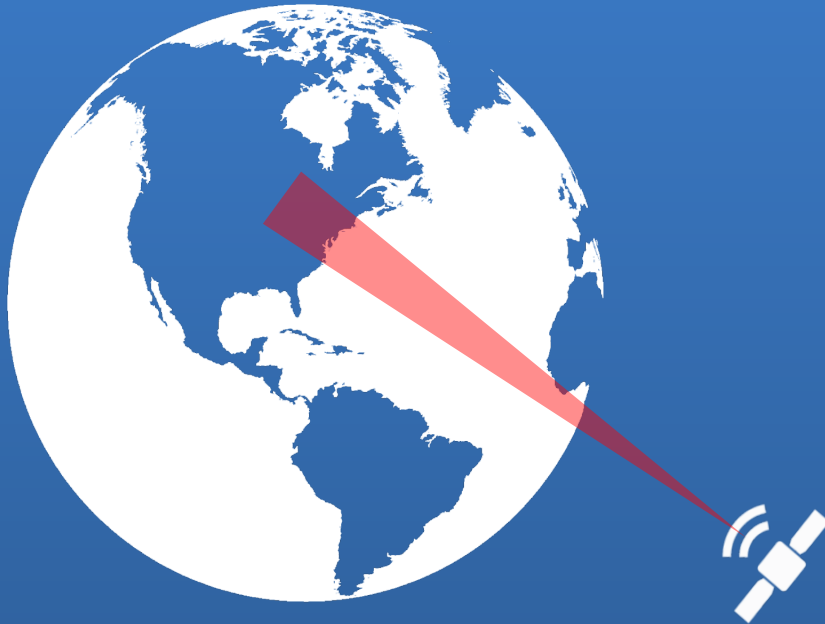


Traditional Tasked Imaging



“Point and Shoot”
Operations

High Resolution, Low
Coverage

Have to know what
you’re looking for

Human-in-the-Loop
operations

Cubesat Earth Imaging



“Always-on”
Operations

Medium resolution,
wide and frequent
coverage

Alerts the news
instead of chasing it

Autonomous
operations

Planet Labs – Deforestation



04-24-13 FROM DOVE 1

IMAGE © 2013 PLANET LABS INC. ALL RIGHTS RESERVED.

Planet Labs – Sea Ice



04-26-13 FROM DOVE 2

IMAGE © 2013 PLANET LABS INC. ALL RIGHTS RESERVED.

Planet Labs – Agriculture



Planet Labs – Wildfires



IMAGE © 2014 PLANET LABS INC. ALL RIGHTS RESERVED.

Planet Labs – Reservoir Levels



Planet Labs – Shipping Lanes



Planet Labs Launches (2014)

