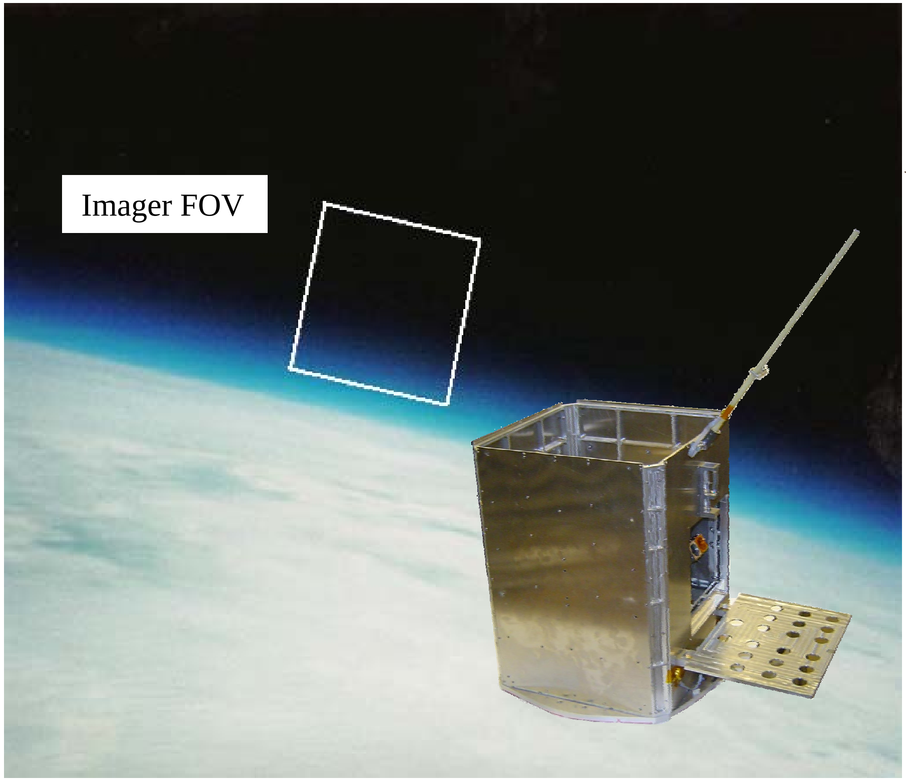
A Highly Modular Scientific Nanosatellite

Taylor University
University of Illinois
University Nanosat III

August 9th-12th, 2004
Logan, Utah
SSC04-VIII-6

Test is dedicated to:

- Student education and training in space science and technology.
- The execution of innovative design strategies for real-world nanosatellite mission objectives.
- Cutting-edge space science and research.



Science

- Source and propagation of acoustic gravity waves.
- Lightning induced electron precipitation and coupling into radiation belt.
- Thunderstorm coupling to the ionosphere, heating, quasi DC electric fields, and global electric circuit fields.

