SpinSat Mission Overview

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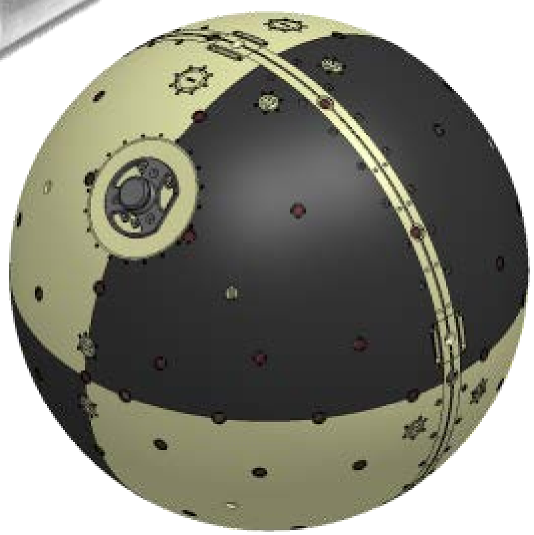
Outline

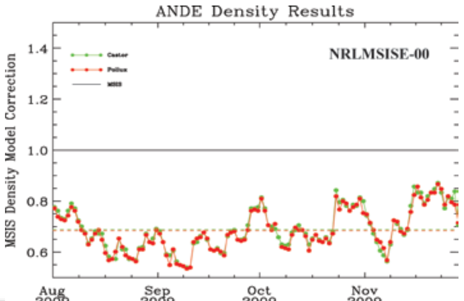
- Mission Concept
- Thruster Design
- Thruster Testing
- Spacecraft Design
- Mission Operations
- Acknowledgements

Mission Overview

Objective

Provide a test platform to demonstrate and characterize Electrically-controlled Solid Propellant (ESP) thrusters in space, test the ground-based detection and characterization capabilities, and provide an atmospheric drag experiment during a more active solar period.





Safe Electrically-controlled Solid Propellant thruster

- Only fires when a current is applied.
- Insensitive Munitions (IM) Compliant
- Low Hazard class, green & non-toxic

Fly an array of ESPs placed around a spherical spacecraft

- Align in pairs to increase/decrease spin
- On board instrumentation to measure spin rate and spin axis
- Observe state changes from SSN assets

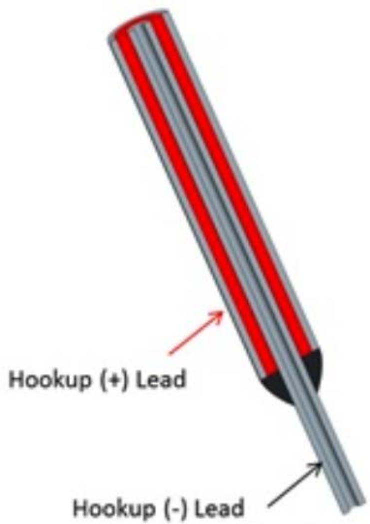
Space Situational Awareness

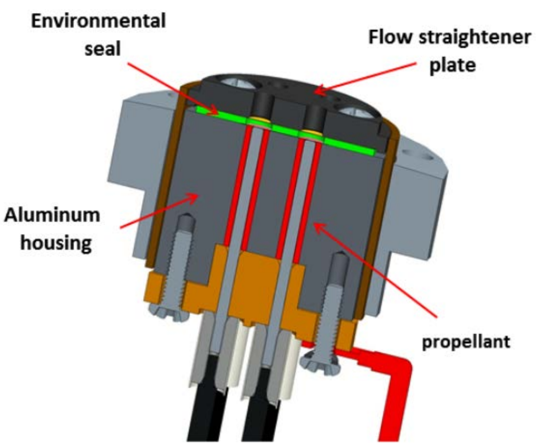
- Change Detection
- Space Object Characterization
- Optical & IR signatures of thruster

Atmospheric drag experiment

- Spherical 22” diameter spacecraft is fitted with retro-reflectors for satellite laser ranging

Thruster Design





Thruster Geometry

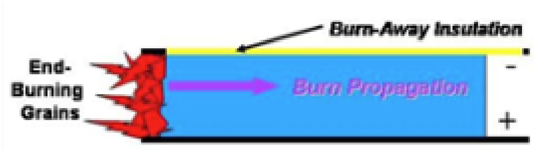
- Cylindrical form factor
- A thin stainless steel rod is installed down the center of the cylinder
- Cylinder shell acts as one conductor (+)
- The center rod acts as another conductor (-)
- Thrusters packaged into groups or ‘clusters’ of 6

Thruster-Cluster Features

- Aluminum body serves as common positive electrode
- Straightener plate routes exhaust gas to achieve thrust at a 45º angle or perpendicular to satellite surface.
- Environmental seal protects propellant from humidity, etc.

