NASA-Ames Research Center ... in Silicon Valley

NanoSatellite Missions In the NASA-Ames Small Spacecraft Division

Fifth Annual CubeSat Developer's Workshop

11 April, 2008

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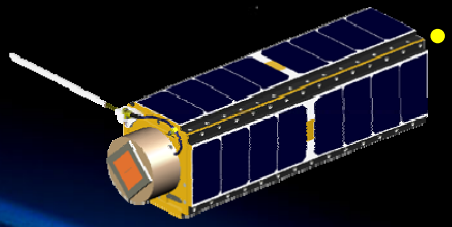
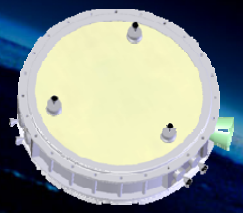
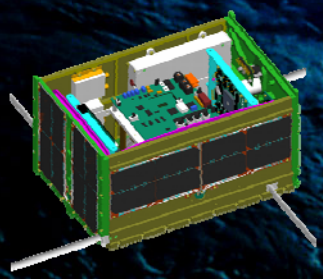
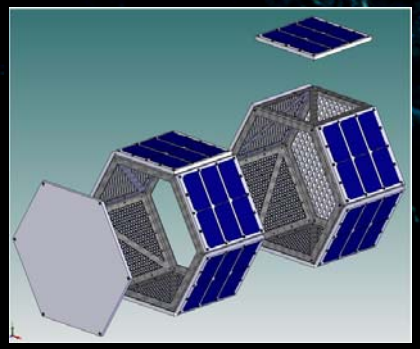
Small Spacecraft Division

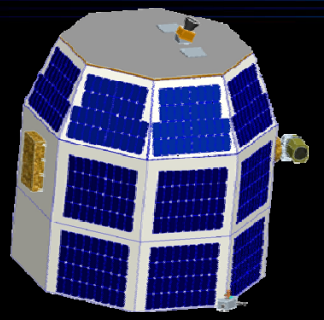


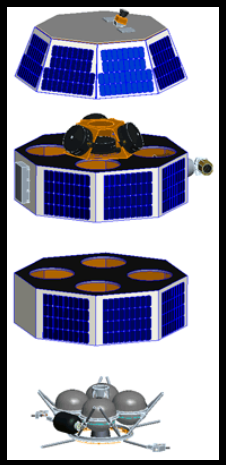


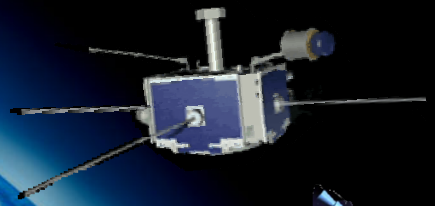


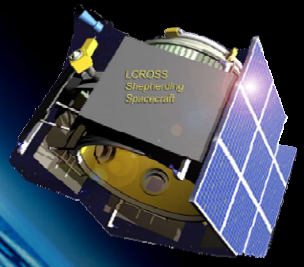


- Develop spacecraft and related systems to make access to space routine [VENTURE CLASS, < $100M]
  - Common, reusable architectures
  - Place emphasis on payloads and science missions
- Secure and provide methods to access space reliably, frequently
  - Small space systems
  - Secondary payloads
- Reduce overall mission costs
  - Goal: Maintain or increase scientific and exploration return while reducing life cycle costs









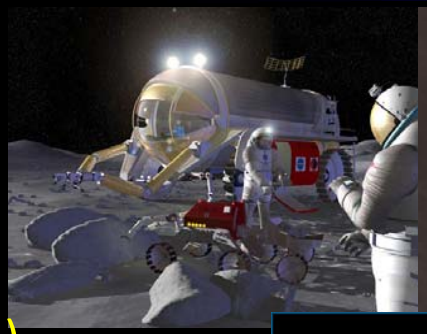
NASA's Missions

Exploration

- Local space environment
- Return to the Moon
- Manned presence on Mars (future)
- Space Biology/Human Health

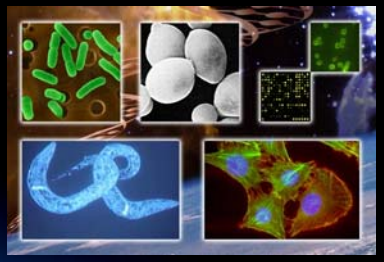
Science

- Understand the nature of the solar system and universe
- Near Earth Objects (NEO)
- Lunar sciences
- Astrobiology
- Earth Science/Environmental Monitoring/Energy Mgmt



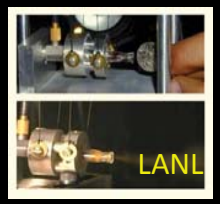
Roles of Very Small Spacecraft

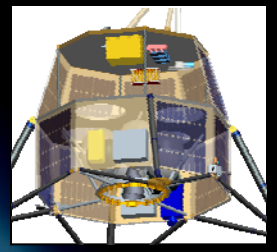
- Science and Exploration Missions
  - Space Biology
  - Space Sciences
  - Astrobiology
  - Space Physics
  - Lunar Sciences



