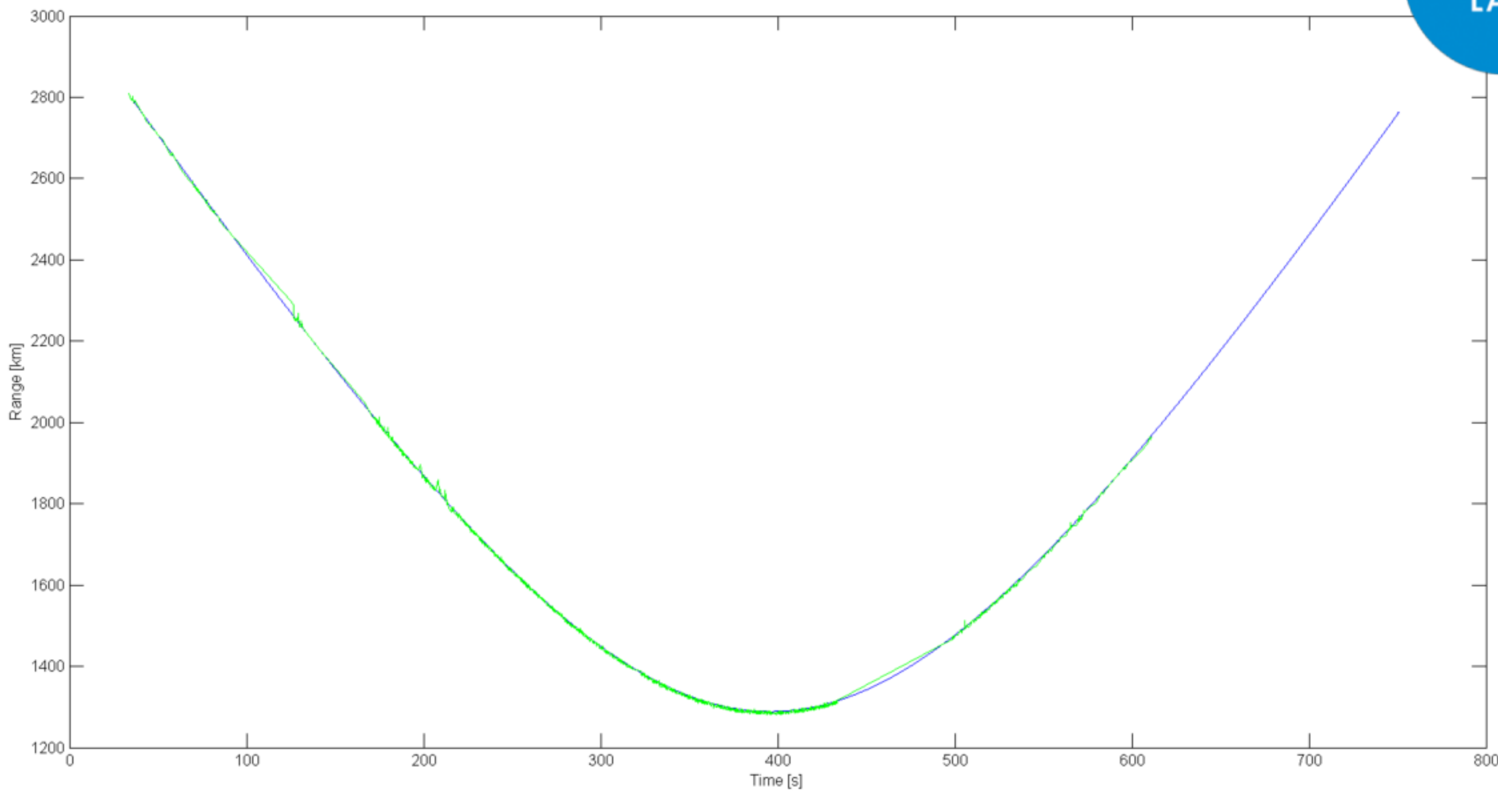
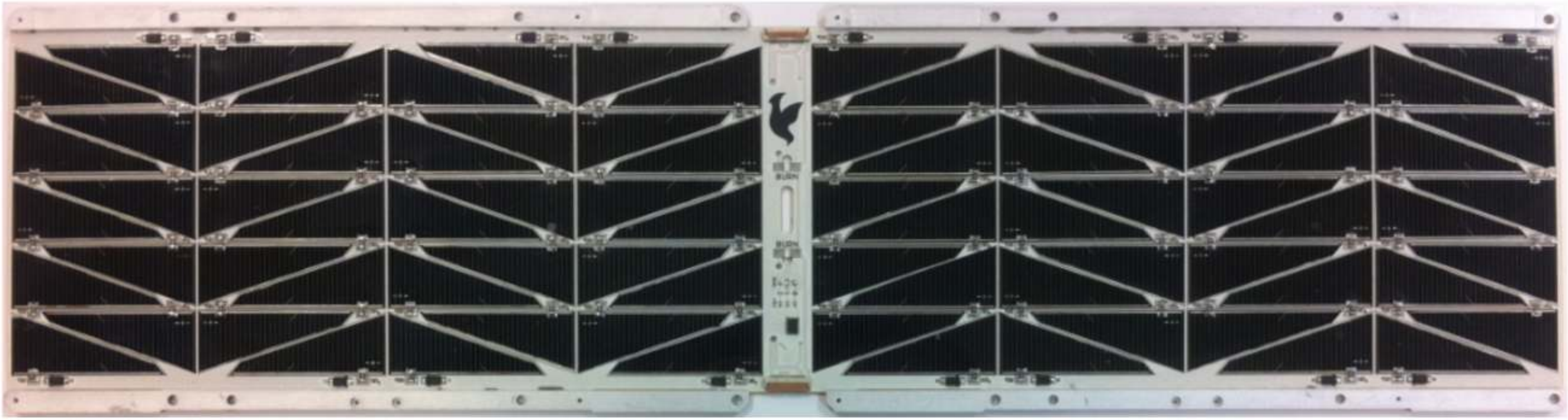


