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The Voyages

University of Hawaiʻi's Spaceflight-Ready, Low-Cost, Open-Source, Educational Artemis CubeSat Kit

By: Aksel Sloan, Kelly Ngo, Chris Amendola, Luke Clements, Evan Takushi, Amber Imai-Hong, Dr. Frances Zhu

Figure 1. Artemis CubeSat Hardware

According to the most recent 2021 Accreditation Board for Engineering and Technology (ABET) evaluation, only 11% of the 689 ABET-accredited universities in the United States have aerospace programs. Furthermore, 23 of the 50 states do not have an aerospace program, meaning nearly half of the United States cannot provide aerospace education to interested students. However, as the aerospace field has expanded, the educational barrier to building a small spacecraft has lowered. What would typically be achieved by personnel with Ph.D. and Master's degrees can now be achieved by undergraduates. Unfortunately, the number of aerospace-accredited schools does not reflect the growing field nor the lowered educational barrier. Thus, we propose to bring aerospace engineering education to anyone at the undergraduate level through a small satellite kit and curriculum, called the Artemis CubeSat Kit.

The Artemis CubeSat Kit is a spaceflight-ready, low-cost, educational 1U cube satellite kit that acts as a foundation enabler in aerospace engineering education and small satellites commercial launches. The Artemis CubeSat hardware, shown in Figure 1, accompanies a standalone "Spacecraft Mission Design" in the public domain, which includes a self-guided course outline, textbook, and digital lab

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modules. Funded by NASA's Artemis Student Challenge Program, the kit is developed and maintained by university students, engineers, and faculty at the Hawai'i Space Flight Laboratory (HSFL). The Artemis CubeSat Kit and accompanying curriculum provide educational accessibility for university-level students and faculty interested in designing, building, and flying their own small satellite missions.

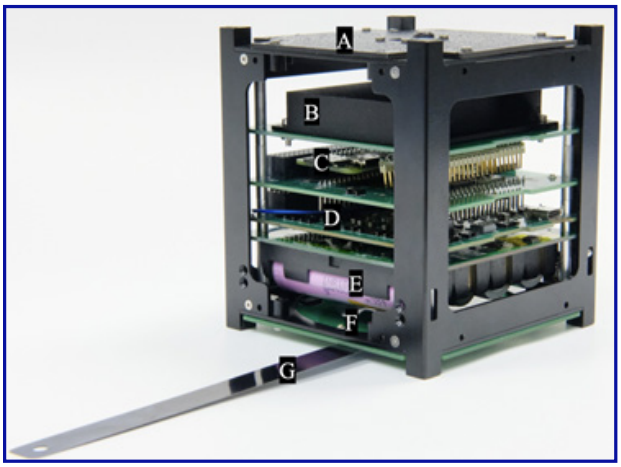


Figure 2: Labeled PCBs of Artemis 1U CubeSat with No Solar Panel Boards; A: Payload Board; B: Mock Payload; C: OBC, D: PDU; E: Battery Board; F: Antenna Board; G: Antenna

The Artemis CubeSat utilizes HSFL's Comprehensive Open-architecture Solution for Mission Operations Systems (COSMOS) for satellite and mission operations. A simple diagram of COSMOS's capabilities is shown in Figure 3. More information on COSMOS is publicly available online.

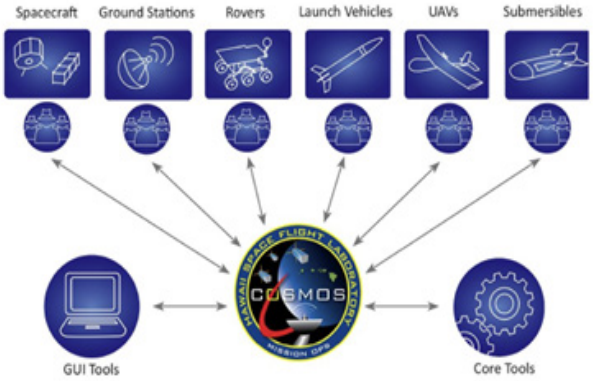


Figure 3: COSMOS capabilities diagram

To ensure the Artemis 1U CubeSat is functional and meets spaceflight and launch provider standards established by the CSLI Program, several design verification methods are performed before the kits are sent to the end user. These include charge tests, interface tests, and vibration testing, seen in Figures 4, 5, and 6 respectively. The Artemis CubeSat Kit can be ordered as spaceflight-ready or non-spaceflight ready.

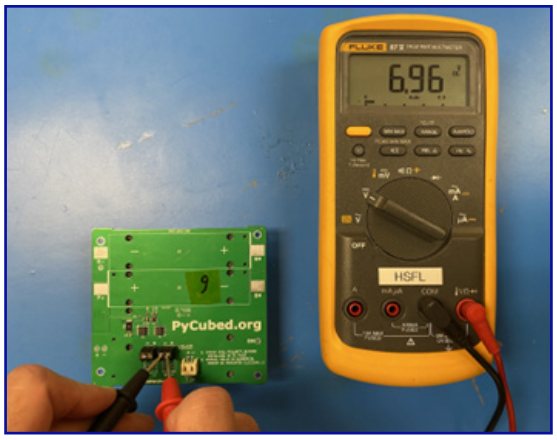


Figure 4: Battery Board Voltage Charge Test

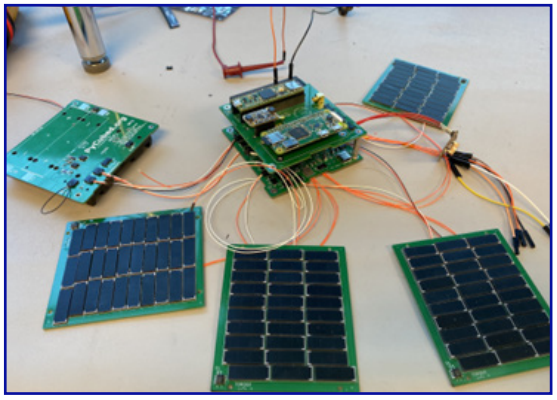


Figure 5: Artemis CubeSat Assembled as a FlatSat for Interface Testing

Figure 6: Vibration Test Preparation

The intent of the Artemis CubeSat Kit's educational materials is for institutions to develop an understanding of the satellite and give instructors insight on how to teach spacecraft mission and bus design. When an institution acquires the Kit, end users can work through the physical lab modules to augment their education in satellite design. There are no prerequisites for the course and textbook readings, though any background knowledge helps.

Following the textbook chapter by chapter parallels completing a spacecraft mission design course. The textbook is intended to be a comprehensive resource for those interested in LEO mission design concepts and small satellites. Topics are aligned with the capabilities of do-it-yourself aerospace engineering groups. The textbook itself is a standalone learning guide – an instructor is suggested but not needed. Topics are aligned with the capabilities of do-it-yourself aerospace engineering groups.

As the hardware platform is a 1U CubeSat, the spacecraft lectures focus on the nuances associated with small satellite design and capabilities. Hands-on lab modules are geared toward self-discovery and team communication, with structured concrete goals to inspire progress. The lab modules and software tutorials serve as exercises within the curriculum and can be found at the end of each textbook chapter. Each subsystem has a digital lab based in software and a physical lab requiring the hardware satellite kit, shown in Figures 7 to 10.

