Picosatellites and Nanosatellites at The Aerospace Corporation

In-Space Non-Destructive Inspection Technology Workshop
Feb 29 – Mar 1, 2012
Johnson Space Center
Houston, Tx

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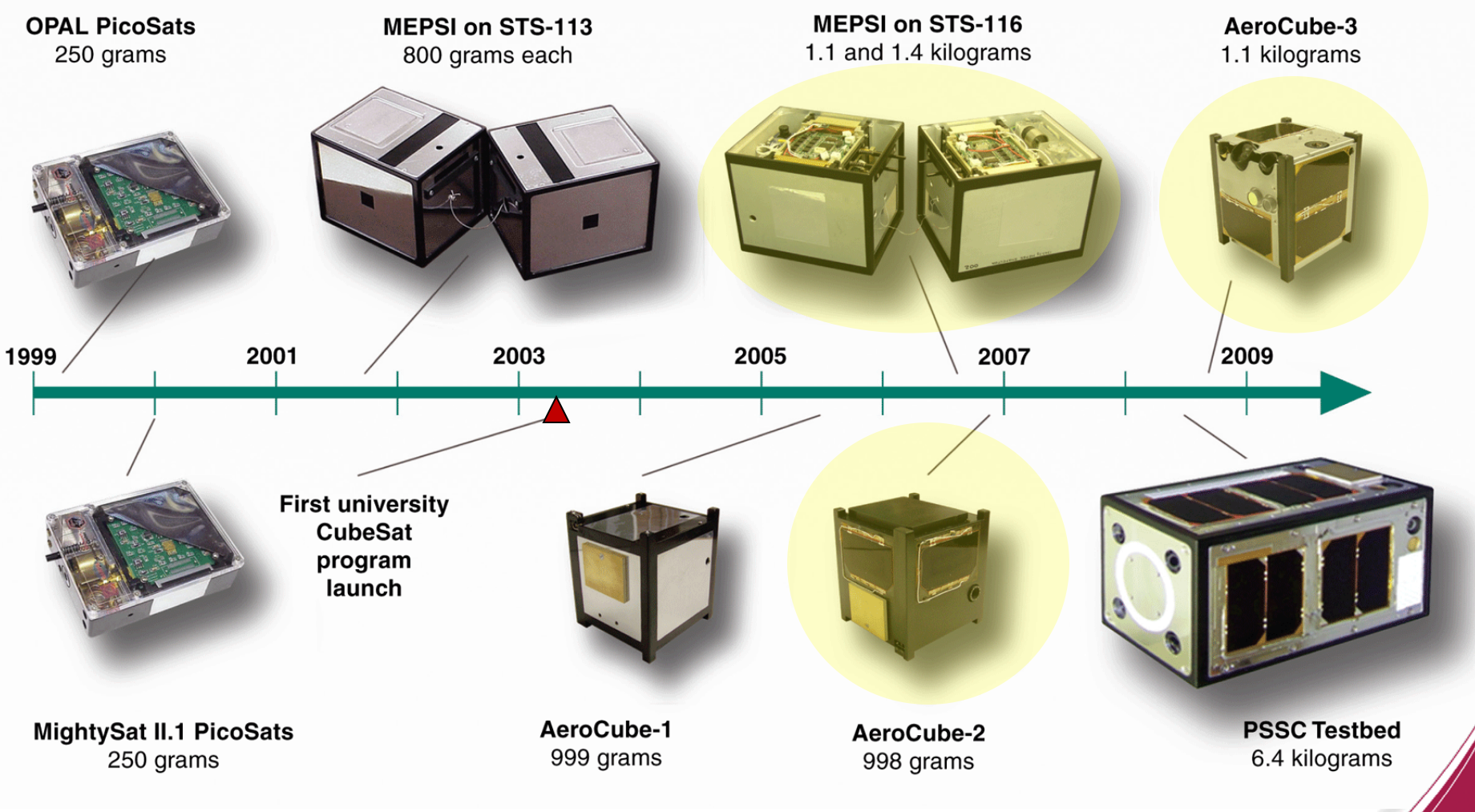
Outline

- Past Missions and Experience
  - *MEPSI Satellites*
  - *Aerocube Satellites*
  - *PSSC2*

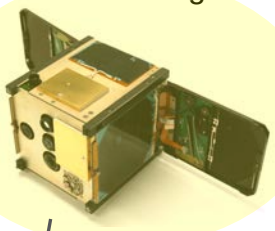
- Autonomous Inspector Technologies
  - *Imaging Capability*
  - *Attitude Control*
  - *Propulsion System*
  - *De-orbit Capability*

The Aerospace Corporation Pico and Nanosatellites



The Aerospace Corporation Pico and Nanosatellites

AC4
1.2 kg



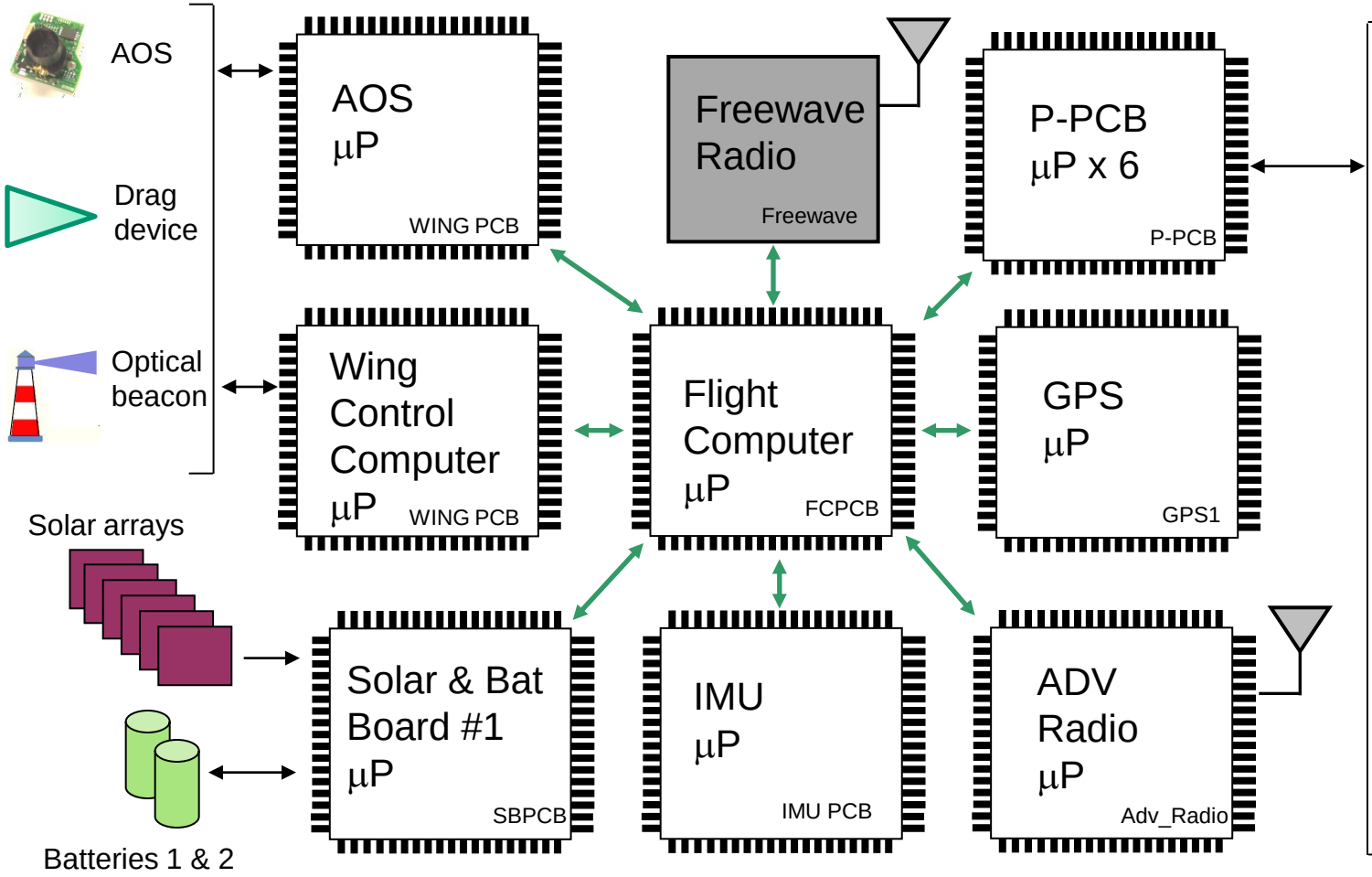
2010 2012 2014

PSSC2
3.5 kg

2011 The Aerospace Corporation's Picosat Capabilities

- Design, build and operate miniature satellites (< 7 kg)
  - Average of 1 flight per year for last 10 years
- Develop custom sensors
  - Sun sensor; Earth sensor; RAM sensor; Visible cameras
- Develop custom capabilities
  - Cold gas propulsion system; De-orbit capability
- Mature and capable bus
  - Robust with redundancies
  - Precision short-term tracking (< 1 degree precision)
  - High peak-power payloads (30W for 5 minutes in 1U form factor)
- Strong organization
  - The Aerospace Corporation is a California nonprofit corporation that operates a Federally Funded Research and Development Center dedicated to technical excellence in National Security space.

