

# MSFC Small Spacecraft Development Experience



**ES10/MacLeod**

- **FASTSAT-0**
  - Developed in 2007 (12 Month development)
  - Scheduled to carry an Army payload and launch on a Super Strypi rocket
  - Total Budget was \$4M
  - Weighed approximately 200 pounds
  - Body mounted solar panels produce approximately 100 Watts
  - First satellite design to exclusively use magnetic torque rods for attitude control
  - Early in the project, issues with the Army payload and the Super Strypi programs caused the mission to be cancelled. The satellite was completed without a known payload or launch vehicle.



- **FASTSAT-HSV-01**

- Developed in 2009 – 2010 (~15 Month development)
- Partner with the Air Force, Von Braun Center for Science and Innovation and Dynetics Corporation
- External NASA funding (Air Force and Dynetics) was coordinated through VCSI
- Carried 7 payloads from NASA GSFC, NASA MSFC, Naval Research Laboratory and the Air Force
- Launched in November 2010
- Ground operations controlled by MSFC
- Planned 6 month mission was extended to over 2 years
- No significant anomalies during the mission
- Decommissioned June 2013



# Mission Overview



Integrated at Kodiak  
Launch Complex



Launched Nov. 19  
2010 on Minotaur IV



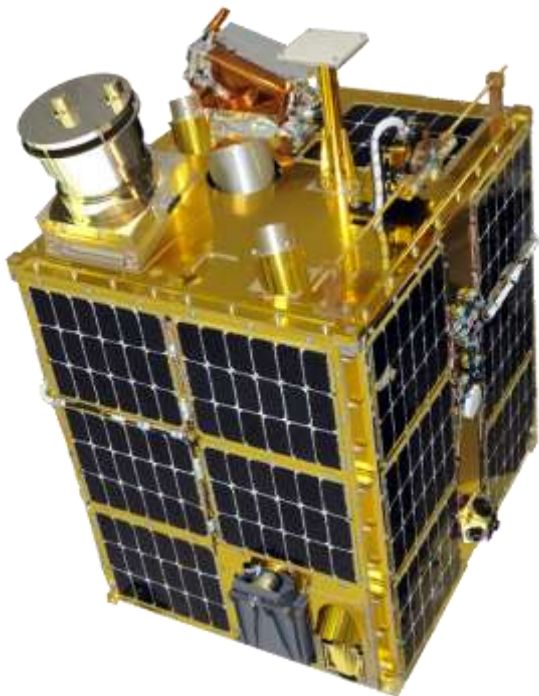
Carried 6 Experiments on  
FASTSAT-HSV01

- Demonstrate multi-payload capability on Minotaur IV
  - 4 EELV Secondary Payload Adapter (ESPA) class spacecraft and 2 CubeSats
  - FASTSAT-HSV01 manifested as 1 of the ESPA class spacecrafts
  - Successful deployment of all 6 spacecraft into the desired orbit
- Access to Space for Space Experiment Review Board (SERB) experiments
  - STP-S26 launched 16 total experiments on 6 spacecrafts
  - **FASTSAT-HSV01 would carry 7 experiments and perform the first launch/ejection of a CubeSat from a free-flying ESPA class mini satellite**



- Mission Selection: Dec 2008
- Preliminary Design Review: Feb 2009
- Critical Design Review: June 4, 2009
- PSR: May 7, 2010
- ORR: August 15, 2010
- FRR: September 27, 2010
- Launch: November 19, 2010
- Mission Completed Nov 2012
- End of Life June 2013

**FASTSAT was designed, developed, integrated, tested and certified for flight in 15 months using an innovative business model, tailored processes, co-located and experienced team.**



- 12-month LEO mission
- Class D ESPA class spacecraft
- 7 instrument capacity
- NanoSat (CubeSat) Payload Deployer (P-POD)
- Spacecraft mass: ~150 kg
- Size 24" x 28" x 38" (ESPA)
- Payload mass: 21 kg
- Payload power: 30 W average
- S-Band downlink 1 Mbps
- S-Band uplink 50 Kbps
- Stabilization: single axis (magnetic torque rods)
- Pointing accuracy: 20° /3-axis; 10° /single axis
- Pointing knowledge: 0.1°

