

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

PhoneSat 2.0

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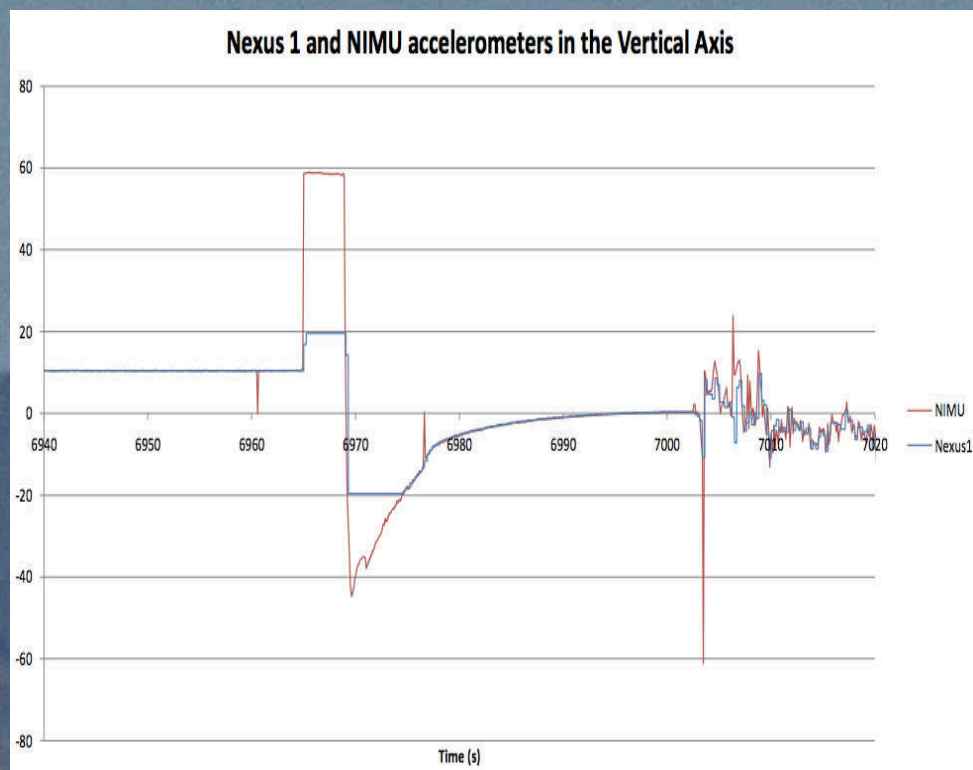
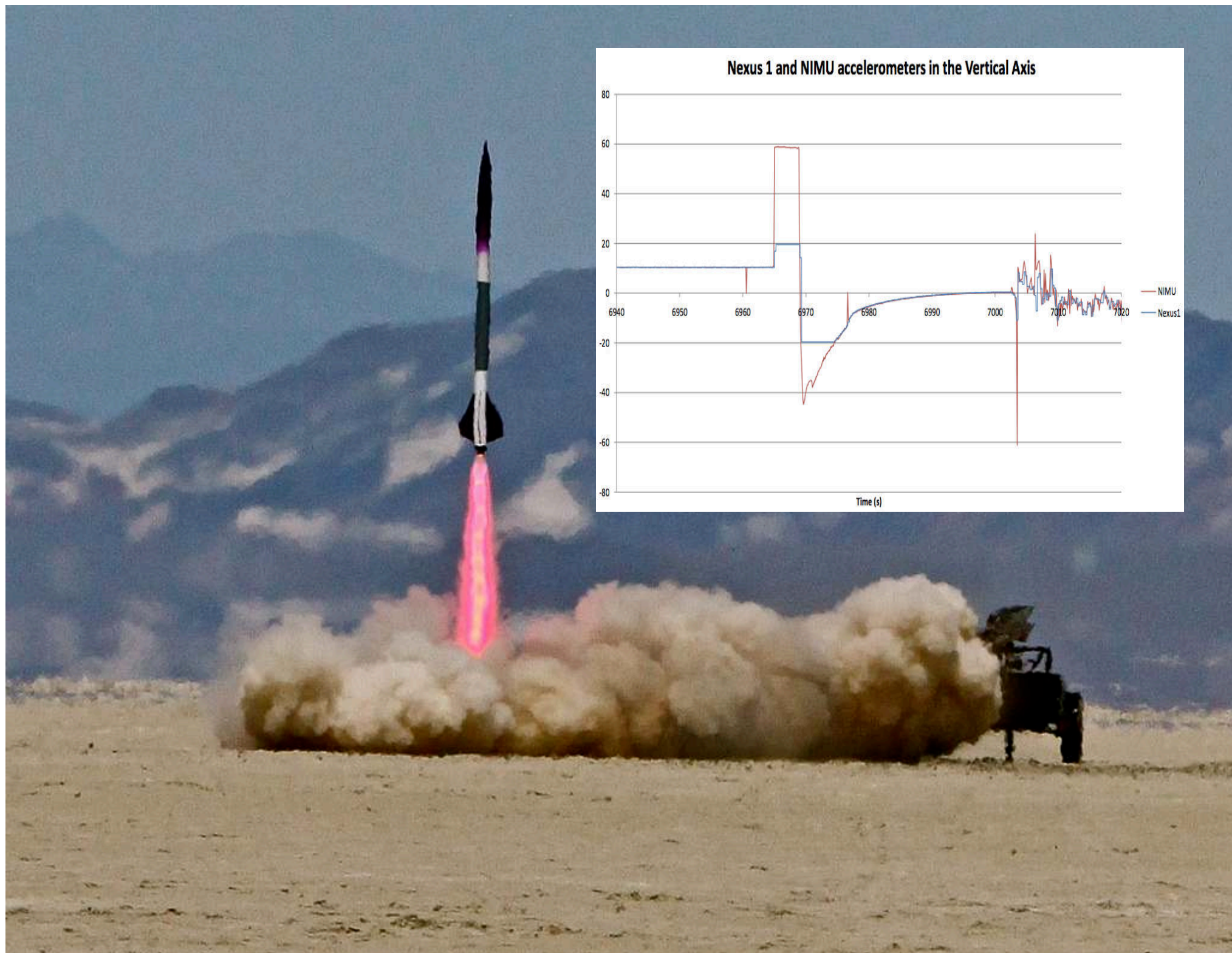
PhoneSat 1.0





