

BisonSat, the Salish Kootenai College CubeSat



***Briefing for the Tribal College Engineering
Working Group, 19 August 2015***

Tim Olson
Chairman
Division of Sciences
Salish Kootenai College

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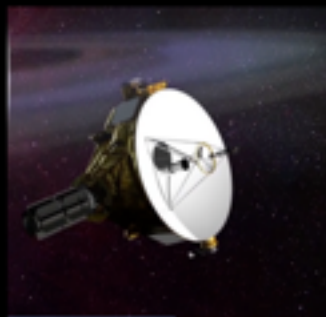
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Getting ready to interview Dr. Tim Olson, Principal Investigator for BisonSat. We are at Salish Kootenai College. pic.twitter.com/MNGOHnKJUA

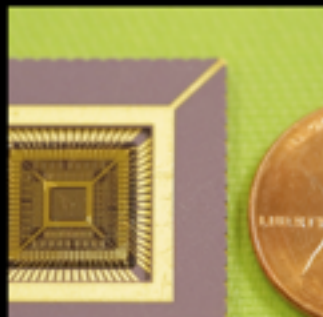


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What is NASA EDGE?

NASA EDGE. One NASA. Two hosts. Twenty thousand plus rocket scientists. We have liftoff!

NASA EDGE is different. Unscripted and unpredictable, NASA EDGE takes a unique look in and around the greatest space program on the planet.

Whether it's the latest launch or the coolest gadgets, NASA EDGE hosts provide an offbeat, funny and informative look behind the scenes.



NASA EDGE video on *BisonSat*

- NASA CubeSat Launch Initiative program active since 2010
- To date six rounds of selections, 105 satellites selected for flight, 37 launched, 12 more to launch within the next 12 months
- SKC *BisonSat* selected for flight in the third competition in 2012, scheduled for launch on 23 Sept 2015 as a secondary payload on the NRO GRACE/NASA ELaNa XII mission from Vandenberg Air Force Base



The screenshot shows the NASA website's layout for the CubeSat Launch Initiative (CSLI). At the top is the NASA logo and navigation links for News, Missions, Multimedia, Connect, and About NASA. Below this is a search bar and a horizontal menu for different audiences: For Public, For Educators, For Students, and For Media. The main content area is titled "Human Exploration and Operations" and features a large banner image of a satellite in space. To the left of the main content is a sidebar with links for "Human Exploration & Operations (HEO)", "About the Directorate", "Programs", "Shuttle Retirement", "Education and Outreach", "Space Flight Awareness", "Frequently Asked Questions", and "Related Links". The main content area has a section for "CubeSat Launch initiative (CSLI)" which includes a description of the program, a photo of a CubeSat, and a list of "ELaNa Cubesat Launches" with links to ELaNa V, ELaNa IV, and ELaNa III. To the right of the main content is a section for "2015 CSLI Announcement of Opportunity" with a date of 08.10.2015 and a link to the announcement. Below this is a section for "50 CubeSats from 50 States" with a map of the United States showing the locations of the CubeSat launches.

Human Exploration and Operations
Human exploration in and beyond low-Earth orbit

CubeSat Launch initiative (CSLI)

NASA's CubeSat Launch initiative (CSLI) provides opportunities for small satellite payloads to fly on rockets planned for upcoming launches. These CubeSats are flown as auxiliary payloads on previously planned missions.

CubeSats are a class of research spacecraft called nanosatellites. The cube-shaped satellites are approximately four inches long, have a volume of about one quart and weigh about 3 pounds. To participate in the CSLI program, CubeSat investigations should be consistent with NASA's Strategic Plan and the Education Strategic Coordination Framework. The research should address aspects of science, exploration, technology development, education or operations.

By providing a progression of educational opportunities including CSLI for students, teachers, and faculty, NASA assists the Nation in attracting and retaining students in STEM disciplines. This strengthens NASA's and the Nation's future workforce. Further, the CSLI promotes and develops innovative technology partnerships among NASA, U.S. industry, and other sectors for the benefit of Agency programs and projects. NASA thus gains a mechanism to use CubeSats for low-cost technology development and validation.

2015 CSLI Announcement of Opportunity

08.10.2015 - NASA announces the 2015 CSLI call for proposals, due Nov. 24, 2015. See official details here: <http://go.nasa.gov/1J06ic4>

50 CubeSats from 50 States

NASA seeks to expand the CubeSat Launch Initiative to include launching 50 small satellites from 50 states within five years.

» Read more
» Download the announcement full text



NASA CubeSat Launch Initiative

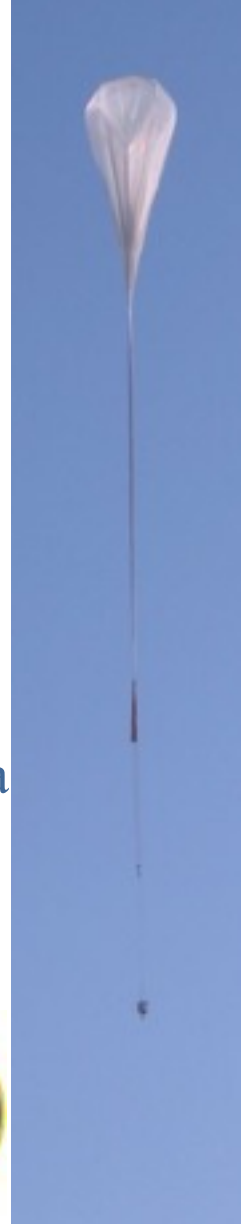
- NASA award to SKC, “Attracting Tribal College Students to NASA-focused STEM Careers Through Participation in Flight Missions”, NASA TCUP program, Dec 2010 - June 2015
- Flight of a prototype of the *BisonSat* camera on a NASA HASP flight August 2011 from the Columbia Scientific Balloon Facility, Ft. Sumner, NM
- SKC CubeSat elected for flight, Feb. 2012, 3rd CubeSat Launch Initiative competition
- Manifested March 2013 on the NASA ELaNa XII mission
- Flight unit design, build, and test Sept 2012 - March 2015
- Delivery to the launch provider March 2015
- Launch scheduled from Vandenberg AF Base, 23 Sept 2015



***BisonSat* development timeline**

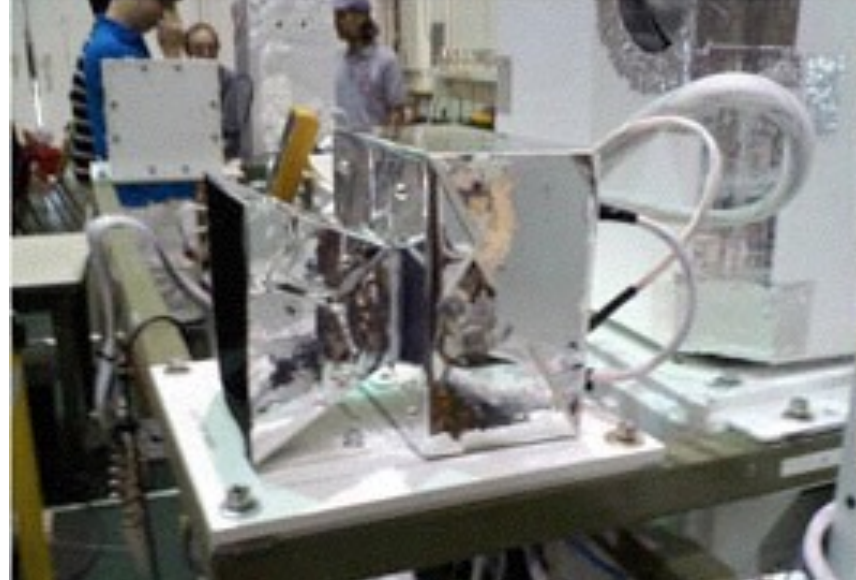


- NASA HASP (High Altitude Student Platform) program provides launch opportunities for student-built payloads to fly to 36 km altitude for 15-20 hours.
- Provided the *BisonSat* team an experience with space hardware development from conceptualization, through design, build, test, and flight operations - great for building the capacity to do a CubeSat mission.
- SKC flew a SKC-designed CubeSat camera prototype on the August 2011 HASP Flight from the NASA Columbia Scientific Balloon Facility at Ft. Sumner, New Mexico.