- Technology Demonstrations
  - Propulsion
  - Communications
  - Mass reduction - MEMS and smaller
  - Autonomous operations
  - Formation flying/constellations
  - Novel space architectures - tethers
  - Evolvable, reconfigurable satellites

- Payload packages on larger spacecraft
  - Flight heritage from Cubesat missions
  - Use Cubesat derived technologies to support other spacecraft missions
    - Lunar Orbiters
    - Lunar Landers

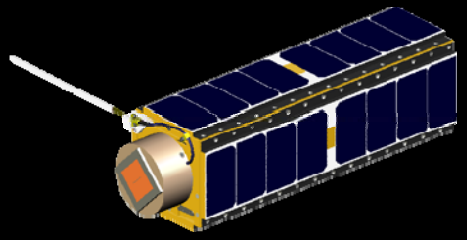


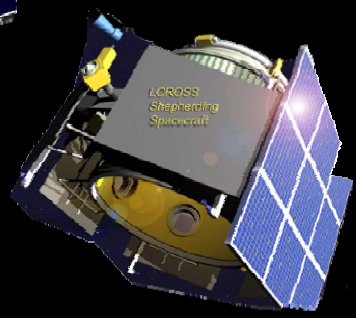


Small Spacecraft Projects

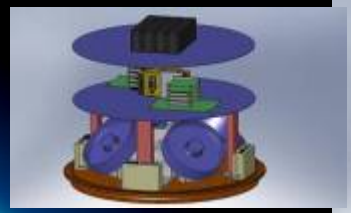
(active)

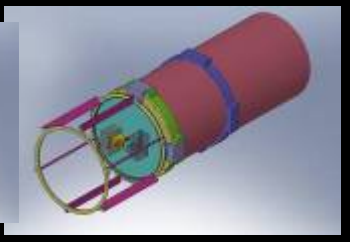
- **Micro/Nano Spacecraft**
  - **Genesat, GeneBox, flown in 2006**
  - **PharmaSat, 3 others (2008-9)**
  - **AstroBiology Small Payloads**
  - **NanoSail-D**
  - ***Target 3/yr beginning in 2008 => >6/yr (2009+)***



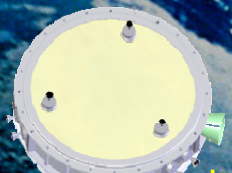


- Lunar Crater Observation Sensing Satellite (LCROSS - in development)

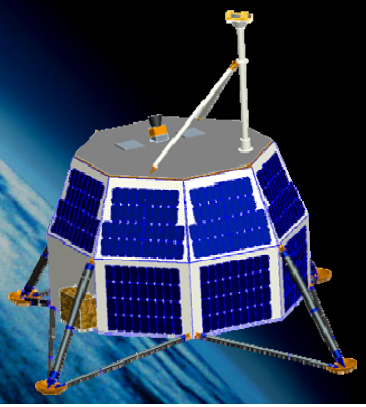




- Low-Cost Responsive Spacecraft "CheapSat" - in development



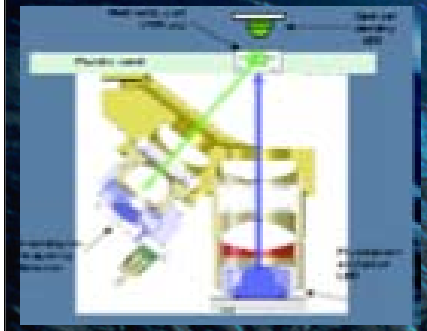
- Advanced Nano Spacecraft
- Common Bus (lunar lander concept shown); Modular Arch.; Multiple Embodiments

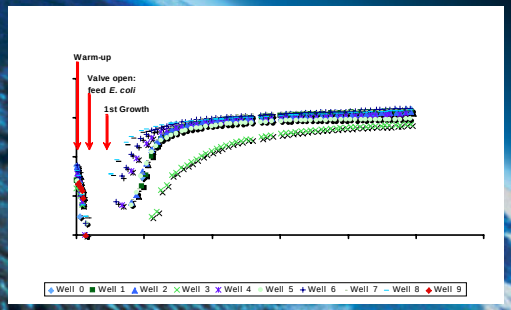


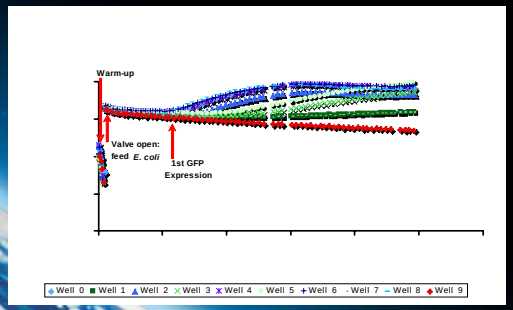
GeneSat-1 System/Mission Overview

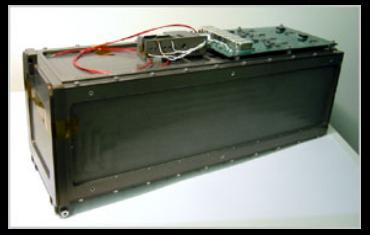
Launched 16 Dec 2006 aboard USAF Minotaur-1