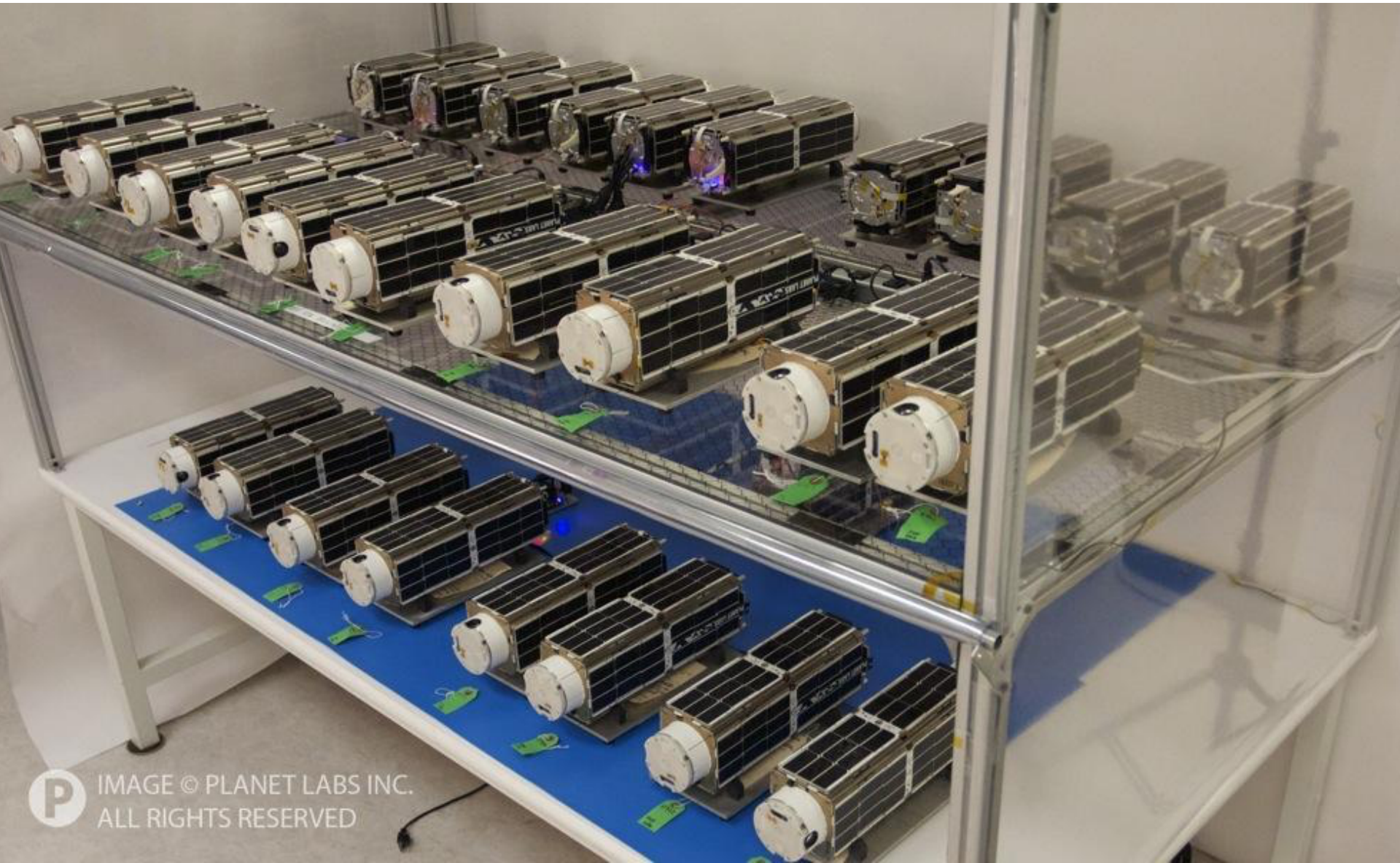


IMAGE © PLANET LABS INC.
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Planet Labs Launches (2014)