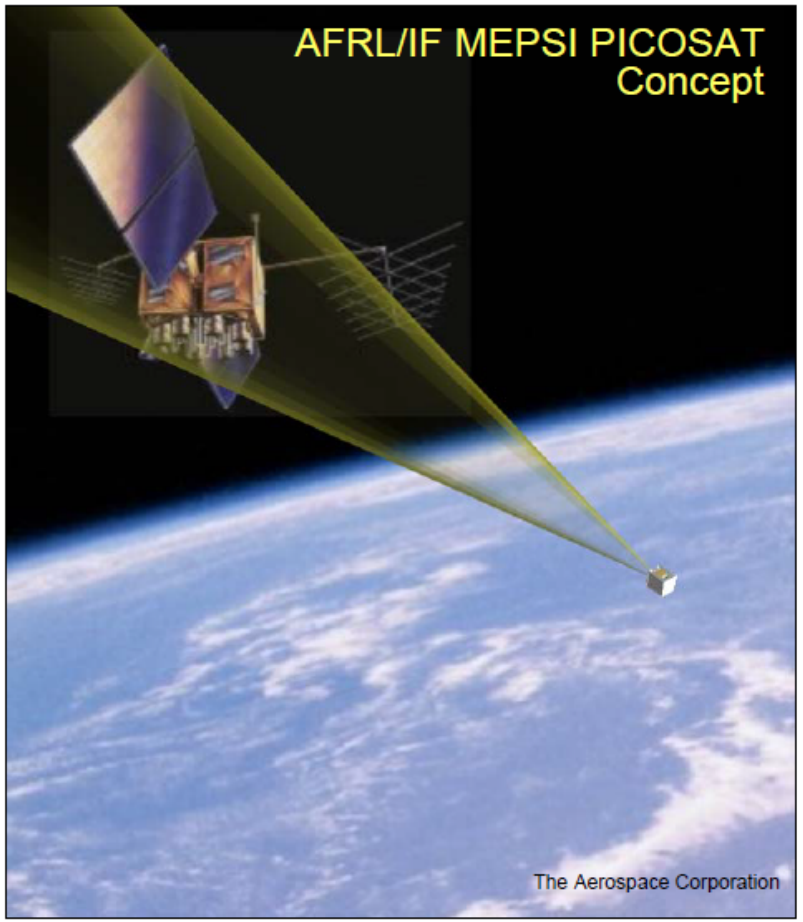
2011 Common 1U Picosatellite Avionics and Sensors



2006 MEPSI* Mission Goal

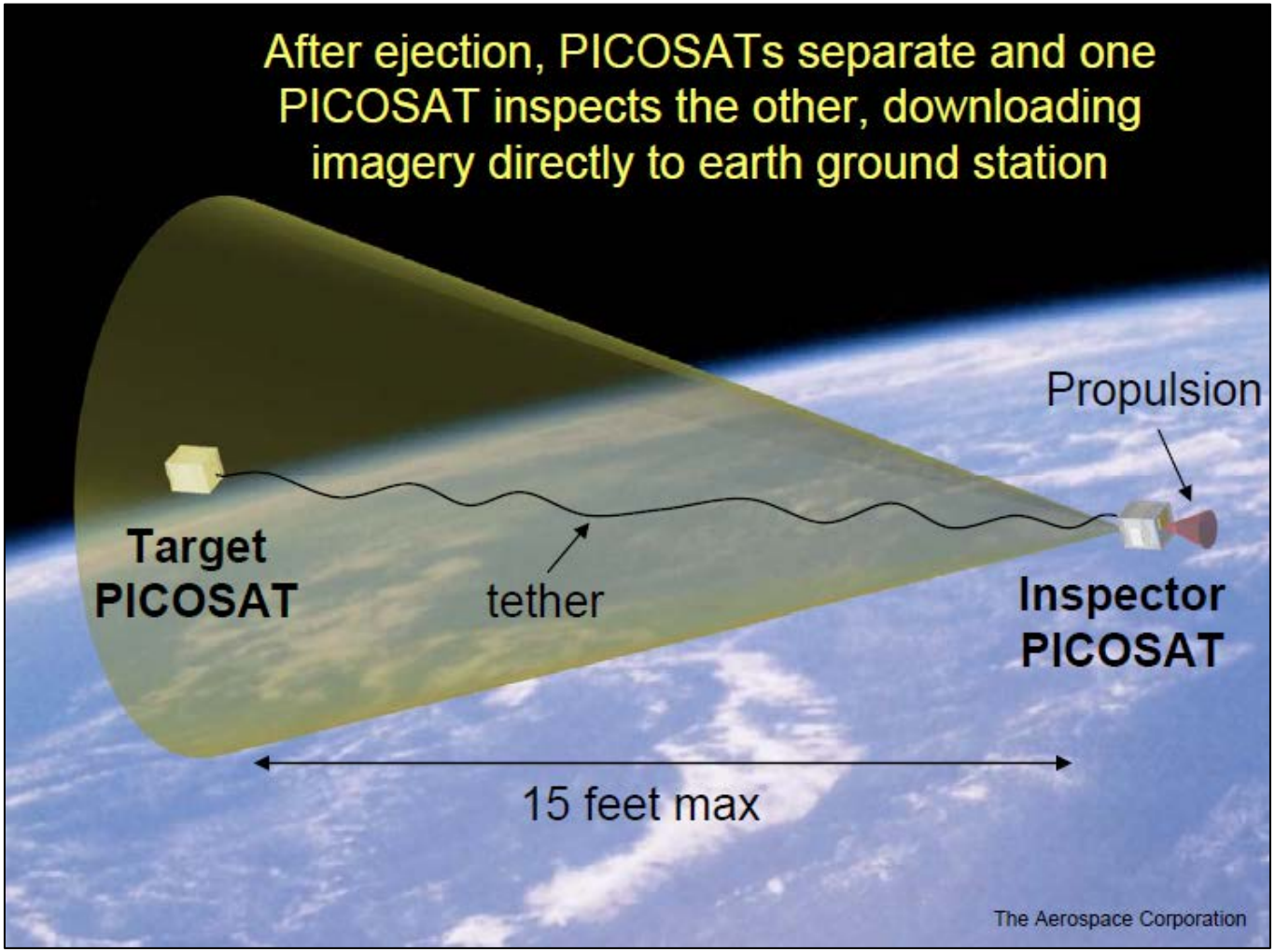
Launched December 2006

- MEPSI Concept legacy
  - Derivative of UFO (1995)
  - Presented to SERB in 2000
- Host-resident daughtership
  - ~1 kg in mass
  - ~Cubesat size
- Requirements
  - Ejection system
  - Sense host location
  - **Propulsion**



* MEPSI = Micro-Electromechanical-based PICOSAT Satellite Inspector

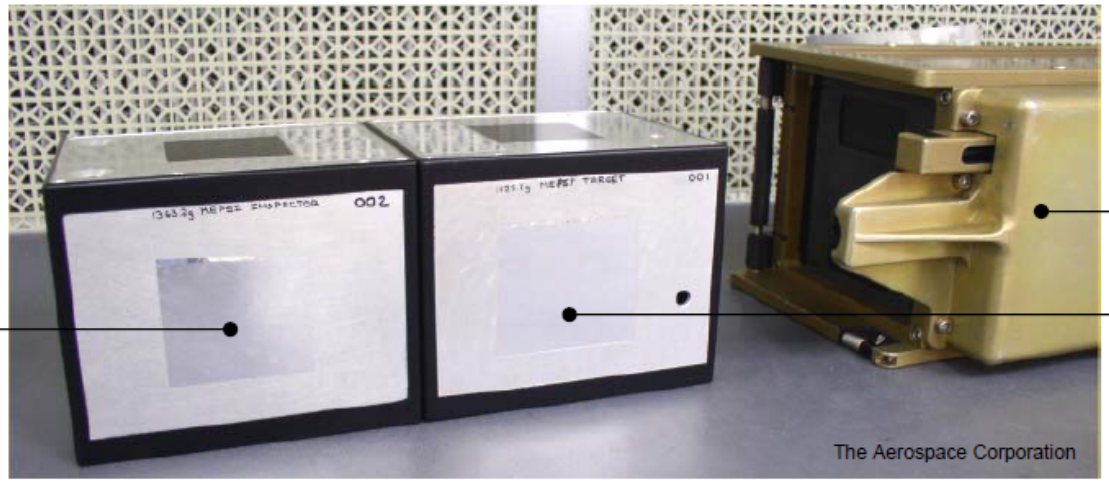
2006 MEPSI Mission Concept



2006 MEPSI Mission Hardware

Delivery included one launcher and two picosatellites

"Inspector"
4x4x5"
1365 g
60 w-hr battery
$I_x = I_y = 10.3$ lbm-in^2
$I_z = 8$ lbm-in^2



Space Shuttle
Picosatellite
Launcher
(SSPL) 4410

"Target"
4x4x5"
1125 g
60 w-hr battery

THE AEROSPACE CORPORATION

- Developer, operator
- Supplied ¾ of development funding
- PI from 2004-2006

DARPA

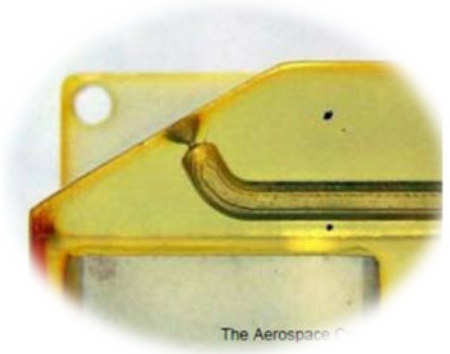
Supplied ¼ of required development funding