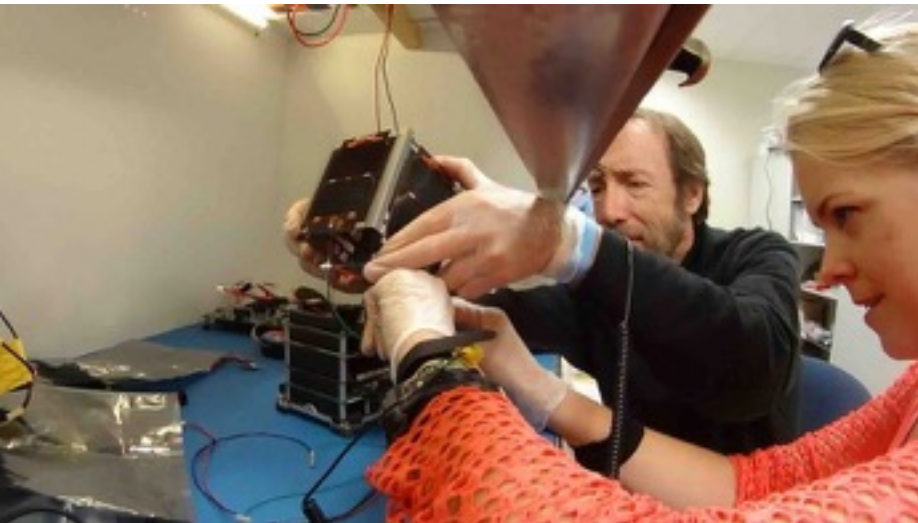
SKC HASP flight

- Micron MT9M131 CMOS sensor (on a Micron head board)
 - 1280 x 1024 active pixels
 - 1/3-inch optical format
 - Bayer pattern filter
 - System on a chip capability
- 4.5 mm focal length, F/2 lens, 68° field of view
- Controlled by Altera EP3C25 Cyclone III FPGA (on a SKC designed interface board)
- Image acquired every 90 seconds in flight, written to a 2 GB microSD card, retrieved post flight
- Uplink commands controlling operation
- Thumbnail and temperature data via downlink

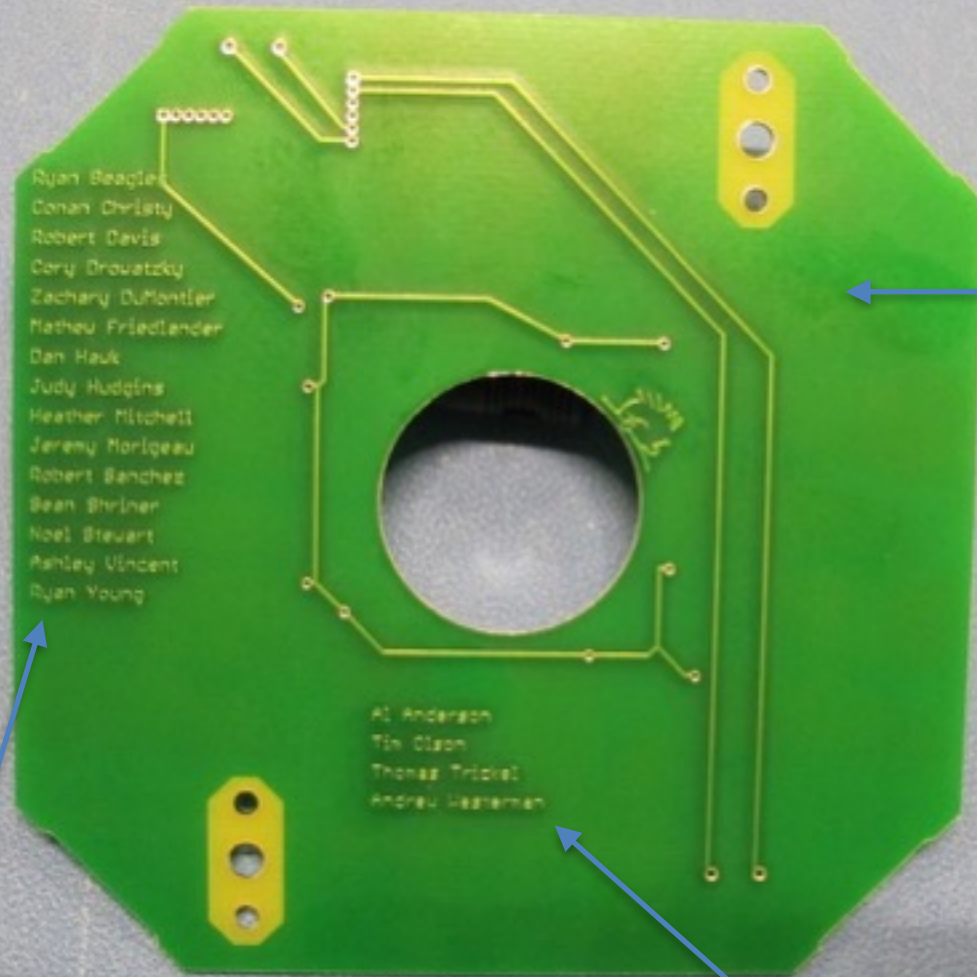


SKC HASP camera

- *BisonSat* has primarily an educational objective of training undergraduate engineering and science students on design, build, test, and operation of space hardware.
- The science payload is a SKC-designed visible light camera for land cover classification, cloud cover, and cloud height measurements.



***BisonSat* mission**



Back side of the
BisonSat top solar
panel

Students (engineering, IT, hydrology, and
secondary science education majors)

