



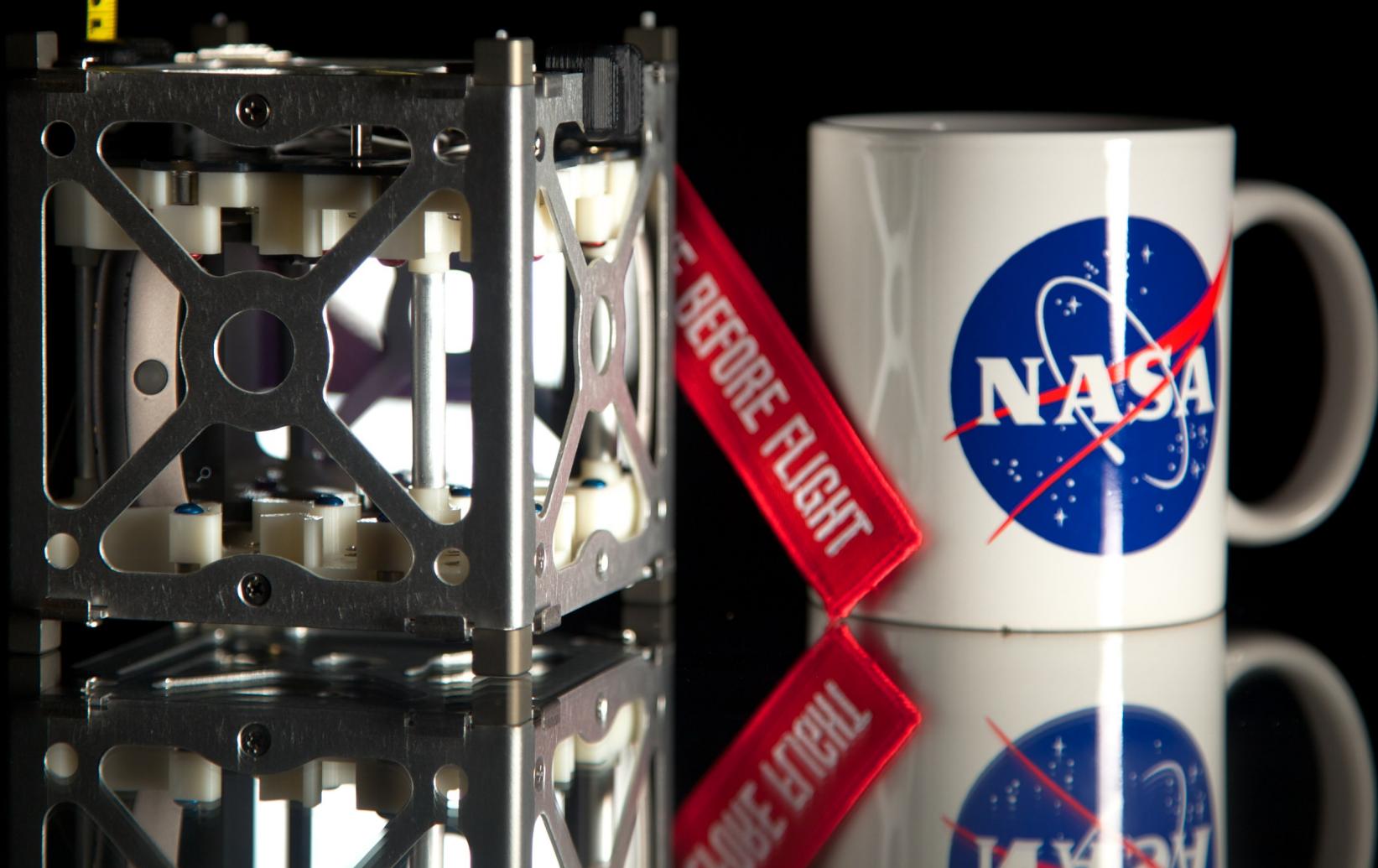
9th Annual Spring Cubesat Developers Workshop Cal Poly San Luis Obispo