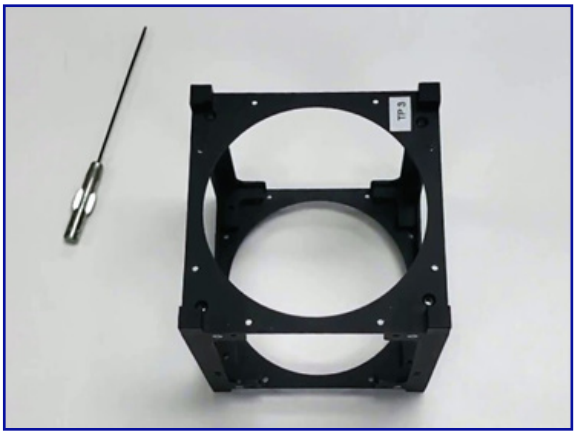


Figure 7: Structure Lab:
Assembled Artemis CubeSat Kit Structure

Figure 8: Electrical Power System Lab:
Measuring Battery State of Charge

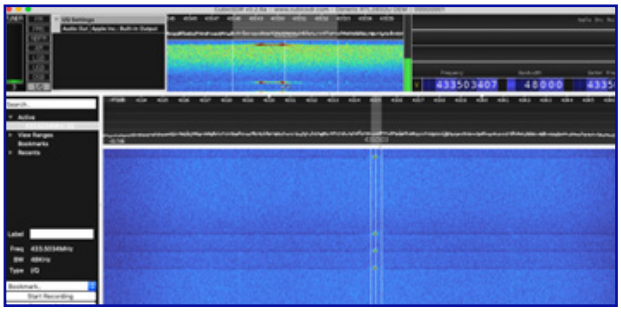


Figure 9: Communications Lab:
Receiving Radio Signals

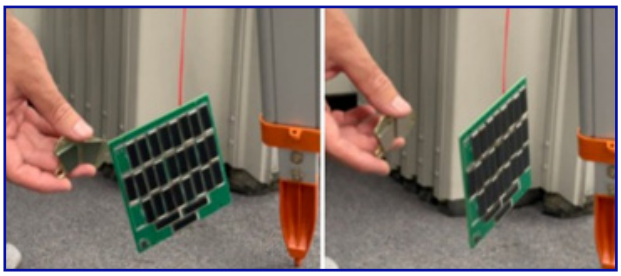


Figure 10: Attitude Control Lab:
Deflecting an Activated Torque Coil with a Magnet

Although the Artemis CubeSat Kit was initially intended for university-level students, its versatile course materials, provisions, and hardware design have already proven themselves beyond the university-level. Such applications include Project POKE (Providing an Opportunity for the Keiki in Engineering), which is an adaption of the Artemis CubeSat Kit released for middle and high school education. Through its low-cost, spaceflight readiness, open-source design, and online course, the Artemis CubeSat Kit establishes itself as a unique 1U CubeSat kit. The Kit will remain open-source, with all of its designs in the public domain. End users are welcome to build the kit themselves from the ground-up or purchase it prefabricated from the University of Hawai‘i. The team consistently updates and improves upon the hardware design, software modules, and educational materials to suit the needs of the community.

The Artemis Team would like to thank NASA grant 80NSSC20K0988 for supporting this program. The team would also like to express their gratitude to Hawai‘i Space Grant Consortium for assistance in obtaining the grant and the Hawai‘i Institute of Geophysics and Planetology office staff for consistently and courteously handling the teams’ orders. Lastly, the team sincerely appreciates and thanks the end users for their helpful feedback.

DIRECTOR'S MESSAGE, *Dr Luke Flynn*

COVID Impacts on HSGC

Few could predict the once-in-a-century illness that COVID-19 would become. At the time of our NASA Space Grant Directors' Annual Meeting in late February 2020, COVID-19 cases had begun cropping up in most States. By the end of March 2020, air travel and other forms of transportation were disrupted as the COVID crisis deepened, and by the end of the following month, most institutions of learning (K-12 through University) were only holding virtual classes, and UH faculty/staff were discouraged from coming to campus.

The effects of COVID-19 on Hawai'i Space Grant activities were immediate and highly disruptive. Before COVID, our State enjoyed a greatly expanding robotics effort - even boasting the highest number of VEX IQ teams (350+) per capita in the nation. COVID-19 would quickly reduce that number to less than 100 teams by Fall 2019. Our University Research Internships plummeted due to necessary lab restrictions that affected mentor-student research. Hawai'i Space Flight Laboratory projects and the new Artemis 1-U CubeSat project faced significant delays due to lack of satellite parts from a growing international supply chain problem. Our NASA summer challenge events, including First Nations Launch and RockOn, were previously well-attended by our HSGC Community Colleges, but were all canceled due to COVID.

And yet, sometimes dark times allow us to recognize the brightest stars. The Provost gave permission for HSFL lab activities to continue, and students and staff delivered Neutron-1, a 3-U CubeSat, in summer 2020. Neutron-1 was launched to orbit in November 2020 and outlasted the worst of COVID by continuing to operate for ~600 days until late June 2022. Our own UH-Maui College team won first place honors for a virtual American Astronautical Society CanSat competition in Summer 2020. The Windward CC rocketry team won a first place award for their hybrid rocket at the 2021 ARLISS competition. The Artemis team persevered by developing their 1-U CubeSat kit along with over 800 pages of online course support material that will be used by teams across the country. Two of our brightest stars, Amber Imai-Hong and Dr. Frances Zhu, won a $440,000+ State GEER grant to bring Artemis CubeSats to Hawai'i middle schools and high schools. While the number of URI applications decreased, the quality of URI research remained top notch, and we would like to recognize the students and mentors that produced outstanding research under difficult circumstances. We look forward to return to post-COVID "normal"!

Spring 2022 HSGC URI Symposium - Group photo of students, mentors, and affiliates with and without masks. First in-person symposum event since start of COVID-19 pandemic.

"The View from the Pipeline"

By: Michael Ito, Former URI Research Intern

Michael Ito
(Research Intern, Fall 2020 - Spring 2021)

I recently graduated from UH Mānoa with a Mathematics and Computer Science degree. During this time, I had the pleasure of participating in the HSGC research internship program in the Fall 2020 and Spring 2021 semesters. The internship program funded my undergraduate research, granting me the opportunity to work on DKIST, the new Daniel K. Inouye Solar Telescope.

Figure 1: Daniel K. Inouye Solar Telescope (DKIST)

Located atop the Haleakala volcano in Hawai'i with favorable viewing conditions, DKIST is the world's largest solar telescope and has recently begun producing unprecedented observations of the sun. These observations are used to predict solar activity potentially harmful to the earth such as coronal mass ejections, solar flares, and solar winds. One of the direct benefits of utilizing DKIST is the production of massive datasets of the solar atmosphere. Higher quality datasets are necessary for better predictions of solar activity. However, as data grows in size, it becomes more and more difficult to process and utilize by current methods. In my research with HSGC, I proposed instead to use neural networks, artificial intelligence (AI) techniques, to quickly process DKIST observations and leverage key properties of the solar telescope dataset.

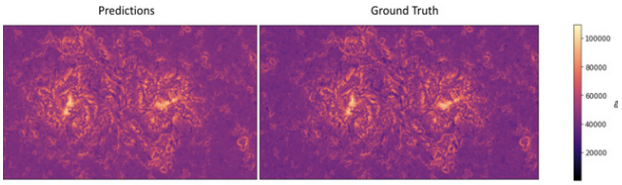


Figure 2: Neural Network predictions (left) compared to the ground truth (right) of solar atmospheric pressure at a sunspot region of the sun.

The research was my first introduction to real-world big-data. Even designing a pipeline to simply process the datasets, a trivial task with small-data, was a learning experience on its own. I had the opportunity to work with state of the art AI techniques on a significant scientific problem. Previously, I had only learned about AI through coursework without any practical hands-on experience. Throughout the project, I encountered various unexpected challenges which required engineering unique solutions which I was previously unexposed to. Finally at the end of the project, our team pursued publication which required rigorous academic writing and preparation.

HSGC's internship program has had a monumental impact on my career. Currently, I am headed to pursue a PhD in Computer Science at the University of Michigan where I'll be continuing my work with Artificial Intelligence and Deep Learning. HSGC's internship program provided the experience necessary for me to realize my future research directions and begin graduate school pursuing impactful research. I am also fortunate to be funded by the Department of Energy's (DOE) Computational Science Graduate Fellowship during my PhD. In one of the crucial steps to being chosen as a fellow, I detailed to the DOE my experiences with big-data and how I used DKIST solar telescope observations along with AI to make predictions about solar activity. HSGC directly provided me with this experience, and without it I would not have any expertise with big-data for the DOE fellowship.

I am extremely proud to have been called an HSGC research intern. Not only was I able to conduct meaningful research, but the program also jump started my career. Because of HSGC, I am able to currently begin my graduate career, pursuing my own research passions.