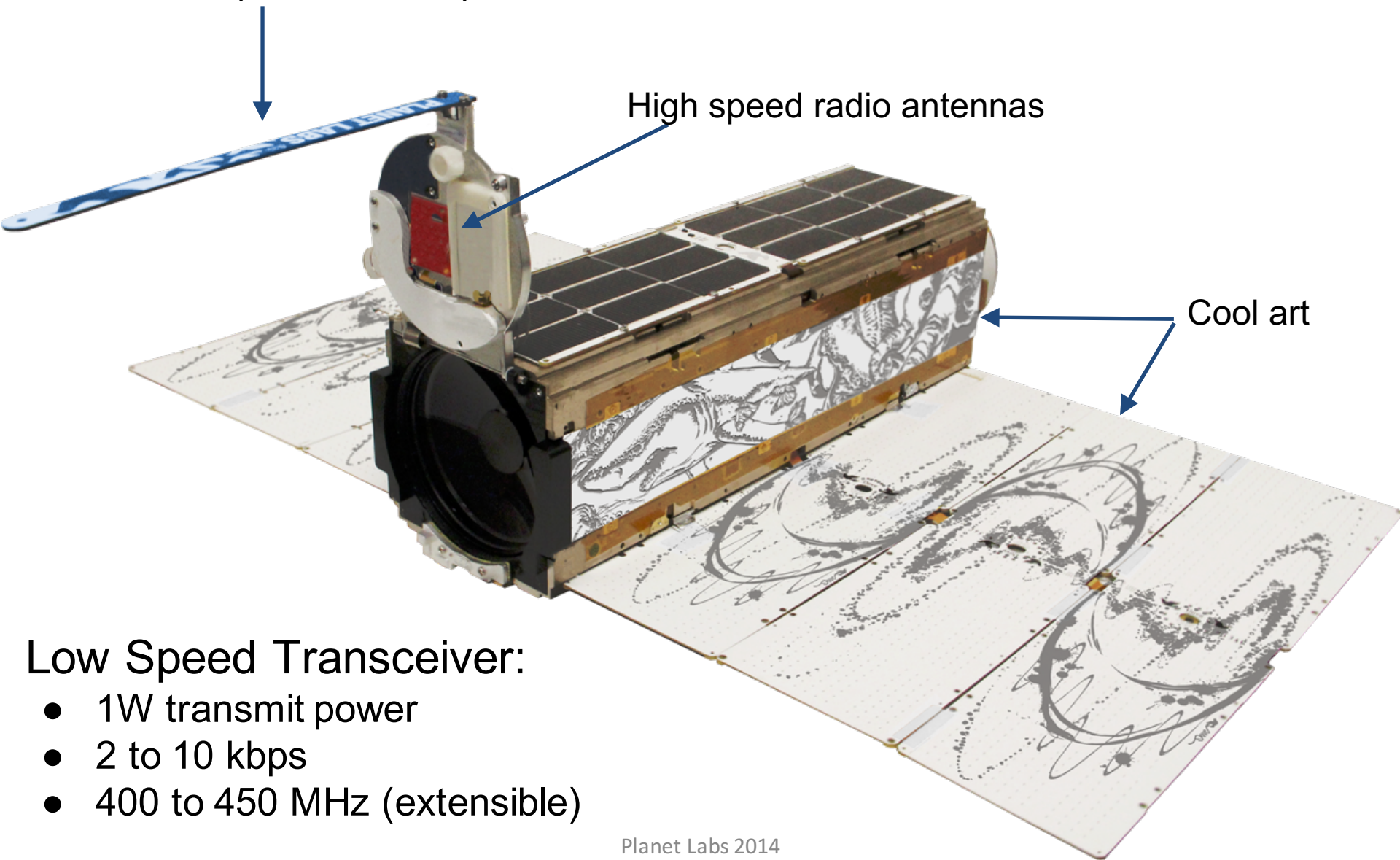
UHF monopole for Low Speed Transceiver

High speed radio antennas

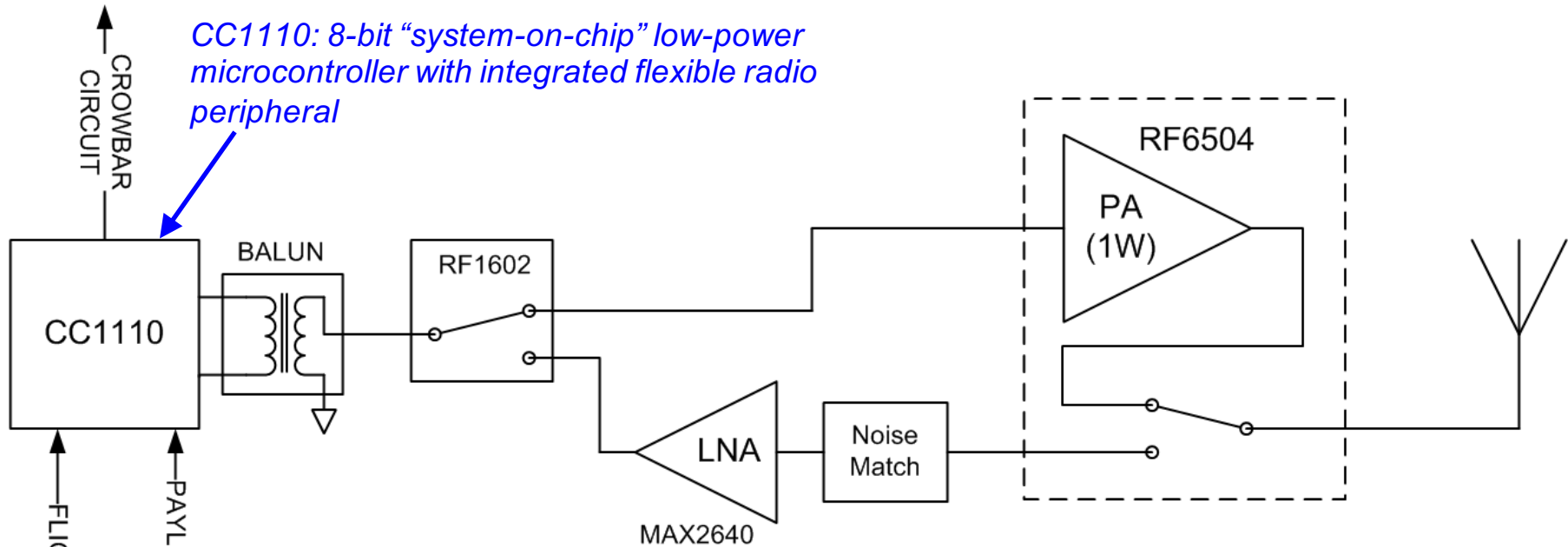
