Looking Up: The MCubed/COVE Mission

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2014 SPRING CUBESAT DEVELOPER’S WORKSHOP
OUTLINE

• Introduction
• Motivation and Inspiration
• JPL and University of Michigan Collaboration
• COVE Board Design and Development Experiences
• 1st Launch and Deployment
• MCubed/COVE-2 Re-flight and Current Status
• Next Generation
• Conclusion
• Resources
• Acknowledgements
CubeSat On-Board Processing Validation Experiment (MCubed/COVE-2)
Multiangle Spectropolarimetric Imaging Algorithm Validation

Mission Description

- NASA JPL and U. Michigan Project
  - JPL provides processing payload
  - U. Michigan provides spacecraft

- Advances instrument signal processing technology for high data rate Earth observing instruments

- Will enable two-orders of magnitude data reduction for climate science observations

- Orbit: High inclination polar


Sponsored by NASA’s Earth Science Technology Office (ESTO)
Multiangle Spectropolarimetric Imager (MSPI) for ACE Decadal Survey Mission

- Measures cloud and aerosol properties via 9 cameras
- Each camera processes 95 Mbytes/s of raw video data that must be reduced by two-orders of magnitude for spaceborne deployment
- Achieved via instrument signal processing not compression

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<th>Ground Test</th>
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<td>Development board processes imagery within laboratory environment</td>
<td>ER-2 flights store data on rack-mounted disks for ground processing</td>
<td>M-Cubed/COVE CubeSat verifies algorithm and hardware for future MSPI instrument</td>
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INSPIRATION

- 2009 Cal Poly SLO CubeSat Workshop
- UM Team, impromptu participation in review
- Extra space for another payload
- 3-month feasibility study

OBJECTIVES:

1. Capture and downlink mid-resolution images of the Earth

2. Educate and train the next generation of engineers in the Aerospace Industry

1. Raise TRL of ESTO Technologies relevant to the Earth Science Decadal Survey Missions
   - MSPI On-Board Processing (OBP) algorithm
   - Xilinx Virtex-5QV Single event Immune Reconfigurable FPGA

SmallSat platforms can rapidly advance the TRL of key instrument components and serve as platforms for new science observations
COLLABORATION

- Student CubeSat team mentored by Dr. Jamie Cutler (COVE Co-I)
- Weekly M-Cubed team meetings with JPL telecon participation
- ESTO Interim (6-month) and Annual Reviews held at Univ. of Michigan
- Collaborative development of the M-Cubed/COVE Interface Control Document (ICD)
- Univ. of Michigan develops CubeSat bus, integrates JPL payload, acquires FCC and NOAA licenses, integrates with P-Pod, performs ground station support for mission operations

M-Cubed (Michigan Multipurpose MiniSat) Flight Model
Image Courtesy of U. Michigan
1,700+ Column Grid Array (CGA) Pins – Largest Placement on JPL Record
GETTING TO SPACE

Real-time Onboard Processing for MSPI (AIST, Pingree/JPL)

Integrated into P-POD (Poly-PicoSatellite Orbital Deployer)

Xilinx Virtex-5QV FPGA

Michigan COVE S3FL Team

COVE Flight Unit

NPP Satellite and P-PODS (in red) on the Struts

Courtesy: M. P. Mackley
ELaNa-3 NPP Launch with M-Cubed/COVE
October 28th, 2011 Approx 2:48:01am PT
- Several upgrades were made to MC2 based on MC1 and RAX flight lessons
  - Structural lesson: MC1 was difficult to manufacture and build to tolerance.
  - MC2 structure was redesigned to be robust and easier to fabricate and integrate.

- COVE-2 build-to-print
ELaNa-2 NROL-39 Launch with M-Cubed/COVE-2
December 5th, 2013 at 11:14:30pm PT

Firebird SNaP Mcubed-2 Alice AeroCube5 (A/B)
CunySat-1 IPEX/CP-8 SMDC-ONE (C/D)
TacSat-6 (not shown)

8 P-PODS
Up to 24U volume of CubeSats
ESPA and ABC Compatible
TRACKING MCUBED/COVE-2 (JSpOC-710)
COVE-2 FLIGHT VALIDATION

1. Auto-run sequence on 12/13/2013 (L + 1 week)
2. Additional COVE runs on stored image
3. COVE validation on Earth images taken with MCubed Camera