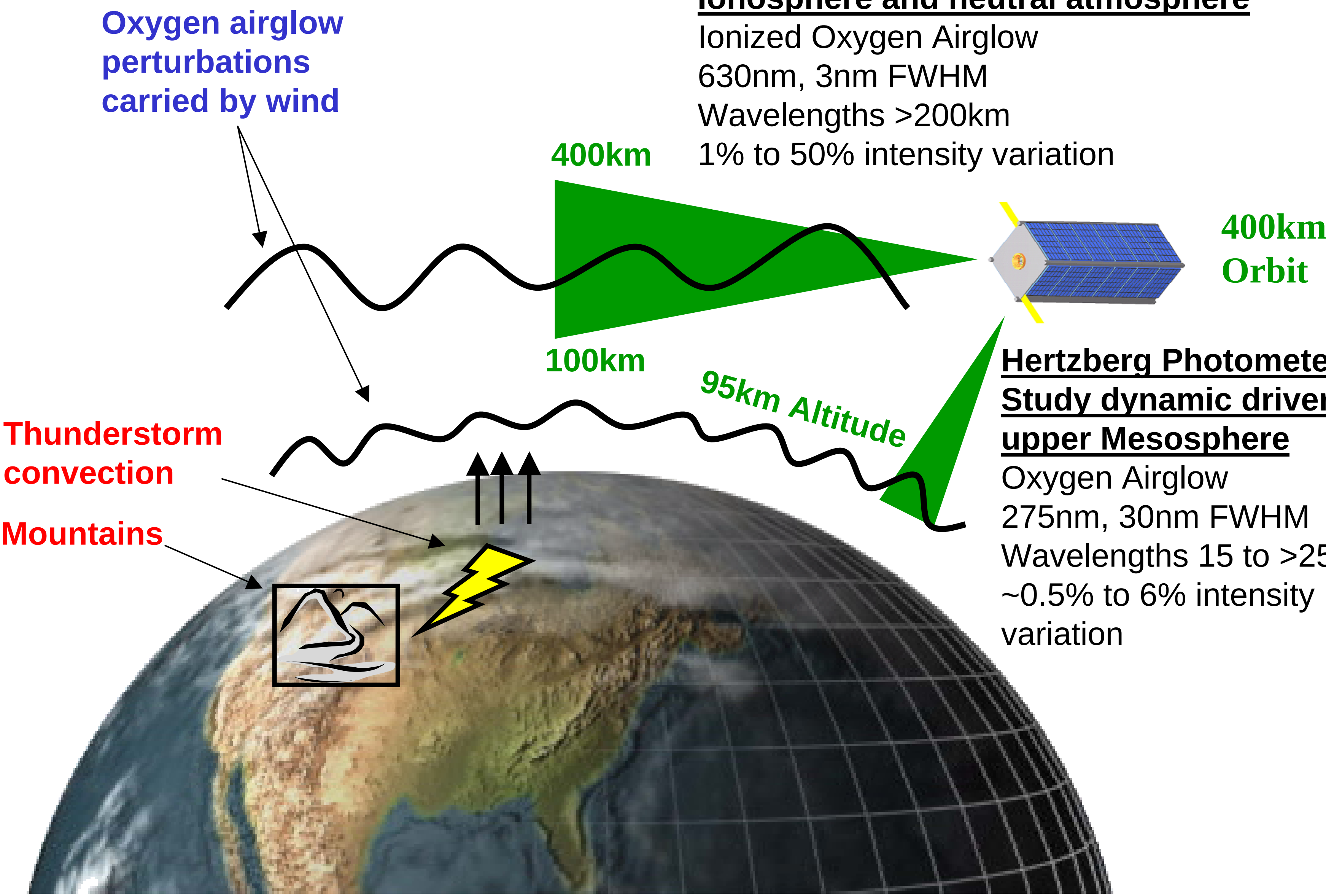
Technology

- Multiple complementary instrumentation in a small package.
- Modular mechanical and electrical busses.
- Onboard CubeSat launch platform.
- Two-stage passive radiator.
- 900 MHz spread spectrum communication.
- 3-axis reaction-wheel attitude control.

Experiment 1 & 2 : Imager & Hertzberg Photometer

<u>Imager – Study dynamic effects in Ionosphere and neutral atmosphere</u>

Ionized Oxygen Airglow
630nm, 3nm FWHM
Wavelengths >200km
1% to 50% intensity variation



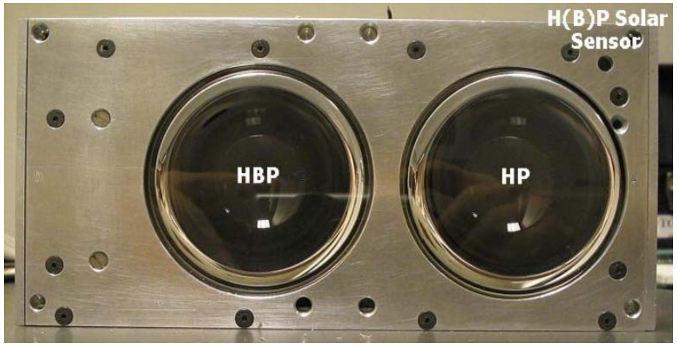
<u>Hertzberg Photometer – Study dynamic drivers of upper Mesosphere</u>

Oxygen Airglow
275nm, 30nm FWHM
Wavelengths 15 to >2500km
~0.5% to 6% intensity variation

CCD Imager

- Purpose:

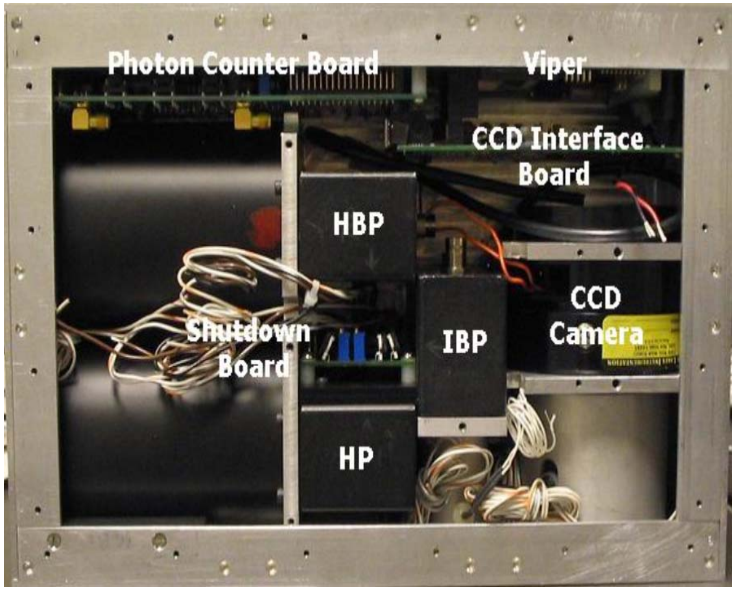
  Provide information for study of AGWs, TIDs, and lightning by sensing emissions in the 630 nm region.
- Modes of Operation
  - Main Mode: Keogram
  - Full Frame
- Hardware Specifications
  - S/N > 50 w/ 8 deg FOV
  - Camera: 512 pixel array
  - Resolution of 2 to 5 km
  - PMT: R7400U-20, Gain of $5x10^5$
  - Background Imager



Hertzberg Photometer

- Purpose:

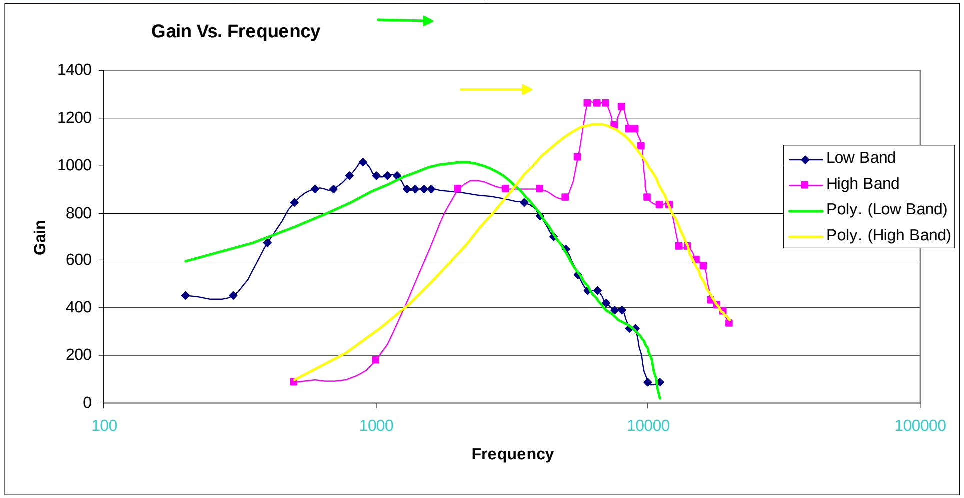
  Provide information for study of AGWs, TIDs, and lightning by measuring the intensity of the O_2 Hertzberg band.
- Hardware Specifications
  - 200 w/ 0.9 deg FOV
  - Photodiode protection circuit
  - Low voltage protection
  - Background photometer



Experiments 3, 4, & 5 : Plasma Probe, Electric Field Probe, & VLF Receiver

Electric Field Probe

- Measures local DC electric field
- Hardware/Operational Specifications
  - Probes extend in the vertical and horizontal directions.
  - AC modulations monitored



Langmuir Plasma Probe

- Measures local electron density.
- Hardware/Operational Specifications
  - Extends 20 cm from satellite body.
  - Conducting sphere w/ programmable voltages attracts oppositely charged particles.

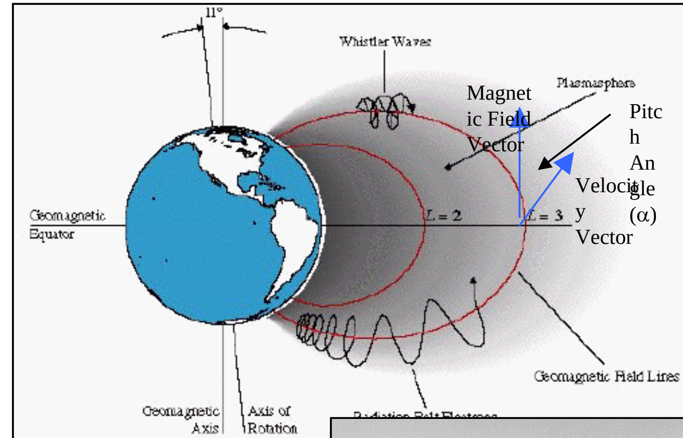
VLF Receiver

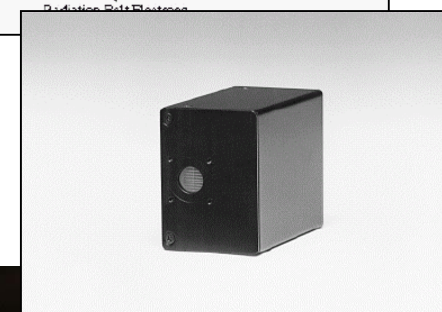
- Measure VLF radio energy
- Hardware/Operational Specifications
  - Connected to log electrometer and amplifier.
  - 500 Hz – 3 KHz and 8 KHz – 33 KHz frequency ranges are attained using two switch-capacitor band-pass filters.
  - Capacitor and bleed resistor used for data digitization.

Experiment 6 & 7 : Particle Spectrometer & Transient Photometer

Particle Spectrometer

- Measures quasitrapped electron and ion particle flux.
- Hardware/Operational Specifications
  - Primary and secondary radiators mounted on dark side of orbit to maintain –60 deg. C temperature.
  - 10 KeV to 1 MeV electron energy range.
  - 80 KeV to 2 MeV ion energy range.
  - Permanent magnets sweep out low mass particles.
  - 1000 channel digital pulse processor.





Transient Photometer

- Captures light emissions from lightning and aurora
- Hardware/Operational Specifications
  - Barr filter locks onto peak nitrogen band frequency.
  - Hamamatzu PMT w/ built in power supply.
  - Programmable gain and resolution.

