Proposed Abstract: Under the combined Category and Title:
"FASTSAT a Mini-Satellite Mission…..A Way Ahead"

Authors: Mark E. Boudreaux, Joseph Casas, Timothy A. Smith

The Fast Affordable Science and Technology Spacecraft (FASTSAT) is a mini-satellite weighing less than 150 kg. FASTSAT was developed as government-industry collaborative research and development flight project targeting rapid access to space to provide an alternative, low cost platform for a variety of scientific, research, and technology payloads. The initial spacecraft was designed to carry six instruments and launch as a secondary "rideshare" payload. This design approach greatly reduced overall mission costs while maximizing the on-board payload accommodations. FASTSAT was designed from the ground up to meet a challenging short schedule using modular components with a flexible, configurable layout to enable a broad range of payloads at a lower cost and shorter timeline than scaling down a more complex spacecraft. The integrated spacecraft along with its payloads were readied for launch 15 months from authority to proceed. As an ESPA-class spacecraft, FASTSAT is compatible with many different launch vehicles, including Minotaur I, Minotaur IV, Delta IV, Atlas V, Pegasus, Falcon 1/1e, and Falcon 9. These vehicles offer an array of options for launch sites and provide for a variety of rideshare possibilities.

FASTSAT a Mini Satellite Mission

…..A Way Ahead

15th Annual Space & Missile Defense Conference
Session Track 1.2 : Operations for Small, Tactical Satellites

Mark Boudreaux/NASA MSFC

Space Systems Department

256-544-7007

Mark.E.Boudreaux@nasa.gov

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The STP S-26 Mission

Introduction

- Motivation: When the DoD Space Test Program (STP) received notification of withdrawal of a previously manifested payload on a Minotaur mission, only 14 months before launch, the STP program faced launching an ELV mission with greater than a 20% payload mass and volume margin.

- Call to Action: The DoD STP, along with NASA Marshall Space Flight Center (MSFC), immediately began to identify probable substitutes and the risks associated with each. The short timeline imposed limitations which only mature options could normally satisfy, and yet the STP and NASA teams insisted on looking "outside the box" for solutions to increase sustainable access to space for small secondary missions.

  In the fall of 2008, the STP and the NASA MSFC rapidly formed a partnership to target the time critical opportunity. Inter-Agency alignment of shared vision, goals and assets of the partnership where the technical, schedule and budgetary aspects were higher risk by traditional standards. While a challenge, the aspects represented a payoff for both the NASA and DoD research space communities and an opportunity for an industry provided spacecraft development investment that could also be rewarding if successful.

- Solution for STP S-26: A rapid deployment, responsive science and technology mission leveraging NASA MSFC's Fast Affordable Science and Technology Satellite-Huntsville (FASTSAT) spacecraft concept, a low complexity- low cost mission approach coupled with an innovative multi-organizational collaborative partnership. This partnership afforded a highly synergistic inter-governmental solution which satisfied the DoD STP SERB priority ranking for six S&T payloads and near term spacecraft launch schedule requirements with a complementary spacecraft & payloads. The development process would ready all assets for launch in than 12 months.