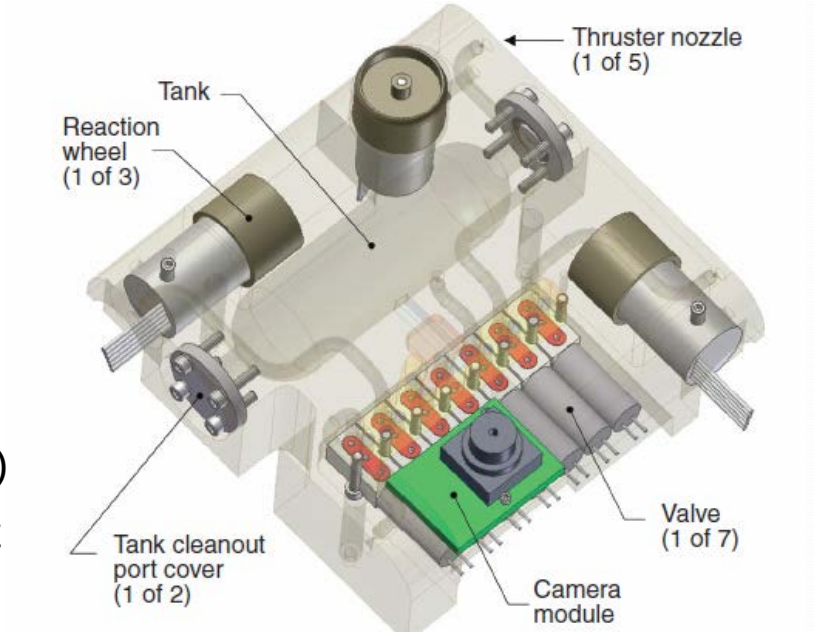
MEPSI PI from 2000-2004

- Capabilities
  - 2W radio link (915 MHz)
  - Space Shuttle compatible launcher
  - Triaxial magnetic and rotation sensors
  - VGA cameras
  - 5-DOF Cold gas propulsion
  - Triaxial reaction wheels
- Mission Results
  - Satellites nominal but short lived

2006 MEPSI Propulsion Unit - Design

1x4x4 inches
250 grams

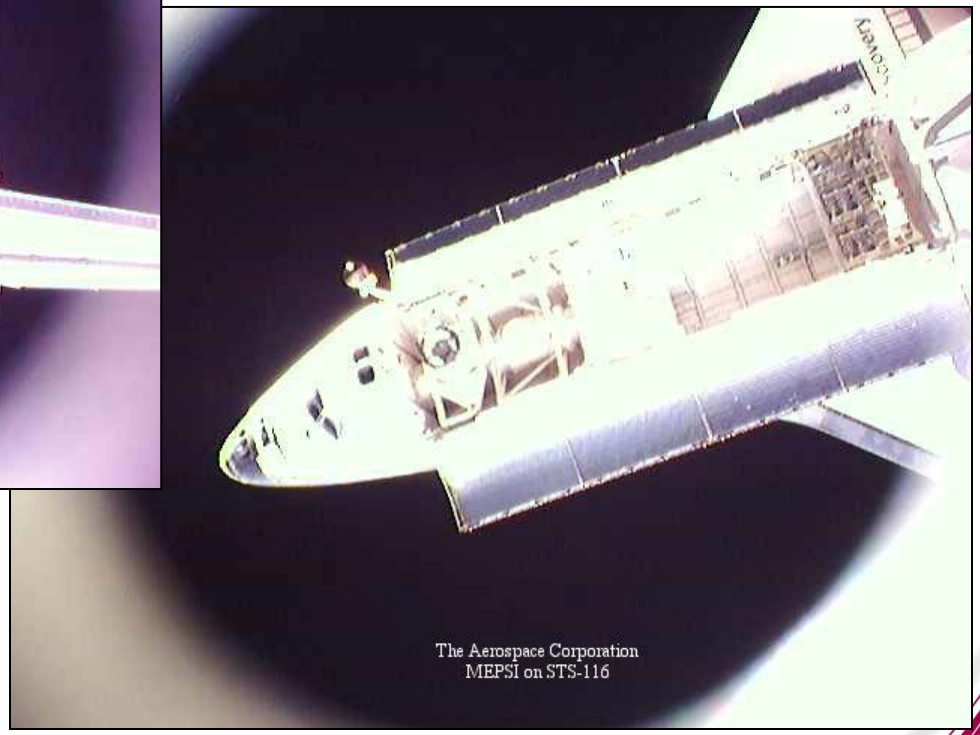




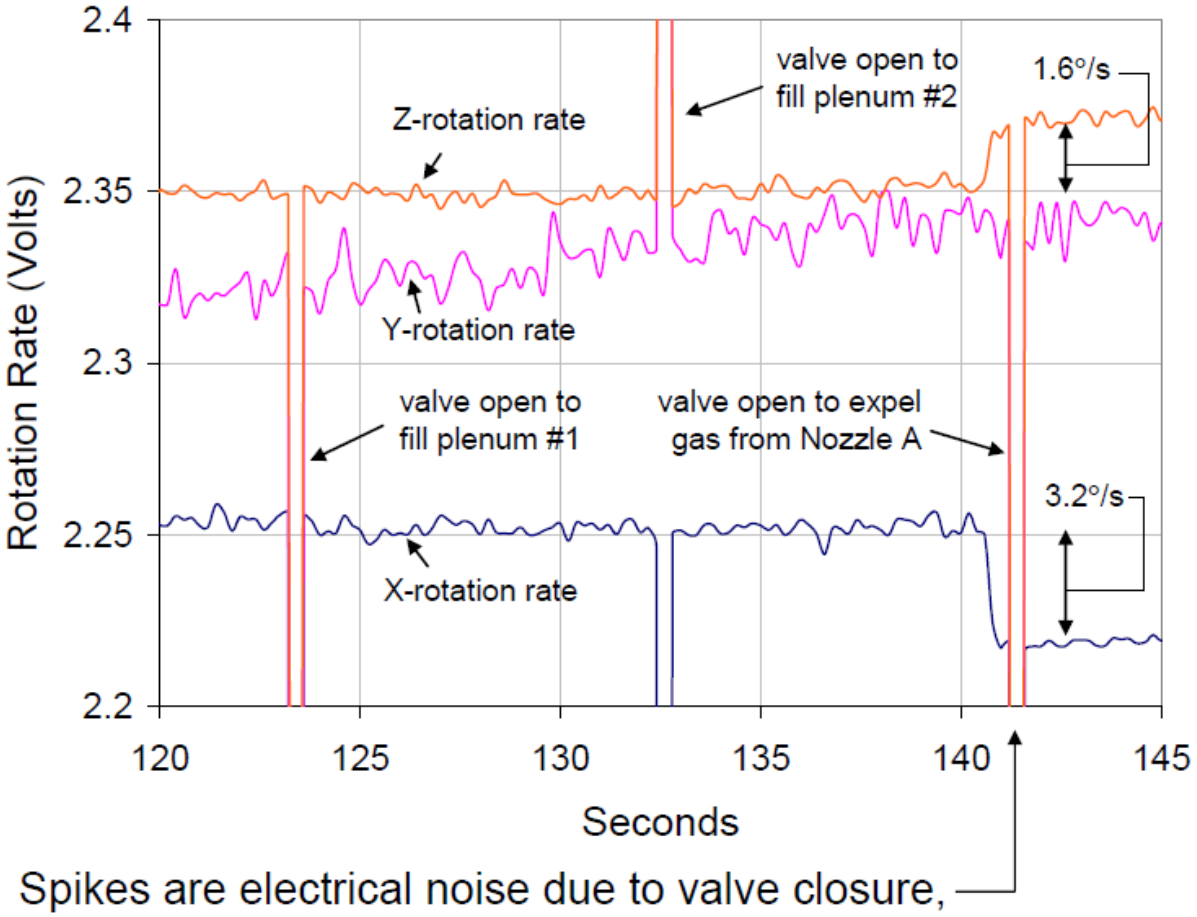
- Cold-gas propulsion
- Fabricated with stereolithography (leakless)
- Designed for use with refrigerant propellant
- Capable of 20 m/s delta-V
- 1x4x4 inches and 250 grams

STS-116 (Discovery)

