



Overview of NASA GSFC CubeSat Activities

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Goddard Space Flight Center

GSFC is the largest combined organization of scientists and engineers in the United States dedicated to increasing knowledge of the Earth, the Solar System, and the Universe via observations from space

Established in 1959 as NASA's first Space Flight Center

- ***End-to-End Science and Technology Missions capabilities***
- ***Integrated Science, Engineering, and Project Management***
- ***Nearly 300 Missions – from the world's first weather satellite (1960) to Hubble Space Telescope servicing and beyond***
- ***Communication and Navigation systems for NASA and National Programs***
- ***5500+ Scientists and Engineers***

Our Mission: We do Earth and Space Science Missions

- ***Conception, development, deployment, and operation of science and technology missions***
- ***Address fundamental questions in Earth and Space Science***
- ***Deliver data and information to the public in ways that they can use it***
- ***Identify and aggressively pursue technology advancements that enable science breakthroughs***

GSFC has built more in-house spacecraft than any other NASA center!

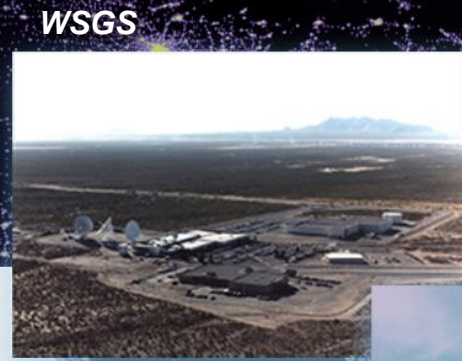


NASA Goddard Facilities

- *Goddard Space Flight Center, Maryland*
- *Wallops Flight Facility, Virginia*
- *IV&V Facility, West Virginia*
- *Goddard Institute for Space Studies, New York*
- *White Sands Ground Station, New Mexico*



GSFC



WSGS

WFF



GISS



IV&V

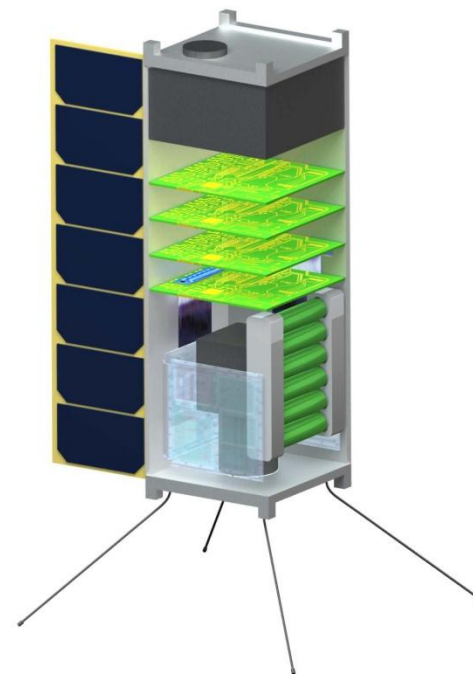




GSFC CubeSats/SmallSats

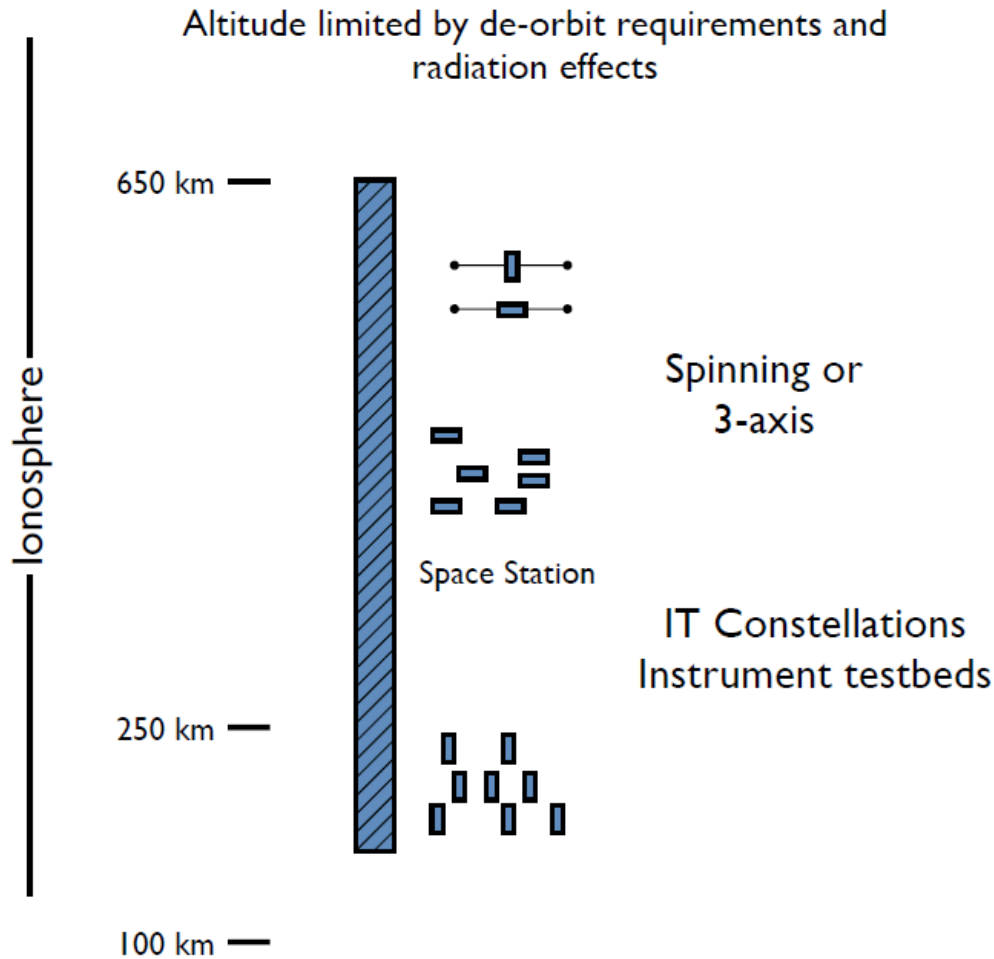
“To enable a new class of future Goddard missions by developing technology for small spacecraft architectures, mission concepts, component subsystem hardware, and deployment methods.”

