PhoneSat: Balloon Testing Results

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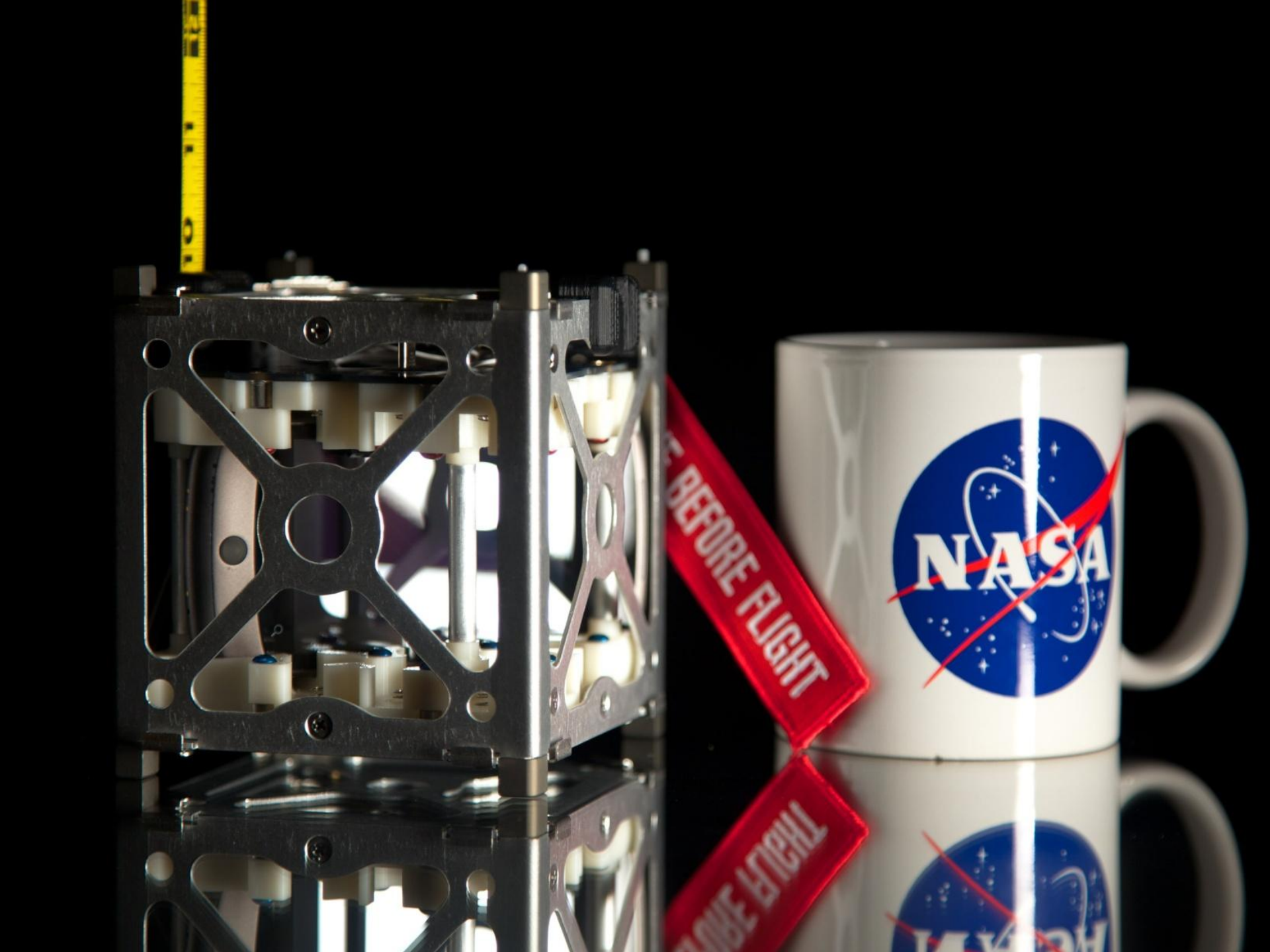
2011 Summer CubeSat Developers' Workshop


BEFORE FLIGHT
NASA

Why use a phone?

