The Hawai‘i Institute of Geophysics and Planetology
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The Hawai‘i Institute of Geophysics and Planetology

The Hawai‘i Institute of Geophysics and Planetology solves fundamental problems in Earth and Planetary Science by the invention, development, and application of state-of-the-art instrumentation, exploration, measurement, and data analysis technologies and techniques.

Over the past five fiscal years (FY15-FY19, inclusive), HIGP PIs have won $47.3M in extramural funding (mainly from the DoD, NASA, DoE, and NSF), and published 330 peer-reviewed science papers. Our faculty are internationally regarded in their fields, and our students learn from scientists who are recognized as such, either through recognition by professional societies or their involvement in high profile earth and planetary science projects, including membership of 25 NASA instrument or mission science teams. Since 2014 our faculty have advised and supported 64 graduate students and have taught (or co-taught) 39 undergraduate and graduate level classes on the Mānoa campus. As an Organized Research Unit (ORU), our educational mission is to bring our research into the university lecture theaters, and school classrooms, of Hawai‘i, so they too can experience the thrill of discovery. Our community outreach has reached over 20,000 school children, teachers, and parents in the last year alone. Our research is world-class, well funded, laser-focused on STEM disciplines, and is highly relevant to the issues facing the State of Hawai‘i, both now and in the future. On the following pages we will describe the research we and our students do, the new areas of scientific and technological endeavor we have identified as major opportunities for growth in the next five years, as well as how our future plans will benefit the student experience at the wider Mānoa campus level.

HIGP’s research can be divided into four main foci, with three further concentrations at the interfaces.
Our Extraterrestrial Materials and Planetary Science research group is an extremely diverse team of researchers, who use laboratory-based analyses of cosmic dust and meteorites, as well as data acquired by satellites orbiting around, and roving on the surface of, other planets, to unravel the mysteries surrounding the origin and evolution of our solar system.

HIGP is world-renowned for excellence in the study of Extraterrestrial Materials. We study the chemical, isotopic, and structural properties of meteorites, lunar samples, interplanetary dust particles, and samples returned by various space missions including most recently NASA’s Stardust (comet dust) and Genesis (solar wind) spacecraft and the Japanese Hayabusa (asteroid) mission. This work is conducted in state-of-the-art facilities. The W. M. Keck Cosmochemistry Laboratory is built around a Cameca ims 1280 ion microprobe, which measures isotopic and trace-element abundances in natural and man-made materials. The Advanced Electron Microscopy Center features a Titan aberration-corrected scanning transmission electron microscope (STEM) and a Helios NanoLab 660 dualbeam focused ion beam instrument (FIB). Collectively, about $20M of instrumentation supports extraterrestrial materials research. These laboratories are training grounds for students and attract scientists from throughout the University, the nation, and the world. The discoveries we make allow us to glimpse into the very birth of our solar system.

The Planetary Science group uses remote sensing (from spacecraft orbiting our planetary neighbors as well as roving on their surfaces), laboratory experiments, mathematical modeling, and traditional field geology, to understand the processes that occur on planetary surfaces and in their interiors. Planetary Science faculty have a long history of participation in planetary exploration missions (current faculty are members of the science teams for the upcoming Mars 2020 rover mission, and the OSIRIS-Rex sample return mission, which recently arrived at asteroid Bennu), as well as conducting fundamental science pertaining to the evolution, composition, and workings of the planets and moons of our solar system. Current projects include the search for water and volatiles on the Moon and asteroids, how space weathering alters the surfaces of planetary bodies and confounds our attempts to decipher their chemical composition, how studying Hawaiian volcanoes can tell us about the origins of Martian volcanoes, and how biological material might be transported to the surface of Saturn’s moon, Titan, from the ocean beneath, such that we might detect it and answer the question: are we alone?
HIGP’s ability to maintain its position as a leader in *Extraterrestrial Materials and Planetary Science*, and increase its extramural funding base, will be strongly enhanced by targeting faculty recruitments in the following areas during the next five years:

**Returning to the Moon – Lunar Resources and Human Exploration**

US Space Policy Directive One (SD-1) provides for a US-led program, with international and commercial partners, for a human return to the Moon, and eventually to Mars. This drives a need for understanding resources available on the Moon to support prolonged human exploration. Recasting the traditional roles of HIGP planetary geologists to include planetary resources as a focus will align HIGP with NASA’s Moon focus, and with commercial entities such as Blue Origin or SpaceX for landing site selection and analysis. Adding lunar and/or martian sample expertise will keep HIGP competitive for future NASA funding in these growing areas, complement our current expertise in analysis of comets, asteroids, interplanetary dust particles, and meteorites, and maximise UH’s return on its investment in the state-of-the-art laboratories that HIGP hosts.