- ***Two primary application areas***
 - ***Short-term demo/test (months)***
 - ***“Real” science missions (1 to 3+ years, orbits other than LEO)***
- ***Strong science rationale for using small spacecraft platforms & constellations***
- ***The way to “get things done” with current and near-term future budgets flat or decreasing***
- ***Partnerships with universities, industry and other government agencies are critical***
- ***Scalable components for 3U, 6U, 12U, SmallSat***



The heliophysics smallsat spectrum

— 3/6U Cubesats —



Mass [kg]	4
Payload Mass	2
Total Power [W]	6-30
Payload Power	2-28
# Launch Ops/yr	50
Stabilization	3-Axis or Spinning
Instrumentation	Ionospheric particles & fields; Small imagers



Science Applications

Heliophysics / Astrophysics

- *Simultaneous distributed measurements using constellations*
- *“System science” observatories*

Earth Science Decadal Survey Missions

- *HyspIRI, ACE, ASCENDS, GEO-CAPE, LIST, 3D WINDS, etc*

Planetary

- *Lunar, Asteroid, Mars*

Exploration

- *Subsystem technology, vehicle inspection, orbital debris clean-up*



Design Reference Missions

Heliophysics DRM #1

- *Distributed in-situ measurements, 1U-6U platforms*

Heliophysics DRM #2

- *Sensor clouds, 'Sprite' platforms, picosats, femtosats 10 to 1 improvement in spatial resolution*

Earth Science DRM #1

- *LEO remote sensing missions, multispectral imagery, atmospheric sounding, RF reflectometry, 3D cloud structure*

Planetary Science DRM #1

- *Lunar and Mars missions; Remote sensing of planetary surfaces, comm relay constellations*

Planetary Science DRM #2

- *Outer Planet missions, NEO missions and planetary landers, astrobiology*

Astrophysics DRM #1

- *Distributed aperture telescopes, occulters*



GSFC CubeSat Program

Current Activities

- ***Flight Projects: NSF, Air Force, LCAS***
- ***Technology Projects: IRAD, SBIR, STTR***
- ***Proposal Activity: OCT, HOPE, ESTO, SEED, EPSCoR, NSF, SMD/Explorer***
- ***Collaborations: Universities, Other NASA Centers, OGA's, Industry, Consortia, ESA, Korea***
 - ***UNLV, Auburn, U of Alabama, Cal Poly, Utah State, U of Florida***
 - ***JPL, AFRL, NRL, Maryland Aerospace Inc. (MAI)***

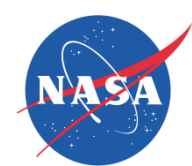
Current Development Efforts and Applications

- ***Science missions using commercially available small spacecraft***
- ***Technology validation for larger spacecraft platforms***
- ***In-house instrument design for CubeSats/SmallSats***
- ***In-house high-reliability spacecraft bus and deployer development***
- ***Subsystem technology development for small spacecraft***
- ***Integration, launch, ground support, and mission operations***
- ***Lower cost, scalable engineering processes***



Key Technology Activities

- ***Technologies applicable to spinning platforms***
- ***Communications: Low power, multiple access, distributed control***
- ***Deployers: Picosat deployer designs for multiple potential designs (chipsats, sprites, cubesprites)***
- ***Propulsion: High delta-V capable propulsion systems (> 3 km/s)***
- ***Power: Deployable solar arrays, extended battery life, improved efficiency solar cells, alternative generation/storage***
- ***Thermal Design: Design for long unpowered transit as secondary payload, and challenging lunar orbit thermal environment***
- ***Propulsion: 6DOF micropropulsion with thrust resolution ~ 0.1mN, total delta-V ~ 1Km/s***
- ***Precision 3-axis pointing capability (< arcmin), relative navigation sensors (RF and optical)***
- ***Virtual telescope formation flying***
- ***Structure fabrication using 3D printing technology***
- ***SpaceCube Mini On-Board Science Data Processor***
- ***Micro Core Flight Executive (MicroCFE) flight software***



