



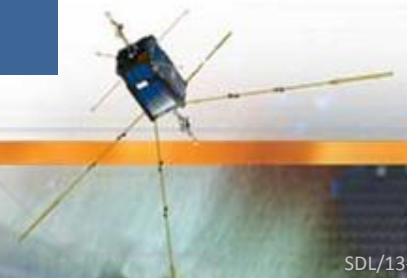
Integrated Test Facility for Nanosat Assessment and Verification

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Introduction

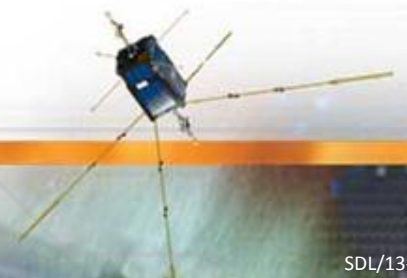
- Motivation/Justification
 - Requirements-based missions need verification prior to launch
 - Current industrial verification base is for larger spacecraft
 - CubeSats need novel approaches due to comparatively small size
 - Need is warranted by anticipated rate of 30-50 US CubeSats per year
- Goal
 - Provide verification capability to enable requirements-based missions
 - Make test facility available to community
- Implementation
 - Phase 1: Class 1 and Class 2 spacecraft up to 10 kg (see table below)
 - Phase 2: Class 3 upgrades will include a star-field simulator for testing CubeSat-sized star trackers

Class	Descriptive Feature	Typical Knowledge Accuracy	Typical Control Accuracy
1	Spinning	1°	5°
2	Sun Sensor/ Magnetometer	0.2°	0.2°
3	Star Tracker	0.01°	0.02°



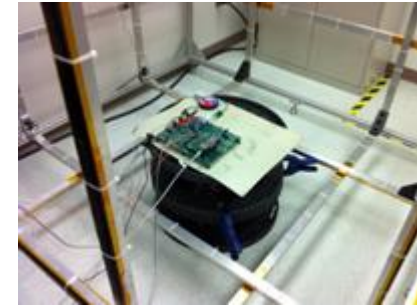
Overview

- Internally funded project
- Phase 1 operational since August 2010
- Has supported a number of programs (see next slide)
- Focus for Phase 1
 - Class 1 and Class 2 spacecraft
 - Verification of attitude control components
 - Verification of mass properties
 - End-to-end verification of power subsystem
 - End-to-end verification of attitude control subsystem
 - End-to-end system test

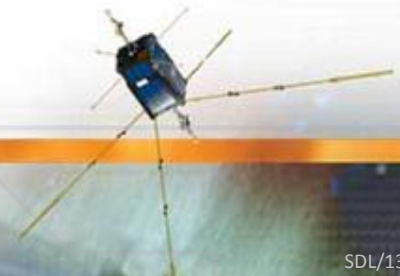


Examples of Systems Tested

- DICE
 - ADCS board test
 - Helmholtz cage creates orbiting magnetic field
 - HWIL simulation sends voltages to sun sensors
 - Flight processor uses ADCS magnetometer readings and sun voltages to find attitude solution
 - Functional test of 8 solar panels
 - Sun sensor calibration
 - Boom deployment with spin table
 - Mass and CG
- PEARL
 - Sun sensor calibration
 - ADCS and torque coil test using Helmholtz cage and air bearing
- Falling sphere: Mass, CG, inertia
- STAROP: Mass, CG



Video Clip of PEARL Testing (click to play)



