The Aerospace Nano/PicoSatellite Program

In-Space Non-Destructive Inspection Technology Workshop
July 15-16, 2014
Johnson Space Center
Houston, Tx

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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

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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

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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

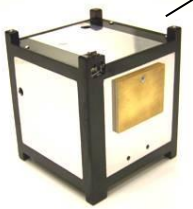
PSSC Testbed-2
STS-135
3.6 kilograms

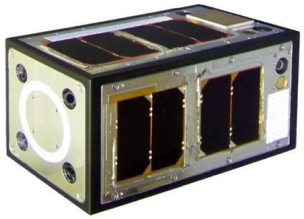
REBR2 (2)
H-IIB
4.5 kilograms
with heat shield

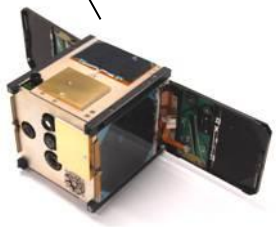





1999 2001 2003 2005 2007 2009 2011 2013





First University CubeSat Launch

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

AeroCube-1
Dnepr-1
999 grams
Failed to Reach orbit

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

> Consistent funding, resident expertise and frequent flights are enabling

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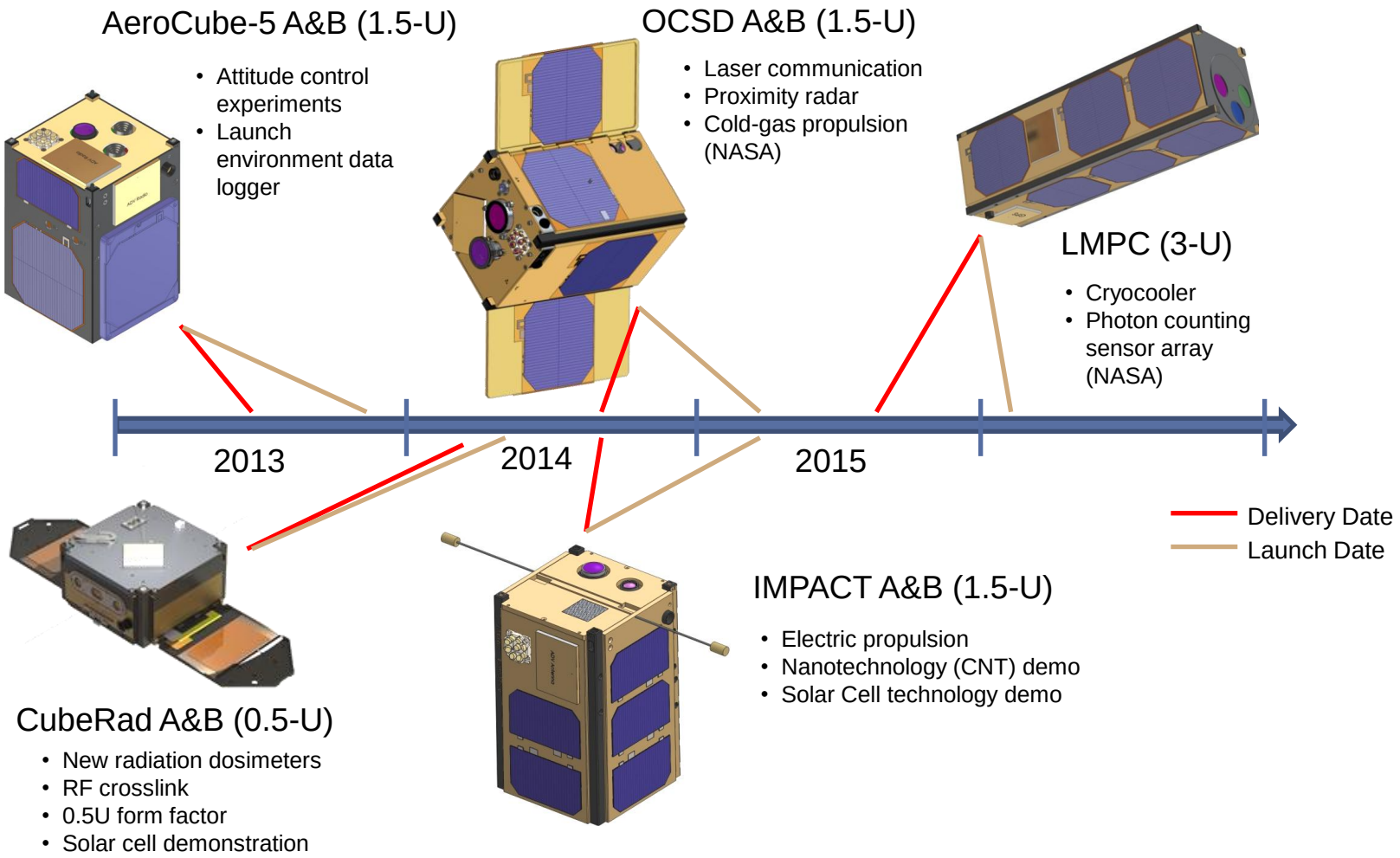
The Aerospace Corporation's future missions