2006 MEPSI Mission Results - Photographs

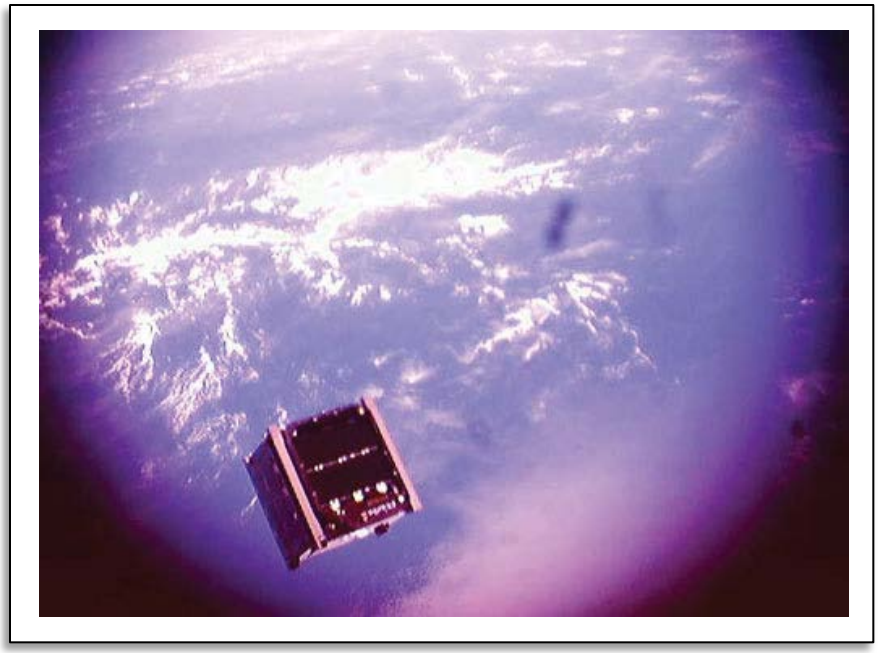


2006 MEPSI Mission Results - Propulsion



2006 AeroCube-2: 1-day of fame

Launched April 2007; ~1kg, 1U

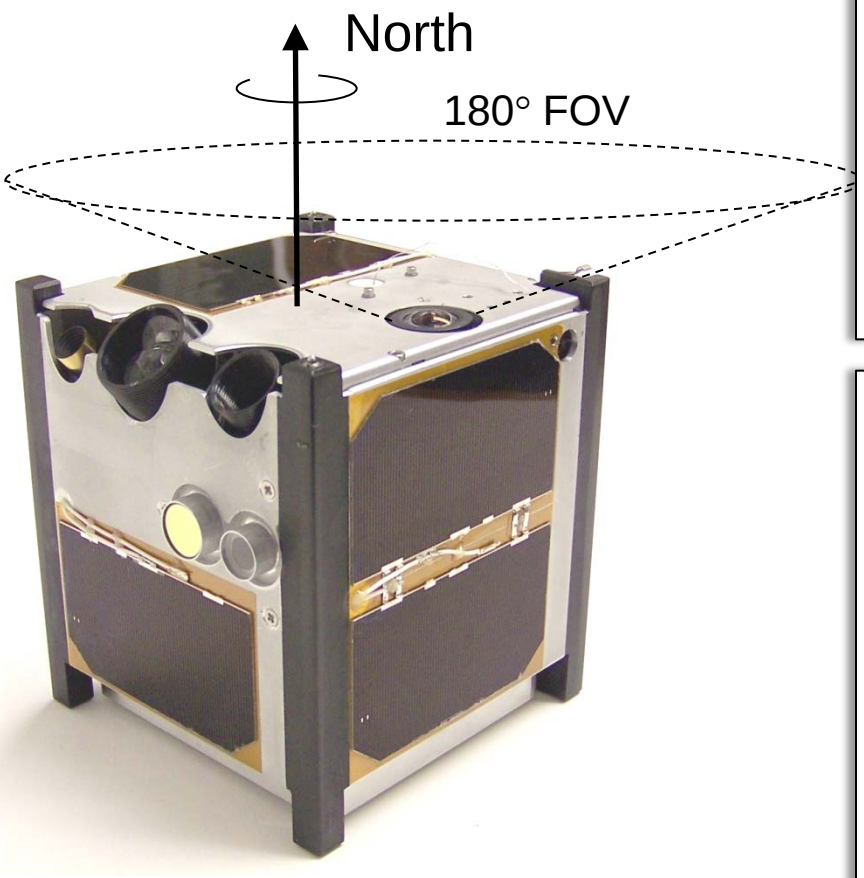


AeroCube-2 CubeSat

- A picture of the Cal Poly CubeSat CP-4 taken by AeroCube-2—the first and, so far, only instance of one CubeSat photographing another.

2008 AeroCube-3

Launched May 2009; 1kg, 1U

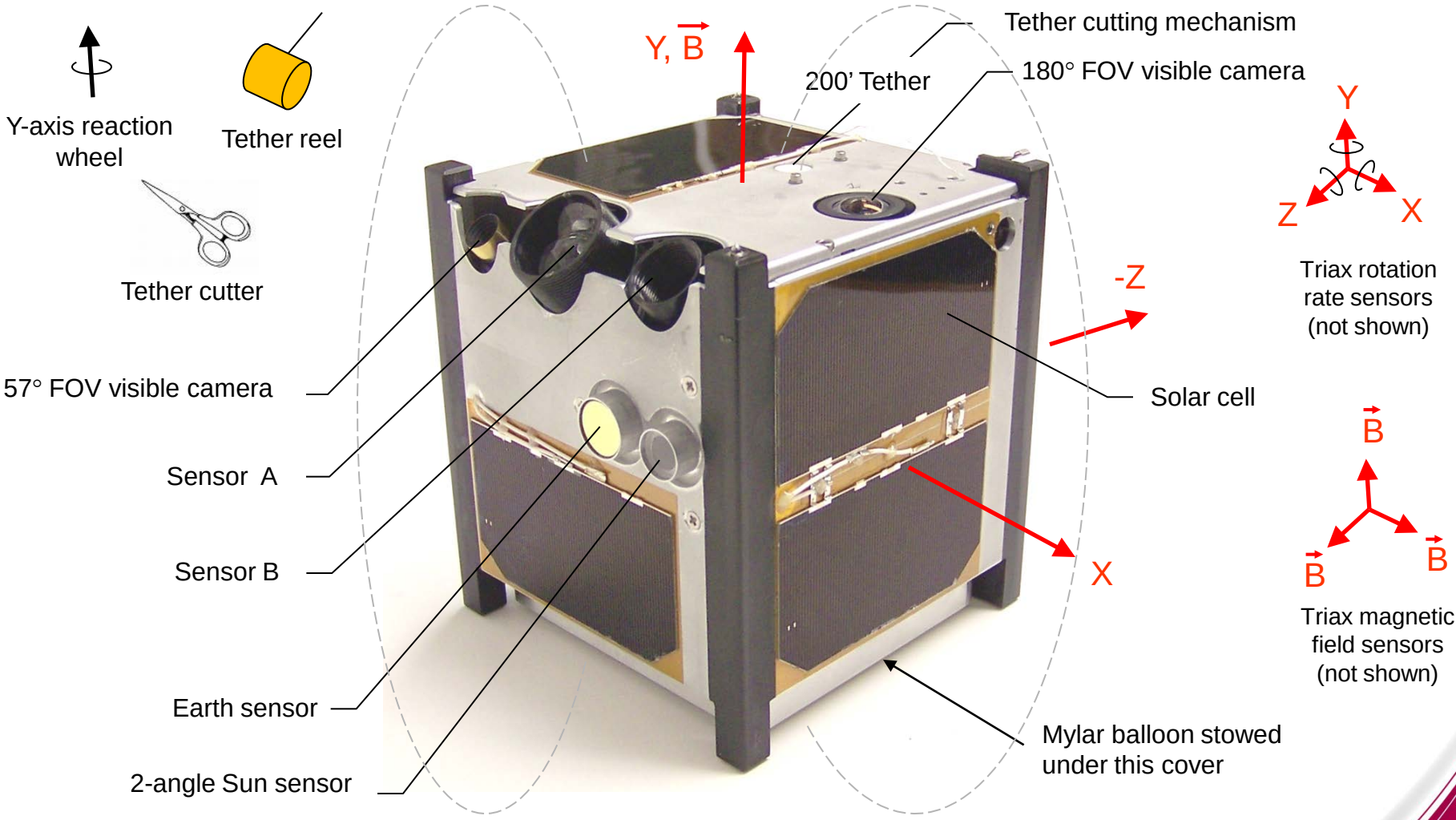


AeroCube-3 CubeSat

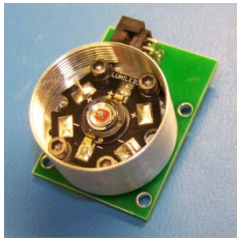
Central Mexico

California Coast

2008 AeroCube-3 Features



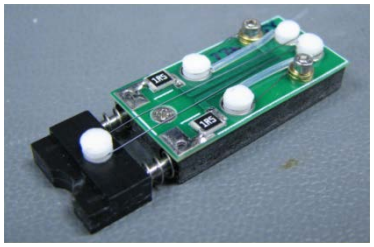
2008 AeroCube-3 Technology



High-brightness LED

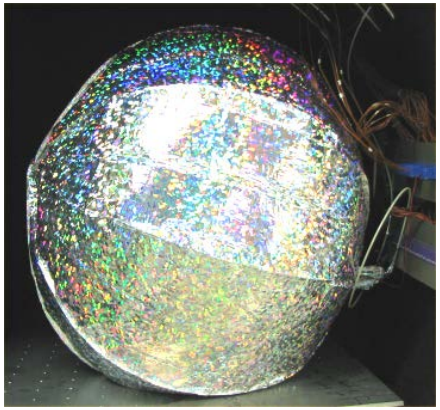
Tether Reel

Inflation Module w/ balloon pressure sensor

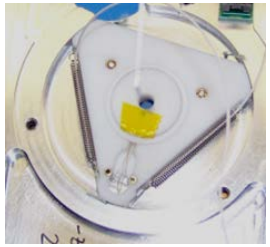


Balloon Cover Latch

AeroCube-3 (1084.4 g)