GSFC TechCube Goals

Problem:

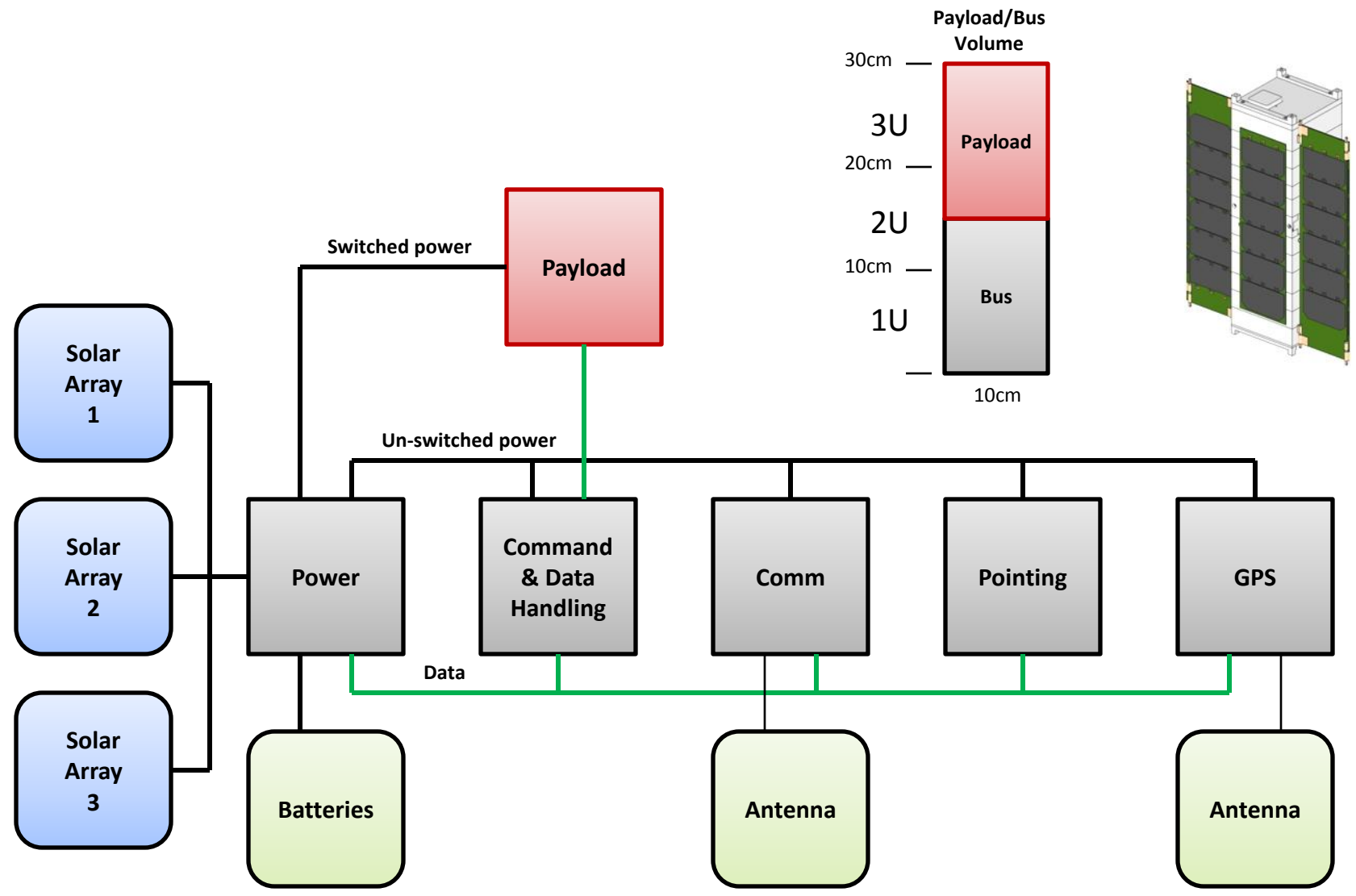
- *Typical CubeSats have very limited resources/capabilities and historically have a 50/50 chance of working*
- *Mission duration is typically months*
- ** NASA needs higher performance, higher reliability, longer duration CubeSat/SmallSat bus systems to enable future low-cost missions**

TechCube:

- *Subsystems developed using same design “techniques” as full-size NASA missions*
- *Full-feature, high performance avionics suite (25+W power, 1M+bps comm, <1° pointing, GPS), 3+ year mission life*
- *Collaborating with other government agencies, universities and industry (DoD also very interested in high-rel CubeSats)*



