Looking Up: The MCubed/COVE Mission

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2014 SPRING CUBESAT DEVELOPER'S WORKSHOP

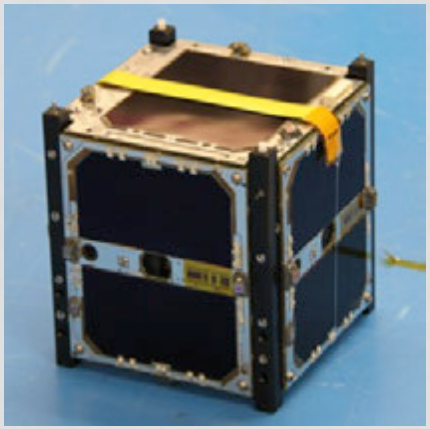
OUTLINE

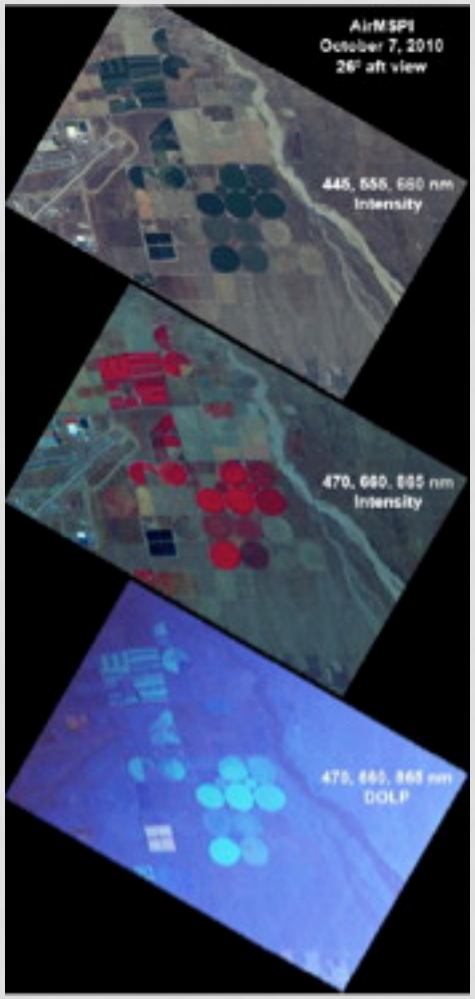
- Introduction
- Motivation and Inspiration
- JPL and University of Michigan Collaboration
- COVE Board Design and Development Experiences
- 1st Launch and Deployment
- MCubed/COVE-2 Re-flight and Current Status
- Next Generation
- Conclusion
- Resources
- Acknowledgements

CubeSat On-Board Processing Validation Experiment (MCubed/COVE-2)

Multiangle Spectropolarimetric Imaging Algorithm Validation

Jet Propulsion Laboratory
California Institute of Technology





Mission Description

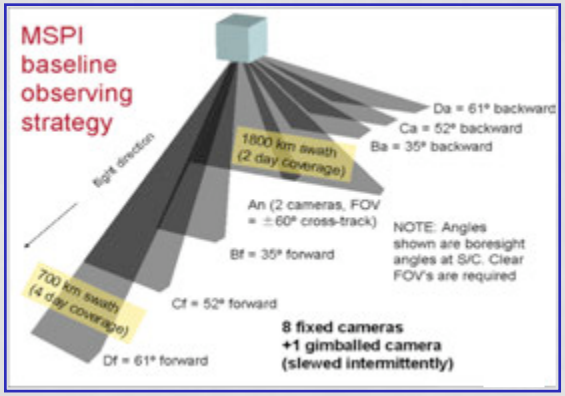
- NASA JPL and U. Michigan Project
  - JPL provides processing payload
  - U. Michigan provides spacecraft
- Advances instrument signal processing technology for high data rate Earth observing instruments
- Will enable two-orders of magnitude data reduction for climate science observations
- Orbit: High inclination polar
- Launch: Dec. 5, 2013 from VAFB on NROL-39 GEMSat Atlas V (NASA CSLI)

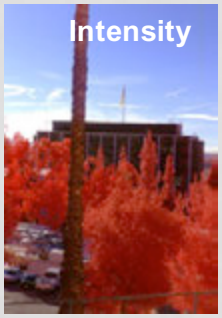
Sponsored by NASA's Earth Science Technology Office (ESTO)

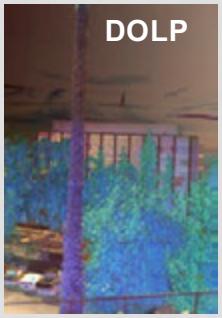
MSPI INSTRUMENT PROCESSING VALIDATION

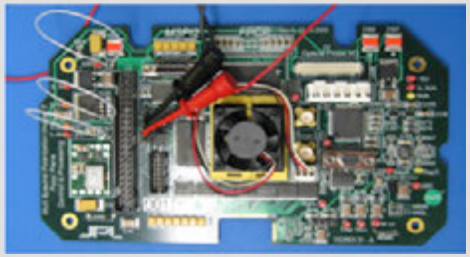
Multiangle Spectropolarimetric Imager (MSPI) for ACE Decadal Survey Mission

- 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

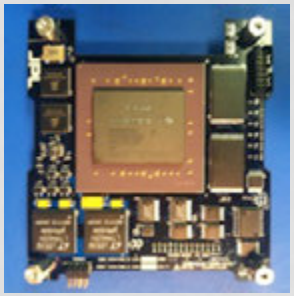




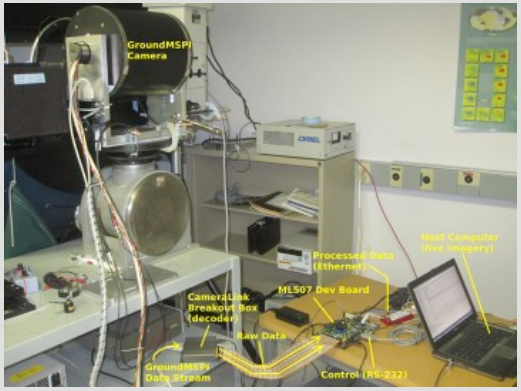


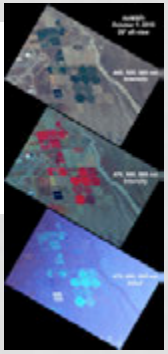


AirMSPI board with military-grade Xilinx Virtex-5 FPGA demonstrates data reduction