Why use a phone?

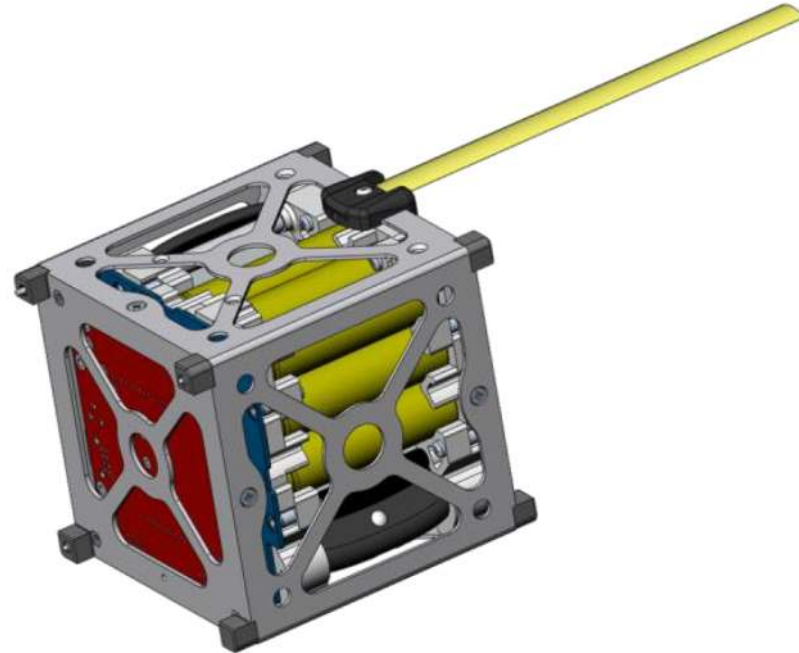
- Increase on-orbit processor capability by a factor of 10-100
- Decrease cost by a factor of 10-1000
- Free up cubesat volume for additional payload through avionics miniaturization
- Demonstrate COTS approaches to all subsystems (ie, power, ADCS, comms)
- ➔ Produce high-capability spacecraft for \$1-10k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





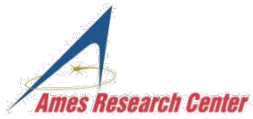
Phonesat VS1

- 1U cube
- Entire phone
- Batteries
- Watchdog board
- Stensat radio



- Main goal: test phone is viable solution





Phonesat VS2

New Features

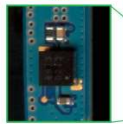
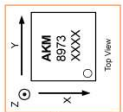
- Solar panels
- Reaction wheels
- Magnetorquers
- 2 way radio (μ Hard 2420)
- Nexus S