Faculty mentors



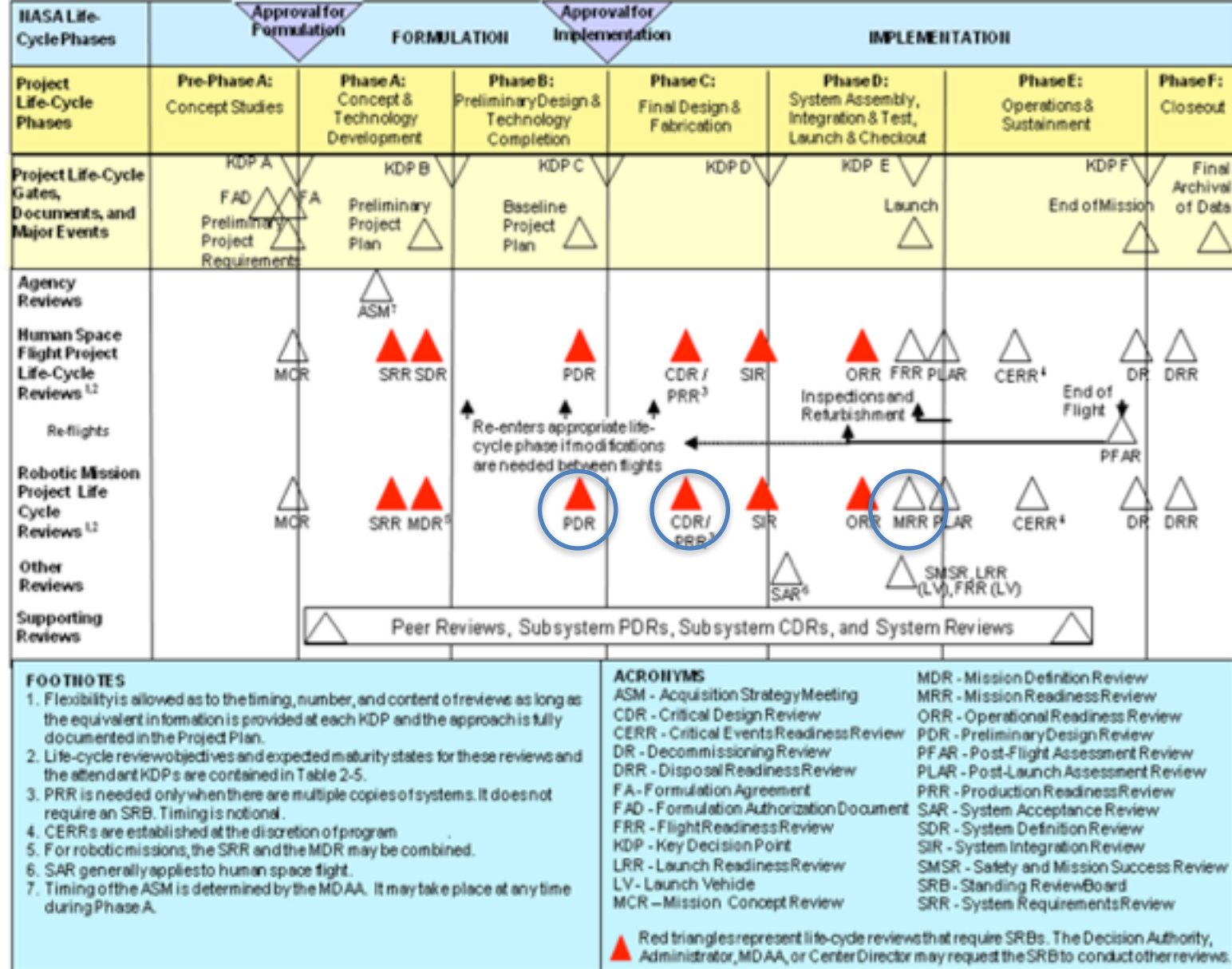
***BisonSat* team members**

- Launch Services Program - Program Level Poly Picosatellite Orbital Deployer and CubeSat Requirements (LSP-REQ-317.01 Rev B): All CubeSats must meet these requirements (overall mass, physical dimensions, materials, etc.). Ensures the CubeSat fits in the standard deployment mechanism (P-POD).
- NASA Procedural Requirements for Limiting Orbital Debris (NPR 8715.6A)
- Range Safety Requirements (AFSPCMAN 91-710)
- NASA Technical Standard - Standard Materials and Processes Requirements for Spacecraft (NASA-STD-6016)
- CubeSat to P-POD Interface Control Document: Additional requirements specific to each mission that ensure the CubeSat will not harm the primary mission (battery protections, vibration environment survivability, multiple independent power on and transmission inhibits, venting area, mass moment of inertia, etc).



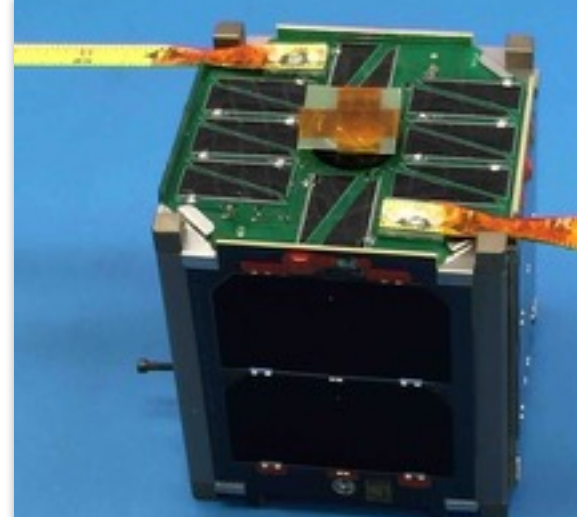
Design constraints

BisonSat development guided by NASA systems engineering best practices and independent reviews.

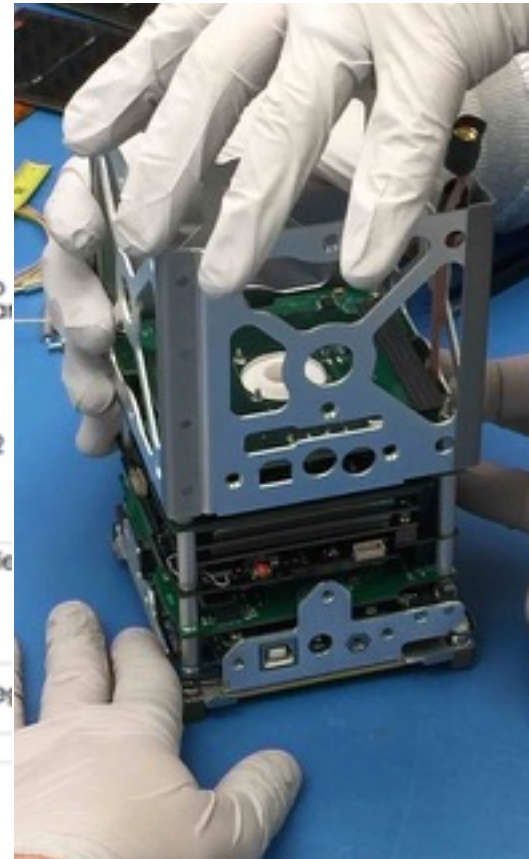
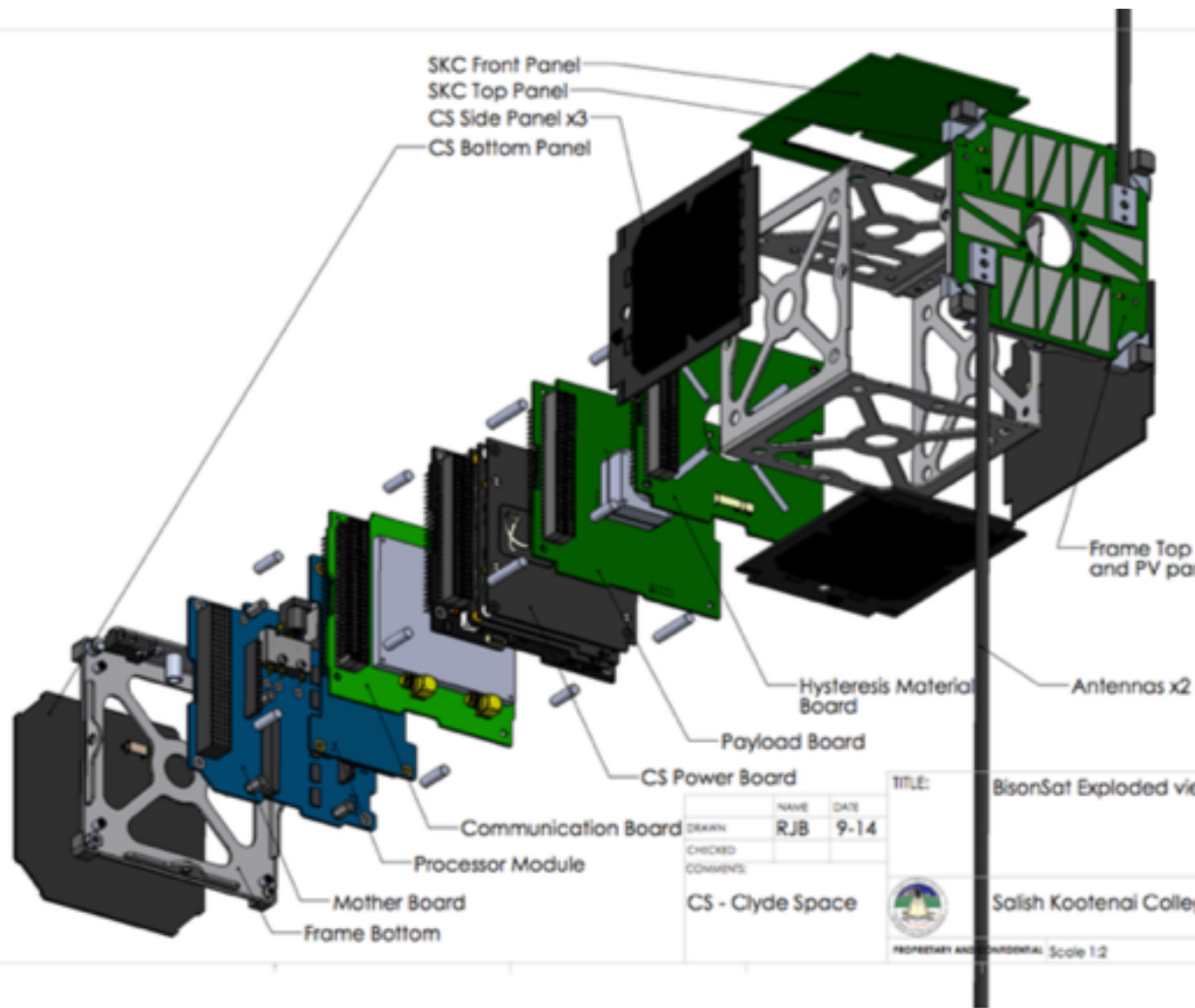


Design process

- Mix of COTS and SKC-designed subsystems
- Pumpkin 1U structure and Command and Data Handling Subsystem
- AstroDev VHF/UHF radio board with SKC-designed and fabricated antennas
- Clyde Space Electric Power Control board with four Clyde Space solar panels and two SKC-designed and fabricated panels
- Attitude control design by SKC (passive magnetic control)
- Camera board design by SKC
- Power switching board design by SKC
- Flight software written by SKC

