

The Aerospace Nano/PicoSatellite Program

In-Space Non-Destructive Inspection Technology Workshop
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Houston, Tx

Richard P. Welle, PICOSAT Program Manager
David Hinkley, PICOSAT Chief Engineer

Physical Sciences Laboratories
The Aerospace Corporation
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Outline

- The Aerospace Corporation's (Aerospace) program evolution
- The Aerospace Corporation's mission history
- The Aerospace Corporation's future missions
- AeroCube-4
- CubeRAD (AeroCube-6)
- OCSD (AeroCube-7)
- IMPACT (AeroCube-8)
- LMPC (AeroCube-9)
- Summary

Aerospace PICOSAT Program Evolution

1995 ... Aerospace study of a concept of 1-kg mass spacecraft

Uses identified include satellite inspectors; distributed apertures

1998-2003 ... Aerospace PICOSAT program starts under DARPA-sponsorship

2004 to present ... Internal MOIE funds keep the program going

Better alignment with AF needs

2009 to present ... Program offices see utility and fund specific missions

2005-2008 STSS: AC3

2011 DMSP and GEOINT: PSSC2

2009-2014 XR & Others: AC4.0, AC4.5, AC5, AC6, and AC8

2012 to present ... NASA funded awards

2012: AC7

2013: AC9

2014: ISARA

> Aerospace has been involved in miniature satellites for almost 20 years

Aerospace Nano/PicoSatellite History

OPAL PicoSats (2)
Minotaur I
250 grams

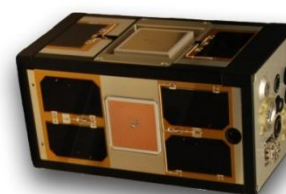
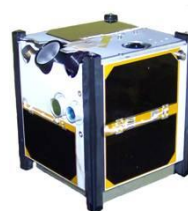
MEPSI
STS-113
800 grams each

MEPSI
STS-116
1.1 and 1.4 kilograms

AeroCube-3
Minotaur I
1.1 kilograms

PSSC Testbed-2
STS-135
3.6 kilograms

REBR2 (2)
H-IIB
4.5 kilograms
with heat shield



1999

2001

2003

2005

2007

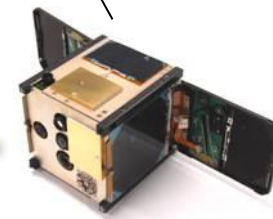
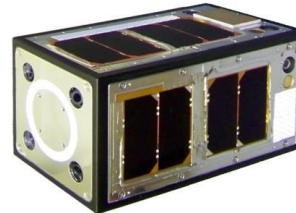
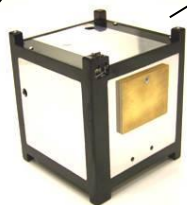
2009

2011

2013



**First University
CubeSat Launch**



MightySat II.1 PicoSats (2)
Minotaur I
250 grams

AeroCube-1
Dnepr-1
999 grams

AeroCube-2
Dnepr-1
998 grams

PSSC Testbed
STS-126
6.4 kilograms

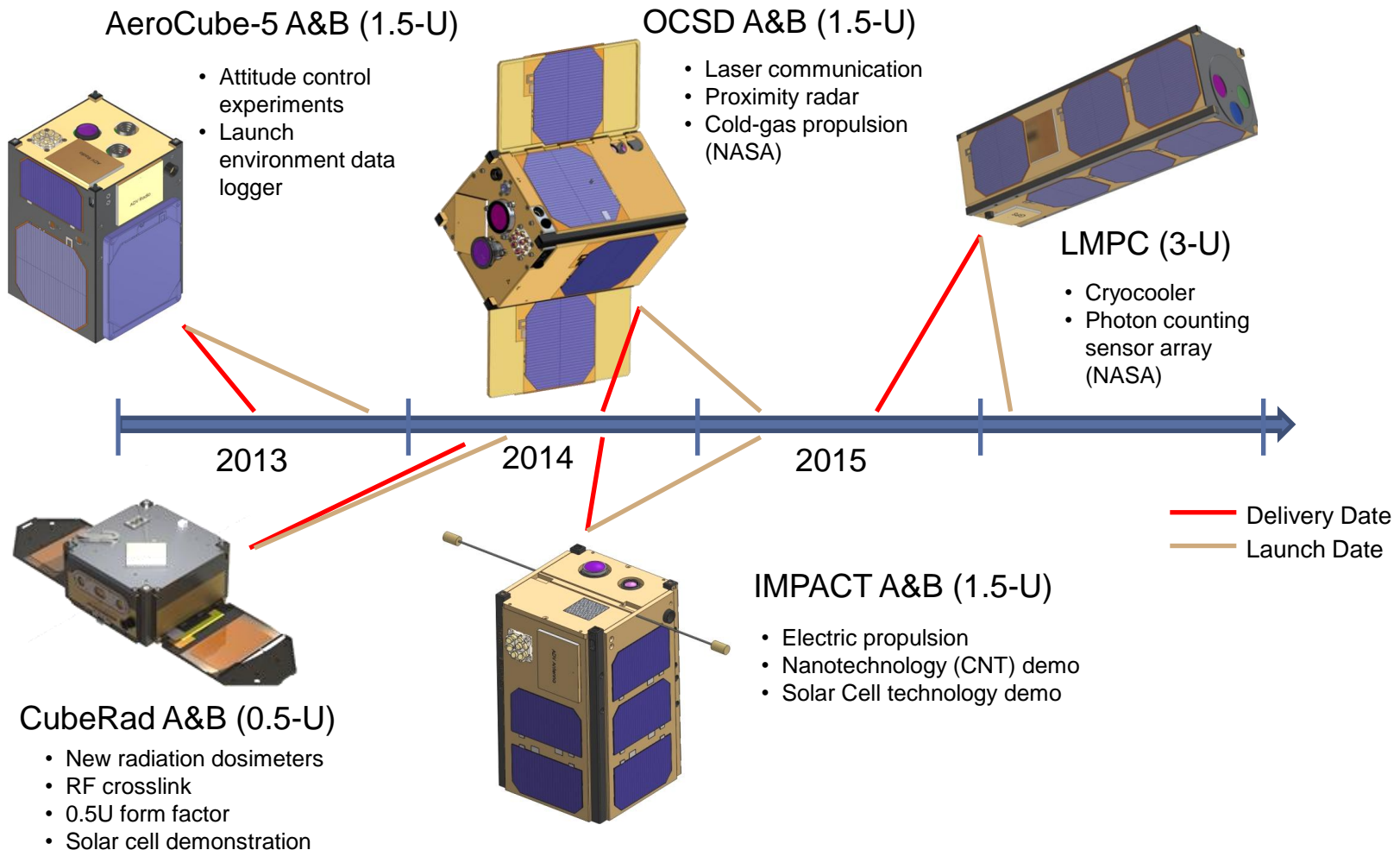
REBR (2)
H-IIB
4.5 kilograms
with heat shield