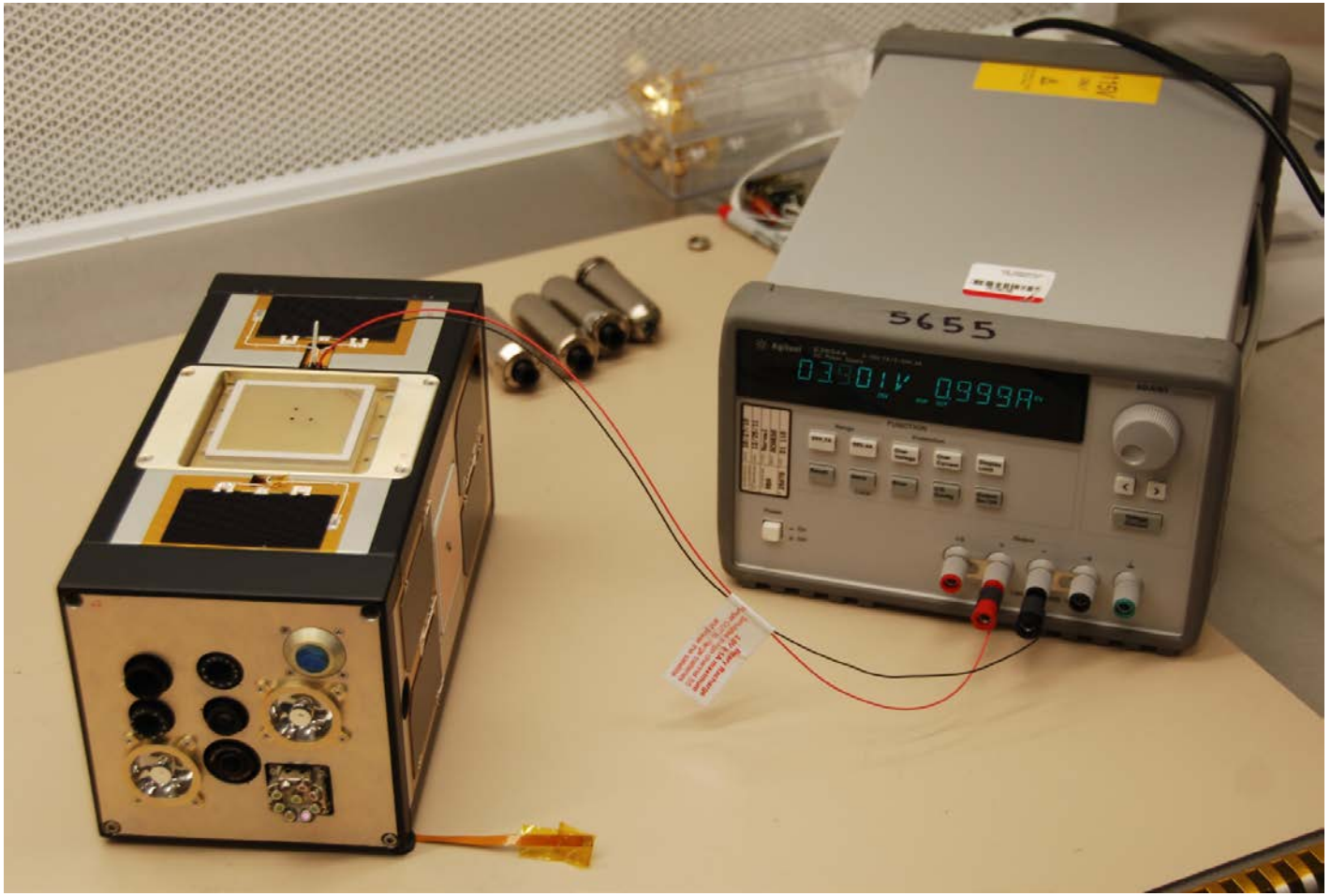
24 inch dia Balloon



Tether Cutter

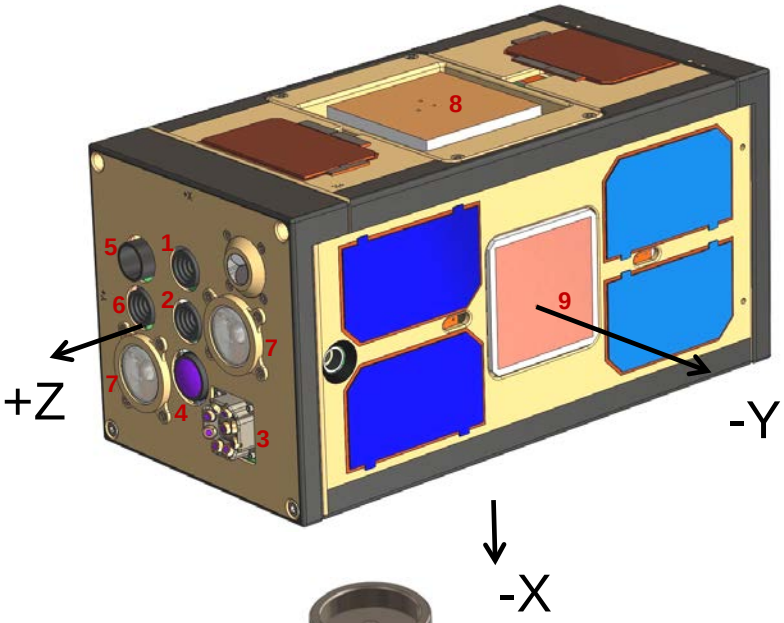
2011 PSSC2 Nanosatellite

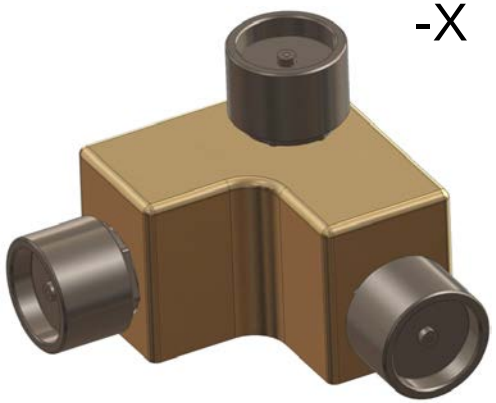
Built by Aerospace for STS-135 mission, flown July 20-Dec 7 2011



2011 PSSC2 Design

- Magnetic torque coils to detumble or spin-up the spacecraft
- Three orthogonally mounted reaction wheels for pointing control
- Earth horizon sensor for nadir sensing
- Magnetometers to provide full three-axis knowledge of orientation
- Sun sensors to orient various faces to the sun to perform solar cell experiments
- **Demonstrated closed-loop, 3-axis attitude control based on sun, earth, and magnetic field sensors**





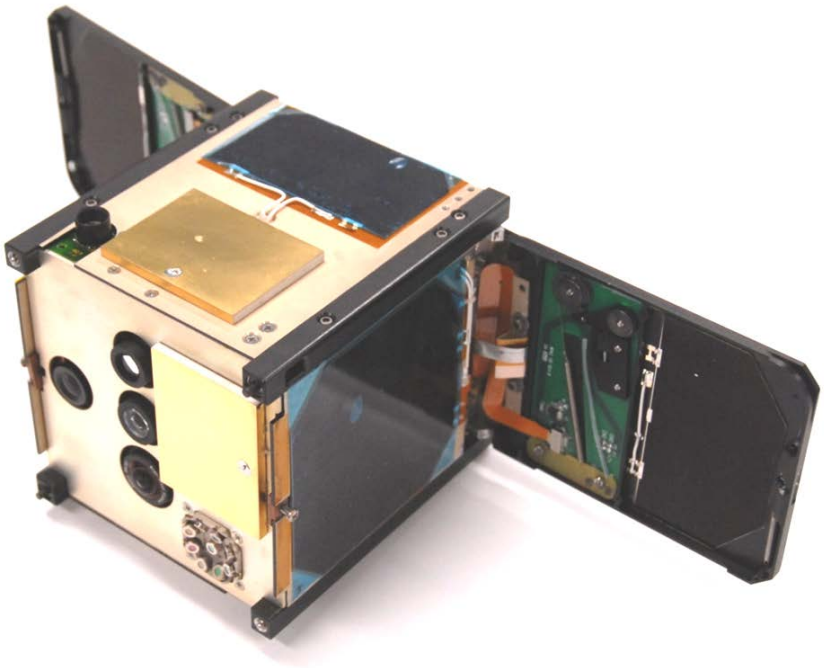
Reaction Wheel Block

PSSC-2 photograph of Atlantis on STS-135
40 seconds after deployment
Narrow angle lens

