The NASA Ames PhoneSat Project

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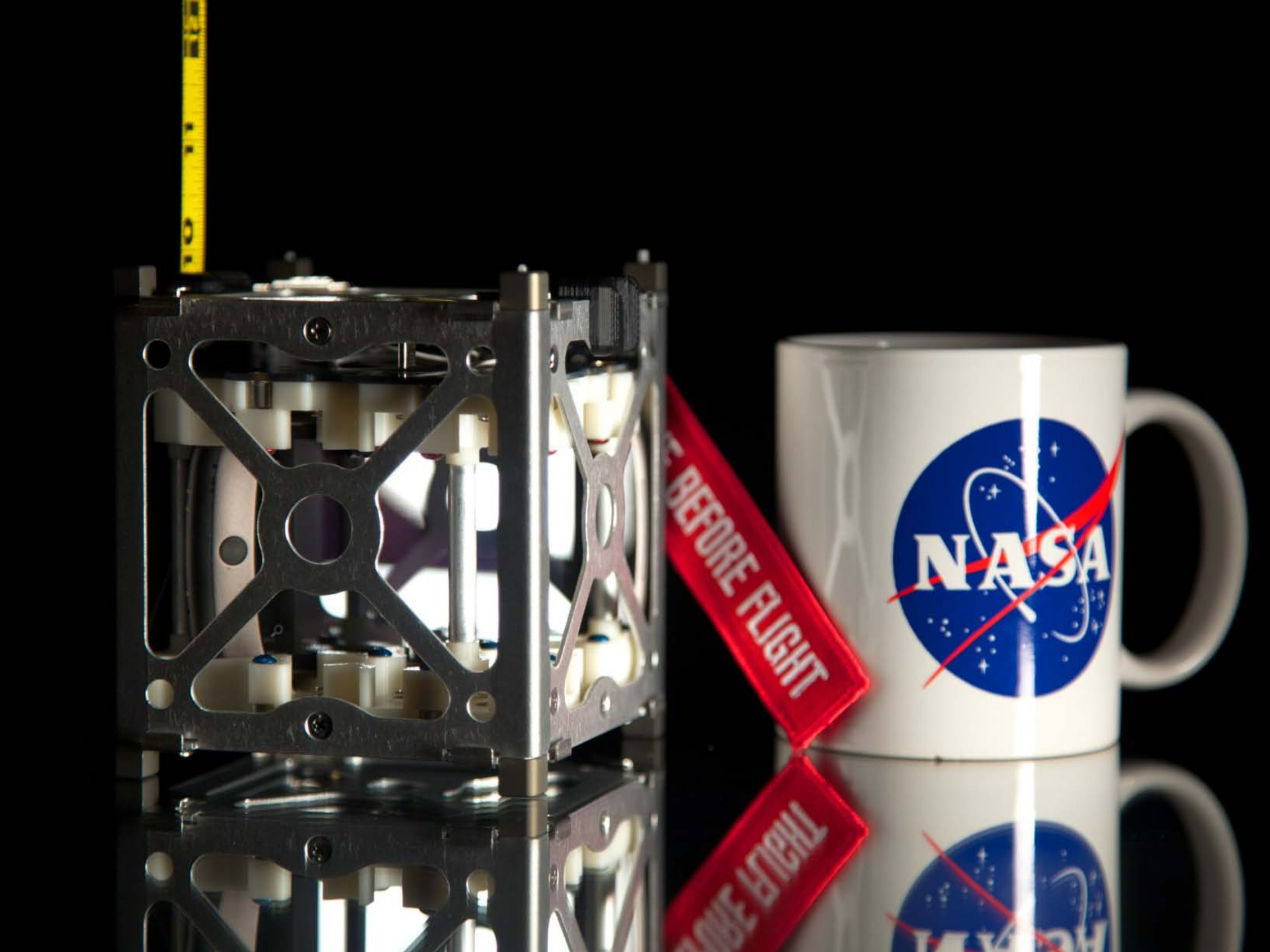

NASA
BEFORE FLIGHT

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)