AeroCube-4.0 (1)
AeroCube-4.5 (2)
Atlas V, NROL-36
1.3 kilograms

**Failed to
Reach orbit**

> Consistent funding, resident expertise and frequent flights are enabling

The Aerospace Corporation's future missions



Practical Goals of Inspector Technology

Useful characteristics

- Low Size, Weight & Power
- Minimize on-orbit crew time to address risks
- Locally derived information to minimize data transfer
- Less than 2 years to flight
- Multiple NASA aerospace program applicability – supporting recent roadmaps
- Broad use case for other than space industries and government agencies
- Take advantage of other investments to sustain maturity/long term improvements.

> ***Taken from JSC workshop announcement***

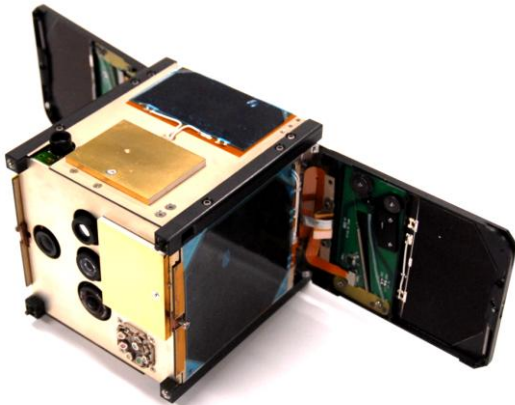
Free-flying Inspection Platform Technology List

- Propulsion
- Sensors
- Local communication
- Direct ground communication
- Safety
- High-resolution imaging
- Illumination
- Multispectral imaging
- Autonomous operations
- Rendezvous and docking

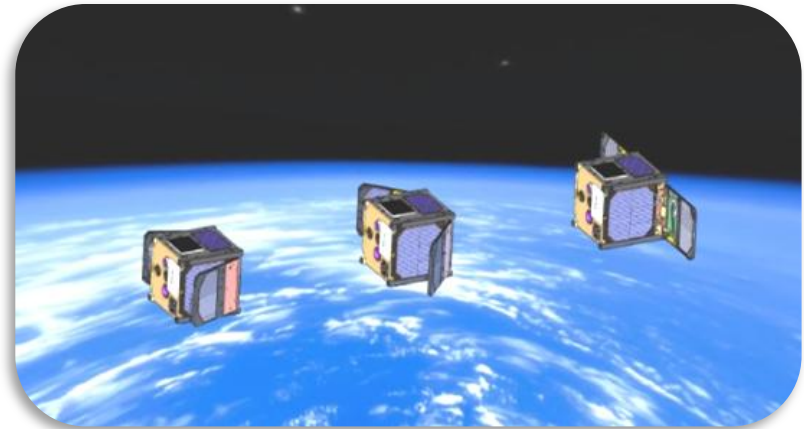
AeroCube-4

Attitude control demonstration

- Launch-environment data-logger
- Attitude control algorithm development and demonstration platform
- Three 2 megapixel color cameras with 185, 57 and 22 deg FOVs for mission demonstrations
- Demonstrate orbit rephasing using drag control
- A platform to develop our autonomous ground station network



