PhoneSat: Balloon Testing Results

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2011 Summer CubeSat Developers' Workshop

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)

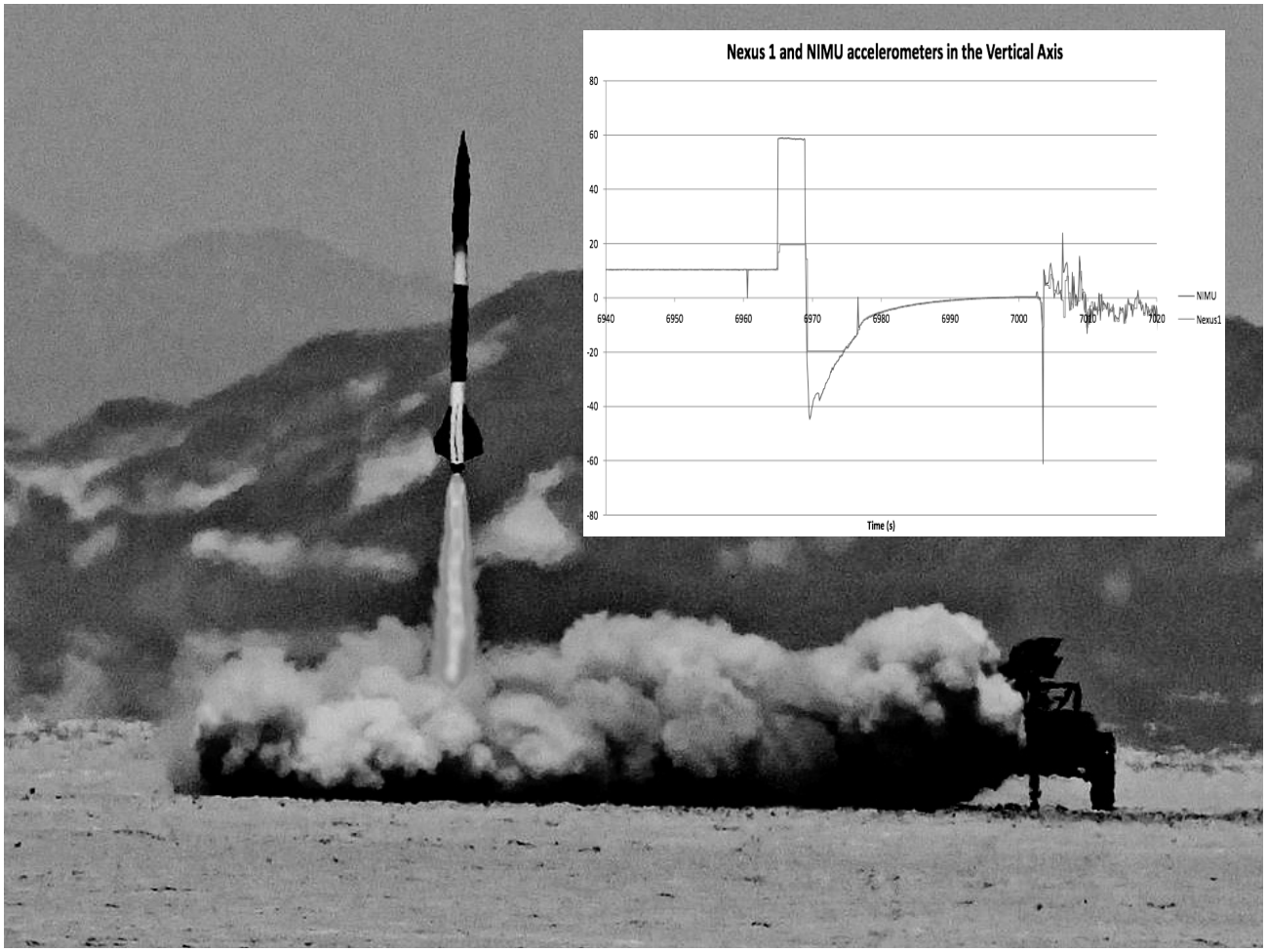
➔Produce high-capability spacecraft for $1-10k

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)