- Low cost, low power spacecraft radio and ground station
- No precision pointing needed, no dedicated ranging HW in space or on ground
- Orbit updates approach quality of JSpOC TLEs
- Avoid satellite identification ambiguity during early operations and short missions

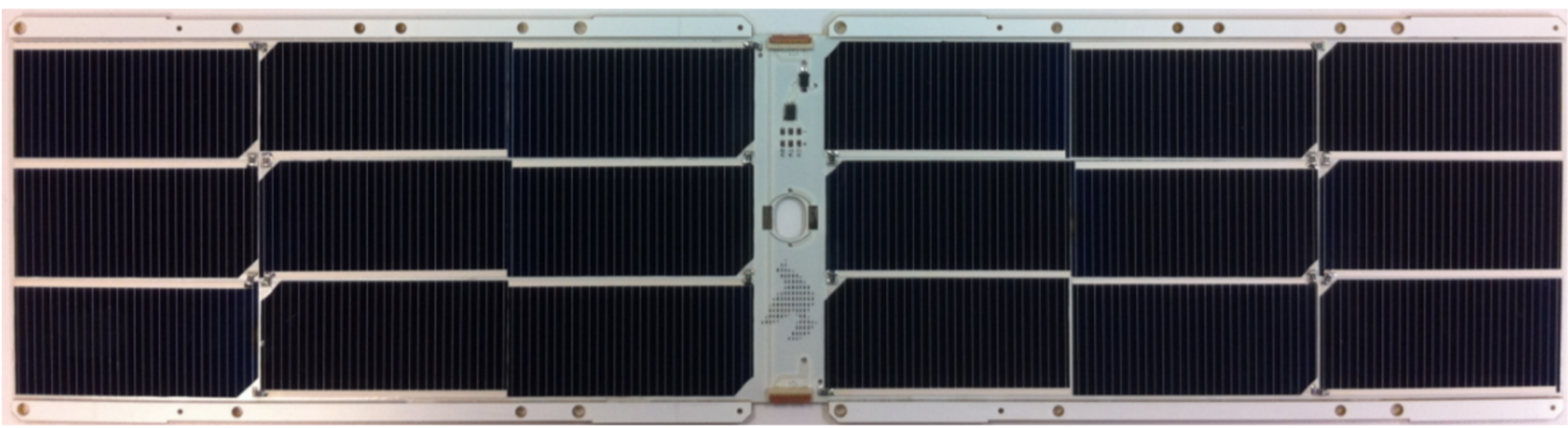