1.3 kg mass
10 x 10 x 10 cm



Three AC4 satellites were launched together

> Currently 18+ months in operation and going strong

AeroCube-4

Attitude control demonstration

- NROL-36 Centaur Upper Stage taken immediately after deployment

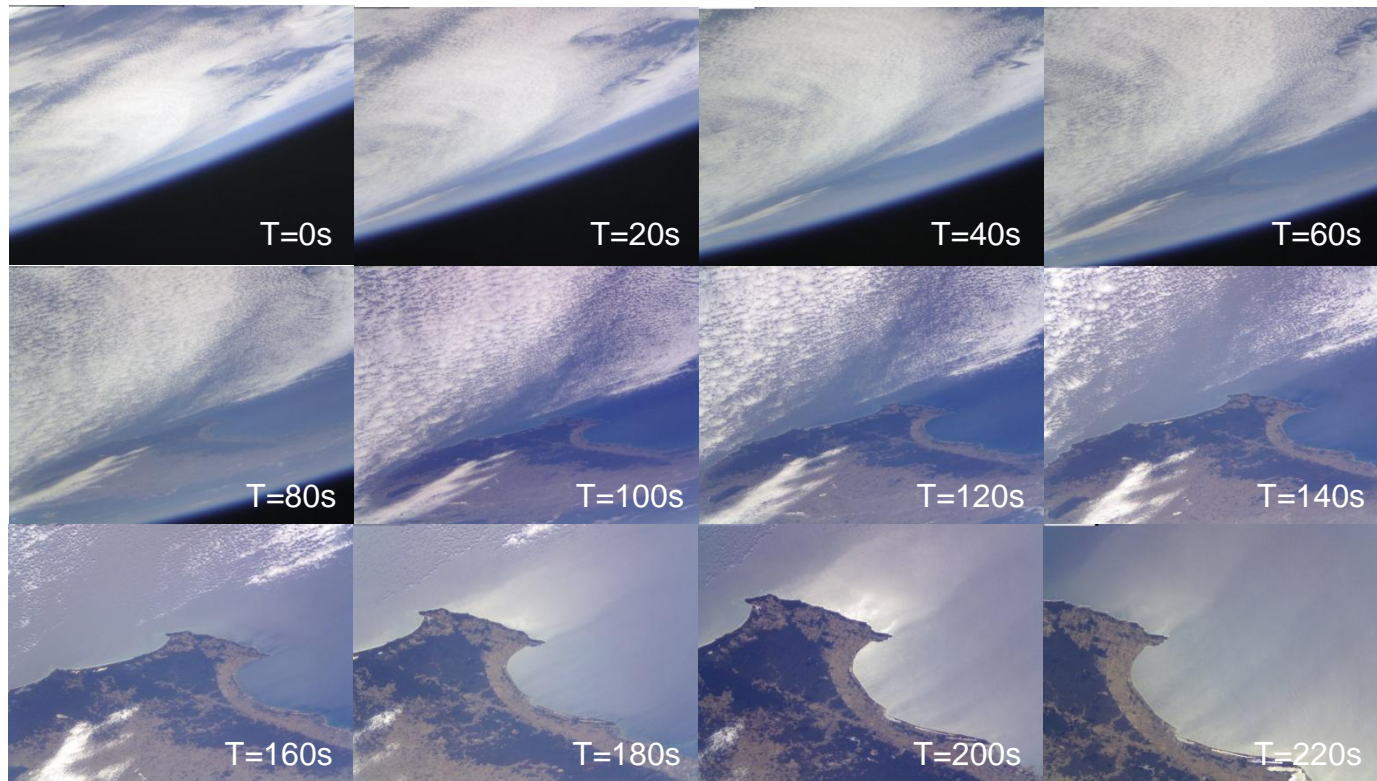


> Satellite is tumbling – not ability yet to hold a object in the FOV

AeroCube-4

Attitude control demonstration

- Open loop pointing towards a predetermined ground point for 20 seconds