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AEROSPACE

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

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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

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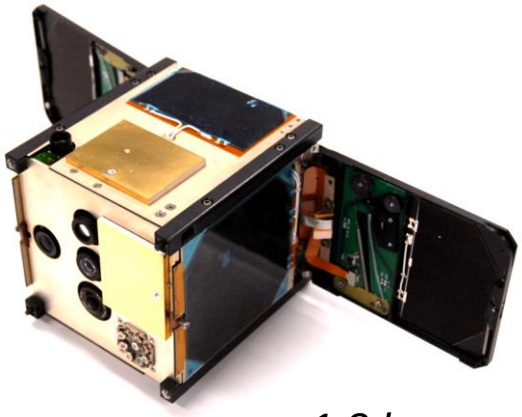
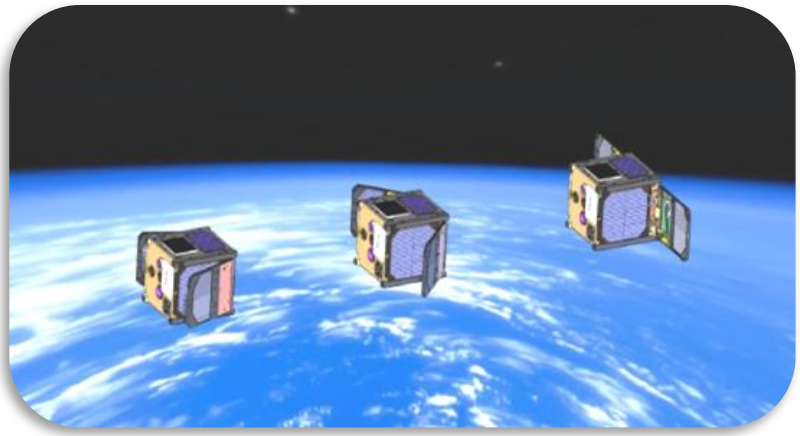
AeroCube-4

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

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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

