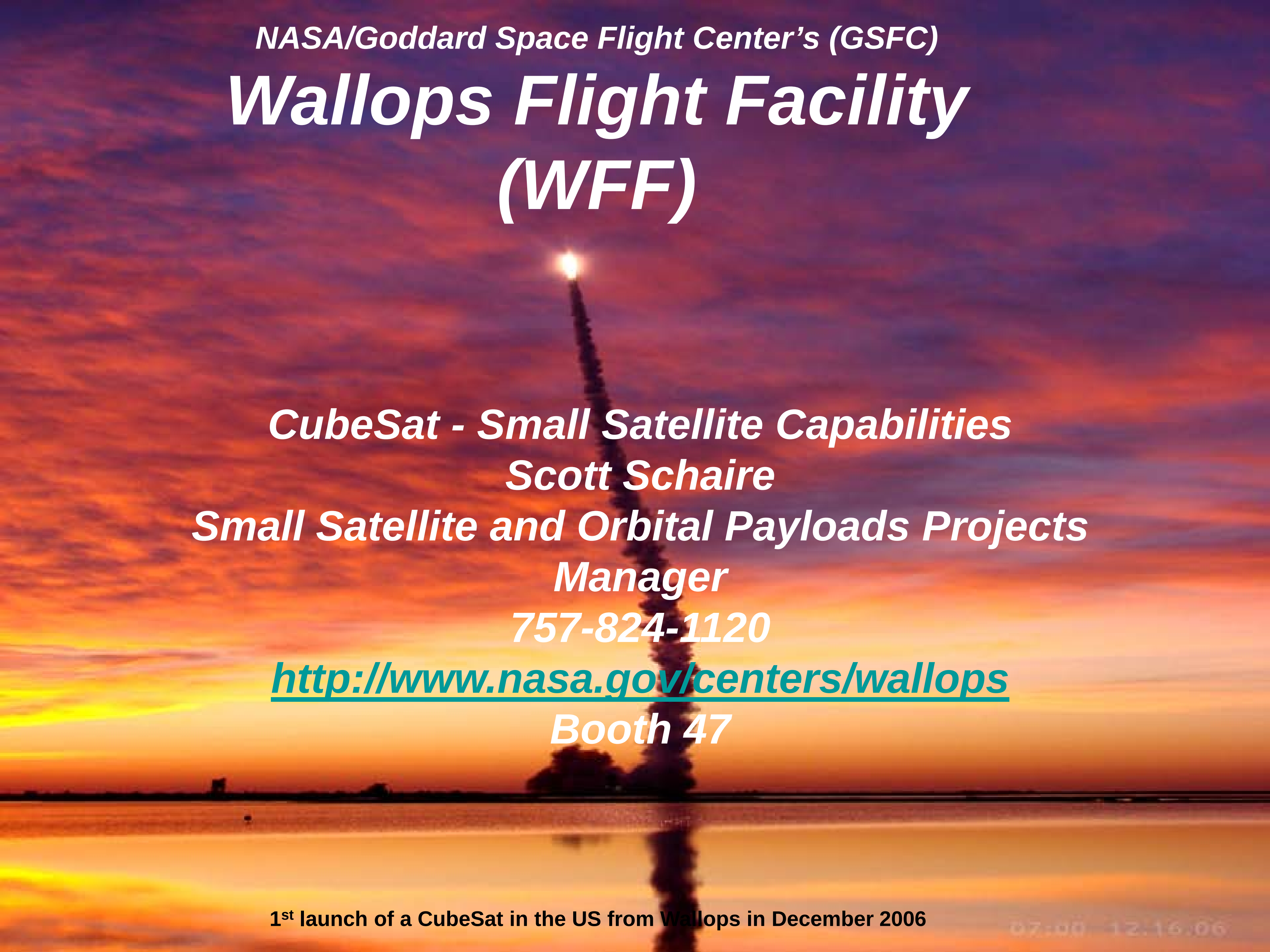
NASA/Goddard Space Flight Center's (GSFC)

Wallops Flight Facility (WFF)



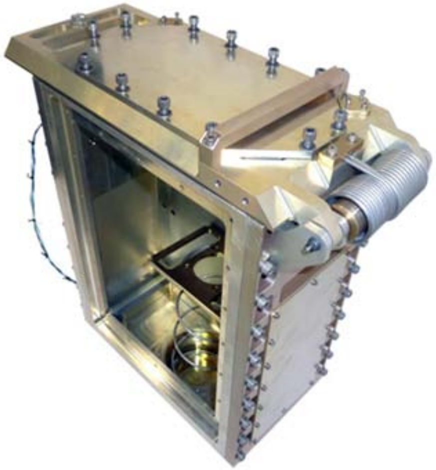
CubeSat - Small Satellite Capabilities

Scott Schaire
Small Satellite and Orbital Payloads Projects Manager
757-824-1120
http://www.nasa.gov/centers/wallops
Booth 47