**Icy Worlds and the Search for Life**

A core theme of the 2013–2022 Planetary Science Decadal Survey is the search for signs of life. Europa is now known to be an active ocean world, Titan has a global ocean beneath its icy crust (and an atmosphere that rains organic compounds), and Enceladus’ rocky interior heats the subsurface ocean above it. As the ingredients for life come together they produce biosignatures detectable by remote sensing instruments. Planned NASA missions to explore these icy and water worlds drive a need to recruit an ice worlds planetary scientist with astrobiological interests, in order to keep HIGP competitive for NASA mission science funding opportunities. Russia plans to return a cryogenic sample from the lunar South Pole in 2025, and returning samples from comets and the water-rich plumes of Europa and Enceladus is under active discussion. We will extend our expertise to the analysis of extraterrestrial organics and ices, with a new emphasis on samples from unique micro-environments such as comets or plumes from icy satellites.

**Exploration of the Solar System using Small Satellites**

A key new NASA objective is to have a small secondary spacecraft accompany each primary spacecraft in future planetary missions. There will be an increasing number of NASA SIMPLEx opportunities for small (<150 kg) missions to Mars, the Moon, and Venus to which HIGP needs to propose, in collaboration with the Hawai‘i Space Flight Laboratory, and the College of Engineering. Increased opportunities to propose for instrument and payload development funding will accompany the mission proposals themselves. New faculty who cross the traditional boundaries of field studies, instrument design, and mission operations are vital to take advantage of funding opportunities at the intersection of these disciplines.
Our Mineral Physics and Extreme Materials group discovers how materials behave (i.e., how the atoms and molecules present react and reconfigure their positions relative to one another) when subjected to extreme pressure and temperature. This allows us to predict the composition of the interiors of the Earth, other planets in our solar system, as well as planets in other solar systems.

Pressure and temperature control the structure and properties of both natural and man-made materials, and this offers the opportunity to discover, synthesize, and characterize new high-performance technological materials for many applications including energy storage, so-called “super-hard” materials, abrasives, and semi-conductors.

HIGP has a wide range of facilities for both research and graduate and undergraduate education and training in the fields of Mineral Physics and Extreme Materials. The Multi-Anvil Press Laboratory (MAPLab) has been commissioned to become a research and teaching/training ex-situ large volume press facility for high-pressure sample syntheses and experimental petrology research. The X-Ray Atlas Diffraction Laboratory is engaged in cutting-edge crystallographic research focused on characterization of the discontinuous structural transformations that silicates undergo as a function of depth, and has been leading the field in the development of innovative solutions in hardware, measurement methodology and data analysis software for high-pressure research. The X-Ray Atlas lab also features spectroscopic and laser-heating instrumentation for high-pressure and high-temperature research. The Laser Spectroscopy Lab allows us to measure how crystal lattices vibrate by Raman spectroscopy, Brillouin Scattering, and Fourier transform infrared (FTIR) spectroscopy, as well as high-temperature sample syntheses and measurements by laser heating. The group also manages and operates a state-of-the-art synchrotron user facility located at Argonne National Laboratory in Illinois. All are used by our graduate and undergraduate students.

With our research base in Earth and planetary science-focused mineral physics already very well established, the group is currently in the process of actively expanding the research agenda and building new collaborations in the areas of smart molecular materials, gas storage and sorption, and super-hard materials.
Because of its intrinsically interdisciplinary nature, great diversity exists in the experimental and computational techniques involved in extreme conditions research. To further strengthen our ability to compete and excel in this arena, we have identified two areas in which future recruitment should be focused:

**Spectroscopy at Extreme Conditions**

One of the most exciting areas of recent growth and development in experimental high pressure science involves state-of-the-art laser spectroscopic experiments at elevated pressure and temperature conditions. These laser heating experiments enable inducing and controlling micro-scale chemical reactions and physical transformations. Using this method, complex chemical gradients that are considered to be present in Earth’s interior can be recreated and studied, and the conditions of meteorite impacts simulated. These applications tie directly to the goals of major funding agency programs, such as NSF, NASA and DOE, as well as to State agency initiatives related to energy efficiency. Extreme condition spectroscopy has been a hallmark of HIGP high pressure research for several decades, and an extensive instrumentation is available on campus. We are looking for a faculty lead with advanced spectroscopy expertise, so we can implement some of the newest and important ideas (e.g. advanced heating laser pulse control) in our labs.