DoD Space Test Program

The STP-S26 Mission Objectives

Integrated at Kodiak Launch Complex

Launched Nov. 19 2010 on Minotaur IV

Carried 6 Experiments on FASTSAT-HSV01

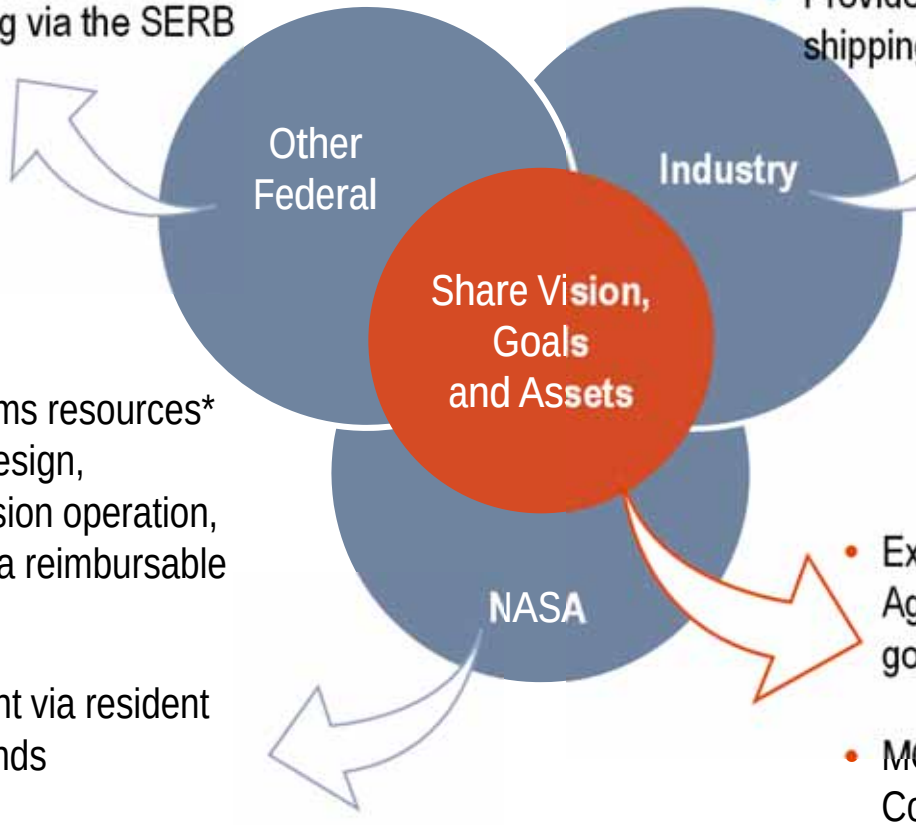
- Demonstrate multi-payload capability on Minotaur IV
  - 4 EELV Secondary Payload Adapter (ESPA) class spacecraft and 2 CubeSats
  - FASTSAT-HSV01 manifested as 1 of the ESPA class spacecrafts
  - Successfully deployed all 6 spacecraft into desired orbit
- Access to space for Space Experiment Review Board (SERB) experiments
  - STP-S26 launched 16 experiments on 6 satellites
  - FASTSAT-HSV01 carried 6 experiments and performed the first launch of CubeSat from free-flying ESPA class satellite

The STP S-26 Mission

A Collaborative Partnership is Forged

- DoD funding of the launch, payload integration and mission operations (STP)
- DoD payload development and manifesting via the SERB

- Industry funding for NASA resources provided via a “not for profit” organization (VCSI and Dynetics, Inc)
- Provide spacecraft manufacturing, shipping and technical support



- NASA MSFC Space Systems resources* provided for certification, design, development, test and mission operation, payloads and spacecraft via reimbursable agreement
- NASA Payload development via resident center IRAD investment funds

* Technical skills, tests facilities and process

- Executed via Inter-Agency and industry to government collaborative
- MOU, MOA, FOA and Cooperative Agreements

Partnering Organizations

Dynetics
The Power of Solutions®

United States
Naval Academy

VCSI
Innovation • Research • Partnership

The FASTSAT on STP-S26

Partnership Roles

Multi-federal Agency, multi-NASA center and industry collaborative science, research and technology flight mission with:

NASA MSFC, GSFC, ARC, Wallops, JSC and KSC

DoD STP , U.S. Air Force, U.S. NAVY, AFRL, Army Space and Missile Defense Command (SMDC)

Industry Dynetics, Inc. and the Von Braun Center for Science and Innovation (VCSI)

NASA program and project governance process standards (NSTS 7120.5)

DoD payload selection, ranking and manifesting process (DoD SERB)

Six jointly sponsored NASA/DoD SR&T SERB payloads flown on a single platform

Flight readiness in less than 12 months from ATP

NASA ODAR waiver sponsorship and approval for USAF inclusion in ELV flight certification

Spacecraft is a Class D mini-satellite (~165 kg) and is compatible with the DoD ESPA standard

Launched on a DoD provided Minotaur IV via Kodiak, AK, on November 19, 2010

Mission Operations performed via NASA Marshall Space Flight Center control center

NASA project leadership role with technical assets for mission formulation, design, development, manufacturing, assembly, testing, flight certification ad mission operations for both the payload instruments and the spacecraft systems. These resources were provided for all key product deliverables throughout the project life cycle via reimbursable agreements with MSFC.