## Seven Instruments on One Platform



### NASA and USNA Miniature Imager for Neutral Ionosphere Atoms and Magnetospheric Electrons (MINI-ME)

- Improve space weather forecasting for operational use



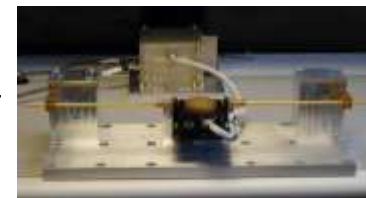
### NASA and USNA Thermospheric Temperature Imager (TTI)

- Increase accuracy of orbital predictions for low-Earth orbiting assets



### AFRL Light Detection System (LDS)

- Evaluate atmospheric propagating characteristics on coherent light generated from known ground stations



### NASA & USNA Plasma Impedance Spectrum Analyzer (PISA)

- Permit better predictive models of space weather effects on communications and GPS signals



### NASA + ARMY SMDC + AFRL + VCSI Nano Sail Demonstration (NSD)

- Demonstrate deployment of a compact 10-m<sup>2</sup> solar sail ejected as a CubeSat



### NASA MSFC Memory Test Experiment (MTE)

- Flight Demonstration of Ferroelectric Memory technology



### AFRL + NASA + AF Miniature Star Tracker (MST)

- Demonstrate small and low-power star tracker





- The project followed NPR-7120.5 with significant tailoring
  - The number of documents were reduced by combining and elimination
  - The proscribed number of project reviews were reduced to 4
  - Configuration Management was accomplished through a simplified Project Release system
  - A small co-located team reduced the number of formal status meetings
- The project followed NPR-7150 on software development with significant tailoring
- The project only carried workforce when they were needed by the project. Once a person's task was completed they were rolled off the charge code.
- The project was managed as a Class D project with additional rigor only given to areas perceived as high risk
- Use of NASA's Near Earth Network for downlink was a cost savings
- Most of the project personnel already had experience in working low-cost flight projects, including small satellites

# Mission Parameters



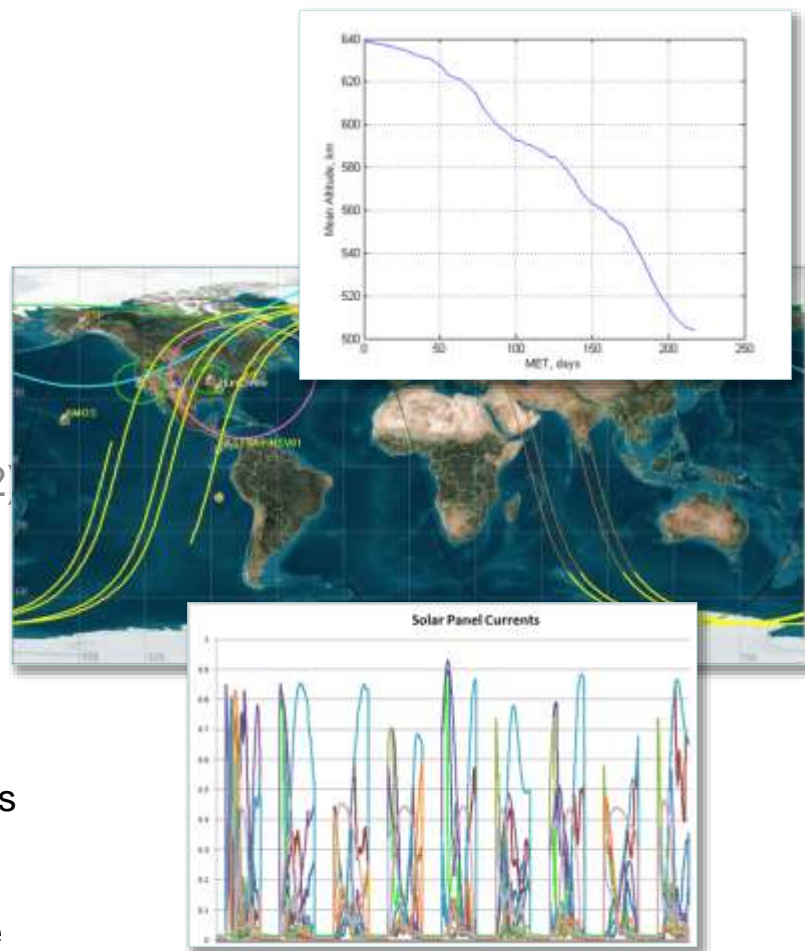
**Launch Date @ ATP – December 2009**  
**Actual Launch Date – November 19, 2010**  
**Orbit – 650 km circular**  
**Inclination – 72 degrees**  
**Location - Kodiak, Alaska**