**Computational Mineral and Materials Physics**

Experimental approaches in high pressure science are always limited to some extent in their ability to probe the sample state and behavior by the sample size, geometry, and constraints of the in-situ probes. Computational methods of quantum mechanics such as Density Functional Theory and Molecular Dynamics are an ideal complement to experiments, which can utilize any partial information retrieved from experiments to guide simulations that reveal a more complete picture of the studied phenomena. Computer simulations of material properties can also significantly reduce the cost of new materials synthesis at extreme conditions. All major funding agencies currently prioritize data-driven science as one of the main funding areas. With the existing on-campus supercomputing infrastructure, a computational mineral and materials physicist could immediately add another dimension to any collaborative materials-focused proposal, and could explore new technologically and economically relevant areas of extreme materials research which do not lend themselves easily to experiments.
The Space Technology and Sensor Development group develops and proves innovative technical solutions to measurement problems in Earth and planetary science, emphasizing observations of space, from space, and in space.

Comprising the Hawai‘i Space Flight Laboratory (p. 11), the Spectral Technology Group, and the Infrared and Raman Spectroscopy Laboratory, we combine development of small satellite platforms with compact spectroscopic technology to enable a new generation of space-based science, concerned with how we can determine the chemical composition of solids, gases, and liquids without touching them.

Recent projects have included Hiakasat, a 50 kg satellite hosting a UH-patented infrared hyperspectral technology (SUCHI, the Space Ultra-Compact Hyperspectral Interferometer), the Thermal InfraRed Compact Imaging Spectrometer (TIRCIS) funded by the NASA Earth Science Technology Office (ESTO), the Miniature Infrared Detector for Atmospheric Species (MIDAS), funded by NASA EPSCoR, and NEUTRON-1, an on-orbit test of a neutron spectrometer to be sent to the Moon on a CubeSat. Our current flagship project is HyTI, a nanosatellite (<10 kg) project funded by NASA’s ESTO In-Space Validation of Earth Science Technologies (InVEST) program, featuring a high performance successor to SUCHI that will obtain thermal infrared hyperspectral images of the Earth’s surface from a satellite the size of a shoebox.

HIGP is a world leader in the remote detection of life using active laser-based technologies and Raman spectroscopy. HIGP has developed a novel biological sensing fluorescence imaging instrument which can rapidly locate minute amounts of biological material among rocks and minerals from a distance. This instrument detects residues of biological materials including polycyclic aromatic hydrocarbons, amino acids and bio-minerals, and will be a game changing technology for future NASA missions dedicated to searching for life in the solar system.

Straddling the boundary between science and engineering, the group brings technology-minded science faculty and science-minded engineering faculty together to explore the Earth and planets using cutting-edge technology and measurement concepts, and to train a generation of students comfortable in both worlds. This technology-science synergy is highly successful at national laboratories, such as the Jet Propulsion Laboratory, but rare at universities.
HIGP will maintain its position as a leader in *Space Technology and Sensor Development* by making faculty hires in the following areas, to expand the breadth of our science and technological capabilities and increase our future success in bidding for high profile space mission projects.

**SmallSat and CubeSat Mission Development for Earth and Planetary Sciences**

NASA has, in response to the recommendations of the National Academy of Sciences, initiated many programs over the last decade to fund the development of small satellite missions for Earth and Planetary exploration. In the planetary realm, SIMPLEx provides $50M for small satellite planetary exploration, while the Small Satellite Technology program funds in-flight testing of innovative technology, focussing on the smallest satellites. In the terrestrial realm, NASA’s Earth Science Division provides opportunities, via its Earth Ventures and InVEST initiatives, to propose space missions in the $6M to $150M range, on an annual basis. HIGP’s success with HyTI ($5.6M) is an indication of what is possible by marrying HIGP’s science and technology expertise with HSFL’s engineering expertise.