3U "TechCube" Concept





Wallops UHF CubeSat Groundstation

- **Specifications**
 - **Built 1959 by MIT Lincoln Labs**
 - **Valued at \$20M**
 - **Beamwidth: 2.9 degrees**
 - **Frequency Range: 380 to 480 MHz**
 - **Frequency Band: UHF-Band**
 - **Secondary Frequency Band: X-Band available for future high data rate CubeSat communication**
 - **Antenna Main Beam Gain: 35 dBi**
 - **Diameter: 18.3 meters (60')**
- **UHF Radar as a CubeSat Groundstation**
 - **Cutting-Edge CubeSat communication over a government-licensed UHF frequency allocation that enables high data rates (1.5 Mbit/Sec)**
 - **Currently communicating with DICE spacecraft**
 - **Slated for use for Firefly, CeREs, MicroMAS, and many proposed CubeSats**
- **Recent Updates**
 - **NSF and GSFC funding a new antenna control unit**
 - **NSF funding a backup UHF capability at Morehead University using their 21 meter X, S-band dish**



Morehead State University 21 Meter antenna



Wallops UHF on left, S-Band on right



Wallops 6U Deployer Advantages

- **Flight Qualified**
- **Unique lateral and axial CubeSat constraint system provides most predictable loading environment for CubeSat**
 - **Systems relying on friction may allow slip of the CubeSat under high G accelerations**
- **Developed for higher reliability requirements**
- **Conservative design that has potential to allow more payload mass than 12 kg**
- **Interior volume is 19% greater than two 3U CubeSats**
- **6U CubeSat structure available**
- **Flexibility for volume and mass versus 3U**
 - **More orbit options**
- **Starting technology transfer to LASP**



Wallops 6U Deployer with mass simulator



Wallops 6U Deployer during vibration test



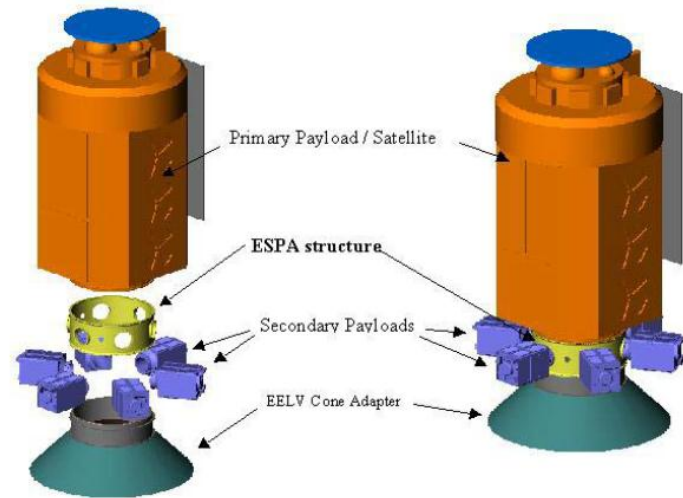
Small Satellite Multiple Ejector System

Description and Objectives:

- Develop a preliminary design for a reliable carrier and multiple ejection system that accommodates the WFF 6U as well as other 1U to 3U size spacecraft and interfaces to the ESPA ring

Key challenge(s)/Innovation:

- Design looks to advance current technology by working to improve satellite constraint reliability and overall system structural efficiency, while providing a platform for 6U multiple satellite opportunities



Approach:

- Design requirements will be derived through experience with the Wallops 6U, referencing ESPA documentation, and other research. Concepts will be generated and evaluated until a single concept is chosen. This concept will proceed through design iteration and preliminary analysis cycle.

Application / Mission:

- Missions that desire to use multiple 1U to 6U satellites to either work together or autonomously collect data

Milestones and Schedule:

- Concept development – 11/1/12
- Design presentation package – 10/1/13

Space Technology Roadmap Mapping:

- Primary Technical Area: TA12
- Secondary Technical Area: NA
- Additional Technical Area(s): NA
- Applicable Space Technology Grand Challenge: Economical Space Access

Technology Readiness Level:

- Starting TRL: 1
- Anticipated Ending TRL: 2

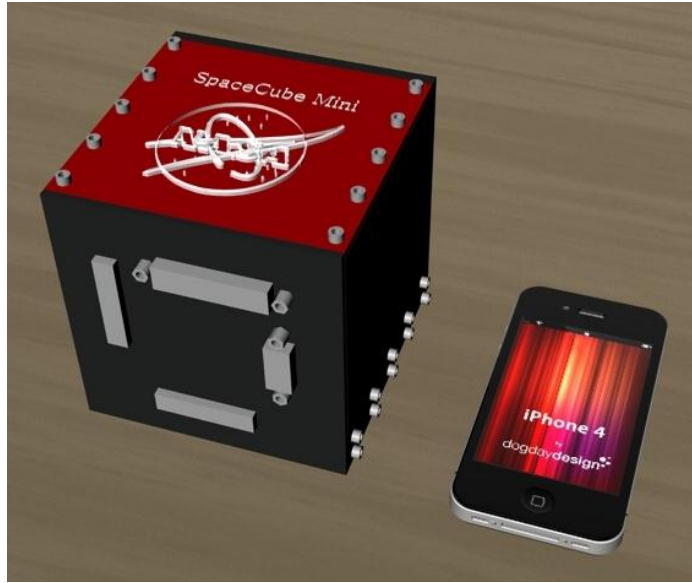


SpaceCube "Mini"



SpaceCube is a cross-cutting, in-flight reconfigurable Xilinx FPGA based on-board hybrid science data processing system that provides 10x to 100x improvements in on-board computing power.