2011 AeroCube-4

To be Launched Fall 2012; three 1kg, 1U CubeSats

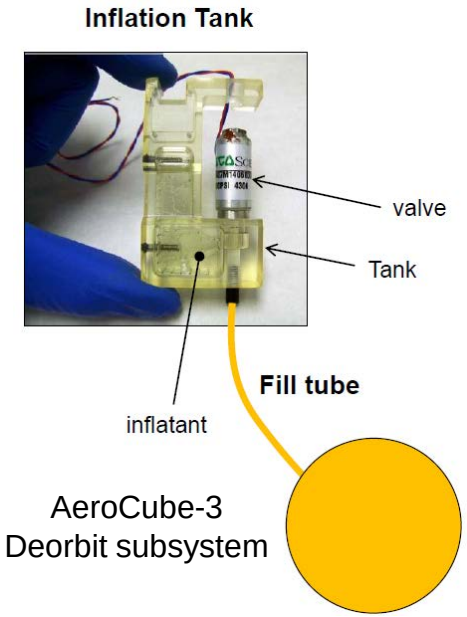
<u>Functionality (new in bold)</u>
Radio1 (915 MHz, 1 W)
Radio2 (915 MHz, 1 W)
GPS
Deployable panels
Non-inflatable deorbit device
3 cameras (1600x1200)
3X Reaction wheel
3X Torque coils
Redundant architecture
On-orbit software reprogrammability
Lithium Ion batteries (2 x 18650)
Magnet field sensors
Earth and sun sensors
High fidelity 3-axis rate gyro

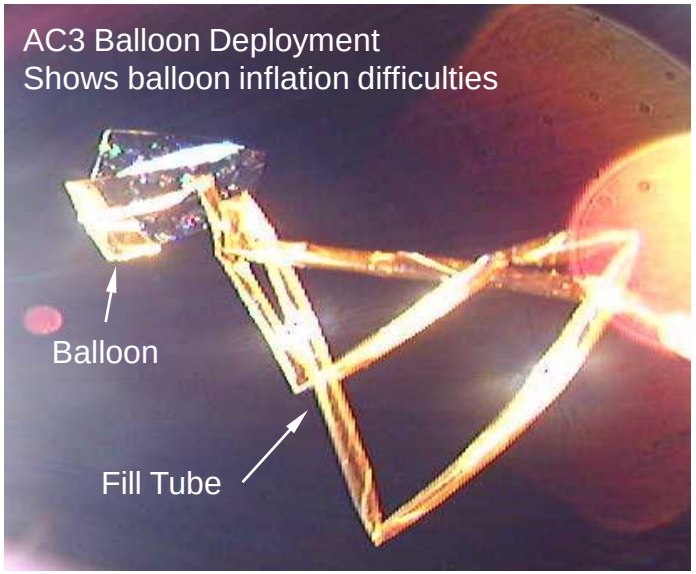


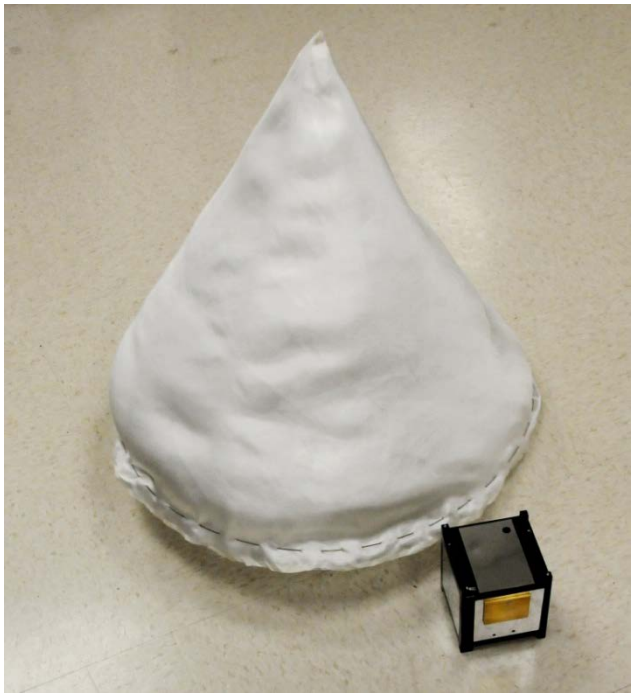
<u>Closed-Loop Attitude Control based on IMU</u>
Capable of < 1 degree of pointing precision

2007, 2011 Deorbit Capabilities

- Developed to meet FCC 25-year deorbit requirements
  - Orbits above ~700 km in altitude require assistance to deorbit within requirement
- AeroCubes 2 & 3 contained balloons
  - Difficult to inflate
- AeroCube 4 possesses a mechanically deployed, parachute-like, deorbit device







AeroCube-4 Drag device shown next to a CubeSat

Conclusion

- Over the past 13 years The Aerospace Corporation had developed and flown many of the enabling technologies for an Autonomous PicoSatellite Inspector
  - *High resolution imagery*
  - *3-axis attitude control*
  - *Cold-gas propulsion system*
  - *Deorbit device*
  - *Robust and flight proven satellite bus architecture*

Backup Slides

PSSC2 Deployment from Atlantis (STS-135)

Image Courtesy of NASA

PSSC-2 leaving Atlantis on STS-135

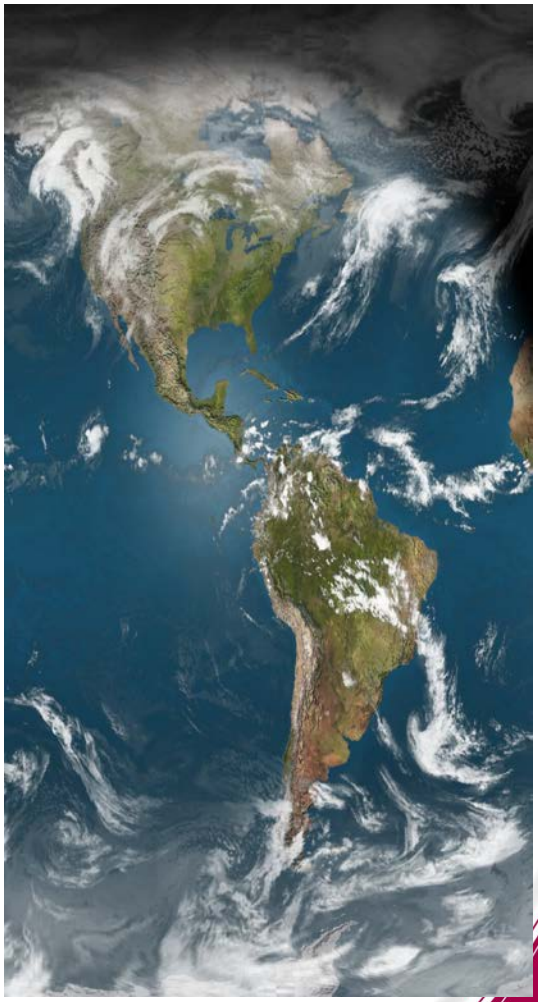
PSSC-2 photograph of Atlantis
40 seconds after deployment
Wide angle lens