**Autonomous Operation of Spacecraft Swarms and Planetary Rovers**

The next frontier for planetary small satellite missions is surface landing and sample return. Expertise in the robotic devices that enable autonomous selection, ingestion, and processing of samples by instruments on SmallSats and rovers will be needed to take advantage of these opportunities. The volume of scientific data these instruments acquire continues to balloon, necessitating autonomous on-board processing to allow missions to perform more science with limited transmission bandwidth. The NAS has encouraged NASA to fully explore alternative space mission architectures, including swarms of small satellites, to complement the traditional large-satellite paradigm over the next decade. Satellite constellations and swarms will require a large degree of autonomy.

**Miniaturization of Sensors for Deployment in Space**

Designing scientific measuring instruments is not necessarily difficult. Making instruments that can make those measurements on a spacecraft, where size, weight, and power are an issue, is. NASA has expanded its opportunities for miniaturizing existing (and developing new) measurement approaches for exploring the Earth and planets. Technology development for planetary science at the level of $0.5-1.5M per year is supported by the PICASSO, DALI, LSITP and MATISSE programs. NASA’s Earth Science Division regularly competes IIP, ACT, and AITT ($0.75-$2M per year) for instrument prototyping. HIGP has a long history of instrument development for both terrestrial and planetary remote sensing instrumentation, leaving us well placed to take advantage of these opportunities.
The Resources and Hazards in Hawai‘i group brings together several faculty members and their students to perform cutting-edge scientific and technological research and development, focused on the critical issues of i) the availability and sustainability of natural resources in Hawai‘i, and ii) the nature, magnitude, and mitigation of natural hazards in Hawai‘i, including tsunamis, earthquakes, landslides, sea-level rise, coastal stability, volcanic eruptions, and flooding.

HIGP is mandated to provide information relevant to the State of Hawai‘i regarding geophysical phenomena. Members of this group form a well-integrated, multi-disciplinary, strongly collaborative group, committed to study, tackle, and solve issues of short and long-term societal relevance, issues that represent challenges and threats to the State of Hawai‘i, and other Pacific Island communities. Notable recent projects include i) developing a method for using GPS receivers on commercial ships to provide early warning of the magnitude of tsunami's in the Pacific basin, ii) using earthquakes to understand the way in which the summit of Kīlauea volcano rose and fell during the recent 2018 eruption, iii) drilling test wells in the Hawai‘i Island ‘Saddle’ region between Mauna Loa and Mauna Kea volcanoes which revealed groundwater at a much shallower depth than expected, and a potential geothermal reservoir, and iv) continuous operation of infrasound arrays on the Big Island as part of the International Monitoring System for the Comprehensive Nuclear Test Ban Treaty. HIGP faculty also play a key role in the NSF “Ike Wai” project, which aims to quantify the nature of groundwater resources in the State.

The group uses four main tools. Geophysics non-destructively images the rocks and water beneath Earth’s surface using advanced instrumentation, data processing, and Machine Learning algorithms. Groundwater chemistry allows us to trace the origin and flow path of groundwater, and to identify anomalies that take place when geothermally heated groundwater reacts with rocks. Geodesy uses GPS to measure how Kilauea and Mauna Loa shrink and swell as magma moves in the subsurface. HIGP’s State-wide GPS network provides a high-accuracy reference frame within which others in Hawai‘i can work out exactly where they are. This will increase in importance as autonomous navigation impacts the lives of Hawaii’s residents. In addition to monitoring the globe for nuclear explosions, HIGP’s Infrasound capability uses low-frequency sounds in the atmosphere to study a wide-variety of natural phenomena that impact the State, such as volcanic eruptions, hurricanes, tsunamis, and high surf.
The next five years

As the Resources and Hazards in Hawai‘i group’s research foci are closely aligned with both short- and long-term societal needs at the State and national levels, there are many opportunities for new scientific discovery and concomitant extramural funding. Over the next five years these opportunities would be facilitated by faculty recruitment in the following areas:

**Hydrogeologist**
A hydrogeologist will allow us to conduct the full range of research required to obtain a complete understanding of complex and dynamic groundwater systems, geothermal resources, and other subsurface fluid flow processes. Combined with existing hydrologic modeling expertise in SOEST’s Department of Earth Sciences and UH Mānoa’s Water Resources Research Center, this will enable us to be fully self-sustaining, making us the go-to entity for the State and the whole Pacific Region for any subsurface fluid flow projects. Both Federal and State agencies are funding research into the effect of global climate change on groundwater recharge and resources, and the impact climate change has on those resources.