PhoneSat 2.0

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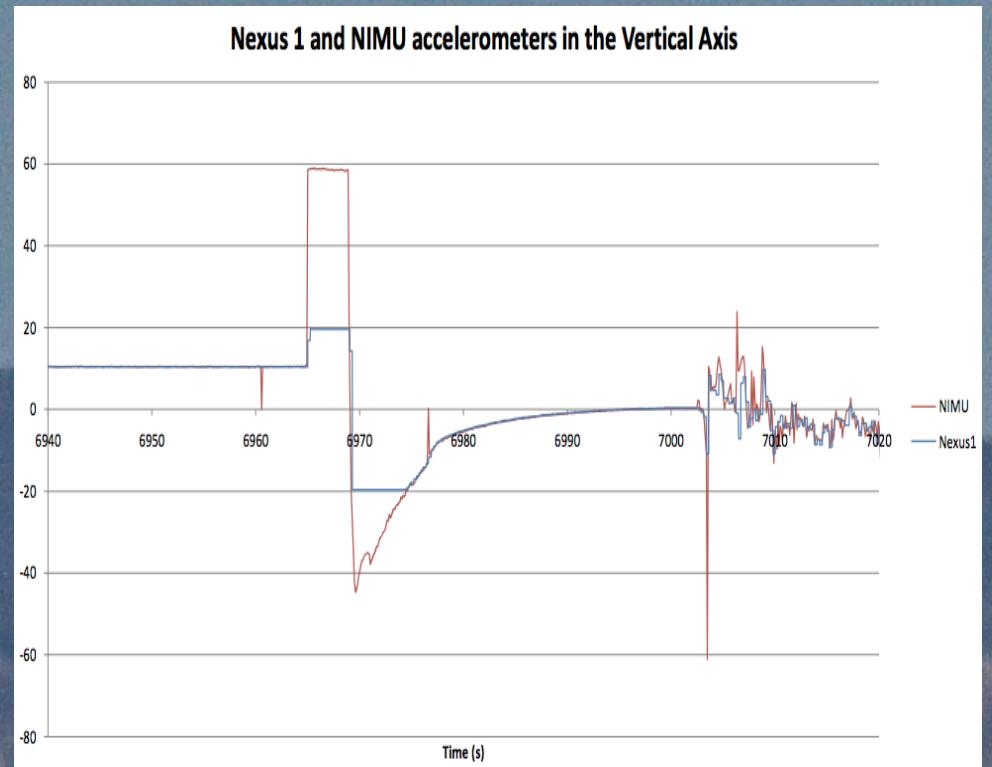
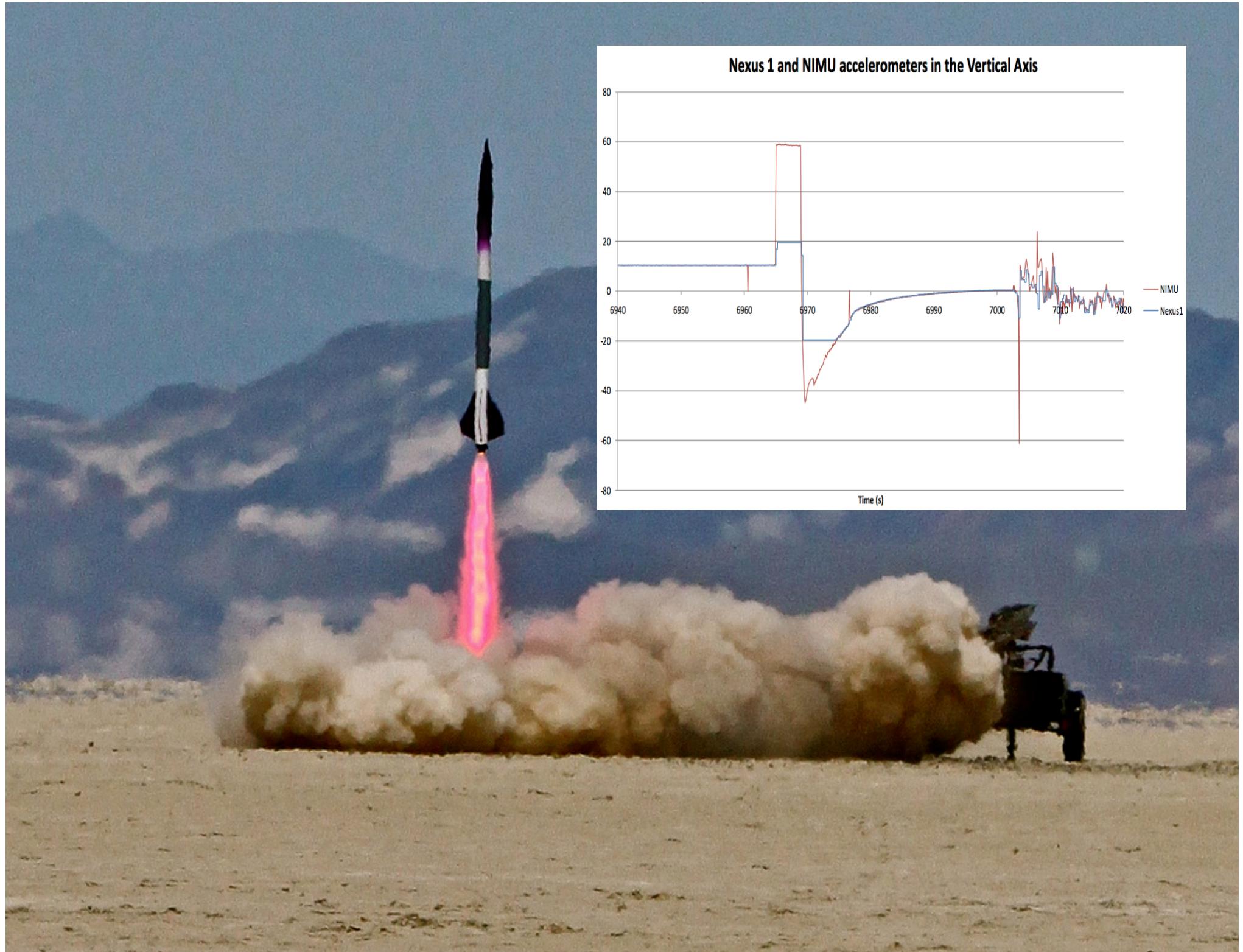
PhoneSat 1.0





Why use a phone?

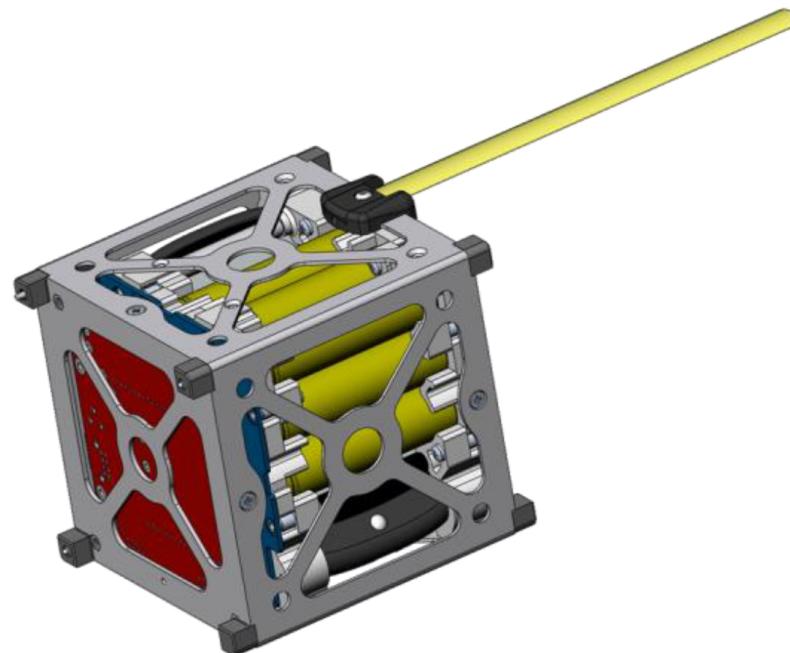
- Increase on-orbit processor capability by a factor of 10-100
 - Decrease cost by a factor of 10-1000
 - Free up cubesat volume for additional payload through avionics miniaturization
 - Demonstrate COTS approaches to all subsystems (ie, power, ADCS, comms)
- Produce high-capability spacecraft for \$1-10k (exc. LV)