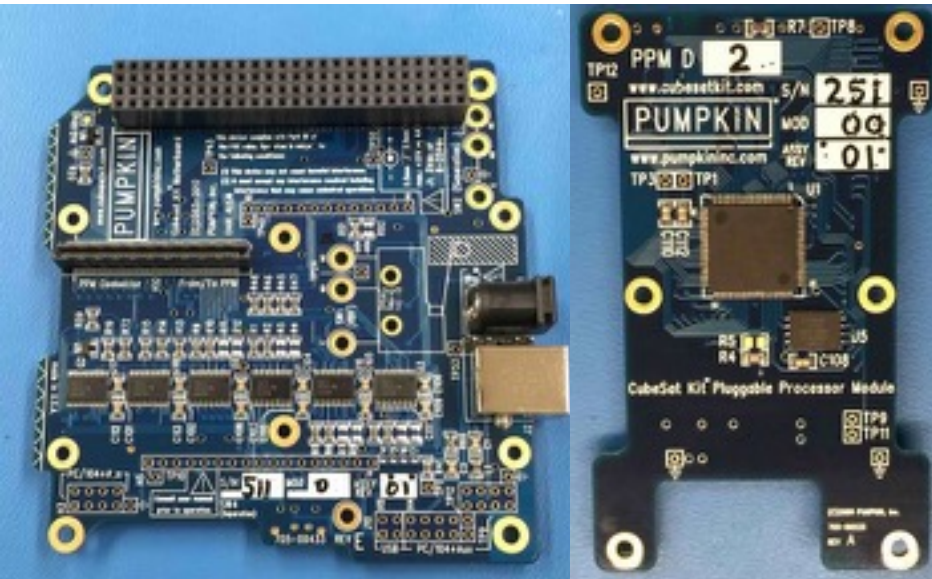


***BisonSat* design overview**

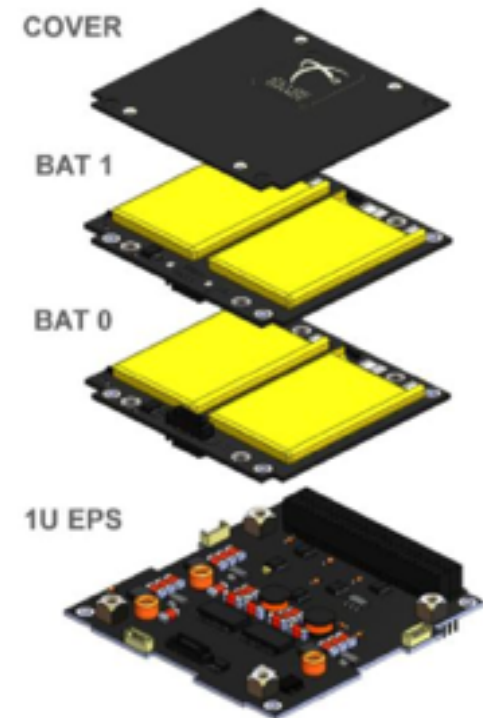


BisonSat stack layout

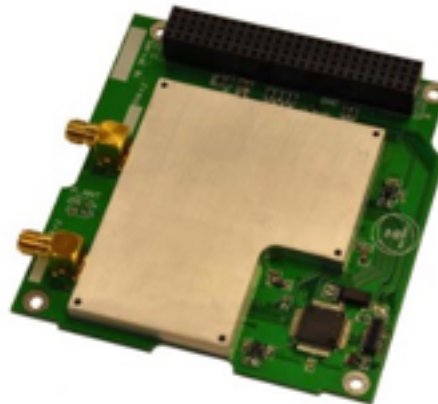
CDH (Command and Data Handling): uses a 16-bit MicroChip dsPIC33FJ256GP710 microcontroller



EPS (Electric Power System): Clyde Space CS-1UEPS2-NB-20 power management board and 20 W•hr batteries

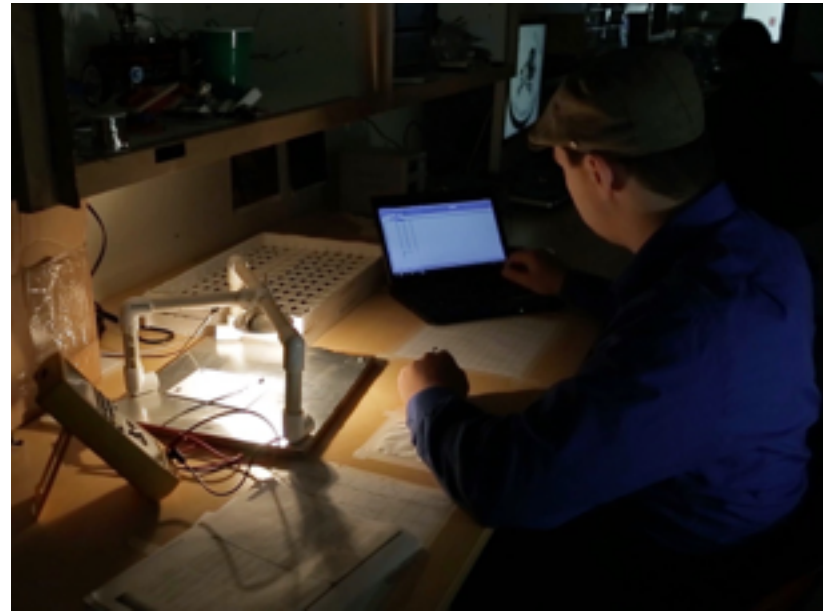
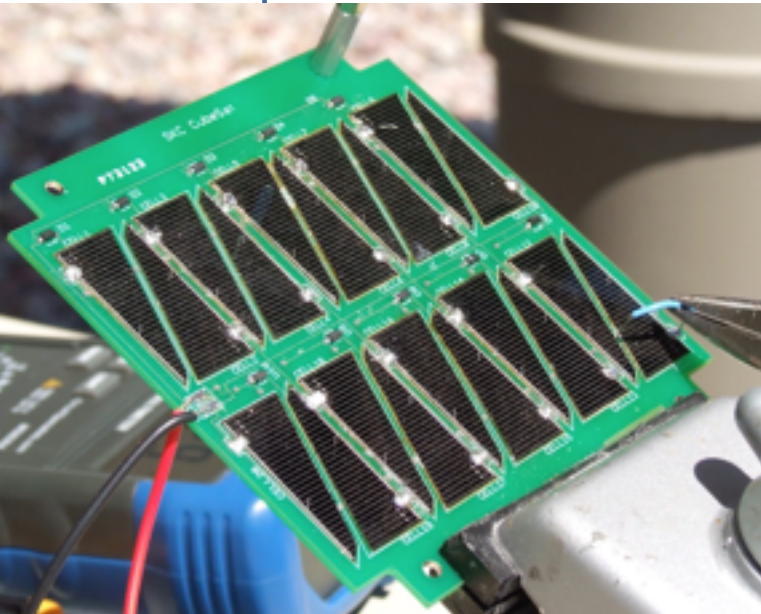


COM (Communications): AstroDev He-100 VHF/UHF transceiver



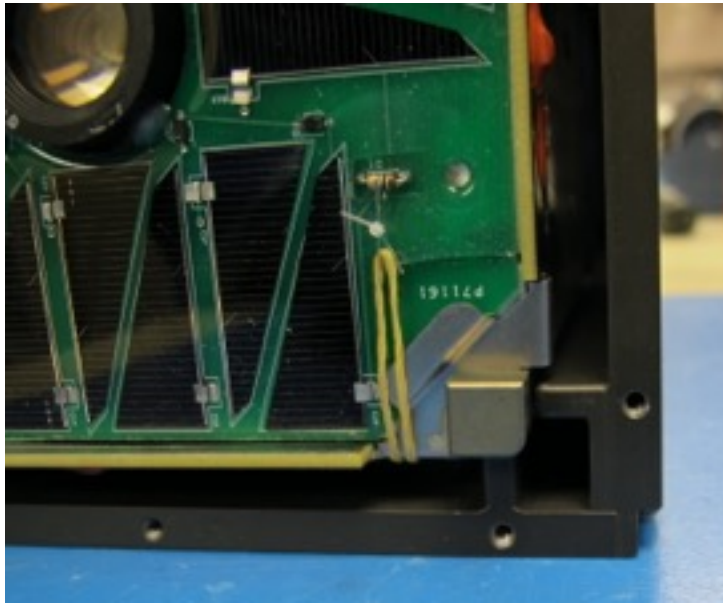
***BisonSat* COTS subsystems**

- Two of the six BisonSat solar panels were designed and manufactured by SKC.
- Performance is comparable to COTS CubeSat panels.