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

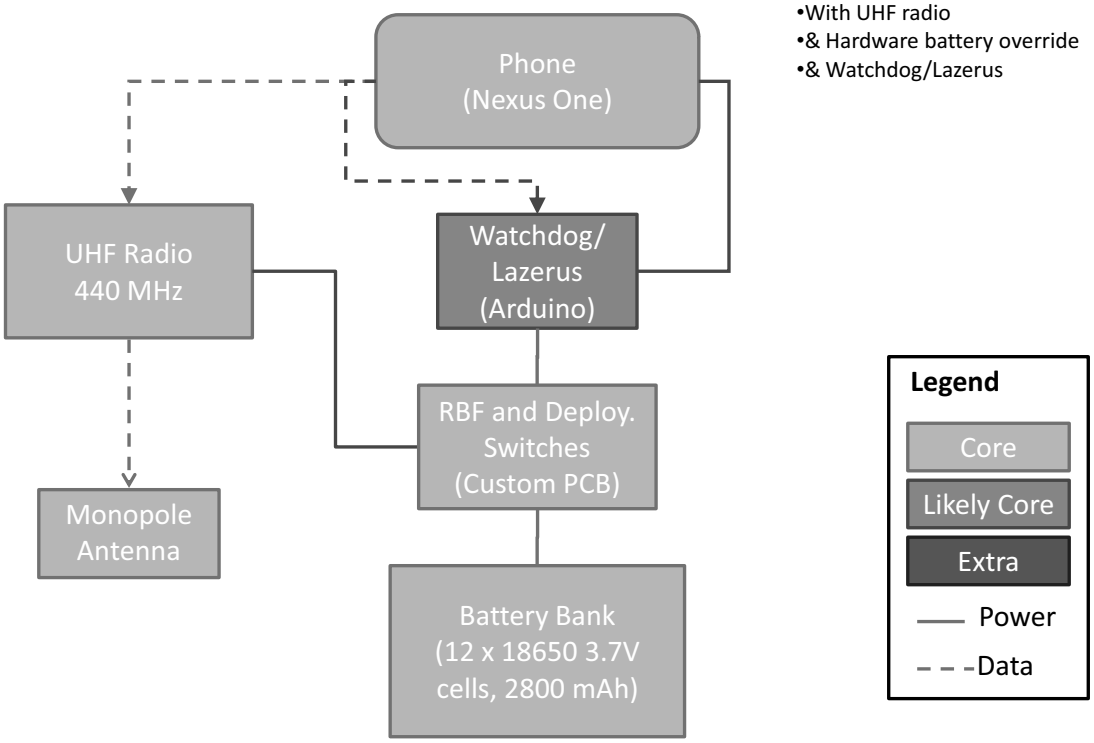


Image Downlink Challenge

- 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