**Satellite Geodesy**
Interferometric Synthetic Aperture Radar is a pillar of modern geodesy. It provides data that can be applied to geologic hazard monitoring and research, ground water flow, coastal stability assessment, and disaster response. NASA will soon launch the NISAR satellite, which, along with the ESA Sentinel-1 mission, will make available a huge amount of no-cost radar data. NASA will be supporting projects that utilize these data to generate societally relevant products, while NSF is increasingly funding sustainability and resilience projects for which InSAR provides crucial information. An InSAR scientist will complement existing geodetic, geophysical, and environmental observational and modeling expertise in HIGP and the Department of Earth Sciences. In particular, it will leverage the HIGP-run GPS spatial reference network in the State of Hawai‘i. An InSAR scientist will position us to be able to provide the State, and the Pacific region, with, for example, detailed assessments of coastal stability and the local impact of sea-level rise, and continuous monitoring of landslide motions, volcano activity, and ground water storage and migration.
HIGP’s Aerospace effort facilitates the exploration of the Earth and planets by designing, building, testing, launching, and operating small satellites from the Hawaiian Islands, and by augmenting orbital observations with higher temporal and spatial analysis using unmanned aerial systems.

The centerpiece of HIGP’s Aerospace effort is the Hawai‘i Space Flight Laboratory (HSFL) – a collaboration between SOEST and UH Mānoa’s College of Engineering. HSFL provides vertically integrated small space mission solutions and acts as a catalyst for a Hawai‘i aerospace industry by providing local facilities to launch, design, fabricate, test, and communicate with satellites. Communication facilities.

Small Satellites: HSFL has state-of-the-art clean-rooms for satellite integration, a thermal-vacuum chamber, vibration table, and attitude determination and control test-bed. In addition to the SUCHI, Neutron-1, and HyTI missions (p. 7), HSFL is currently working with Space and Naval Warfare Systems Command on a small satellite mission to calibrate DoD radars.

Launch: HSFL facilitates launch in the “geo-advantageous” State of Hawai‘i to promote a new local aerospace economy. On November 3, 2015, HSFL participated in the Operationally Responsive Space-4 Mission from the Pacific Missile Range Facility on Kaua‘i, assisting rocket development via a strategic agreement with Aerojet-Rocketdyne, and building and operating the world’s largest rail launcher. HSFL is now assisting US commercial companies with the next launch from Kaua‘i, due in 2020.

Unmanned Aerial Systems: HSFL is working with Japanese companies HAPSMobile and Softbank to create a temporary UAS test range on Lāna‘i. HSFL will manage the development and operation of the range, supporting very-high altitude and long duration UAS flights. Well above commercial air routes, such UAS could be very beneficial for long duration, large area monitoring of local hazards such as volcanic eruptions and forest fires.

Mission Operations: HSFL maintains UHF/VHF, S-band and X-band ground stations. HSFL has also developed mission operations software system called COSMOS. Including flight software for satellites, COSMOS is designed to run autonomously and handle the command/control and data downlinks from multiple small satellites.

Workforce Development: In the last 5 years, HSFL faculty and engineers have provided interdisciplinary experiential learning opportunities for approximately 300 students of which 55% are underrepresented and about 30% are women. HSFL will train an increasing number of students in the future since ME296 Design Class and ME496 Senior Design Class have sections that focus on HSFL issues. The proposed HIGP Earth and Planetary Exploration Technology certificate (p. 16) will also feature a Spacecraft Mission Design course and a senior level interdisciplinary Small Mission Development course.
Materials Science

Materials Science encompasses the study of material properties and processing, and is highly interdisciplinary in nature. HIGP’s advanced instrumentation is a powerful enabler of a wide range of materials science research and education across the University.