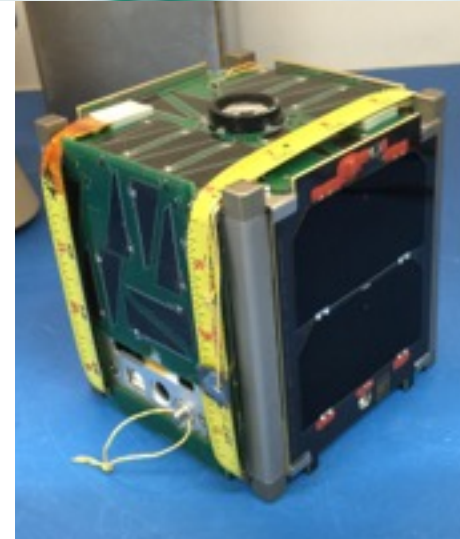
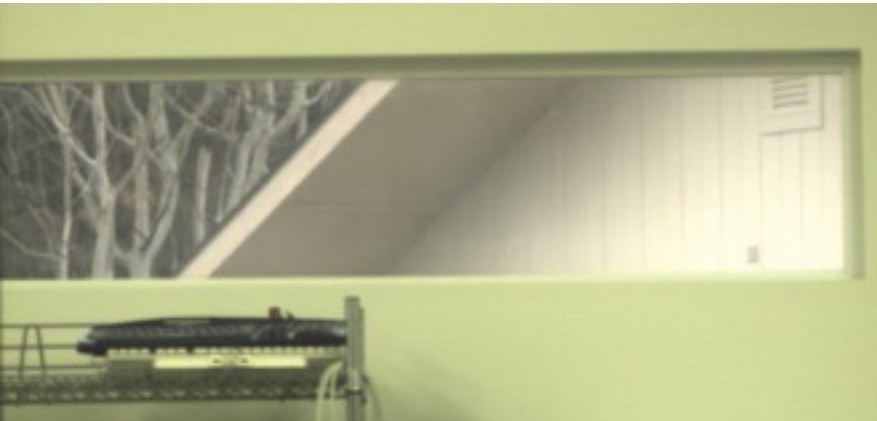
***BisonSat* solar panels**

- SKC-designed monopole transmit and receive antennas based on spring steel tape measure material.
- ITU frequency allocation transmit = 437.375 MHz (shorter antenna), receive = 145.860 MHz (longer antenna).
- Deployed on orbit by switching on resistors that burn through monofilament lines.



***BisonSat* antennas**

- SKC design based on Aptina MT9T031 CMOS sensor, Bayer pattern filter for color, 3.2 μm pixels, subframe to 1608x1208 or less, 46 meter ground sampling distance at perigee.
- Image data transferred to 2 MB SRAM and then to a SD card on the CDH board for later downlink.
- JPEG and lossless compression software written by SKC.
- Image acquisition scheduled by uplink command.

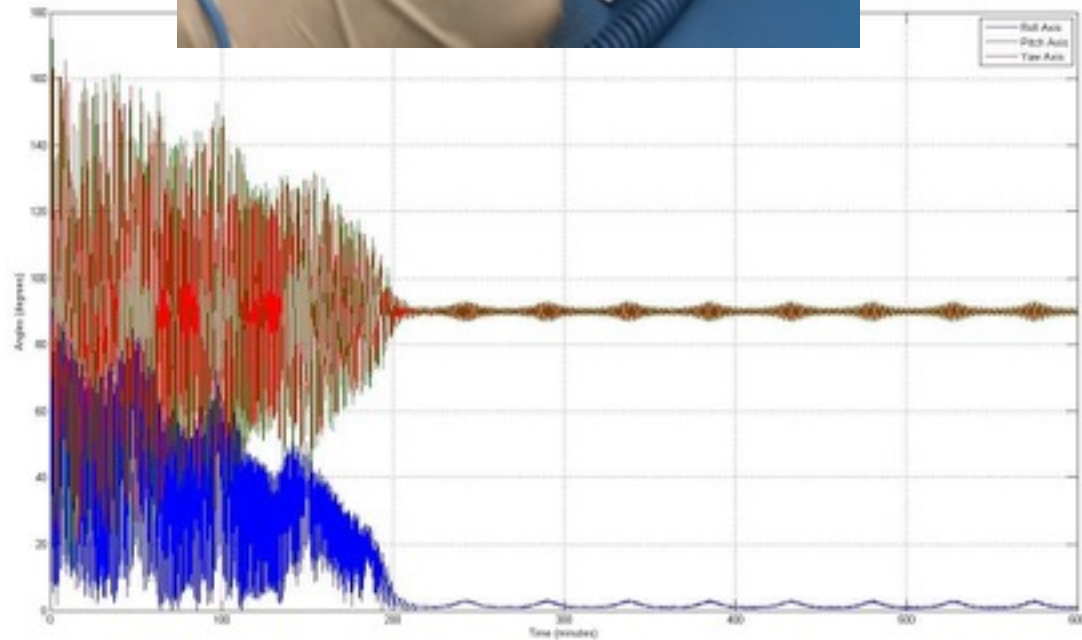
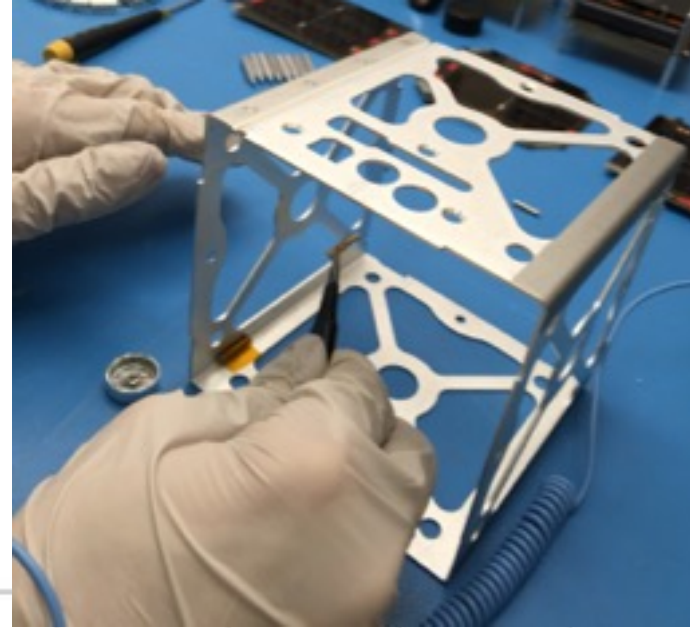


BisonSat camera



Simulated BisonSat view of the Flathead Reservation

- Passive magnetic control design: Alnico permanent magnets align the optical axis along Earth's local magnetic field, HyMu-80 magnetic hysteresis material dampen initial rotation and later perturbations.
- Approximately 2 deg pointing accuracy
- Downward pointing over the northern hemisphere, oblique view into the atmosphere over the tropics.



Attitude control subsystem

- Accurate total mass, center of mass, and moment of inertia measurements are needed for modeling the motion of the CubeSat
- Student Cory Drowatsky constructed a torsion pendulum for the moment of inertia measurements.



Mass properties measurements

- CIR (CubeSat Interface Review)
- MSPSP (Missile System Prelaunch Safety Package)
- Outgassing materials list
- ODAR (Orbital Debris Analysis Report)
- Monthly Quad Charts (development status, identify significant issues)



BisonSat
Salish Kootenai College







Mission Description
BisonSat has primarily an educational objective of training undergraduate engineering and science students on design, build, test, and operation of space hardware. The science payload is a visible light camera for land cover classification, cloud cover, and cloud height measurements.

Major Milestones	Size	Mass	RF Power
11/15/11 PDR	1U	1.00 kg	2.8 W
06/14/13 CDR			
11/20/13 Engineering unit completed			
12/17/14 Flight unit bakeout			
01/12/14 Day in the life testing			
01/19/15 Protocol vibration testing			
02/23/15 Acceptance vibration testing			
02/24/15 MRR			
03/16/15 Delivery			

Deliverables Status
RF License: UNRQ frequency coordination complete, submitted FCC inputs
ODAR: Inputs provided to LSP
NOAA: License awarded 3/6/14
MSPSP: Salish system has passed safety and USA review

Issues/Concerns
(1) Saw most 6.5 mm limit with tighter Rx antenna wrap.
(2) Have identified the cause of the sticky deployment switch found during protocol vibration testing. Will perform acceptance vibration testing to verify the fix works.