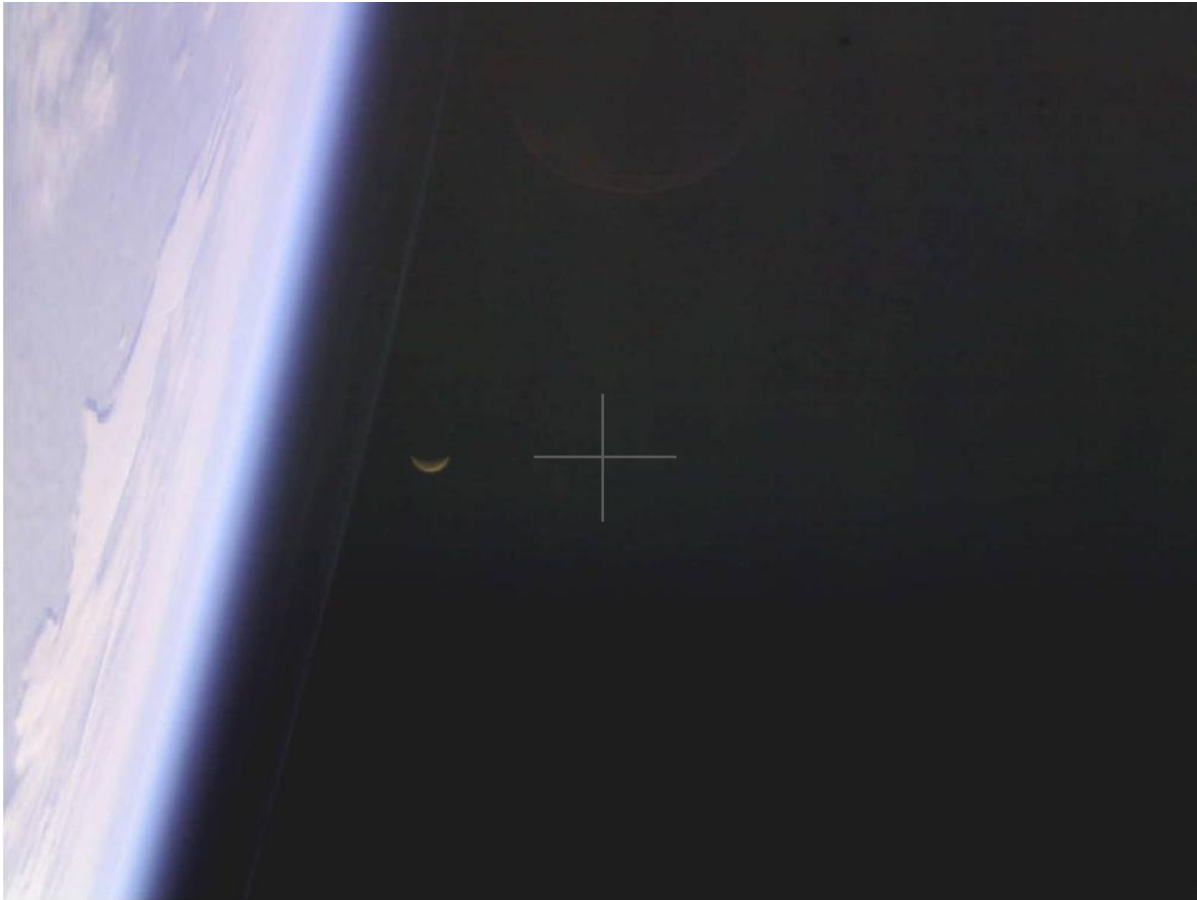


> *Flyby*

AeroCube-4

Attitude control demonstration

- Open loop pointing towards a celestial object – the moonrise



> Moon is off-center by 3 degrees – use this to calibrate pointing errors

AeroCube-4

Attitude control demonstration

- Photographing the Nov 3, 2013 solar eclipse from space

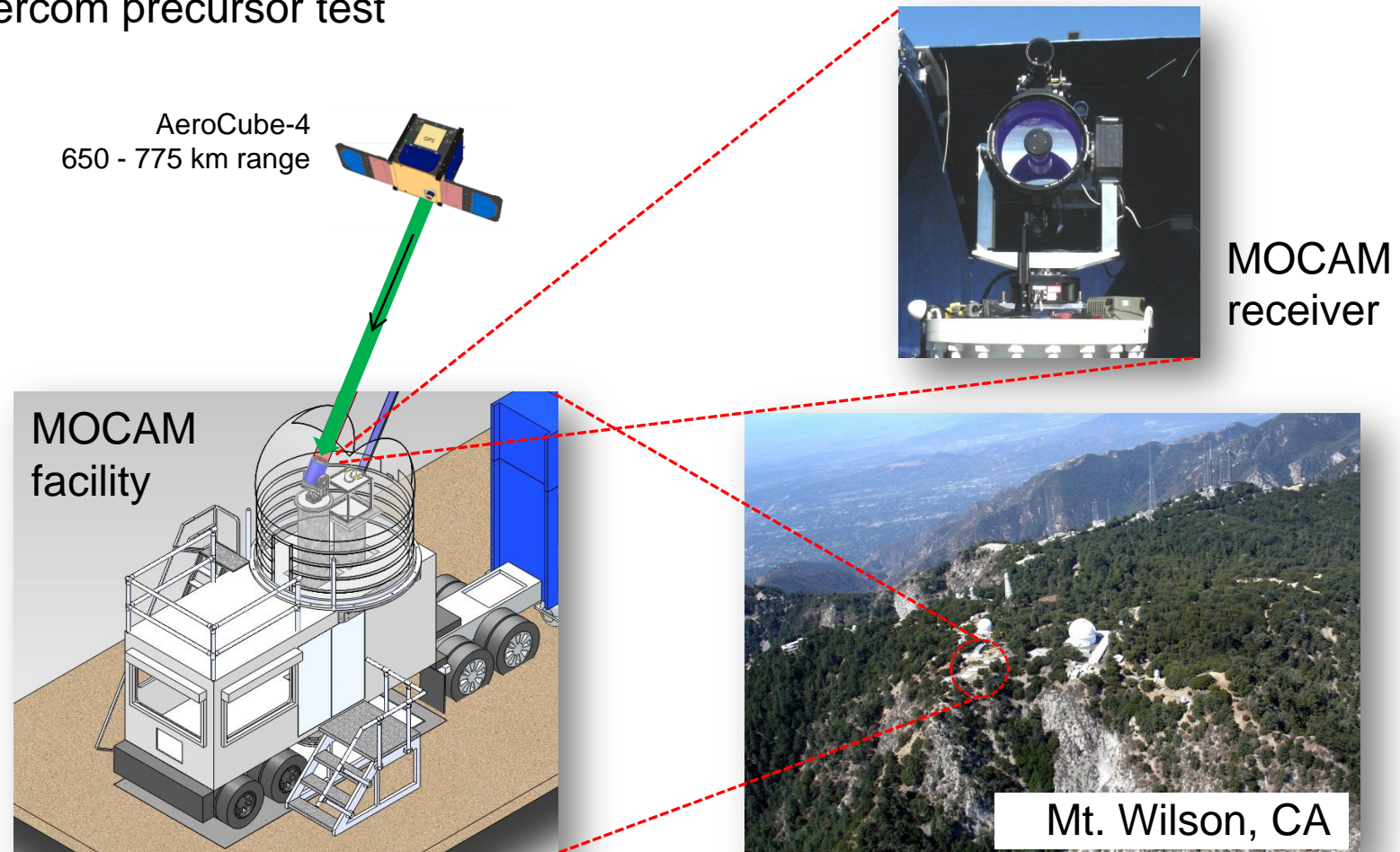


> *Just because we could...*

AeroCube-4

Attitude control demonstration