HAWAI‘I SPACE GRANT CONSORTIUM SUCCESS STORIES

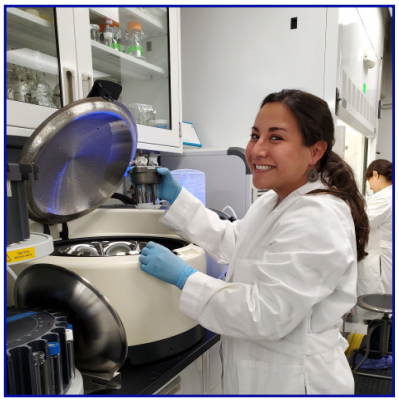
Following HSGC's previous fellows, trainees and interns - Where are they now?

Vannesa Zepeda

(NASA Intern, Summer 2019)

M.S. BIOLOGY, NOW PURSUING PHD IN ASTROBIOLOGY QUEENSLAND UNIVERSITY OF TECHNOLOGY

“ It was during my MS program where I secured an internship with NASA’s Jet Propulsion Laboratory (JPL) in the Astrobiogeochemistry lab. I received funding from Hawai‘i Space Grant Consortium (HSGC) to support this internship. Additionally, I developed another project during my internship at JPL that allowed for a second internship that was also funded by HSGC. This second project involved the isolation and detection of amino acids in meteorites. I’m currently a junior scientist on the Mars 2020 Perseverance rover mission and my research focuses on the analytical procedures we will use on the Mars rocks once they are brought back to Earth. I have one more year of research to complete my PhD. I would not have been able to go to JPL without funding from HSGC and NASA. Space Grant provided me the opportunity to grow my academic career and continue my collaboration with NASA. ”



Vanessa K. Zepeda isolating biomarkers preserved in rocks.

Chris Okubo

(Fellow, Fall 1994 - Spring 1995)

SUPERVISORY RESEARCH GEOPHYSICIST U.S. GEOLOGICAL SURVEY’S ASTROGEOLOGY SCIENCE CENTER

“ I was a Space Grant Fellow from 1994-1995. The project was to use Landsat data of the Puna area on the Kīlauea volcano to test the idea that vegetation cover could be used to map lava flow fields of different ages. This project drew me into research and sparked my interest in some of the other features of Kīlauea, namely its pit craters and how they formed. I began looking into the structure and formation mechanism of these pit craters under the guidance of Steve Martel, and this work eventually led to my first published paper. I continued on space-related research at UHM, and eventually moved on to study faults on Mars as a part of a Ph.D. program at the University of Nevada, Reno, followed by a post-doc position at the University of Arizona with the High-Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter. I am currently the Deputy Director for the US Geological Survey’s Astrogeology Science Center and continue to do research on Earth and Mars as time allows. ”

HAVE A STORY TO SHARE?

If you are a past participant and have an interest in sharing how our space grant program has benefited you, we would love to hear from you. By doing so, you can help spread the word to others how NASA’s efforts in promoting education has made an impact on all our participants - like you! If interested, please email with a Subject Line of “Success Story” to HSGC@spacegrant.hawaii.edu.

Undergraduate Programs: Research Interns & Trainees

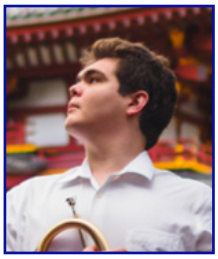
UH Mānoa Research Interns: Fall 2021 - Spring 2022

Spring 2022

Ashten Akemoto, a sophomore in computer engineering, has worked with mentor Dr. Frances Zhu of the Department of Hawai'i Institute of Geophysics and Planetology. His work focused on improving Gaussian Process Active (GPAL) algorithms by determining parsimonious models with the highest fit kernel for any given surface. GPAL aids autonomous robots to quickly and accurately model an unknown planetary surface.

Spring 2022

Bret Witt, a sophomore in Computer Science, worked with mentor Dr. Frances Zhu of the Department of Hawai'i Institute of Geophysics and Planetology. His work aims to design a Neural Network-based system that allows rovers to utilize sensor data to identify the characteristics of terrain. More specifically, this system analyzes how soil interacts with the wheels of the rover, to make conclusions about its properties.



Fall 2021 - Spring 2022

Alan McFall, a senior in Earth Sciences, analyzed sediments from Kaneohe Bay, in order to characterize amorphous minerals on the Martian surface. He was mentored by Dr. Przemyslaw Dera, Hawai'i Institute of Geophysics & Planetology.

Spring 2022

Hershel Weiner, a sophomore in Astrophysics studied flux created by the collisions of cosmic rays and the General AntiParticle Spectrometer (GAPS). The GAPS is scheduled to launch in late 2022 to probe an unknown detection channel of dark matter. His studies aims to aid the GAPS in its analysis of the unexplored area. He was mentored by Philip von Doetinchem, Department of Physics and Astronomy.

Spring 2022

Aláine Lee, a sophomore in Astrophysics, worked with mentor Dr. Eugune Magnier of the Institute of Astronomy at the University of Hawai'i. Her work focused on compiling data that quantifies satellite streak artifacts in Pan STAARS images. The Panoramic Survey Telescope and Rapid Response System (Pan STAARS), is an astronomical imaging system which protects life on Earth by discovering hazardous asteroids. Her data aimed to improve the efficacy of Pan STAARS

Fall 2021
Spring 2022

Chinenye Ndili, a junior in Computer Science, worked on a project to detect ocean phenomena from satellites using artificial intelligence (AI). One objective was to improve upon an existing ML (Machine Learning) model to detect ocean images. He was guided by his mentor Dr. Peter Sadowski of the Department of Computer Science.

VIA-SEES Team: UH Mānoa Spring 2022

Kenny Son

Katlynn Vicuna

Matthew Leonard

Haile Brown (Volunteer)

"Variability in Atmosphere from Solar Energetic Electrons" (VIA-SEES) utilized one 3U CubeSat in Low Earth Orbit (LEO) to measure the direct correlation between Solar Energetic Electrons (SEEs) and the variability in total reactive Nitrogen Oxides (NOy) and Ozone (O3) concentration in the mesosphere.

UH Mānoa Rover Challenge Team: Spring 2022

Morgan Misra *Mackenzie Cammack* *Faith Rolark*

Team RoSE has developed an integrated suite of life-detection instruments for the University Rover Challenge. It featured a multiplexed microfluidic platform, a high-resolution geological camera, and a custom Raman spectrometer to investigate in-situ mineralogical and geological sites for the presence of extant or extinct life in a simulated Martian environment.

UH Mānoa Trainee Interns: Fall 2021 - Spring 2022

Fall 2021

Kalila Phillips, a junior in Mechanical Engineering, worked on integrating hands-on satellite lab modules for a space mission design course in the public domain. The main objective of this project was to develop an open-source textbook that revolves around a low-cost spaceflight-ready CubeSat kit. Guidance was provided by Dr. Frances Zhu of the Department of Hawai'i Institute of Geophysics and Planetology.

Fall 2021

Evan Takushi, a junior in Mechanical Engineering, focused his research on designing open-source cube satellite structures to optimize and design a structure for the Artemis CubeSat kit. His mentor was Dr. Frances Zhu of the Department of Hawai'i Institute of Geophysics and Planetology.

Spring 2022

Ian Padgett, a junior in astrophysics, worked with mentor Dr. Eugune Magnier, Institute of Astronomy at the University of Hawai'i. His work focused on assessing and improving the image stacking algorithm for the Pan-STARRS 1 telescope, which minimizes and eliminates areas of detection error from saturation effects and instrumental artifacts.

Windward CC Trainee Interns Project IMUA Apophis Fall 2020 - Spring 2021

Left to right: Dr. Joseph Ciotti, Jared Estrada, Nikki Arakawa, Dr. Jacob Hudson, Quinn Patrick

The Windward Community College E.S.R.A team worked on the fabrication of a hybrid rocket. The recent motor test yielded results comparable to other hybrid motors. A successful deployment test resulted in the installation of the rocket's avionic components and the completion of construction.

UH Maui CC Trainee Interns LunarSAT Team: Fall 2021

Clockwise from top right: Delaun Prentice, Christian Falcon, Tishri Prentice, Angelica Juarez

LunaSats are based on ChipSats and will evolve to reflect GLEE's mission to the lunar surface. LunaSats collect temperature, magnetic field, and inertial measurements. The teams were able to work through the same 10 hands-on modules learning about the science sensors onboard and the functionality of the LunaSat.