Freewave Radios, Cubesat Launch Platform, & Passive 2-Stage Radiator

Freewave 900 MHz Spread Spectrum Radio

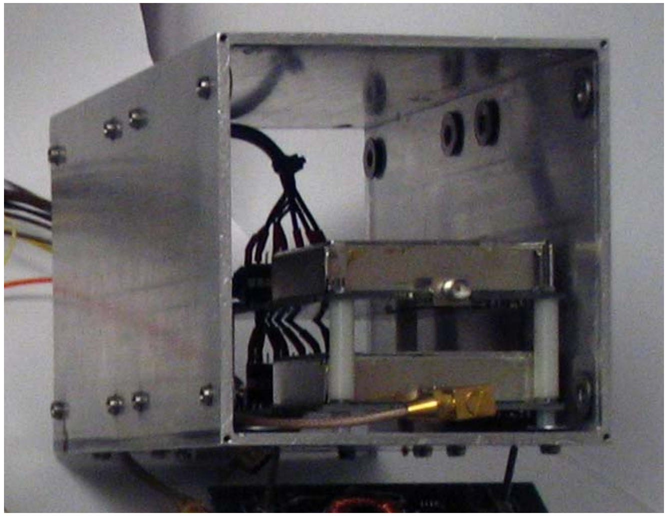
- High data rate transmission.
- Hardware/Operational Specifications
  - -106 dBm sensitivity.
  - 56 Kbps throughput with Doppler shift correction.
  - Grand master-slave operation allows for dual transmission and system redundancy.

CubeSat Launch Platfom

- Allows for secondary CubeSat payload and launch capabilities.

2-Stage Passive Radiator

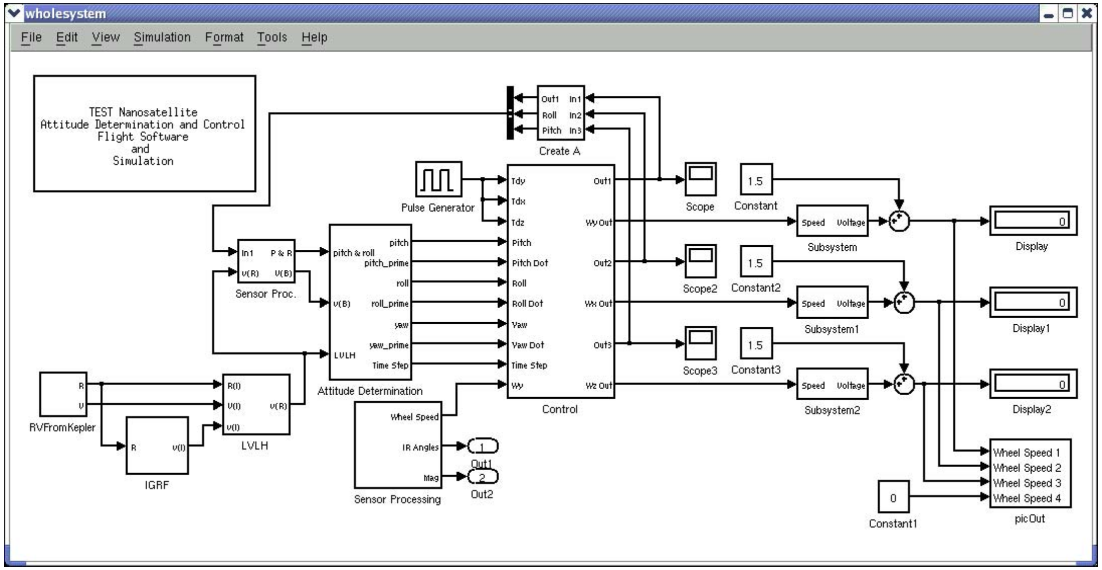
- Cools solid state particle detector to –60 deg C.
- Hardware/Operational Specifications
  - Isolated by stainless steel connectors, reflective tape, and thermal blankets.
  - Fiberglass standoffs isolate primary radiator from secondary radiator.