The FASTSAT on STP S-26
Mission Parameters

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

The FASTSAT-HSV Spacecraft

Requirements and Design

- 12-month LEO mission
- Class D ESPA class spacecraft
- 6 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°

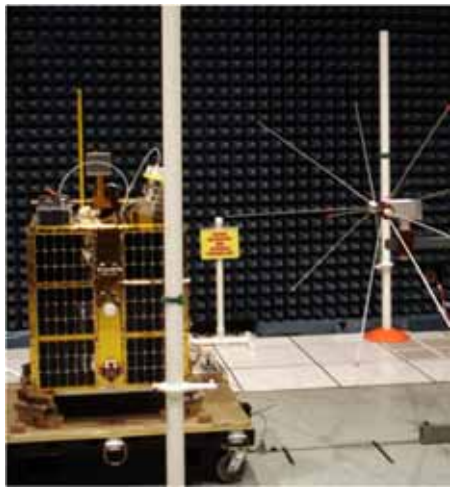
FASTSAT was developed, integrated, tested and certified for flight in 17 months using an innovative business model, tailored processes, co-located and experienced team.

FASTSAT-HSV01 Development

Huntsville Based Team

Machining & Design Center, Dynetics Inc.

Assembly & Integration Clean Room @ the NSSTC



EMI and EMC Test Facility, MSFC

Thermal Vacuum Test Facility, MSFC

- Design, integration, and test by co-located project team in Huntsville
- Leveraged existing manufacturing, integration, and testing facilities
- Designed from the ground up to meet short schedules with modular components at a lower cost
- Spacecraft and payload design, manufacturing, assembly completed in 10 months with environmental testing completed within 11 months from ATP
- Rigorous systems engineering and test approach used to achieve flight readiness certification from NASA and DoD

FASTSAT-HSV01

Six Instruments on One Platform

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

- Improve space weather forecasting for operational use

AFRL Light Detection System (LDS)

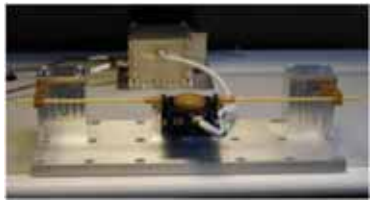
- Evaluate atmospheric propagating characteristics on coherent light generated from known ground stations

NASA + ARMY SMDC + AFRL NanoSail-Demo

- Demonstrate deployment of a compact 10-m^2 solar sail ejected as a CubeSat

NASA and USNA Thermospheric Temperature Imager (TTI)

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



NASA & USNA Plasma Impedance Spectrum Analyzer (PISA)

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

AFRL + NASA + AF Miniature Star Tracker (MST)