- Increase on-orbit processor capability by a factor of 10-100
- Decrease cost by a factor of 10-1000
- Free up cubesat volume for additional payload through avionics miniaturization
- Demonstrate COTS approaches to all subsystems (power, attitude determination, comms)

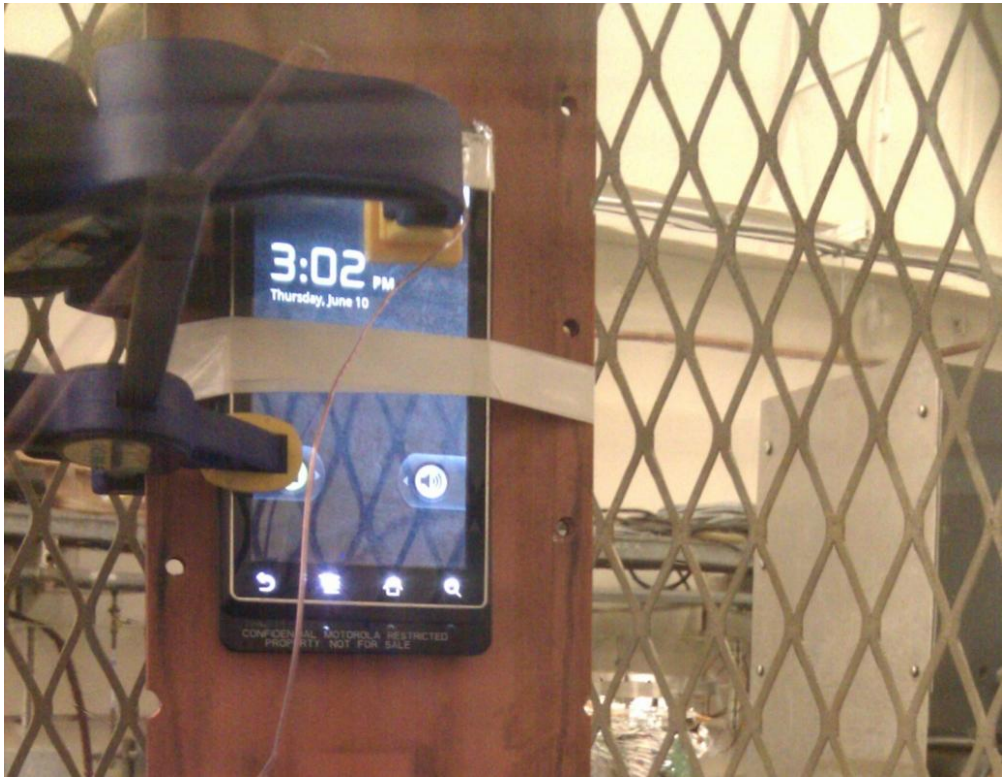
➔Produce high-capability spacecraft for $1-10k