- Lasercom precursor test



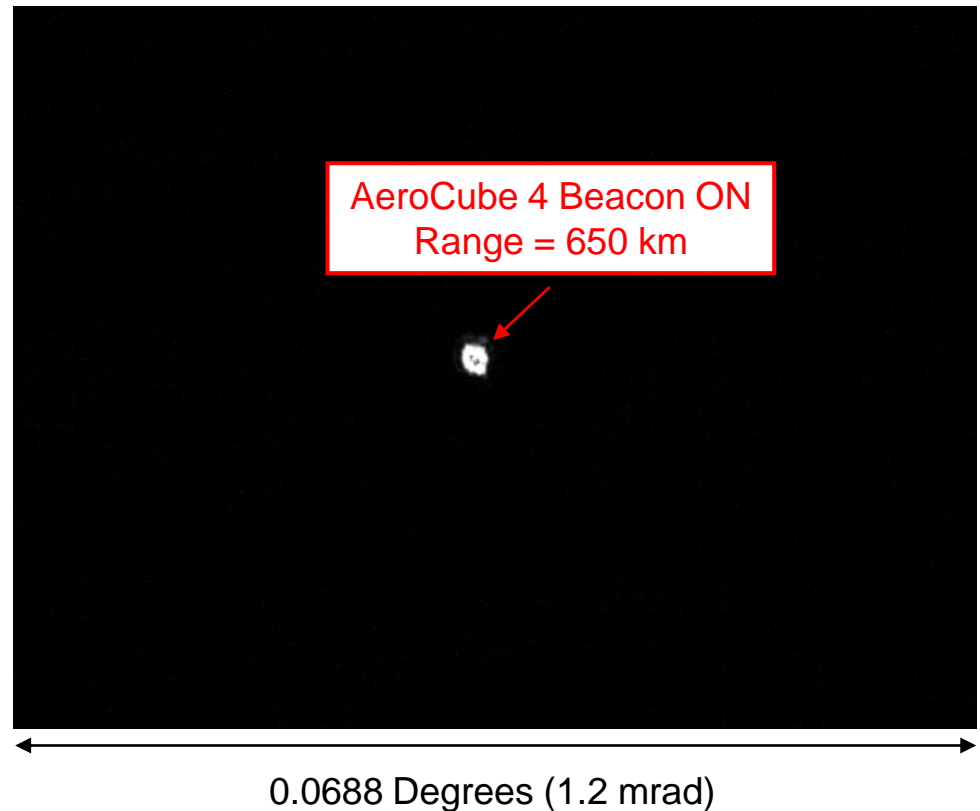
> ***AeroCube-4 performed an end-to-end risk reduction test for AeroCube-7***

AeroCube-4

Attitude control demonstration

- AC4 tracked ground station for 84 seconds
- AC4 aimed at ground station with 1deg accuracy
- Ground station telescope acquired AC4 open loop
- Ground station telescope switched to closed loop tracking after acquisition
- This test proved the way for the future AC7 lasercom experiment