- Demonstrate small and low-power star tracker

STP S26 Mission

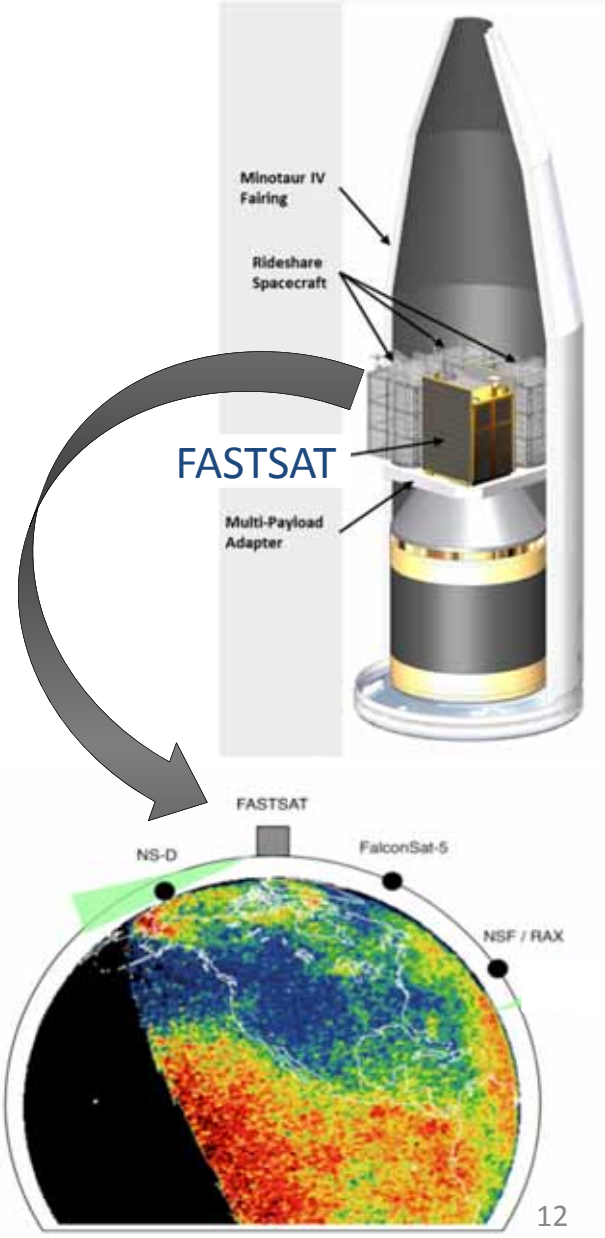
CONOPS

The Space Test Program mission STP-S26 was launched from Kodiak Launch Complex, in Kodiak, AK, in November, 2010 on a Minotaur IV launch vehicle.

This was a multiple payload launch, with a large number of secondary payloads launched for scientific and technology demonstration purposes.

FASTSAT-HSV01 is one of several spacecraft with space weather-relevant instrumentation, including the first National Science Foundation-funded scientific satellite, the Radio Aurora Explorer Cubesat (RAX), and another in a series of US Air Force Academy student-built satellites (FalconSat-5).

These spacecraft were placed into a “pearls-on-a-string” orbit, and the resulting in a small constellation of spacecraft with instrumentation suitable for science and technology research at 650km, 72 degree inclination.

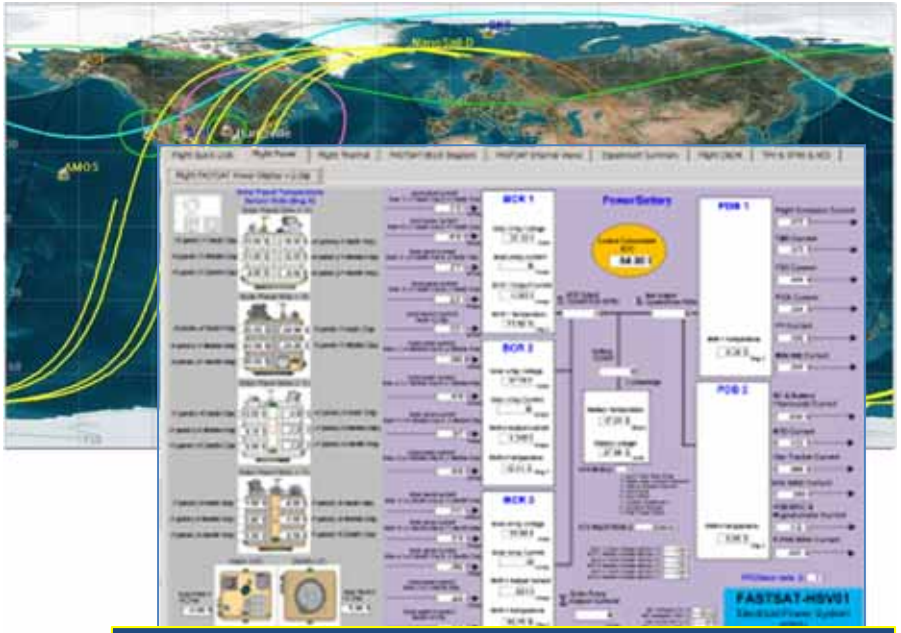


FASTSAT-HSV01

Mission Operations

- **Support Bus/Payload Integration**
  - Mechanical, Electrical & Software Integration
  - Verification of Interfaces
  - System Level Proto-flight Testing
- **Launch Operations**
  - Development of Procedures
  - Develop Ground Support Equipment
  - Shipment of Flight Hardware
  - Certificate of Flight Readiness (CoFR)
  - Pre launch Testing and Operations of Ground Support Equipment
- **Mission Operations**
  - Develop Mission Operations Procedures
  - Develop and Verify Commands & Timelines
  - Mission Operations Simulations
  - Develop & Maintain Flight Support Systems
  - Develop Telemetry Displays
  - Develop Data Analysis Tools
  - 24/7 Spacecraft Commissioning
  - In-flight Command and Timeline Execution
  - Anomaly Investigation and Resolution
  - Orbital Analysis & Planning
  - Spacecraft Systems Analysis & Planning
  - Real Time Telemetry Review
  - Post Pass Data Analysis