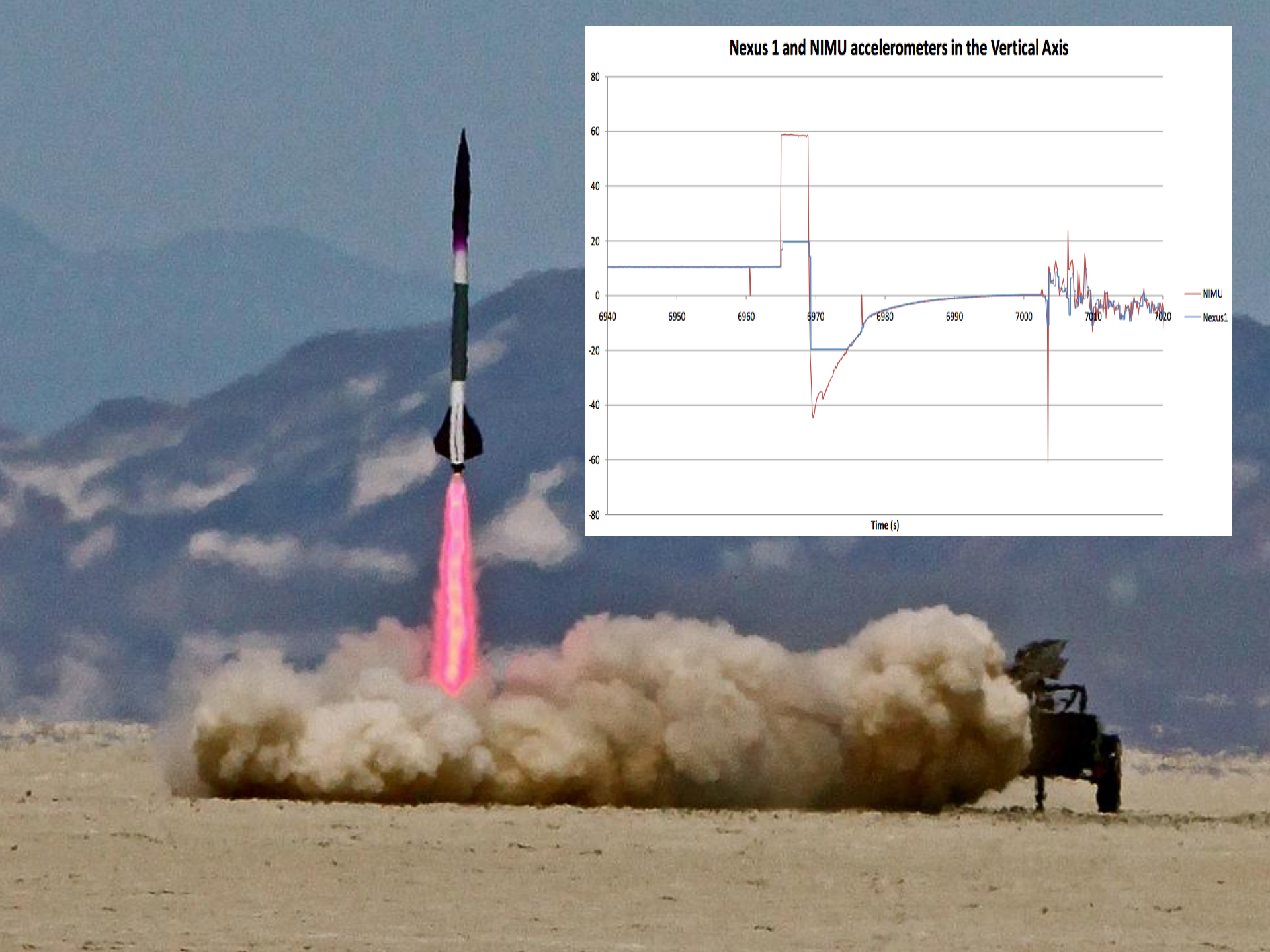
Nexus One

- Android OS
- 1 GHz Processor
- 500 MB RAM
- 16GB Data Storage
- 3-axis accelerometer, 3-axis magnetometer
- 5MP Camera/VGA Video Camera
- GSM, WiFi, Bluetooth, FM radio
- GPS (restricted)

Environmental Testing

1. Thermal-Vac testing to 10-5 Torr, -35C to +40C
2. Suborbital Rocket Testing to 10,000m readiness
3. Launch vibe and shock to NASA GEVS standards
4. Balloon flights for system level qualification (30km altitude)