Kapi'olani CC Trainee Intern: Spring 2022

Spring 2022

Alyson Wirtz, a sophomore in Astronomy, worked with mentor Dr. Radovan Milincic, Department of Math & Sciences. Her work analyzed the densities of galaxies around the galaxy cluster MS 0735.6+7421 to determine the density of one of the largest black holes in the known universe. She hopes this project will serve as a model to determine the densities of other massive black-holes.

Trainee Interns - RockSAT-X Team: Fall 2021 - Spring 2022

Caleb Yuen *D'Elle Martin* *Frank Bolanos*

RockSat-X is an annual sounding rocket launch put on by the Colorado Space Grant Consortium. There are five full payload sections available for Universities and Community Colleges (Imua mission 10) to submit their proposals for. The payloads are being launched in August 2022 at Wallops Flight Facility, Virginia. HCC collaborated with Windward Community College (WCC) on an electronic payload and sublimation rocket. HCC worked on cameras to take videos and pictures of WCC's Super Simple Sublimation Rocket (S3R). The HCC team will also be working on an IMU that will measure parameters of the flight deck. IMU measurements, pictures and videos will be used to analyze the motion of the S3R.

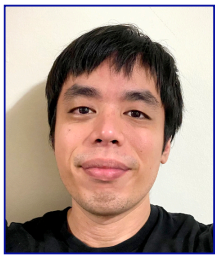
Trainee Interns Panopticon Team UH Maui College: Spring 2022

Dominic Manzano *Reinhard Salacup*

This team aimed to support the design, build, and test phases of a novel space surveillance system. More specifically, (1) compare and contrast different power supply options to enable remote control, (2) develop a robust leveling system, and (3) investigate VPN configurations with virtual machines to mitigate failure modes related to autonomous operations. This also includes developing a temperature sensor consisting of a custom (1) small form factor, printed circuit board, (2) 3Dprinted weatherized enclosure, and (3) and program that records and organizes data autonomously.

Graduate Programs: UOG Fellows & Master's Apprentice

University of Guam Fellows: Fall 2021 - Spring 2022



James Pangelinan, a graduate student at the University of Guam, studying environmental science worked with Dr. Chris Yeo from the Water & Environmental Research Institute. His project focused on statistical modeling of extreme precipitation processes within the Pacific Islands regions with the use of General Climate Models (GCMs). GCMs helped to describe reasonably well the main features of the distribution of basic climate parameters at a global scale.

Jonelle Sayama, a master's student at the University of Guam, in environmental science was guided by Dr. Romina King from the Micronesian Area Research Center. Her study area was to map the effects of sea level rise on Guam's Mangrove Forests. The use of unmanned aerial vehicles were deployed to create 3D maps of the study areas. The main purpose of this study was to gain a better understanding of Guam's mangroves.

HSGC Master's Apprenticeship Program: Fall 2020 - Fall 2021

Kaiaka Kepa-Alama, an M.S. student in Mechanical Engineering, who was guided by Dr. Frances Zhu of the Hawai'i Institute of Geophysics and Planetology. His research project was titled "Planetary Surface Rover Localization in Permanently Shaded Regions". The goal of this project was to develop a novel navigation method by combining absolute localization and terrain relative navigation (TRN) for an autonomous rovers in the permanently shadowed regions (PSR) of the lunar surface.

HSGC URI Research Internship Experiences

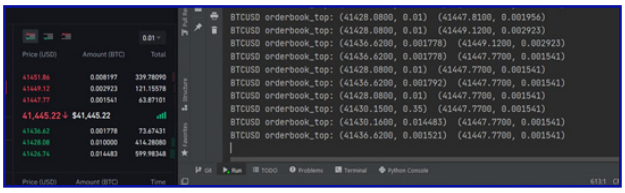
By: Chinenye Ndili, Former HSGC Research Intern

Chinenye Ndili

My dad came here from Nigeria after completing his undergraduate studies to pursue a Ph.D. at Stanford University and quickly became a successful entrepreneur after obtaining two doctorate degrees. I was born at the Stanford Medical Center in Palo Alto, CA, and grew up in San Jose. Whenever I was asked what I wanted to be when I grew up, I'd say 'engineer', believing that was the profession my dad was in.

Right now, I'm a Junior undergraduate student studying computer science at the University of Hawai'i at Mānoa. I aspire to become a successful entrepreneur, and my immediate career goal is to become a Quantitative Trader living and working in New York City, trading cryptocurrencies.

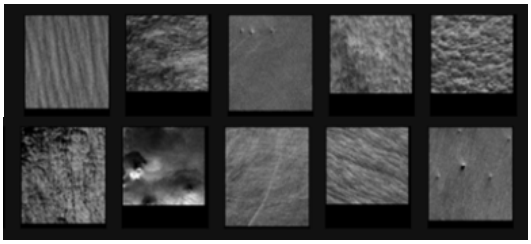
I'm currently working on a High-Frequency Trading (HFT) project. This involves designing and implementing an automated trading system to execute arbitrage trades across a couple of cryptocurrency exchanges. I'm also looking to build a 'DeFi' (decentralized finance) protocol that will allow traders to 'short' NFT projects. I'm very interested in crypto and the opportunity it creates!



Live price data feed from crypto exchange BinanceUS.

During the Spring 2021 - Fall 2021 semesters, I worked as a University Research Intern under faculty mentor Peter Sadowski. Approved by the Hawai'i Space Grant Consortium (HSGC) and sponsored by NASA, our project was titled 'Detecting Ocean Phenomena from Satellites with AI'. The project involved creating, training, and evaluating artificial neural networks in order to automate the classification of Satellite Aperture Radar (SAR) images. It was an invaluable contribution to my academic and professional career. Below, I've put the project abstract.

> *"Satellite Aperture Radar (SAR) technology enables image collection across the world's ocean basins from space-based satellites. Found in these images are oceanic and atmospheric weather patterns that are of interest to weather scientists. However, over a million images are collected by satellites each year, which is far too large a quantity to analyze by hand. This project explores the use of deep convolutional neural networks (dCNNs) to automate the classification of oceanic phenomena in these SAR images."*



Sample SAR images.

Technologies used include Python, TensorFlow 2, Keras, Numpy, matplotlib, Sci-kit learn, and others. During my participation as a research intern, I gained experience with the most prominent deep learning software packages and several popular Python data science packages. I also learned to apply the scientific method; to ask relevant questions and use large amounts of data to derive answers.

The technical and coding experience I gained throughout the project is directly applicable to the career I am pursuing, in the short, and long term. As such, I value it immensely. However, I can confidently say that the most valuable contribution to my academic and professional development was through the mentorship provided. My mentor Peter Sadowski has been a foundational element in my career and continues to provide me with opportunities, connections, and knowledge to further advance my aspirations.

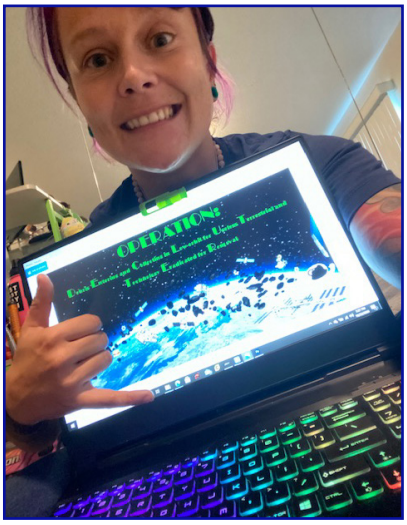
I'd like to thank NASA, HSGC, Peter, my colleagues at Hawai'i AI, and many more for this wonderful experience. My mother is an avid reader and creative writer, and she always took the time to read to my brothers and me growing up. I'd like to thank her for nurturing a sense of curiosity and desire for exploration within me. It's only because of her that I continually learn about these interesting new technologies, and am as a result able to pursue them academically and professionally.