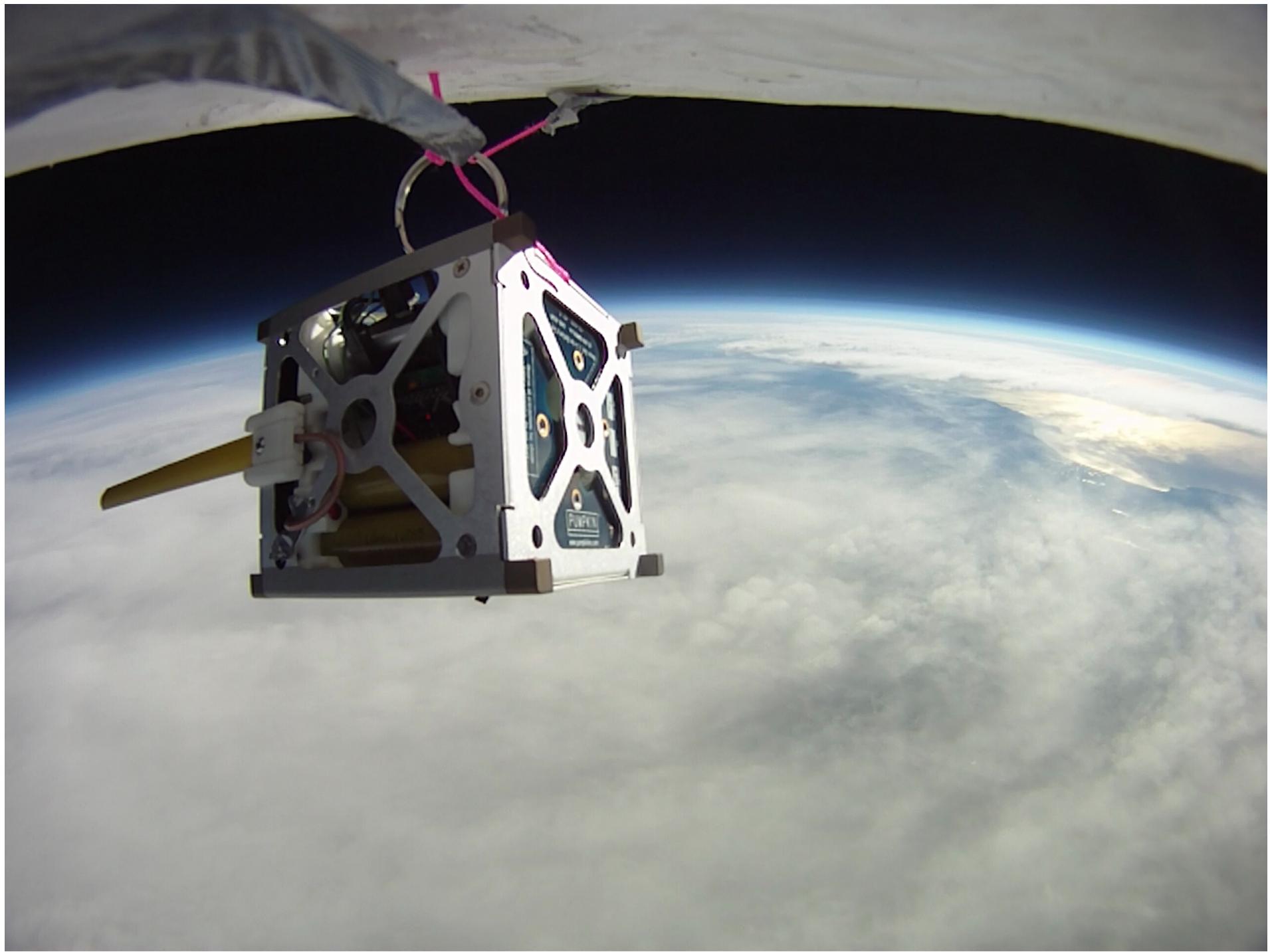




PhoneSat VS1

- 1U cube
- Entire phone
- Batteries
- Watchdog board
- Stensat radio
- Main goal: test phone is viable solution







Phonesat VS2

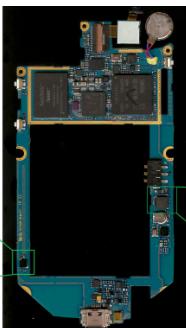
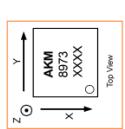
New Features

- Solar panels
- Reaction wheels
- Magnetorquers
- 2 way radio (μ Hard 2420)
- Nexus S

ADCS block diagram

SENSORS

Magnetometer



Gyroscope



Coarse Sun Sensor



ADCS COMPUTER



Phone

ACTUATORS

Magnetorquers



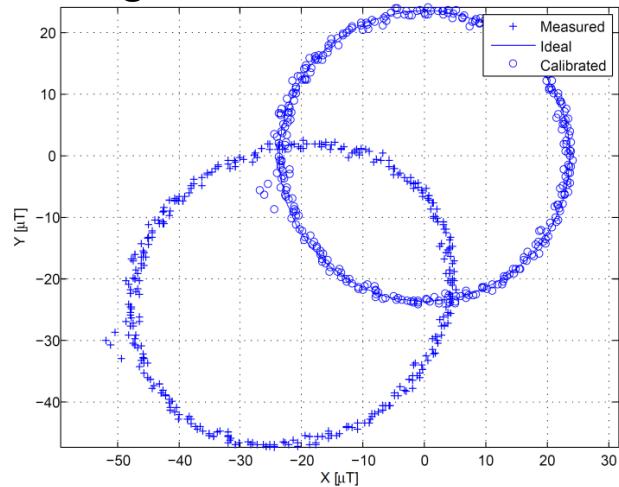
Reaction wheels





Sensor tests

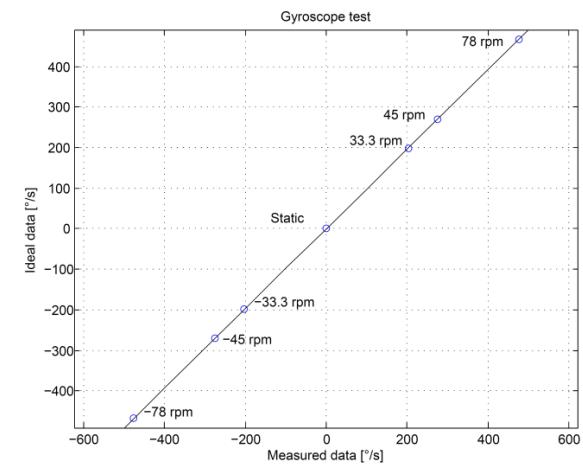
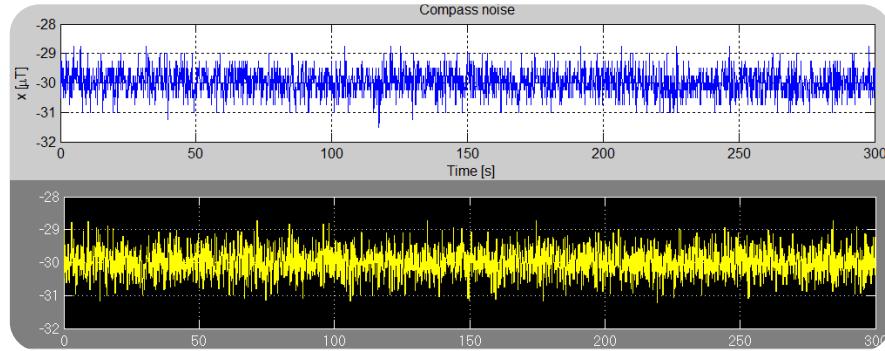
Magnetometer calibration



Gyroscope calibration



Noise characterization



- Interferences when GSM antenna removed
 - Solution: Turn on airplane mode!