February 2015

MSPSP CubeSat Support Document
Page 1

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Missile System Prelaunch Safety Package (MSPSP)
CubeSat Support Document for the GRACE Mission

Appendix 1
BisonSat CubeSat

Version 1, 02/06/2015

Prepared by: Timothy Olsen, Salish-Kootenai College

MSPSP CubeSat Support Document
Page 1

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CubeSat
Experiment
Pipeline

CubeSat Interface Review (CIR)
Page 1

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CubeSat Interface Review (CIR)



Document Number: Version 5

Project: GRACE CubeSat

Date: 2 February 2015

CubeSat Name: BisonSat

CubeSat Serial Number:

Location: Salish Kootenai College

QA Engineer: Tim Olsen

Support Engineers: Al Anderson, Ryan Douglas, Cory Dronowicz, Zachary DuMont, Daniel Hawk, Judy Hudgins, Heather Mitchell, Noel Stewart, Thomas Trickett, Ashley Vincent, Ryan Young

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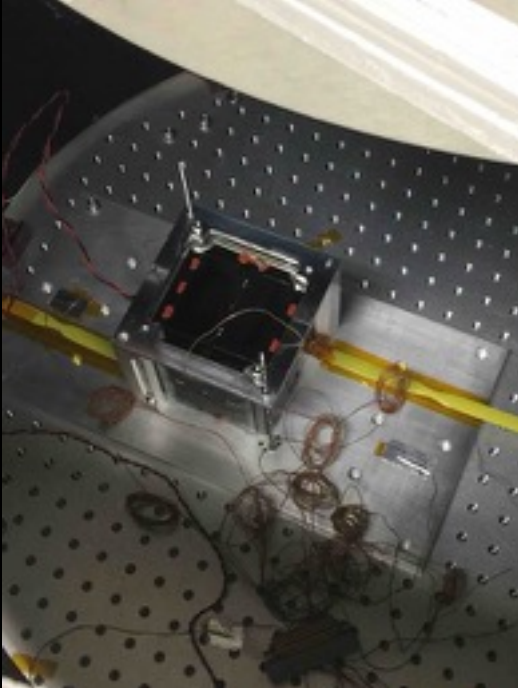
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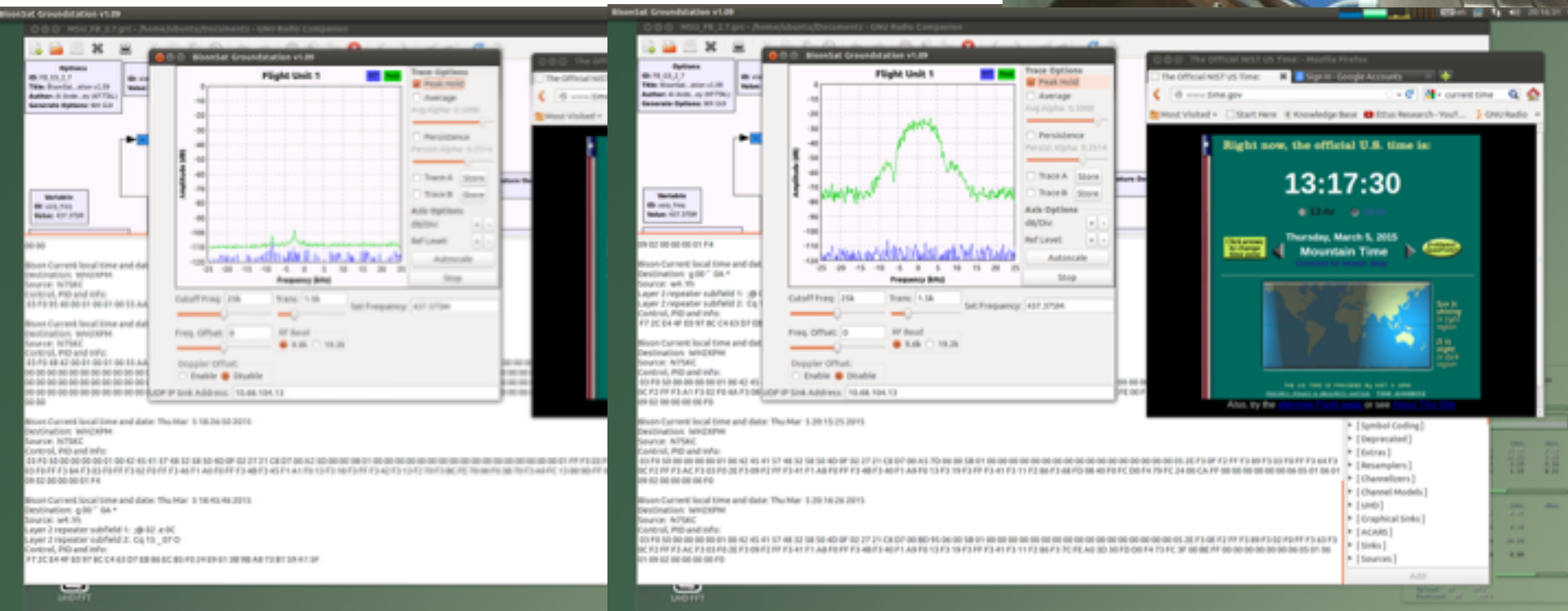


Design safety documents



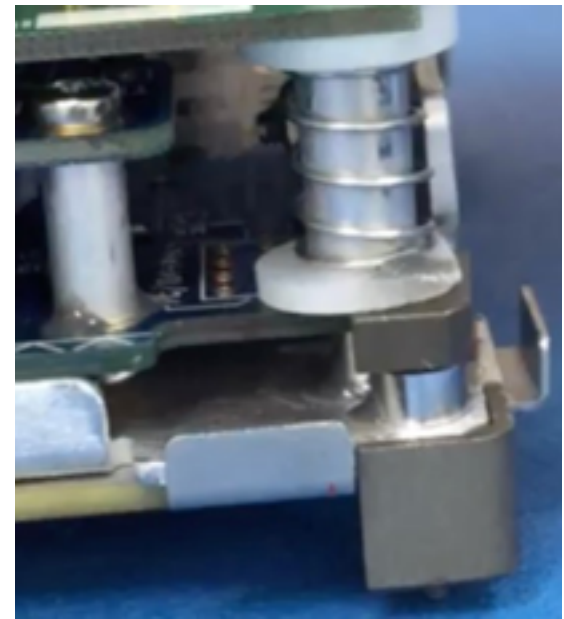
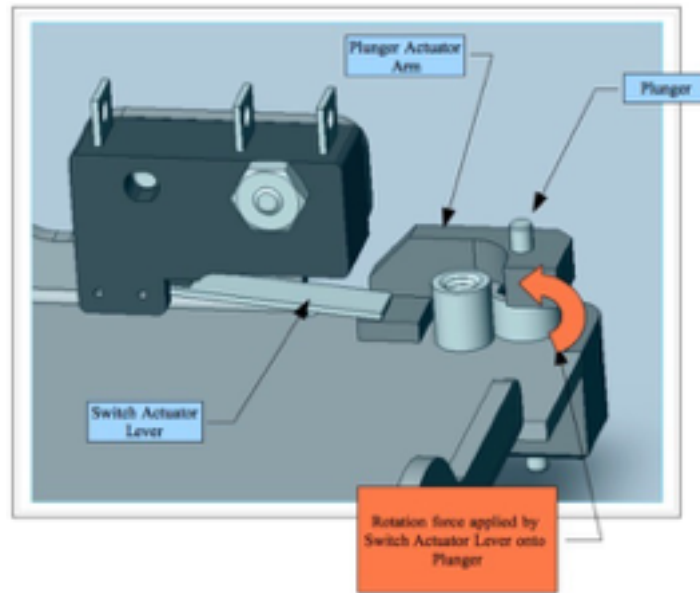
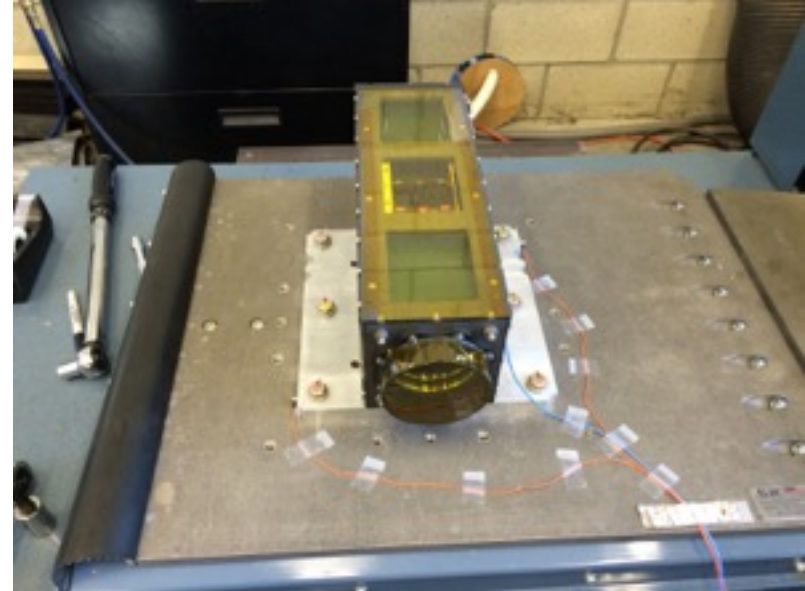
***BisonSat* flight certification testing Dec 2014 - Mar 2015**

- Requirements for staying powered off until deployment, no transmission until 30 minutes after deployment.
- Design must have three independent inhibits preventing premature power on and transmission.
- “Day in the Life” testing verifies these requirements are met. Successfully completed 5 March 2015.