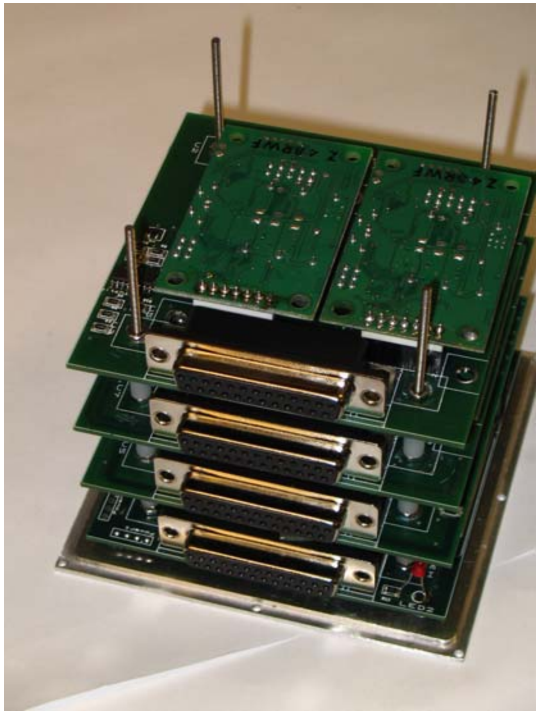


3-Axis Attitude Determination and Control

- Purpose

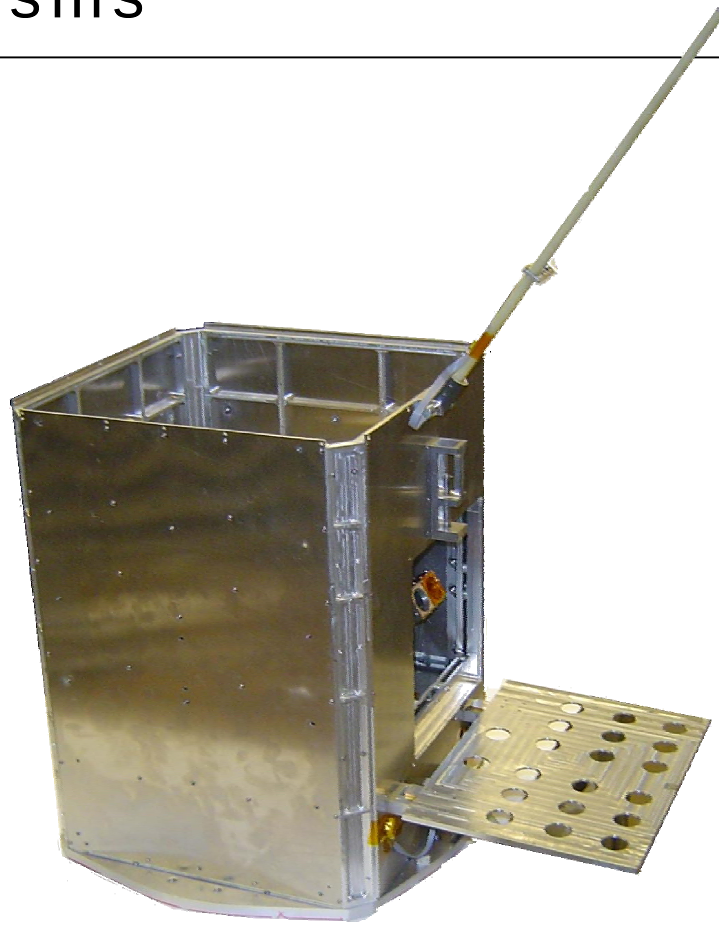
  Maintain three-axis stability for limb and nadir viewing.
- Hardware/Operational Specifications
  - Three-axis Honeywell magnetometer
  - Pitch and Roll horizon sensors.
  - Four-wheel 88 mNm reaction wheel assembly.
  - 6-torque coil configuration for momentum dumping.
- Algorithm and Flight Software
  - State-space controller design.
  - Automatic gain determination.
  - Flight and simulation software written with Simulink
  - Automatic code generation with Real-Time Workshop allows for platform independence.





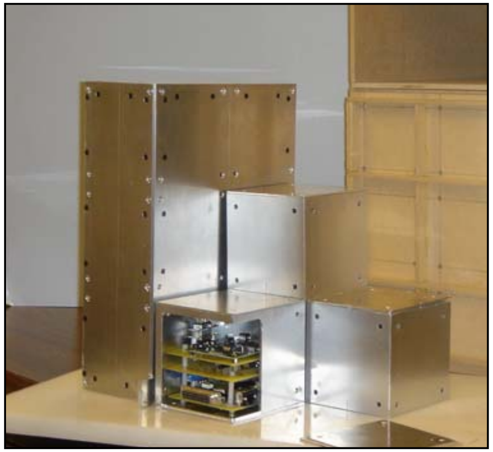
Structures and Mechanisms

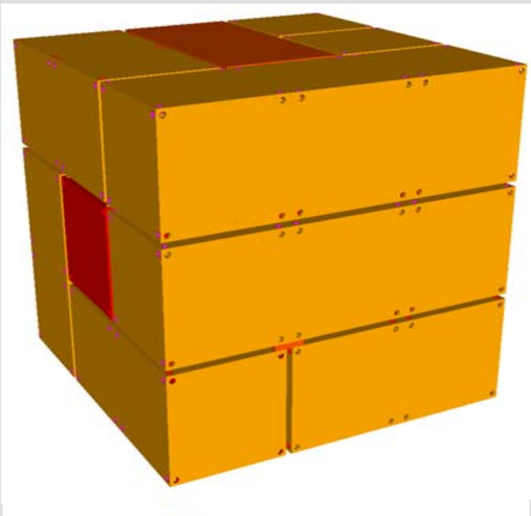
- Bus:
  - 32cm x 32cm x 47cm
  - Constructed of Al 6061
  - Fasteners: Stainless steel, Fiberglass
  - Satellite Weight < 30 Kg
- Structural Components
  - Exoskeleton: Four primary load bearing walls with interconnecting ribs
  - Bottom plate of Exoskeleton designed for Lightband® attachment with bolt back-out protection
  - Top Plate designed for addition of secondary Lightband® unit or a four unit CubeSat P-Pod Deployer
  - Shear plane added to structure to increase the satellite's fundamental frequencies
  - Interior cube matrix for stress relief and load translation