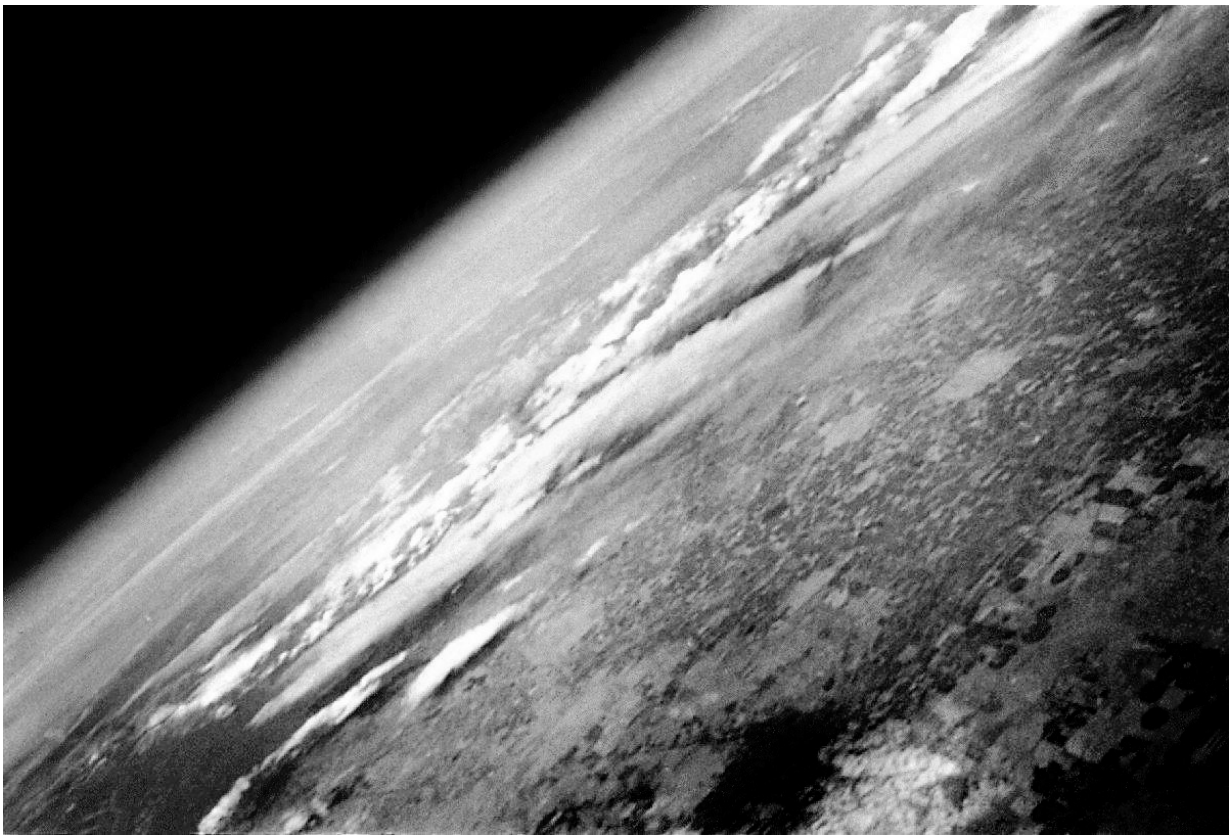
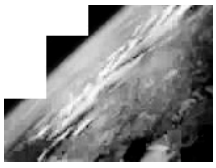
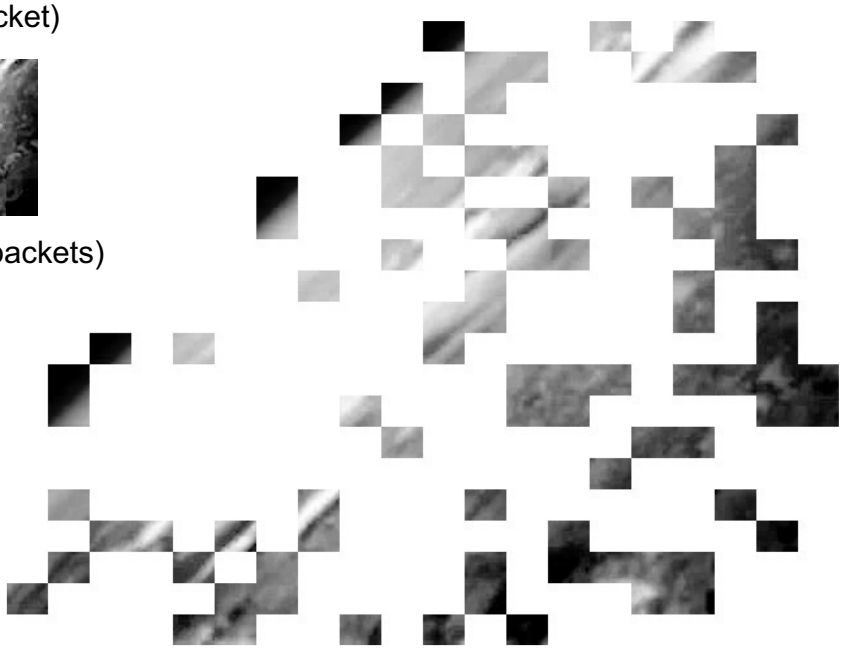