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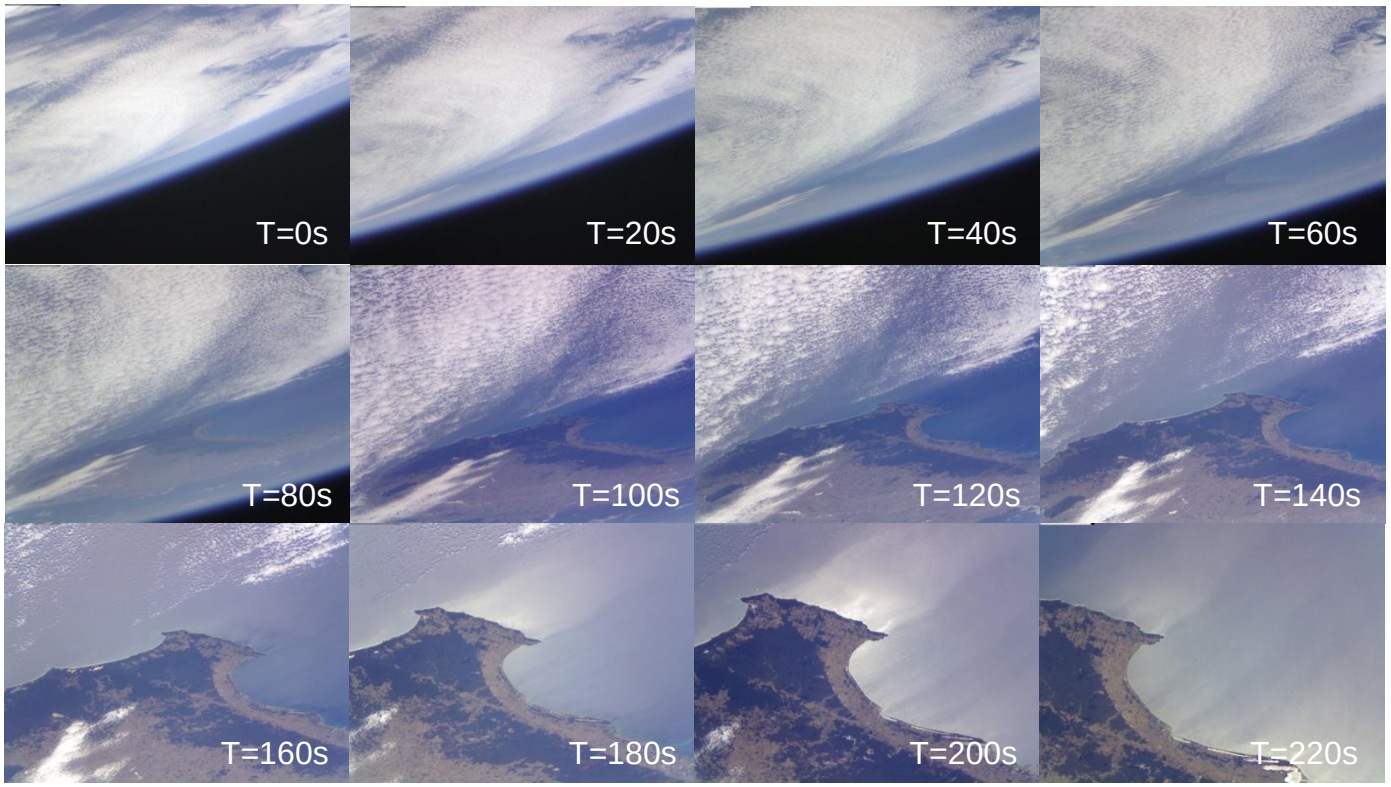
AeroCube-4

Attitude control demonstration

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

Google Maps



> Flyby

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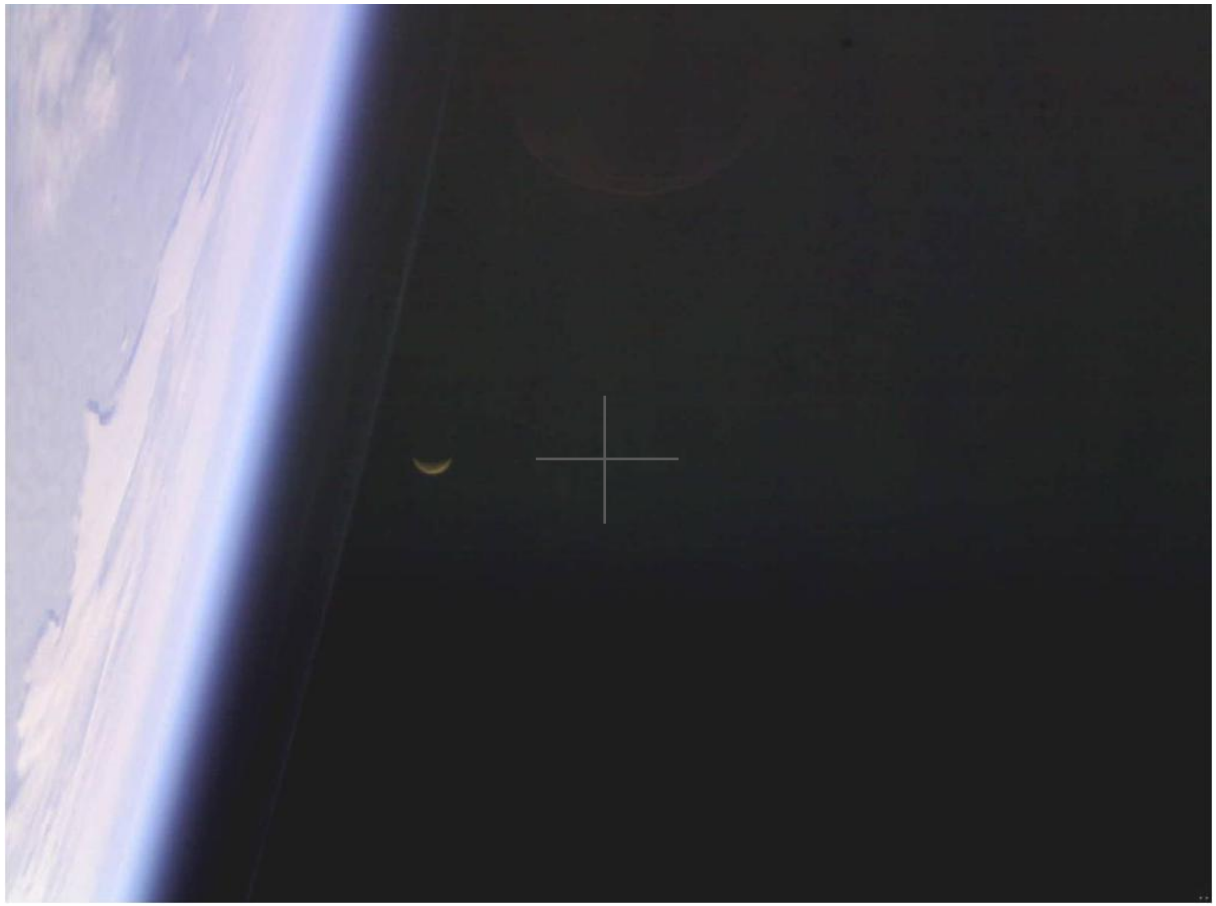
AeroCube-4