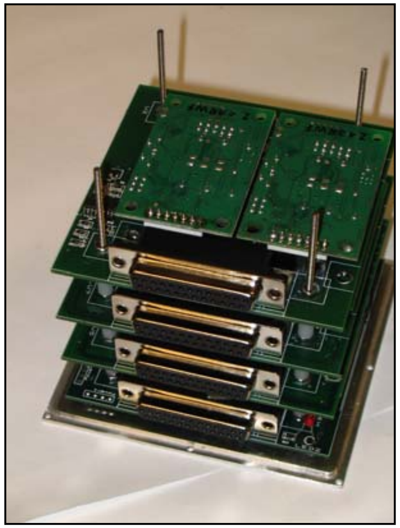
Structures and Mechanisms

- Modular Subsystem Design
  - Standard 4”x4”x4”
  - Internal connecting of subsystem boxes by stainless steel or Teflon bolts for thermal or electrical isolation of subsystems
  - Low-cost, able to be manufactured in-house. Cubes fabricated from 4”x4” extruded aluminum
  - Standardization for future satellite buses
- Standardized mounting and fasteners
  - All subsystem modules mount to external exoskeleton walls
  - Standard “Scoop-Proof” electrical connector interface: D-sub 9,15, or 25
  - PCB stack with internal D-subs



