Integrated CubeSat Test Facility for Precision Pointing and Power Generation

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Introduction

Motivation
- Requirements-based missions need pre-mission verification
- Current industrial verification base is for larger spacecraft
- CubeSats need novel approaches due to small disturbance torques

Goal
- Provide verification capability to enable requirements-based missions
- Make test facility available to community

Implementation
- Class 1 and Class 2 spacecraft up to 10 kg (see table below)
- Upgrades to follow as required

<table>
<thead>
<tr>
<th>Class</th>
<th>Descriptive Feature</th>
<th>Typical Knowledge Accuracy</th>
<th>Typical Control Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spinning</td>
<td>1°</td>
<td>5°</td>
</tr>
<tr>
<td>2</td>
<td>Sun/Mag</td>
<td>0.2°</td>
<td>0.2°</td>
</tr>
<tr>
<td>3</td>
<td>Star Tracker</td>
<td>0.01°</td>
<td>0.02°</td>
</tr>
</tbody>
</table>

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Overview

- Internally funded project
- Phase 1 complete August 2010
- 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
System Level Testing

Purpose
- End-to-end system testing and verification

Capability
- Flat-sat (real-time-model-based) avionics and flight software verification
- End-to-end attitude control verification
- Assembled spacecraft independent operation and verification
System Level Attitude Control Verification

- Single-axis testing uses air bearing and encoder
- Three-axis testing uses real-time simulation and hardware-in-the-loop
- Predicted accuracy < 0.2°
- Class 3 upgrades will include Stewart platform, star simulator

![Graph showing single DOF estimated 1σ errors: Spacecraft and Test Facility]
Reaction Wheel Testing

Purpose
- Characterization of reaction wheels or similar components

Capability
- High-precision measurement of wheel speed
- Analytical (model-based) and empirical determination of torque
- Characterization of jitter

![Graph showing torque vs. time with data and simulated lines]

![Image of reaction wheel]

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Magnetometer / Torquer Coil Testing

Purpose
- Characterization and/or calibration of magnetic field sensors and actuators

Capability
- Three-axis Helmholtz cage
- Closed loop control of magnetic field
- Dual differential magnetometers
- Two-meter cage, 60-cm nominal working volume
- Moveable coils provide choice of smaller highly-uniform field or larger less-uniform field
- Zero-gauss chamber for calibration
Sun Sensor Testing

Purpose
- Calibration and characterization of sun sensors

Capability
- Sun source
- Two-axis precision gimbal
  - ≤0.002° repeatability
  - ≤0.01° accuracy
Horizon Sensor Testing

Purpose
- Calibrate and characterize horizon sensors

Capability
- Earth simulator (variable temperature)
- Space simulator (liquid nitrogen cooled)
- Rotary mount to simulate terminator crossing
Solar Panel Testing

Purpose
- Test solar panel assemblies and/or 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 (≤ 5%)
  - A: Temporal Stability (≤ 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

- **Capability**
  - Center of mass (CM) table
    - Three-point kinematic mount with load cells
    - Static and dynamic balancing
  - Moment of inertia (MOI) table
    - Innovative design restricts translational motion
    - Leverages SDL experience with special pivots
    - Optically measure period of oscillation
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 transition from current CubeSat capabilities to the next generation