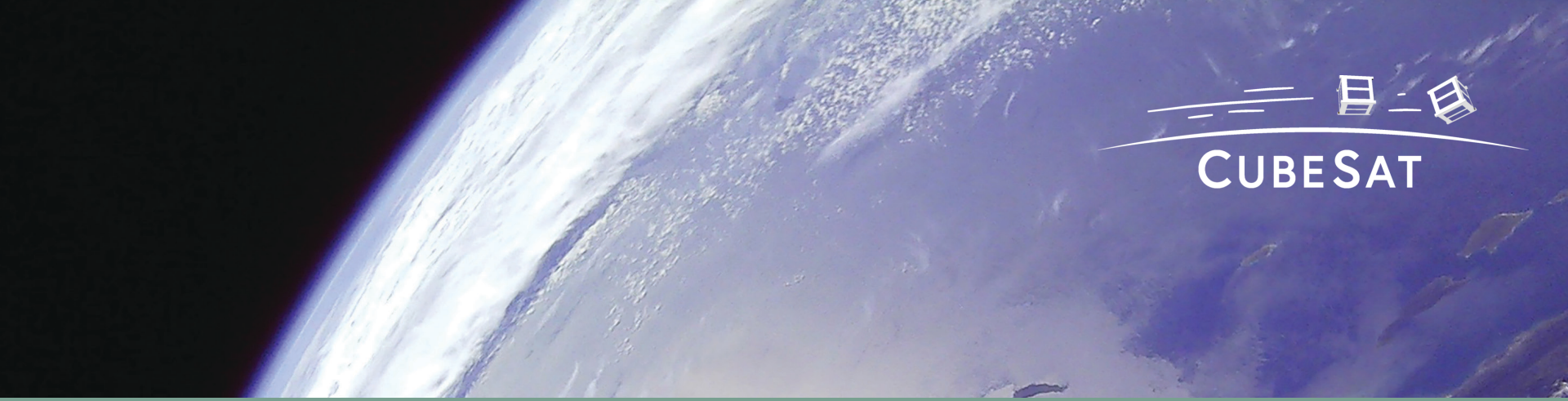

CUBESAT

CAL POLY

CUBESAT LABORATORY

2018–2019 ANNUAL REPORT

New Guinea by CubeSat DAVE

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STUDENTS PERSPECTIVE

Justin Nguyen, Lab Manager

This past year has been amazing. We have been working on four missions and operating many spacecraft. It has been an exciting time being involved in spacecraft at every stage of the development pipeline. Also, the lab has grown to over 100 members and I am so grateful to all my peers and this great community that is super excited about space and technology. I look forward to another fruitful and fun year full of new experiences and working with amazing folks in the Cal Poly CubeSat Laboraotory next year!

Kate Parkinson, ATLO Lead

As a member of lab I have had the incredible experience of witnessing every stage of satellite missions. From participating in public design reviews at the Jet Propulsion Laboratory in Pasadena, and to watching the launch for DAVE on the last Delta II rocket in person at Vanderberg AFB, and everything in between. At the same time, the legacy of Cal Poly as the birthplace for the CubeSat standard and home to the Poly-Picosatellite Dispensers (P-POD) has opened my eyes to the larger CubeSat community. Companies and institutions from around the world come to San Luis Obispo to attend the annual workshop, to use our facilities, or to integrate into our dispensers. It has allowed me to network with engineers from aerospace companies and members of other college satellite programs. This lab is one of the reasons I came to Cal Poly in the first place and joining lab has been one of the most rewarding and valuable opportunities I have had in college.

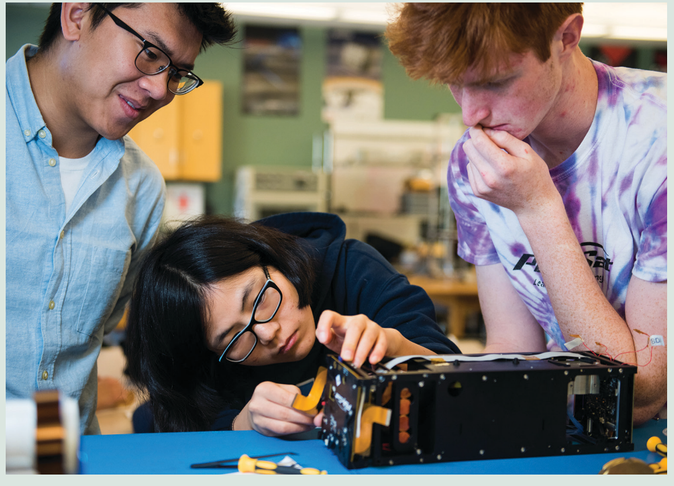
Cole Gillespie, Asst. Lab Manager

I have learned so much from my experience in lab. My work at the Cal Poly CubeSat Laboratory provides an incredible supplement to my class work. I am able to implement what I learn about design in class to the missions that I work on in lab, and the collaboration with outside companies provides a valuable perspective on how the industry operates. I've worked on various different projects in lab and learned so many different things. I've learned how to follow proper clean room assembly procedures, how to operate satellites in orbit, how to reduce complexity and integrate aspects of systems engineering to our processes, as well as many other things. I am sure that my experience in the lab with better prepare me to work in the aerospace industry.

OUR MISSION

Cal Poly's CubeSat Lab advances the space industry by providing inclusive, high-quality workforce development and community engagement programs that enable the next generation of space discoveries.

OUR GOALS



1. Provide the Cal Poly community with unique learn-by-doing opportunities using small satellite projects

2. Foster and develop innovative satellite technologies

3. Participate in public policy discussions and outreach to ensure space remains both safe and beneficial for future generations

4. Partner with external collaborators to ensure that CPCL remains productive and sustainable

5. Stimulate learning in a diverse, inclusive, and safe work environment

CUBESAT HISTORY

Developed in 1999 to facilitate student involvement and applied research in spacecraft, the CubeSat standard has become the de facto standard for university satellites. By standardizing a satellite form factor, access to space becomes more affordable and feasible for everyone, particularly for universities which have limited resources. At its essence, the standard defines a CubeSat unit as a 10cm x 10cm x 10cm structure and provides detailed requirements for the satellite including mechanical systems, electrical systems, and operations. Over the last 5 years, CubeSat development has exponentially increased with missions ranging from education to advance space research; between 2014 and 2019, over 900 CubeSats were launched. Today, Cal Poly continues to play a key role in the CubeSat community through the development of tomorrow's aerospace workforce and maintaining the CubeSat standard.