- VIRTEX-5 FX130T**
- FPGA**
- 512MB RAM**
- 12GB FLASH**
- 16 Channel A/D**
- (4) LVDS/Spacewire**
- (8) RS-422**
- (4) MGT**
- Gigabit Ethernet**
- SATA**
- (70) GPIO**
- Special Cmd Reset**
- JTAG**





Firefly: An NSF CubeSat (launch in 2013)



- The National Science Foundation provides the funding, contracts for the launch vehicle, and provides overall management and oversight.

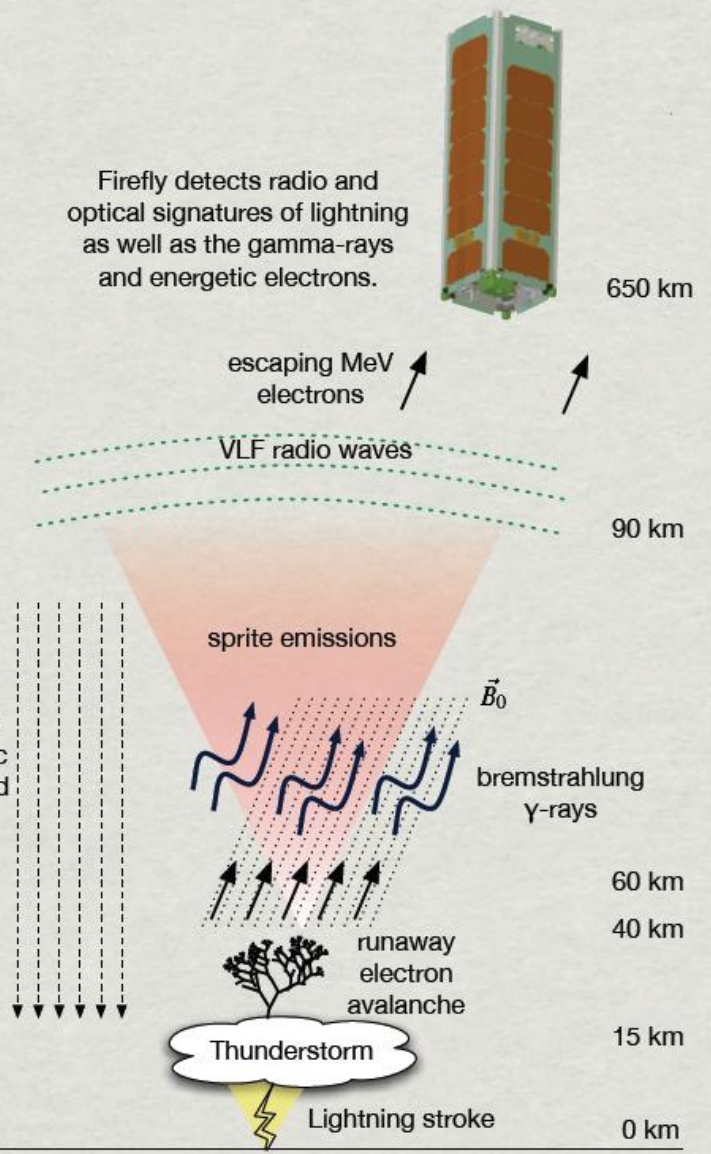


- NASA Goddard leads the project and provides the Gamma-Ray Detector instrument. NASA Wallops provides technical oversight and a UHF ground station.



- Siena college will provide systems engineering, the VLF receiver / photometer experiment, the experiment controller FPGA system, and E/PO support. Siena students will be involved with every aspect of the mission.

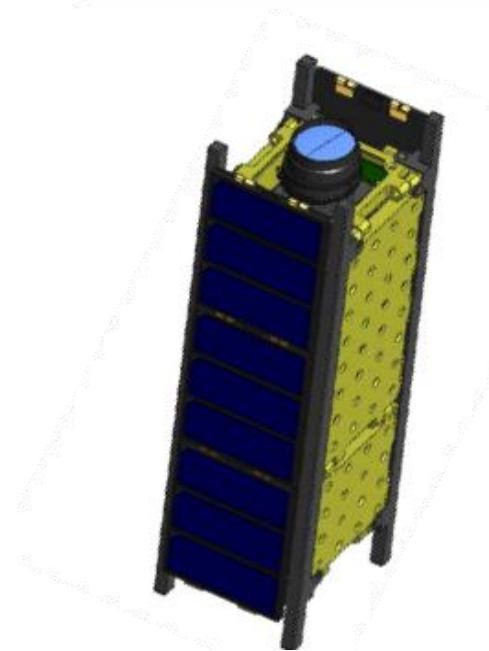
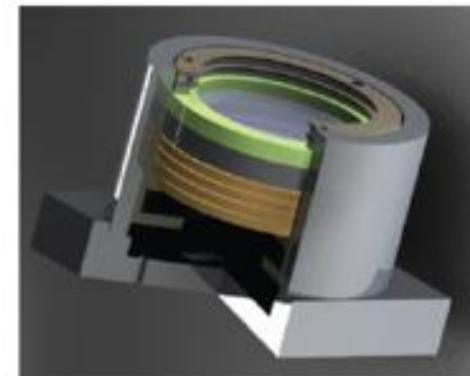
- The Hawk Institute for Space Sciences helped design the spacecraft bus and flight software.