Summary of Capability

Mass Properties

- Center of mass
- Moments of inertia



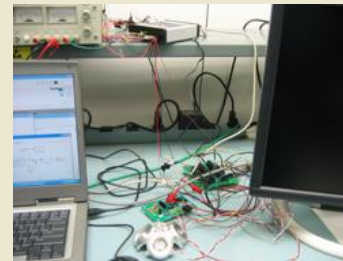
Sun Sensors

- Calibrate and test sun sensor



Reaction Wheels

- Test, characterize, and calibrate



Magnetometers/ Torque Coils

- Test and characterize



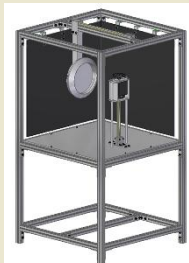
Solar Arrays

- AMO illumination



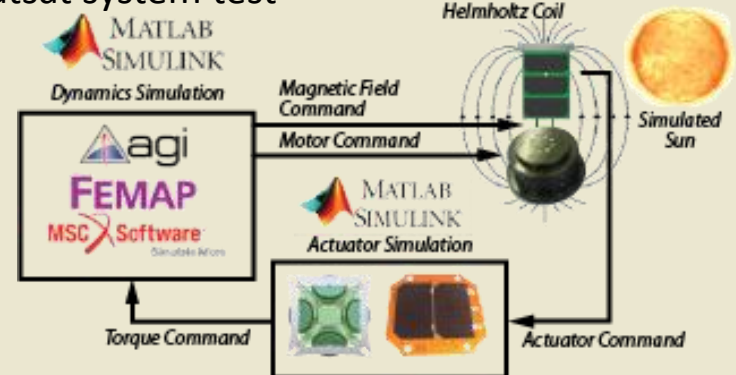
Horizon Sensors

- Earth/space simulator
- Sensor mount rotates



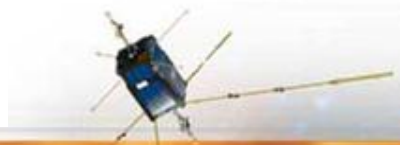
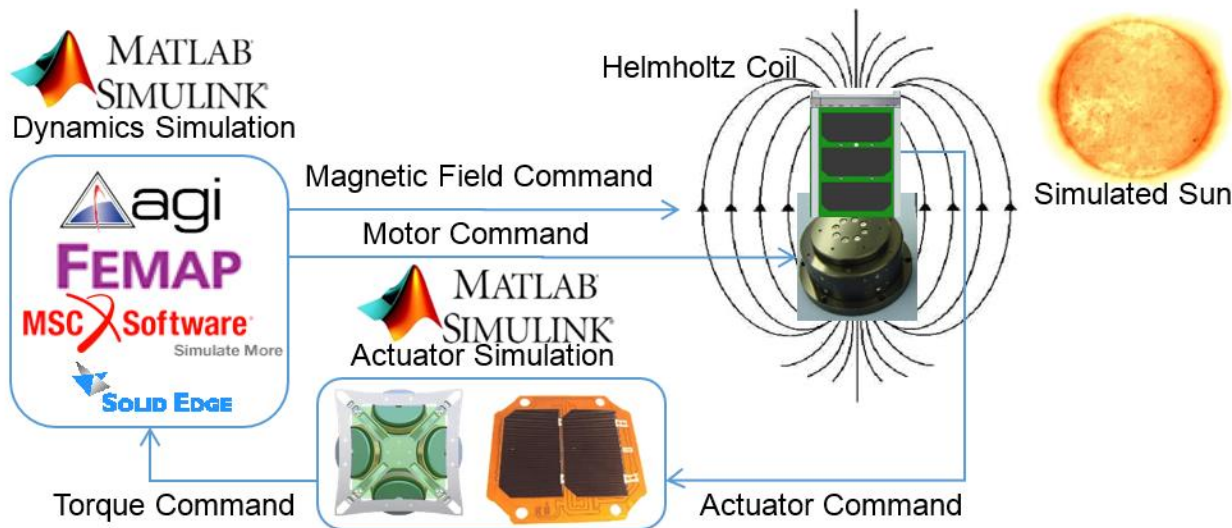
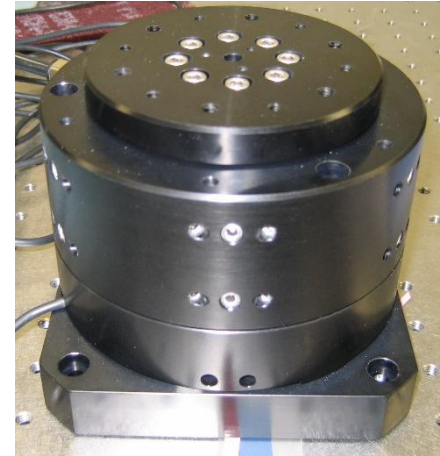
System Test