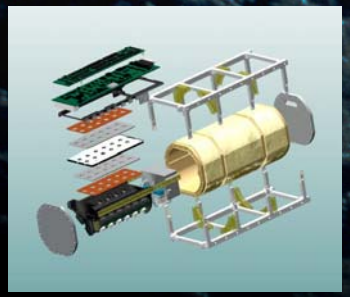
- Secondary Payload with Tacsat-2 primary
- 45° orbit inclination; 390 km altitude
- Spacecraft mass 7.1 kg (4.1 kg + 3 kg adapter)
- 4-5 W on-orbit average power
- 60 day mission duration; 96 hr Biology exp.
- Measured GFP and Optical Density w E. coli
- All Mission objectives fully accomplished

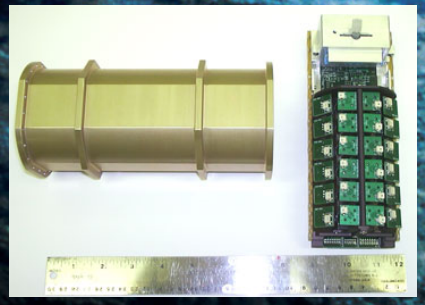


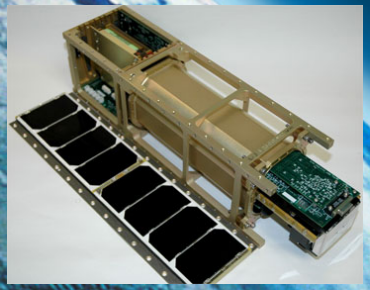


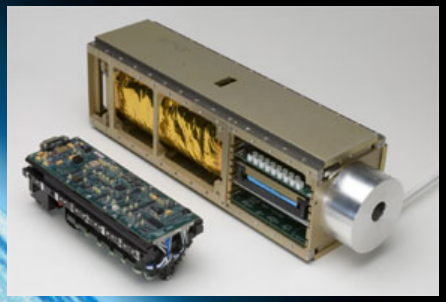










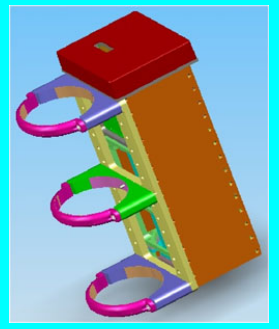


Genesat Performed Flawlessly: First Biological Nanosatellite Experiment

GeneBox: (Genesat Precursor)
Launched July 12, 2006

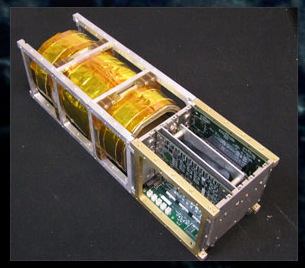
Bigelow Spacecraft Carries NASA 'GeneBox' for Tests in Orbit

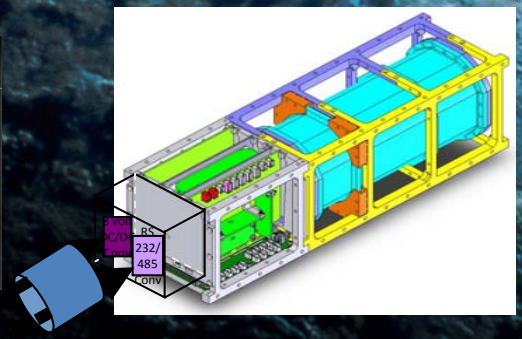
PRESS RELEASE
Date Released: Monday, July 17, 2006
Source: Ames Research Center



A NASA shoebox-size payload, called 'GeneBox,' is now orbiting Earth as a passenger inside Bigelow Corporation's one-third scale, inflatable Genesis I test spacecraft.

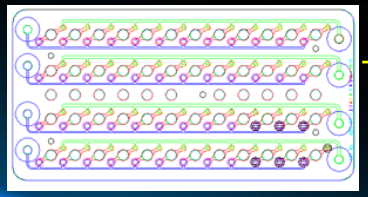
On July 12, a Russian rocket lofted 'GeneBox' into Earth orbit within Bigelow Corporation's Genesis I test spacecraft. Attached to the large inflatable spacecraft's internal structure, GeneBox contains a miniature laboratory. In future flights, it will analyze how the near weightlessness of space affects genes in microscopic cells and other small life forms.