# FASTSAT Mission Accomplishments



- ✓ Launch Nov 19 at 7:25 PM CST
  - Spacecraft Powered Up 52 minutes Later (nominal)
  - Sustained Ground Contact within 12 Hours (nominal)
  - Completed all level I S&T payload data gathering for SERB payloads by April 30, 2011 (nominal)
  - Spacecraft to ground contacts entering 21<sup>st</sup> month
- ✓ Mission Operation Center at NASA MSFC
  - Reliable Commanding and Telemetry Established
  - Portal and Remote Telemetry to PI's Established
- ✓ Science Operations (Continued through Nov 2012)
  - ✓ Aliveness Tests Successful for PISA, TTI, MINI ME, LDS, & Miniature Star Tracker
  - ✓ NSD Ejected and Sail deployed with planned re-entry
  - ✓ PISA achieved full science level I requirements
  - ✓ MINI-ME achieved full science level I requirements
  - ✓ TTI achieved full science level I requirements
  - ✓ Miniature Star Tracker successfully acquired star fields images, quaternion(s) generated
  - ✓ Additional data gathering for PISA, TTI, MINI-ME and LDS underway for acquisition of reach goals (Science Continues)



**FASTSAT-HSV01 project accomplished the mission goals within nine months of launch and the payload technology readiness levels are now  $\geq$  TRL 8**

- **NanoSail-D**

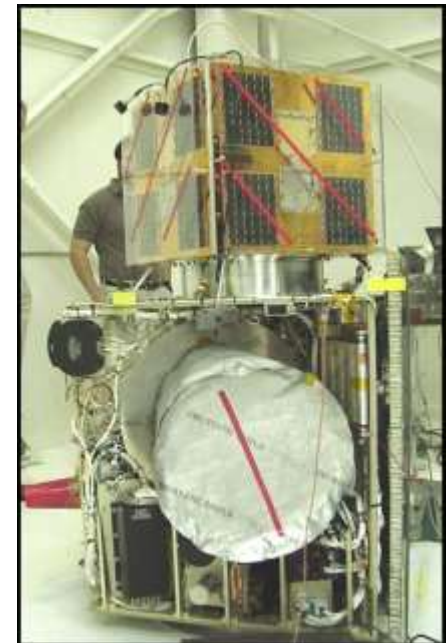
- Developed in 2007 -2008
- Launched on Falcon 1 on 8/3/2008 (Launch vehicle failure)
- Launched Backup spacecraft in FASTSAT-HSV01 in November 2010
- Partner with Ames Research Center and NeXolve
- Deployed from FASTSAT-HSV01 in January 2011
- Deployed a 10 meter square solar sail in LEO
- The Nanosail-D spacecraft de-orbited in approximately 120 days. Analysis showed that that the spacecraft would have taken approximately 50 years to de-orbit without the sail