The Cal Poly CubeSat Lab (CPCL) has given Cal Poly students a robust Learn-by-Doing experience for almost two decades. During the 2018-2019 academic year, CPCL was comprised of about 70 students from all majors within the College of Engineering and many students from other colleges on campus such as the College of Science and Math, the College of Business, and the College of Liberal Arts. Around 90% of student lab members are undergraduates with the remaining 10% being graduate students. This makes CPCL a prime hub for undergraduate-led research in space.

Student involvement in CPCL projects is key to all activities – Cal Poly students have developed and launched eleven spacecraft since the start of the program, with three currently in operation in orbit and three more in development. The students continue to support LightSail-2 orbital operations, showing the effectiveness of the solar sail which was first proposed by Carl Sagan of The Planetary Society. CPCL students also provided support to NASA's Jet Propulsion Lab during operations for the MarCO mission, the first CubeSats to travel beyond Earth's orbit and reach Mars.

While CPCL is currently developing more advanced CubeSat systems, the foundation of the lab's expertise in the field is based on years of working as CubeSat launch integrators. Cal Poly developed the first flight-proven CubeSat dispenser, the Cal Poly Poly-Picosat Orbital Deployer (P-POD) which has delivered to orbit over 175 CubeSats from around the world. Cal Poly helped launch the very first satellite for 5 separate countries. As CubeSat integrators, CPCL worked with 8 different launch vehicle companies (including Orbital, ULA, SpaceX), various government agencies, and a number of international collaborators.

CPCL was an early leader in the CubeSat industry and since then has strived to develop a diverse knowledge base in all aspects of the small satellite segment. CPCL has used that know-how to develop future generations of engineers, while developing successful working partnerships with a variety of community contributors. We look forward to continuing this role in the industry and further expanding the boundaries of space education and exploration.

ACCOMPLISHMENTS

Presented the inaugural CubeSat Training Course at Cal Poly

Provided support for a project in the DARPA launch

Launched CubeSats:

ISX
DAVE
LEO

Workforce Development Summer Program for 20+ Students

Provided operational support for:

The Planetary Society's Lightsail-2

JPL's MarCO Missions

LOOKING FORWARD

- Provide technical support for Cambodia's first CubeSat
- Expand the CubeSat Training Course offerings
- Host 17th Annual CubeSat Developers Workshop
- Introduce the Cal Poly CubeSat Kit
- Launch and operate flight missions
    - » ExoCube-2
    - » XCube
    - » Spinnaker3
    - » ADE
- Develop deep space communications system for small spacecraft
- Expand micro-propulsion testing capabilities
- Establish Cal Poly SCIF (Sensitive Compartmented Information Facility)