Solar panels

Space-qualified cells



Efficiency: 27-30%

Expensive
Long lead time

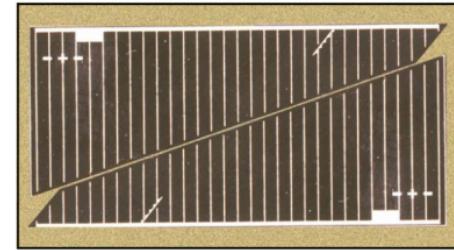
Portable smartphone chargers



Cheap
Easy assembly

Efficiency: 14%

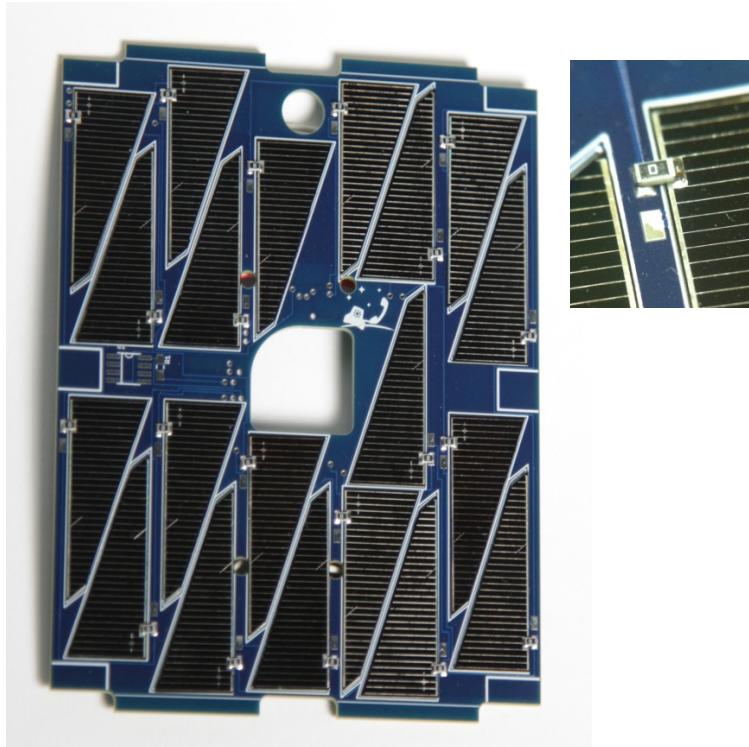
TASC cells



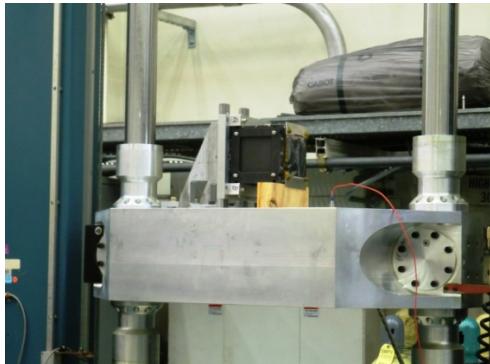
Cheap: \$2.5/cell
Efficiency: 27%

Handling (brittle)
Mounting process
- Double-sided Kapton tape
- Conductive epoxy
- RTV coating
- ...

Pick-n-Place solution



Shock (NASA GEVS)



Vibe (NASA GEVS)



- Use Pick-n-Place machine
- Treat cell as SMT component

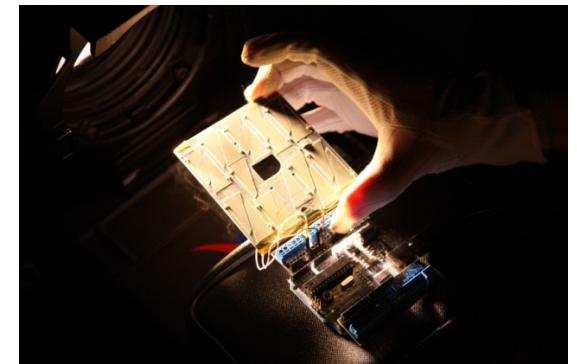
RESULTS

- \$150/panel
- Integrated magnetorquer
- 2 weeks
- Reliable quality
- Great accuracy
- No coverglass

Vacuum



Thermal cycling

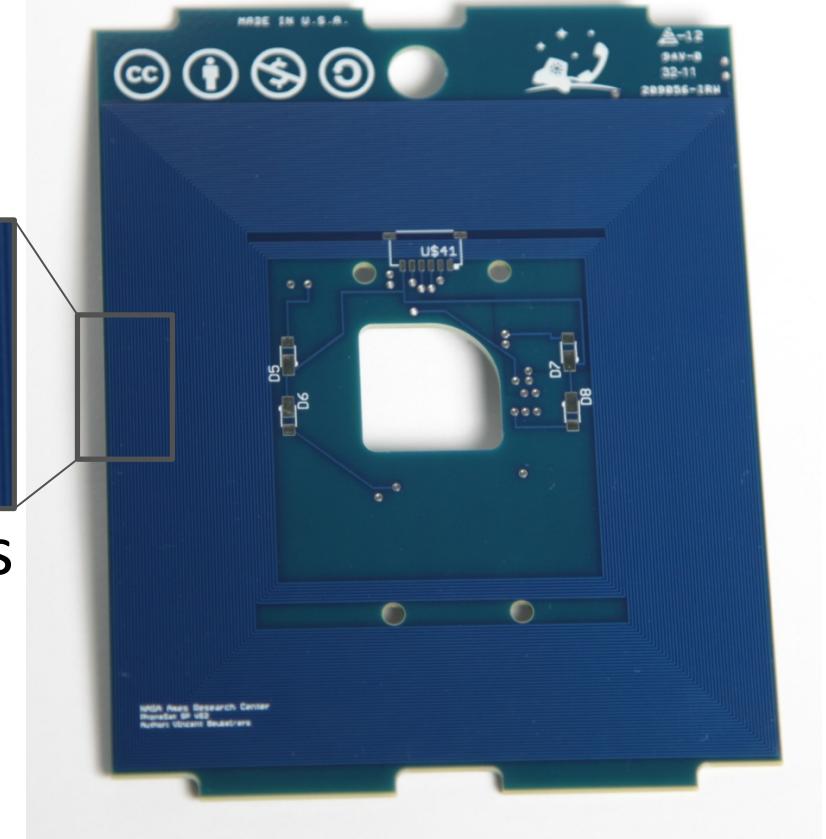
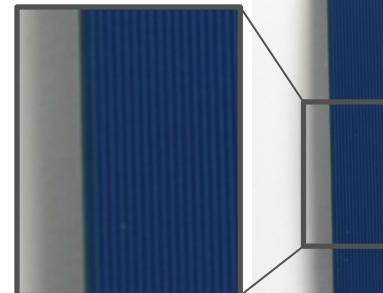