HSGC/HSFL Internship Experiences

By: Katlynn Vicuna, Former HSGC Research Intern

Katlynn Vicuna

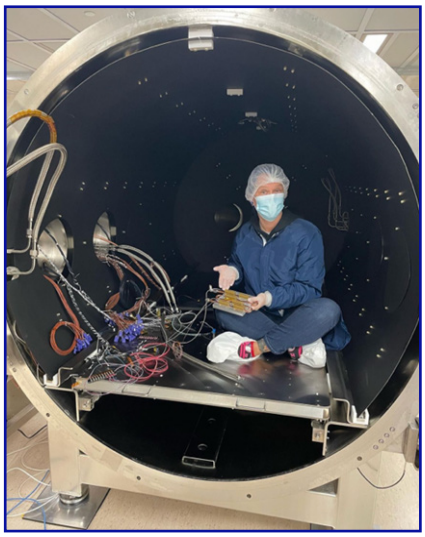
Participating in the HSGC Program over the past couple of years has considerably impacted my research capabilities. I worked with Dr. Aaron Hanai during the pandemic, and he and my research project kept my mind off of the pandemic. I didn't even feel like I skipped a beat with my education. He taught me how to develop research strategies and look at problems from an engineering perspective. I learned a lot from that experience. I applied what I learned to my school work and projects. Also, I was able to improve my writing skills. Throughout the process, I wrote reports which helped me present my work to knowledgeable individuals.



Katlynn presents her HSGC Research project titled: "Operation DECLUTTER"- Debris Entering and Collecting in Low-orbit for Useless Terrestrial and Technology Eradicated for Removal.

I continued to be part of another Hawai'i Space Grant Consortium project that ties into the EPET program under the council of Dr. Peter Englert. Our project group had to create a meaningful scientific mission and then engineer a corresponding satellite that might someday get launched into space. I feel HSGC helped me pave the way to work at Hawai'i Space Flight Laboratory (HSFL), which helped me attain an internship this summer at Lockheed Martin through the Brooke Ownes Fellowship.

At HSFL, I have gained the opportunity to work with many interesting people and space-related projects. I have been able to work with Dr. Frances Zhu to create an open-source aerospace engineering textbook with a corresponding CubeSat kit used in the EPET program. It will be available to those that do not have an aerospace program. I have also been able to work on the avionics side with Amber Imai-Hong, to assist in the tests for a satellite called the Hyperspectral Thermal Imager (HyTI).



Katlynn wiring in the vacuum chamber on a project with HSFL/HIGP on a satellite called HyTI.

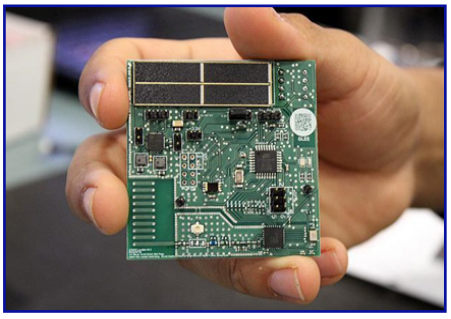
This summer, I am interning at Lockheed Martin in Littleton, Colorado, working in the Human Space Flight Department. The official project could be anything from working on the lunar rovers they will be using on the moon on the upcoming Artemis missions to NanoRacks systems. I am very excited about that opportunity. Working with Aaron on my HSGC project, Frankie with the EPET textbook, and Amber in avionics has given me real-world experience, which has prepared me to work over the summer at an aerospace company.

The Great Lunar Expedition for Everyone (GLEE) 2021 Workshop

By: Angelica Juarez, Delaun Prentice, Tishri Prentice, Christian Falcon (Trainees/Interns)

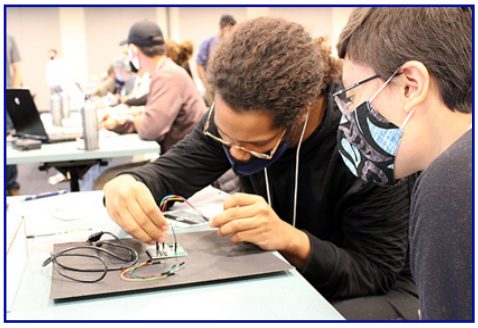
Tishri and Christian Testing the LunaSat accelerometer

The GLEE workshop is a science and technology mission conducted by students worldwide to send 500 satellites called LunaSats to the moon by 2023. The workshop was held in person at the University of Colorado Boulder in the Sustainability, Energy, and Environment Community (SEEC) building and took place daily from October 21, 2021, to October 24, 2021. This workshop allows students to create missions using LunaSat's onboard sensors to gather data on the moon's surface. The program was organized and led by undergraduate students from the University of Colorado, Boulder, who taught and guided us in testing the first iteration of the LunaSat production. Two two-student UHMC teams out of nineteen teams from across the country participated in the GLEE workshop. Each team received a LunaSat kit comprised of two LunaSat units. The LunaSat consists of a circuit board with various sensors and an Arduino-based microprocessor. Components included onboard the LunaSat are a temperature sensor, accelerometer, magnetometer, thermopile, and capacitance sensor.



Front of LunaSAT

The GLEE program was split into 12 modules, starting at module 0 and ending at module 11. It introduced each group to the GLEE 2023 mission, analyzing every individual component and concluding by having teams create a unique science mission. This mission will be performed on the moon using the collective knowledge of the LunaSats gained from the previous modules. In addition, every module had an activity to test and familiarize students with each component.



Angelica and Delaun connect the wires to establish communication between LunaSat and the computer

Tishri and Christian testing the solar panel on the LunaSat

The GLEE workshop was a fun, inspirational, and educational experience for everyone in attendance. We met many people from multiple universities around the U.S. and shared our love for astronomy and space exploration. We were fortunate to get selected to participate in this entertaining and informative workshop and cannot wait to join in on the worldwide workshop this April. The UHMC team would like to thank the NASA Hawai'i Space Grant Consortium (HSGC) for allowing our teams to participate in the GLEE workshop, an amazing experience. In addition, we want to thank the GLEE team for providing the program, being kind, and persevering through the COVID-19 hardships.

University of Guam Drone Corps
Fall 2021 - Spring 2022

By: Keanno Fausto, Communications Coordinator at NASA Guam Space Grant

UOG Drone Corps students visit the hangar facility near Tech Center Guam during a Part 107 Preparatory Knowledge Course session. (Photo Courtesy: Maria Seanna Minas)

The University of Guam Drone Corps is a comprehensive one-year program that provides UOG students and faculty with a pathway to become certified drone operators. The program aims to introduce members to the fundamentals of drone technology through immersive workshops, to give them hands-on experience with technological applications, and to inspire them to create their own drone-based solutions in addressing the island's unique issues.

It is the institution's first drone certification and training program for students, staff, and faculty. The program aims to build technical capacity by creating a cadre of FAA-licensed, informed, and responsible pilots through knowledge courses, training workshops, and hands-on flying opportunities. Collaboratively administered by the NASA Guam EPSCoR and NASA Guam Space Grant programs at the University of Guam, the UOG Drone Corps is focused on increasing education and awareness of drone technology through responsible use.

> " There is so much potential for the drone industry on Guam. For NASA Guam EPSCoR, we are interested in growing the cadre of FAA-licensed, responsible operators who can provide support to research projects in our region. Our first cohort of students learned that flying a drone involved much more than they first imagined. Now, in less than a year, many of them have shown that they are ready and capable to take part in the variety of opportunities within the drone industry here on Guam. "
>
> *- Dr. Leslie Aquino, NASA Guam EPSCoR Program Director*

Upon acceptance into the UOG Drone Corps program, members will receive stipends while undergoing a three-step certification process: completion of the FAA Part 107b knowledge course, FAA Part 107b examination, and accumulation of flight hours. This year, the program will be partnering with the local UAV company Bella Wings Aviation to offer drone flight and test preparation training. The three-week preparatory knowledge course will be held in-person during Summer 2022 and will provide students with the necessary skills to understand remote flight regulations and safety procedures.

Licensed pilots will be granted opportunities throughout the year to earn flight time by pursuing internships and simulator experience with private corporations, government agencies, or NGOs requiring drone services. The program will be augmented by workshops that explore the wide-ranging applications of drones. Through these opportunities, students can apply their remote-piloting skills in drone operation missions such as search-and-rescue, remote sensing, mapping, and aerial photography.

UOG Drone Corps students hold up their study materials during the Part 107 Preparatory Knowledge Course. Photographed from left to right: Jeremy D. & Alexis E. (Photo courtesy: NASA Guam Space Grant - Keanno Fausto)

> " The UOG Drone Corps has provided me with a gateway to different experiences and realizations of this newly evolving industry. The multitude of drone applications to everyday life, most notably to public safety and protection response teams is unimaginable by many. "
>
> *- Christopher Salas, UOG Drone Corps member*

UOG Drone Corps students get hands-on training with a drone simulator during a Part 107 Preparatory Knowledge Course session. Photographed from left to right: Mr. Art D., Thor H., Ulysses S., and Queensly D.