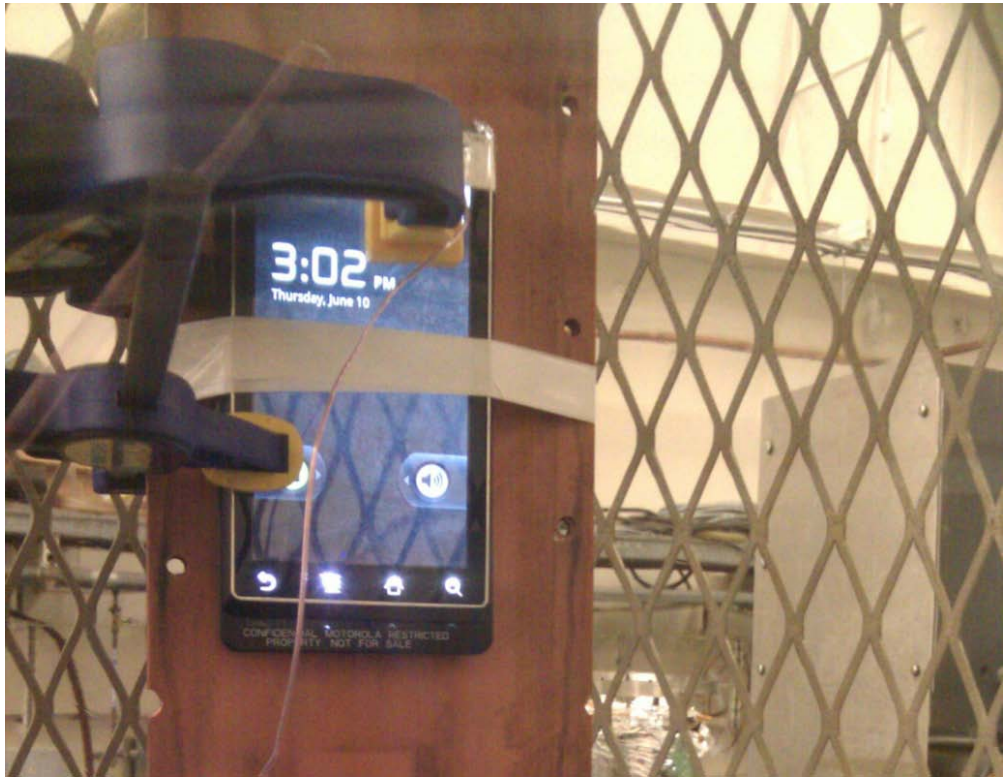
➔Produce high-capability spacecraft for $1-10k