HIGP is positioned to be the primary resource for materials expertise on campus. SOEST faculty, with HIGP’s Hope Ishii as Deputy Lead, recently received an internal grant from the Office of the Vice Chancellor for Research to develop the UH Materials Science COnsortium for Research and Education (UH Materials Science CoRE) to identify and expand collaboration and sharing of materials science resources across UHM unit and school boundaries, and to jump-start materials science research on campus. Both graduate and undergraduate students are integrated in this effort. HIGP hosts state-of-the-art instruments for Materials Science research and education. These include a dual aberration-corrected and monochromated (Scanning) Transmission Electron Microscope (TEM/STEM; one of about 10 worldwide), a dual beam Focused Ion Beam instrument (FIB), an IMS 1280 ion microprobe with ion imaging capability (all unique to Hawai‘i), a high resolution scanning electron microscope (SEM), high pressure materials synthesis facilities, powder and single crystal x-ray diffraction (XRD) instruments, and Brillouin, Raman and infrared spectrometers. Faculty have regular access to national synchrotron x-ray facilities. Instrumentation is complemented by powerful analytical, visualization and modeling software, and a computational laboratory.

These instruments are a resource for UH-wide research, including characterization of natural and synthetic materials to answer questions in the fields of geology and mineralogy of extraterrestrial (and terrestrial) rocks, solar energy and energy storage, water filtration, catalysis, graphene based materials, and nanoparticles for drug delivery and biophysical manipulation. These instruments are also the basis for an exciting new undergraduate materials science course in the College of Engineering, cross-listed with Chemistry, being developed and led by HIGP faculty, and are central to the new Earth and Planetary Exploration Technology (EPET) certificate curriculum developed by HIGP. Advanced materials are critical to meeting key needs for Hawaii’s economic development identified in the Hawai‘i Statewide Science and Technology Plan, the HI2 Innovation Initiative, the Hawai‘i Economic Development Strategy and the Hawai‘i Clean Energy Initiative.
HIGP has long been involved in inventing technology with which to monitor our environment, a natural evolution from our origins as both a planetary science research group (initially focused on telescopic observations made from the Earth) and a geophysical observatory charged with providing the State of Hawai‘i with expertise regarding local geological phenomena.

Hawaii's environment is, after its people, its greatest asset. Preserving and managing that environment will increasingly rely on the development of new sensors with which to monitor the world around us, as well as methods for analyzing those data and making them available to decision makers. HIGP faculty members have developed, patented, and installed (for the USGS Hawaiian Volcano Observatory) a system for measuring the sulfur dioxide emitted by Kīlauea volcano, the basis for assessing health hazards associated with vog. We have developed technology for using cellular telephones to crowd-source measurements of air-pressure variations (http://www.redvoxsound.com/), and using these measurements to monitor, for example, high surf, hurricanes, and volcanic eruptions. We have developed automated systems that use NASA satellites moving at 7 km per second, 800 km above our heads, to monitor volcanic eruptions anywhere on Earth, providing data within minutes of satellite overpass (http://modis.higp.hawaii.edu). We have developed extensive archives of information relating to geothermal exploration and development in the State of Hawai‘i (including historical photographs, maps, videos; https://www.higp.hawaii.edu/hggrc/). We have invented active fluorescence imaging systems for detecting plastics in the ocean.

Understanding Hawaii's changing natural environment over the coming years will rely upon accurate measurements of our air, water, and land. HIGP is well placed to invent, build, and deploy the cutting-edge measurement technologies the State will need to do this.
HIGP in the local community

In addition to traditional campus-based instructional activities, HIGP brings its STEM-focused research into the schools of Hawai‘i

The NASA Hawai‘i Space Grant Consortium (HSGC) is part of HIGP, led by HIGP Specialist Luke Flynn. Chartered under the National Space Grant College and Fellowship Program, the Hawai‘i Space Grant Consortium (HSGC) is a vibrant space-themed educational program, with affiliates on seven other campuses within the UH system (Windward CC, Kapi‘olani CC, Honolulu CC, Leeward CC, UH Hilo, Hawai‘i CC, Maui College) as well as the University of Guam. HSGC provides K-12 educational programs, two different types of undergraduate financial support, as well as an apprenticeship program for graduate students. In the last reporting year (2017) HSGC provided 70 undergraduate fellowships to conduct research with faculty advisors on NASA-related topics (53% to underrepresented minorities; 30% to women). Through its sponsored activities at the state level, HSGC reached 20,298 pre-college students, primarily through the work of Art and Rene Kimura (HIGP staff members) and their “Future Flight Hawai‘i” program. HSGC engaged 1447 teachers, mostly as part of Families Exploring Science Together (FESTival) nights or the 250 VEX-IQ Robotics teams that HSGC coordinates.