8/31/2011



PCB-integrated magnetorquers

- 6-layer PCB
- 5 layers of coil & 1 layer of solar cells
- 50 turns per layer
- Magnetic moment: 30 mA.m^2
- Voltage: 5V
- 100mW per axis
- Temperature sensor
- Integrated reverse-bias diodes



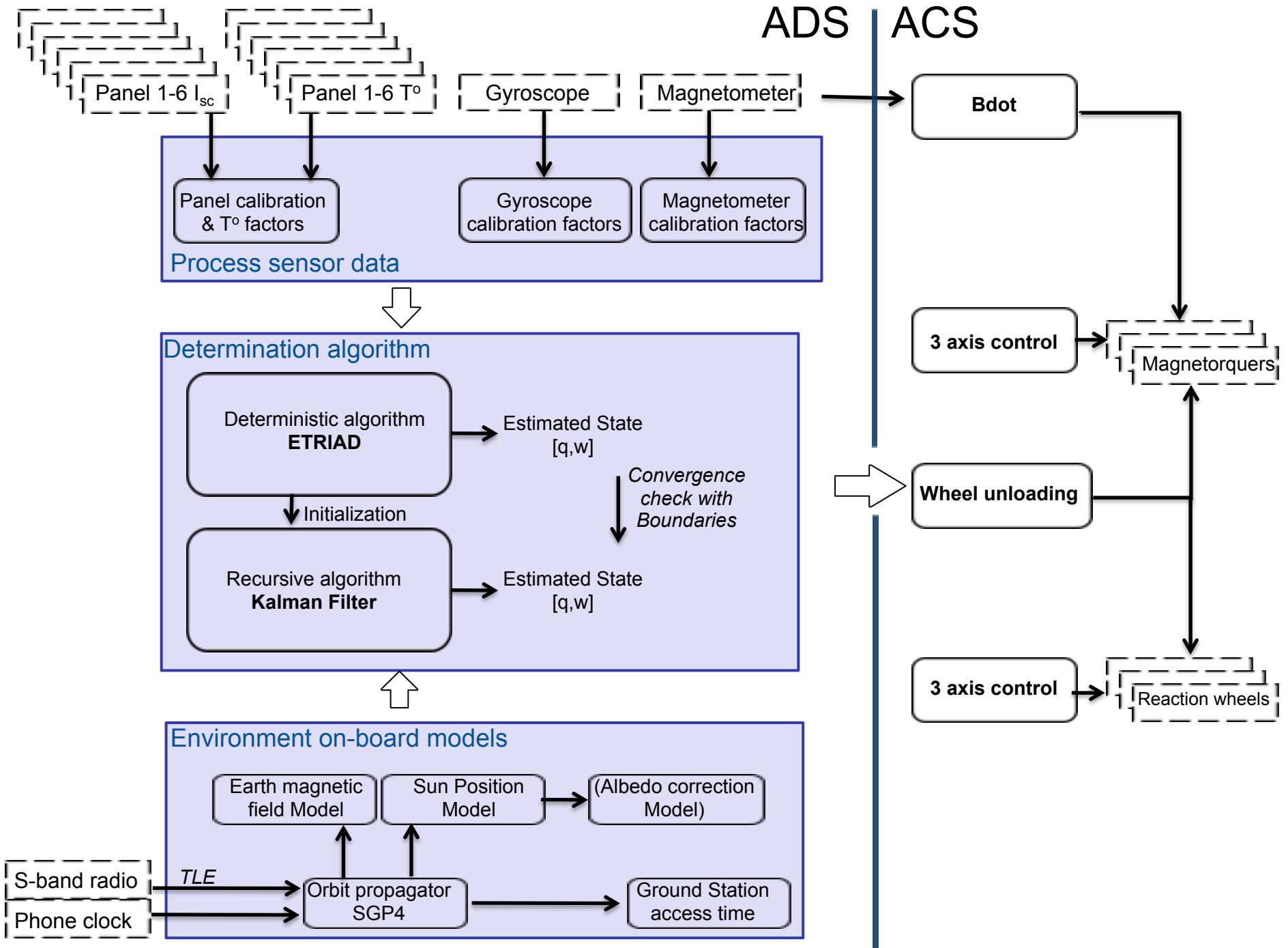


COTS reaction wheels

- Brushless DC motor
- Angular momentum (@7000rpm): 5.9e-4 Nms
- Maximum speed: 7000 rpm
- Inertia: 8.1e-7 kg.m²
- Integrated speed controller
- Hall effect sensors
- Mass: 20g
- 26x26x12mm³
- Operating T range: [-25 ... +80]C
- Vacuum-proofed lubricant
- Price: \$200

No extra inertia wheel needed for 1U!