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

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AeroCube-4

Attitude control demonstration

- Photographing the Nov 3, 2013 solar eclipse from space

> Just because we could…

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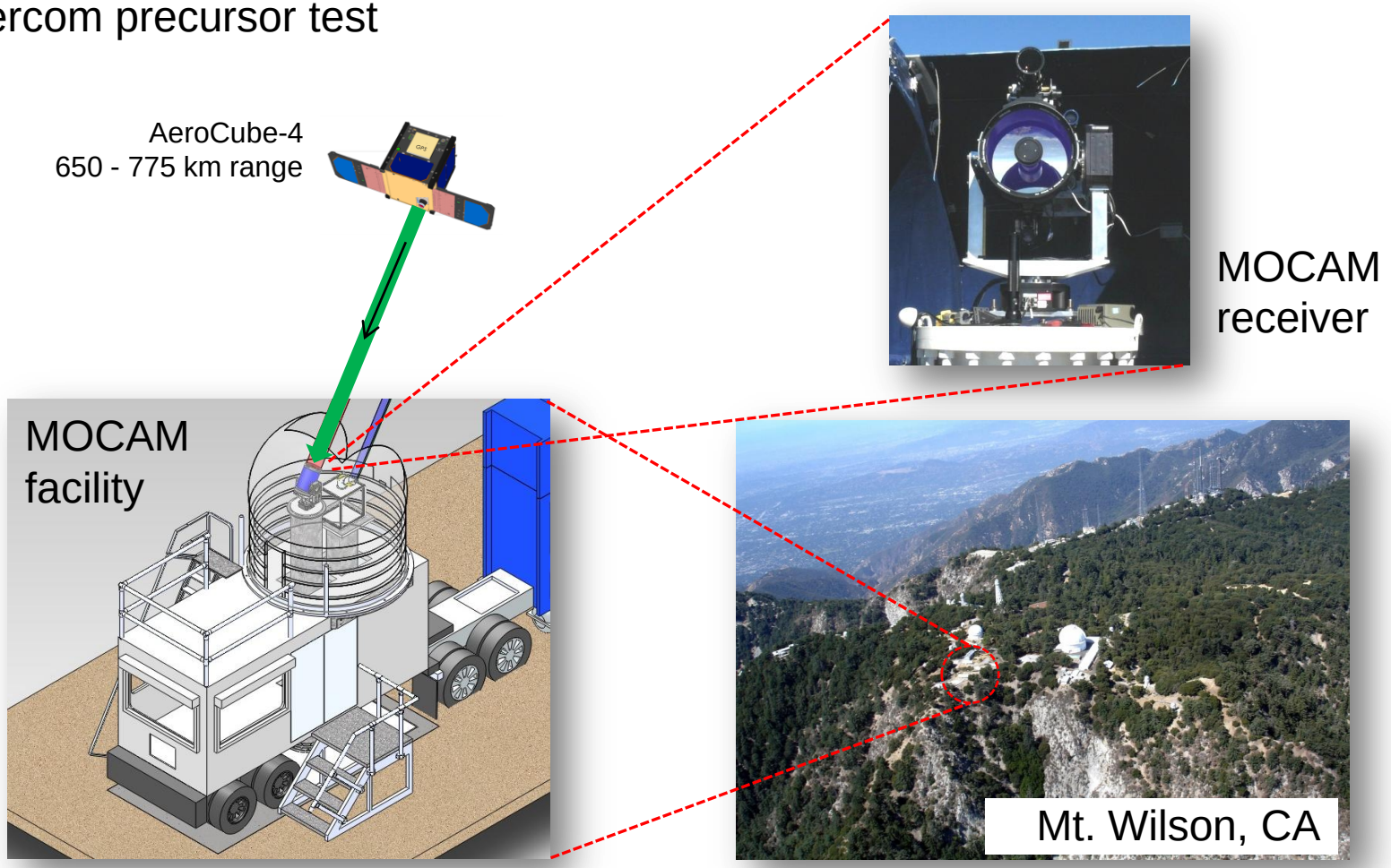
AeroCube-4