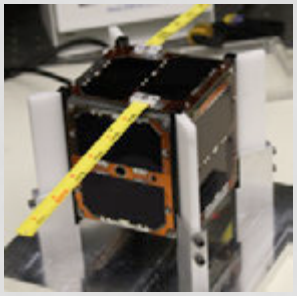


COVE board validates Xilinx Virtex-5 SIRF Rad-Hard by design FPGA and polarimetry algorithm for SpaceMSPI





ER-2 with first engineering flight data from AirMSPI



Ground Test

Development board processes imagery within laboratory environment

Airborne Test

ER-2 flights store data on rack-mounted disks for ground processing

Spaceborne Validation

M-Cubed/COVE CubeSat verifies algorithm and hardware for future MSPI instrument

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

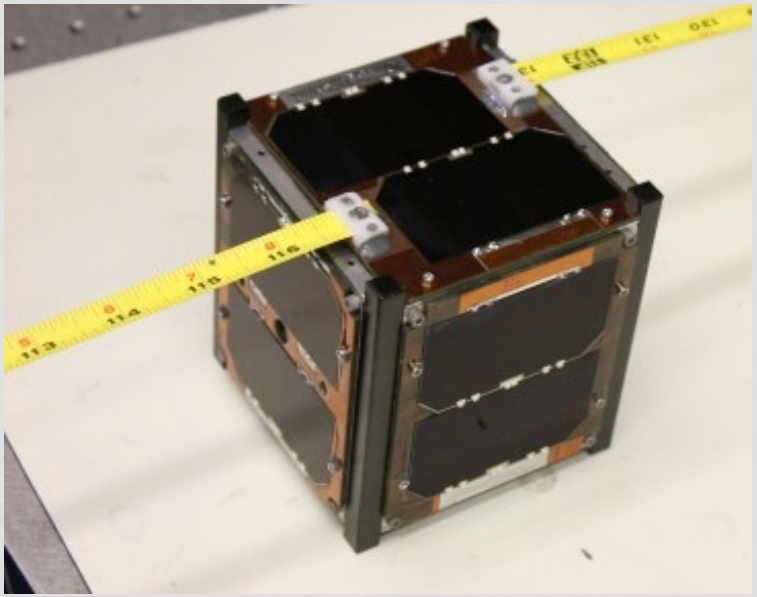
2. Educate and train the next generation of engineers in the Aerospace Industry

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

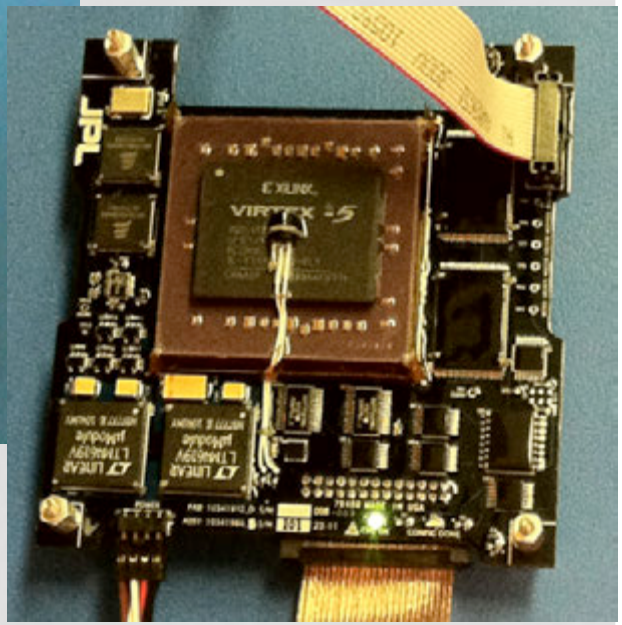


M-Cubed (Michigan Multipurpose MiniSat) Flight Model
Image Courtesy of U. Michigan

COVE BOARD DEVELOPMENT

Engineering Model
(Commercial Virtex-5)

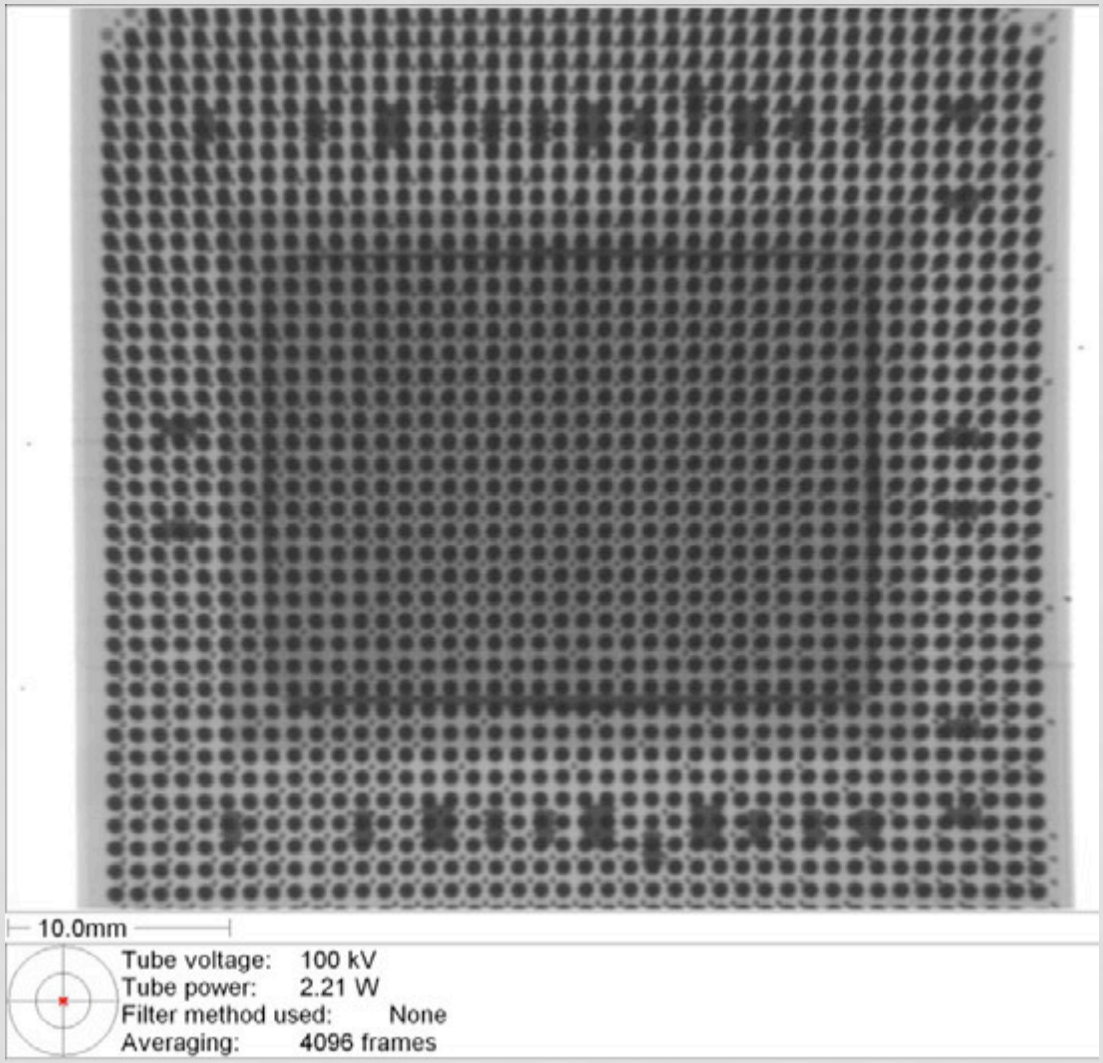
Flight Model
(V5QV Production SIRF)