1st launch of a CubeSat in the US from Wallops in December 2006

GSFC/Wallops CubeSat and Small Satellite Capabilities

- *Wallops history with CubeSats and small satellites*
- *6U CubeSat deployer*
- *UHF CubeSat Groundstation*
- *Mission Planning Lab (MPL) for suborbital, CubeSat and small satellite missions*
- *CubeSat and small satellite integration and test facilities*
- *CubeSat and small satellite S-Band antenna*
- *Generic Reusable Aerospace Software Platform (GRASP) software for small satellites and CubeSats*
- *GSFC Lunar CubeSat studies*
- *GSFC SpaceCube 2.0 Mini CubeSat Processor*
- *Other advanced CubeSat and small satellite subsystems capabilities in development*



Wallops 6U Deployer

Wallops UHF and S-Band CubeSat Groundstations

Wallops History with CubeSats and Small Satellites

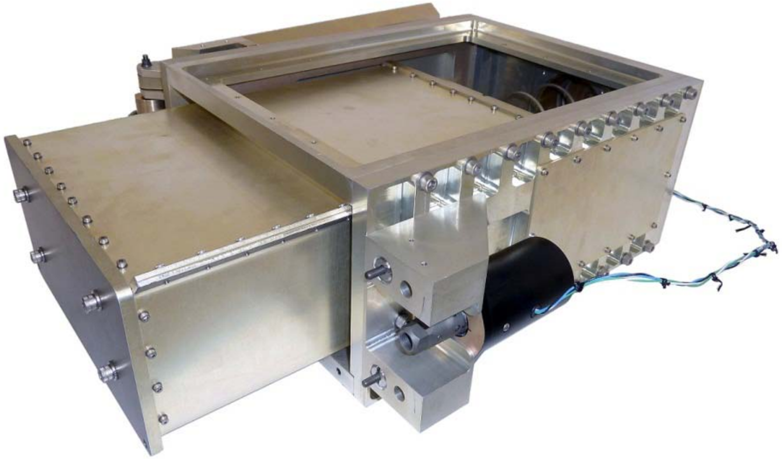
- *Manage and implement Low Cost Access to Space (LCAS) programs (Sounding Rockets, Balloons, Aircraft) for decades – supporting Principal Investigators (PI's)*
- *Managed Shuttle Small Payloads Office, including Get-Away Special (GAS) & Hitchhiker*
- *Managed small satellite missions (e.g. UNEX/CHIPS)*
- *Provide engineering support for GSFC managed satellite developments (e.g. Global Precipitation Measurement)*
- *Develop small satellite technology including the 6U CubeSat and deployer projects*
- *Manage an ISS external payload development*
- *Developed a Multi-Payload Ejector*
- *Manifested CubeSats on a Minotaur launch from Wallops (2009)*
- *Support the National Science Foundation (NSF) CubeSat Program – from inception - supporting investigators through the entire lifecycle of CubeSat missions*
- *Provide UHF Groundstation support for CubeSats*