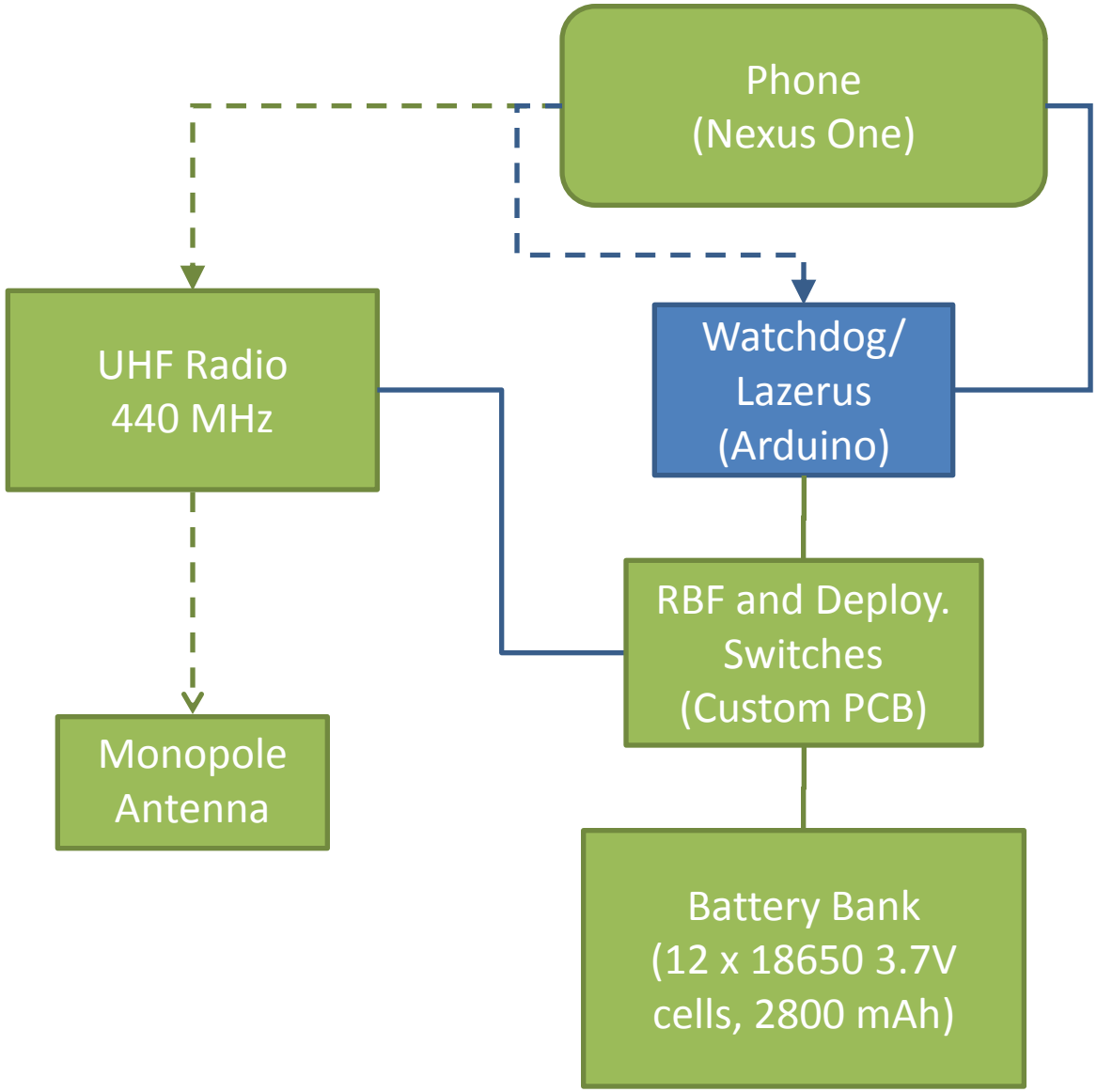

Nexus 1 and NIMU accelerometers in the Vertical Axis
80
60
40
20
0
-20
-40
-60
-80
6940
6950
6960
6970
6980
6990
7000
7010
7020
Time (s)
NIMU
Nexus1

PhoneSat 1: Requirements

1. Work for > 1 orbit
2. Send minimum health data
3. Send 1 image taken by the phone to ground
4. Parts cost << $10,000, leading towards $1,000 unit cost
5. Schedule < 3 months from ATP to flight readiness

PhoneSat 1: System Architecture

Spacecraft 1.0
Concept A
- With UHF radio
- & Hardware battery override
- & Watchdog/Lazerus