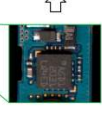
ADCS block diagram

SENSORS

Magnetometer



Gyroscope

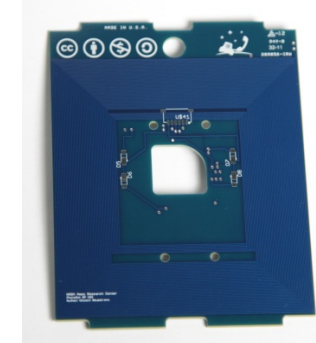


Coarse Sun Sensor



ACTUATORS

Magnetorquers



Reaction wheels



ADCS COMPUTER

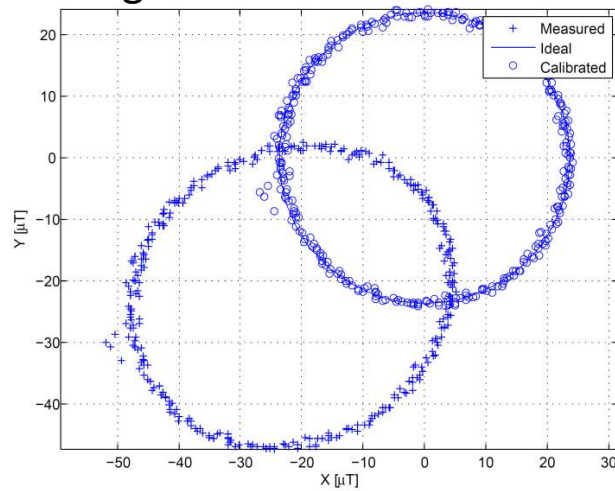


Phone



Sensor tests

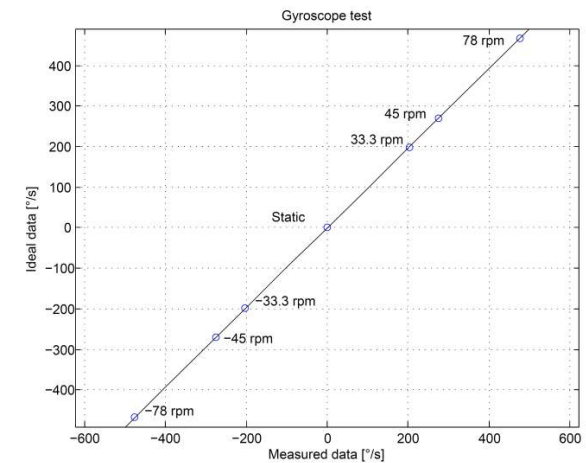
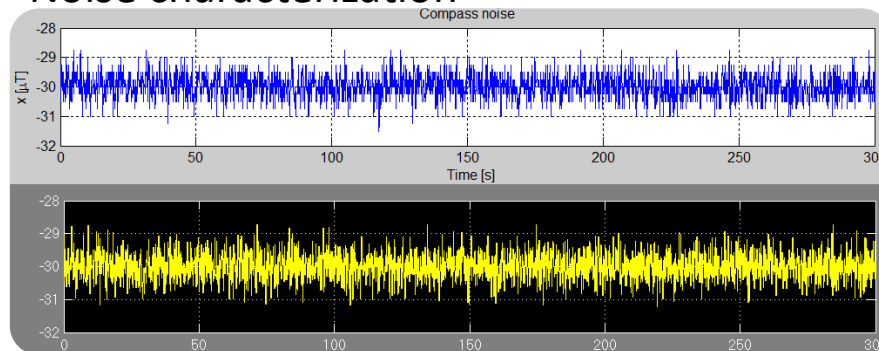
Magnetometer calibration



Gyroscope calibration



Noise characterization



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



Solar panels

Space-qualified cells



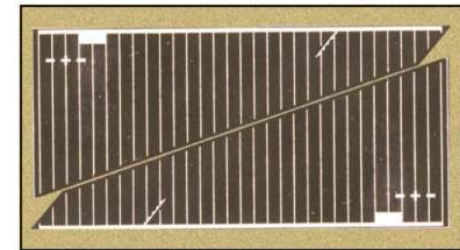
- Efficiency: 27-30%
- Expensive
Long lead time

Portable smartphone chargers



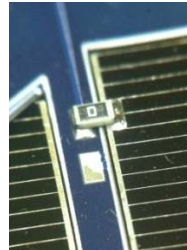
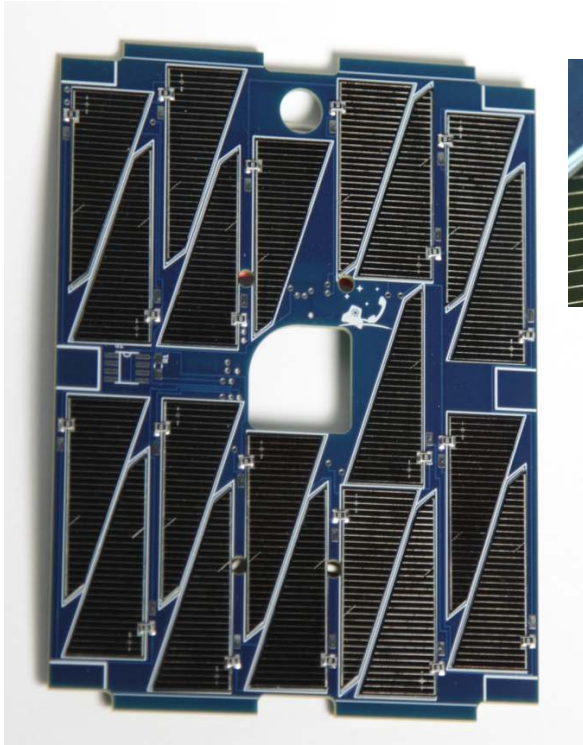
- Cheap
Easy assembly
- Efficiency: 14%

TASC cells



- Cheap: \$2.5/cell
Efficiency: 27%
- Handling (brittle)
Mounting process
 - Double-sided Kapton tape
 - Conductive epoxy
 - RTV coating
 - ...