Ignition Mechanism

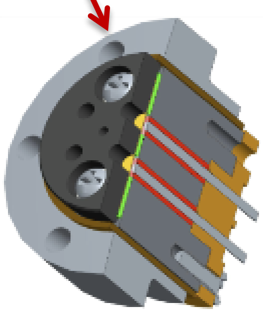
- Center electrode is insulated from the base to within 0.02” of the thruster face.
- When current is applied across electrodes, insulation gap ensures that ignition starts at the face and travels down as the insulator burns away
- DSSP proprietary

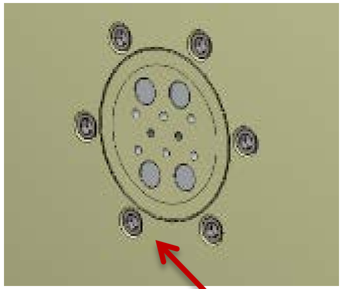


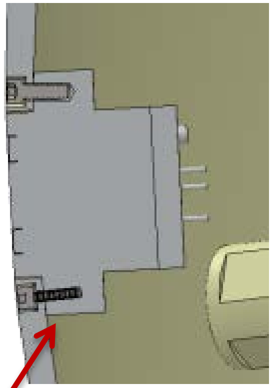
Clusters

- 12 total clusters (4 Normal for translation, 8 45º angled for rotation)
- Each cluster contains 6 thrusters, Total of 72 thrusters
  - The max thruster fire duration for each hemisphere, based on a full capacitor charge, is 200ms *per pulse*.
  - If a translational thruster fires for a full 200ms (max thrust of 75 mN), and then SpinSat rotates a full 180 degrees so the first fire is followed by a second, perfectly aligned, 200ms fire the maximum ΔV based on a 57kg mass is 0.052 cm/s

