



ANNUAL REPORT 2016

PISCES
Pacific International
Space Center for
Exploration Systems





The two top photographs on the cover page and this rocket blast picture are courtesy of 'Ena Media Hawai'i.

SINCE ITS INCEPTION, PISCES HAS BEEN STRIVING TO UNDERTAKE AND PROMOTE SPACE EXPLORATION ACTIVITIES THAT CONTRIBUTE TO THE DEVELOPMENT OF A LONG-TERM AND SUSTAINABLE AEROSPACE INDUSTRY IN HAWAI'I. OUR GOALS ARE TO EXPAND HAWAI'I'S ECONOMIC BASE AND BROADEN THE DIVERSITY OF OPPORTUNITIES AVAILABLE FOR FUTURE GENERATIONS. TO THIS END, PISCES HAS BUILT A PROGRAM BASED ON THREE PILLARS:

- APPLIED RESEARCH & TECHNOLOGY**
- WORKFORCE DEVELOPMENT**
- ECONOMIC DEVELOPMENT**

THE FOLLOWING PAGES DESCRIBE PISCES' FISCAL 2016 ACCOMPLISHMENTS IN THESE AREAS.



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Above photographs courtesy of 'Ena Media Hawai'i

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LETTER FROM PISCES

BOARD CHAIR HENK ROGERS



Dear PISCES supporters, as a State organization, and having received limited funding from the State since our inception, one might think PISCES would not have been able to accomplish anything noteworthy. Quite to the contrary, we've achieved some phenomenal milestones. Going forward, we should focus on both the low-hanging fruit and the long-term infrastructure opportunities that make Hawai'i a perfect place to both promote and enable the exploration of space.

One notable benchmark has been our sintered regolith testing. Regolith is a building material composed of substrate found on the Moon, Mars, and our own unique volcanoes here in Hawai'i. We have worked with NASA to build a rocket launch and landing pad using regolith. Regolith building blocks may well be the basis for future structures on the Moon and Mars. The significant additional potential here is that we could manufacture regolith building materials on Earth. As renewable energy prices plummet, so will the cost of sintering.

HI-SEAS

The shining star of space exploration in Hawai'i has been the Mars Habitat, the Hawai'i Space Exploration Analog & Simulation (HI-SEAS) on Mauna Loa. This August, the fourth crew will emerge after having spent a full year in a simulated Mars environment. This project has been fully funded by NASA, and it now appears that they've secured another three years of funding to continue Manned Moon and Mars Mission testing. We believe many Manned Exploration tests will be undertaken in the near future as countries and companies compete to put human colonies on the

Moon and Mars, and that PISCES will be able to play a significant role in advancing these efforts.

Spaceport Hawai'i:

We have been in conversations with several space tourism as well as small satellite launch companies who have expressed strong interest in partnering with Hawai'i. New Mexico spent more than \$250 million dollars building a spaceport in their desert (far from residential communities to ensure public safety during launch). Hawai'i's advantage of course is that it is surrounded by ocean (our equivalent of their desert). Both Space Tourism and Small Satellite launches will be supported through the horizontal take-off and landing of "spaceplanes." Kona Airport has space for hangars as well as a long enough runway (11,000 feet) to support the horizontal take-off and landing of "spaceplanes" that will carry scientific and commercial payloads, as well as tourists, to space!

Moon & Mars Hawai'i:

Building on our HI-SEAS success on Mauna Loa, we should invite the international Moon and Mars missions being developed by space-faring nations worldwide to test and validate their technologies in Hawai'i. An area like Pohakuloa on the Big Island would be a perfect location to test and validate technologies for future Moon and Mars missions. Other areas in Hawai'i could also be used to support both manned and unmanned (robotic) missions. Hawai'i's youth have shown they can compete on an international level in robotics competitions. Let's enable them to explore challenging opportunities in Hawai'i after they leave school by providing an environment where they can build and test robots that will eventually go to the Moon and Mars. This could be their future!