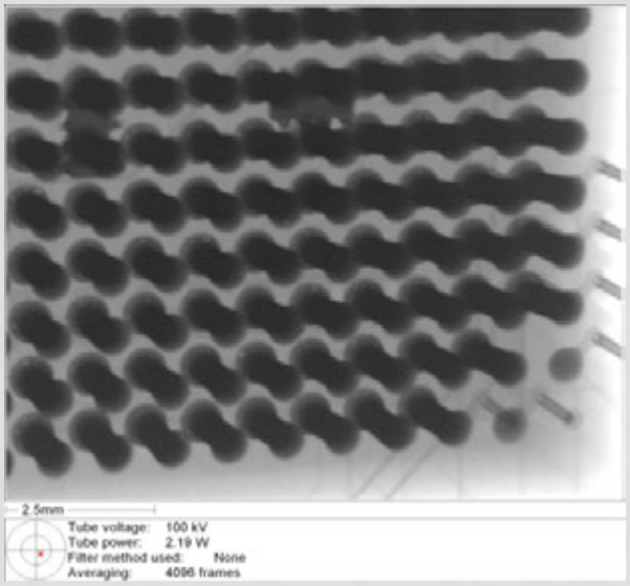


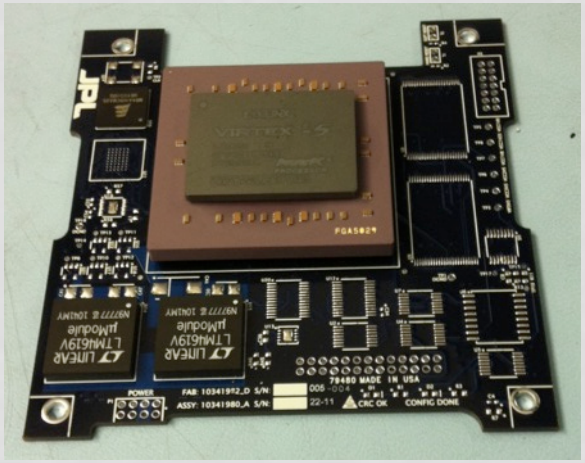
Flight Spare
(V5QV Engineering Sample SIRF)

Press Release: Xilinx Space-Grade Virtex-5QV FPGA in Production with Mega-Rad Capability (July 21, 2011)

VIRTEX-5QV DAISY CHAIN X-RAY CGA





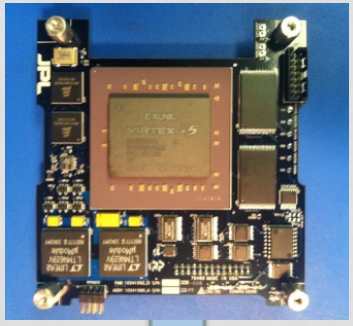


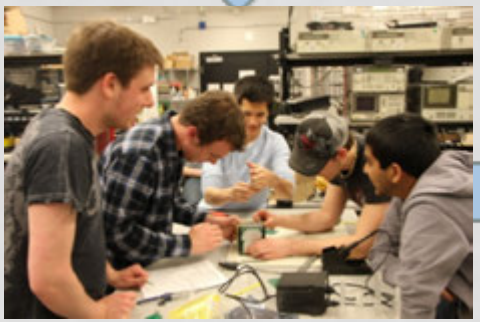
1,700+ Column Grid Array (CGA) Pins – Largest Placement on JPL Record