UMS Enclosure

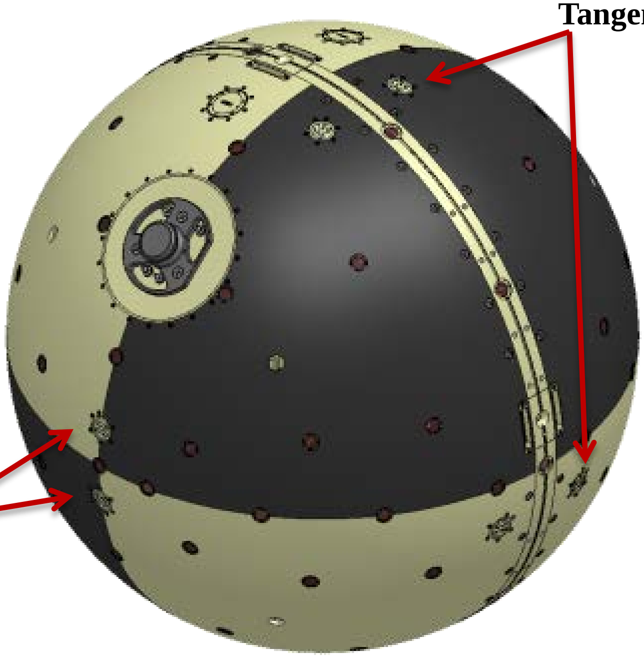






Thruster in SpinSat

Tangent



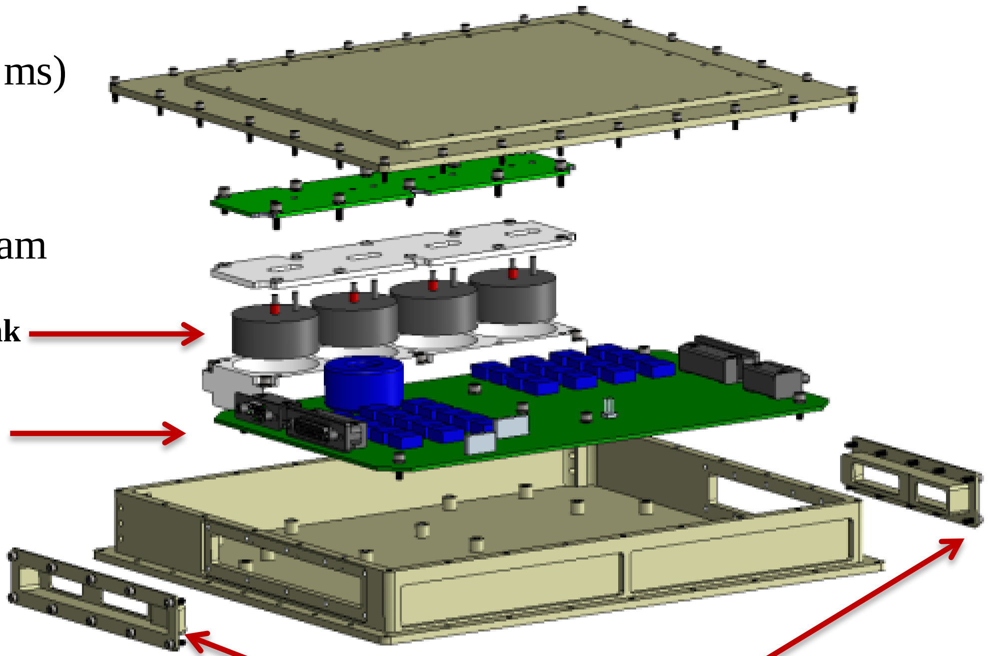
Normal

Thruster Safety

- HIPEP (propellant) is safe
  - Insensitive Munitions (IM) Compliant
    - Analysis per MIL-STD-2105 is in progress at China Lake, supported by Navy contracts.
  - Explosives testing performed by independent contractor. DSSP has received 1.4S shipping classification issued by DoT.
  - Flame Insensitive
  - Bullet impact insensitive. Tested with .30 and .50 cal ammunition.
  - Safe, "green", non-toxic sol-gel chemistry. No volatiles.
  - Combustion products include
    - H_2O, CO_2, and N_2 as major species (99.5+ %)
- HIPEP Quantity
  - Each thruster contains ~66.67 mg of HIPEP
  - Each cluster contains 6 thrusters
  - 12 * 6 * 66.67 = 4.8 grams of total HIPEP on SpinSat

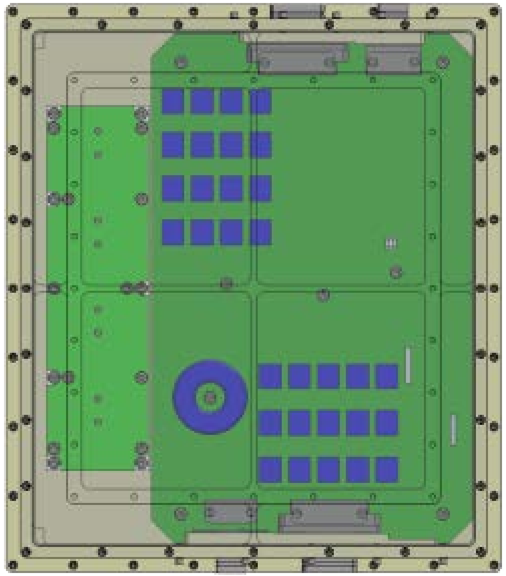
Propulsion Control Module (PCM)

- One PCM in each hemisphere
  - 5V regulated, 0.2 A bus
  - RS-422 serial communications
  - Bank of wet tantalum capacitors to power thrusters (unpowered prior to deployment from ISS)
    - 3000uF charged to 190V (54 Joules)
  - Capacitors feed switching power supply at 200W output power
  - Controls up to 36 thrusters per hemisphere
    - Adjustable pulse width (50, 100 & 200 ms)
    - Able to fire 2 thrusters simultaneously
  - µD connectors for thruster harnesses, connection to NRL comms, and debug/program