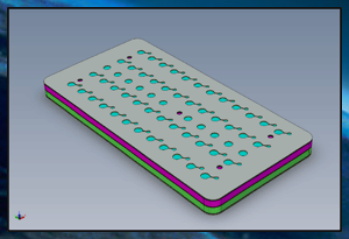


Pharmasat-1

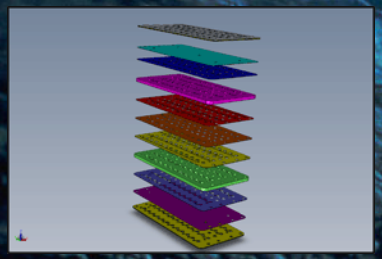
Microsatellite - Free Flyer Project



60-well BioFluidics card

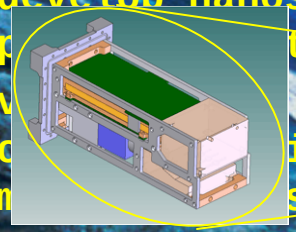


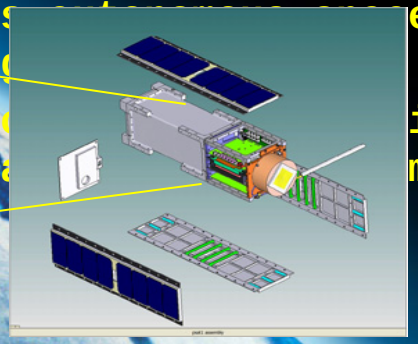
Card Laminate Assembly



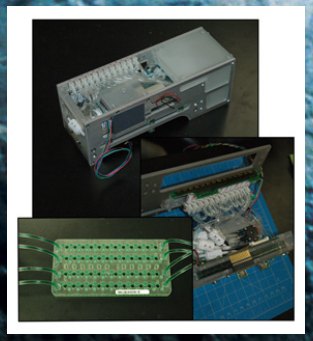
Card Assembly Exploded View

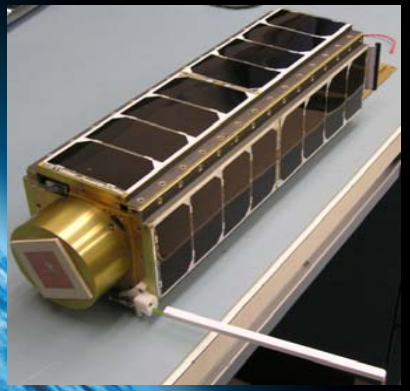
- Science goal: measure effects of antifungal agent on yeast
  - clinically accepted, well-controlled test protocols
- Manifested to launch w/ USAF Tacsat-3 1° spacecraft
  - Minotaur-1 launch vehicle, Wallops Flight facility; Jun08
- µSat Free Flyer: ESMD-funded, 4 mission, 5 year effort
  - develop nanosat-class
  - v





Fluidics/Sample Handling Block Diagram

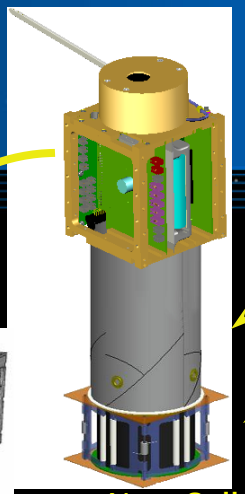




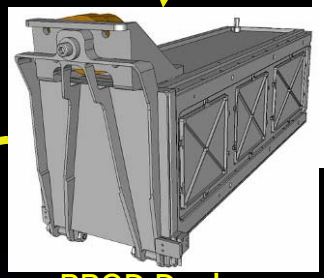
NanoSail-D Tech Demo Mission Overview

Objectives
- Primary
  - *Establish ARC-MSFC collaborative relationship for small satellite initiatives*
  - *Deploy solar sail leveraging directed work performed by MSFC in prior years under the SMD In-Space Propulsion Program*
- Secondary/Opportunity
  - Demo Orbital Debris Mitigation technology – drag sail
  - Ground Imaging to reduce spacecraft instrumentation
  - Add to flight experience - ARC Bus "light" experience

Relevance
- Planetary & Heliophysics Science missions
- Most smallsats orbiting above 450 km struggle to meet <25 year life MOD requirement



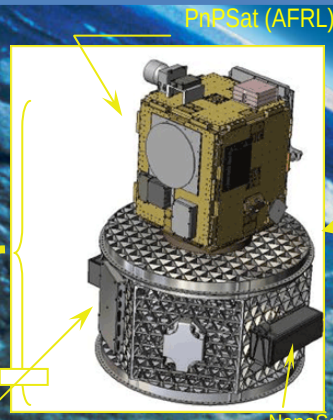
NanoSail-D
(Aluminum Closeout Panels Not Shown)



PPOD Deployer
(Cal-Poly)

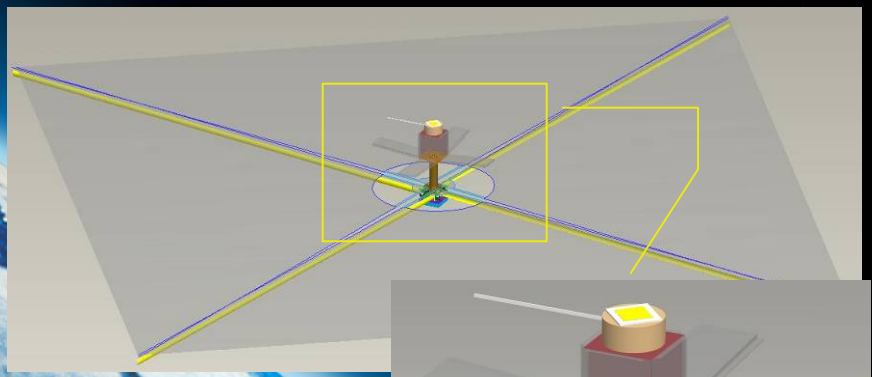
Stowed Configuration

Falcon-1 Third Launch
(SpaceX)



Ride Share Adapter
(Space Access Technology)

Launch Date: June 10, 2008
Launch site: Omelek Island, RTS (Kwaj)
Orbit: 685 X 330 km, 9º inclination
De-Orbit Period: Approximately 14 days