# MSFC Engineering Capabilities for Small Satellites



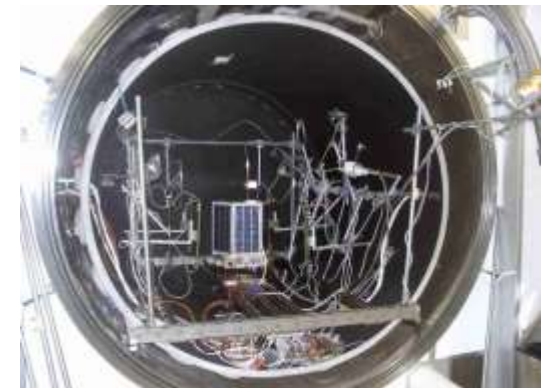
- **Plasma Experiment Satellite Test (PEST)/ Joint Air Force Weber State Satellite (JAWSAT)**
  - Developed in 1999 (6 month development)
  - Launched 1/27/2000 on Minotaur 1
  - MSFC developed plasma detector, command and data system, power system and instrument deployment system
  - Weber State bus failed to transmit data



# MSFC Engineering Capabilities for Small Satellites



- **Small Payload Access to Space Experiment (SPASE)**
  - Developed in 2000 (12 month development)
  - Partnership with AeroAstro to develop low-cost small satellites
  - Scheduled to Launch on Shuttle (Hitchhiker) originally in 2001. Rescheduled for 2003, but the Columbia accident canceled its launch
  - Approximately 80 Lbs, passive magnetic attitude control, no moving parts
  - Contained a micro-gravity crystal growth experiment
  - Used in ground tests by the Air Force for imaging of small satellites



# MSFC Engineering Capabilities for Small Satellites



- **Demonstration for Autonomous Rendezvous Technology - DART**
  - Developed in 2003-2004
  - Launched 4/15/2005 on a Pegasus
  - Joint project with MSFC and Orbital Science
  - DART was to rendezvous with the Multiple Paths, Beyond-Line-of-Sight Communications (MUBLCOM) satellite, but due to system failures the DART spacecraft made contact with the MUBLCOM and use up all of its propellant
  - MSFC developed the Advanced Video Guidance System (AVGS) to perform the proximity operations. The AVCG system was never fully activated during the mission
  - MSFC also performed development testing using the Flight Robotics Laboratory



# MSFC Engineering Capabilities for Small Satellites

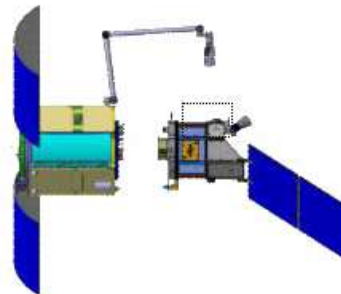


- **Orbital Express**

- Developed in 2005 -2006
- Launched March 2007
- Partner with DARPA, Boeing and Ball Aerospace
- The project rendezvous and docked two spacecraft ASTRO and NEXTSAT to demonstrate proximity operations and refueling.
- MSFC developed the Advanced Video Guidance System (AVGS) to perform the proximity operations. The AVCG system work flawlessly during the mission
- MSFC also performed development testing using the Flight Robotics Laboratory