THE CAL POLY

CUBESAT LAB

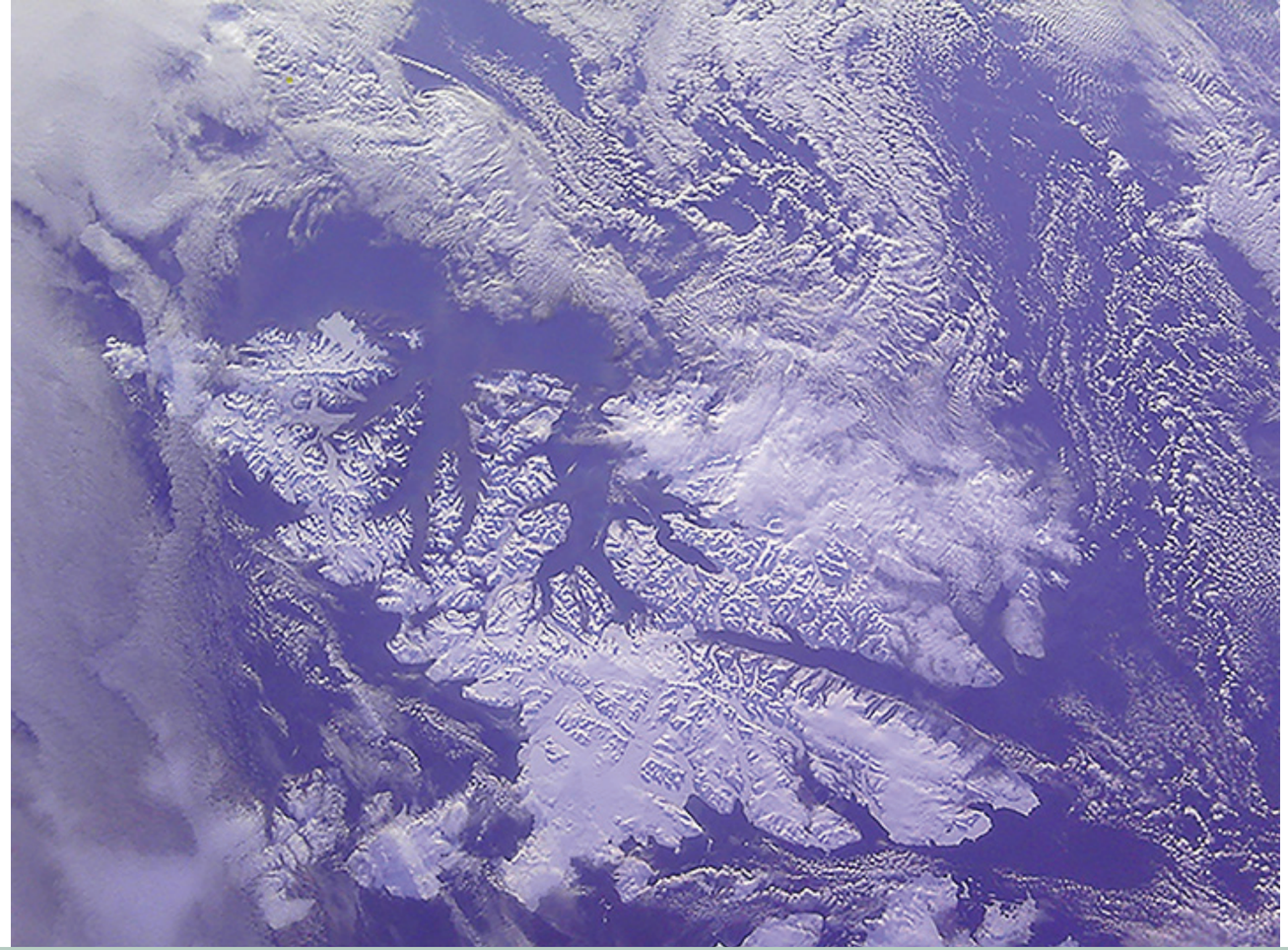
MISSIONS

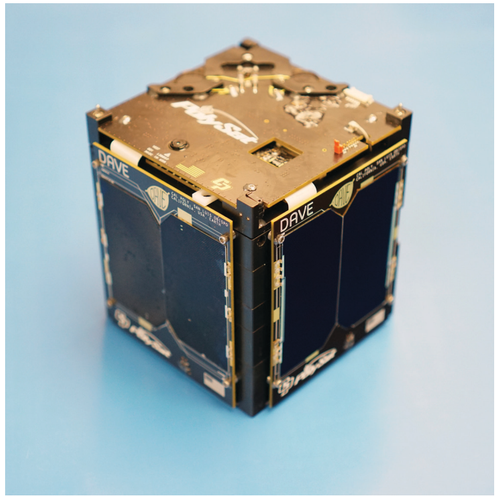
DAVE
LEO
EXOCUBE II
ADE

DAVE

DAVE (Damping and Vibrations Experiment), or CP-7, is a 1U CubeSat that launched September 19, 2018 from Vandenberg Air Force Base along NASA's ICESat-2 mission. DAVE, part of the ELaNa-18 mission, has been active since launch and has returned significant amounts of data from its vibrations payload. The payload consists of three aluminum beams driven by piezoelectric actuators, including a control beam and two experimental beams containing tungsten particles. The beams can be cycled through a range of frequencies, allowing for a vibration spectrum to be downlinked and analyzed on the ground.

This data will help to characterize the tungsten damping system tested on DAVE and evaluate its use for vibration damping on future spacecraft payloads. The spacecraft is also equipped with a small cell-phone camera, allowing it to take images of Earth in between payload experiments, which are downlinked using Cal Poly's ground station.

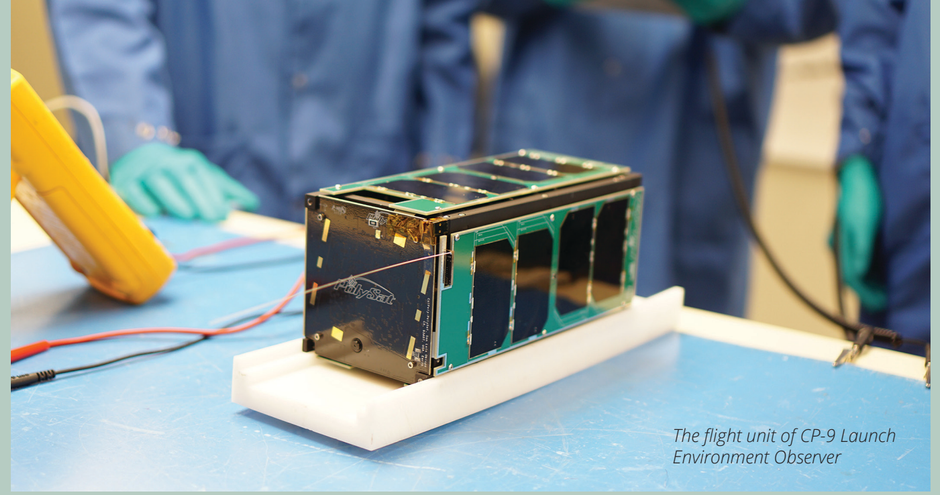




Center Photo: Svalbard captured by DAVE

Right Photo: CubeSat DAVE

LEO



The flight unit of CP-9 Launch Environment Observer

Launch Environment Observer (LEO/CP9)

LEO (Launch Environment Observer) is a 2U CubeSat designed and built at Cal Poly in collaboration with StangSat, a 1U developed by a team from Merritt Island High School in Florida. Sponsored by NASA Launch Services Program, the mission of these two CubeSats is to measure and record the vibration and thermal environments a CubeSat is exposed to within a P-POD during launch vehicle ascent.

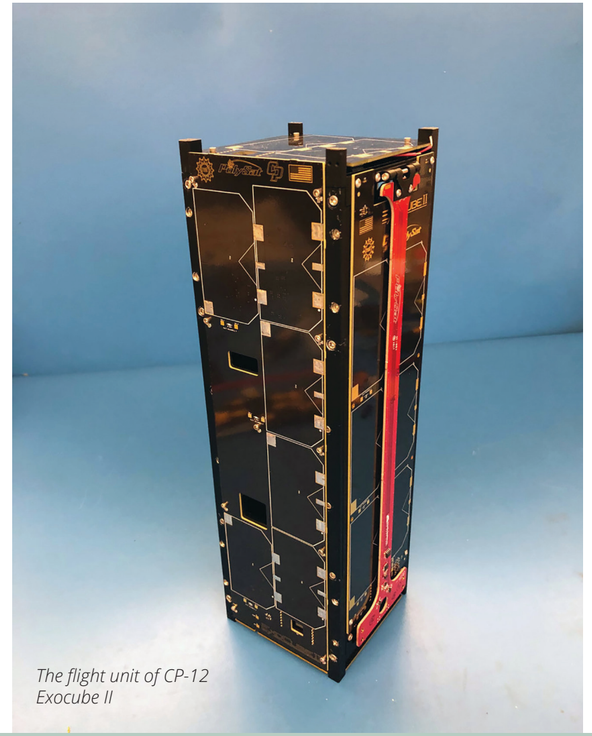
LEO triggers StangSat's data collection upon launch detection, then collects launch environment data using its own set of accelerometers and a Type K thermocouple. The set of CubeSats then communicate and transfer StangSat's data to LEO over Wi-Fi within the radio-frequency shielded Mark IV P-POD.