GETTTING TO SPACE

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

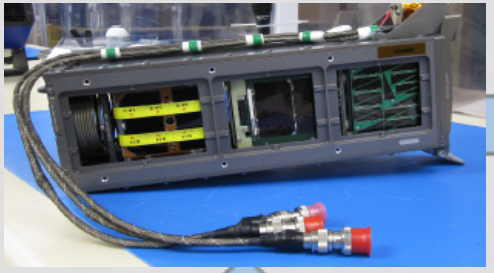
Xilinx Virtex-5QV FPGA

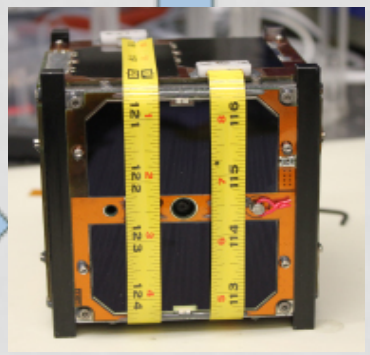




Michigan COVE S3FL Team

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





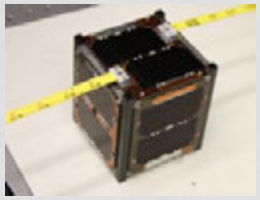
COVE Flight Unit

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

P-Pod 1



M-Cubed/COVE

E1P

AubieSat

P-Pod 2

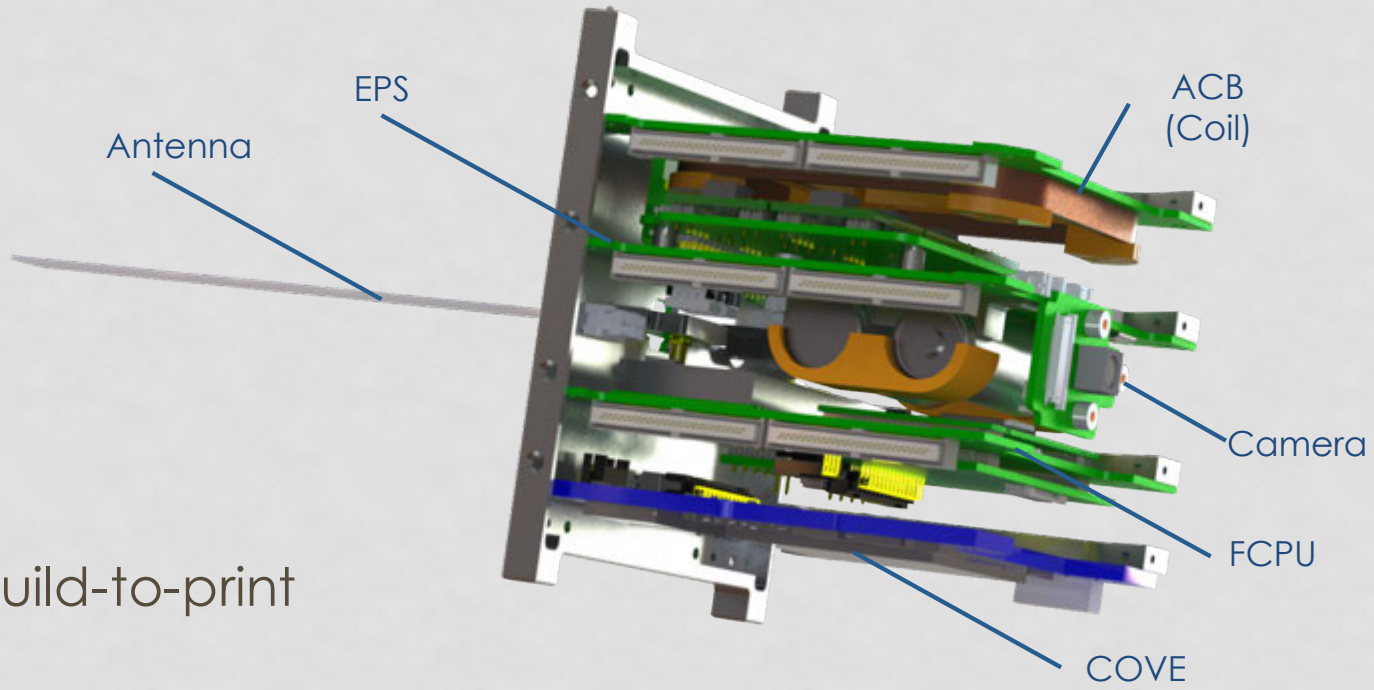
RAX-2

P-Pod 3

DICE

MCUBED/COVE-2 RE-FLIGHT MISSION IS FUNDED BY ESTO

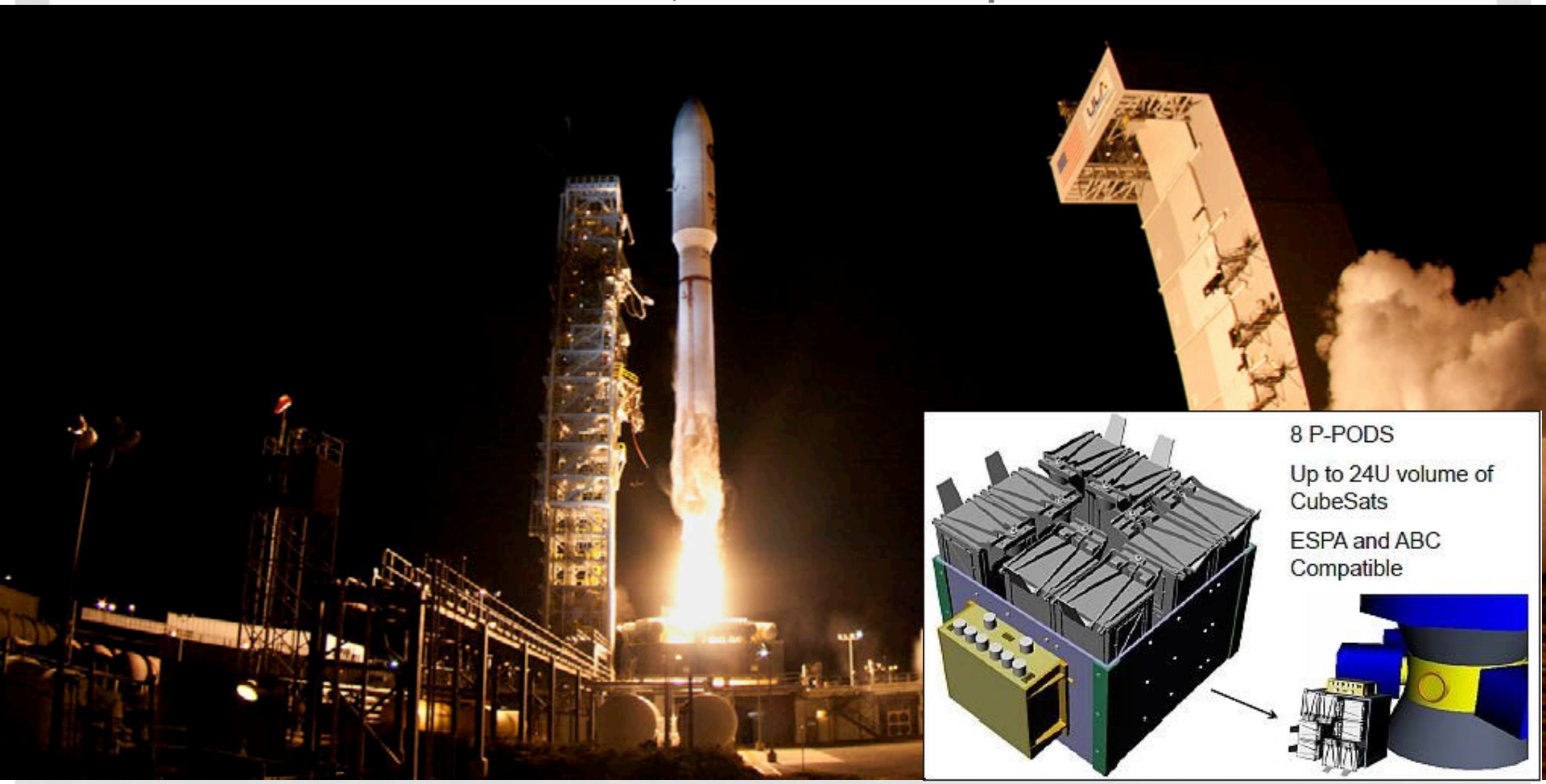
- Several upgrades were made to MC2 based on MC1 and RAX flight lessons
  - Structural lesson: MC1 was difficult to manufacture and build to tolerance.
  - *MC2 structure was redesigned to be robust and easier to fabricate and integrate.*