Since its launch in April 2021, the program has produced 12 FAA-certified remote pilots. Many of its licensed pilots have taken on positions at local drone businesses and will be available to serve as mentors to new cohort members.

Scan QR code for more information

Teddy Estrellado, technical director of Drone Optics Guam, holds up a drone for UOG Drone Corps members to see during a Dec. 4 workshop

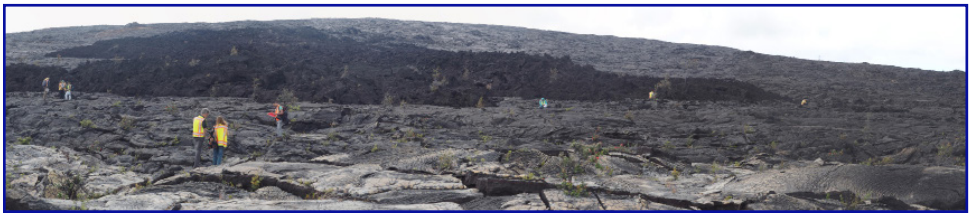
> " We are extremely happy with the accomplishments of our inaugural cohort's members. Seeing them progress from drone students to pilots to even teachers in some cases was a rewarding experience for everyone. This year, we're looking forward to delivering an even more robust and engaging UOG Drone Corps experience for our upcoming members by collaborating with local experts in the drone industry. "
>
> *- Dr. Romina King, NASA GUAM Space Grant Associate Director*

ERTH 460: Geological Remote Sensing on Hawai'i Island

By: Dr. Scott Rowland, Hawai'i Institute of Geophysics, University of Hawai'i at Mānoa

ERTH 460 students and Rob Wright (fifth from the left) at the start of the ground-truthing project.

After a hiatus of 4 years thanks to Covid, ERTH 460 (Geological Remote Sensing) returned to Kīlauea so that students could ground-truth their final projects. Some students had never seen volcanic features in-person and a couple of them weren't even Earth Science majors! (we accept them anyway). For everybody, it was an eye-opening experience to see with their very own eyes the same features they had only seen in nadir view at various wavelengths and at various spatial resolutions. Mahalo to the Hawai'i Space Grant Consortium for generously continuing to support this trip!



Students scatter over the landscape to learn about p-type pāhoehoe, s-type pāhoehoe, and 'a'ā.

Journey from HSFL to NASA

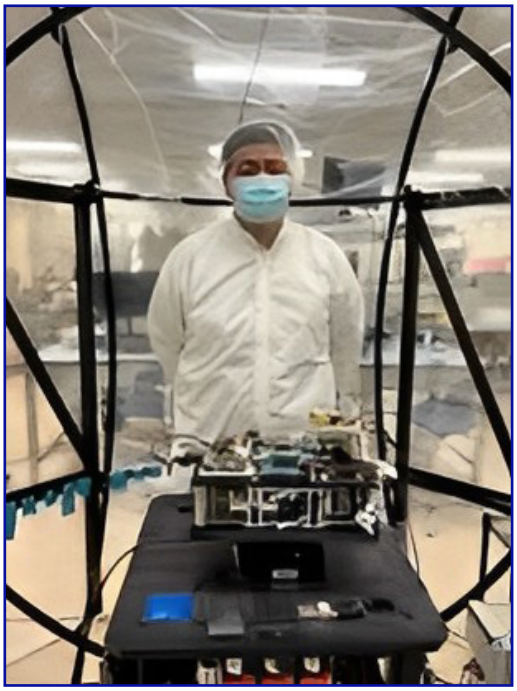
By: Ethan Ariyoshi, Former HSFL Employee

Ethan Ariyoshi

My name is Ethan Ariyoshi and I am employed by KBR as a Flight Dynamics Officer (FDO) at Johnson Space Center. I have lived in Hawai'i my whole life and went to the mainland for college. After graduating in 2021, I returned home and started working for the Hawai'i Space Flight Laboratory (HSFL). The majority of my work at HSFL was working on the HyTI (Hyperspectral Thermal Imager) CubeSat. HyTI's mission goal is to demonstrate high performance on-board processing of payload data into L1 and L2 products on a CubeSat platform. With this technology, Earth scientists will be able to receive data like volcano degassing, surface temperature, and agriculture metrics a lot quicker.

I was a part of a team of engineers and students that tested the Attitude Determination and Control System (ADCS) on HyTI. The ADCS controls the satellite's ability to accurately point in space. Without the ADCS, we would not be able to point our camera at the ground, point our solar panels at the sun, or point our antennas at ground stations. We used HSFL's state of the art ADCS testbed to test commissioning and operational modes of the ADCS on HyTI. Another part of my job was to be an orbital analyst for HyTI and other proposals. I ran a lot of simulations of HyTI in orbit and obtained data like number of communication passes, power generation, and expected orbit lifetime. This data would be analyzed and used to support the design of a mission profile that would contribute to the highest chance of a successful mission.

My work as an orbital analyst is very relevant to my current position as an FDO in the Artemis Program. Artemis aims to perform a crewed landing on the lunar south pole around 2025. FDOs are responsible for monitoring the trajectory of the launch vehicle and spacecraft from pre-launch through ascent, on-orbit, cislunar, in lunar orbit, and through entry and splashdown. FDOs also evaluate the risk of orbital debris collision and calculate trajectory correction burns to mitigate that risk while keeping the vehicle on-track with its flight plan. We'll also perform rendezvous and proximity operations with the SpaceX Starship for lunar landing and for future Artemis missions, the Gateway Space Station.



Ethan with HyTI on the ADCS Testbed

HSFL is a unique place that bridges the divide between education and industry. Working for HSFL allowed me to apply the engineering concepts that I learned in school to a real project for the first time. I was able to develop new skills and learn a lot of lessons thanks to all the engineers and professors at HSFL. The engineering foundations that I built at HSFL will allow me to help return humans to the Moon for the first time in 60 years. Even though I worked for HSFL for only a little over a year, I have gained an experience that will stay with me throughout my career.

Astronaut Lacy Veach Day of Discovery

> “ …Part of a team that sets big goals and works together to achieve them like the exploration of our solar system. Past astronauts such as Lacy Veach paved the way for our future exploration to the moon, mars, and beyond”
>
> *- Astronaut Megan McArthur, Veach Day 2021*

Due to factors such as the re-opening of tourism, the efficacy of vaccines, and the reality of new variants with unknown impact, COVID cases continue to stabilize and fall in Hawai‘i. Thus, the 2021 Astronaut Lacy Veach Day of Discovery was virtual, similar to 2020.

The 20th annual Astronaut Veach Day of Discovery pivoted to a virtual event. It was unveiled on YouTube on October 30, 2021, at noon Hawai‘i time. Both the promotional video and the Astronaut Veach Day of Discovery programs continue to gain views on YouTube. As of January 24, 2022, the promotional video has 392 views, and the complete program video has 368 views.

Video Link

https://youtu.be/LAQow3lFGgo

(1) STEM Workshops and Demonstrations by Bryan Silver, Kalani High School, (2) I Am a Scientist program at Chaminade University, (3) Astronaut in a Bottle by Katlynn Vicuna, and (4) Harvey Ouchi, Hawai‘i Magicians

(1) STEM Girl-Powered All-Stars including Cristina Felicias, Northrup Grumman, (2) Nicole Yamase, 1st Pacific Islander to reach the deepest part of the ocean, (3) Amber Imai-Hong, Hawai‘i Space Flight Lab, and (4) Christianne Izumigawa, Naval Information Warfare Center

Governor David Ige proclaims October 30, 2021 as Lacy Veach Day

VEX Scholastic Robotics

> “ ...the future for robots is wide open...for the participants…the energy you put into this activity and the things you’re learning as you’re doing, are already making you a better expert and leader, opening the doors for a brighter future for robotics and for all of humankind ”
>
> - *Astronaut Stan Love, NASA Johnson Space Center*

The Hawai‘i VEX scholastic 2021-2022 robotics program saw a revival of hibernating teams and pivot from completely remote events in 2021 to the transition back to a new normal of robotics tournaments. The 2021-2022 Hawai‘i roster included 64 VEX IQ and 61 VRC registered teams. Many hibernating teams were provided game element sets and were able to participate in this past year’s competitions. HSGC also supported a few rookie teams. Tournaments offered this past year included a mix of live remote tournaments, skills-only, and in-person tournaments. In Live Remote Tournaments, teams stay in their own classroom bubble and competed remotely on their own field. Out-of-state teams could register and participate in these Live Remote Tournaments. In January, HSGC hosted a Live Remote Tournament with teams from Hawai‘i, mainland U.S., China, Japan, and Taiwan. In Skills-only, teams have three attempts to independently achieve their highest score. In an in-person tournament, teams competed in head-to-head alliances to score the highest number of points. The Hawai‘i VEX robotics 2021-2022 season concluded with three in-person live State Championships at Kamehameha Schools, Kapālama, Saint Louis School, and the University of Hawai‘i at Hilo. A total of 12 VRC and 20 IQ teams represented Hawai‘i at the 2022 World Championships in Dallas, Texas.