ASTRO & NEXTSAT

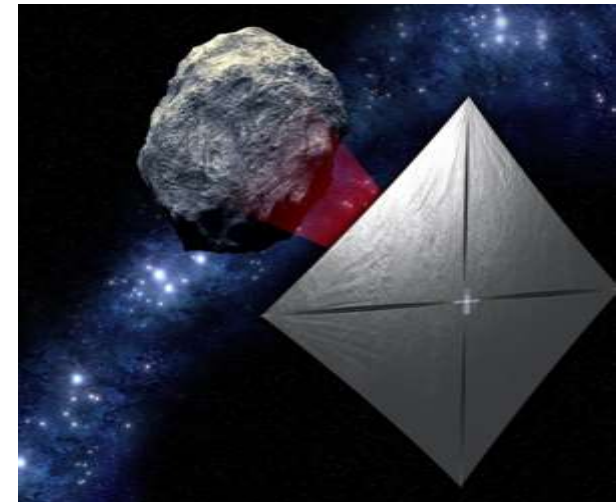
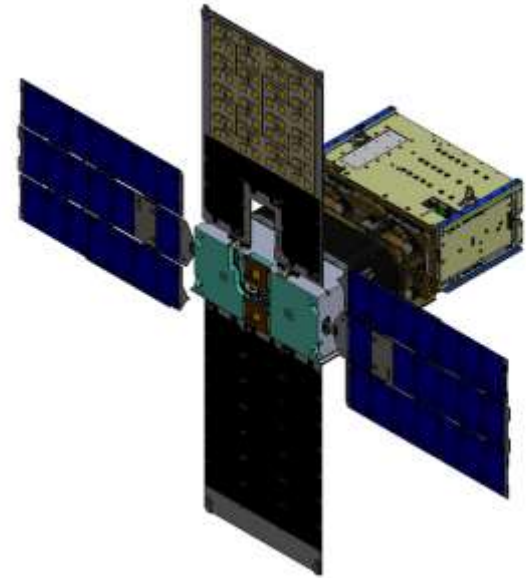


# MSFC Engineering Capabilities for Small Satellites



- **NEA-Scout**

- In development
- Funded by Advanced Exploration Systems (AES)
- Scheduled to launch on SLS EM-1 in 2019
- 6U cubesat form
- Partner with JPL
- MSFC manages the overall mission and is developing the solar sail
- The mission is to fly in deep space and flyby one or more Near Earth Objects
- The system has an imaging system to characterize the NEA

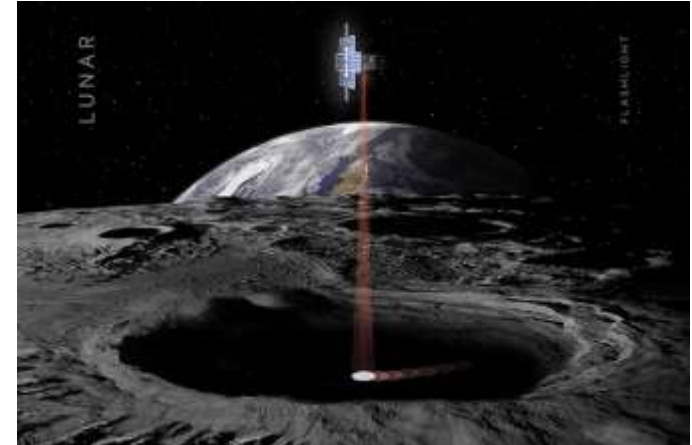


# MSFC Engineering Capabilities for Small Satellites



- **Lunar Flashlight**

- In development
- Funded by Advanced Exploration Systems (AES)
- Scheduled to launch on SLS EM-1 in 2019
- 6U cubesat form
- Partner with JPL
- MSFC scientist is the Principal Investigator
- JPL manages the overall mission, MSFC is developing the propulsion system
- The mission is to orbit the moon and shine a laser into a shadowed crater at the pole and observe it with a spectrometer