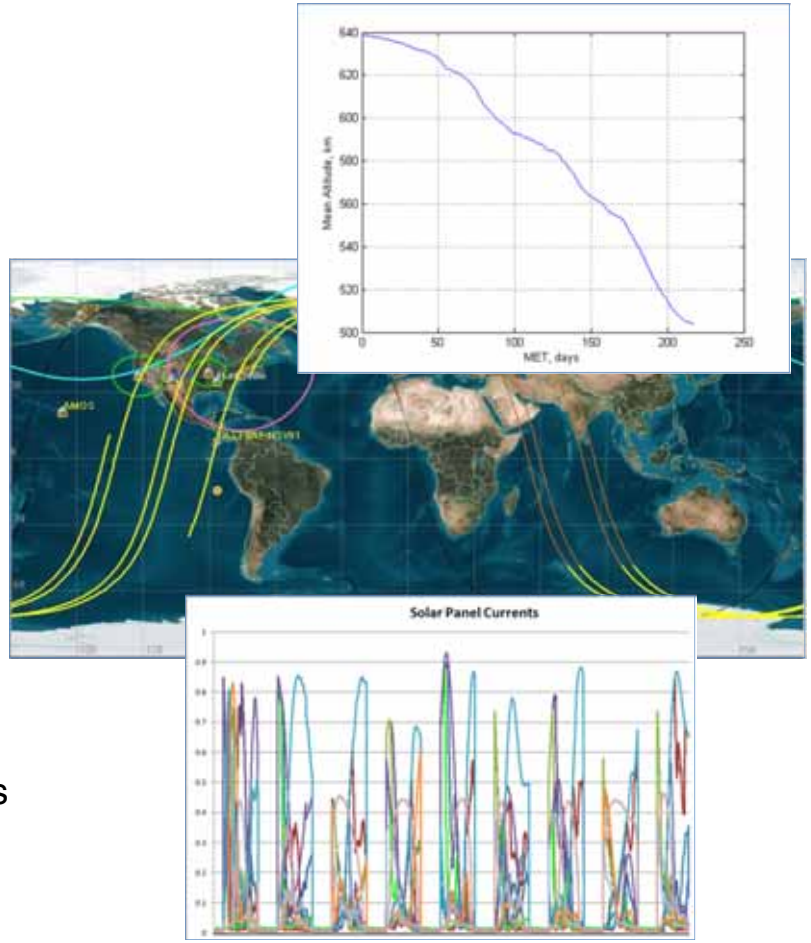
Small Satellite Control Room located @ MSFC



On-Orbit Displays Status Spacecraft's Health and Location

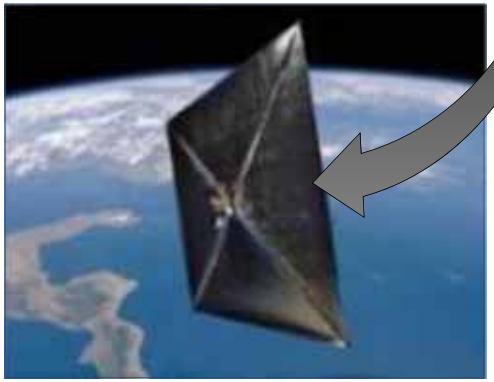
FASTSAT Mission Accomplishments

- ✓Launch Nov 19 at 7:25 PM CST
  - Spacecraft Powered Up 52 minutes Later (nominal)
  - Sustained Ground Contact within12 Hours (nominal)
  - Completed all level I S&T payload data gathering for SERB payloads by April 30, 2011 (nominal)
  - Spacecraft to ground contacts entering 21st month
- ✓Mission Operation Center at NASA MSFC
  - Reliable Commanding and Telemetry Established
  - Portal and Remote Telemetry to PI's Established
- Science Operations (Continuing through Nov 2012)
  - ✓Aliveness Tests Successful for PISA, TTI, MINIME, 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 has accomplished all six SERB payload mission goals and payload technology readiness levels are now ≥ TRL 8