Image from MOCAM receiver telescope camera

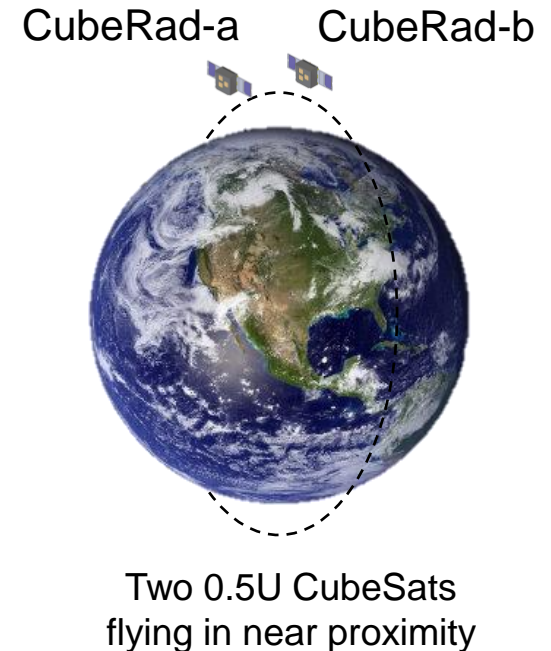


> ***AeroCube-4 performed an end-to-end risk reduction test for AeroCube-7***

CubeRAD (AeroCube-6)

Two similar spacecraft flying new dosimeter suites

- Launch in June 2014 as a 1-U CubeSat that then splits into two 0.5U-CubeSats
- CubeRAD will quickly raise the TRL of three new micro-dosimeters
 - Dosimeter 1 accepts only high energy deposit particles (mainly protons) rejecting low energy deposit particles (mainly electrons) for greater distinction of hazardous effects for anomaly resolution
 - Dosimeter 2 and 3 lower the electron limit to 600 keV and 50 keV, respectively allowing better design and anomaly resolution support for thinly-shielded subsystems and harnessing

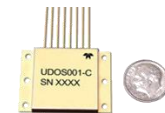


Then



7 x 10 x 6 inches

Now



1.4 x 1 x 0.2
inch

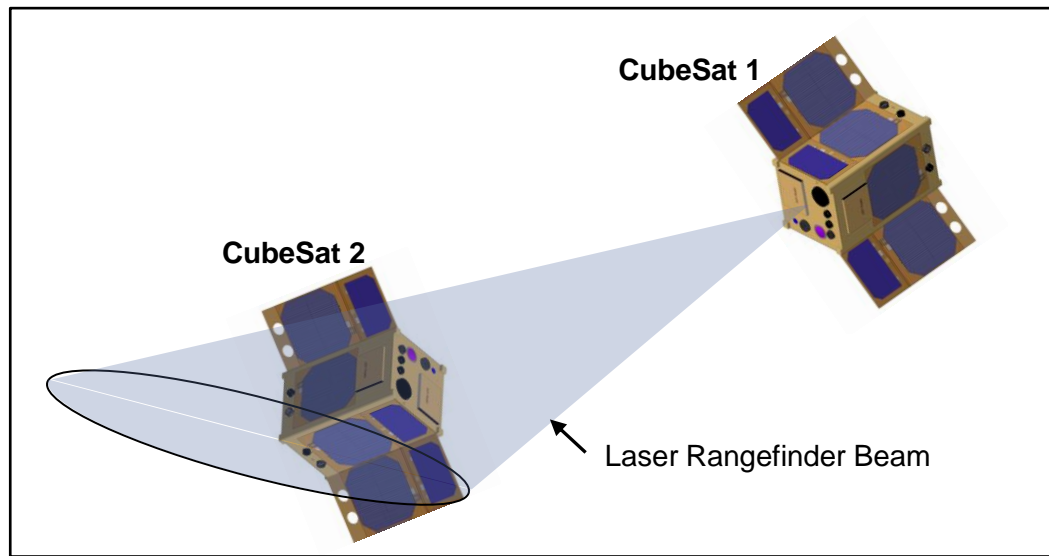
> A start at an inexpensive distributed space sensor system

OCSD (AeroCube-7)

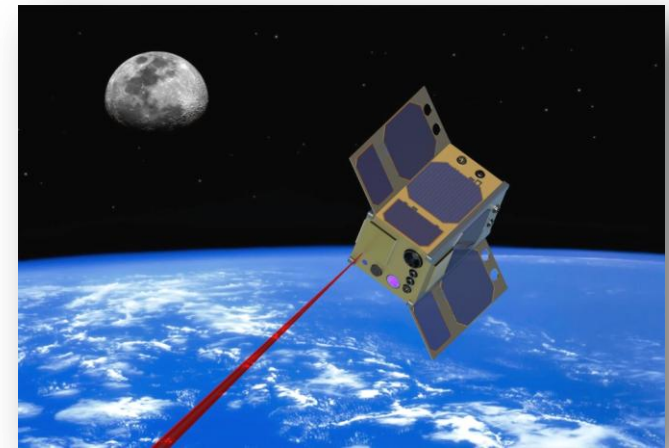
NASA funded lasercom and proximity operations demonstration

- Two 1.5U CubeSats
- Demonstrate passive and active orbital rephasing to achieve 200 meter proximity operations
- Demonstrate space-to-ground lasercom of 5 to 100 Mbps