Wallops Get-Away Special (GAS) Canisters

Wallops 6U CubeSat

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*

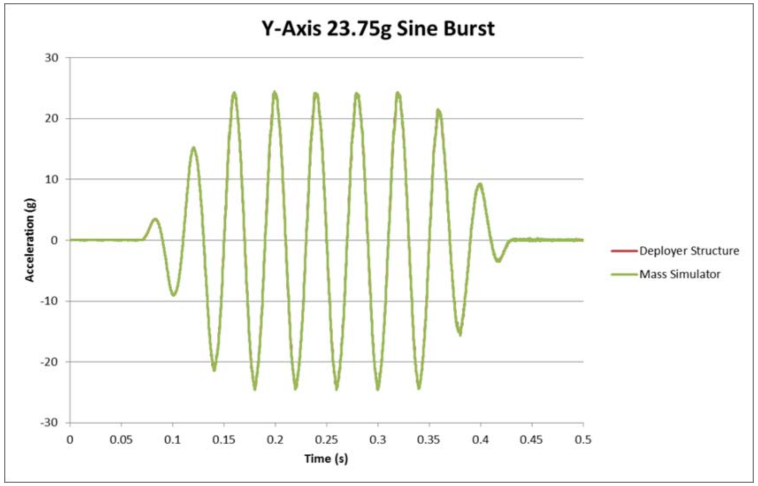


Wallops 6U Deployer with mass simulator

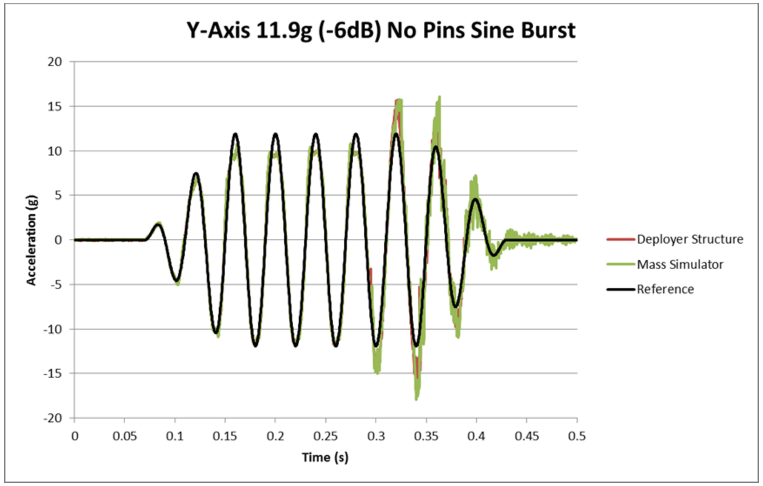
Wallops 6U Deployer during vibration test

Goddard Space Flight Center

Wallops 6U Deployer Advantage of Shear Pins

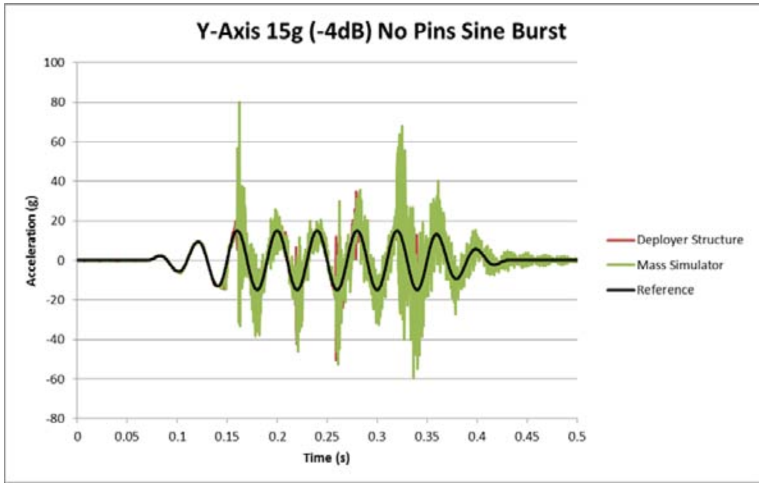


No issue with shear pins at ~24 g test



Began slipping at ~12 g without shear pins

- *Y-axis sine burst test was conducted on the deployer structure without the shear pins to evaluate the effectiveness of the pins in comparison to the friction generated by the axial preload*
- *Mass simulator first began to slip at 11.9 g and was definitely moving within in the deployer at 15 g when the test was stopped*
- *Results demonstrate the need for the pins at the 23.75 g qualification level and serve as an indication for their effectiveness in the constraint system*

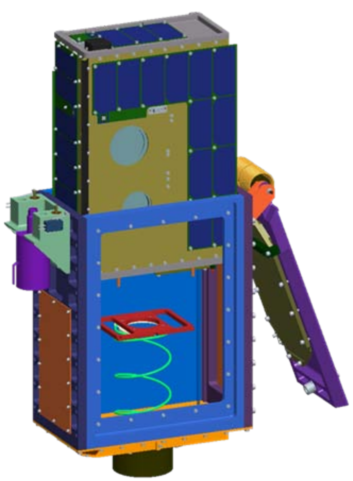


Movement within the deployer at ~15 g without shear pins

Wallops 6U CubeSat Deployer Specifications

ITEM			VALUE
Physical	Empty Mass [Kg]		10.0
	Max Payload Mass [Kg]		12.0
	Deployer Stowed, Outside Dimensions	Length [cm]	48.1
		Width [cm]	40.3
		Height [cm]	16.5
	Satellite Stowed	Length [cm]	38.6
		Width [cm]	25.6
		Height [cm]	12.7
	Life [reset cycles]		15
	Time to initiate [sec]		< 0.080
	Initiation voltage [V}		10 @ 4A
	Initiation current [A]		2.75 to 8.75
	Random Vibration Test [G rms]		14.1
	Sine Burst Test (g)		23.75
	Sine Sweep Test (g)		12.5 (20-100 Hz)
	Design Safety Factors		2.0 Yield / 2.6 Ultimate
	Preloaded Load path [-]		Y
	Non-friction 3 axis constraint [-]		Y
	Flight Heritage Release Mechanism [-]		Y
	Door Operation Range [deg]		0 - 270
	Exit Velocity [m/s]		1.25