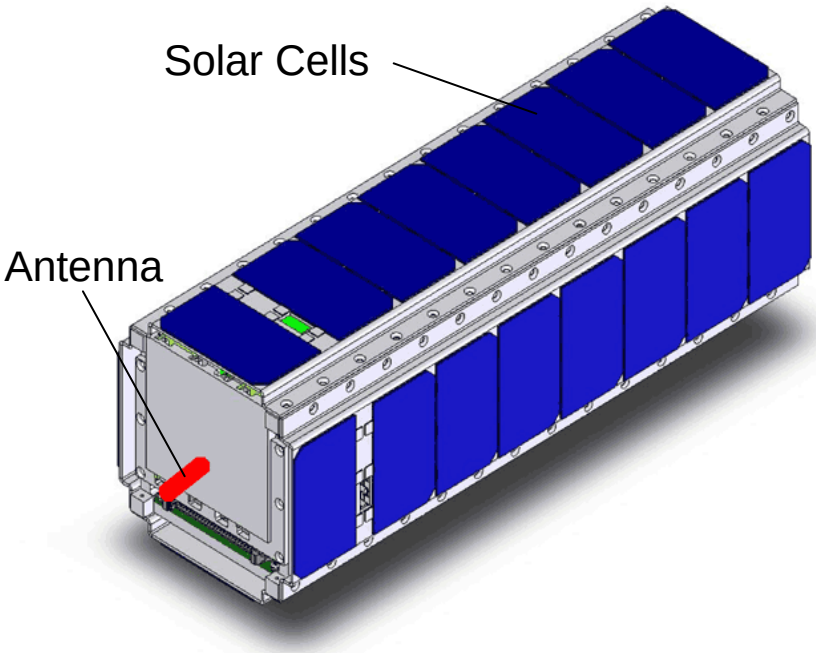
- GeneSat heritage Bus
- 10 m^2 , 3 micron CP-1 Sail
- 2.2 m Tape Spring Booms
- UHF & S-Band comm
- Closeout Panels
- Magnetic Passive Stabilization
- E/PO outreach

Deployed Configuration

O/OREOs Satellite Concept

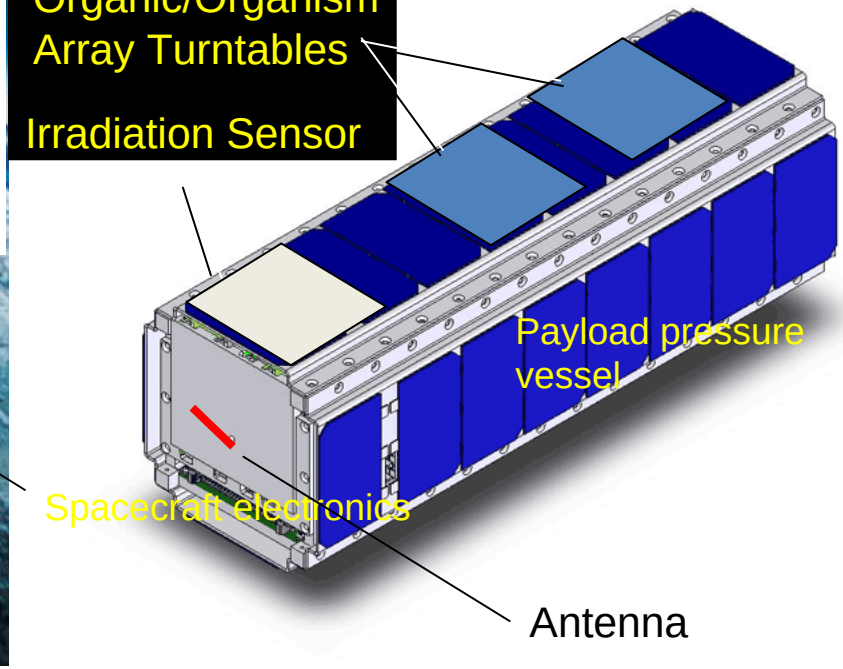
Organism/ORganic Exposure to Orbital Stresses

"Top" Side



Exposure experiments (organics, organisms) to space environment with on-orbit monitoring/ analysis (can vary solar exposure amount, quality, and timing) using internal UV (or other) Raman