HIGP is also home to HawaiiView, a K-12 education project funded by the USGS. HawaiiView uses ‘Landsat in a box’, lesson plans to introduce students, teachers, and parents to the science of remote sensing, Landsat 8, and the wider program of ‘Sustainable Land Imaging’. Students learn about light, spectroscopy, precision, accuracy and the scientific method. Since 2016, HawaiiView has conducted 19 school visits and eight community events, impacting 1302 students, 46 teachers, and 61 parents. Most of these workshops were presented at public schools with a high number of minority and underrepresented students, as well as a high number of students in the free/reduced lunch program.
Exposing students to our cutting-edge research and technology, and having them take part in that research and use that technology, is important to us.

In the past five academic years HIGP faculty have advised a total of 64 graduate students, and taught (or co-taught, often in collaboration with colleagues in the Department of Earth Sciences) 39 undergraduate or graduate level classes. Our graduate students are paid from our federal grants and are absolutely integral to the success of those projects - they do not work for the faculty, instead, they work with the faculty.

The funded projects we lead, are ideal environments in which to integrate R1 research into the undergraduate experience. In 2007 HIGP, SOEST, and UH Mānoa’s College of Engineering created the Hawai‘i Space Flight Laboratory (HSFL) to design, build, test, launch, and operate small satellites from the Hawaiian Islands. In 2015 HSFL launched HiakaSat-1, onboard the ORS-4 (Operationally Responsive Space) mission from the Pacific Missile Range Facility on the island of Kaua‘i. HIGP and CoE faculty, staff and students worked alongside each other to design, build, and test HiakaSat and its payload SUCHI. This eight year project provided interdisciplinary experiential learning opportunities for approximately 300 undergraduate students, of which 55% were underrepresented and about 30% were women. Several of the UHM undergraduates who worked on HiakaSat are now employed within HSFL as staff engineers.

“I am very fortunate to be a part of the SOEST community because I have been showered with a wide variety of opportunities since I transferred to University of Hawai‘i at Mānoa. As an undergraduate student now in her last year in pursuing a B.S. in Geology and Geophysics, all the experiences I have gained all started from visiting the 5th floor of the Pacific Ocean Science and Technology building, when I first met my mentor, Hope Ishii. Having never been exposed to the world of materials science, she took me on a tour inside her lab that is home to state-of-the-art instruments of advanced electron microscopy. She showed me the work she does on cosmic dust, and since then, I was hooked.”

Undergraduate student Lean Teodora operates the Helios NanoLab 660 dual-beam Focused Ion Beam.
In the next five years HIGP seeks to impact more undergraduate students, both in SOEST and the Mānoa campus as a whole, by initiating (and participating in) new undergraduate learning initiatives.

**Earth and Planetary Exploration Technology (EPET):**
a new undergraduate certificate in space mission design

The objectives of the program are to provide a coherent body of classes through which students majoring in the physical sciences and engineering disciplines can obtain a formal qualification in the science and technology that underpins the human exploration of the Earth and Solar System via orbiting spacecraft, planetary landers and planetary rovers. The program is designed to link the “why” of planetary exploration (what scientific questions do we wish to answer about the Earth and planets) with the “how” (how do we design instruments, spacecraft, and missions that can collect the necessary data). The certificate includes a capstone design project where students will work together, with HIGP faculty and staff, to design a space mission. All four courses have been approved, and delivery will begin in Spring 2020.

**Increasing our contributions to campus-wide undergraduate curricula**

Much of HIGP’s undergraduate classroom instruction has historically been through the Department of Earth Sciences (formerly Geology and Geophysics). However, much of our research is more closely aligned with other schools on campus, mainly engineering and the physical sciences. We will seek opportunities to cross-list current and new courses such that undergraduates outside of SOEST have opportunities to learn how their chosen major can translate into a career in Space, Earth, and Planetary Sciences. For example, GG460 “Geological Remote Sensing” (currently co-taught by HIGP’s Robert Wright) has been listed as an elective on CoE’s new BS in Engineering Science (as part of the Aerospace Engineering track). HIGP faculty Hope Ishii and Przemek Dera will be part of the teaching team for ME 435 “Experimental Methods in Materials Research”, in collaboration with faculty from Mechanical Engineering, the Hawai‘i Natural Energy Institute, and the Department of Chemistry.
Captions and Credits

Cover: Launch of HiakaSat, Operationally Responsive Space ORS-4 mission, from Pacific Missile Range Facility, Kaua’i, 2015.