Wallops 6U CubeSat Deployer



Wallops 6U Deployment

Wallops 6U CubeSat Deployer Qualification

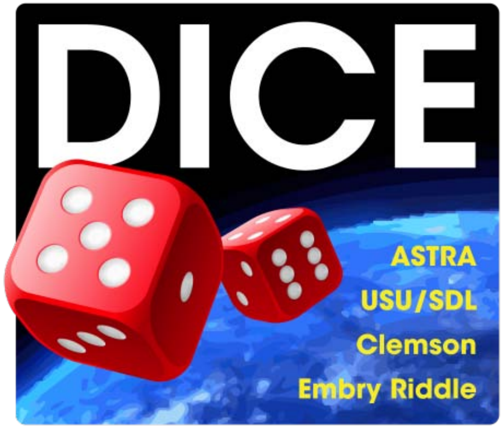
WFF Engineers conducted qualification testing of the 6U deployer to ensure functionality of the hardware under flight like conditions

- **G-negated deployment testing ensures reliable & predictable egress of the spacecraft from the deployer; representative conditions allow validation of engineering analysis models**
- **Vibration testing ensures design survivability of launch loads, with functionality verified pre- and post-testing**

Wallops UHF Groundstation

- *Achieving 1.5 Mbit/sec with each Dynamic Ionosphere CubeSat Experiment (DICE) 1.5U CubeSat over a government licensed frequency band*
  - ***DICE team worked with the National Science Foundation (NSF) on using government frequencies rather than amateur***
- *Beamwidth: 2.9°*
- *Frequency Range: ~380 MHz to ~480 MHz*
- *Antenna Main Beam Gain: 35 dBi*
- *Diameter: 18.29 meters*
- *Resolved local interference issues*
- *Slated for use for NSF/GSFC/Siena Firefly CubeSat (Launch August 2013), JPL/ARC CubeSat Hydrometric Atmospheric Radiometer Mission (CHARM) (Launch December 2013) and other pending CubeSats*

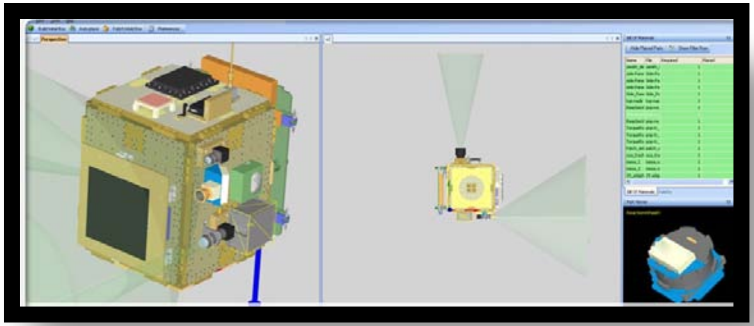
Wallops UHF and S-Band CubeSat Groundstations



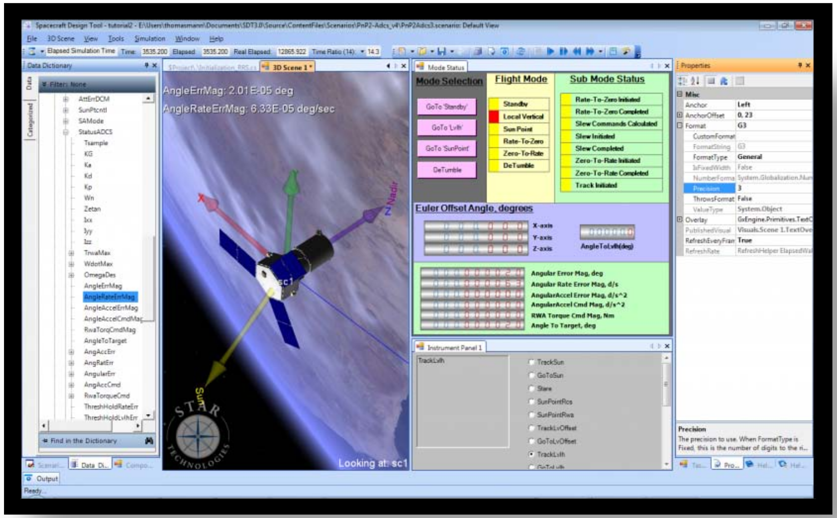
Dynamic Ionosphere CubeSat Experiment (DICE)