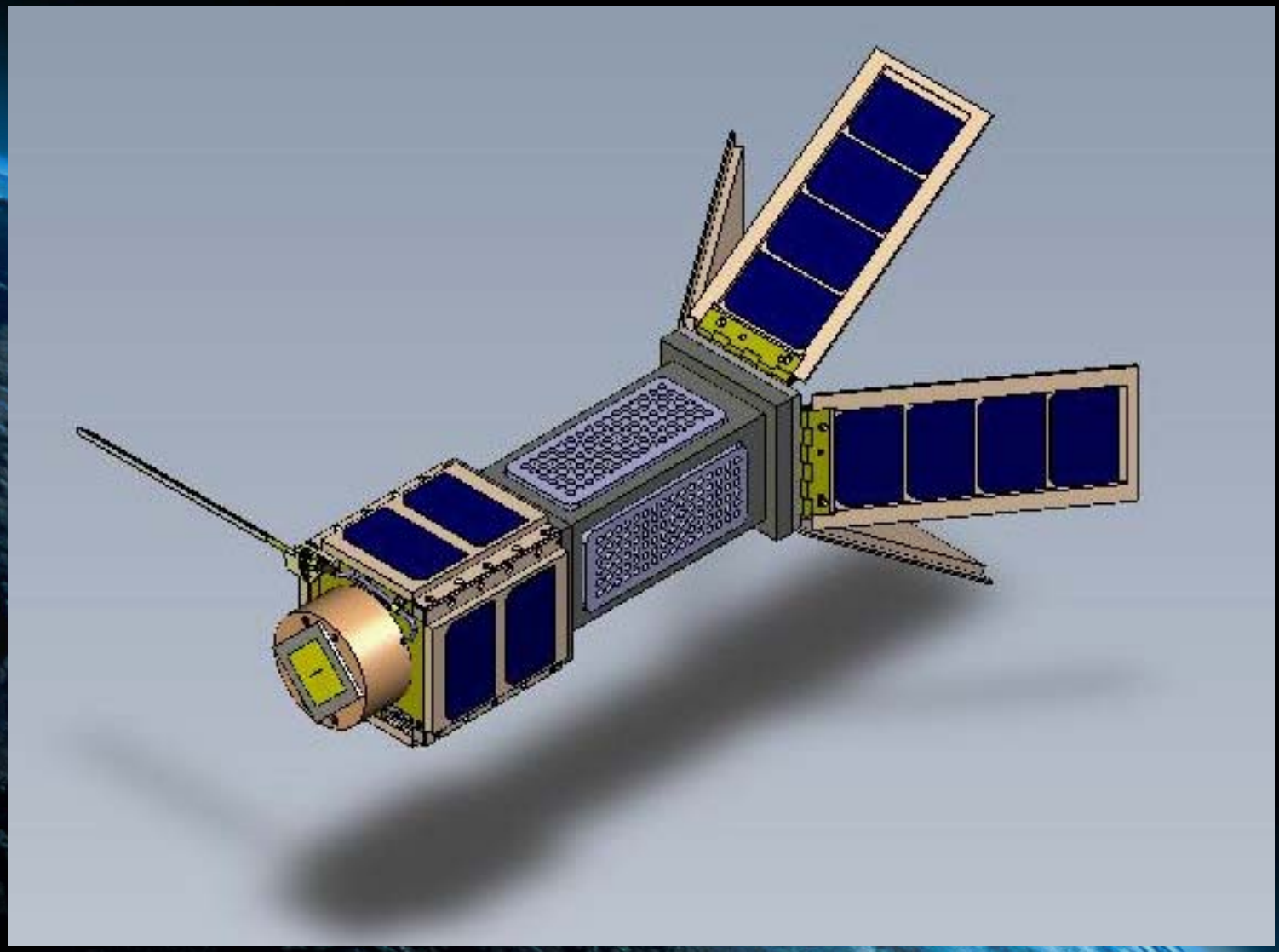
"Bottom" Side



Spacecraft can be naturally tumbling, or may provide micro-pointing capabilities, if available.

Mission length is determined by organic exposure times desired.

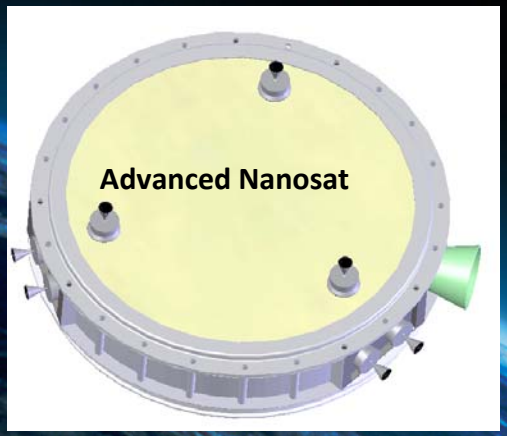
Astrobiology OOREOS Concept
(notional)



Advanced Nanosats

Advanced NanoSat Program Goals:

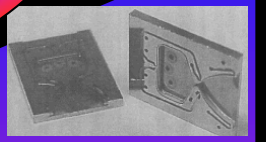
- **High Capability** Achieve 80% capability of larger spacecraft (100-150 kg class)
- **Low Recurring Costs** ~$ 1 M for bus
- **Leverage** Latest technology advancements & existing Ames Nanosat bus (GeneSat) for space validation of key sub-systems
- **Enable Space Exploration** Big science in a small, highly functional form factor



Advanced Nanosat 2

- Delta-V >700 m/s
- 3-axis Stabilized, <10 arc-sec pointing
- Ultra-low power ADACS
- Advanced Multifunctional Materials
- <4 kg bus mass
- 6 W payload power
- 1 kg payload capability

NASA Ames NanoSat
In-Space Validation of Key Technologies



Micro-Propulsion

Nano-ACS Thrusters

High Capacity, Lightweight Batteries

Advanced Nanosat I

- High Data Rate Downlink (Gb/day)
- 30 arc-sec pointing accuracy
- High performance Avionics
- Nano-thruster validation
- <5 kg bus mass
- Mission Opps