PSSC-2 photograph of the Earth
Preparation for SRM firing
Wide angle lens

2011 PSSC2 Earth imaging Capability

- Series of images taken while nadir pointing

Satellite Orbit Trajectory



Earth daylight / cloud image

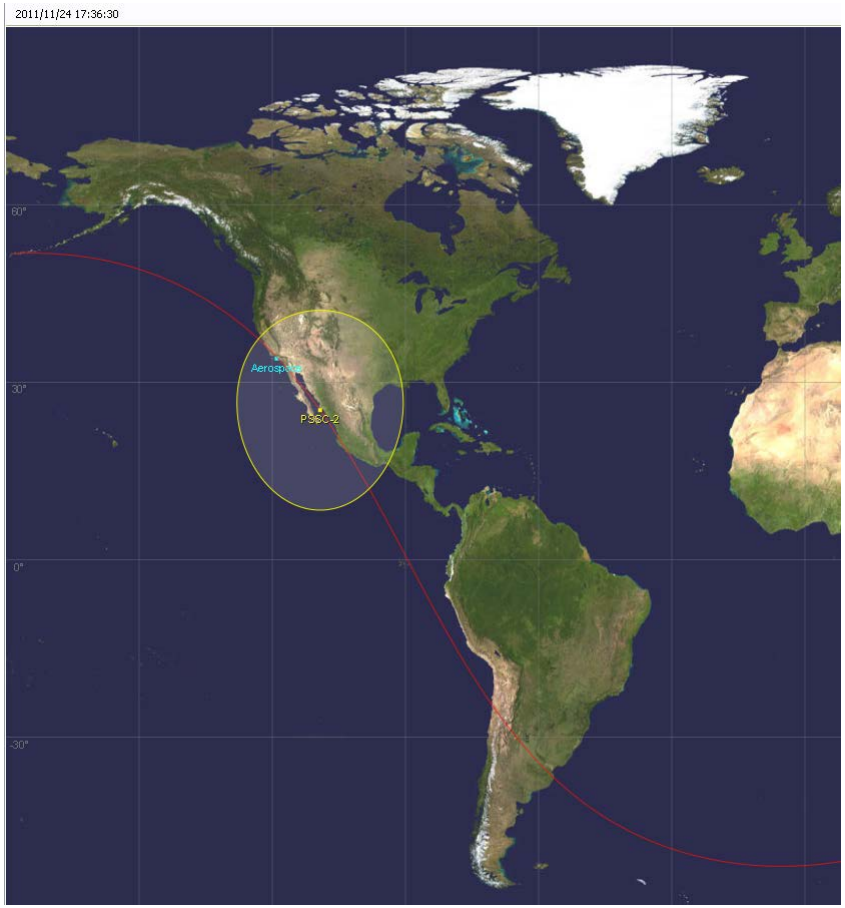
Earth imaging

Satellite Orbit Trajectory

Earth imaging

Satellite Orbit Trajectory

Earth imaging



Satellite Orbit Trajectory

Earth imaging

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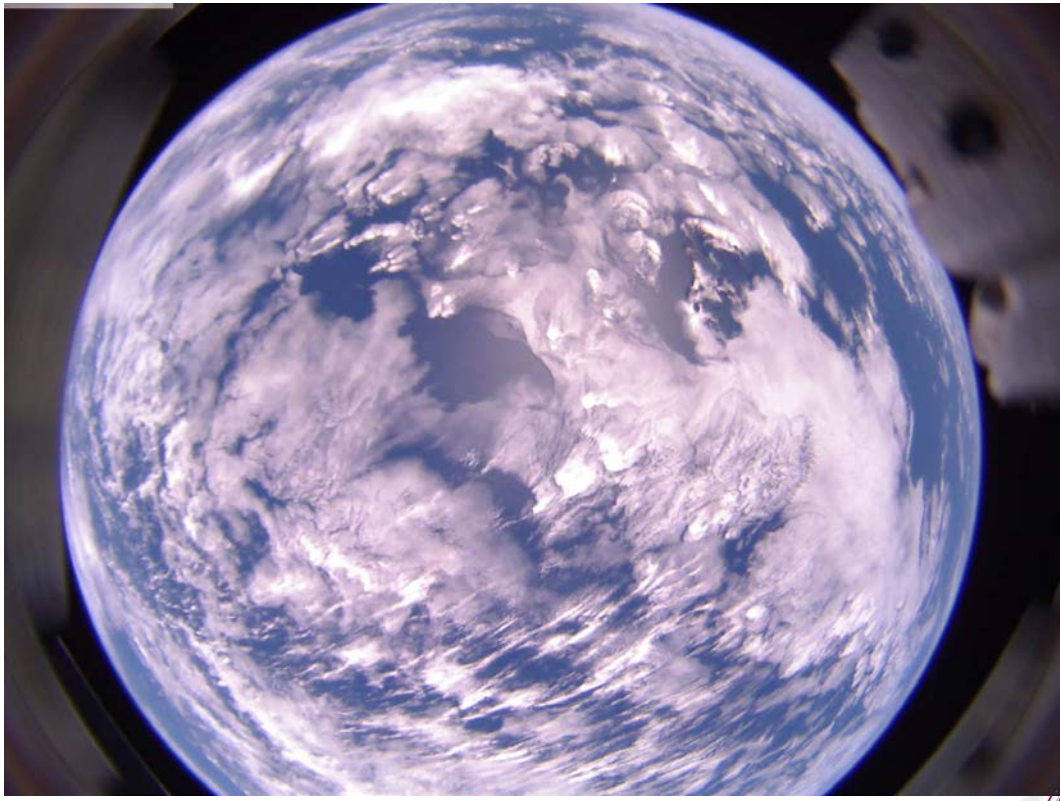

Earth imaging

Satellite Orbit Trajectory

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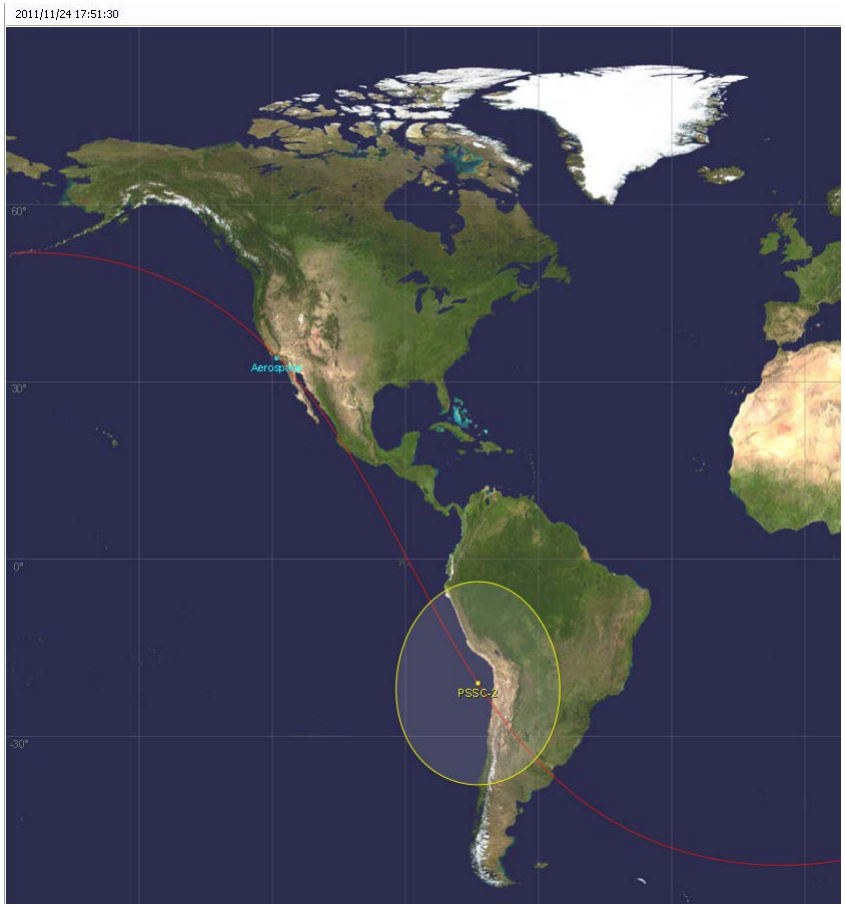
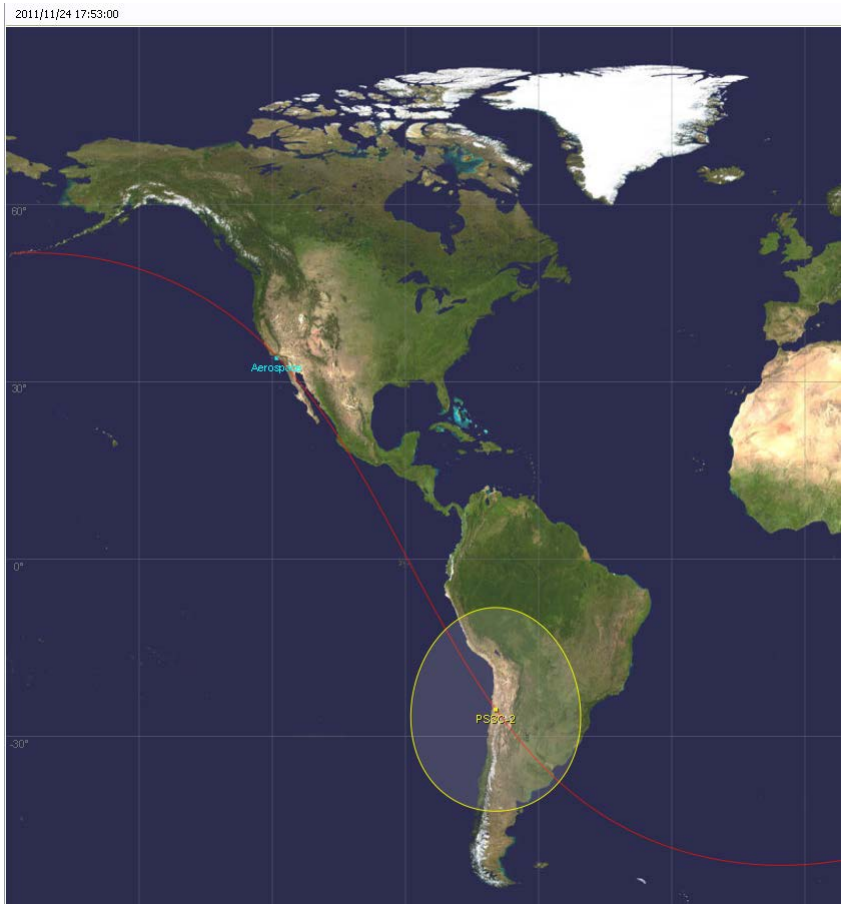