Image Pyramid Packetization

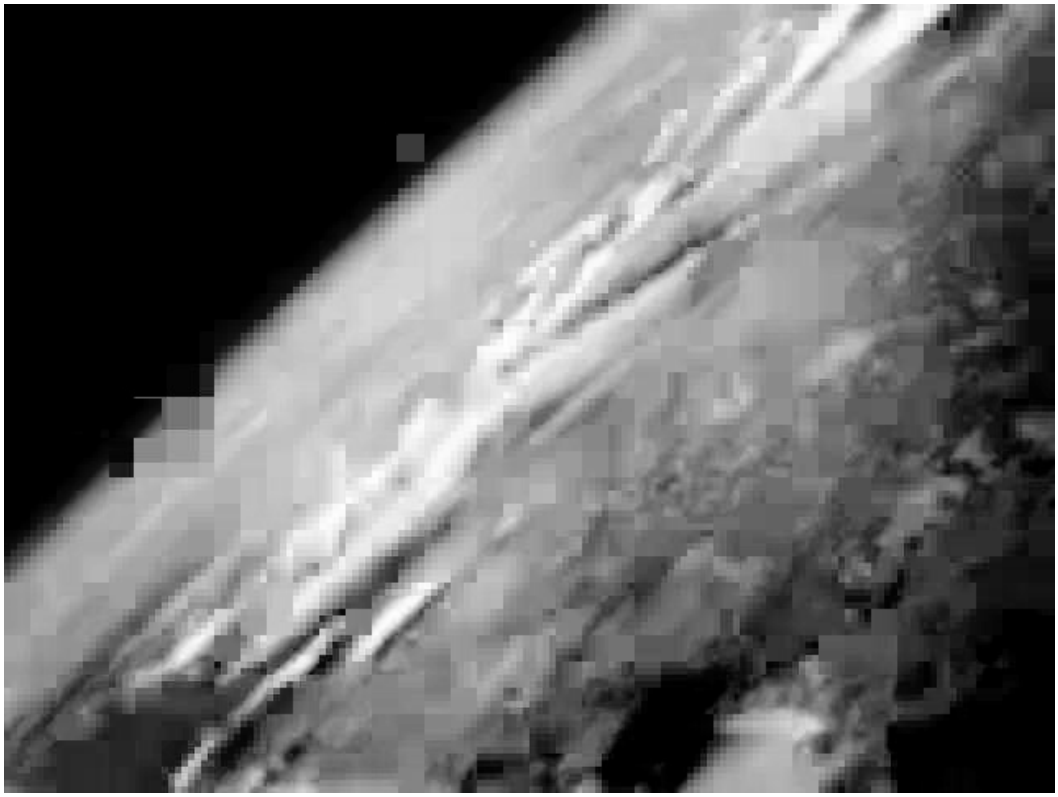
Low-res (1 packet)



Medium-res (5x5 packets)