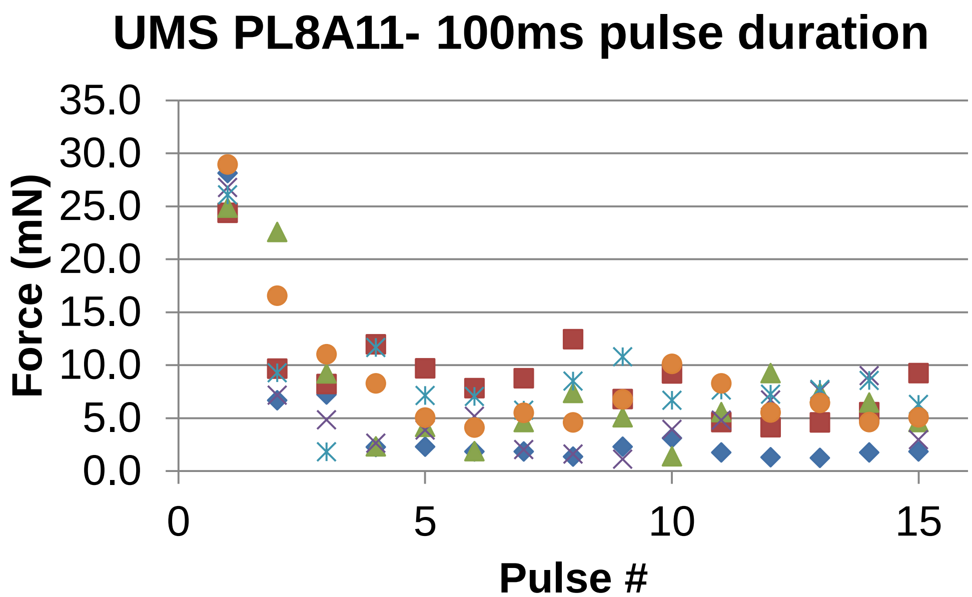


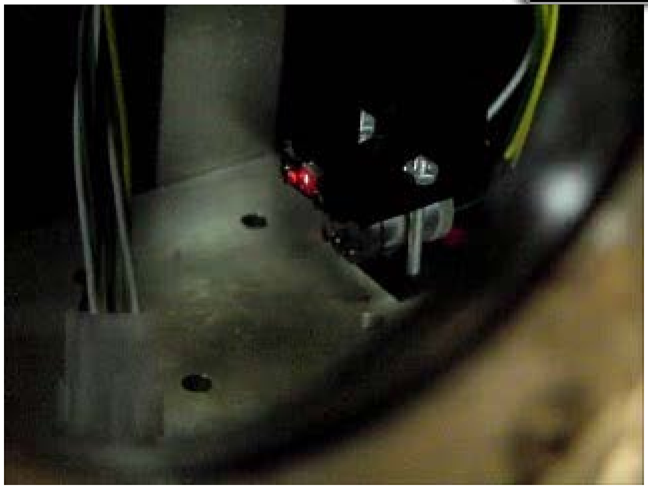
PCM Enclosure

- Design
  - Aluminum 6061-T6 enclosure
  - Contains the DSSP thruster control electronics
  - Contains the Delrin DSSP capacitor bank
    - 4 capacitors in series
  - µD connectors for thruster harnesses, connection to NRL comms, and debug/program
  - Capacitors are unpowered until after deployment from the ISS