- Flatsat system test

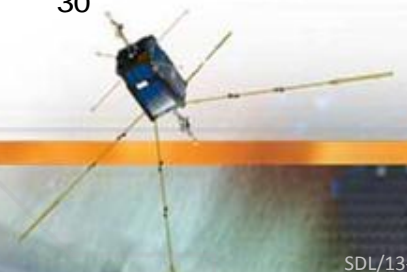
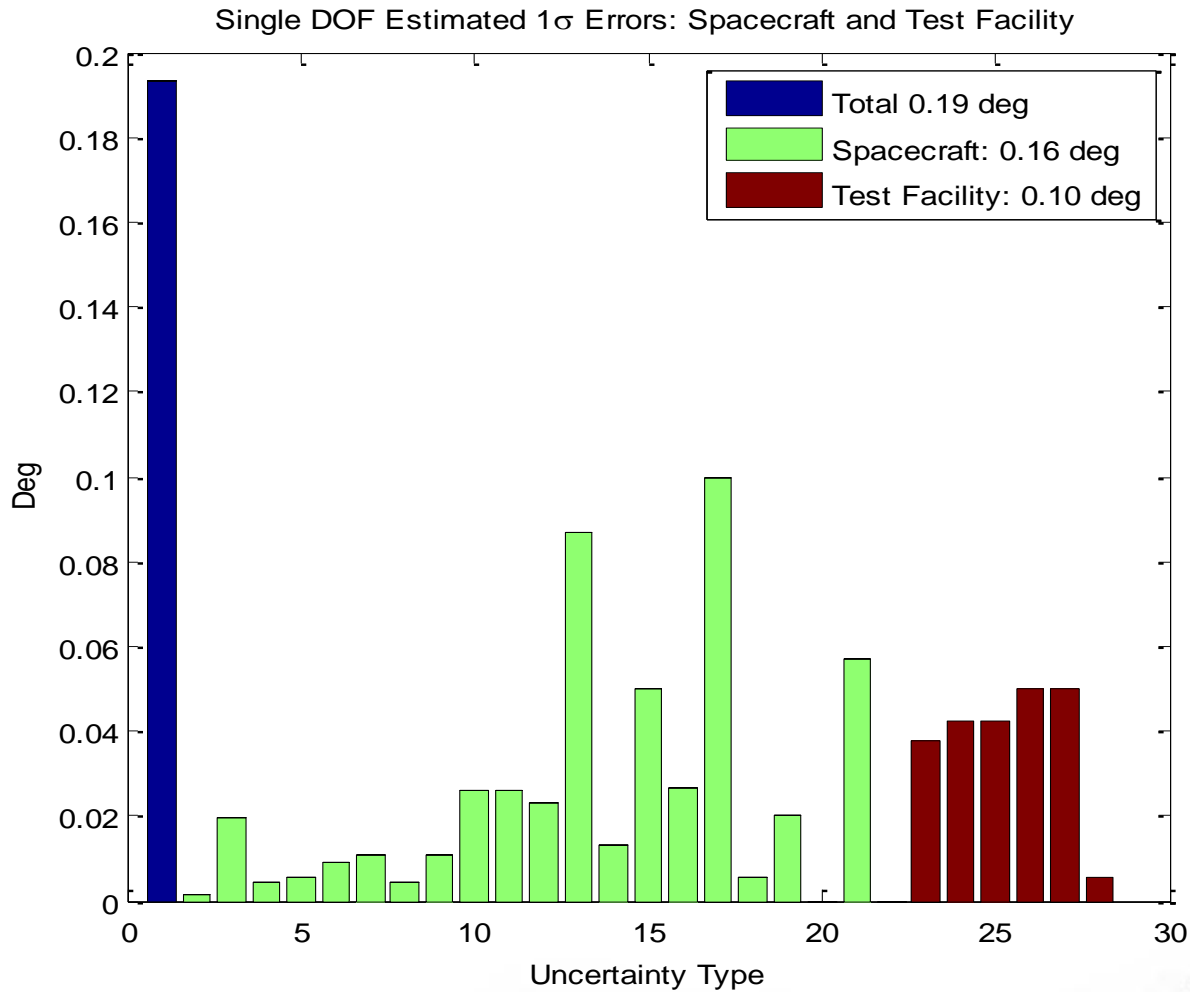