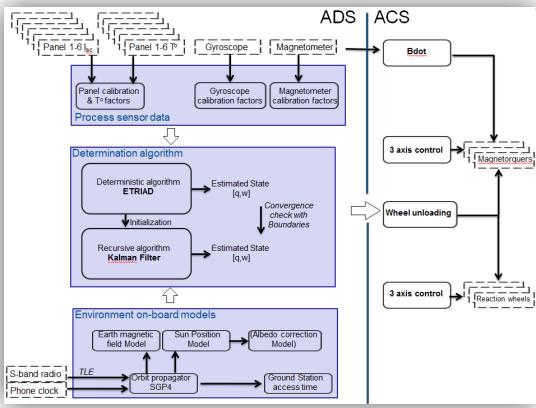






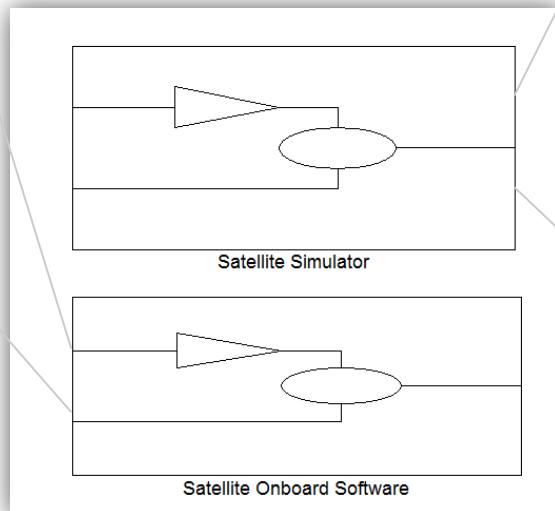
Software-in-the-loop simulator

ONBOARD SOFTWARE

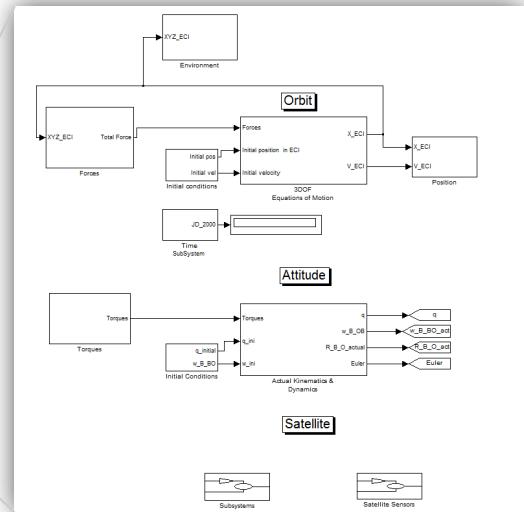


- Kalman Filter
 - ETRIAD
 - RW
 - Magnetorquer
 - ADCS modes

SIMULINK SIL SIMULATOR



SATELLITE SIMULATOR

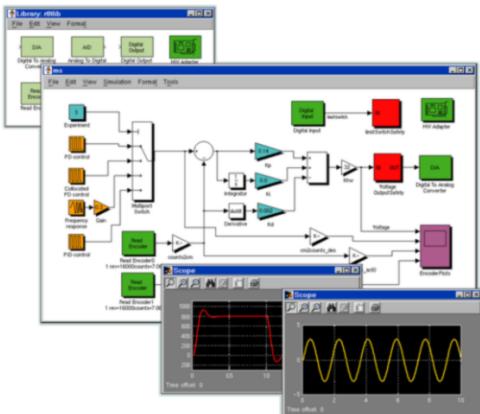


- Orbit Propagation
 - Sunlight & GS Access
 - S/c kinematics & dynamics
 - Disturbance Torques
 - Sensors emulation
 - ...



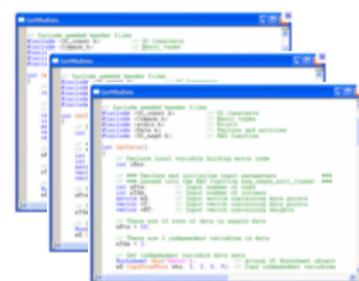
ADCS software

- Matlab/Simulink running on the phone!



Simulink Model

Matlab Embedded coder



C Code

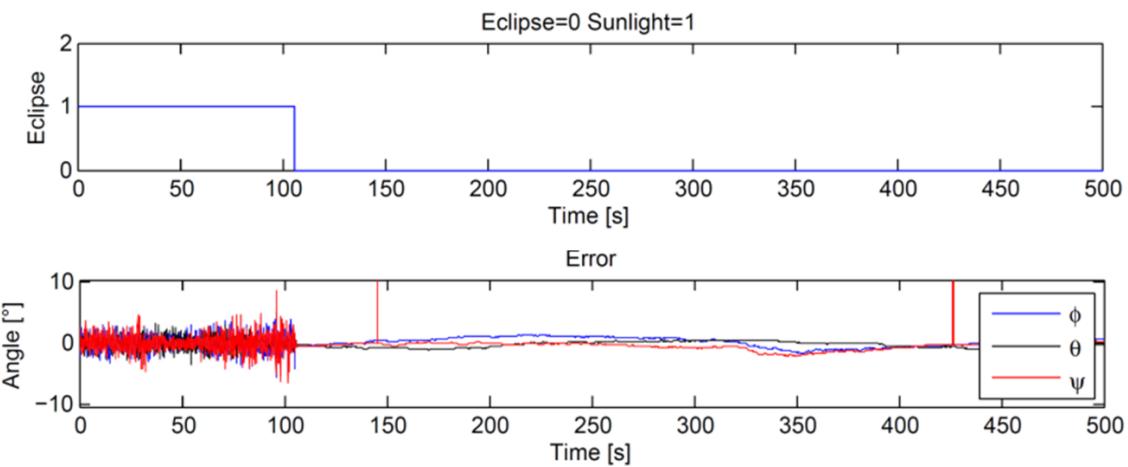
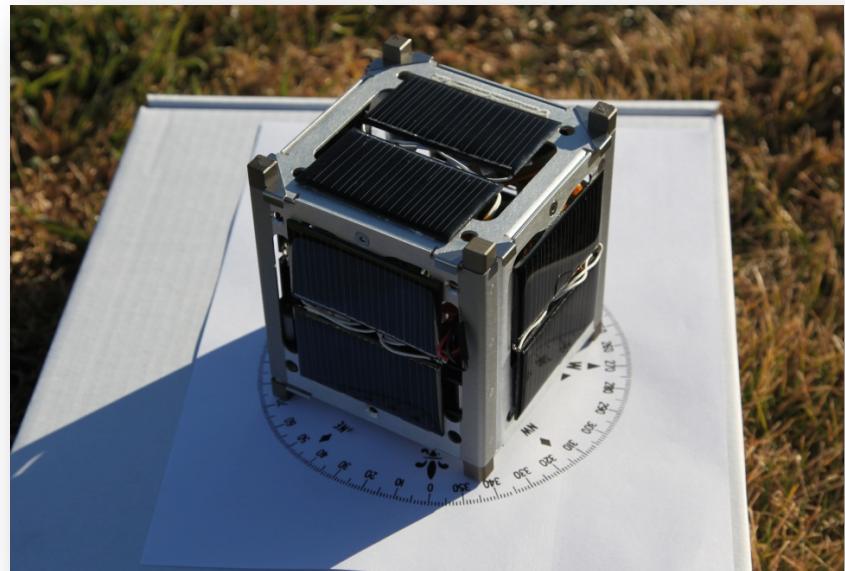