Attitude control demonstration

- Lasercom precursor test



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

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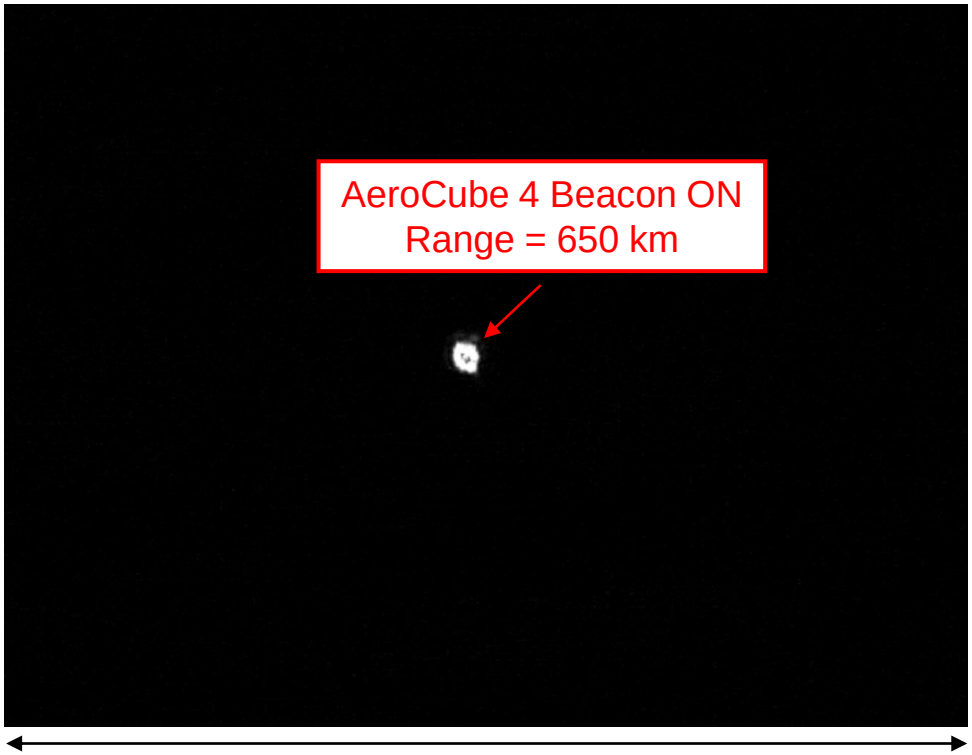
AeroCube-4

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



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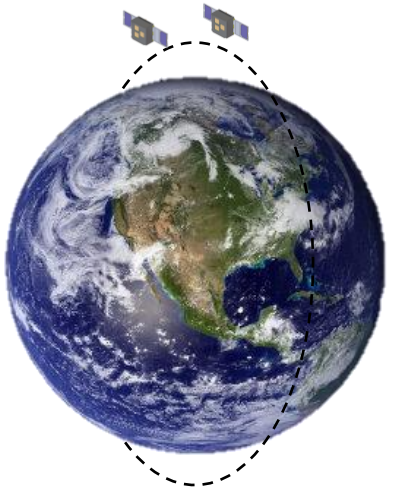
CubeRAD (AeroCube-6)