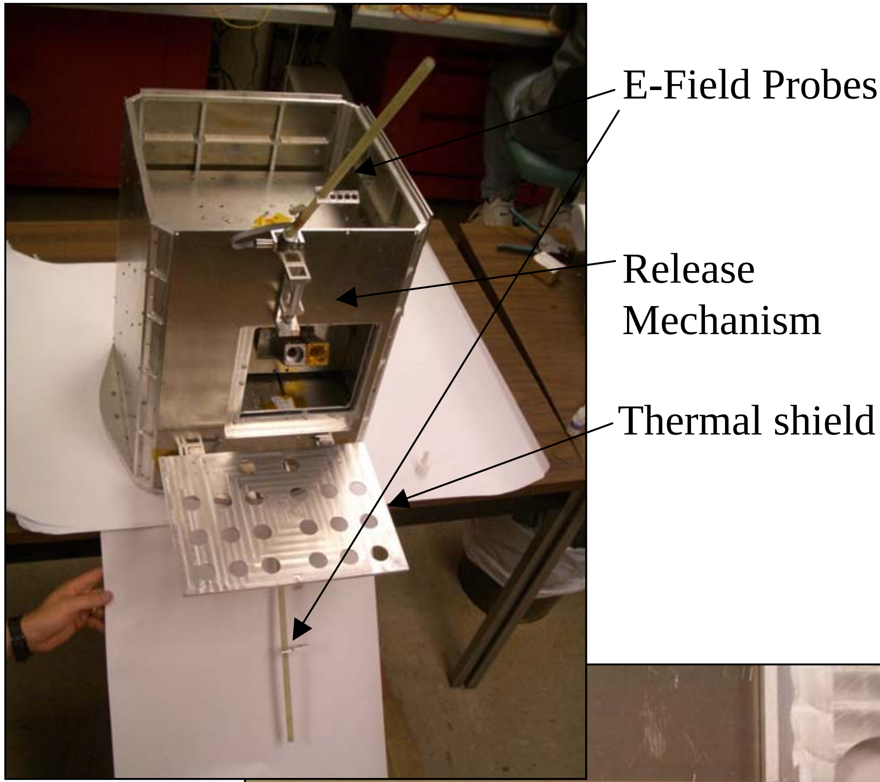


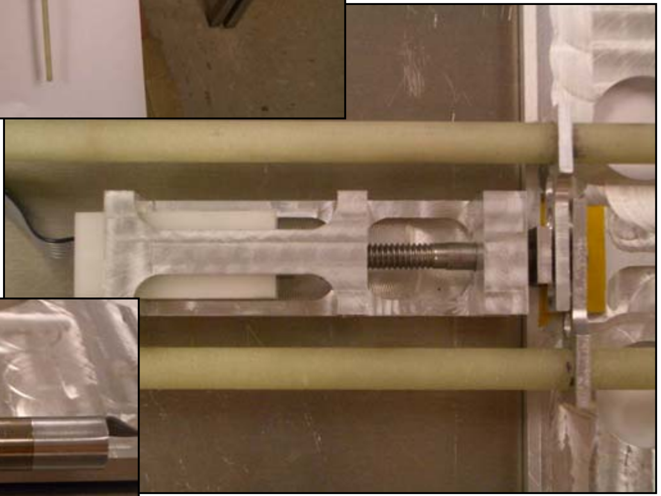
TEST’s Modular Subsystem

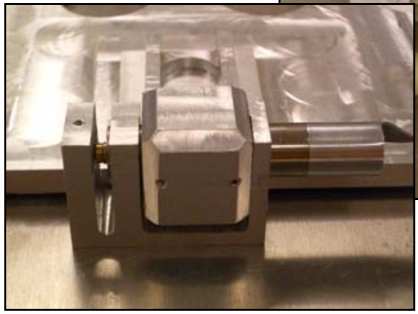


Structures and Mechanisms

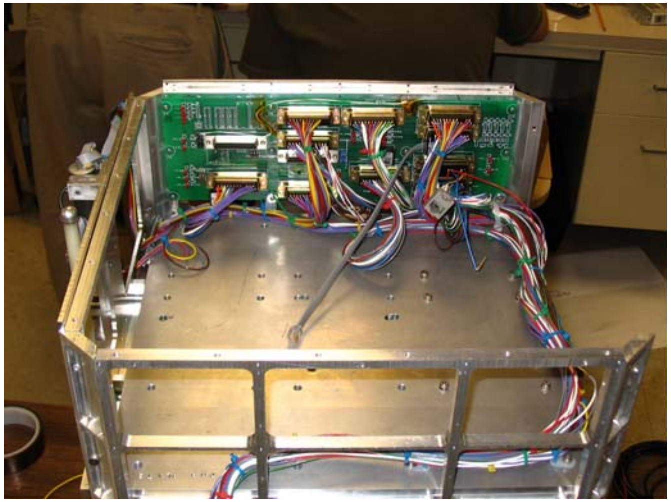
- Release Mechanism
  - Pin puller design utilizes MicroMotor DC motor with 1024:1 planetary gear head and encoder
  - Built in bearing for easy shaft rotation
- Electric Field / VHF Antenna Booms
  - Aluminum hinge with motor built into hinge assembly providing controlled deployment
  - Encoder provides precise location of deployment
  - Shaft Material: hollow Garolite meets probes electrical and mechanical requirements
  - Length per boom: 46 cm
  - Magnetometer boom: isolation of Honeywell Magnetometer
- 70cm/2m Antenna
  - Antenex ¼ wave whip antenna
  - Feed point below Reflector Shield for optimum earth propagation
- Thermal Shield
  - Aluminum wall structure
  - In house hinge assembly utilizing deployable motor assembly
  - Shields the earth’s albeto from the thermal radiator
  - Plasma probe boom: housing fastened to exterior of shield







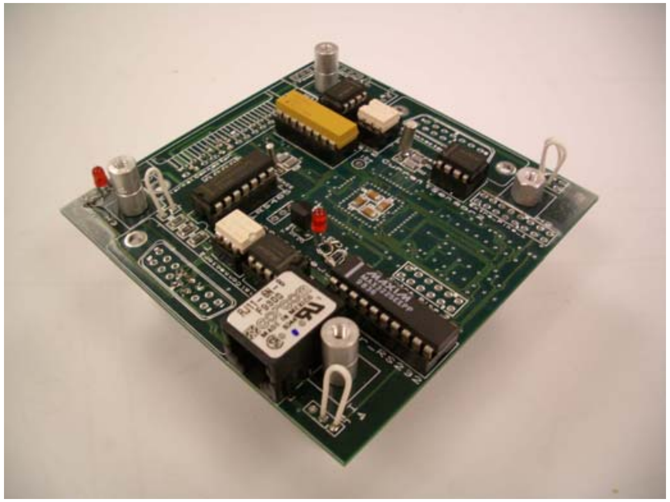
Wire Harness



- Motherboard
  - Central routing board minimizes external subsystem wiring
  - LED's placed onboard for subsystem diagnostics
  - Subsystem microcontroller programming connectors placed on board
  - Six diagnostics pins defined by subsystem teams for debugging after assembly
  - Provides interface for redundant beacon inputs
- Harness
  - Harness from subsystems directly to Motherboard
  - All cables utilize D-Sub connectors providing a high degree of reliability
  - Cables able to be made in-house

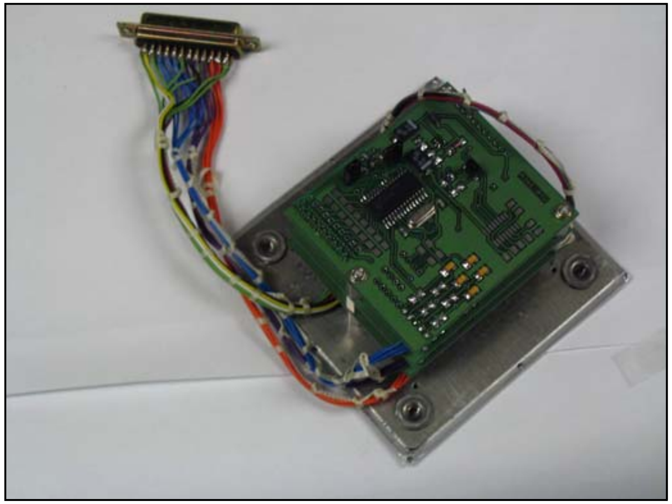
C&DH Architecture

- Purpose
  - Acquire and store data from the instruments and command each instrument
  - Standardized software and multiple applications
- Hardware
  - Two Arcom Vipers, Intel PXA255 400 MHz processor (Runs embedded Linux)
  - 512 Mbytes Compact Flash
  - Five MicroChip 18FXXX Microcontroller’s
- Interface Board
  - Customized interface board standardizes common subsystem functions
  - Acts as a smart A/D (Microcontroller)
  - Interface board has the capabilities of up to 8 Analog, 25 I/O, subsystem current monitoring and shut off, and up to 512 Kbytes of SRAM
- TEST supports multiple data busses
  - RS485 – Primary Data Transfer Bus
  - RS232 – Communication with COTS components
  - I^2C – Beacon/Back up Data bus
  - Dallas 1-Wire – Power system relay/ADC
  - Scadata 1-Wire – Beacon and Educational cube bus