Pick-n-Place solution



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

RESULTS

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

Shock (NASA GEVS)



Vibe (NASA GEVS)



Vacuum



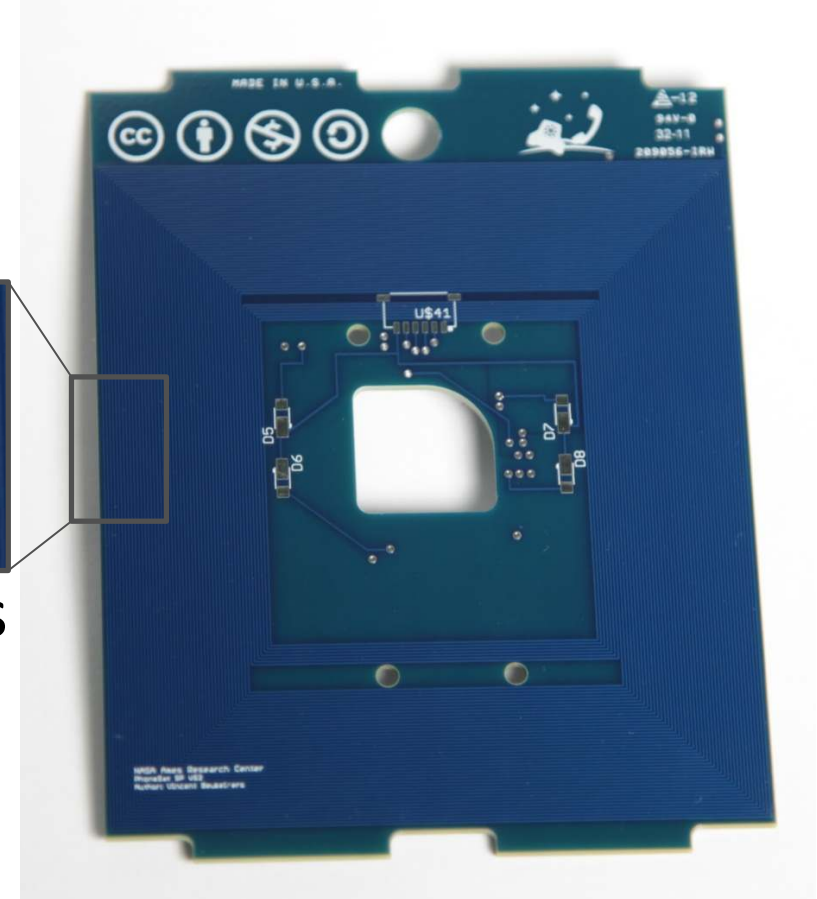
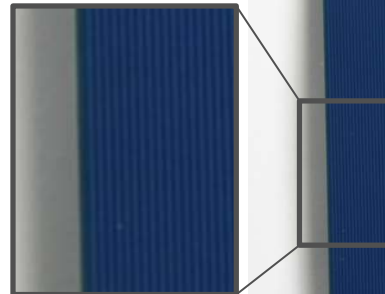
Thermal cycling