NASA Ames NanoSat
In-Space Validation of Key Technologies

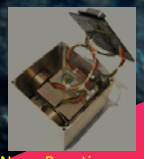
5.8 GHz Transceiver

Advanced Nanosat X

- Delta-v > 300 m/s
- Sub-arc min pointing accuracy
- Ultra-low power commercial CPUs
- Micro/Nano based attitude position & tracking sensors
- Integrated GPS receiver/antenna

GPS Receiver

Sun Sensor



Nano Reaction Wheels

Mini Star Tracker

High Performance, Low Power Computing

Ultra light weight IMU

Enables a Variety of Science Missions:

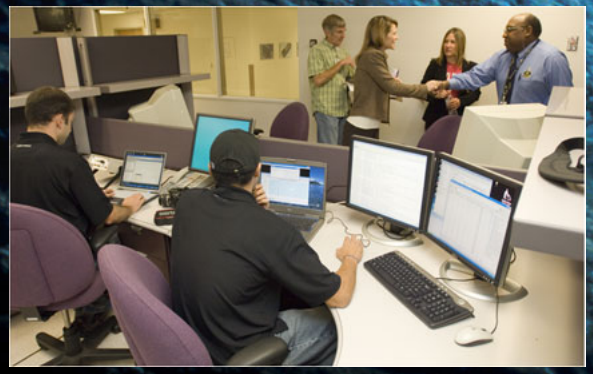
Precision Formation Flying
Remote Imaging- Earth/Lunar Science
Autonomous Satellite Maintenance
Space Physics & Astrophysics
Exploration- Lunar, NEOs, Comets

NANOSAT CAPABILITY

6-9 Months | **12 Months** | **12-15 Months** | **Month 18** | **18-24 Months**

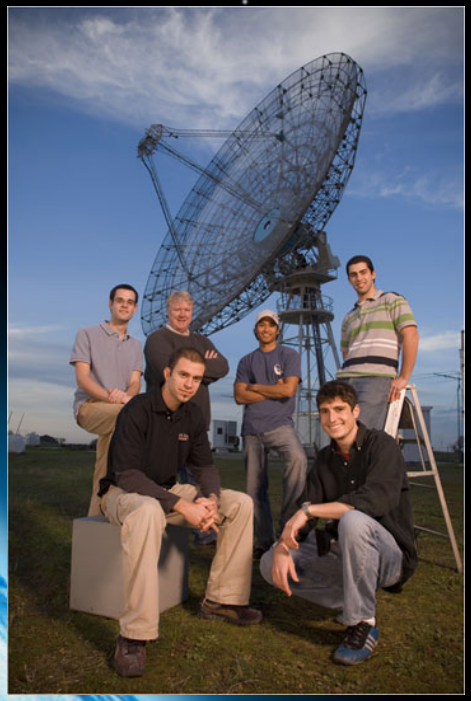
Roles of Cubesats

- Education and training
  - Space systems development and test
  - Systems Engineering
  - Operations



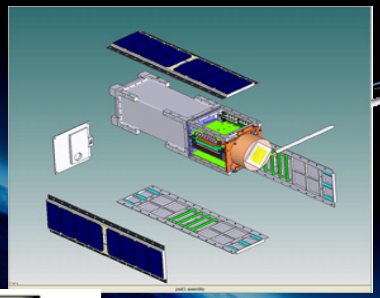
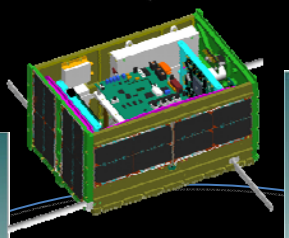
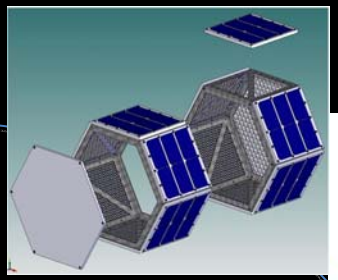
Santa Clara University

CalPoly SLO



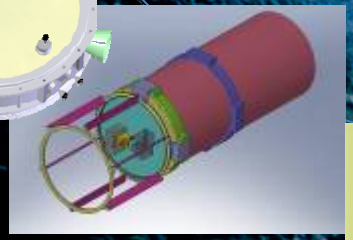
SRI/Santa Clara

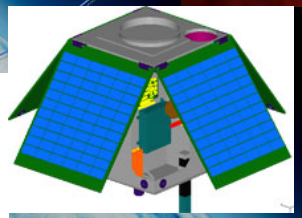
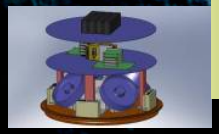
Micro-Nano Spacecraft Candidates







jwh 090107

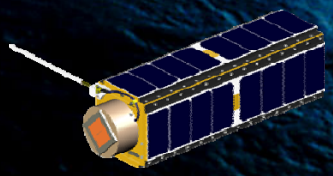
Nanosatellite Roadmap (notional)

2008 | 2009 | 2010 | 2011 | 2012

Missions/Science Disciplines

- Space Biology
- Astrobiology
- Space Sciences / Space Physics
- Technology Demo

Platforms



- 3U Cubesat
- 6U Cubesats / Microsats
- Microsatellite Sorties
- Microsatellite Constellation