CeREs: A Compact Radiation bElt Explorer

- *Mission Implementation* *3U CubeSat in high inclination LEO*
 2 years to launch; 1 year of data taking
- *Science Primary* *Radiation belt energization and loss electron spectra, and microbursts*
 Secondary: Solar electron spectra from > 5 keV
- *Sensor* **MERiT, Miniaturized Electron and pRoton Telescope**
 Concept: SSD stack behind a Silicon APD
- *GSFC PI* *Shri Kanekal, Code 672*
- *PI institute role* *SSD stack, Processor, Science, S/C bus, Instrument calibration, Integration*
- *Col Institute role* *SwRI*
 APD, mission SOC, Science
- *Total Funding* *~ \$1.5M*

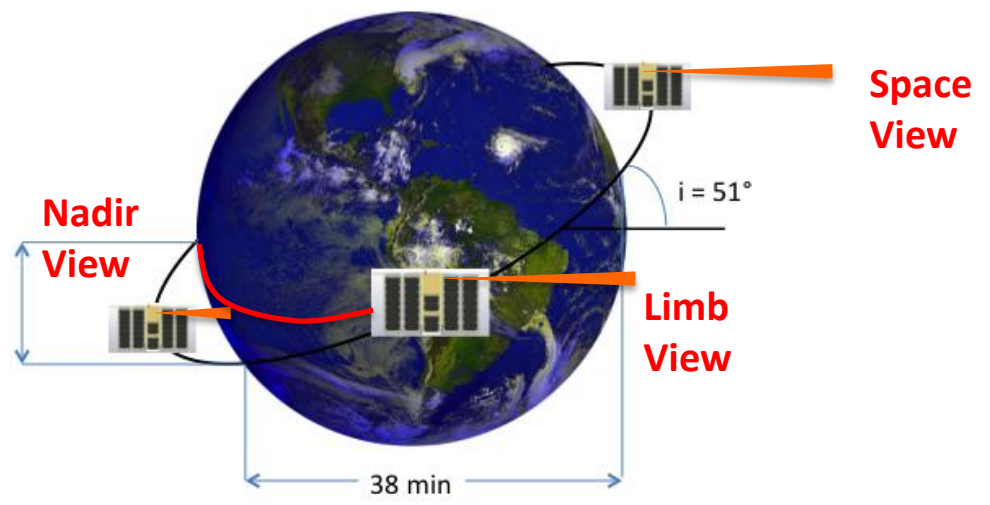
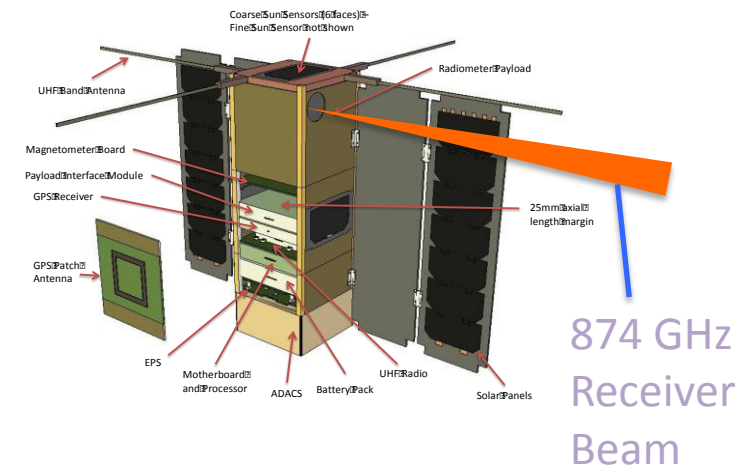




IceCube: Submm-Wave Remote Sensing from CubeSat

PI: Dong Wu, NASA Goddard Space Flight Center

- *A proposed project to NASA InVEST program*
- *Develop a flight-qualified 874-GHz receiver for future cloud remote sensing*
- *Validate 874-GHz radiometer hardware, operation and calibration performance in space on a 3U CubeSat*
- *Launch 3U COTS-component CubeSat to LEO orbit with >350-km altitude*
- *Observations of Earth atmosphere and space for 28+ days, and data return for NEDT, calibration error, and response to clouds*