FASTSAT Mission *By The Numbers*



- Spacecraft Status (as of July 25, 2012)
  - Launch Nov 19 at 7:25 PM CST
  - 613 days mission elapsed time
  - 9050 orbits at 650 km
  - Spacecraft subsystem hardware checkout accomplished by day 7
  - COMM, ADCS, Power and attitude control modes functional
- Spacecraft Operations
  - Command & telemetry nominal for all NEN ground stations
  - Down linked 223-M packets for over 17 GB
  - Uplinked 450,000+ commands
  - 9 spacecraft software updates, 5 instrument software updates
- Payload Operations
  - Payload hardware checkout completed on mission day 10
  - Ejected NSD CubeSat day 59, deployed Sail on day 62. The **first ESPA and NASA mini satellite spacecraft to eject a CubeSat**
  - All six SERB experiment operations successfully implemented within first 5 months of launch. The **first STP mission with SIX SERB payloads on a single spacecraft.**
  - Ongoing operations continue for MINI-ME, PISA, TTI, MST, and LDS
    - Over 8.4 GB of data downlinked

FASTSAT-HSV01 has completed > 20 months of flight operations, doubling pre-mission requirements and further demonstrating capabilities of an affordable ESPA class mini satellite S&T mission.

Conclusions

Key Mission Enablers

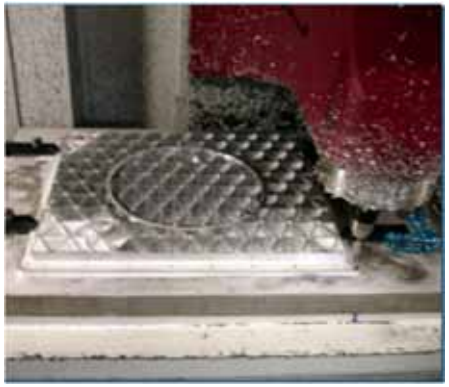
Conclusions

Key Mission Enablers

- DoD STP and NASA "buy in" of the risk versus investment standards and the implementation approach for S-26 Mission that includes:
  - NPR 8705.4 Appendix A for Class D a Spacecraft and Payloads
  - Application of tailored NASA's NSTS 7120.5 project standard
  - NASA's Governance model as applicable for projects
  - NASA's and DoD's Flight Certification process standards
  - ODAR assessment by NASA with DoD acceptance
  - The Alignment of government and industry resources to "enable an integrated S&T solution for all stake holders"

Conclusions

Enablers for Rapid Spacecraft Manufacturing




- Co-located, flat team model greatly improved efficiency
- “Faster and cheaper” from “ground up” easier than optimizing “slow and expensive”
- Get Class-D risk buy-in from leadership up-front to avoid scope creep
- Streamline approval processes to eliminate waiting on signatures
- 3D collaboration tools facilitated rapid spacecraft and payload layout
- Multiple avionics test beds are needed to accelerate hardware and software testing
- “Test as you fly” early including long duration runs to avoid system test problems

Conclusions

Key Mission Enablers

- Highly motivated, competent, committed and innovative "outside the box" thinking team with integrity and "can do spirit"
- Leveraging of existing processes for rapid deployment of procurement, contracts and purchasing elements
- Leveraging of existing capitol investments and "buying by the yard"
- "Test as you fly" philosophy and implementation approach
- Infusion of independent subject matter experts technical review at KDP milestones