Educational/Additional Cubes

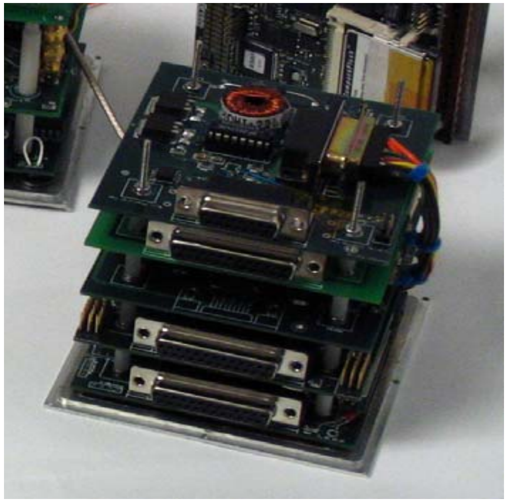
- Beacon Module
  - Collects data from multiple number of additional cubes
  - Provides a buffer from the primary (tested) C&DH
  - Connected to Beacon transceiver through RS232 for transmission to earth
- Educational/Additional Cubes
  - Common interface board able to be utilized or customized boards
  - Communicates with the Beacon Module through Scadata 1 wire bus
  - Can be "plug and play"
  - Confined cube allows for educational institution, or additional scientific instrument
  - Standardized connector/data format allows complete development externally with little communication

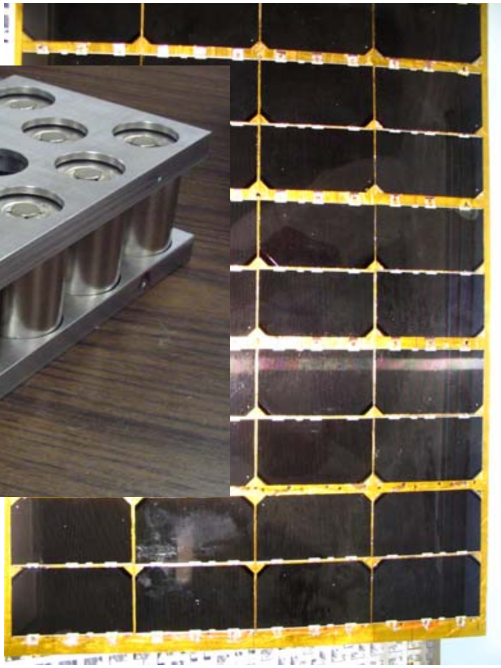


Power Subsystem

<u>Specifications</u>

- Minimal Single Point Failures:
  - Redundant battery packs
  - Resettable fuses to prevent latch-up
  - Redundant 5V regulators
- Provide –5V, 5V, 8V, 12V, and an unregulated power bus, capable of 3A each
- DC-DC Conversion Efficiencies > 80%
- Hardware Peak Power Tracker
- Industry proven Dsub connectors for all internal and External connections
- Centralized buck regulators reduces risk of noise injection into sensitive science instruments
- Star ground topology to prevent ground loops, along with an analog ground for sensitive instruments

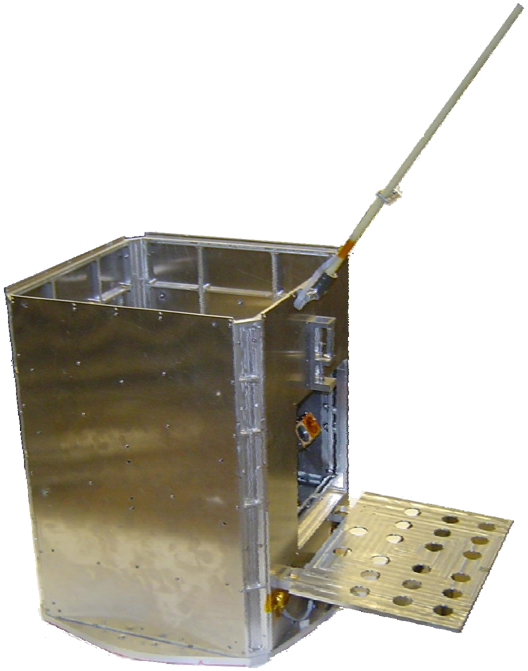




Summary of Modularity: Disruptive or Complimentary?

Mechanical Advantages	Boxes can be rotated due to standard structure & connectors Early definition of system 3-D symmetry gives strength and damping Cubes can be summed in x,y,z for larger size boxes Fixed attachment points for 3-D mounting Defined wiring channels between cubes
Modeling Advantages	Rapid prototype models of satellite Simple and well defined x,y,z mechanical model Simple and well defined x,y,z thermal model
Electrical Advantages	Common interface board defines common subsystem functions Greatly simplified wire harness (Motherboard)
Software Advantages	Software defined early with common interface board Protocols for commanding and data defined by the common interface board
Systems Integration Advantages	Common shake plate and thermal-vac attachments Rapid assembly and testing of electromechanical subsystems
Mass Production Advantages	All mechanical boxes and lids symmetrical and quantized Storage of qualified modules for rapid assembly

Questions?



Visit our booth on the second floor for more information