Thruster Testing/Performance



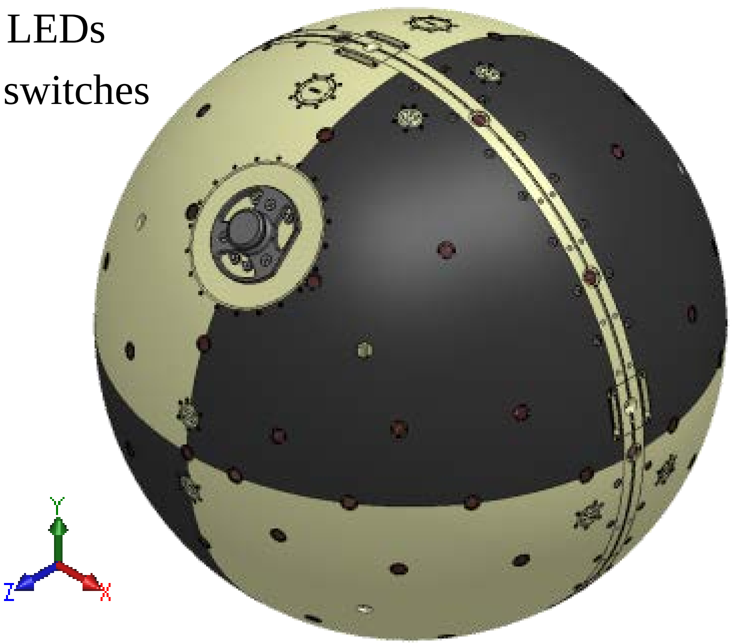


Metric	Value	Variability
Total Impulse (mN*s)	12.3	+/- 2.5
Thruster Lifetime (s)	1.39	+/- 0.13
% of pulses > 2.5 mN	85%	N/A

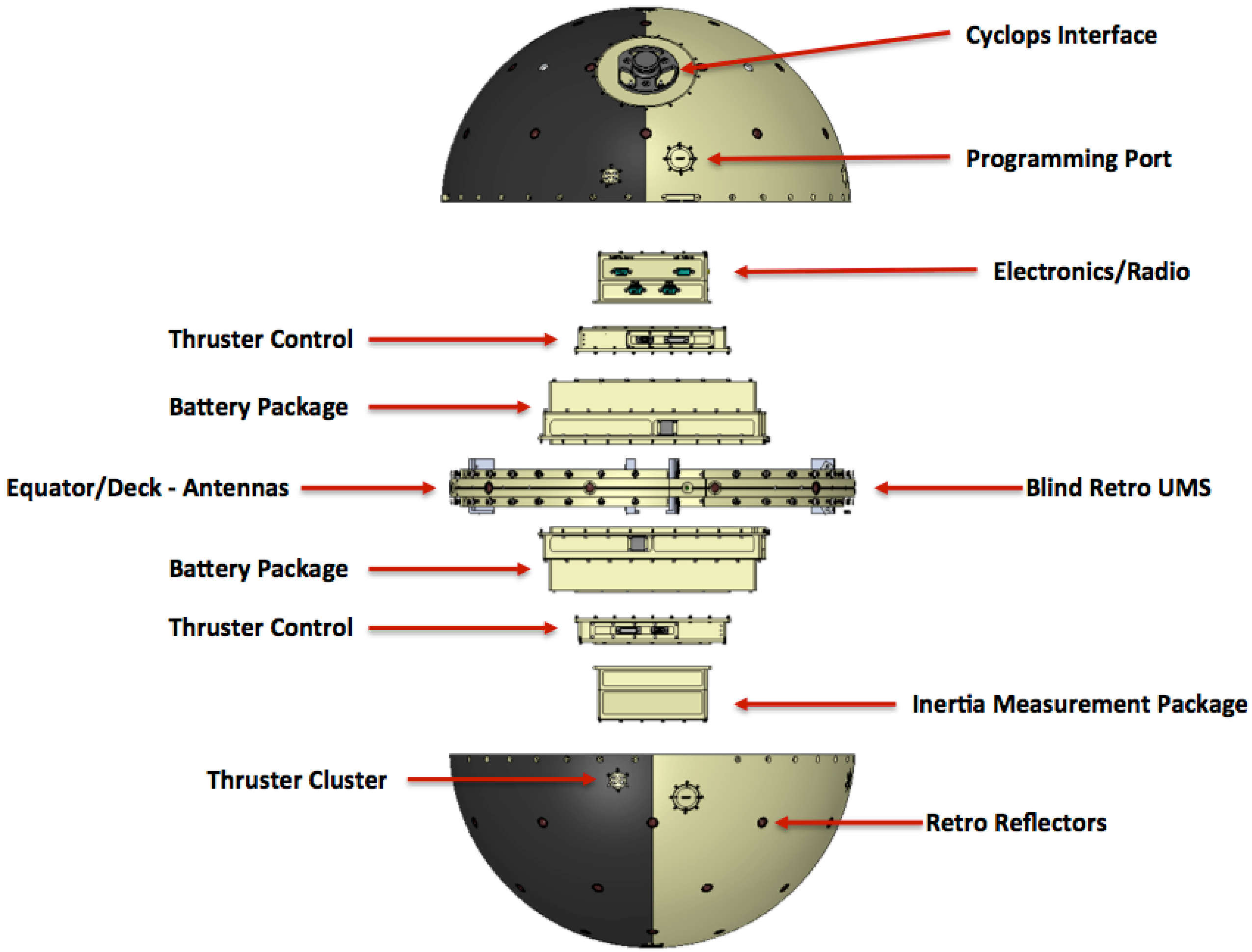
- Thrust measured on DSSP's high-accuracy thrust stand at 10^{-6} torr
- Performance tested after full environmental qualification: thermal cycling to +60/-30 C in atmosphere (+40/-20 C in vacuum), vibration to full launch loads, vacuum storage and humidity soak each for 2 weeks
- Firing multiple thrusters simultaneously, and at +50 C and -20 C in vacuum
- Thrusters are capable of repeated spinup/spindown maneuvers of satellite with multi-pulsed, controllable firing capability