Regolith Hawai'i:

Regolith is the basic building material found on the Moon and Mars. If one day we are going to build Moon and Mars bases, they will be made of regolith. Our Hawai'i volcanoes are also made of regolith, and any group that plans to build anything on the Moon or on Mars could be prototyping their technologies on Hawai'i volcanoes using PISCES robots. This research and development will also spin off building materials that we can use in Hawai'i. Let's use international money to develop building materials that we can produce locally and reduce our State's dependency on imported cement.

So, as the world prepares to switch to micro satellites, send tourists to space, send robotic missions to the Moon and Mars, and build places for humans to live on extraterrestrial bodies, let's prepare Hawai'i to take a significant piece of that business going forward.

This is going to be the best year ever for PISCES. We are ready. We are able. We have the will. I congratulate the people involved in PISCES and look forward to many exciting years to come.

LETTER FROM PISCES

EXECUTIVE DIRECTOR ROB KELSO



Fiscal Year (FY) 2016 (July 1, 2015 – June 30, 2016) was a year of accomplishment for the Pacific International Space Center for Exploration Systems. And as we enter another fiscal year, I'd like to reflect on where we started, where we've been, and where we're going.

In November 2012, I spoke for the first time as Executive Director to our new Board of Directors. During my inaugural speech, I laid out my vision for PISCES to become a recognized 'center-of-excellence' for applied research in space technology.

Three years later, PISCES has successfully accomplished that goal through its various programs and research in planetary robotics and in-situ resource utilization (ISRU) construction. PISCES has also built amazing partnerships since 2012, developing 18 strategic alliances with numerous industry, international, and academic groups to further our work in technology development testing for the Moon and Mars.

Our Hilo-based organization is well on its way to establishing itself in both the public and private sector, and continues to strive to meet the demands of our State legislature by focusing on economic development.

Creating high technology jobs and industries is an important strategic direction for Hawai'i and PISCES hopes to assist in this goal by creating new opportunities for future generations.

As we move forward into FY17, PISCES is expanding its focus on economic development opportunities to match our on-going efforts in applied research in planetary surface systems. By using our strong branding of accomplishment in complex engineering challenges, PISCES aims to attract new partners, create new positions and train more students during the next year.

"One lesson I have learned and strongly embraced through my many years in senior management is that 'people do business with people.'

That is certainly true in Hawai'i!"

-ROB KELSO

PISCES EXECUTIVE DIRECTOR

But we can't do it alone. That's why this past year PISCES has made it a top priority to further expand our close relationships with the business community of Hawai'i, with the Chamber of Commerce, universities, Hawai'i economic development organizations and potential emerging high-technology sectors within aerospace.

One lesson I have learned and strongly embraced through my many years in senior management is that "people do business with people." That is certainly true in Hawai'i! I have been blessed with so many wonderful business relationships across our State.

Thus, I extend sincere thanks to the many legislative supporters who have faithfully advocated for PISCES. I would also like to thank our board members, cultural advisors, academic advisors, NASA and our many friends in the Hawai'i business sector for their input, guidance, interest and partnership.

With much aloha and grateful thanks,

A handwritten signature in black ink that reads "Rob Kelso". The signature is written in a cursive, flowing style.

EXECUTIVE SUMMARY

KEY ACHIEVEMENTS

PISCES accomplished many goals during the past fiscal year, from training our local workforce to developing state-of-the-art technology for future space missions. Here's an overview of all that we made possible in Hawai'i:

During our third full year of operations, our team of scientists finished a very high profile engineering project in basalt construction using robotics. More than 15 publications throughout the U.S. followed the story about our project, including five local media outlets and multiple news sites around the U.S.

While focusing on the basalt construction project, PISCES simultaneously worked to leverage key strategic partnerships with federal government and private sector organizations to accomplish what many only dream about - performing actual applied science on-location in sites similar to the Moon and Mars. These innovative projects have put PISCES and Hawai'i on the map.