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



Radio Range Tests

Balloon Flights

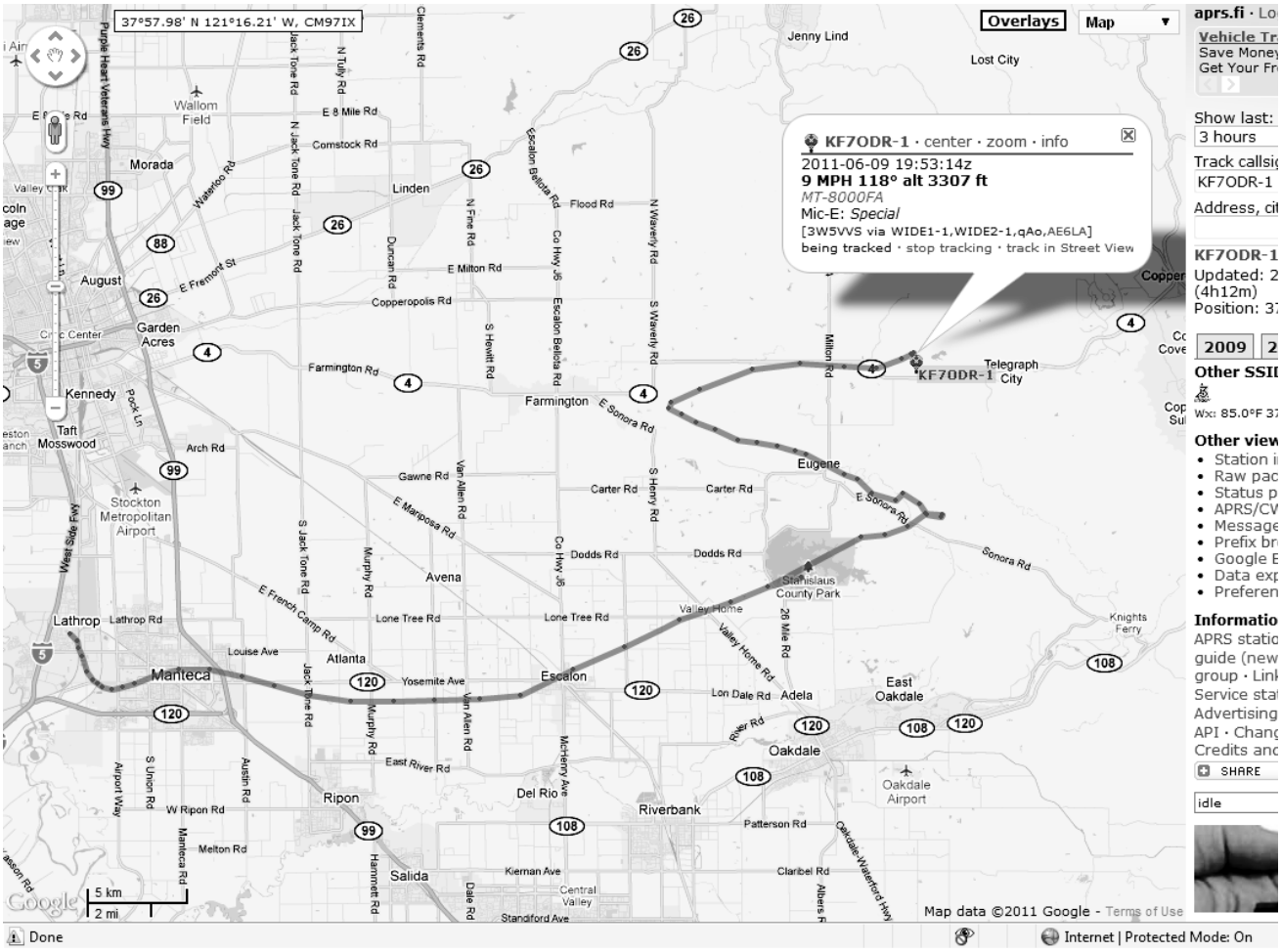
Balloon Flight Motivation

- 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



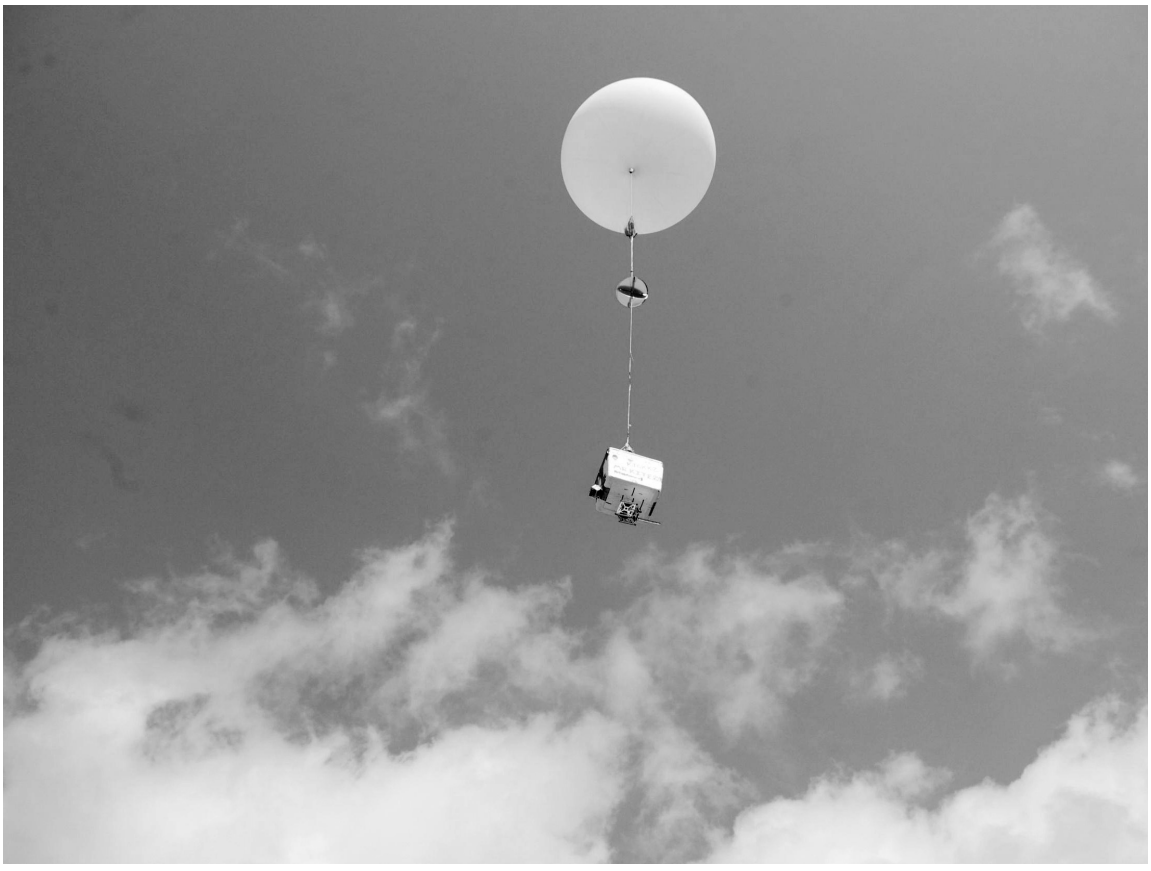