Launch Vehicles (Domestic)
(- indicates flown** or manifested*)

Minotaur I**

Falcon 1*

Minotaur IV

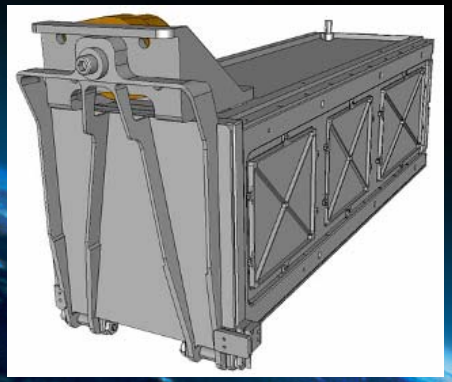
Super Strypi

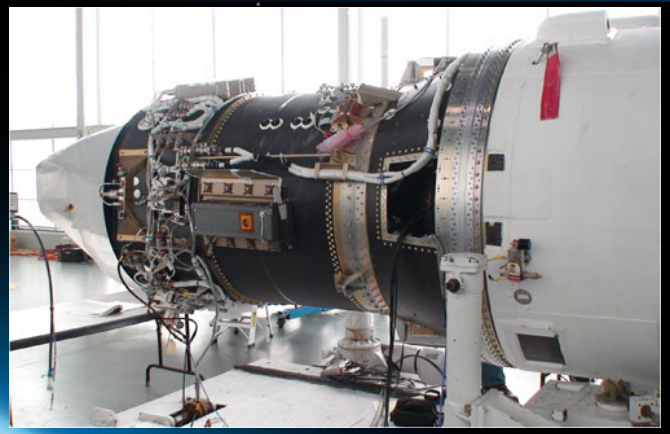
Taurus

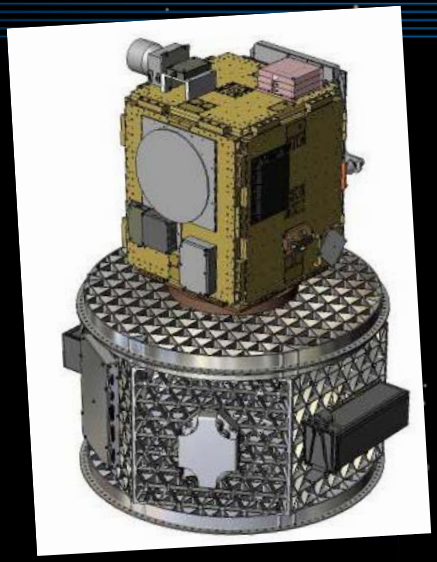
Atlas V

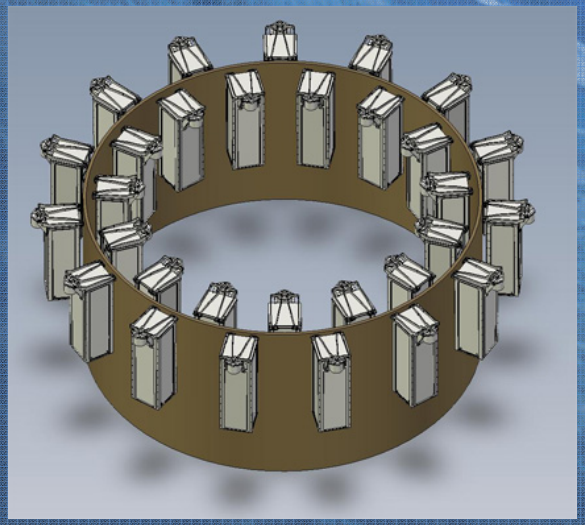
Delta IV

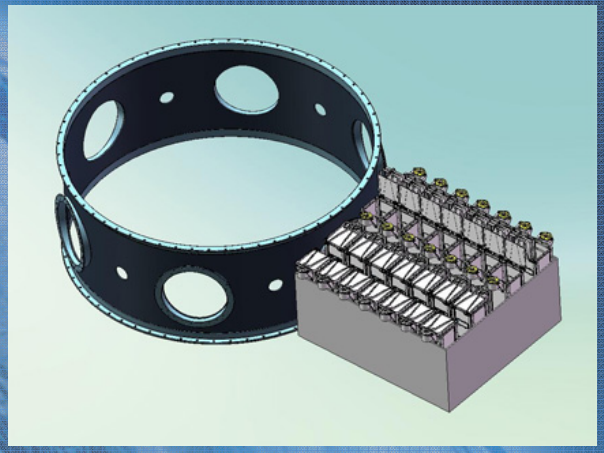
PPOD Adapter Concepts











Notional Concepts only

ARC NanoSatellite Missions Office

1-Stop Shopping

Micro-Nano Spacecraft and Payloads

Collaborator's Guide

The **Micro-Nano Spacecraft and Payloads (MNSP) Office** designs, develops, and executes missions according to NASA Procedural Requirement 7120.5D–NASA Space Flight Program and Project Management Requirements. This user's guide presents concise representations and examples of standardized processes, documentation, and interactions required for each element of a spaceflight mission. The examples provided are ones developed over the course of the GeneSat-1 mission as well as other experiences and resources developed for our current PharmaSat-1 mission slated for launch in August 2008.