System Level Testing

- Purpose
 - End-to-end ADCS testing and verification (hardware and software)
- Capability
 - Single-axis testing uses air bearing with high-count encoder
 - Three-axis testing uses flat-sat avionics and real-time hardware-in-the-loop simulation
 - Predicted accuracy $< 0.2^\circ$ (see next slide)
 - Upgrades to support Class 3 spacecraft will include hexapod (already owned by SDL) and star-field simulator

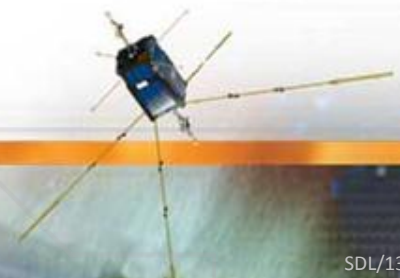


Predicted Class 2 Pointing Accuracy



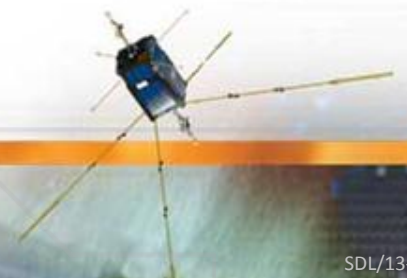
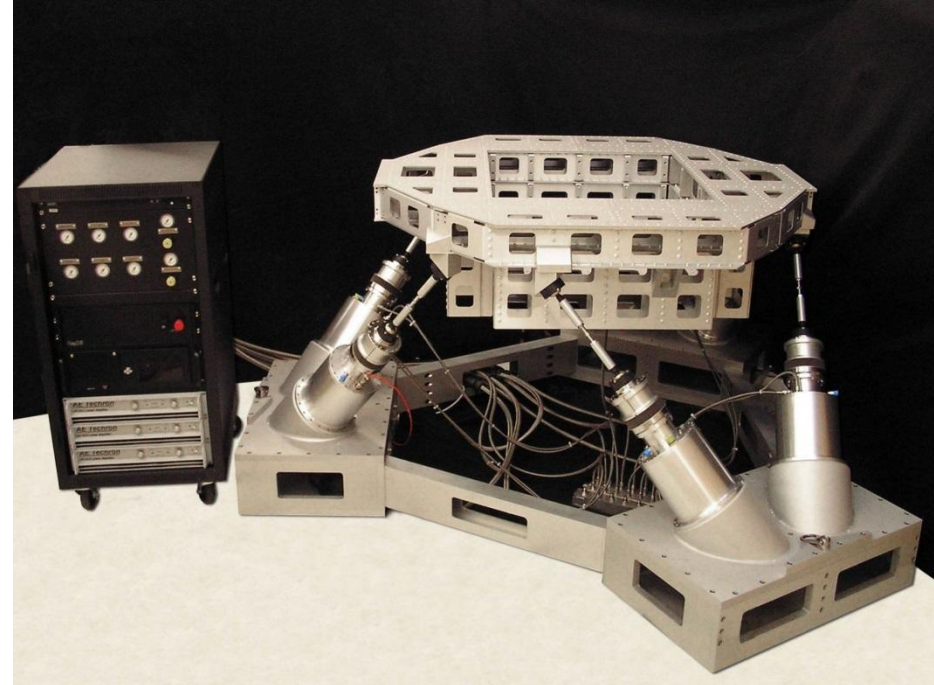
Three-Axis ADCS Simulator