- COVE-2 build-to-print

ELaNa-2 NROL-39 Launch with M-Cubed/COVE-2

December 5th, 2013 at 11:14:30pm PT



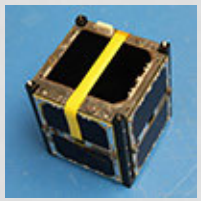
TacSat-6 (not shown)

Firebird

AeroCube5 (A/B)

Alice

SMDC-ONE (C/D)



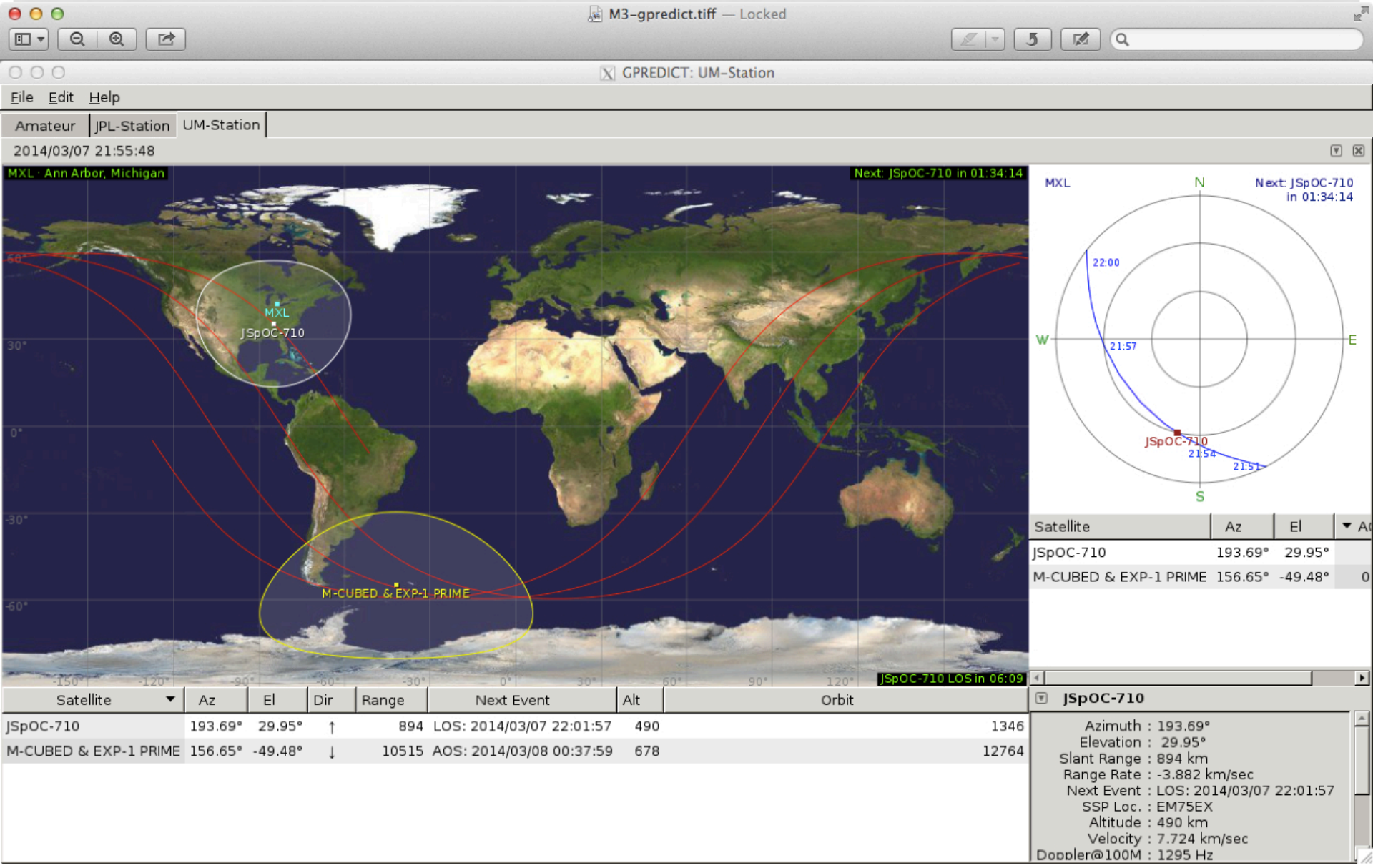
Mcubed-2

CunySat-1

IPEX/CP-8

SNaP

TRACKING MCUBED/COVE-2 (JSpOC-710)



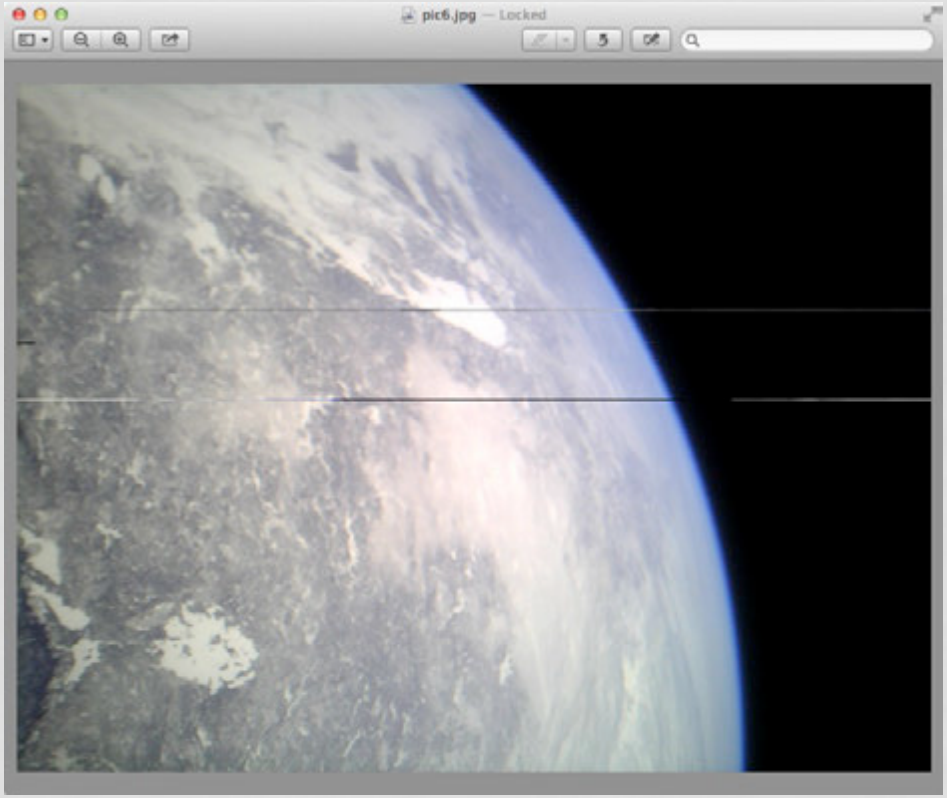
COVE-2 FLIGHT VALIDATION

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)