Page 3: (top) STEM image of a cometary dust particle, showing the concentration of carbon, magnesium, silicon, sulfur and iron; (bottom) HIGP making its presence felt at the annual Lunar and Planetary Science Conference in Houston, Texas, (left to right - Current HIGP Post-doc Shuai Li; Former HIGP graduate student Sarah Crites (now at Japanese Space Agency); current HIGP graduate students Emily Costello and Casey Honniball; HIGP faculty member Paul Lucey; former HIGP Post-doc Heather Kaluna (now Assistant Professor of Physics at UH Hilo); former HIGP grad student, and presently HIGP faculty, member Kawika Trang).

Page 4: (top) Neil Armstrong on the Moon; (middle) geysers on Enceladus (a moon of Saturn) observed by NASA’s Cassini spacecraft; (bottom) artist’s impression of the MarCO CubeSats that accompanied the recent landing of NASA’s Insight mission on Mars (source: NASA).

Page 5: (top) HIGP graduate student Tommy Yong, and the recently graduated Dr Hannah Shelton, in HIGP’s X-Ray Atlas laboratory; (bottom) one of HIGP’s Diamond Anvil cells, used to simulate the pressures and temperatures of Earth's core-mantle boundary.


Page 7: (top) HSFL engineers work on HiakaSat-1; (bottom) CAD models of HIGP’s HyTI spacecraft and instrument.

Page 8: (top) CAD model of HSFL’s Neutron-1 spacecraft; (middle) HIGP’s NASA-funded TIRCIS instrument; (bottom) artist’s impression of the Mars 2020 rover on the surface of the Red Planet (source: NASA).

Page 9: (top) Simulation of tsunami run-up height in Waikiki resulting from an hypothetical Mw 9.25 mega-quake in the Aleutian Islands, a study led by HIGP faculty member Rhett Butler (Butler, R., et al., Nat. Hazards (2017) https://doi.org/10.1007/s11069-016-2650-0); (bottom) drilling for groundwater resources on the Big Island with HIGP faculty members Nicole Lautze and Don Thomas (bottom row, third from left and far right, respectively).

Page 10: (top) Image of the electrical resistivity of subsurface rocks beaneath the south-western flank of Hualālai. The light blue region is rocks saturated with fresh water, the dark blue is dry rocks, and the red either saltwater saturated and/or chemically altered rock; (bottom) interferogram showing ground deformation at Kīlauea and Mauna Loa volcanoes, along with location of HIGP’s permanent GPS monitoring network.

Page 11: (top) HiakaSat integrated atop the Super Strypi launch vehicle before launch; (bottom) undergraduates in the HSFL clean-room

Page 12: (top) HIGP faculty member John Bradley with the FEI Titan3 G2 60-300 dual aberration-corrected TEM/STEM; (bottom) conductive and mechanically supportive platinum strap and platform fabricated to support a particle of comet dust from NASA’s Stardust mission for further analysis, constructed using the Helios NanoLab FIB.

Page 13: (left) HIGP graduate student Macey Sandford testing a HIGP-built fluorescence sensor for finding plastics in the ocean; (right) HIGP graduate student Casey Honniball using the HIGP-built MIDAS sensor to measure volcanic gases at Kīlauea volcano.

Page 14: (top) NASA HSGC event at which students and parents use wind tubes to learn about Bernoulli’s principle and how aeroplanes fly; (bottom) Students learning about studying the Earth from space using the HawaiiView “Landsat in a box” science kits.

Page 15: (top) Department of Earth Sciences undergraduate student Lean Teodora analyzing comet samples on the Helios NanoLab 660 FIB; (bottom) some of the many faculty, staff, and students who comprised the HSFL/CoE HiakaSat team.

Page 16: (top) HSFL engineer Amber Imai-Hong wiring the SUCHI instrument stack prior to spacecraft integration; (bottom) On the left, Department of Earth Sciences undergraduate Amber Mokulele simulating the effects of space weathering on asteroid surfaces; on the right, Department of Earth Sciences undergraduates in the field with HIGP faculty member Robert Wright (second left).

Page 18: The Pacific Ocean Science and Technology building (right) and Hawai’i Institute of Geophysics building (left).

Further Information

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