Solar Panels - TASC

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



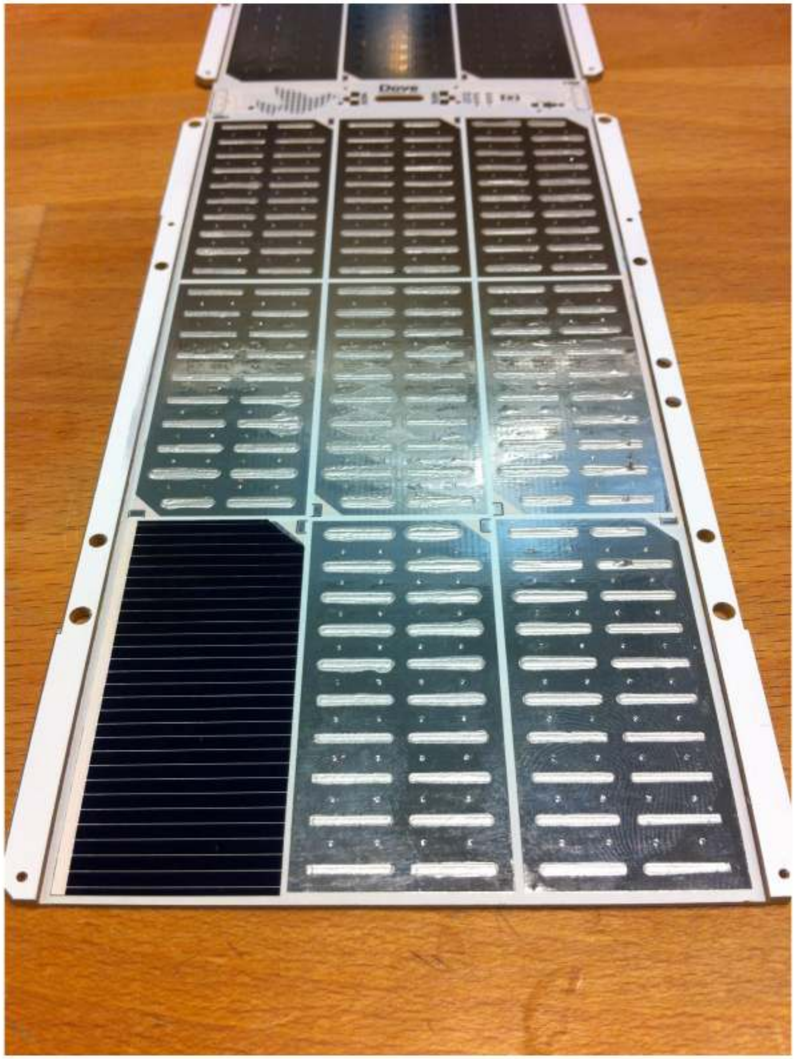
Solar Panels - Silicon

- 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



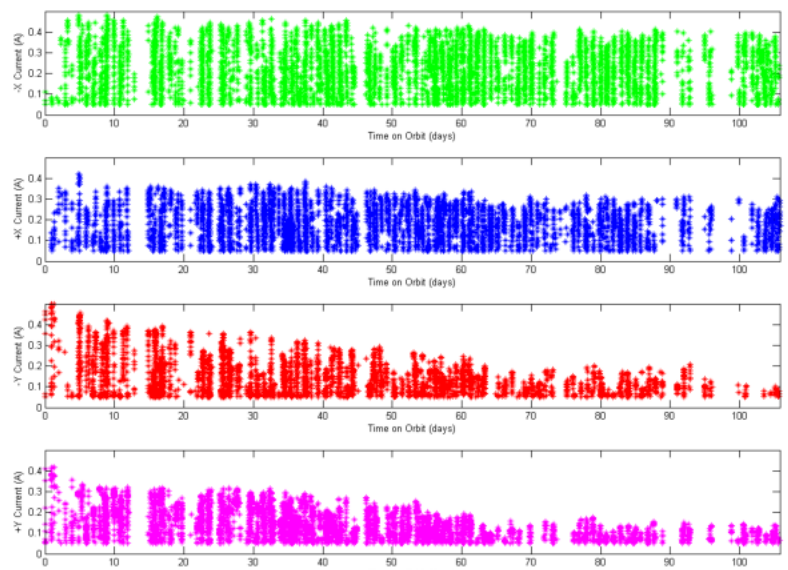
Solar Panels - Assembly

- 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