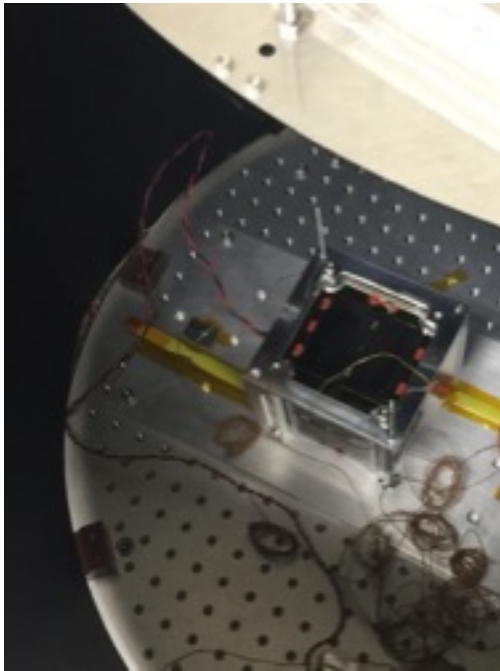
Day in the Life testing

- Requirement that the CubeSat can survive the launch vibration environment.
- *BisonSat* needed to do vibration testing three times before meeting the requirement because of the failure of one of the COTS power on switches.
- Cal Poly was contracted by the NASA ELaNa to provide vibration testing services.



Vibration testing

- Requirement for unpowered “bakeout” of the CubeSat in a thermal vacuum chamber for 6 hours above 60°C while below 1×10^{-4} Torr pressure.
- *BisonSat* bakeout at Montana State University in Dec 2015, and again at NTS Los Angeles March 2015.



Thermal vacuum testing/bakeout

- Battery report
- Electrical report
- Mass properties report
- Venting analysis report
- Day in the Life test report
- Vibration test report
- Bakeout report
- CAC (CubeSat Acceptance Check)



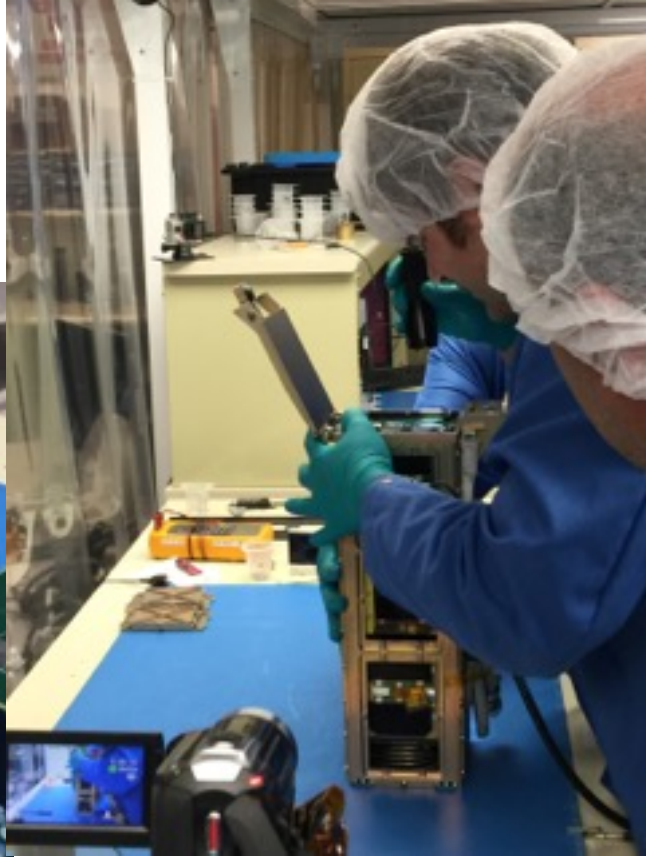
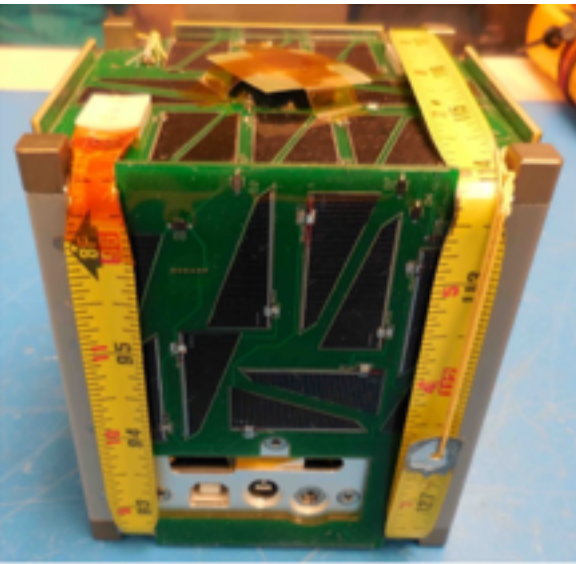
Interface Control Document verification

- Final independent review verifying all safety requirements have been met.
- Review panel consisting of representatives from United Launch Alliance, National Reconnaissance Office, NASA ELaNa program managers, and the Cal Poly CubeSat integration team.
- *BisonSat* passed MRR 20 March 2015. Approved for delivery to the launch provider.



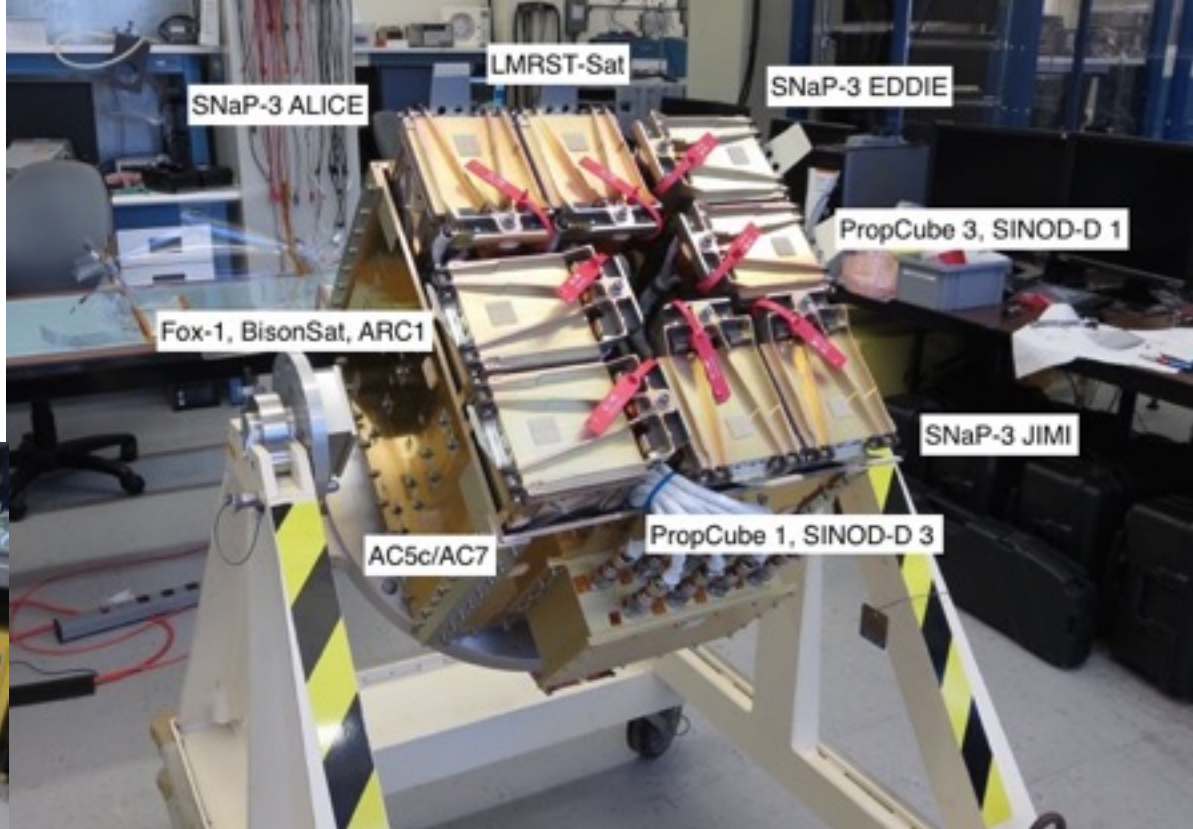
Mission Readiness Review

- BisonSat integrated into its P-POD along with AMSAT Fox-1 and University of Alaska ARC1 at Cal Poly on 25 March 2015.