- Spherical air bearing
- Valuable for verifying and validating closed-loop ADCS algorithms and software
- Structure of ABS plastic created on 3-D printer--allows rapid reconfiguration for mounting alternative ADCS hardware



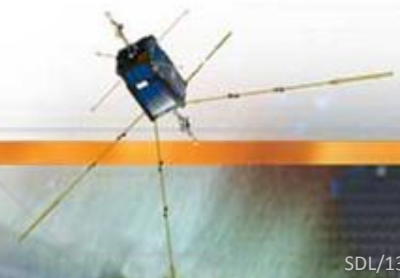
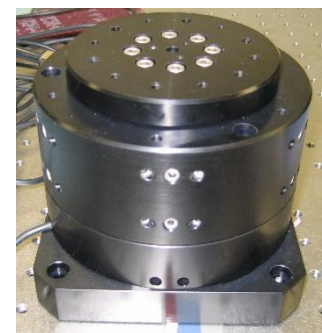
Hexapod for 6-DOF Motion Simulation

- Located at SDL in Albuquerque
- Mass limit 180 kg
- Translation 15 mm
- Rotation 2.5 deg
- Translational repeatability/resolution is 1 micron
- Rotational is 2 microrad
- Vacuum compatible
- Can also impart multi-axis jitter to 40 Hz to simulate launch and on-orbit disturbances



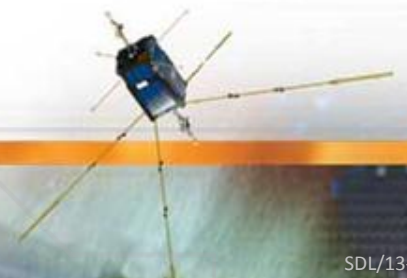
Magnetometer / Torque Coil Testing

- Purpose
 - Characterization and calibration of magnetic field sensors and actuators
- Capability
 - Three-axis Helmholtz cage
 - Closed-loop field control to less than 10 nanoTesla
 - Dual NIST-traceable differential magnetometers for feedback
 - Two-meter cage, 60-cm working volume
 - Moveable coils provide smaller highly-uniform field or larger less-uniform field
 - Zero-gauss chamber for calibration
 - Non-magnetic air bearing for torque coil testing



Sun Sensor Testing

- Purpose
 - Calibration and characterization of sun sensors
- Capability
 - Simulated sun source
 - Two-axis precision gimbal
 - $\leq 0.002^\circ$ repeatability
 - $\leq 0.01^\circ$ accuracy



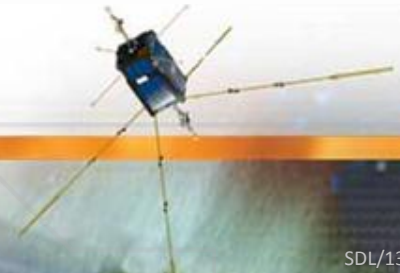
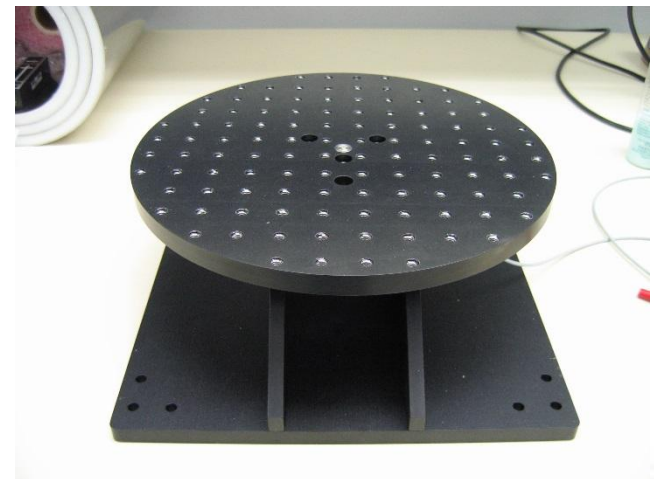
Solar Panel Testing