Satellite Orbit Trajectory

Earth imaging



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Earth imaging

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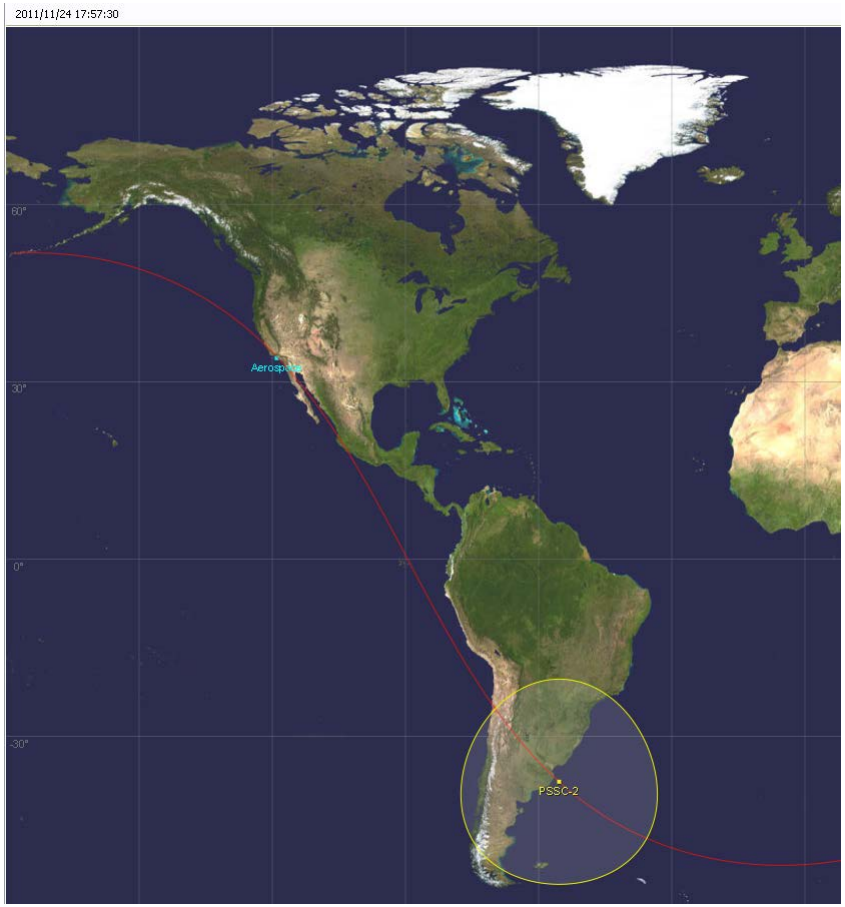

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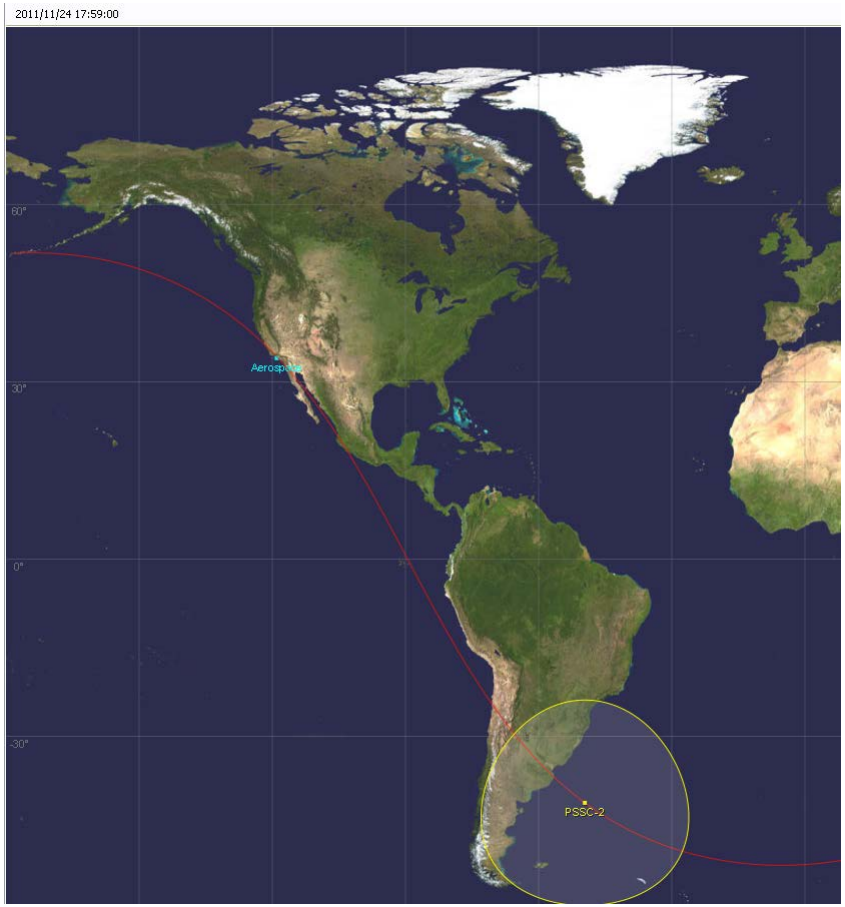
Earth imaging



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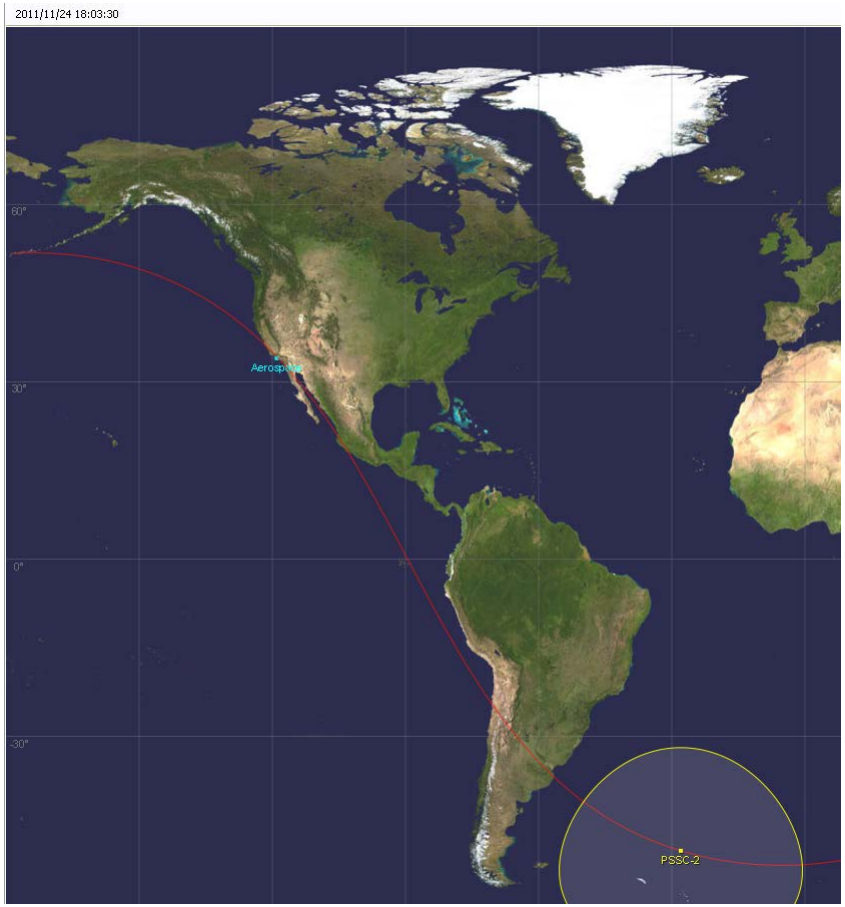

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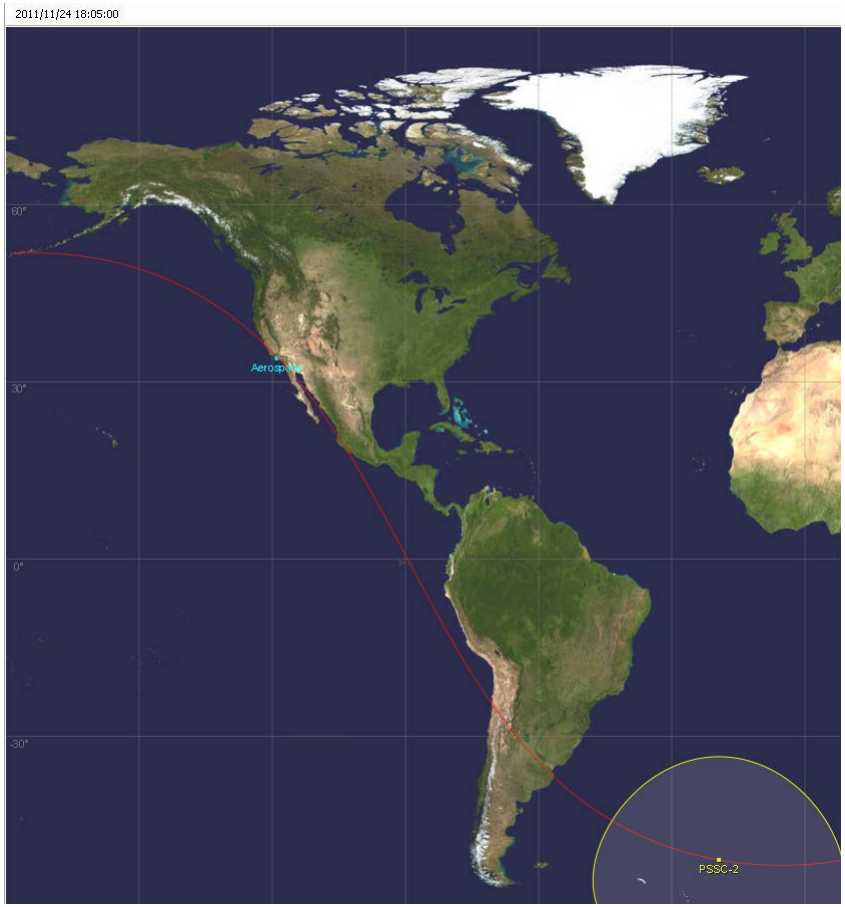

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