Wallops Mission Planning Lab (MPL) for Suborbital, CubeSat and Small Satellite Missions

- *Plan missions, write proposals, and perform visual analysis for launch support, small satellites, CubeSats, and suborbital missions*
- *Tools*
  - *Systems Tool Kit (STK) Professional*
    - *Communications, Coverage, Radar*
    - *Aircraft Mission Modeler (AMM)*
    - *Missile Modeling Tools (MDT, MFT)*
    - *Space Environment and Effects Tool (SEET)*
  - *Orbit Determination Toolkit (ODTK)*
  - *Spacecraft Design Tool (SDT) & Satellite Builder*
    - *Enables users to rapidly design a complete spacecraft, including sensors, actuators, and attitude determination and control systems*
  - *SAP Visual Enterprise Author*
  - *MATLAB, MS Visual Studio, Java*



Spacecraft Design Tool (SDT) and Satellite Builder



Spacecraft Design Tool (SDT) and Satellite Builder

Wallops CubeSat and Small Satellite Integration and Test Facilities

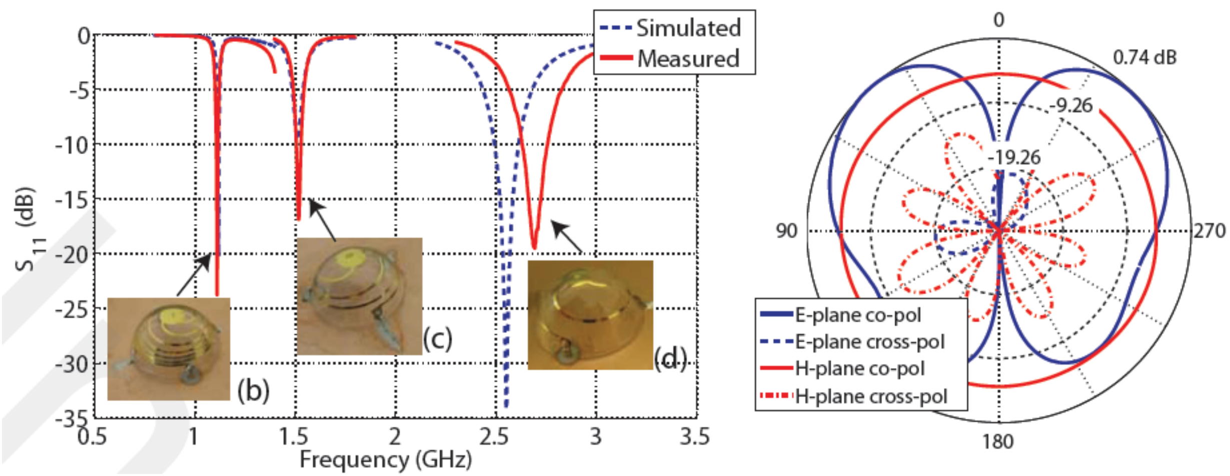
- *Mechanical/electrical fabrication*
- *Moments of Inertia (MOI) and Center of Gravity (CG) determination*
- *Thermal Vacuum Chamber (TVAC)*
- *Spin deployment testing*
- *Electromagnetic Interference (EMI), Electromagnetic Compatibility (EMC) and antenna pattern testing*
- *Payload integration and telemetry testing*
- *High bay integration and test and clean rooms*
- *Vibration testing*
- *Global Positioning Satellite (GPS) simulation lab*
- *Helmholtz cage for magnetic attitude determination and control testing*

Wallops Moments of Inertia (MOI) and Center of Gravity (CG) determination

Wallops CubeSat and small satellite Thermal Vacuum Chamber (TVAC)

Wallops CubeSat and Small Satellite S-Band Antenna Advantages

- *Collaborated with University of Michigan*
- *Considered alternatives to standard Omni-directional antennas*
- *Optimized CubeSat and Small satellite performance around typical limitations such as power, mass and physical size/shape*
  - *Practical shrinkage of 50-75 %*
  - *25-50 % less power consumption with no performance degradation*
- *Investigating X-band downlink to support higher data rates with advanced modulation and forward error correction (FEC) coding*