Two similar spacecraft flying new dosimeter suites

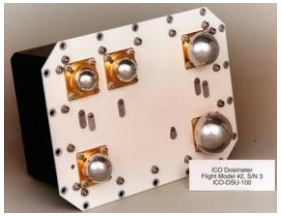
- Launch in June 2014 as a 1-U CubeSat that then splits into two 0.5U-CubeSats
- CubeRAD will quickly raise the TRL of three new micro-dosimeters
  - Dosimeter 1 accepts only high energy deposit particles (mainly protons) rejecting low energy deposit particles (mainly electrons) for greater distinction 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

CubeRad-a CubeRad-b



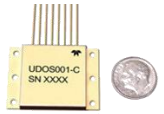
Two 0.5U CubeSats flying in near proximity

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

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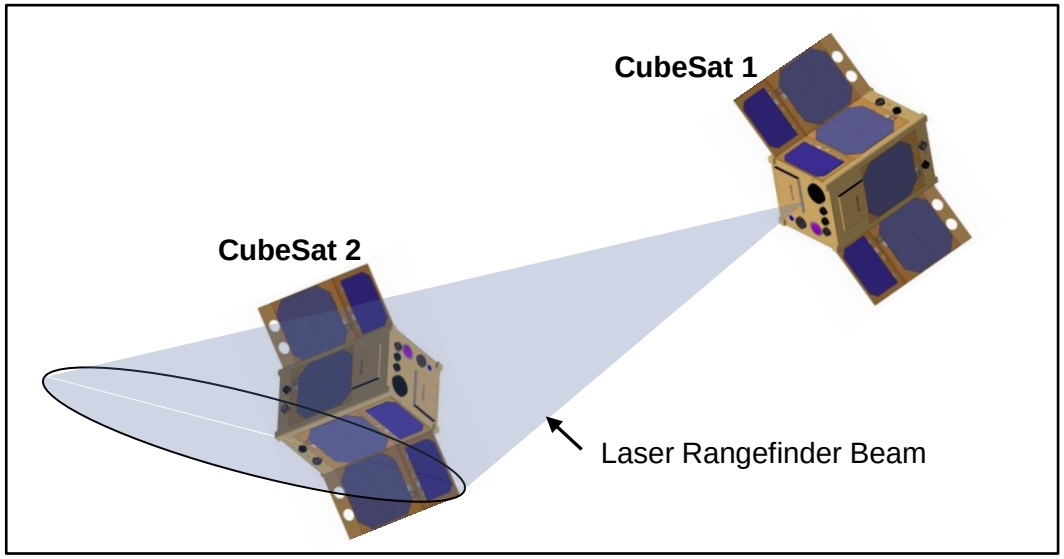
OCSD (AeroCube-7)

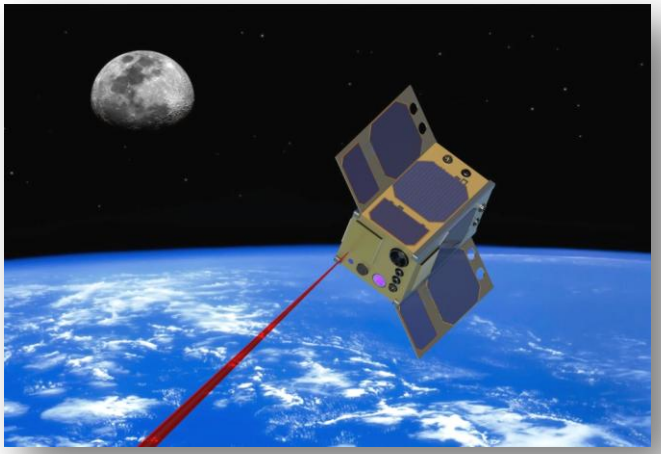
NASA funded lasercom and proximity operations demonstration