On June 24th, 2019, LEO and StangSat launched aboard the SpaceX Falcon Heavy Rocket from Kennedy Space Center in Florida. The two CubeSats successfully carried out their mission and LEO is currently downlinking mission data and images to Cal Poly's ground station.

EXOCUBE II

ExoCube 2 (CP12) is a reflight of ExoCube, which was launched in 2015 but experienced antenna failure. ExoCube 2 is designed to measure ion and neutral densities in the lower exosphere through the use of the Ion Neutral Mass Spectrometer (INMS) developed by NASA Goddard. ExoCube 2's mission is to provide global profiles of various species in the upper atmosphere so that they can be studied. This is to determine how our upper atmosphere is changing over time. There is very little data available for this portion of the atmosphere so it is an exciting mission for Cal Poly.

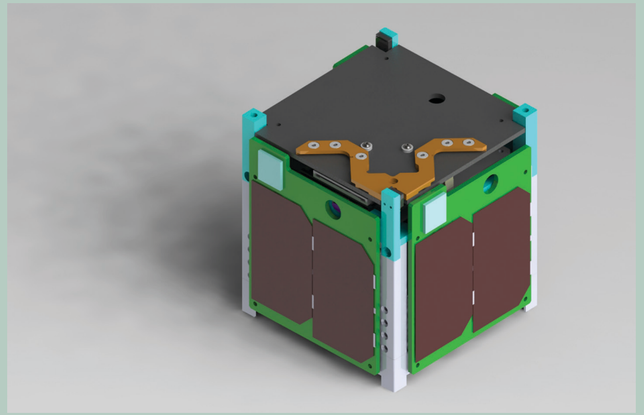
ExoCube 2 is a 3U spacecraft that is developed by Cal Poly to support the INMS, which provides some new challenges for The Cal Poly CubeSat Lab. The largest of which is that the INMS requires pointing in the ram direction (the direction of motion) so that the species can be captured by the INMS. This is accomplished by gravity gradient booms to passively stabilize along the Z (long) axis. The booms are used in conjunction with a momentum wheel and numerous sensors to determine the position of the spacecraft and point accordingly.



The flight unit of CP-12 Exocube II

ADE

ADE (CP-14) is a 1U cubesat with a deployable drag sail payload that will be deployed into a geostationary transfer orbit (GTO). The primary mission objective for ADE is to provide flight qualification for the dragsail and determine its viability. The deployable drag sail is designed to take advantage of the aerodynamic drag forces experienced by the spacecraft near its orbital perigee. The drag it experiences will reduce its velocity, and in turn decrease the time it will take to fully de-orbit.



The third rendering of CP-14

A successful demonstration of ADE's payload would be a step closer to the mitigation of a growing problem in spaceflight—orbital debris. In addition to demonstrating an aerodynamic de-orbit technology, ADE will attempt to characterize the radiation environment in GTO, and provide invaluable data for future small satellite missions in radiation-heavy trajectories.

In the past year, ADE has advanced from the preliminary design phase to the detailed design phase. Many components in the spacecraft's avionics are currently on their second design iteration and will be ready for procurement, fabrication, and testing within the next few months. Additionally, the deployment mechanism was recently changed from a burn wire design to a motor-driven design due to flaws identified during testing of the burn wire deployment mechanism. The payload design will be completely finalized within the next few months, which will mark a huge milestone in the spacecraft development. The earliest possible launch date for ADE is early 2021.

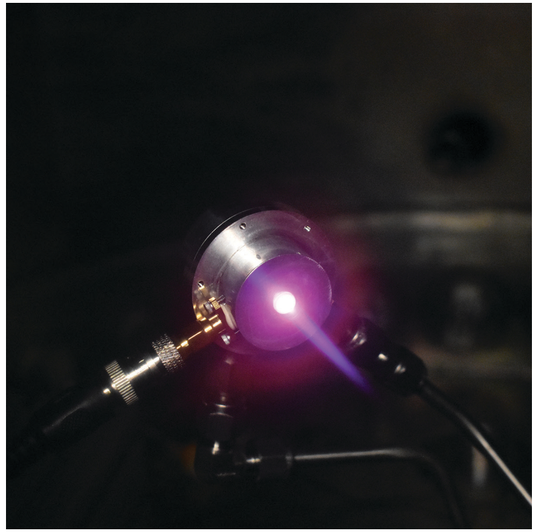
PROJECTS

POCKET ROCKET
SWIS
XCUBE
FALCON ODE
LIGHTSAIL II

POCKET ROCKET

Pocket Rocket is an ongoing propulsion research project with the goal of developing and testing propulsion systems integrated into a 1U spacecraft. Developed at Australian National University, Pocket Rocket is an electrothermal plasma thruster utilizing argon gas ionized by an RF signal. In the summer of 2018, Cal Poly students successfully integrated a pair of Pocket Rocket thrusters into an operational 1U mockup.

Current goals involve further characterizing the thruster, development of an onboard RF generator board and refining the current 1U mock-up, (i.e. Pressure Vessel 1U). The Pocket Rocket team's ultimate goal is to further develop the thruster into a fully self-contained "off the shelf" component that can be utilized by larger missions for use as an onboard propulsion system.