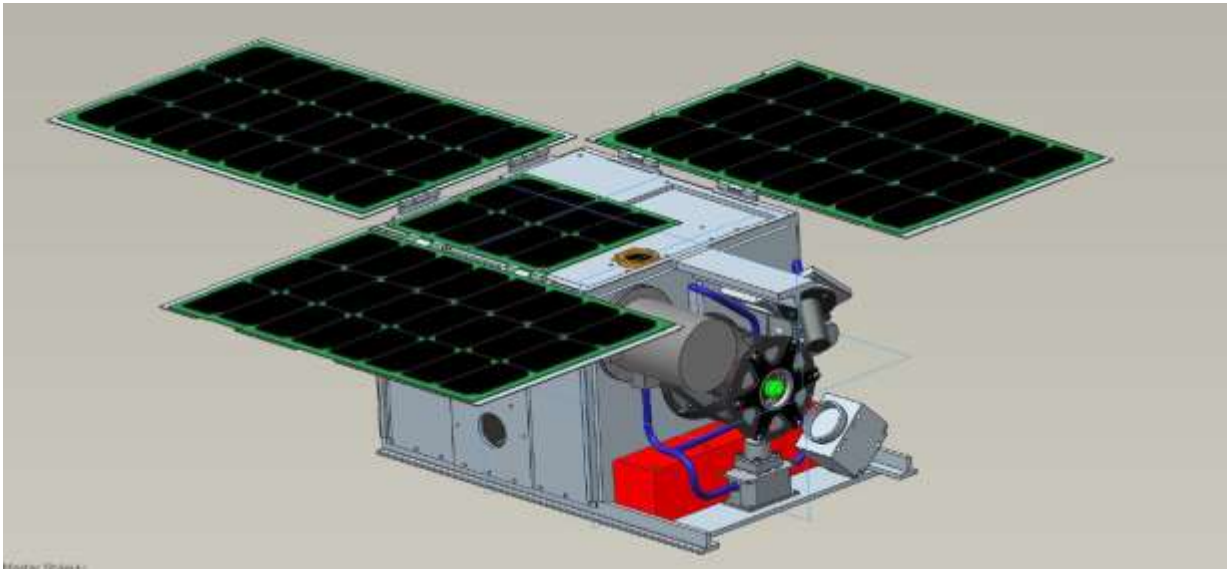


# MSFC Engineering Capabilities for Small Satellites



- **iSAT**

- In development
- The bus system is at a CDR level
- Issues with the propulsion system maturity (at Glenn Research Center) has delayed spacecraft development
- The mission is to demonstrate an Iodine Plasma Propulsion System in LEO
- The iSAT propulsion system consists of a 200W Hall thruster, Iodine tank and support systems





# MSFC Engineering Capabilities for Small Satellites



- **Other On-going Small Sat Activities**

- In-house development of a 3U Green Propulsion Demonstration satellite
- Partnership with Air Force STP for a Green Propulsion system for a 90 Kg spacecraft
- Potential Earth Science, Heliophysics and Astrophysics small satellite missions
- Support for Air Force Research Laboratory development of a 3U cubesat
- In-house development of an Electrically Controlled Solid Propulsion System cubesat demonstration mission
- Small Satellite subsystem developments including:
  - S and X-band communication system (PULSAR)
  - Ultra-Capacitor energy storage
  - Additive manufacturing
  - Attitude determination and control systems
  - De-orbit systems
  - Solar Sail propulsion systems
  - Electronic Sail propulsion systems

# NASA MSFC Flight Robotics Lab



**Provides a full scale, integrated simulation capability to support the design, development, test, integration, validation, and operation of orbital space vehicles.**

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**The Flight Robotics Laboratory (FRL) is built on developed technologies: air bearing vehicles, a servo drive overhead robotic simulator, precision target motion controllers, gimbals, and a mobile solar simulator with 6 lights totaling 42 KVA.**