December 4, 2021 - Pearl City High School VRC Tournament (24 teams)

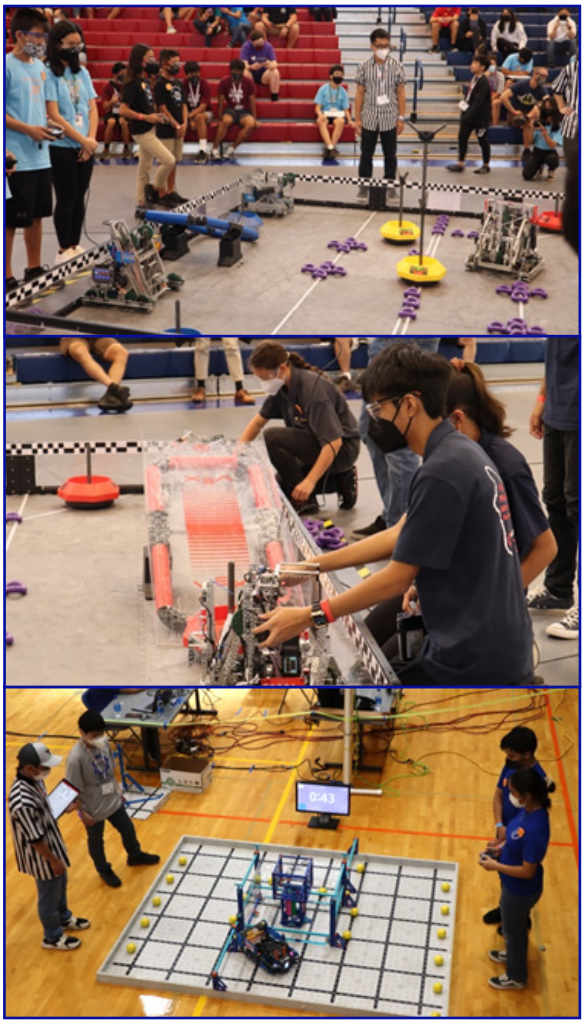
January 15, 2022 - HSGC VEX IQ Live Remote Tournament (18 teams)

Hawai‘i VEX State Championship

Presented by Hawaiian Electric Company

The Hawai‘i VEX Robotics State Championships presented by Hawaiian Electric transitioned back to a live in-person event with no spectators. The State Championships were spread across three events: VEX IQ Middle School, VEX IQ Elementary School, and VRC (Middle and High School). Event Partners for the State Championships adapted to the local county health and safety guidelines while allowing the students to experience an in-person championships event in 2020 once again.

2022 Partner of the Year - Hawaiian Electric Sponsor of the Hawai‘i VEX State Championships for the last 9 years, President and CEO of Hawaiian Electric, Shelee Kimura



Teacher of the Year – Mrs. Joan Okai, Highlands Intermediate School
Retired Dec. 2021, she continues to mentor the Highlands Robotics team in 2022.

Partner of the Year – Richard Enright, Nanakuli High and Intermediate School
He hosted a number of qualifying events in the Nanakuli-Waianae area including tournaments and remote tournaments involving mainland and international teams

> “ This past week was like Christmas morning because it provided valuable public speaking for our kids. The conversations they had with the judges and volunteers sparked some thought provoking questions that we will be reviewing this week after school. Thank you to you and your team, Jared. ”
>
> - *Coach Jared Haiola, Hale'iwa Elementary School*

Ka'ohao Public Charter School – Rookie season with 2 VEX IQ teams qualify to the 2022 World Championships in their rookie season

" We competed I our second tournament o the year at Saint Louis and made it to the semifinals and ended up 8th out of 32 teams. Students had a great time, and we learned a lot. This will probably be the last tournament of the school year we participate in. Thank you for all the support and we look forward to continuing the program next year. "

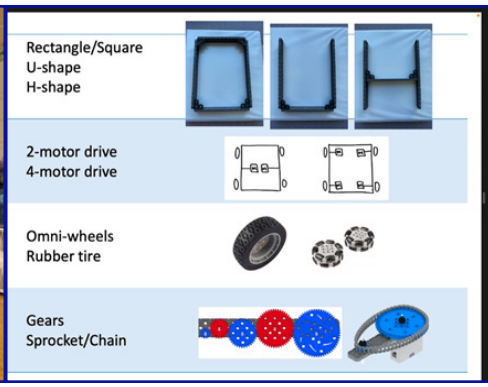
- Coach Bruce Lin, Niu Valley Middle School

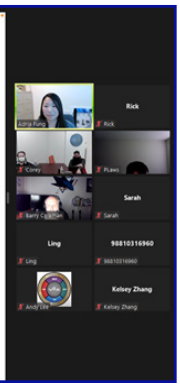
Highlands Robotics teams qualify to World Championships

Engaging Teachers and Students through Robotics


Adria Fung, K-12 Robotics Education Specialist, provides ready-use resources for Middle School and Elementary teachers looking to implement robotics into their classroom. This school year, Robotics Engineering projects designed have been implemented in STEM classes, including at Aiea Intermediate School. The teacher provided hands-on lessons and projects to the approximate 140 students where they learned about the engineering design process, documentation, gear ratios, and drivebases. The students' culminating semester project involved a Sumobot combination where students needed to use their knowledge of gear ratios and drivebases to design and build a Sumobot using the engineering design process. Aiea Intermediate School will also enter the VEX IQ competition next school year.

Kayin Bohnet, a recent graduate of St. Andrews Schools, interned under Adria Fung as part of her Priory in the City class. St. Andrews Schools previously had VEX IQ teams, however their program went dormant since the pandemic. Kayin designed a Mars Rover building and coding workshop for St. Andrews elementary students using VEX GO kits, to engage students and teachers. She hosted two workshops, one for boys and one for girls and taught the students how to design, build, and code their rovers to collect a Mars sample. The workshops had a great ripple effect that a few faculty members will be initiating robotics workshops for the elementary grade levels and restarting their VEX IQ teams next school year.



FACULTY PERSPECTIVE

EPET: Hands-on Learning about Space at UH Mānoa

By: Dr. Peter Englert, Associate Director for Internships & Space Science at HSGC
Hawai'i Institute of Geophysics, University of Hawai'i at Mānoa

The Hawai'i Institute of Geophysics and Planetology (HIGP) has responded to the high demand for an increasing United States space workforce by establishing a unique undergraduate certificate in Earth and Planetary Exploration Technology open to all majors. The expertise of HIGP in space exploration and of the Hawai'i Space Flight Laboratory in building and launching satellites makes the curriculum of this program truly unique: hands-on and relevant to potential employers.

The first EPET certificates were awarded at the end of the 2021 fall semester with the second set expected for the fall of 2022. Students complete a four course 15 credit series starting with an introduction to space exploration (EPET 201), designing of a payload (EPET 301) for a space mission (EPET 400) and a small spacecraft to be built and launched as a capstone project (EPET 401). The courses also have Writing Intensive (WI), Oral Communication (OC), and Contemporary Ethical Issues (ETH) focus designations. Classes do have an enrollment cap of 20 students and are team-taught by faculty experts.