PCB-integrated magnetorquers

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



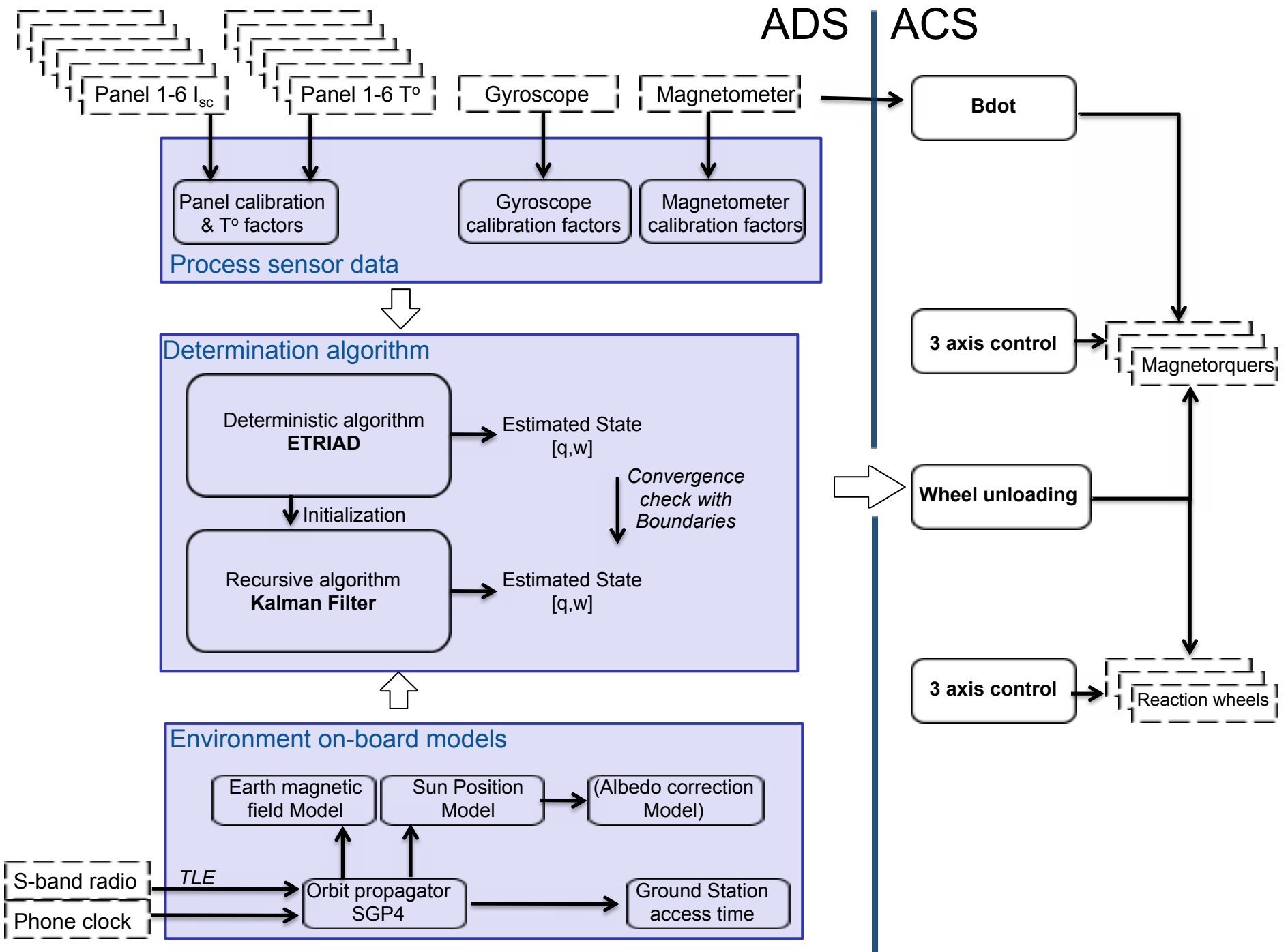


COTS reaction wheels

- 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!

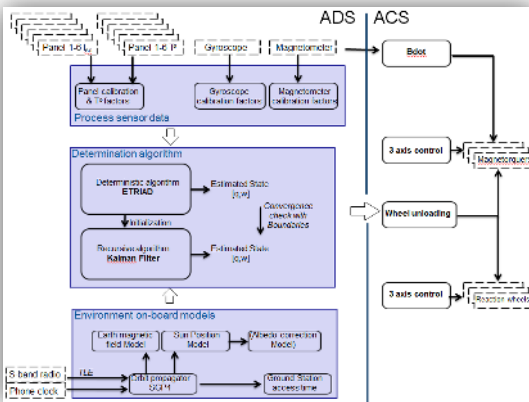






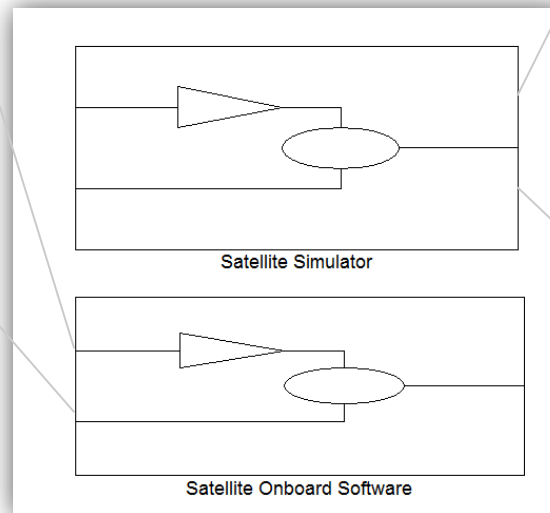
Software-in-the-loop simulator

ONBOARD SOFTWARE

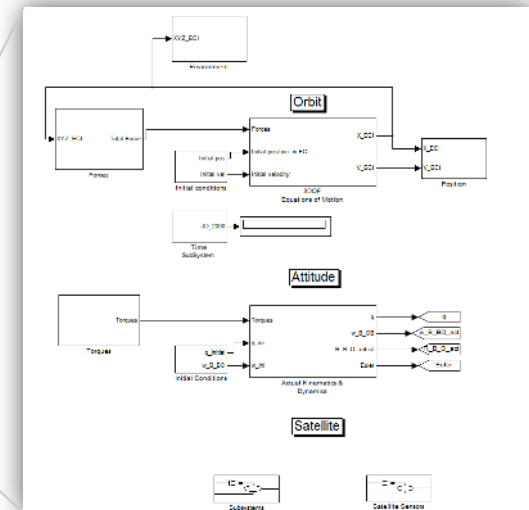


- Kalman Filter
- ETRIAD
- RW
- Magnetorquer
- ADCS modes

SIMULINK SIL SIMULATOR



SATELLITE SIMULATOR

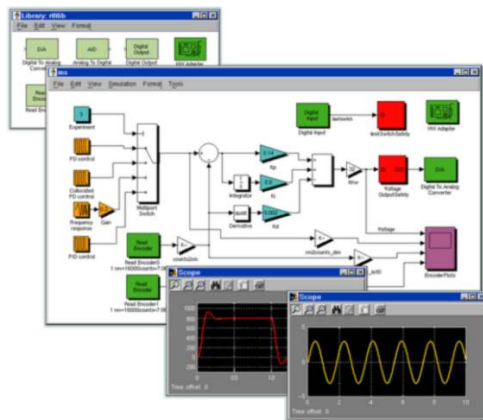


- Orbit Propagation
- Sunlight & GS Access
- S/c kinematics & dynamics
- Disturbance Torques
- Sensors emulation
- ...



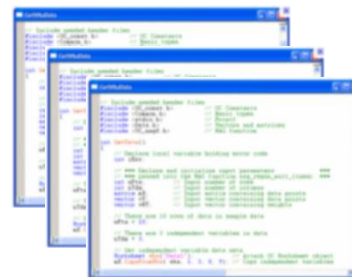
ADCS software

- Matlab/Simulink running on the phone!