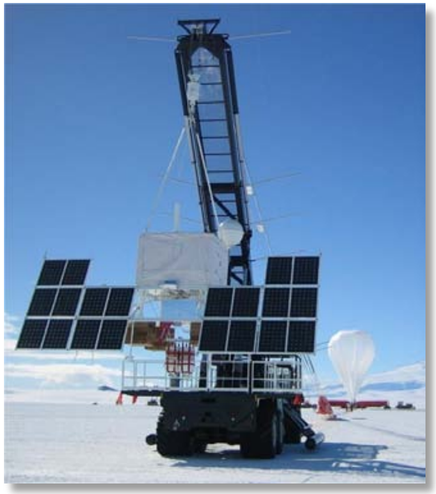
Simulated and measured results of advanced S-Band antennas [1]

[1] C. Pfeiffer, A. Grbic, X. Xu, and S. R. Forrest, “New methods to analyze and fabricate electrically small antennas,” in *Proc. IEEE Antennas Propag. Int. Symp., 2011, pp. 761–764*

Wallops Generic Reusable Aerospace Software Platform (GRASP) Software

Goddard Space Flight Center

- ***Modular, generic, framework for developing real-time, multitasking, software systems***
- ***Flight and ground station software***
- ***Heritage on multiple carriers including the record breaking Cosmic Ray Energetics and Mass (CREAM) Ultra Long Duration Balloon flight in 2005***
- ***Support for VxWorks, Windows XP, and Windows CE***



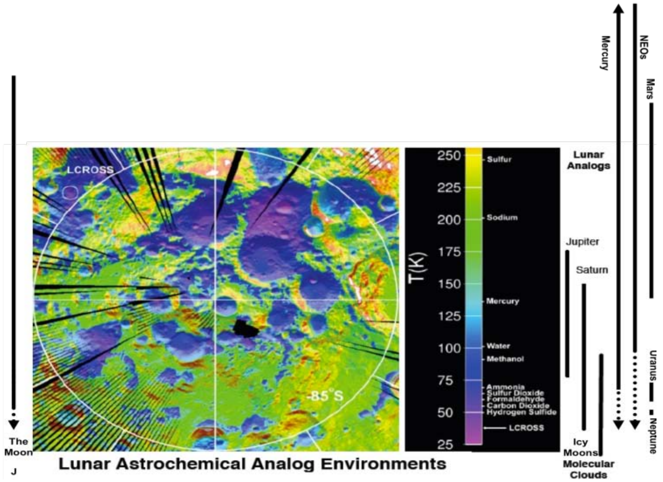
Cosmic Ray Energetics and Mass (CREAM) Missions

CloudSat Unmanned Aerial Vehicle (UAV) flight

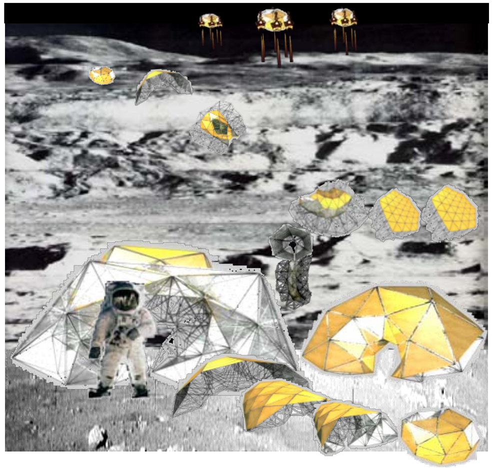
Goddard Space Flight Center

GSFC/Wallops Lunar CubeSat Studies

- ***CubeSats offer opportunity for multi-functional spatially and temporally distributed measurements with greater scientific impact***
- ***Studying enhancements required for propulsion, survival, and intelligence***
- ***Paper submitted for publication in the Journal of Small Satellites***
  - ***LunarCube: Using the CubeSat Model to Support Access to Deep Space, Clark (Catholic University of America (CUA)), Cox and Vasant (Flexure Engineering), Rilee (Rilee Systems Technologies), MacDowall (NASA GSFC), Malphrus (Morehead State), and Schaire (NASA WFF)***



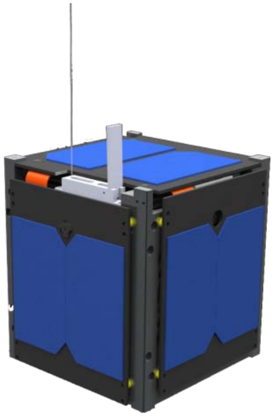
Lunar surface offers rich environment for planetary exploration