Proximity operations mission



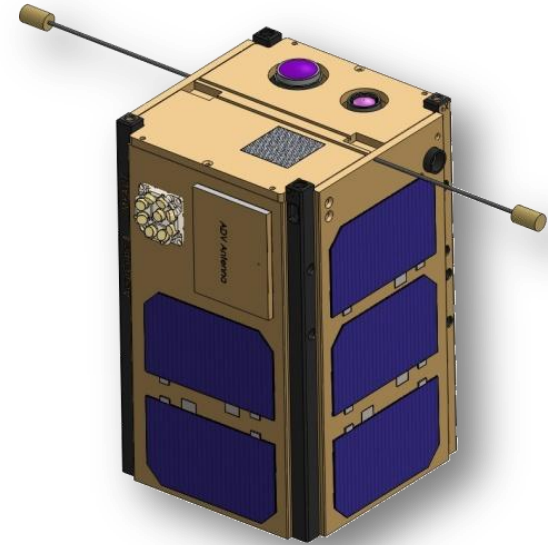
Lasercom mission



> **Delivery October 2014**

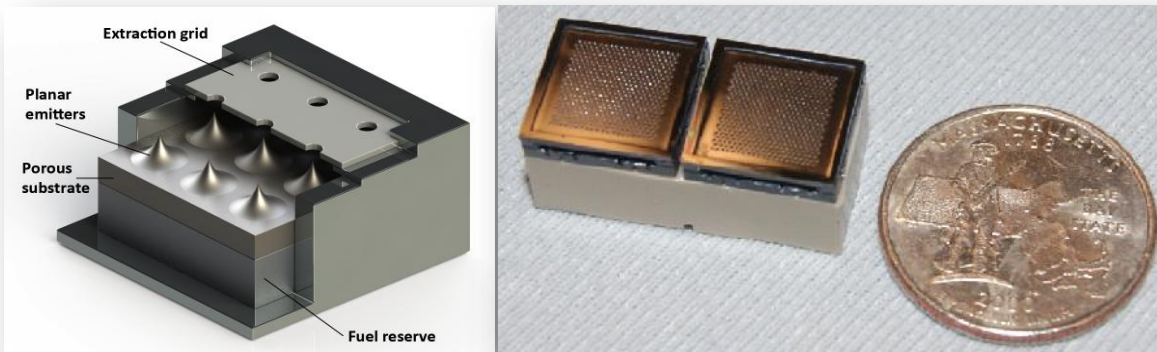
IMPACT (AeroCube-8)

- Two 1.5U Cubesats
- Demonstrate Scalable ion-Electrospray Propulsion system (SiEPro)
- Measure IV curves for 4-junction IMM solar cells and 5-junction SBT cell
- Demonstrate CNT harness and use of CNT/PEEK material
- Evaluate CNT radiation-shielding material

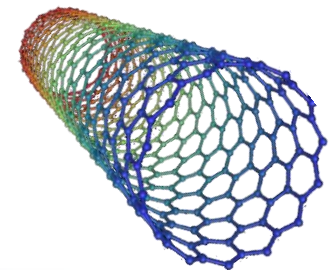


AC8

Electrospray Thruster



Carbon Nanotubes

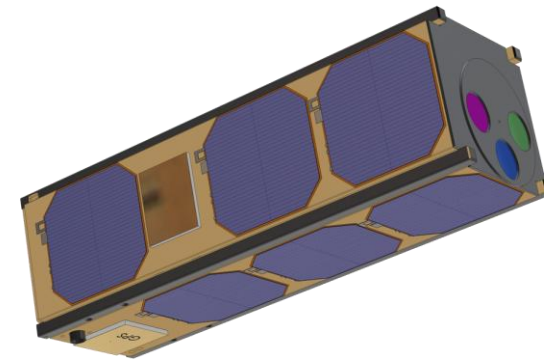


> **Delivery October 2014**

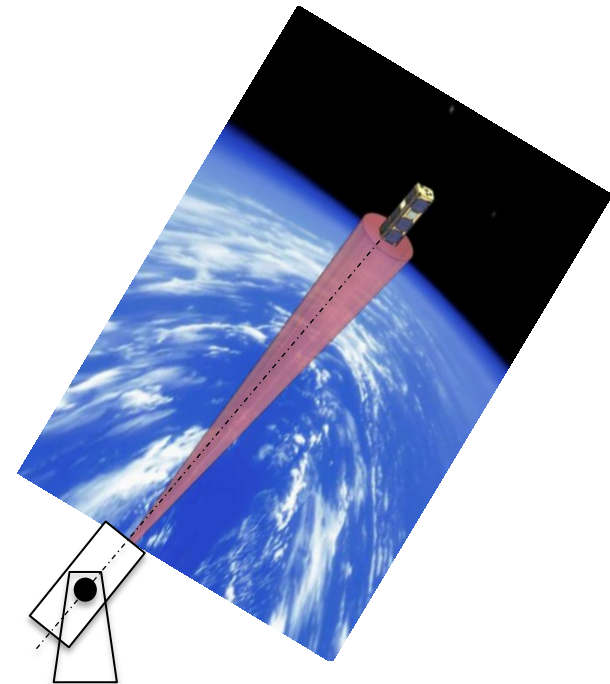
LMPC (AeroCube-9)