Spacecraft Description

- Mechanical Description
  - 22” Sphere
  - Aluminum 6061-T6 shell
    - Black Anodize and Gold Irridite Pattern
  - Aluminum 6061-T6 equator
  - 92 UMS interface locations
    - 68 retros, 12 thrusters, 3 programming, 1 arm, 8 LEDs
  - 1x Cyclops interface bracket w/4x plunger separation switches
  - 4x deploying wire antennas
- Gravimetrics
  - ~ 56 kg (Includes 5% margin on projection)
  - Cg coordinate goal (0,0,0)
  - Projected Inertias
    - Ixx = 1.075 kg-m^2
    - Iyy = 1.026 kg-m^2
    - Izz = 1.255 kg-m^2
  - Expected Drag Coefficient
    - Cd = 2.12

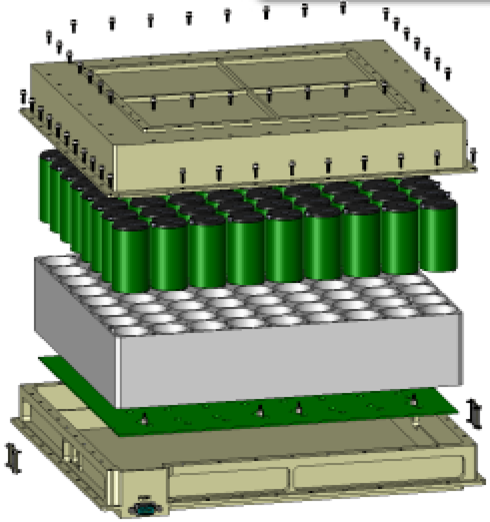


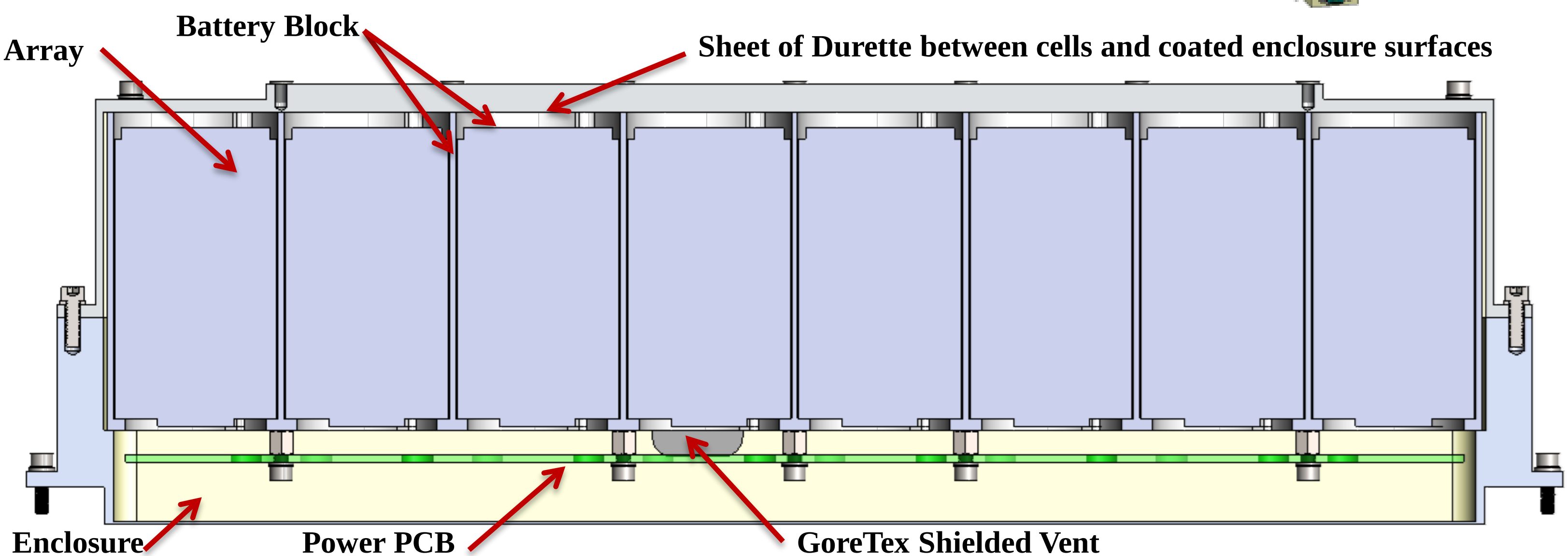
Spacecraft Exploded View



Battery Box Design

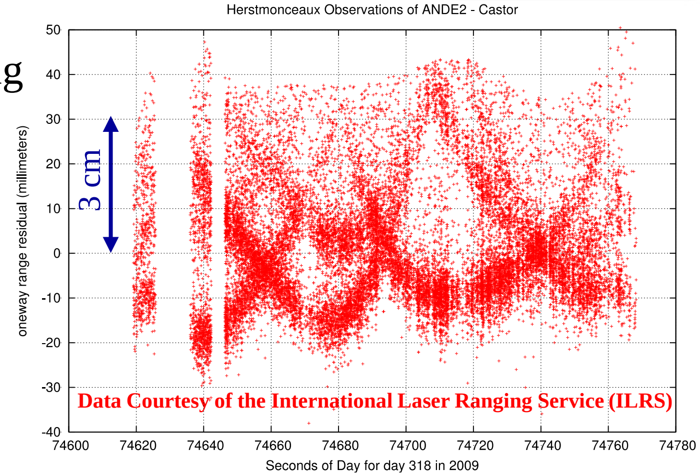
- Aluminum 6061-T6 enclosure
- 72 Ultralife U10026 D-Cell Batteries (per box, one in each hemisphere)
  - Slip-fit packed in a Delrin battery block, aids in cell replacement
- Power PCB attached to battery block, leads from batteries are soldered to board
- GoreTex shielded, vented enclosure
- Empty volumes to be packed with a Durette Felt Gold Wicking
- Interior surfaces of the battery box to be conformal coated with Uralane 5750
- HD DB15 connector