- Purpose
 - Test solar panel assemblies and power control system
- Capability
 - Continuous AM0 light source
 - Meets Class BBA (IEC 60904-9)
 - B: Spectral concurrence to the sun (0.6 to 1.4)
 - B: Irradiation non-uniformity ($\leq 5\%$)
 - A: Temporal stability ($\leq 2\%$)
 - Target area 300 x 300 mm
 - NIST-traceable pyranometer measures intensity



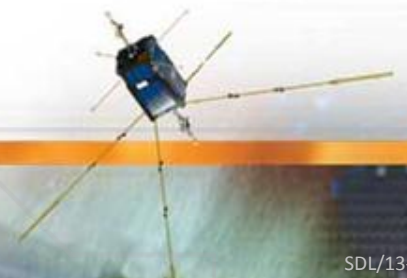
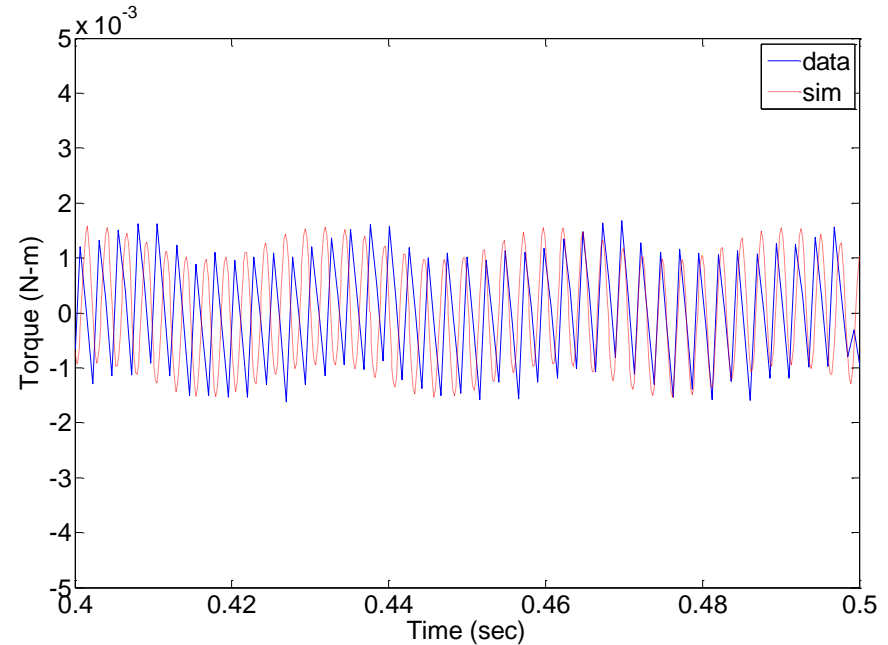
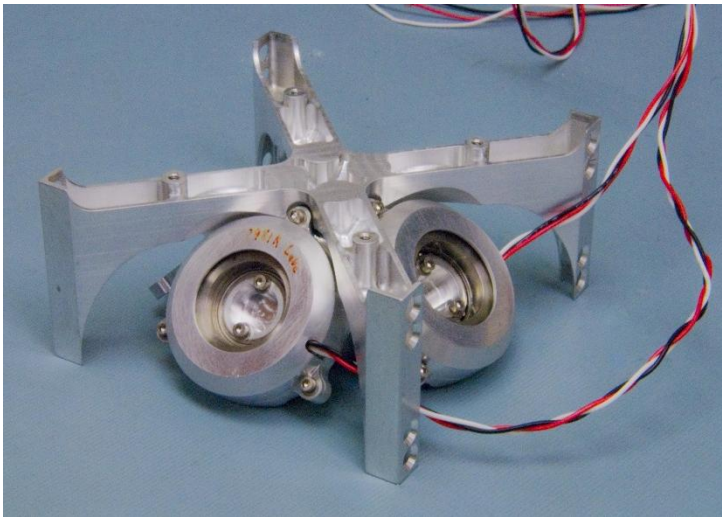
Mass Properties Testing