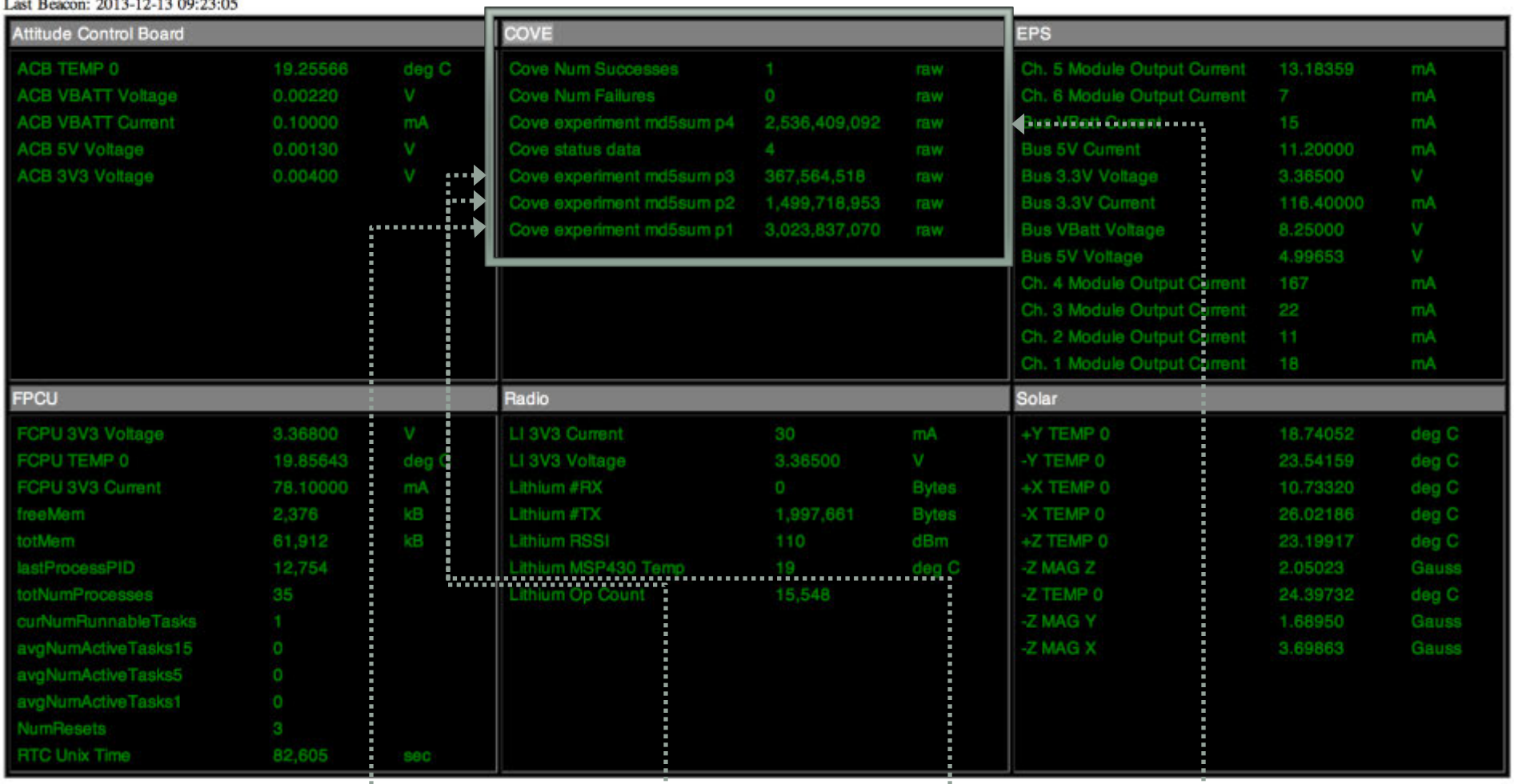
picA (on-board stored image)
b43c178e5963e52915e896e6972e8804
p1 = b43c178e = 3023837070
p2 = 5963e529 = 1499718953
p3 = 15e896e6 = 367564518
p4 = 972e8804 = 2536409092

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)



Live Telemetry

MCubed2 Flight
Last Updated: 2013-12-13 09:44:00
Last Beacon: 2013-12-13 09:23:05

Attitude Control Board		
ACB TEMP 0	19.25566	deg C
ACB VBATT Voltage	0.00220	V
ACB VBATT Current	0.10000	mA
ACB 5V Voltage	0.00130	V
ACB 3V3 Voltage	0.00400	V

COVE		
Cove Num Successes	1	raw
Cove Num Failures	0	raw
Cove experiment md5sum p4	2,536,409,092	raw
Cove status data	4	raw
Cove experiment md5sum p3	367,564,518	raw
Cove experiment md5sum p2	1,499,718,953	raw
Cove experiment md5sum p1	3,023,837,070	raw

EPS		
Ch. 5 Module Output Current	13.18359	mA
Ch. 6 Module Output Current	7	mA
[illegible]	15	mA
Bus 5V Current	11.20000	mA
Bus 3.3V Voltage	3.36500	V
Bus 3.3V Current	116.40000	mA
Bus VBatt Voltage	8.25000	V
Bus 5V Voltage	4.99653	V
Ch. 4 Module Output Current	167	mA
Ch. 3 Module Output Current	22	mA
Ch. 2 Module Output Current	11	mA
Ch. 1 Module Output Current	18	mA