Pocket Rocket undergoes a testfire

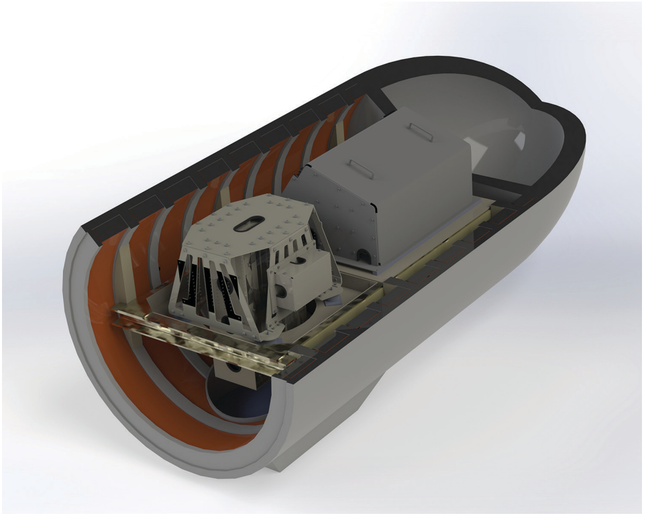
SWIS

The Snow and Water Imaging Spectrometer, or SWIS, is a collaboration with NASA JPL currently in the paper-study phase. The payload, designed and built by JPL, performs snow and ice monitoring in addition to coastal and ocean science. The spectrometer itself fits within a 4U form factor, allowing it to be integrated into a 6U CubeSat, leaving a 2U section for the bus.

A preliminary design review (PDR) has been completed, incorporating mechanical, electrical, and thermal considerations. PolySat mechanical team members designed a CAD model for the bus and worked with the payload structure team at JPL to integrate their model of the payload with the model of the bus. The two electrical teams worked together to develop an Electrical Interface Control Document (EICE). The PolySat aerospace team performed trade studies and other analyses.

Lab members Justin Nguyen and Ryan Statz work in the clean room

XCUBE



This rendering of XCube shows its mounting structure, payload carrier, and electronics box that will interface payloads with the ER-2 aircraft

The Cal Poly CubeSat Laboratory is in collaboration with the NASA Airborne Science Program and USRA (Universities Space Research Association) to design a standard for integration of CubeSats into the NASA aircraft for suborbital flight testing and experiments. The creation of a standard for airborne science experiments creates more opportunities for new developers to collect valuable science data and allows existing science research new means for instrument calibration and testing prior to integration into a spacecraft.

In their current state, NASA aircraft flights often have underutilized spaces that are left empty. These payload bays could be used for smaller, secondary payloads, utilizing this flight opportunity to maximize the amount of science data collected. The ER-2 plane is a potential platform for this project because it already has multiple payload areas and frequently flies without all of the payload areas being utilized. The development of a standard based on the CubeSat formfactor will allow for faster integrations and less on site adjustments, which will minimize secondary payload influence on launch departure delays.

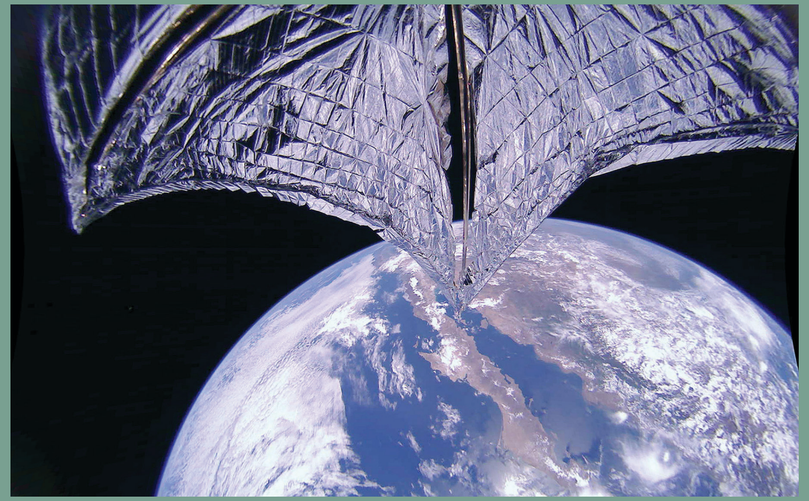
FALCON ODE

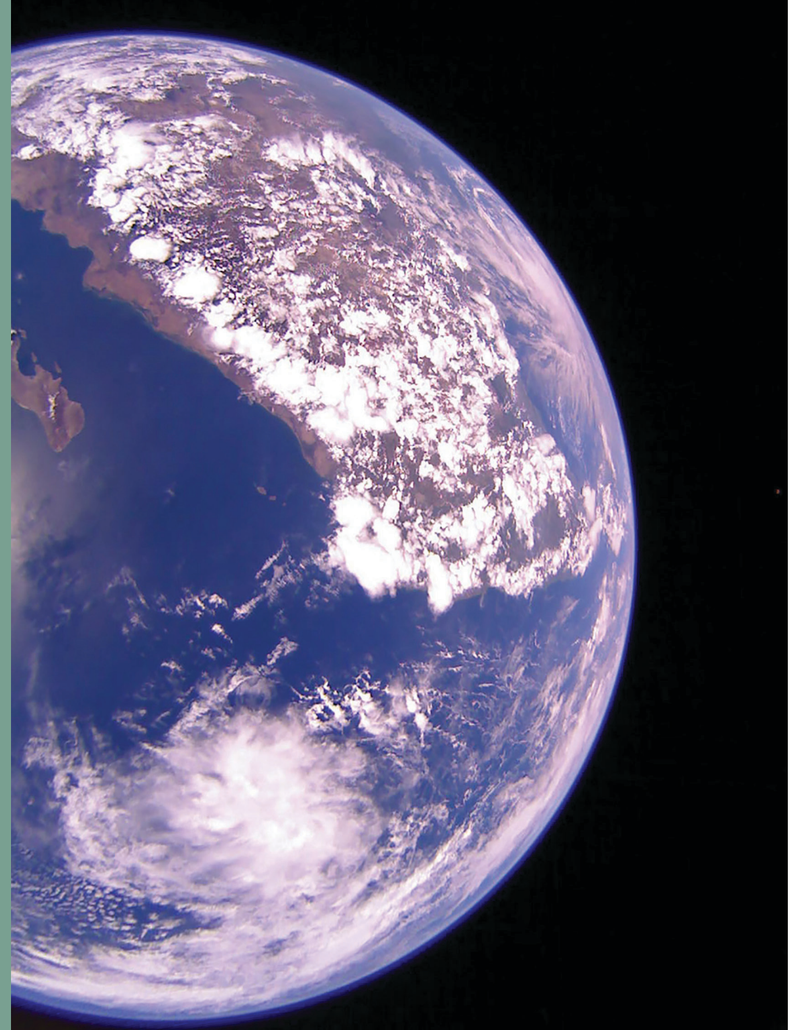
Falcon ODE is a US Air Force Academy (USAFA) mission that is a joint effort between the USAFA and the Cal Poly CubeSat Laboratory. This spacecraft is a 1U CubeSat that will provide calibrated radar and optical targets for the US Air Force Space Fence's ground-based situational sensors. The goal of PolySat lab was to provide the 1U satellite's bus that facilitated the CubeSat's power management, data handling, and radio communications. As the payload that performs the science was designed by the USAFA, ongoing communication with Cal Poly ensured that once the bus was delivered, the bus and the payload would work together seamlessly. Falcon ODE launched on May 5, 2019 on Rocket Lab's Electron rocket.