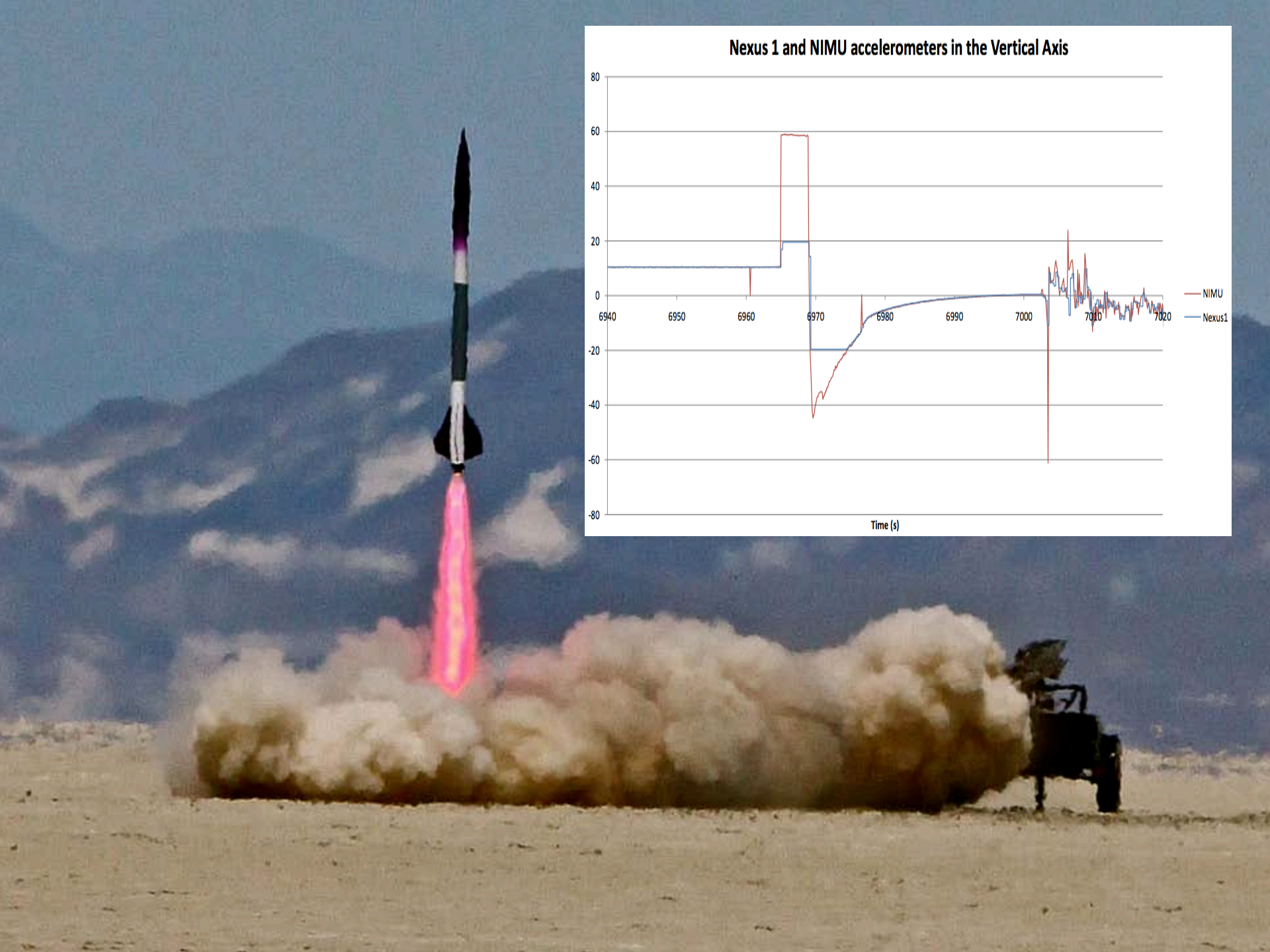
Nexus One

- 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)