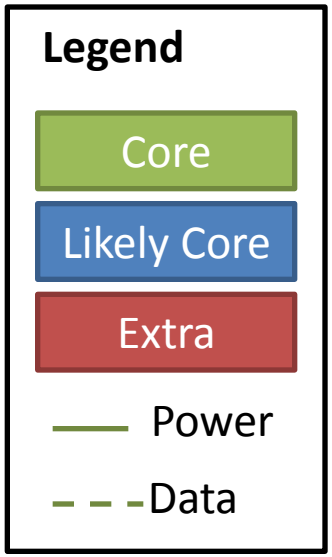


Image Downlink Challenge

- Get a “desktop sized” image to the ground
- 640x480 rgb24 = 200,000 bytes
- 200 byte AX.25 packet transmissions
- 1-week of battery, approx. 10,000 transmissions
- Every 5th transmission is a health packet
- Reach out to HAM operators and volunteer organizations…
- …but not all stations are automated and ½ of them are sleeping
- And 2/3 of the world is ocean
- And no way to command which packets to downlink

Image Pyramid Packetization

Low-res (1 packet)

Medium-res (5x5 packets)

Hi-resolution image tiles (640x480 divided into 20x20 packets)

Radio Range Tests

Balloon Flights

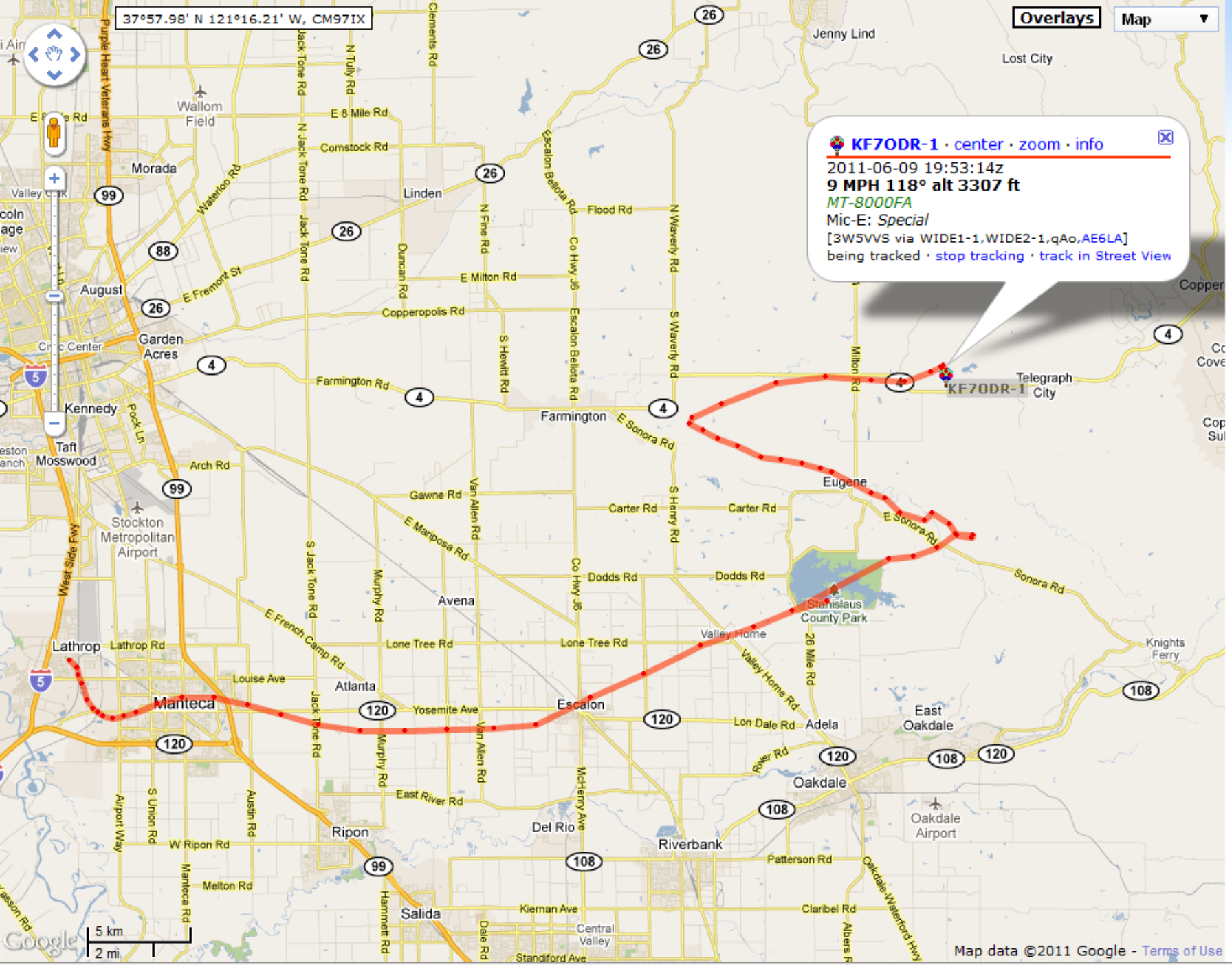
Balloon Flight Motivation

- Analog to space, no ITAR restrictions, low-cost
- Useful radio tests
  - Long distance, simulate tumbling
  - Clean RF environment
- Operationally similar to orbital flight
  - Organizing the team, getting flight experience
  - Ok to fail
- Useful software tests
- **Deadlines help get things done!**

Balloon Procedure

- In-lab dress rehearsal 1-3 days before
- Launch site selection and flight path prediction using http://habhub.org/predict/
- Flight tracking using separate APRS beacon* and http://aprs.fi/
- Recovery

*requires licensed amateur radio operator



aprs.fi · Lo

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Save Money
Get Your Fr

Show last:
3 hours

Track callsig
KF7ODR-1

Address, cit

KF7ODR-1
Updated: 2
(4h12m)
Position: 37

2009

Other SSID

Wx: 85.0°F 37

Other view
- Station i
- Raw pac
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Balloon Launch #1, February 2011

Key results:

- received several packets from the UHF beacon
- phone took 98 images during flight
- gained balloon launching and operations experience

Key issues identified:

- had a power failure in mid-flight
- post-flight analysis revealed loose wire connection was the cause
- discovered software bugs