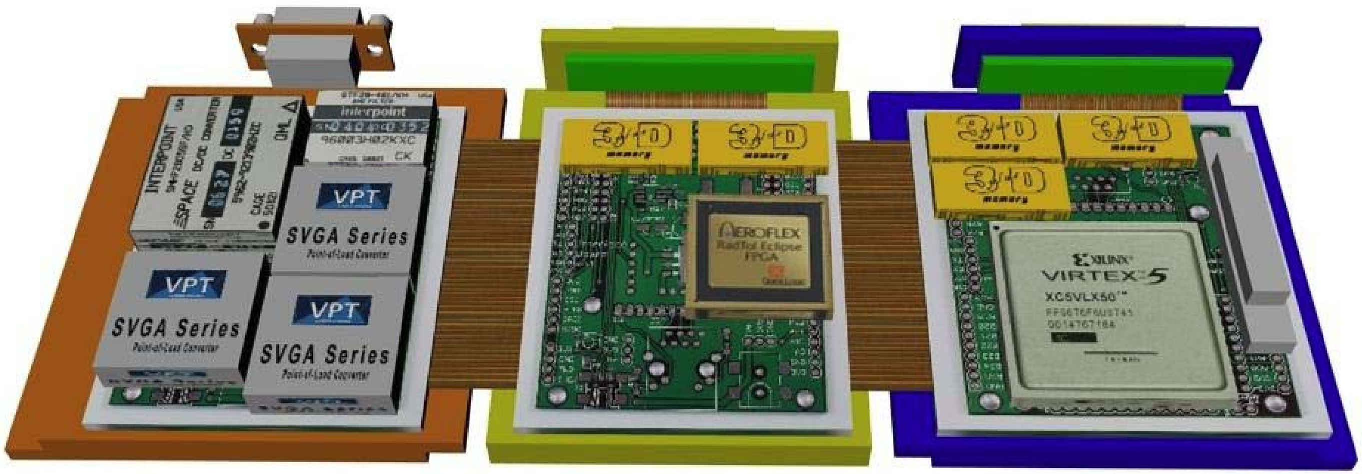
Lunar science collection

GSFC SpaceCube 2.0 Mini CubeSat Processor

- *"Order of Magnitude" improvement in on-board computing power*
- *The first SpaceCube Mini will fly as part of the Intelligent Payload Experiment (IPEX) CubeSat that will demonstrate advanced on-board processing capabilities*
- *3.5" cube*



Intelligent Payload Experiment (IPEX) CubeSat



SpaceCube Mini

Backup

Small Satellite Carrier System – Multiple Payload Ejector (MPE)

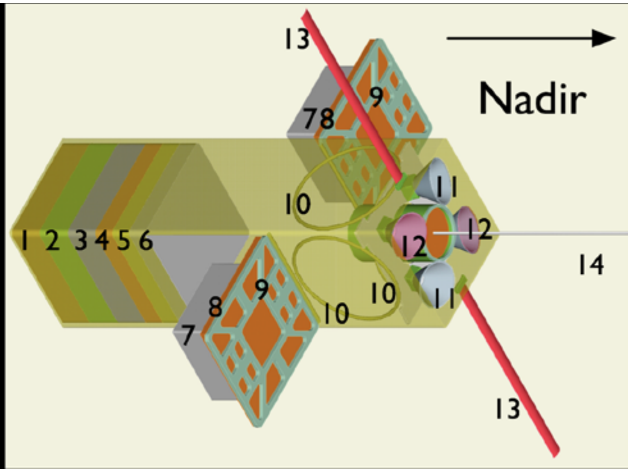
- ***Wallops developed a Small Satellite Carrier System***
  - *Goal of increasing access to space by providing a carrier with multiple payload accommodations for use on emerging small, low-cost launch vehicles*
  - *Modular design allowing multiple small spacecraft of varying size to be flown on small launch vehicles*
  - *Capable of dispensing up to 7-100lb spacecraft and ~12 CubeSats*
  - *Successfully completed carrier preliminary functional and qualification testing*
- ***Wallops continuously seeks out low-cost solutions for launch vehicles and carrier platforms to enable NASA's scientific research and technology development***

Wallops Multiple Payload Ejector

Firefly

- ## *Objective*
  - *Measure terrestrial gamma-ray flashes associated with lightning*
  - *Launch – Manifested on ORS enabler mission July-August, 2013 and as a backup on NROL-39, October, 2013*
- ## *Team Partners*
  - *NASA Goddard Space Flight Center*
  - *Hawk Institute for Space Sciences*
  - *Siena College*
  - *NASA Goddard Space Flight Center's WFF*