**COVE-2 MD5SUM Checksums**
4,294,967,295 (default, 7FFFFFFF)

**picA (on-board stored image)**
b43c178e5963e52915e896e6972e8804
  p1 = 43c178e = 3023837070
  p2 = 5963e529 = 1499718953
  p3 = 896e6972 = 367564518
  p4 = 8804 = 2536409092

**pic6 (Earth image #1)**
be454ff3fe5af1b2727c4469cea1ad10
  p1 = 199513343
  p2 = 1046147506
  p3 = 1920746601
  p4 = 3466702096
COVE CHECKSUM VALIDATION

Beacons contained MD5SUM checksum of results for ground verification (COVE Panel Below)

MD5SUM Checksum \[p1p2p3p4\]: b43c178e5963e52915e896e6972e8804
Checksum in Decimal: \(p1=3,023,837,070\) \(p2=1,499,718,953\) \(p3=367,564,518\) \(p4=2,536,409,092\)
COVE HOUSEKEEPING DATA

Per-Supply Voltages: 11 Feb 2014 PlcA

Per-Supply Current Draw: 11 Feb 2014 PlcA

Total Power Dissipation: 11 Feb 2014 PlcA

Temperature: 11 Feb 2014 PlcA
FUTURE VALIDATION STEPS

• Acquire/analyze statistical data set to characterize COVE performance
  • Over temperature
  • Over time of radiation exposure
  • Longer duration on-time executions

• [option/goal] Demonstrate in-flight reprogramming of FPGA with upload and execution of modified/new configuration file to enable future capabilities such as fault mitigation and new processing support
3 GENERATIONS OF CUBESAT ELECTRONICS

FM COVE-2 (MCubed-2)

Virtex-5QV FX130 FPGA
Launched 12/5/2013

EM MARINA (GRIFEX)

Virtex-5 FX70 FPGA
Launch scheduled for 10/31/2014
(with SMAP)

EM MARINA-2
(INSPIRE/IRIS)

Virtex-5 LX85 FPGA
Launch TBD
PIPELINE OF NEW HIRES AT JPL

• T. Wilson (Aubum)
• A. Klesh (UM)
• M. Bennett (UM)
• S. Tripp (UM)
• S. Spangelo (UM)
• A. Kummer (Penn State)
• D. Muthulingham (Stanford)
• P. Banazadeh (UT-Austin)
• A. Babuscia (MIT)
CONCLUSION

√ JPL's 1st (and 2nd) CubeSat Payload to Launch
√ 1st Xilinx V5QV SIRF production part to fly (COVE) and operate in space (COVE-2)
√ JPL's 1st installation of 1752-pin CGA device

√ Established successful JPL/University of Michigan collaboration with pipeline of very qualified new hires to JPL
√ Advanced the TRL of MSPI on-board processing capability
RESOURCES

• Univ. of Michigan website: http://exploration.engin.umich.edu/
• JPL website: cubesat.jpl.nasa.gov
ACKNOWLEDGEMENTS

HEOMD:
Jason Crusan

NASA Launch Services and Cal Poly Integration Team Leads:
Garrett Skrobot (KSC)
Roland Coelho (Cal Poly)

ESTO POCs:
Mike Pasciuto
Charles Norton

JPL Team:
Paula Pingree (PI)
Dmitriy Bekker
Brian Franklin
Reza Ghaffarian
John Kennedy
Atul Mehta
Nooshin Meshkaty
Noly Neverida
Chris Peay
Joshua Ravich
Hung Truong
Thomas Weme
Thor Wilson

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William Fang
Alyssa Franken
Brad Freyberg
Anton Frokenkov
Kutessa Garnett
Ken Gmerek
Brandon Heidt
Michael Heywood
Steve Howland
Devon Hupp
Vikram Ivatury
So-Hee Kang
Ben Kempke
Charles Lacy
Josh Lipshaw
Kathryn Luczek
Lucas Mason
Daniel Meinzer
Duncan Miller
Mike Mistaleski
John Marc O’Kins
Hetav Patel
Ari Porter
Tyler Rose
Tj Ryan
Fernando Saca
Srinagesh Sharma
Alex Sloboda
Dan Smith
John Springmann
Joshua Synowiec
Scott Tripp
Joshua Weiss
Adam Werries
Andrew Wood

The research described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Sponsored by NASA/Earth Science Technology Office (ESTO)

Q & A

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