The first group completed a 1 U CubeSat with a radiation detector and the second group intends to build and launch a 3U CubeSat for the VIA-SEES (Variability in Atmosphere from Solar Energetic Electrons Study) project measuring Ozone and the effect of Solar Energetic Electrons on its concentration in the atmosphere from Low Earth Orbit. The third group has just completed its introductory course and will begin designing new payloads for 1U and 3U CubeSats in the 2022 fall semester.

All EPET courses are cross listed with Mechanical Engineering (ME) and contribute to a concentration in aerospace engineering within the BS degree in Mechanical Engineering. Associated student space research and engineering projects receive support and recognition from the Hawai'i Space Grant Consortium and through the university's Undergraduate Research Opportunities Program.

Scan QR code for more information or email Dr. Peter Englert at penglert@hawaii.edu

VIA-SEES: An ambitious University of Hawai'i at Manōa Undergraduate Student Project Connecting Space Weather and Atmospheric Ozone.

By: Dr. Peter Englert, Associate Director for Internships & Space Science at HSGC
Hawai'i Institute of Geophysics, University of Hawai'i at Mānoa

Team VIA-SEES, From left to right: Katlynn Vicuna, Sean Maroney, Yanan Zeng, Stephan Devis, Matthew Leonard, Nalu Clemons, Andrew Vu, Kenny Son, and Haile Brown.

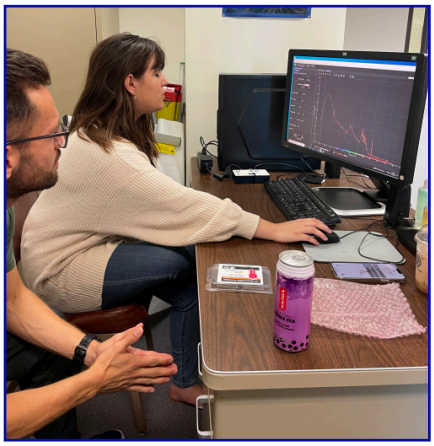
Variability in Atmosphere from Solar Energetic Electrons Study (VIA-SEES) is a student-initiated research and engineering project that emerged as part of a recently established University of Hawai'i certificate program in Earth and Planetary Exploration Technology (EPET).

Most of the nine students of the current VIA-SEES team began acquiring knowledge about space exploration and of designing a science payload for a space mission during the first two courses of the four course EPET sequence.

Students first became familiar with space exploration basics through an introductory course, EPET 201, Space Exploration. The second course of the sequence, EPET 301, Space Science and Instrumentation, provides an introduction into research.

The intent of the EPET 201 and 301 curricula is research education, enabling students through classroom instruction and guided group interaction to develop new/innovative space science objectives, science measurement requirements, and the instruments to deliver them. This includes creating a science traceability matrix and preliminary instrument and/or payload designs, initiating the EPET certificate capstone project which will be completed during the remaining two 400 level design courses.

During the 2021 fall semester EPET 301 through research and discussion, undergraduate engineering and science students developed the principal VIA-SEES science concept. Their research of NASA strategic priorities and decadal surveys uncovered an innovative research opportunity to understand the effect of solar energetic particles on the variability of Nitric Oxide or Nitrous Oxide and Ozone in the mesosphere. The group's work found that to date there has not been an Earth observing mission that has integrated simultaneous measurements of Solar Energetic Electrons and stratospheric Nitrous Oxide and Ozone into one space craft. The real time correlated measurements of solar radiation and upper atmospheric ozone on one spacecraft formed the innovative research project named VIA-SEES.



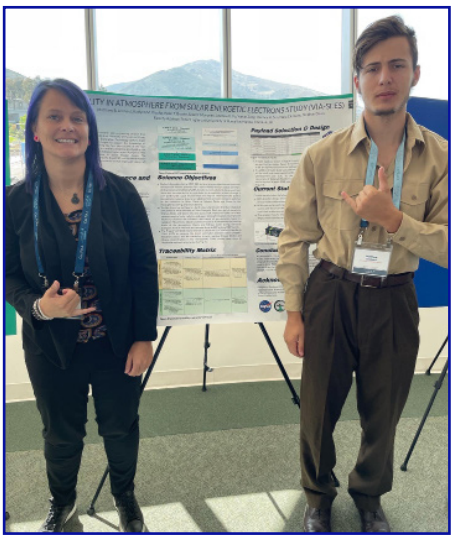
Haile Brown showing Stephan Devis results from a spectral analysis.

Kenny Son showing Yanan Zeng and Katlynn Vicuna the best orbital optimization and pointing angle for the spacecraft for their mission.

The team is designing, building, and testing the project payload through supported extracurricular research projects. A trade study showed that the VIA detector optimal for the project is commercially available while the SEES detector optimal for the project is not available commercially and needs to be specifically designed and built.

Hawai'i Space Grant Consortium (HSGC) group research internships support the testing and integration of the VIA detector while the SEES detector design and development is supported by UH Manōa's Undergraduate Research Opportunities Program (UROP). Students have also reached out beyond departmental and university boundaries to obtain support for this ambitious project.

The extracurricular VIA and SEES detector research flows into the EPET 400 course where the creativity of the students comes into play as they design their mission within science, engineering, and budget constraints. During the 2022 spring semester they have successfully carried the project forward to completing the preliminary design review. EPET 401, this coming fall, will be the culmination of the student experience, building the spacecraft for a mission designed in their preceding courses and extensive and parallel extracurricular activities. Mission design and payload are combined to produce a small deployable spacecraft as a capstone project. The course and extracurricular agenda also include the application for a CSLI launch opportunity of the VIA-SEES spacecraft for operation in a high-inclination orbit during solar maximum in 2025 and the subsequent work on the science outcomes.



Katlynn Vicuña and Matthew Leonard on the presenting their poster at the Cal Poly CubeSat Workshop.

The group's success to date has been recognized. Two group members, Matthew Leonard, and Katlynn Vicuña presented the groups research as a poster at the CubeSat Developers Workshop at California Polytechnic State University (Calpoly) in April 2022. Three group members, Katlynn Vicuña, Matthew Leonard, and Nalu Clemons have entered the research project into the Society of American Military Engineers (SAME) Innovation Design Project Competition and were selected as one of the top three teams. Not only did they win a monetary price, but they are also invited to present, via webinar, to the SAME professional community. Other group members will present the project at the 36th annual Small Sat Conference this coming August at Utah State University. the project to the procurement of a flight ready spacecraft.

Matthew Leonard and Andrew Vu going over a report

The current research group members supported by HSGC are Haile Brown, Katlynn Vicuña, Matthew Leonard, Kenny Song, and Nalu Clemons. Research group members supported by UROP are An Vu, Stephan Devis, and Yanan Vu. Other group members are Sean Moroney. The core EPET faculty are Drs Frances Zhu, Trevor Sorensen, Miguel Nunes, Robert Wright, and Peter Englert (program coordinator). Associate faculty are Drs Elena Dobrica, David Trang, Tayro Acosta-Maeda, and Shuai Li.

The complexity of the VIA-SEES project through the many factors on which its final success depends makes it ambitious However, the ambition of all involved creates the path to success.

The VIA-SEES success to date is the result of several important factors. First there is the student interest and engagement, which is exceptional. Then there is the opportunity provided through the research education focused EPET program, where the dedication to teaching, mentorship, and student support of its core faculty and associate faculty makes the difference. The University of Hawai'i at Manōa and NASA's focus on supporting undergraduate research experiences through UROP and HSGC is enabling advanced and high-level undergraduate research projects. The financial support of HIGP, the host unit of the EPET program and of the laboratories and experience of the Hawai'i Space Flight Laboratory (HSFL), provides a realistic opportunity to complete the project to the procurement of a flight ready spacecraft.

Would you like to make an online donation to Hawai'i Space Grant Consortium? Your support would be greatly appreciated. Secure online donations may be made through the University of Hawai'i Foundation website.

Scan the QR Code for the Donation Page

Mahalo for your support!

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Hawai‘i Space Grant Consortium

Chartered under the National Space Grant College and Fellowship Program in 1990, the Hawai‘i Space Grant Consortium develops and runs interdisciplinary education, research, and public service programs related to space science, earth science, remote sensing, human exploration and development of space, small satellites, and aerospace technology. We accomplish this through a variety of projects: Undergraduate research fellowships and traineeships, innovative college courses, workshops for educators, educational web sites, public exhibitions, lectures, tours, primary school programs, space-themed evening programs, and much more.

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