Balloon Launch #2, March 2011

Key results:

- progress in software since last balloon flight
- received several packets from the UHF beacon

Key issues identified:

- mid-flight failure
- extreme low temperature caused by air convection thought to be the cause

Balloon Launch #3, June 2011

Key results:

- continuous operation of the UHF beacon for the duration of the flight
- consistently decoded packets at an equivalent attenuation of a 500km circular orbit between 25 and 45 degree elevation pass
- met all requirements for flight

Key issues identified:

- Image packetization scheme needs tweaking

PhoneSat v1: Major Challenges Addressed

- Software:
  - Getting access to low level functionality
  - Emulating stock battery to allow boot-up without one
- Hardware
  - Clean power supply to the radio
  - proper antenna design/tuning
  - Wiring and connector reliability

Autonomous Vehicle Control System (AVCS) Software Release

- Approved July 2011 (8 months of paperwork)
- Apache 2.0, instead of NASA Open Source Agreement (NOSA)
- Git hub release end August 2011
- Hope is to stimulate an open source toolkit for satellites
- Get the hacker community involved in space

Conclusions

- Produce a highly capable spacecraft for <$10k using only COTS hardware
- Series of ground tests and orbital missions to iteratively build capability
- Work with what you have
- Release early, release often
- Don’t be afraid to take risks
- Next steps: **final environmental testing for PhoneSat v1 and begin outreach campaign for potential launch end of this year/early next year**

Questions?

And many thanks to the entire PhoneSat Team!

Christian R. Pinto Rey, Benjamin Howard, Vincent Beukelaers, Kenny Boronowsky, Emma Jablonski, Oriol Tintore, Matt Ferraro, Vinh To, Alberto Guillen, Benoit Deper, Julien Dubourg, Adeline Doudoux, Alaeddine Morki, Matthew Leines, James Snow, Carmen Felix, Christopher Boshuizen, William Marshall