Android App



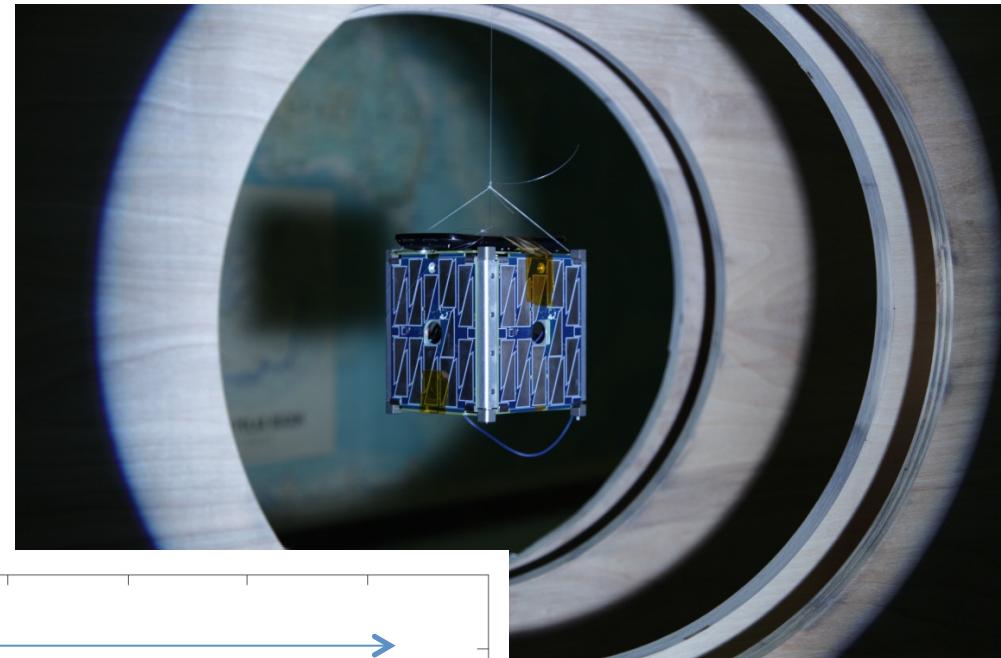
ADS tests

- Integrated test outside
- Attitude estimation based on:
 - Magnetometer
 - Solar cells currents
- Great to debug

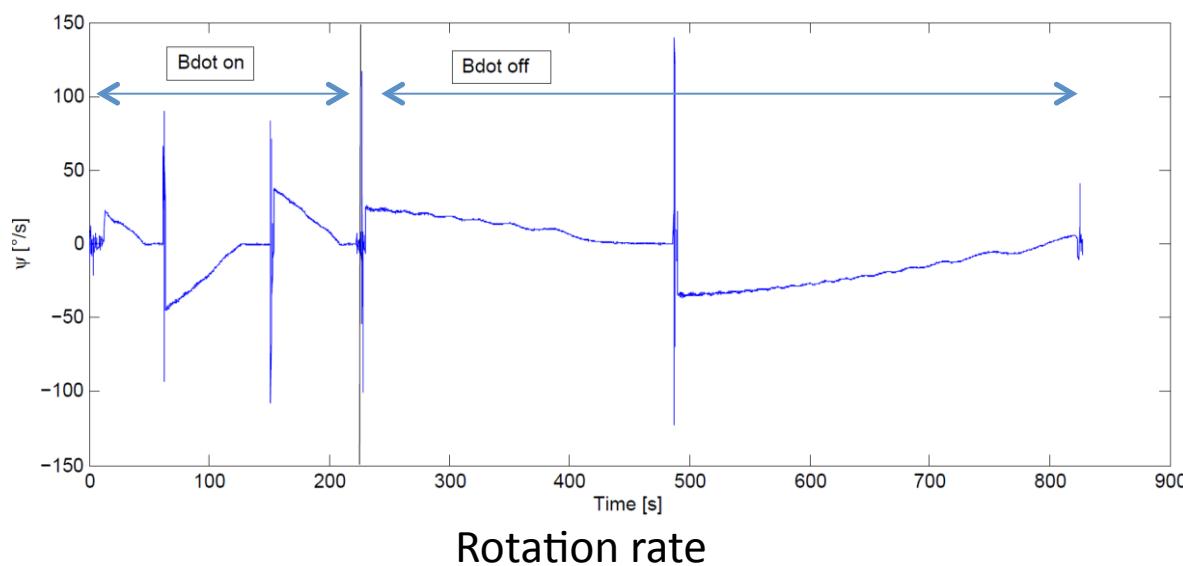




Bdot test

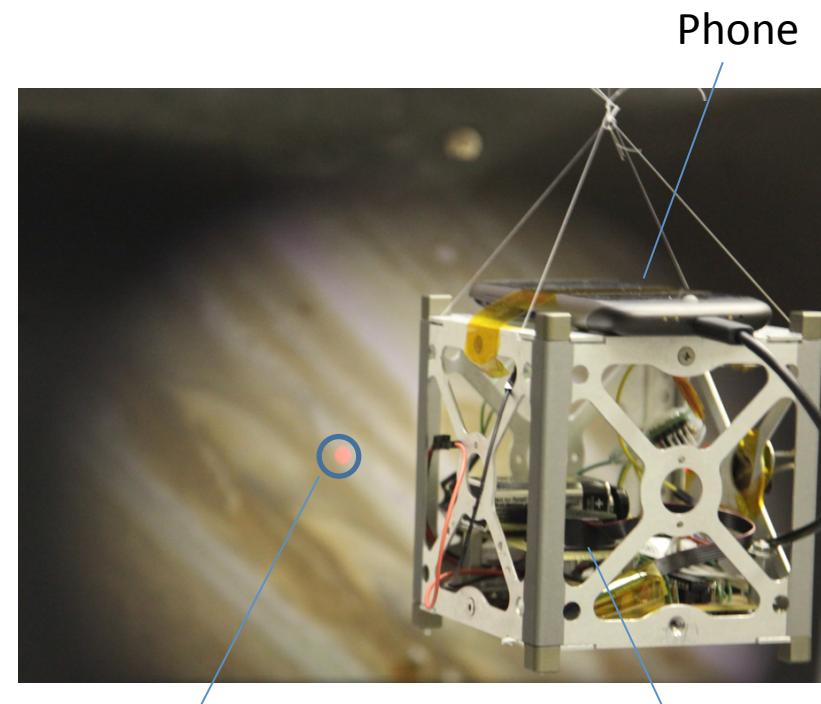
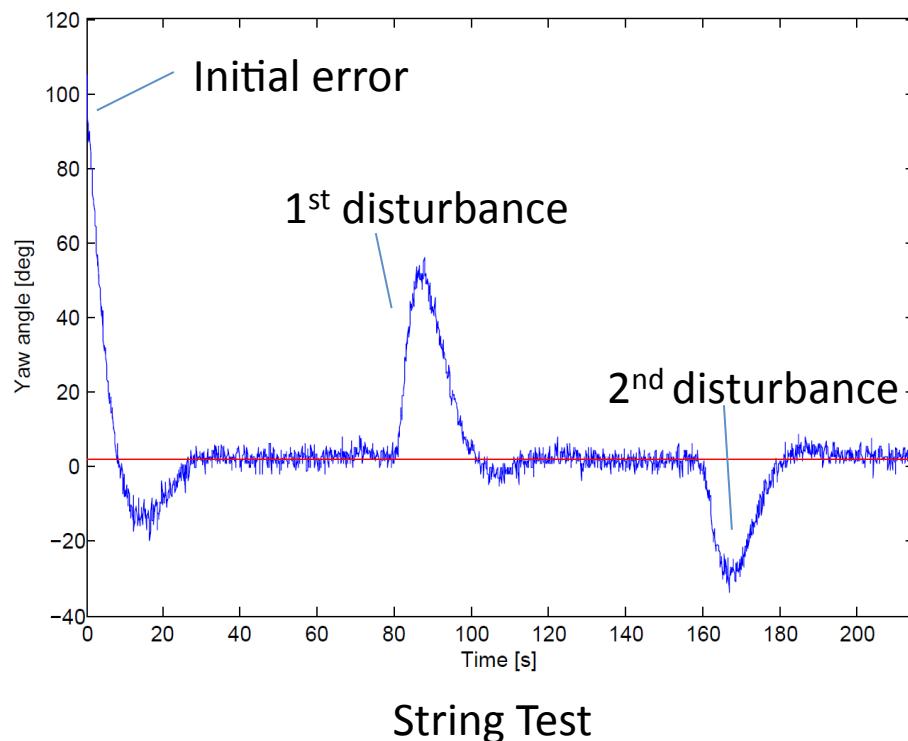