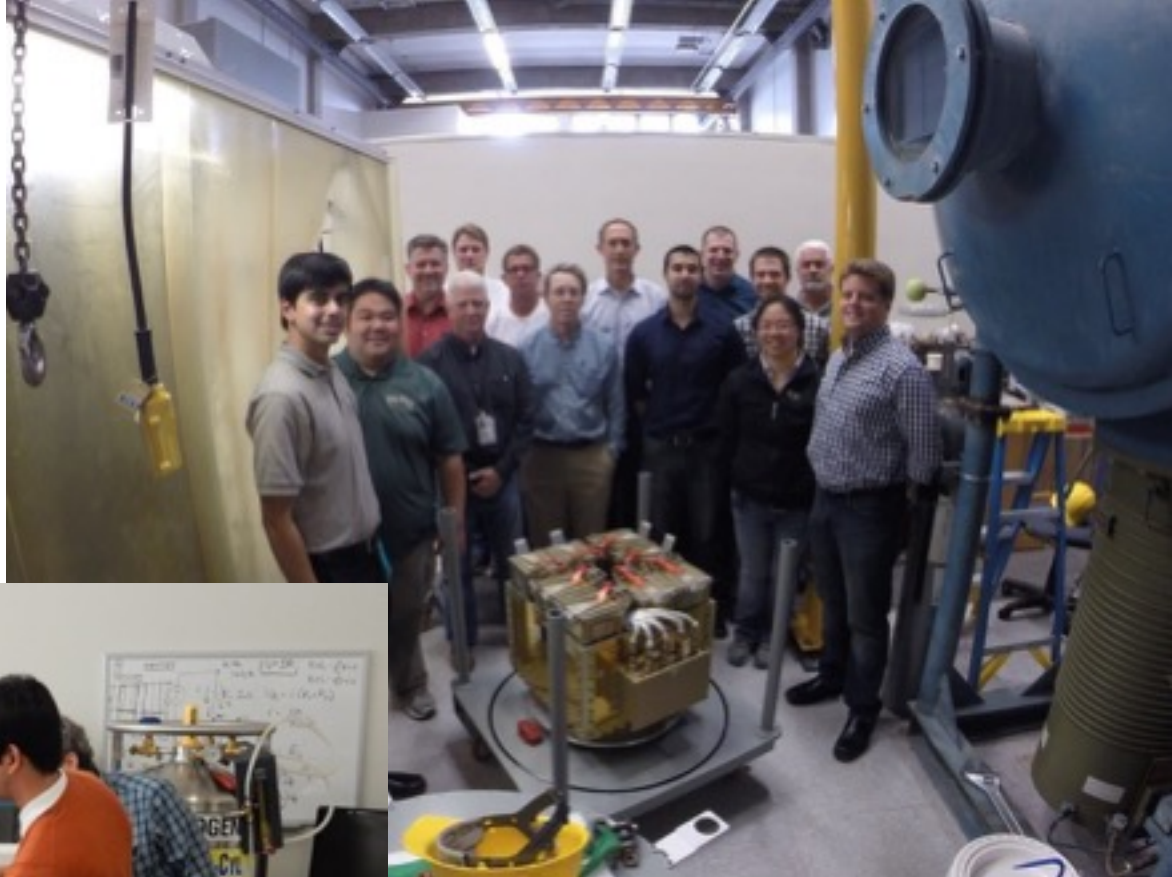
Delivery and P-POD integration

Mounting of the eight P-PODs into the flight deployment unit that will be mounted to the back of the Centaur upper stage.
Image credit: Justin Foley, Cal Poly



P-POD mounting into deployment unit

Flight deployment unit vibration testing at the Naval Postgraduate School in Monterey, April 2015.
Image credit: Justin Foley, Cal Poly



Deployment unit vibration testing at NPS

Ready for delivery to Vandenberg AFB,
9 April 2015.

Image credit: Justin Foley, Cal Poly



CubeSat shipping container

Mounting of the CubeSat deployment unit to the NROL-55 Atlas Centaur upper stage at Vandenberg Air Force Base (29 July 2015).
Image credit: Justin Foley, Cal Poly



Flight vehicle integration

- U.S. CubeSats are deployed as secondary payloads on NASA and DoD missions, also deployed from the ISS
- BisonSat is one of 12 CubeSats (4 NASA-sponsored, 8 DoD sponsored) that will deploy from the NROL-55 GRACE launch vehicle (ULA Atlas V)

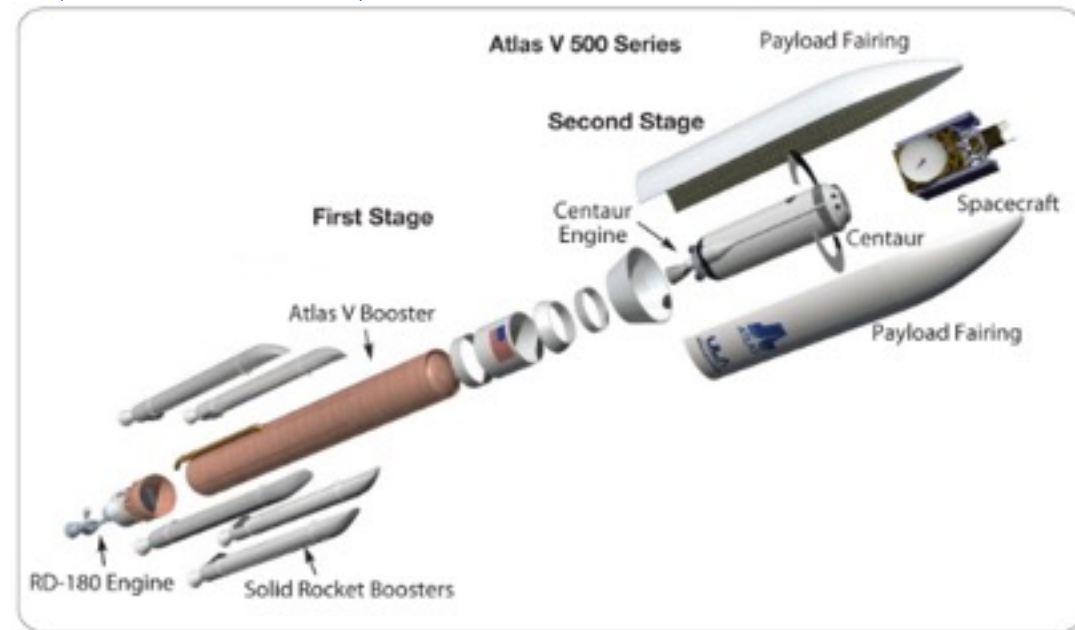


Image credit: ULA

Image credit: ULA



Launch

- The SKC satellite communications ground station will be used for BisonSat uplink commanding and downlink of telemetry and image data.
- Uplink commands are encrypted as required by the NOAA orbital camera license. Downlink data is unencrypted and can be received by anyone able to receive satellite radio signals in the amateur radio band (437.375 MHz).



Flight operations

- *BisonSat* development funding provided by the NASA Tribal Colleges and Universities Project program through grant number NNX10AT95A
- Additional funding provided by NASA Montana Space Grant through grant number NNX12AI11A
- NASA CubeSat Launch Initiative program



Acknowledgements



ELaNa XII and BisonSat mission patches