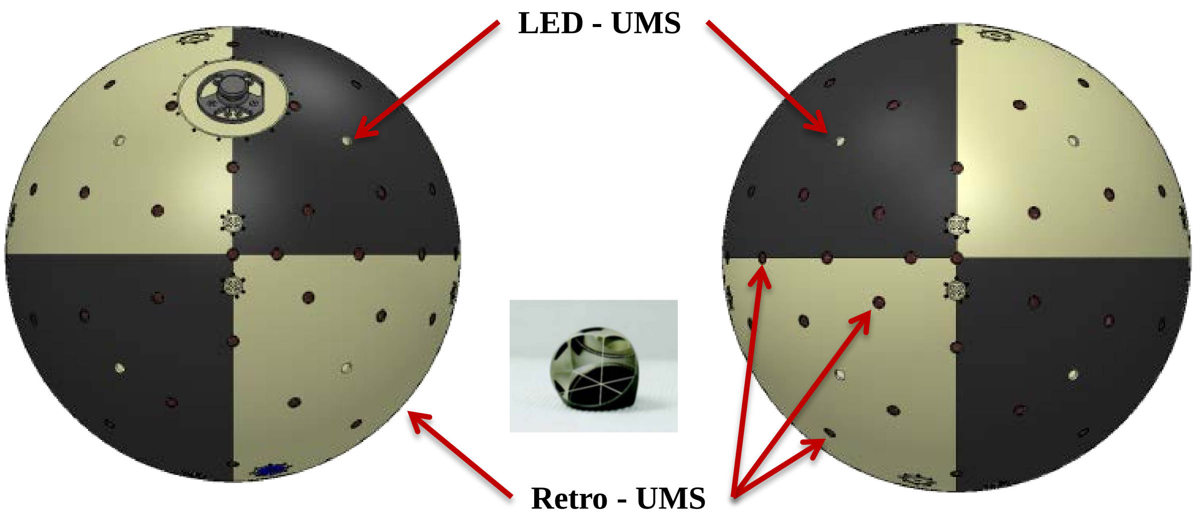


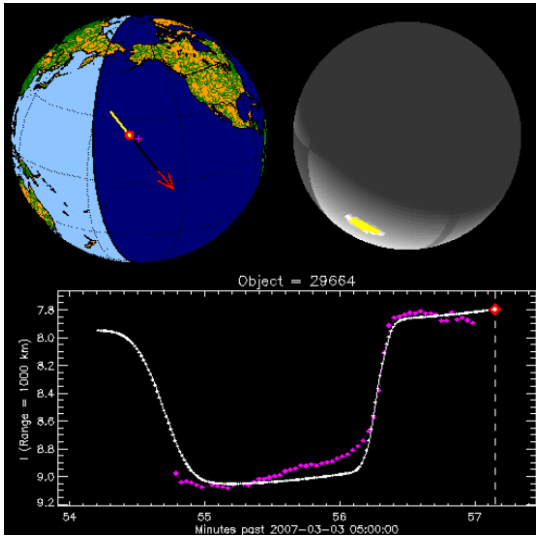


Spin Rate Measurements

- Spin rate will be measured both on-board and from ground sites
  - 12.7 mm retro reflectors (x68) on the sphere for laser ranging
  - Array of 8 LEDs
  - ADIS 16385 Accelerometer
    - Z-axis sensitivity = 0.12 deg/sec
    - Accel = 0.00094 Gs



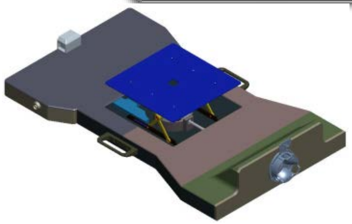


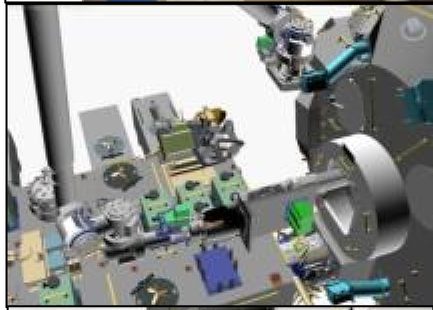


Photometric model analysis of the ANDE MAA using the AEOS 2007 Mar 03 observations, spin rate 0.1 rpm (courtesy of Doyle Hall)

Mission Operations

- Launch (Apr 2014) as soft-stow cargo via SpaceX Dragon vehicle on SpaceX Falcon 9 (SPX-4 resupply mission to ISS)
- Hardware will be transferred to ISS
- Crew Operations
  - ISS crew will remove SpinSat from the launch configuration
  - Remove SAFE plug, verify functionality, and re-install SAFE plug
  - Installing SpinSat onto the Cyclops orbital insertion apparatus developed by NASA JSC
  - Verify that all safety inhibits are functioning properly, remove the SAFE plug, and install the ARM plug
  - Install Cyclops in Japanese airlock, and cycle airlock
  - The ISS team will robotically remove Cyclops/SpinSat and position it in the deploy orientation
  - Cyclops will then deploy SpinSat with a Δv of 0.5 m/s and be re-stowed into the Japanese airlock.
- Once Deployed, SpinSat is operated by NRL in Washington, DC.
- The characterization of the ESP thruster technology will be performed by firing the ESP thrusters in pairs and measuring the changes to the spin rate via on-board rate instrumentation.






SSA Specific

- Spacecraft will be available for pre-flight ground characterization.

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- The authors would like to acknowledge the Cyclops team for developing a unique science enabling deployment technology for the ISS.