- Purpose
 - Measure mass, center of mass, and moments of inertia
 - Balance spacecraft
- Capability
 - Center of mass (CM) table
 - Three-point kinematic mount with load cells
 - Static and dynamic balancing
 - Mass error less than 2 grams
 - CM error less than 1 mm
 - Moment of inertia (MOI) table
 - Innovative frictionless design restricts translational motion
 - High-speed camera measures period of oscillation which is proportional to inertia



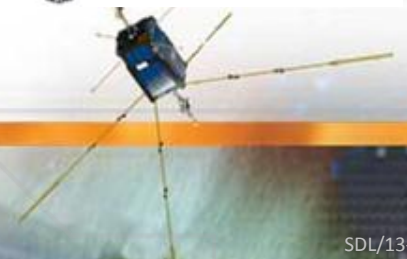
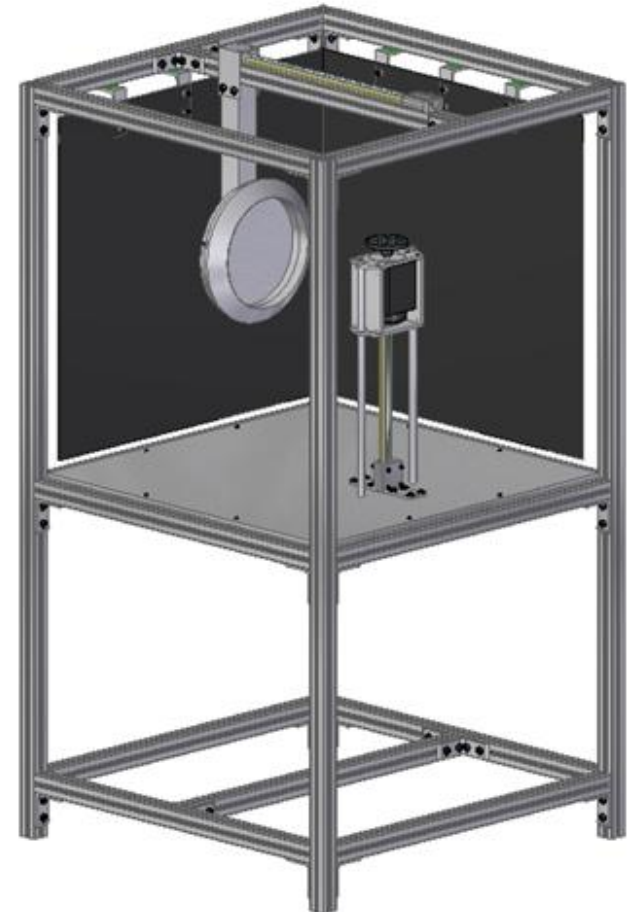
Reaction Wheel Testing

- Purpose
 - Characterization of reaction wheels or similar components
- Capability
 - High-precision measurement of wheel speed at 400 MHz
 - Analytical (model-based) and empirical determination of torque
 - Characterization of jitter



Horizon Crossing Sensor Testing

- Purpose
 - Calibrate and characterize horizon crossing sensors
- Capability
 - Tests for field of view, time delay, sensitivity, spin rate
 - Earth simulator (variable controlled temperature)
 - Space simulator
 - Two hand-operated linear stages to simulate range of altitudes and to position sensor accurately
 - Servo-controlled rotary stage to simulate terminator crossing at varying speeds
- Status
 - Student-led senior design project
 - Successful PDR and CDR
 - Will be built and tested Fall 2013



Summary

- SDL's CubeSat test facility will provide requirements verification
 - Ensure requirements are met prior to launch
 - Enable testing and verification of individual components as well as system
 - Upgrade to higher capabilities as need arises
- Resource to help our government, industry, and academic partners “bridge the gap” from current CubeSat capabilities to the next generation

Current CubeSat
Capabilities and
Missions



Next Generation
CubeSat Capabilities
and Missions