- Effectively damp rotation rate



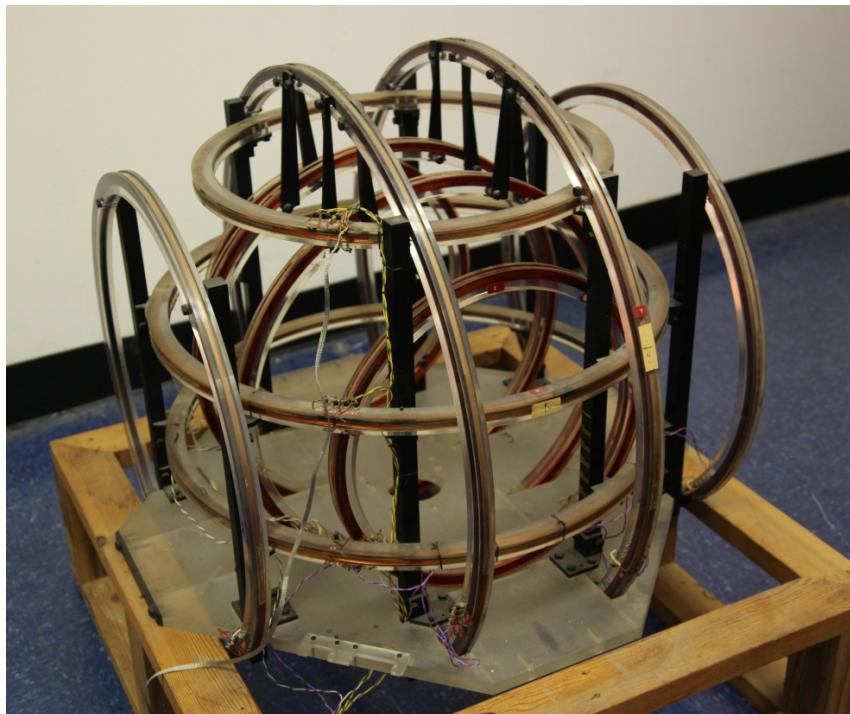


RW test

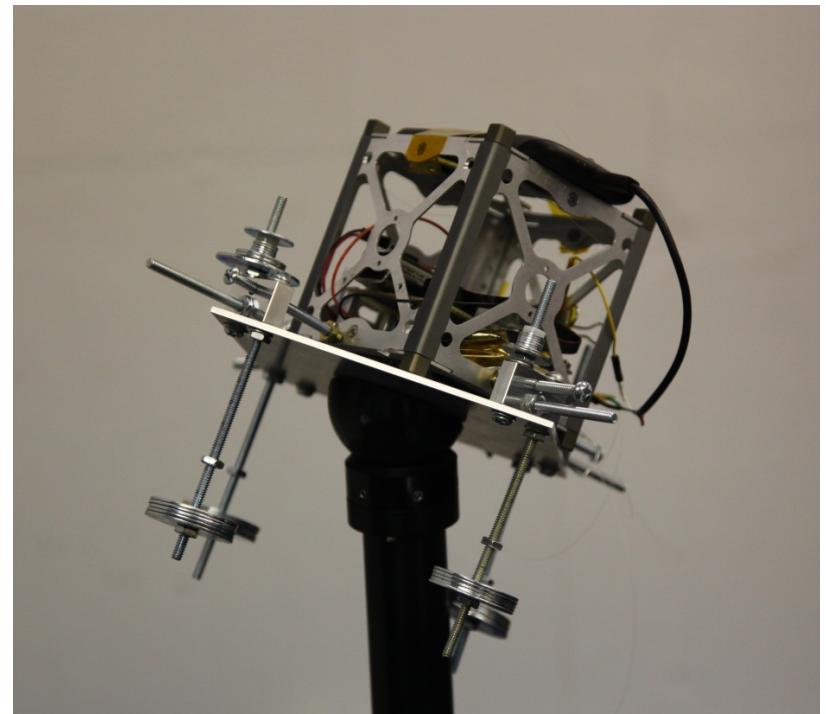




Future tests



3-axis Helmholtz coils



Spherical air bearing



Conclusions

- Goal: Produce high-capability spacecraft for \$1-10k
- Why? Myriad of uses to aid the agency (science, exploration, education & outreach)
- Have standard highly capable platform up there and available for people to develop apps
- Great for crowd sourcing (apps)
- Progress to date:
 - PhoneSat v. 1.0 built and ready to go!
 - PhoneSat v. 2.0 under the soldering iron!
- Launch with Taurus II (2012 Q2)
- Launch with Falcon 9 (2012 Q4)



Thank you!