Simulink Model

*Matlab
Embedded coder*



C Code

JNI

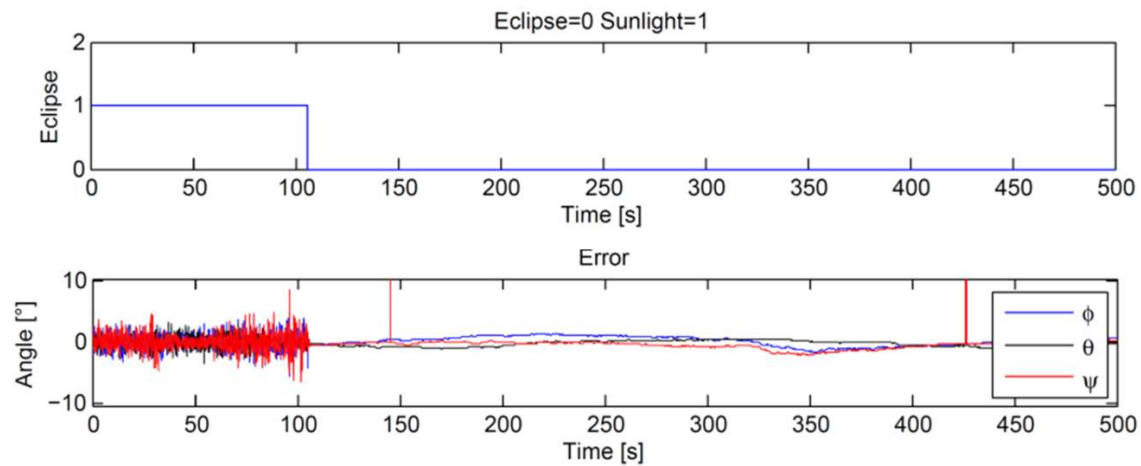
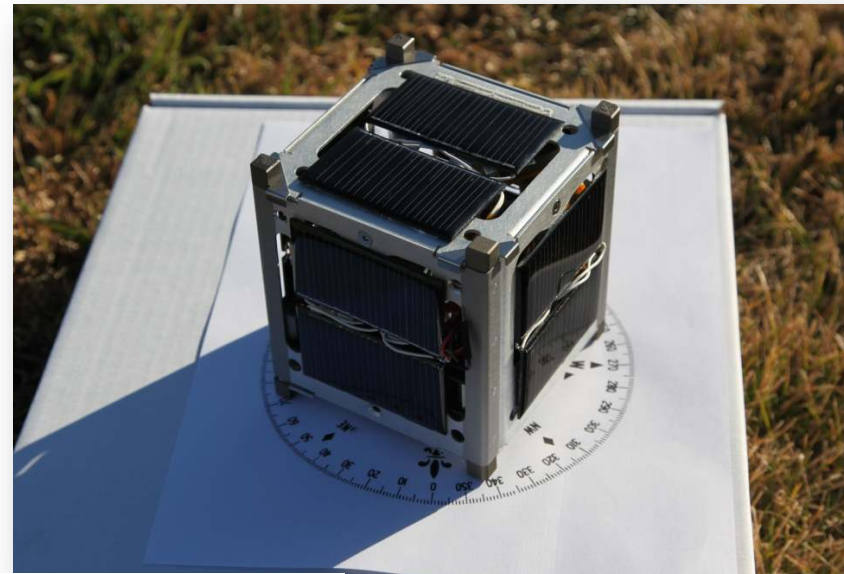