1: FM430 flight computer
2: ClydeSpace EPS
3: Experiment Controller
4: VP Analog board
5: GRD front end board
6: Experiment Power Regulator
7: Burle Planacon MCP (x2)
8: BGO scintillator (x2)
9: Hinged Deployable Door (x2)
10: VLF loop antennas (x3)
11: WL Optical photometer (x2)
12: Red optical photometer (x2)
13: Comm antennas (x2)
14: Gravity-gradient tether

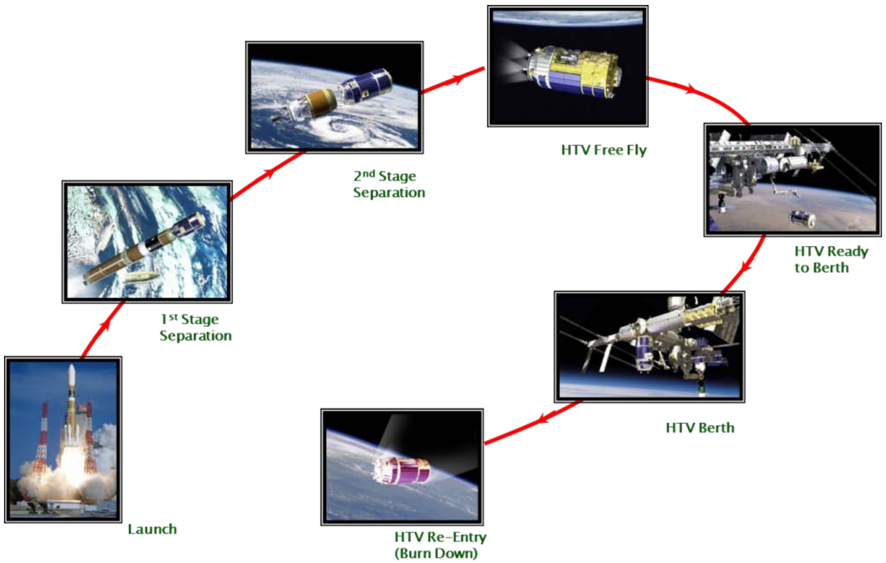


Wallops Spacecraft Development

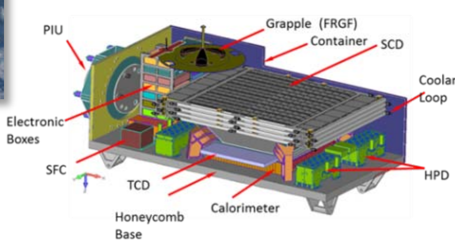
Goddard Space Flight Center

Wallops Supporting International Space Station Research

- *Univ. of Maryland researcher developed instrumentation to conduct high energy cosmic ray research as an external payload on the ISS.*
- *Wallops is providing project management and engineering for the spacecraft development, launch to ISS, and ISS operations*
  - ***Design & develop primary spacecraft structure***
  - ***Design & develop thermal control system***
  - ***Design & develop mechanical & electrical interfaces to the launch vehicle & the ISS***
  - ***Develop operations plans for spacecraft operations on ISS external pallet***
- *~2yr design & development cycle; 2-3 year operational life on ISS*



International Space Station



Engineering Model of ISS Spacecraft

Goddard Space Flight Center

Wallops Role In Space Missions

Wallops has a long history of supporting the nation's space program, from launch vehicle testing to spacecraft development to operations

- ***Early aeronautics research – Since 1945***
- ***Early manned spacecraft systems development & test (1959-1961) Mercury capsules***
- ***Scout Small Satellite Launch Vehicle – 118 orbital launches beginning in 1959***
- ***Shuttle Small Payloads Get-Away Special (GAS) & Hitchhiker programs (1984 - 2003)***

Today Wallops continues this legacy through the Wallops Launch Range & the development of orbital spacecraft

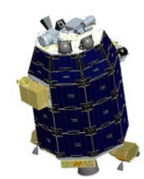
- ***Since 2006, WFF has been the launch site for numerous USAF Minotaur launches carrying research & development spacecraft for the D.O.D – Launched 1st CubeSat in the US***
- ***Wallops is the host site for Orbital Science Corp's Antares launch vehicle which will carry cargo to the International Space Station***
- ***Wallops is coordinating launch services and providing the launch range for a NASA satellite which will be launched into lunar orbit - 2013***
- ***Wallops engineers are developing small satellites and payloads for the International Space Station to further NASA's scientific & technology research***

Scout LV

Early Manned LV R&D

GAS Payloads

Minotaur LV on WFF Pad



LADEE Lunar Spacecraft

Artist Rendering of Antares LV & Cygnus ISS Cargo Vehicle