NASA funded single photon detector demonstration

- Demonstrate a 2x8 pixel array of HgCdTe APDs with photon sensitivities at 1, 1.5, & 2 microns
- Measure detector dark current and radiation dosage throughout the mission
- Demonstrate a 77K cryocooler in a 3U CubeSat
- Demonstrate passive radiometric measurements of the earth
- Receive uplinked laser lines to measure species absorption



*The Linear Mode Photon-counting
CubeSat (LMPC)*

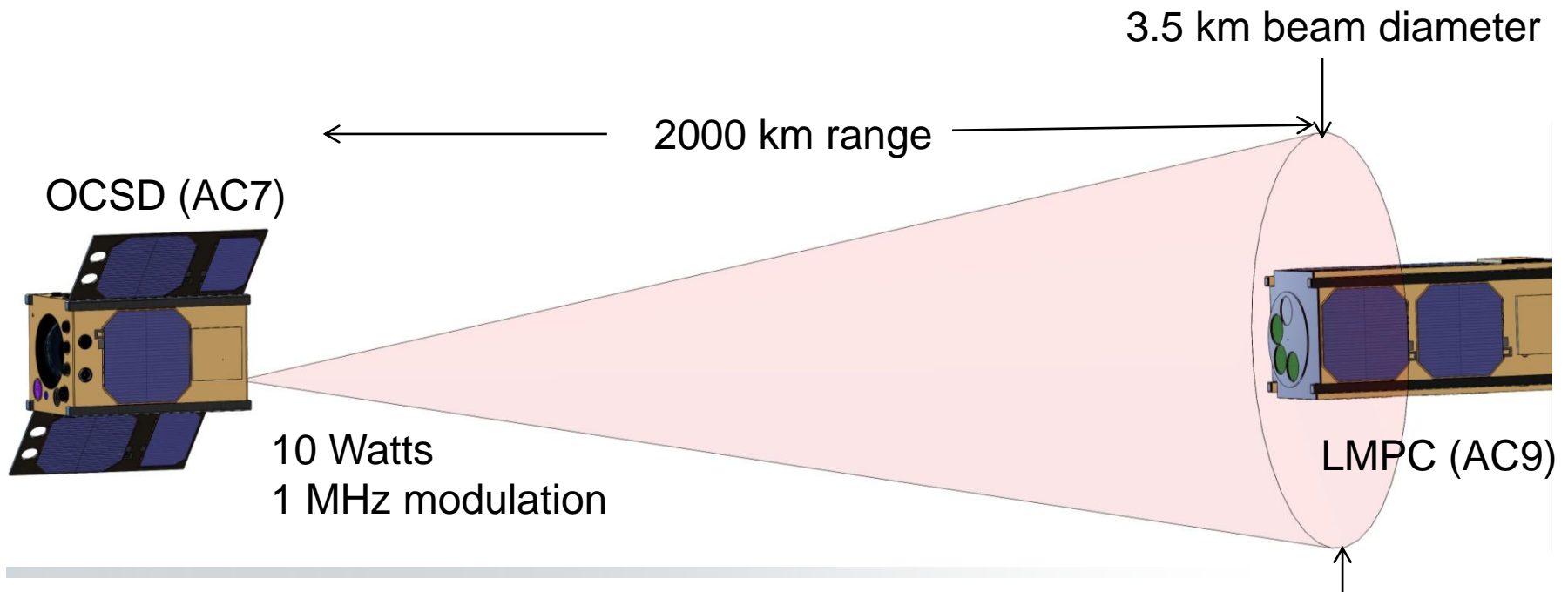


> Flight demonstration of next generation earth sensor array cooled to 77K

AC7 and AC9 Working Together

Laser crosslink demonstration

- OCSD (AC7) emits 10 Watts, 0.1 degree beam full width, 1 MHz modulation
- At 2000 km range from OCSD, the LMPC with a 2.5 cm aperture will collect 2000 photons per pulse
- Because LMPC is sensitive to a single photon, applying a 16 or 64 Airy PPM scheme could increase the data rate 10-100 fold or alternatively increase range



> **High capacity CubeSat-scale crosslink**

Summary

- **The Aerospace Corporation Nano and Picosatellites are moving towards autonomous operation**
- **The Aerospace Corporation miniature satellite program**
 - Demonstrates capabilities from concept design, costing, performance modeling, building, mission assuring, integration, and operation
 - Developing relevant and unique hardware and software such as
 - GPS navigation, GPS occultation, cold gas propulsion, drag devices, radios, attitude sensors and actuators
 - Attitude control algorithm library
 - Automated ground station network
- **The Aerospace Corporation has a unique blend of scientists and engineers with expertise in all satellite subsystems**