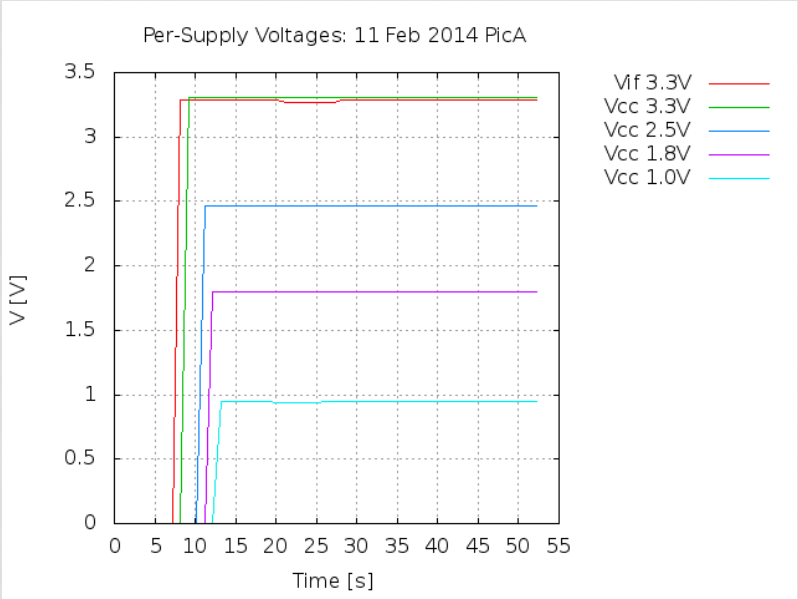
FPCU		
FCPU 3V3 Voltage	3.36800	V
FCPU TEMP 0	19.85643	deg C
FCPU 3V3 Current	78.10000	mA
freeMem	2,376	kB
totMem	61,912	kB
lastProcessPID	12,754	
totNumProcesses	35	
curNumRunnableTasks	1	
avgNumActiveTasks15	0	
avgNumActiveTasks5	0	
avgNumActiveTasks1	0	
NumResets	3	
RTC Unix Time	82,605	sec

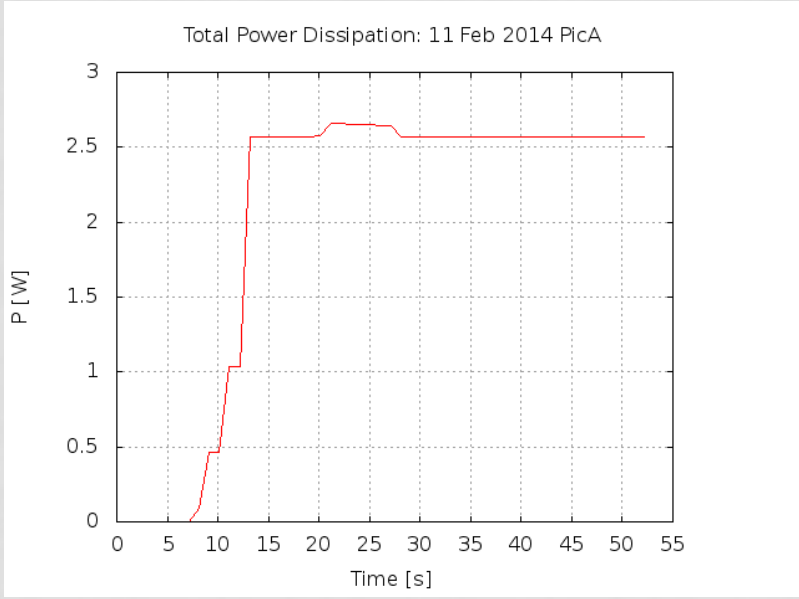
Radio		
LI 3V3 Current	30	mA
LI 3V3 Voltage	3.36500	V
Lithium #RX	0	Bytes
Lithium #TX	1,997,661	Bytes
Lithium RSSI	110	dBm
Lithium MSP430 Temp	19	deg C
Lithium Op Count	15,548	

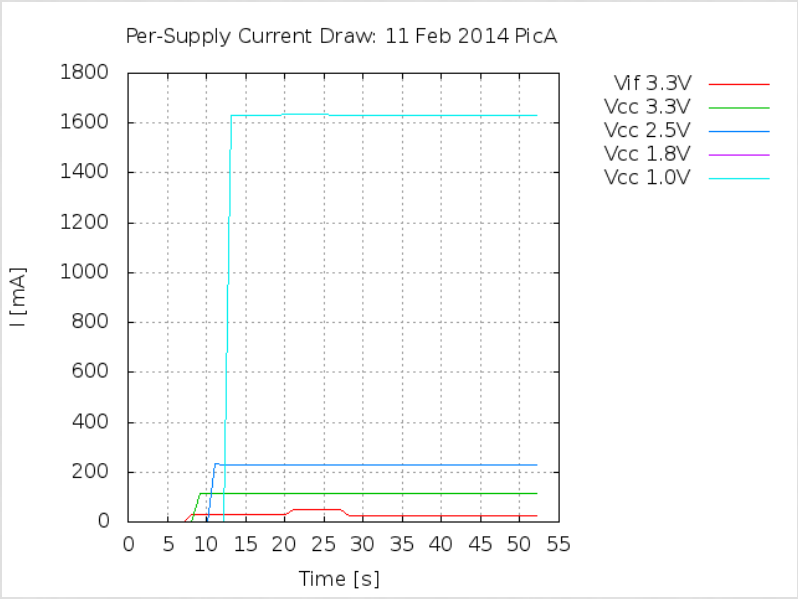
Solar		
+Y TEMP 0	18.74052	deg C
-Y TEMP 0	23.54159	deg C
+X TEMP 0	10.73320	deg C
-X TEMP 0	26.02186	deg C
+Z TEMP 0	23.19917	deg C
-Z MAG Z	2.05023	Gauss
-Z TEMP 0	24.39732	deg C
-Z MAG Y	1.68950	Gauss
-Z MAG X	3.69863	Gauss