Cool art

Low Speed Transceiver:

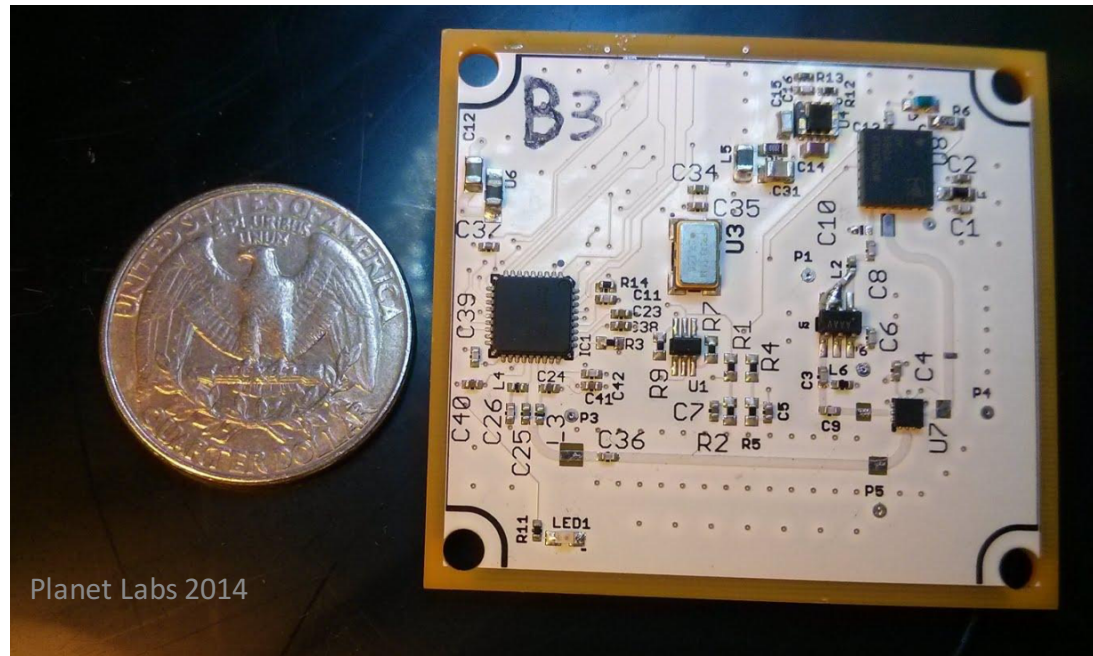
- 1W transmit power
- 2 to 10 kbps
- 400 to 450 MHz (extensible)