Balloon Launch #1, February 2011

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

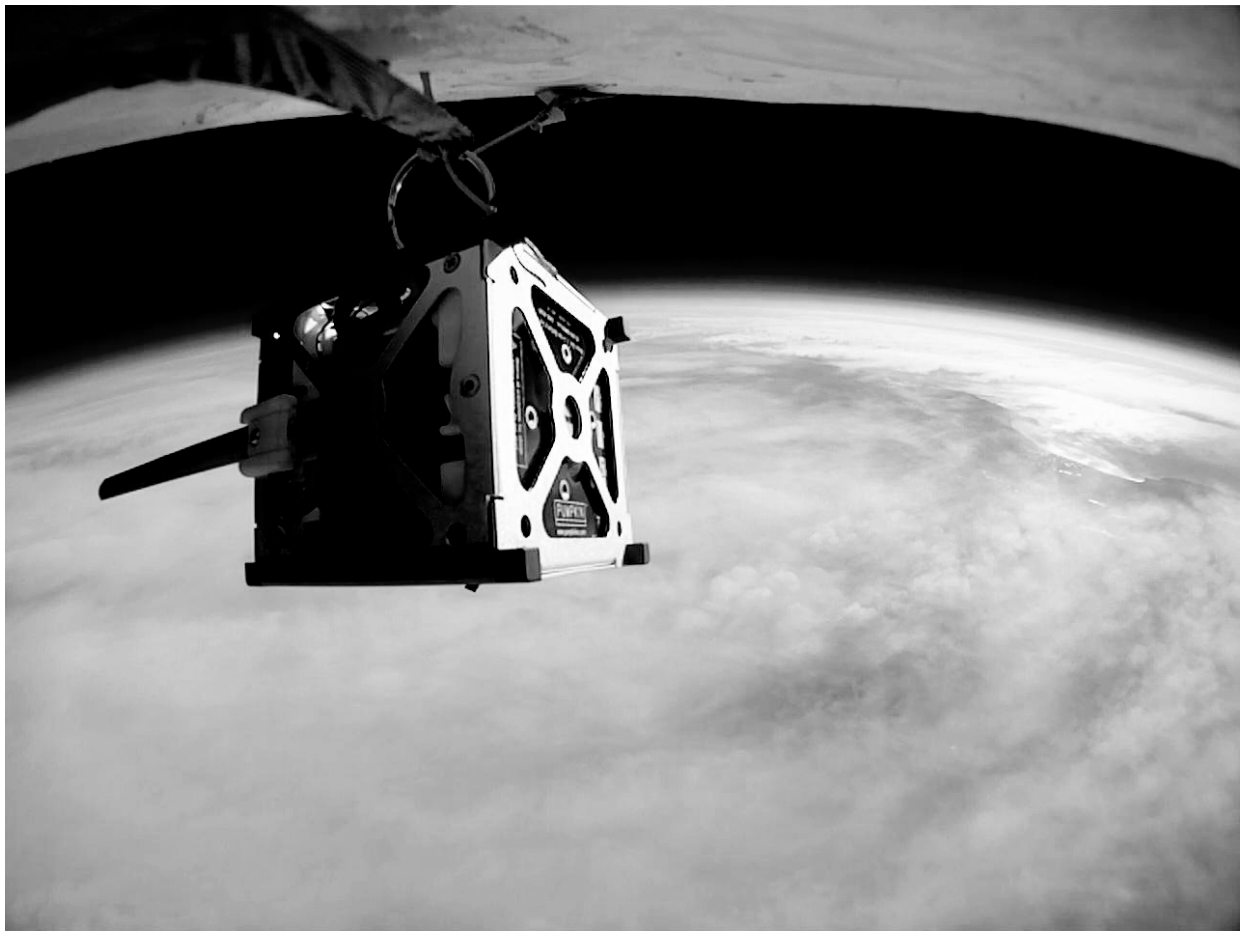
Balloon Launch #3, June 2011

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!

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