Android App



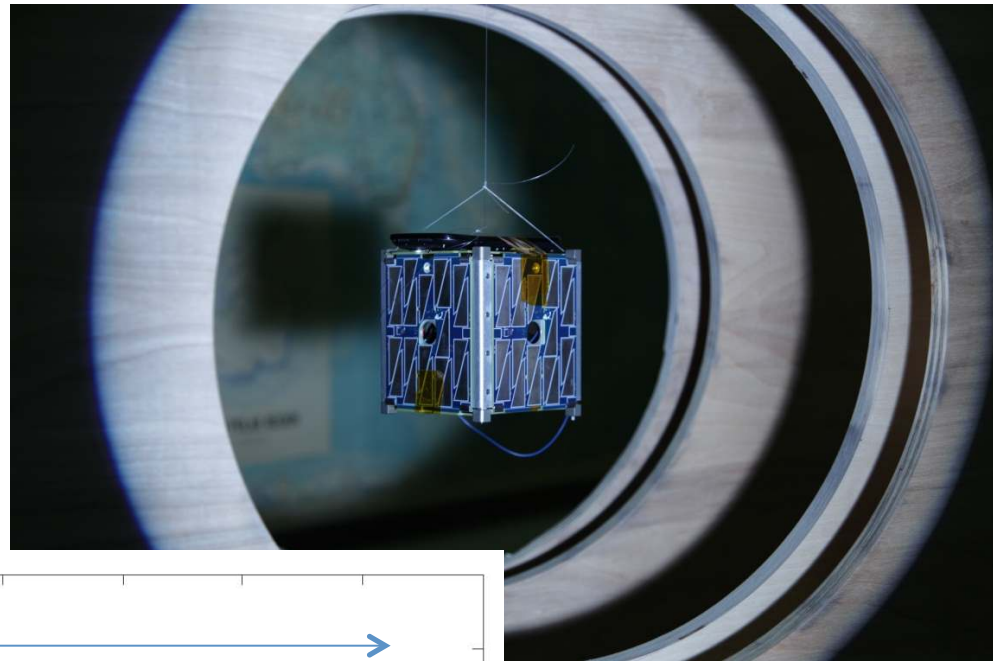
ADS tests

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

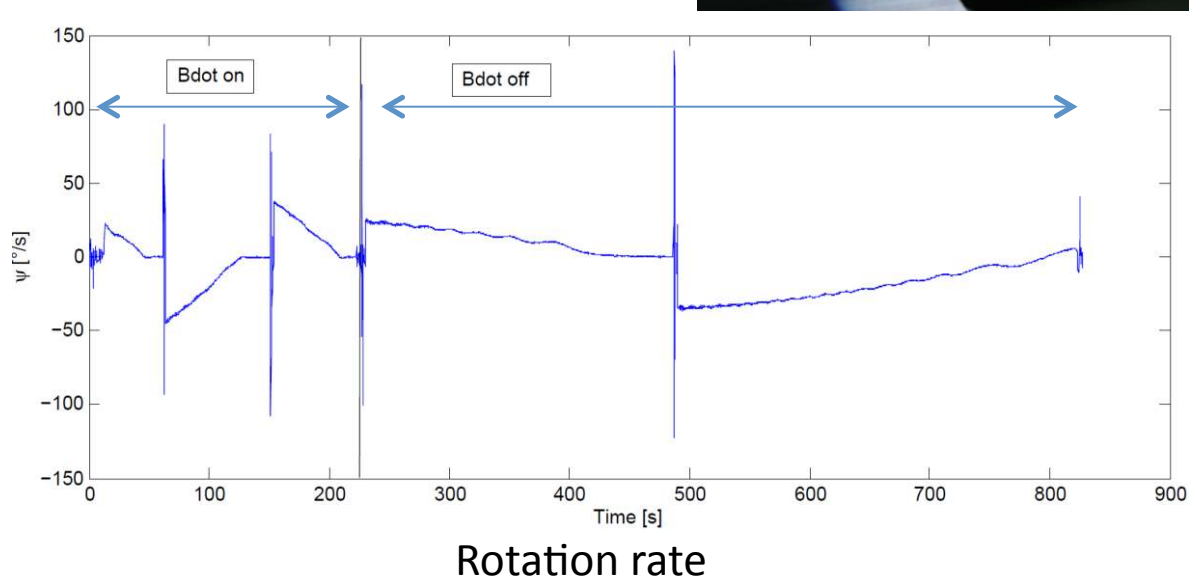




Bdot test

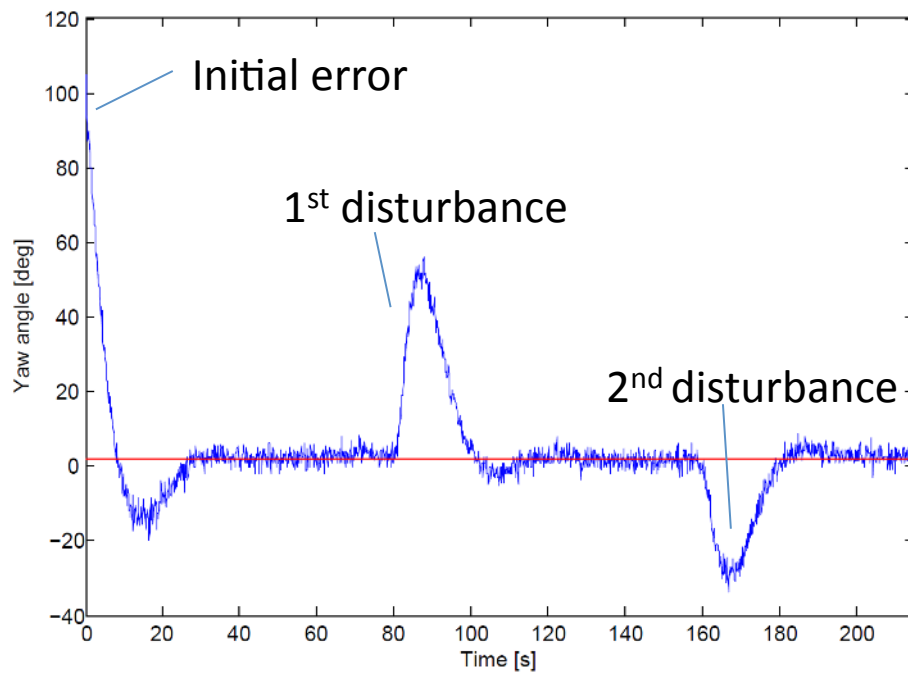


- Effectively damp rotation rate