A Way Forward

A Way Forward

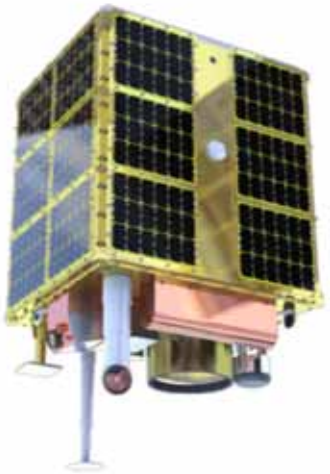
- This Mini Satellite Spacecraft offers low cost access to space with:
  - Simplified Payload Integration and Accommodations for up to six science and technology payloads
  - Access to Rideshare Accommodations and Resources
  - EELV Secondary Payload Adapter (ESPA) Standard Services
  - On-Orbit Operations Utility
  - CubeSat Deployment
  - Mitigation of 25 year Orbital Life Requirement
  - Resource margin within ESPA envelop to enhance bus capabilities and invest in S&T payload resource requirements
  - A low cost pathfinder integrated mission solution for $ < 20M

Designed for Low Cost Rapid Access to Space

A Way Forward

Proposed Mini-Satellite Spacecraft Models

- ESPA Compatible
- Six Payloads
- P-POD Option
- 1-Axis Attitude Control
- 12 to 18 Month Delivery
- Present Spacecraft Design



- 3 Axis Attitude Control (reaction wheels)
- 15 to 20 Month Delivery
- Under Development

- Deployed Solar Arrays
- Payload Power > 100W
- 18 to 24-Month Delivery

- On-Orbit, On-Demand
- Deploy CubeSats
- Power and Comm.
- Constellation Deployment
- Under Development

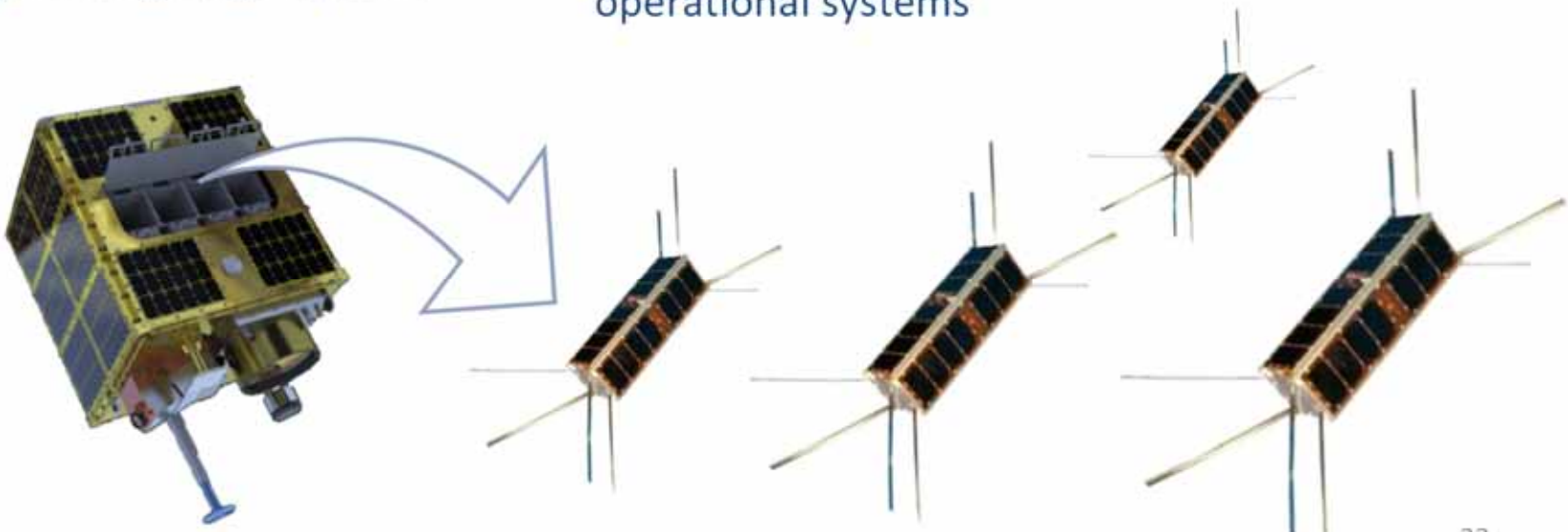
Provide Significant Enhancements to the STP-S26 Mission, Increasing Capabilities to Meet Future Mission Requirements Providing Affordable and Rapid Access to Space.