- 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***

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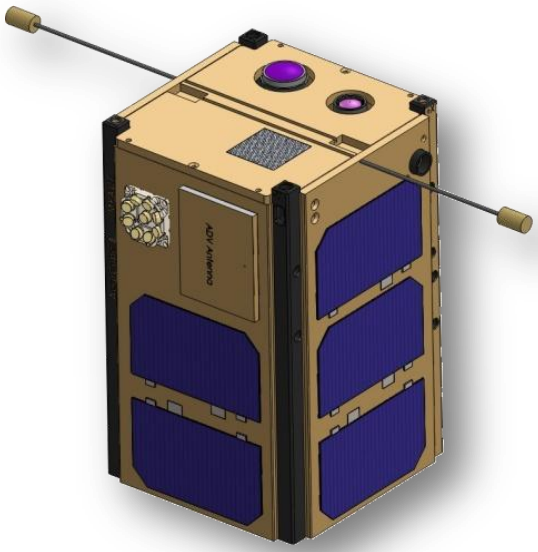
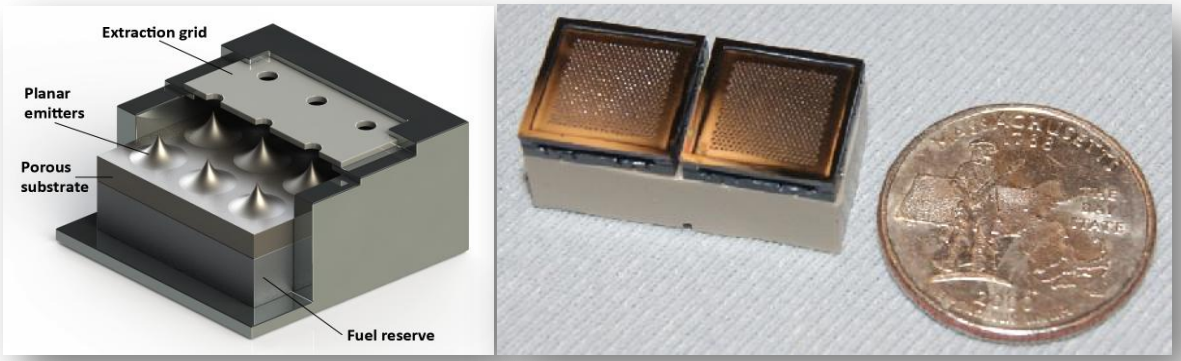
IMPACT (AeroCube-8)

- 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

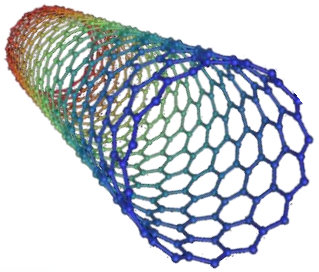


AC8

Electrospray Thruster



Carbon Nanotubes



> Delivery October 2014

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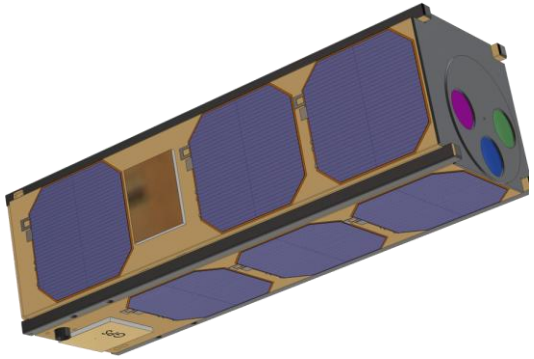
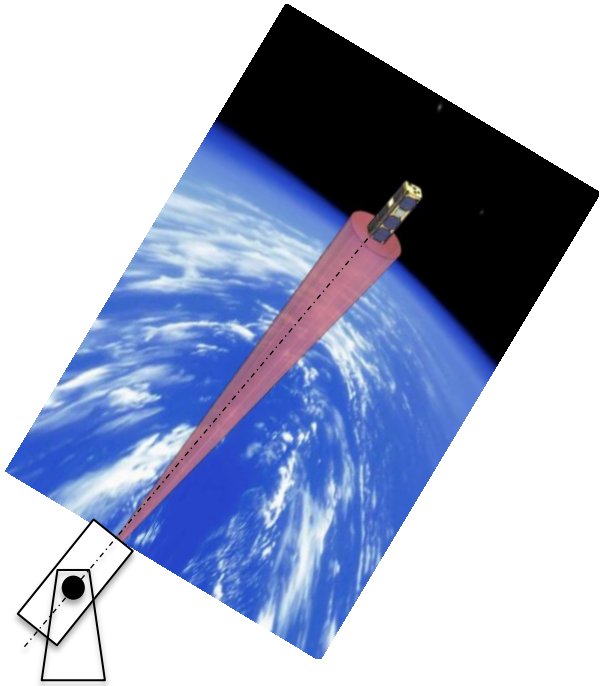
LMPC (AeroCube-9)