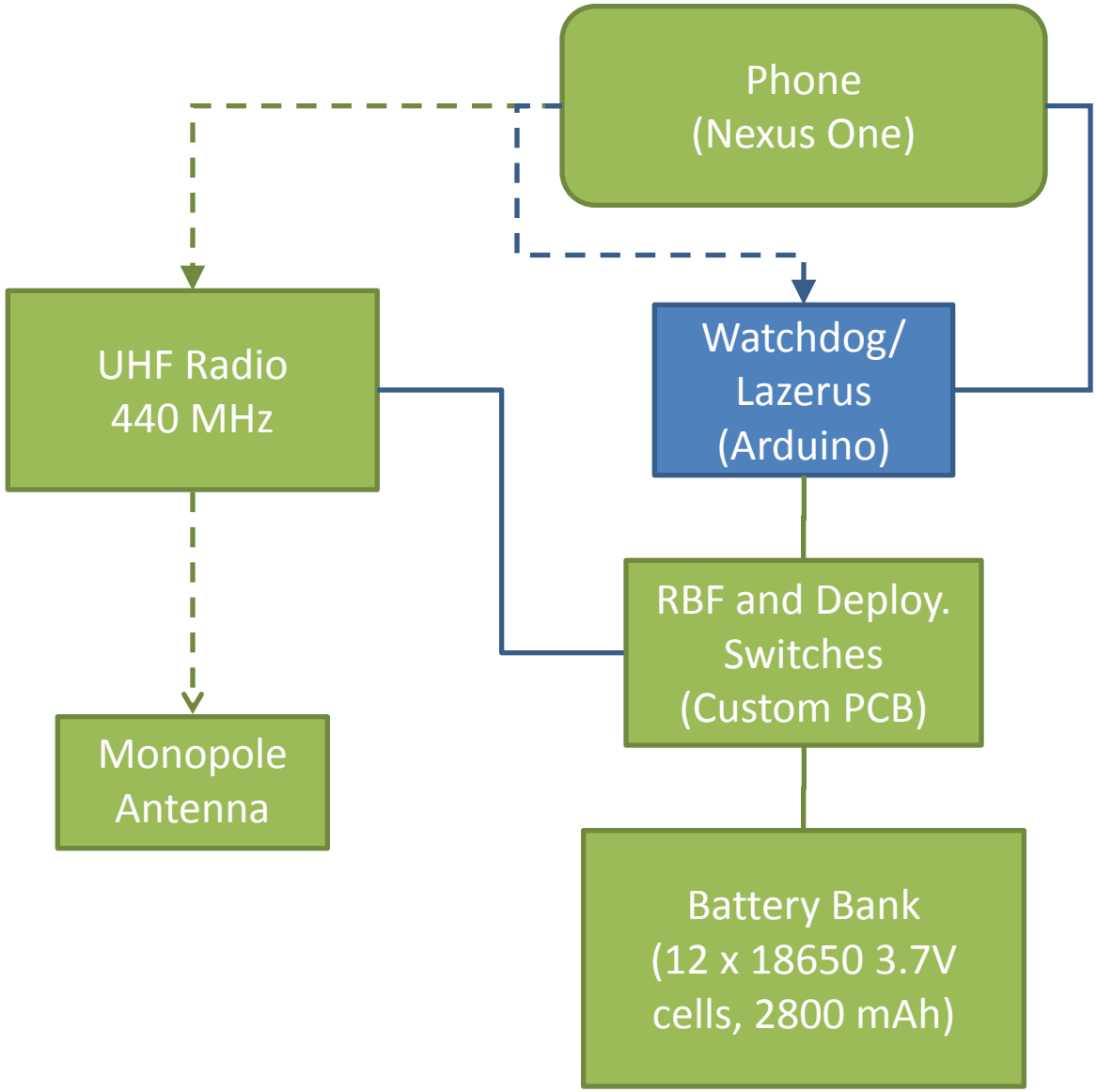

Nexus 1 and NIMU accelerometers in the Vertical Axis
80
60
40
20
0
-20
-40
-60
-80
6940
6950
6960
6970
6980
6990
7000
7010
7020
Time (s)
NIMU
Nexus1

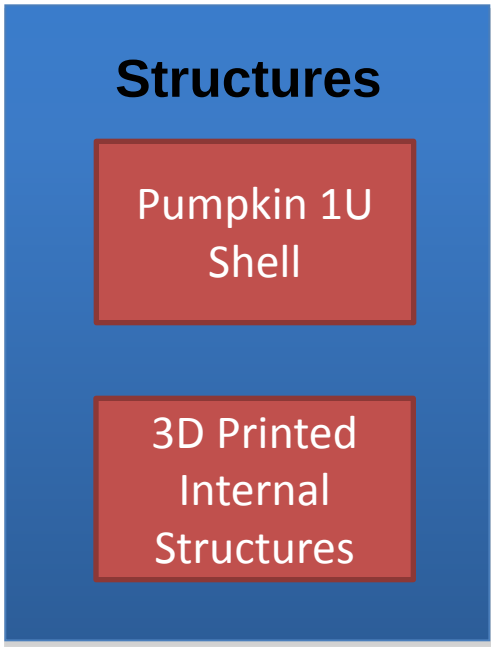
PhoneSat 1: Requirements

1. Work for > 1 orbit
2. Send minimum health data and 1 image taken by the phone to the ground
3. Parts cost << $10,000, leading towards $1,000 unit cost
4. Fast iteration (~3 month design-build-test cycle)

PhoneSat 1: System Architecture

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





Radio Range Tests

Balloon Flights

PhoneSat 1.0: 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

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

Software domain

- Web programmers don’t (always) stress about their hardware
- As hardware platforms become standardized
- And we get large computing capacity in space
- Cheaper, more amazing applications
- Unlimited creativity in software
- New models for constellations

Software/Hardware trades

- Trade off between hardware and software
  - I.e., power comms bandwidth is limited, but CPU is readily available
  - Swap downlink for computation
  - Instead of downlinking 1000 images, process them on board and send the ‘best’ ones.
- Multi-purpose instruments
  - Combined star tracker, science and Nav camera
  - Adapt solar cell voltages for coarse sun sensor in flight

Autonomous eXplorer Control System (AXCS) Software Release

- Approved July 2011 (8 months of paperwork)
- Apache 2.0, instead of NASA Open Source Agreement (NOSA)
- ALPHA version released on Git hub!!!
- 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, but be sure to learn from them
- Next steps: launch scheduled **Feb/March 2011** on the Taurus II, need amateur radio volunteers to help collect data on **437.425 MHz**!

Questions?

Contact: michael.safyan@nasa.gov
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