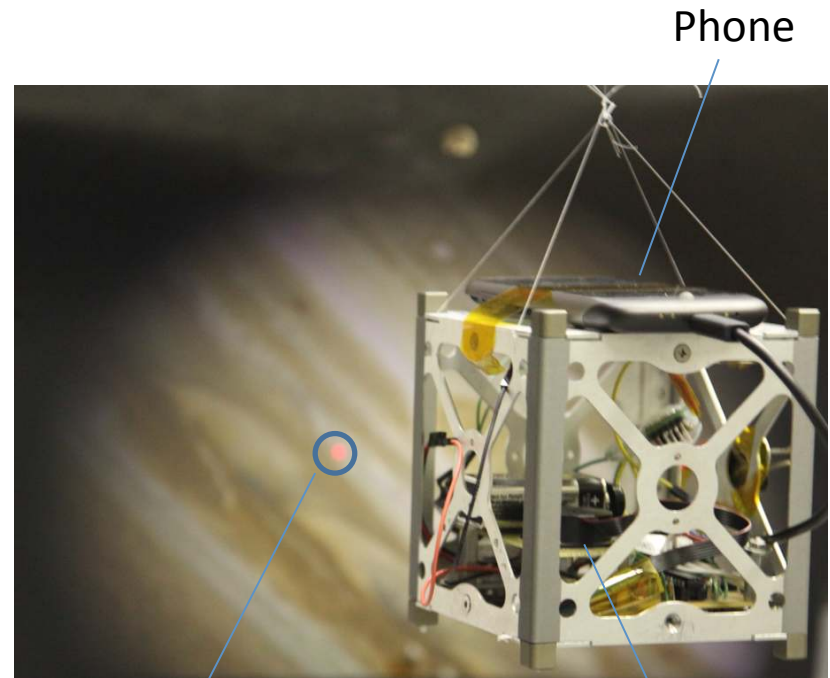




RW test



String Test

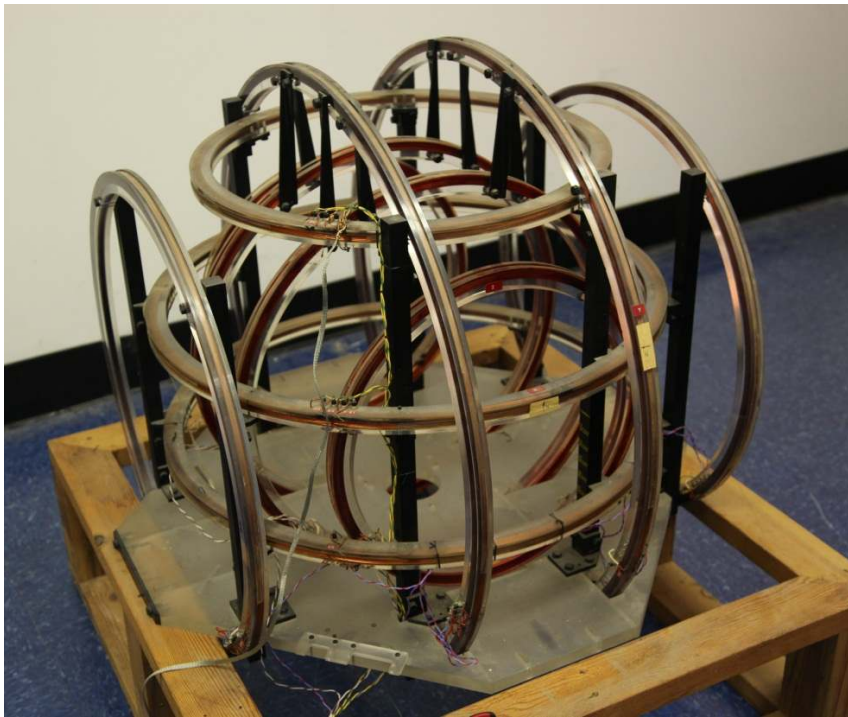


Laser pointer

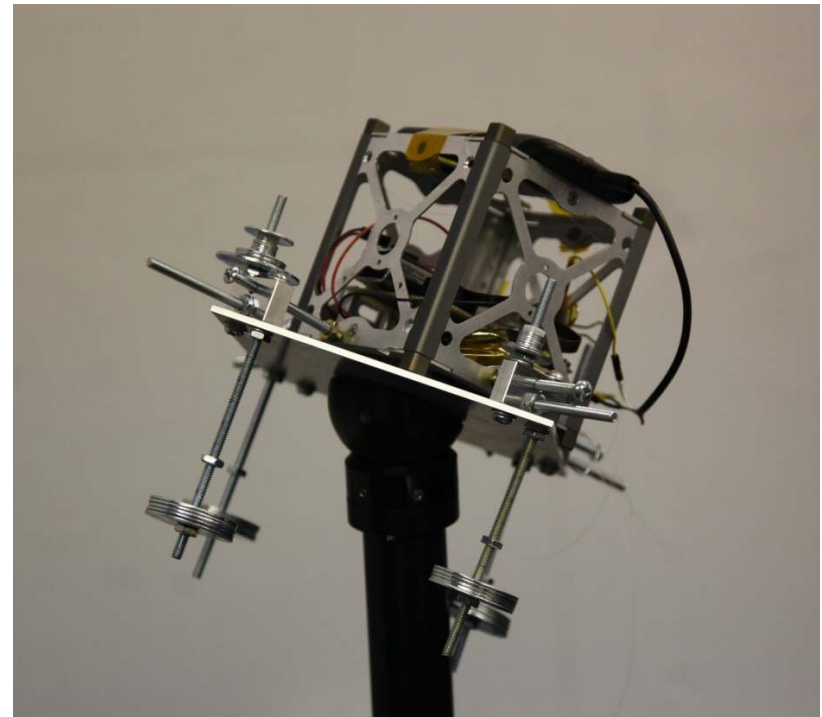
Reaction wheel



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!