Aerospace Team member Stavros Diamantopoulos assembles the satellite bus of Falcon.

LIGHTSAIL II

LightSail 2 is a citizen funded 3U CubeSat created in partnership with The Planetary Society that aims to demonstrate controlled solar sailing propulsion on a small satellite platform. LightSail 2 is equipped with a 32 square meter aluminized mylar solar sail that provides a large surface area for photons to strike and bounce off, giving the spacecraft a small push. Most propulsion systems involve the storage of fuel, a limited resource, to produce the desired push. Once all the fuel is used, the spacecraft can no longer propel itself. Using the sun as its fuel source, solar sailing provides a unique alternative to traditional methods. This promises a nearly endless supply of energy, and enables us to go even farther than we have before.





Left Photo: The first high resolution picture downlinked by LightSail 2. This image was captured just moments after deployment

Right Photo: This image, courtesy of The Planetry Society and commanded by PolySat Lab member Michael Fernandez, was taken by Lightsail 2

Cuba, Jamaica & the Bahamas
captured by Cubesat DAVE

2018–2019 CPCL

Professor John Bellardo

Dr. John Bellardo joined Cal Poly's Computer Science and Software Engineering Department in 2006, after completing his Ph.D. at UC San Diego. While at UCSD he researched the security and efficiency of wireless networks under the direction of Dr. Stefan Savage. Dr. Bellardo earned his B.S. degree in Computer Science from Cal Poly in 1999. In 2019 he received a joint appoint in the Aerospace department and became the Director of the Cal Poly CubeSat Lab. He was honored with the Cal Poly Distinguished Scholarship Award in 2020.

Dr. Bellardo began working with CPCL in 2008, when lab was transitioning to a new generation of embedded linux spacecraft. Since then he has been involved in the design, development, and operation of 5 CPCL CubeSats, and also assisted with high profile missions such as the MarCO mission to Mars with NASA's JPL and LightSail II, with The Planetary Society and Bill Nye. He has helped two high school teams reach space with their first satellites and been involved in numerous additional lab activities.

Professor Pauline Faure

Dr. Pauline Faure obtained her undergraduate degree from the Ecole Européene d'Ingénieurs en Génie des Matériaux (EEIGM), France, in Engineering Sciences, a double master degree from the EEIGM in Material Sciences and from Kyushu Institute of Technology (Kyutech), Japan, in Mechanical Engineering, and her Ph.D. from Kyutech in Mechanical Engineering. Dr. Faure's thesis dealt with decision-making processes in non-traditional satellites program management of assembly, integration, and testing activities.

Since joining Cal Poly in 2018, Dr. Faure has been leading the efforts of the CubeSat Laboratory for the development of the CubeSat kit and deep space communication system. Moreover, Dr. Faure is a strong advocate for the implementation of systems' engineering's good practices for the development of small satellites programs. Within the aerospace department, Dr. Faure teaches among others, the seniors' capstone course on Spacecraft Desgin.

Prior to joining Cal Poly , Dr. Faure was with the Laboratory of Spacecraft Environment Interaction Engineering (LaSEINE) at Kyutech in Japan where she developed the first space debris detector of its kind as a payload of small satellite. In 2014, Dr. Faure became the Project Manager of 10kg-class satellite, HORYU-IV, developed by a team of 40 students and professionals from 18 countries. Then, in 2017, Dr. Faure became the lead for LaSEINE's capacity-building trainings during which engineers from emerging space faring nations came to Kyutech to practically experience the design, development, and testing of missions for CubeSats.

STAFF

Left to right: Ryan Nugent, Dave Pignatelli, Alicia Johnstone

With a combined 30+ years of experience, the staff members of the Cal Poly CubeSat Laboratory advise students in all aspects of small spacecraft development, to include design, manufacturing, and research projects exploring new methods and technologies.

In addition to advising students in technical engineering work, staff members work closely with the students to teach best practices with regard to project management, as well as general lab management.

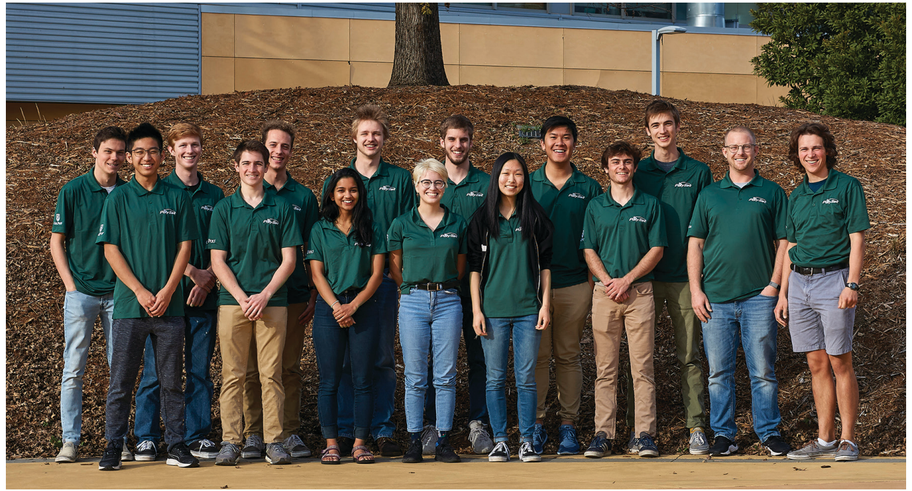
The staff provides much needed continuity for lab operations, allowing a for smooth transition of institutional knowledge in a lab environment that has high turnover in the student workforce. Without this continuity, we've found that knowledge isn't transferred efficiently from generation to generation, hindering the growth of the lab.

