The Aerospace Nano/PicoSatellite Program

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

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

Physical Sciences Laboratories
The Aerospace Corporation
15 July 2014
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

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

First University CubeSat Launch

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
The Aerospace Corporation’s future missions

AeroCube-5 A&B (1.5-U)
- Attitude control experiments
- Launch environment data logger

OCSD A&B (1.5-U)
- Laser communication
- Proximity radar
- Cold-gas propulsion (NASA)

LMPC (3-U)
- Cryocooler
- Photon counting sensor array (NASA)

CubeRad A&B (0.5-U)
- New radiation dosimeters
- RF crosslink
- 0.5U form factor
- Solar cell demonstration

IMPACT A&B (1.5-U)
- Electric propulsion
- Nanotechnology (CNT) demo
- Solar Cell technology demo

2013 2014 2015
Delivery Date Launch Date
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

Google Maps
Dunsborough, Australia

> 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
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

> *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

> 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

> Delivery October 2014
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
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