Traditional Tasked Imaging

“Point and Shoot” Operations

High Resolution, Low Coverage

Have to know what you’re looking for

Human-in-the-Loop operations

Planet Labs 2014
Cubesat Earth Imaging

“Always-on” Operations

Medium resolution, wide and frequent coverage

Alerts the news instead of chasing it

Autonomous operations

Planet Labs 2014
Planet Labs – Sea Ice
Planet Labs – Agriculture
Planet Labs – Reservoir Levels
Planet Labs – Shipping Lanes
Planet Labs Launches (2014)

Planet Labs already launched 67 Cubesats in 2014
Planet Labs Launches (2014)
Low Speed Transceiver:
- 1W transmit power
- 2 to 10 kbps
- 400 to 450 MHz (extensible)
Hardware design overview

**CC1110**: 8-bit “system-on-chip” low-power microcontroller with integrated flexible radio peripheral

**BOM cost**: < $80

**3 x 3 cm**

**140 mW idle power**
Ground station

Same radio + 20W power amp + LNA + cavity filter + Yaesu rotors + 16 dBi Yagi

~$2500

Planet Labs 2014
Software and protocols

- RF modulation: Gaussian Frequency-Shift Keying
  - 9 dB better performance than AX.25 AFSK
  - Good spectral efficiency
  - Highly configurable
  - Half duplex; optionally different uplink and downlink freqs

- Packet-oriented protocol with variable-length frames
  - CRC protected
  - Idempotent commands encouraged
  - Speak-when-spoken-to
  - Address by satellite ID

- Bootload new firmware over the air
Robust

- Large link margin
- Omnidirectional
  - Works with tumbling satellite
- Wide groundstation beamwidth
  - Works with poorly determined orbit
Flexible

● OTA firmware upgradable
  Enabled feature updates (ranging), workarounds for problems

● Backdoors to other satellite systems:
  Crowbar circuit, microcontroller resets

● Radio reliability as a tool for recovery
Two-way ranging: JSpOC isn’t gospel

- Unambiguous identification - no more TLE lottery
- Independent orbit determination

Planet Labs 2014
Results

42 / 42 satellites contacted, mostly on first pass
140 months total flight time
3000 km demonstrated range
Over 6 million packet round-trips (~300 MBytes)
Multiple on-orbit firmware updates across fleet
Cable-free bench
Open Source

Public release in November
- Schematics + layout
- Firmware and host source code
- Orbit determination software

Contact us with questions before then

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Outline (this is not a slide)

Context
Constellation of tens of 3U cubesats
1 of 3 radios
Not trying to be high performance, just robust

Design overview:
Radio
  Importance of LNA matching (specific to our use of 2 freqs)
Software
Sat antenna
Ground station
Protocol (idempotent msgs, valid or not at all)

Use of cheap consumer components

Utility:
Robust: All attitudes, no precise pointing, link margin
Firmware upgrades over the air…
…added ranging
Satellite backdoors (SC reset, crowbar)

Specs:
2…10 kbps
1 W transmit
>3000 km demonstrated range
0.7 km ranging accuracy

Results:
100% success rate on 42 satellites, 140 months cumulative
xx MB transferred
xx firmware updates
Ranging enabled OD when JSpOC failed
Allowed discovery of closed flap

Open-source plans
Public design release in November (ITAR reform)
Contact us with questions before then