A Way Forward

Applicable to a Broad Range of Responsive Missions

Class C-D Spacecraft
Secondary "Rideshare" SV
Low to Mid Complexity Payloads
Space Tests and Experiments
Technology Demonstrations
Rapid Response Gap Filler
Augmenting Large Systems

On-Orbit Multi-CubeSat Deployment
Earth and Atmospheric Observation
Space Weather
Intelligence, Surveillance, and Reconnaissance
Demonstrated Military Utility
Inexpensive way to test new technologies
Perform experiments and risk-reduction for operational systems



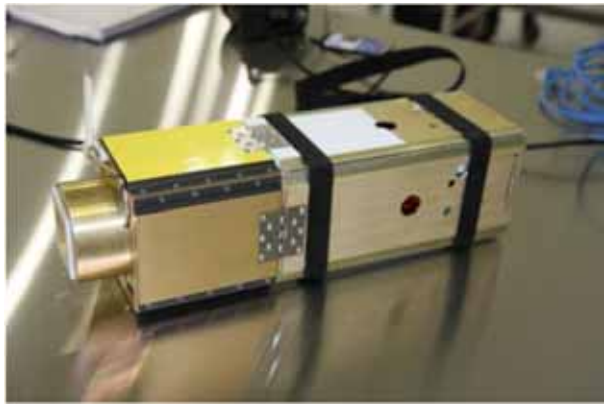
References

- Paper 1, 2, 3 etc……. In work

Back Up Slides

Nano Sail Demonstration (NanoSail-D)

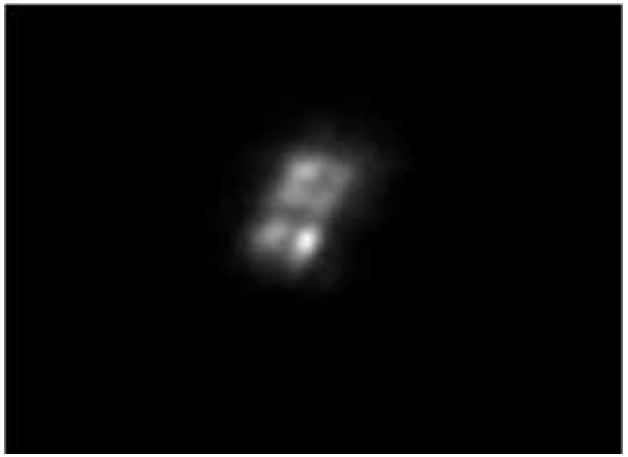
PI: Dean Alhorn (NASA MSFC)



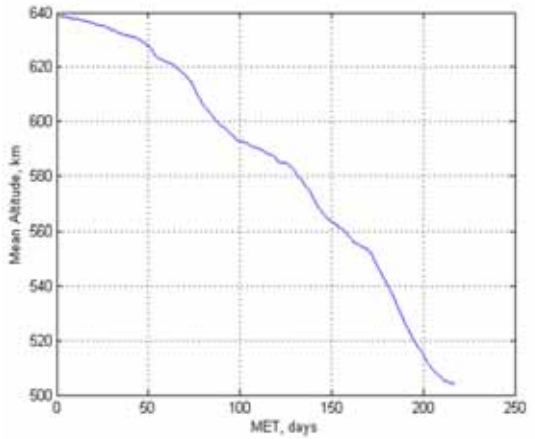
NanoSail-D 3U CubeSat
Pre-encapsulation

- Ejected from FASTSAT: 17 Jan. 2011
  - First CubeSat launched on-orbit from EPSA-class satellite
- Sail deployment: 20 Jan. 2011
  - Demonstrated ability to deploy highly compacted solar sail/boom system
- De-orbited in September 2011 (predicted)
  - Lowered altitude 130 km in 215 days
  - Validate passive (non-propulsive) de-orbit technology
- TRL raised to 9
  - Compact deployable de-orbit systems for future satellites
  - Deployable booms for thin film solar arrays

Ground Deployment Test of
10-m^2 Solar Sail



NanoSail-D In-orbit Image Captured
Clay Center Observatory



130-km Mean Altitude Drop(day 215)

The STP S-26 Mission
Innovative Business Model