NASA funded single photon detector demonstration



The Linear Mode Photon-counting CubeSat (LMPC)

- 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



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

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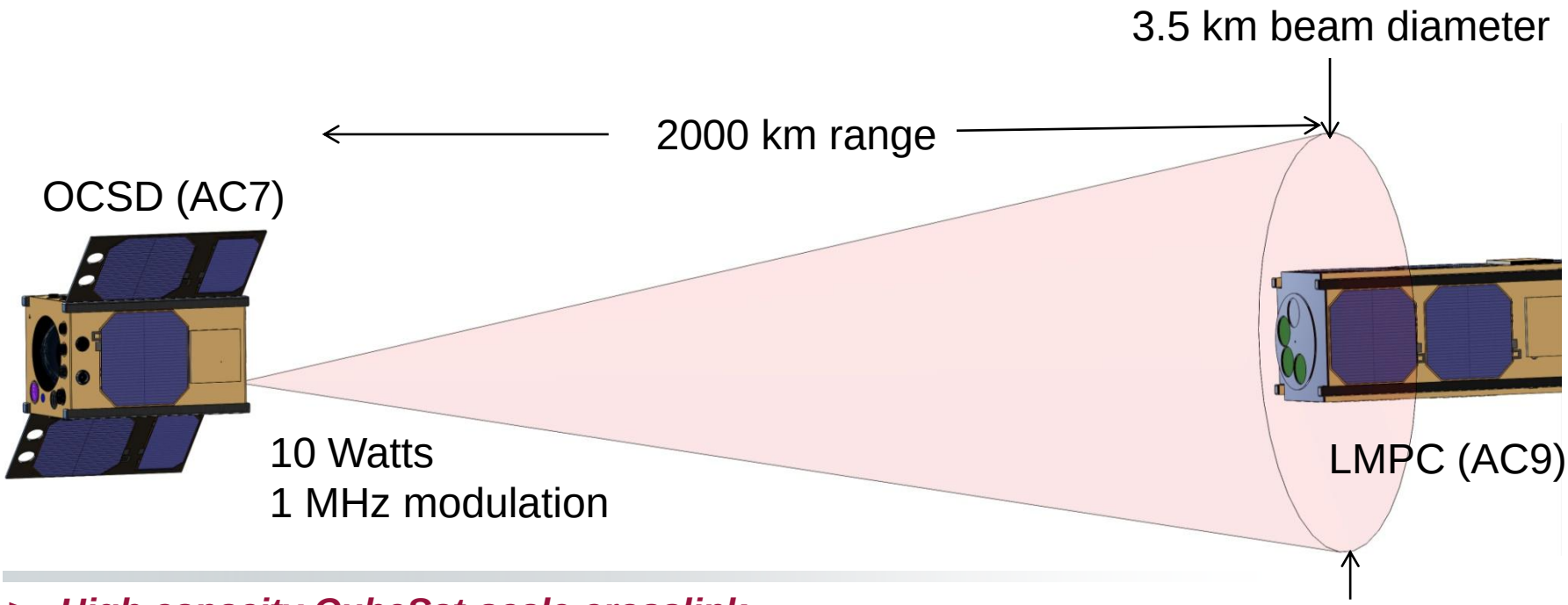
AC7 and AC9 Working Together

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***

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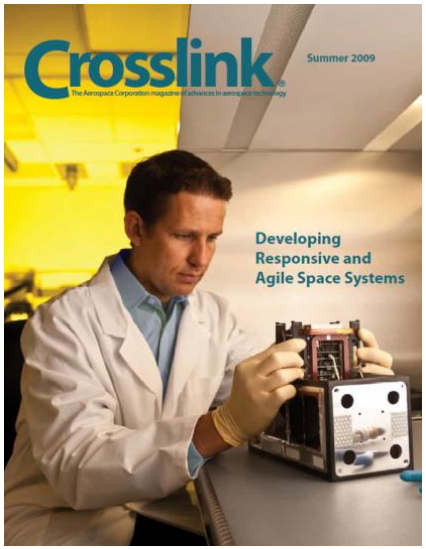
Summary

- **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**



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AEROSPACE