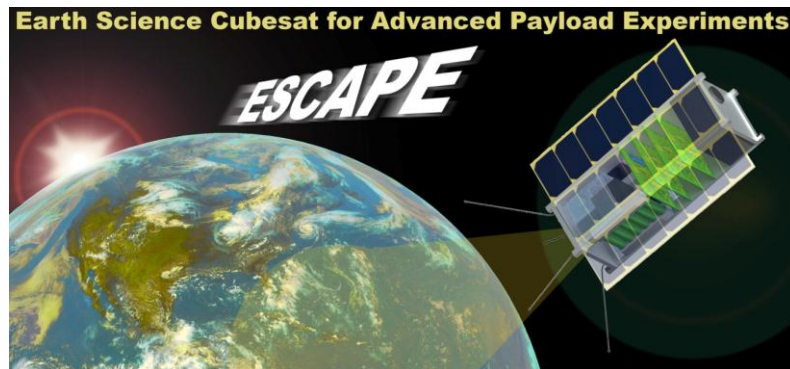
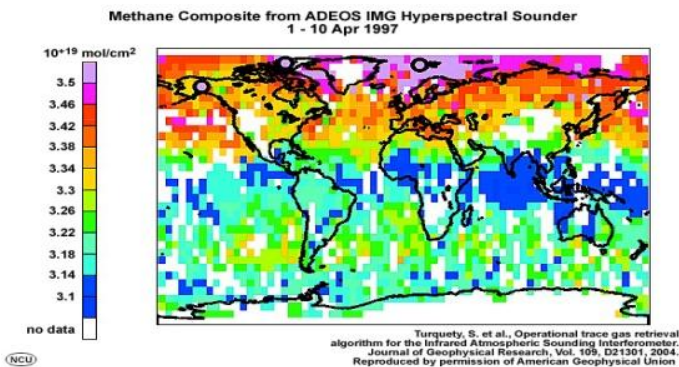




Earth Science CubeSat for Advanced Payload Experiments (ESCAPE)

Key Objective: Demonstrate new Fabry-Perot sensor technology with real-time on-board processing/information extraction, using state-of-the-art commercial processing technology coupled with radiation upset mitigation software (SpaceCube Mini)

- ***New Fabry-Perot radiometer technology that will enable small, light weight, rugged, and relatively inexpensive, yet exquisitely sensitive sensors for monitoring trace gasses***
- ***Enhanced on-board processing to demonstrate real-time spectra extraction, yielding data volume reductions of 300x to 900x***
- ***Results can be leveraged by the Earth Science Decadal Survey era missions***

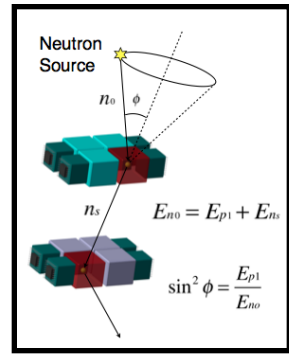
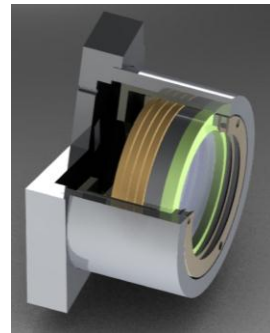




MaRBLES (Measuring Radiation Belt Low Earth Sources/Sinks)

PI: EJ Summerlin, NASA Goddard Space Flight Center

- **Training:** Provide hands-on experience for all aspects of a small mission
- **Science:** Characterize sources and sinks of energetic particles in the radiation belts from a near polar low earth orbit focusing on microbursts measurements at high latitudes to supplement Van Allen Probe measurements at low latitudes and the CRAND source for the inner radiation belts
- **Technology:** Provide flight heritage for instruments and instrument components
- **LOB:** Develop in-house expertise in CubeSats and increase instrument TRL to improve selectability for future proposals