Over the course of their careers, our CPCL staff members have integrated over 160 CubeSats on 25 missions and 12 different launch vehicles. They are able to take advantage of this specific CubeSat experience to provide support services to the greater CubeSat community. These services include environmental testing, regulatory consulting, design consulting, CubeSat training courses, and anything else a CubeSat developer might need help with.

MECHANICAL TEAM

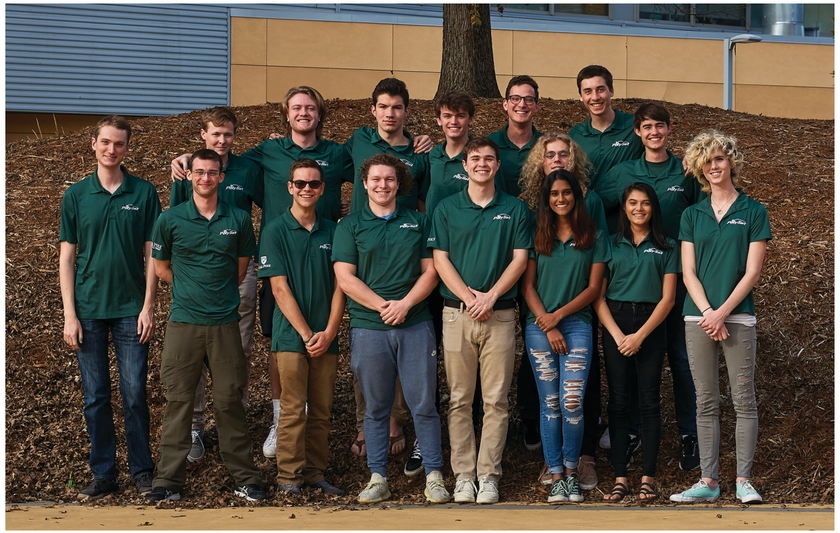
FRONT (Left to right): Jered Bell, Savannah Cheney, Jack McGuigan, Daniel Leon, Tatum Yee, Lucas Martos-Repath
BACK (left to right): Rees Verleur, Ricardo Contreras, Peter Van Ness, Pablo Casillas, Aaron Fielden, Aviv Maish, Zach Stednitz

ELECTRICAL TEAM



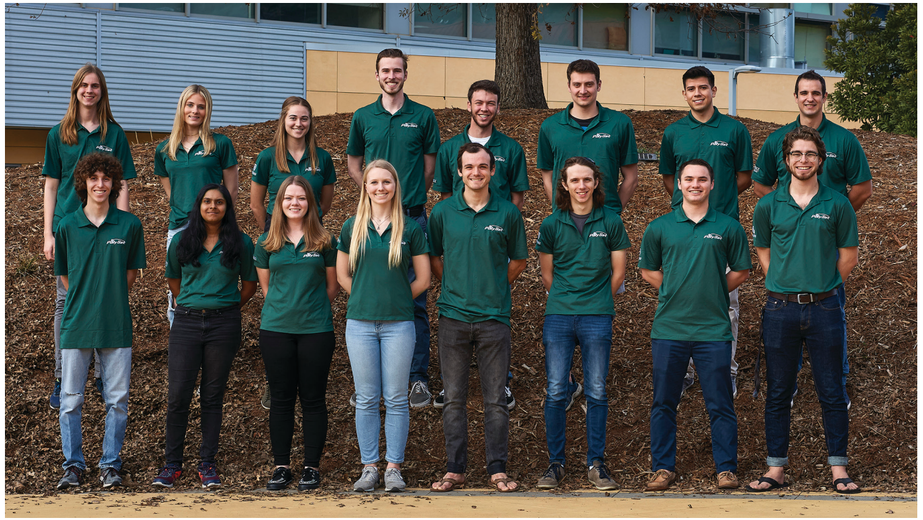
FRONT (left to right): Mark Wu, Drew Evans, Shivani Ganti, Jessica Steward, Helen Zhang, Patrick Jackson, Ryan Luke, Ryan Statz
BACK (left to right): Ben Clark, Danny Maas, Colt Whitley, Spencer Drewery, Kevin Kliner, Justin Nguyen, Jack Ellingson

SOFTWARE TEAM



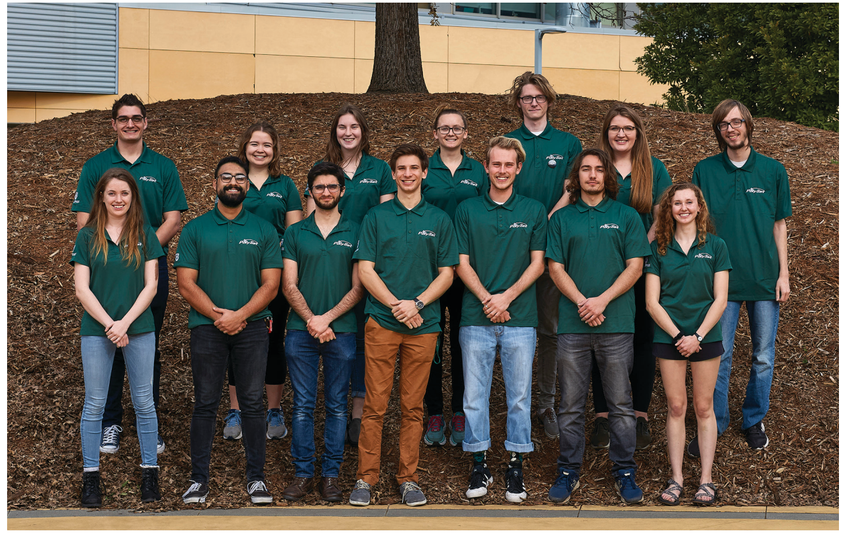
FRONT (left to right): Luca Merlo Paula Soares, Daniel Montgomery, Ethan Goldfarb, Ryan Hunter, Yogi Sunkara, Nayana Tiwari, Lena Hickson Long
MIDDLE: Bailey Wickham, Joshua Anderson
BACK (left to right): Keavon Chambers, Ian Gallagher, Bret Kehle, Alex MacLean, Walden Hillegass, Adam Klein, McClain Howland