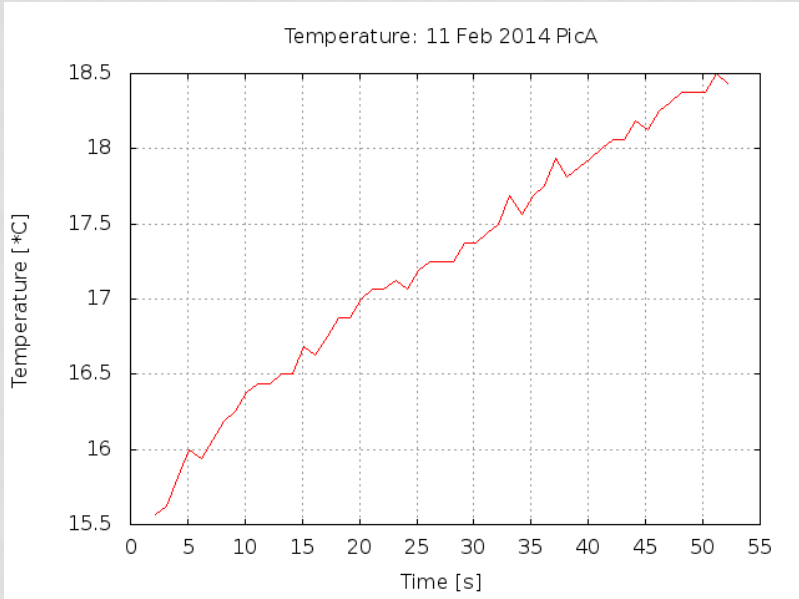
MD5SUM Checksum [p1p2p3p4]: b43c178e5963e52915e896e6972e8804
Checksum in Decimal: p1=3,023,837,070 p2=1,499,718,953 p3=367,564,518 p4=2,536,409,092

COVE HOUSEKEEPING DATA









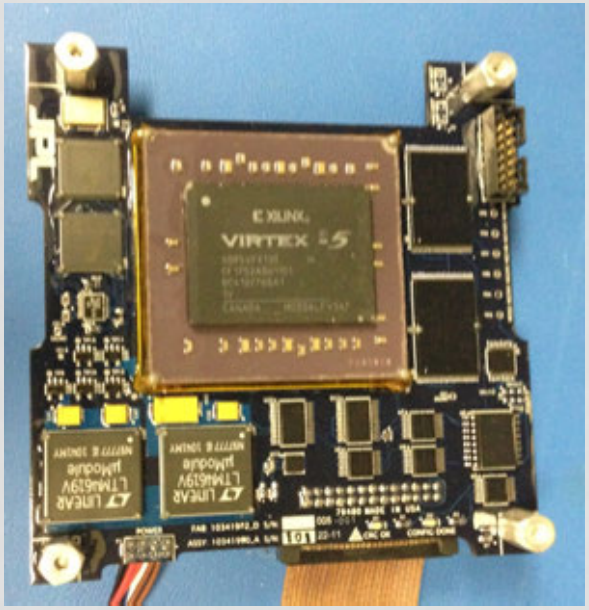
FUTURE VALIDATION STEPS

- 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 (Auburn)*
- 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

√ JPLs 1st (and 2nd) CubeSat Payload to Launch

√ 1st Xilinx V5QV SIRF production part to fly (COVE) and operate in space (COVE-2)

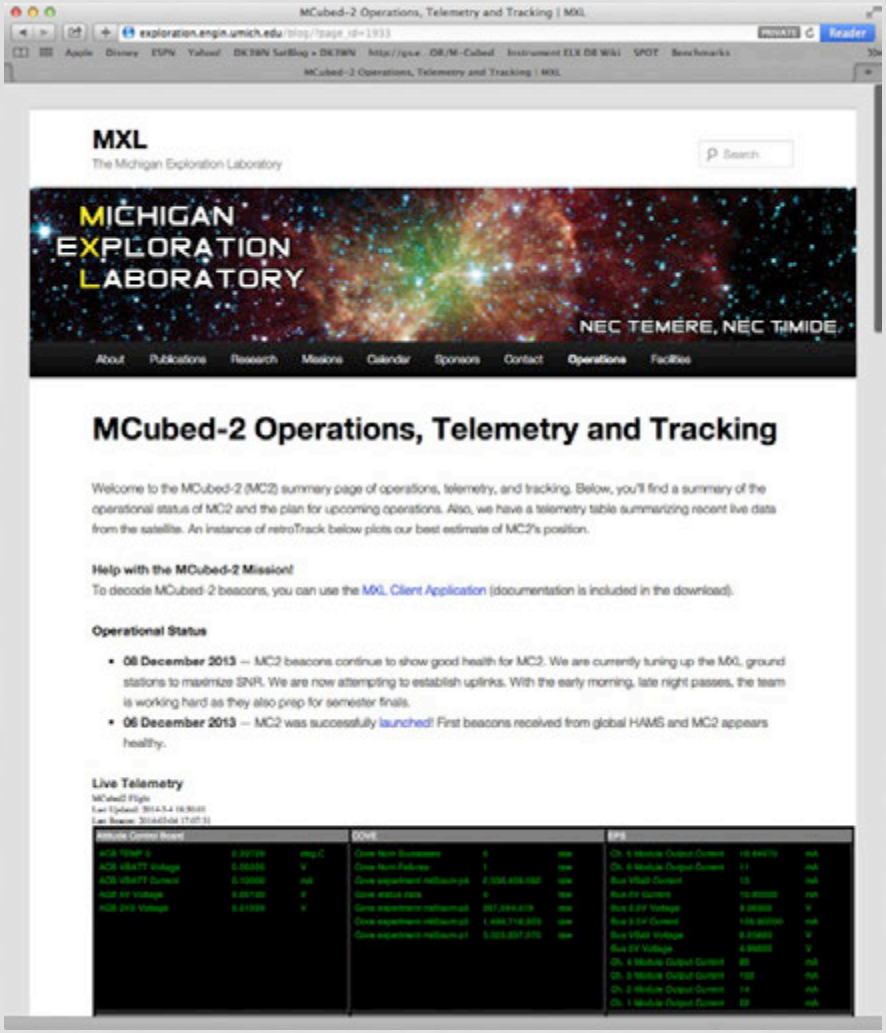
√ JPLs 1st installation of 1752-pin CGA device

√ 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



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Atul Mehta
Nooshin Meshkaty
Noly Neverida
Chris Peay
Joshua Ravich
Hung Truong
Thomas Werne
Thor Wilson

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Roland Coelho (Cal Poly)

University of Michigan Team:
Prof. Jamie Cutler (Co-I)
Students:
Duane Achterhof
Chris Acosta
Jimmy Blanchard
Kaitlyn Burke
David Cardelli
Matthew Chase
Luke DeGalan
William Fang
Alyssa Franken
Brad Freyberg
Anton Frokenkov
Kutessa Garnett
Ken Gmerek
Brandon Heidt
Michael Heywood
Steve Howland
Devin 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
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Srinagesh Sharma
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Q & A

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