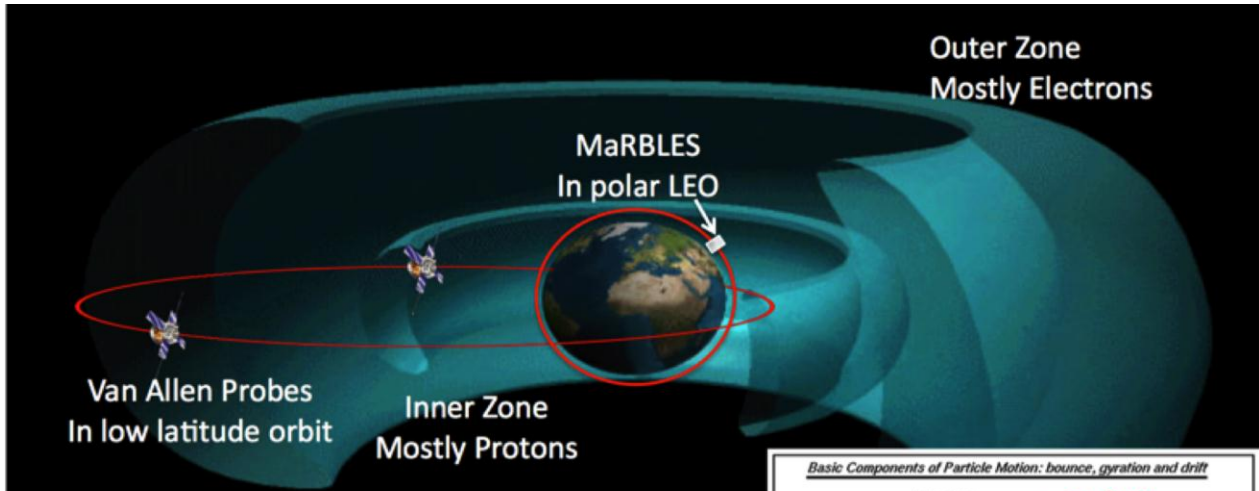
Instrument Concepts

CREPT

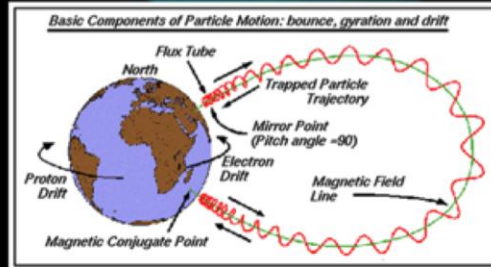
- 1U Solid-State Telescope
- Components: TRL 6+
- Instrument: TRL 5

SNuG

- 1U Scintillator-based Spectrometer for Neutrons and Gamma-Rays
- Components TRL 6+
- Instrument TRL 4



MaRBLES will provide multi-point measurements of outer radiation belt electron loss (augmenting the science return of the Van Allen Probes) and measure the CRAND sources for the inner radiation belts.





Conclusion

- ***GSFC has a vast array of science/mission applications ... spanning all science disciplines***
- ***GSFC has wide ranging technology development interests ... spanning all engineering disciplines***
- ***GSFC has full end-to-end CubeSat/SmallSat capabilities ... PI/Co-I, flight/ground/systems engineering, software, project management***
- ***GSFC is very interested in collaborating with universities, other government agencies and industry in all areas ... working together = mission success for the entire community!***



Questions ?

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Acronyms

APD – Avalanche Photo Diode
ASCENDS – Active Sensing of CO₂ Emissions over Nights, Days, and Seasons
CeREs – Compact Radiation bElt Explorer
COTS – Commercial Off-The-Shelf
CRAND – Cosmic-Ray Albedo-Neutron Decay
CREPT – Compact Relativistic Electron Proton Telescope
DICE – Dynamic Ionosphere CubeSat Experiment
DoD – Department of Defense
DRM – Design Reference Mission or Drafting Room Manual
E/PO – Education/Public Outreach
EPSCoR – Experimental Program to Stimulate Competitive Research
ESA – European Space Agency
ESCAPE – Earth Science CubeSat for Advanced Payload Experiments
ESPA – EELV (Evolved Expendable Launch Vehicle) Secondary Payload Adaptor
ESTO – Earth Science Technology Office
FPGA – Field Programmable Gate Array
GEO-CAPE – Geostationary Coastal and Air Pollution Events mission
GISS – Goddard Institute for Space Studies
GPIO – General Purpose Input/Output
GSFC – Goddard Space Flight Center
HOPE – Hands-On Project Experience
HypIRI – Hyper-spectral Infrared Imager mission
InVEST – In-Space Validation of Earth Science Technologies
IRAD – Independent Research and Development
IV&V – Independent Verification and Validation
JPL – Jet Propulsion Laboratory
JTAG – Joint Test Action Group
LASP – Laboratory for Atmospheric and Space Physics
LCAS – Low-Cost Access to Space
LEO – Low Earth Orbit
LIST – Lidar Surface Topography

LOB – Line Of Business
LVDS – Low-Voltage Differential Signaling
MAI – Maryland Aerospace, Inc.
MaRBLES – Measuring Radiation Belt Low Earth Sources/Sinks
MERit – Miniaturized Electron and Proton Telescope
MGT – Multi-Gigabit Transceiver
MicroCFE – Micro Core Flight Executive
MicroMAS – Micro-sized Microwave Atmospheric Satellite
NASA – National Aeronautic and Space Administration
NEDT – Noise Equivalent Delta Temperature
NEO – Near Earth Objects
NRL – Naval Research Laboratory
NSF – National Science Foundation
OCT – Office of the Chief Technologist
OGA – Other Government Agencies
PI – Principal Investigator
RF – Radio Frequency
SATA – Serial AT Attachment
SBIR – Small Business Innovation Research
SEED – Systems Engineering Educational Discovery
SMD – Science Mission Directorate
SNuG – Spectrometer for NeUtrons and Gamma-Rays
SOC – Science Operations Center
SSD – Silicon Strip Detectors
STTR – Small Business Technology Transfer
SwRI – Southwest Research Institute
TRL – Technology Readiness Level
UHF – Ultra-High Frequency
VLf – Very Low Frequency
WFF – Wallops Flight Facility
WSGS – White Sands Ground Station