AEROSPACE TEAM

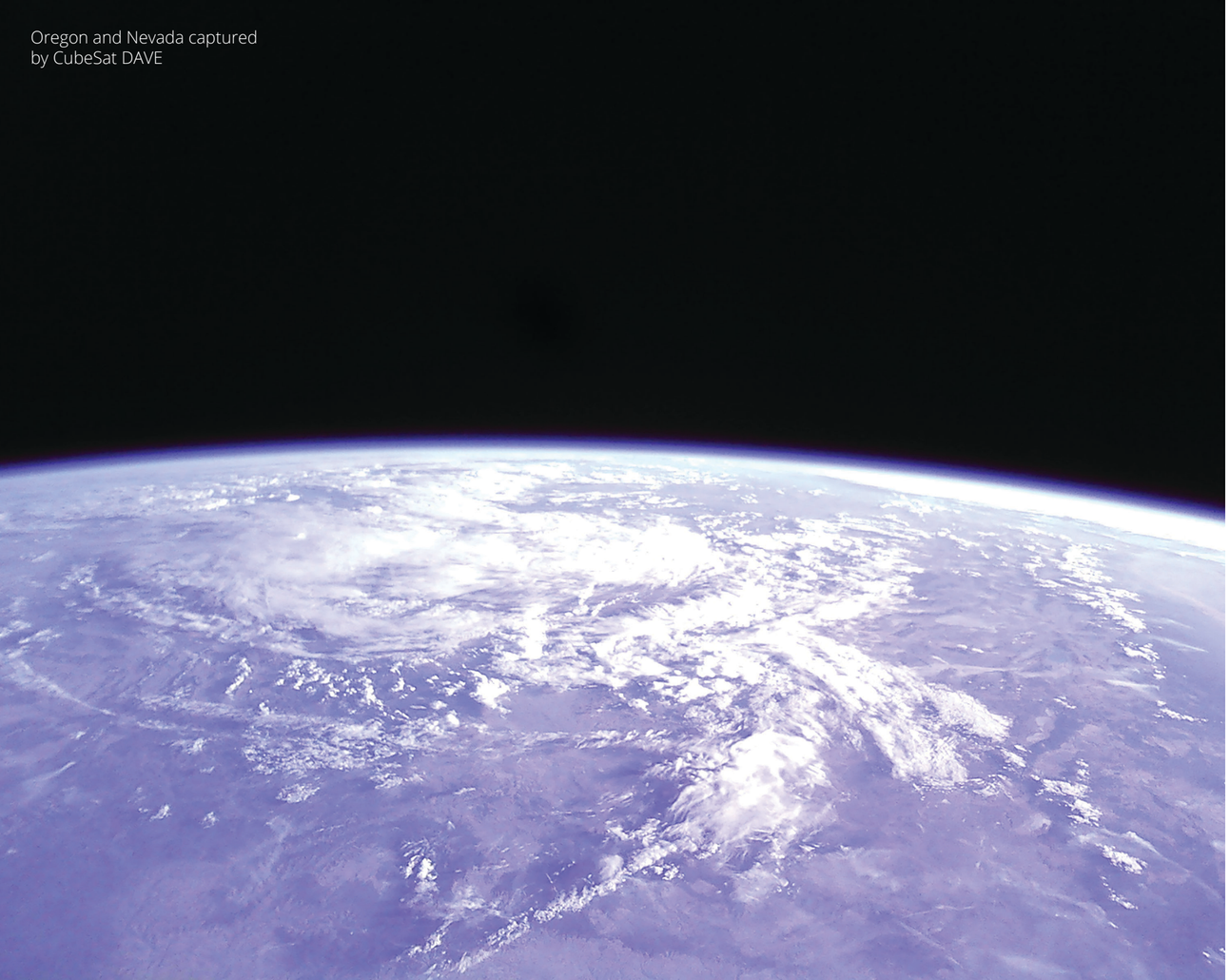


FRONT (left to right): Trevor Loe, Amogha Sarang, Alyssa Ralph, Brigitte Petersen, James Harper, Kent Rush, Nick Snyder, Cole Fehring
BACK: (left to right): Callan Whitney, Grace Guarraia, Maya Gordon, Cole Gillespie, Nicholas Sizemore, Liam Bruno, Giovanni Guerrero, Stavros Diamantopoulos

ATLO TEAM



FRONT (left to right): Sydney Retzlaff, Gagan Thapar, Aviv Maish, Gabe Musen, Josh Franklin, Keilan Ramirez, Madison Lytle
BACK (left to right): Marc Galles, Kate Parkinson, Grace Garmire, Natalia Cieply, Liam Mages, Bailey Garrett, Andy Haase



Oregon and Nevada captured
by CubeSat DAVE

HOW TO
GET INVOLVED

If you are interested in collaborating or partnering with the Cal Poly CubeSat Laboratory for a CubeSat mission or any small satellite related project, please contact **cubesat@calpoly.edu**. We have a wide variety of resources and are interested in pursuing a broad range of projects.

If you would like to stop by and check out the lab facitilites, we can easily schedule a lab tour for you with our lab members. Just drop us a line at **cubesat@calpoly.edu.**

Cal Poly students interested in joining CPCL, visit polysat.org for an application and details on how to apply. We accept applications from all majors, so as long as you have an interest in science, engineering, or space feel free to apply!

If you would like to support the Cal Poly CubeSat lab in providing learn-by-doing educational opportunities for the space industry please visit **https://www.polysat.org/donate.**

Instagram: @cppolysat
Twitter: @PolySat
Facebook: PolySat