Hardware design overview



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

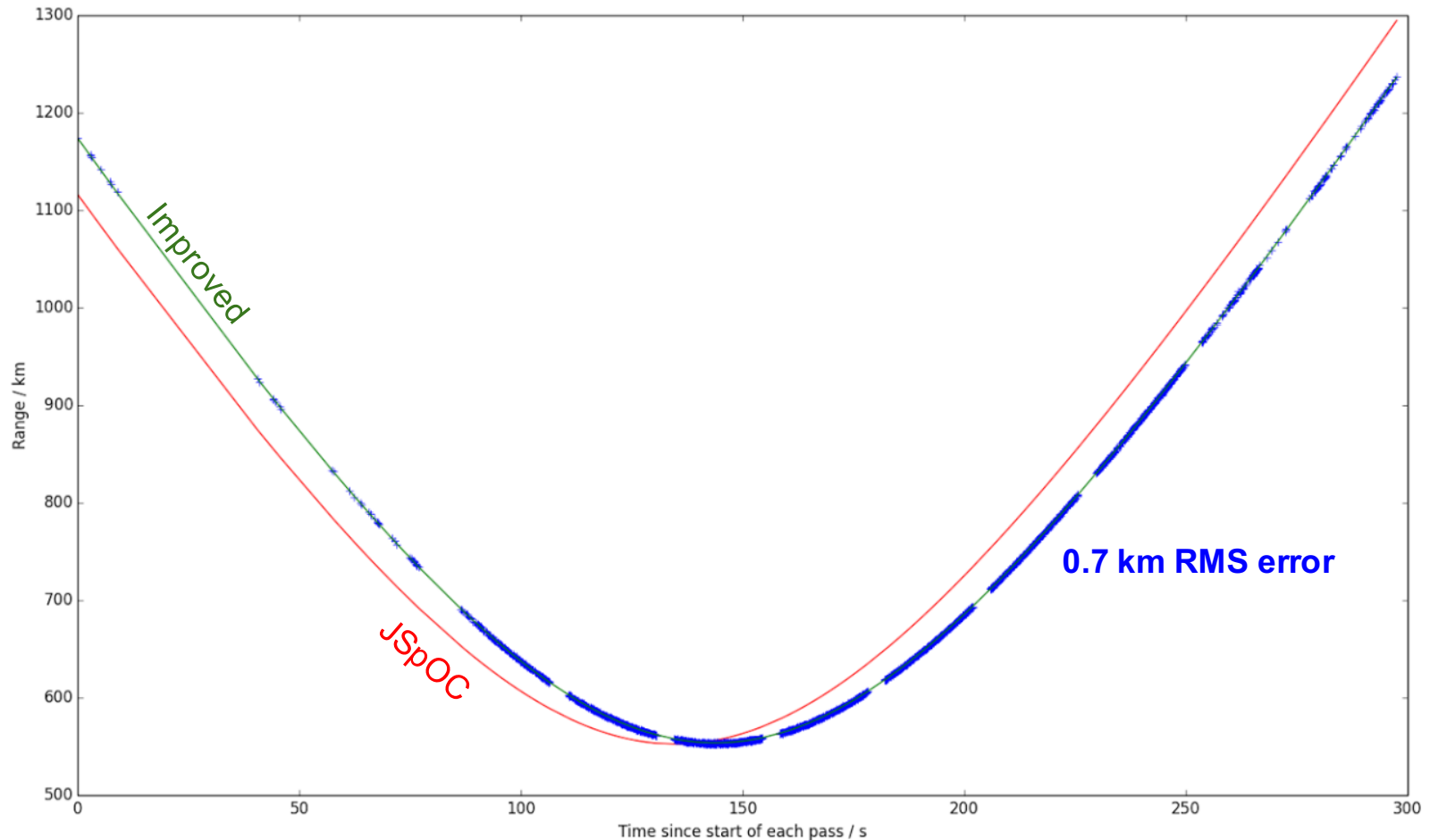
Flexible

- 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**



Planet Labs 2014

Two-way ranging: JSpOC isn't gospel



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

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
henry@planet.com

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