**The facility is centered around a 44 foot by 86 foot precision air bearing floor - the largest of its kind.**

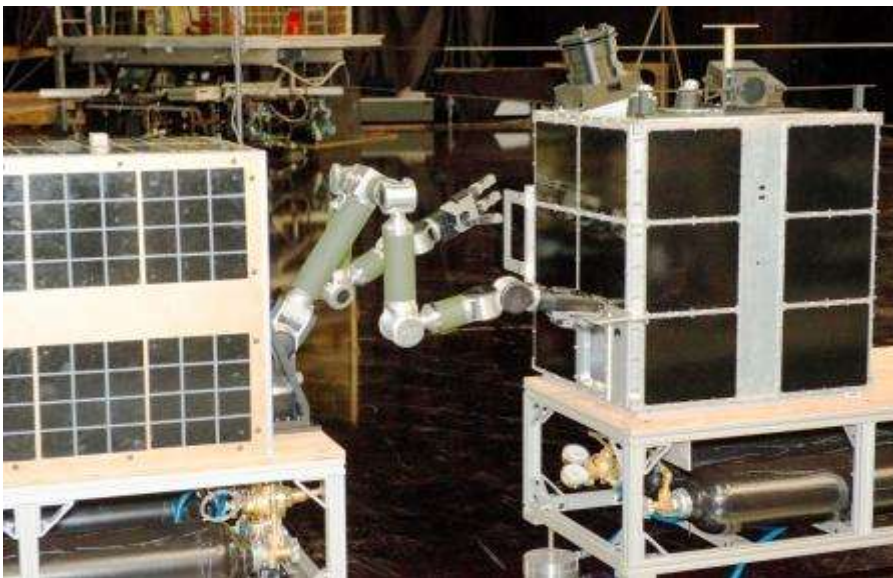


The FRL has air-bearing vehicles ranging in size from 200 lbs to 4000 lbs, each with its own compressed air supply. An 8-Degree-of-Freedom (DOF) overhead gantry (the Dynamic Overhead Target Simulator or DOTS) provides an 800 pound payload capability for simulating relative motion with respect to a fixed target in the facility with a motion envelope of 30' x 160' x 20'. A computer system provides inverse kinematics and allows the gantry to act as a target or as the 6 DOF rendezvous vehicle. The target reaction dynamics can be simulated through force/torque feedback from sensors mounted at the payload interface.

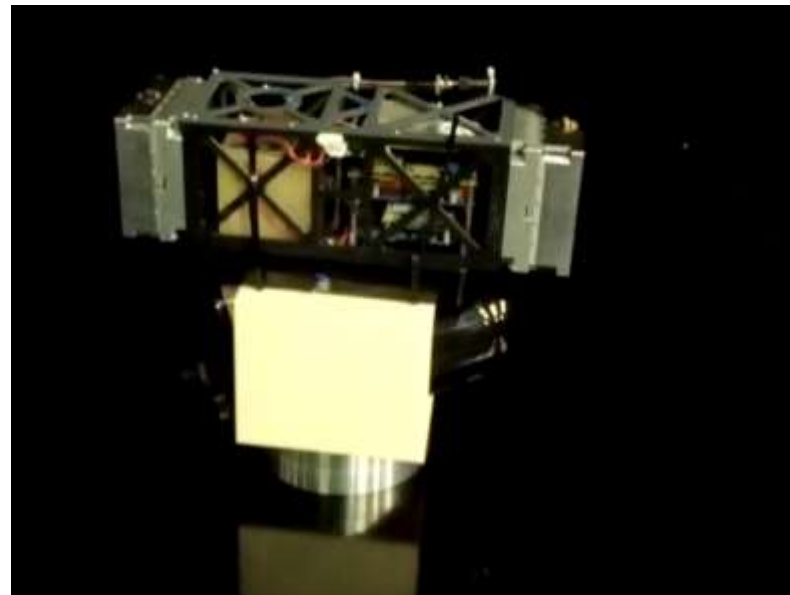
**Collaboration areas could include sensor testing, system testing, multi-vehicle algorithm simulation and testing, orbital debris tracking, automated capture and manipulation, and wireless video and control.**

Past DoD collaborations include DARPA's Orbital Express mission, MARCbot reconfiguration and testing, DART mission to MUBLCom satellite, and sensor tests utilizing Army ranges and facilities.

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Tele-robotic small satellite capture demonstration - MSFC test on Flight Robotics Lab Flat Floor



Cubesat Propulsion - MSFC test on Flight Robotics Lab Flat Floor



# Lightweight Innovative Solar Array

## ◆ Accomplishments

- ◆ Can fit within a 1-U form factor
- ◆ Completed three concept design studies establishing concept feasibility:
  - 3U CubeSat mission
  - Saturn Concept
- ◆ Designed and fabricated test article
- ◆ Conducted successful inflation test