Another accomplishment during FY 2016 was our ability to operate on-budget and on-schedule despite certain challenges. Our organization implemented some necessary reductions in response to a decrease of supplemental funding from the State (about one-third of PISCES' minimum operating budget request was approved in the Governor's budget). In FY 2015, PISCES operated with a skilled staff of 6.25 full-time employees (FTE). By the end of FY 2016, the PISCES staff had been reduced to 3.9 FTE.

While the reduction in staff was challenging, PISCES continues to stay optimistic and focuses on evaluating different models for the organization for future operations that will help PISCES grow and attract new business. We are proud of our achievements thus far. Please continue reading to learn more about our successful endeavors this past year.

PLANETARY SURFACE SYSTEMS TECHNOLOGY DEVELOPMENT

PISCES made significant advancements during FY 2016 in the area of planetary surface systems research and development. We continued to make upgrades and refinements to our 726-pound Ontario Drive Gear (ODG) planetary rover from Canada. Software functionality and mechanical systems enhancements were made to enable the robotic construction of our basalt landing pad. These mechanical systems additions included a compression roller, maneuverable front blade for grading and levelling, and a remote manipulator arm for deployment of the basalt pavers.

Planetary Basalt Research:

PISCES worked on two major basalt concrete research projects this year, a lunar sidewalk and a lunar landing pad. Both projects were partially-funded with a grant from Hawai'i County Research and Development. PISCES continued monitoring the effectiveness of the various basalt paving materials used in the construction of the lunar sidewalk in downtown Hilo in FY 2015. Samples were analyzed after a year-long exposure and the results were promising. The analysis of the fly ash concrete made by a UH-Manoa group showed that it exceeded the compressive strength of commercial concrete. The second generation of basalt pavers made by PISCES exceeded the compressive strength of residential concrete. The other basalt experiment was our lunar landing pad project. During the past year, our researchers refined a production process for fabricating 1-foot by 1-foot basalt paver blocks that contain no binding agent by employing heat sintering in a high temperature kiln. This non-binder fabrication process is essential for future processes needed for the Moon and Mars. The pavers were later tested by NASA engineers who found them to have better flexural and compressive strength properties than residential concrete.

MoonRIDERS:

PISCES continued to lead a remarkable research project between NASA Kennedy Space Center (KSC) and two Hawai'i high schools in developing and testing critical dust removal technologies for surface systems on the Moon and Mars during a lunar surface experiment planned for late 2017. During this past fiscal year, the high schools fabricated support brackets for the dust shield and delivered them to KSC for testing and evaluation. Additionally, students from each of the two Hawai'i high schools travelled to NASA KSC in Florida to perform vacuum chamber testing of various lighting configurations for the lunar surface to optimize photo imagery of the dust shield performance.

FEDERAL/NASA PARTNERSHIPS

PISCES signed an agreement extension with NASA Kennedy Space Center for two Space Act Agreements (SAA). One SAA related to the MoonRIDERS lunar surface flight experiment. The other SAA supported collaborative work between NASA and PISCES for a new project in planetary construction called ACME (Advanced Construction using Mobile Equipment). This was a major project for PISCES completed at the request of NASA Headquarters in Washington D.C. PISCES also participated in another NASA project at NASA Ames Research Center called BASALT (Biological Analog Science Associated with Lava Terrains).

INTERNATIONAL STRATEGIC PARTNERS

PISCES continued to cultivate a rich relationship with two international groups:

JAPAN:

The executive director of PISCES travelled to Japan for a second time in two years to explore partnerships with Japan's space agency JAXA.

EXECUTIVE SUMMARY

KEY ACHIEVEMENTS

Additionally, Japan invited Mr. Kelso to be a guest lecturer in an international science conference on microgravity in Kyoto, Japan.

CANADA:

PISCES continued to work with ODG on the large planetary rover that serves as the basis for PISCES' robotic mobility projects. ODG has loaned the rover to PISCES.

HIGH BANDWIDTH COMMUNICATIONS

PISCES served as the source selection board and technical project manager for two engineering studies of a possible site on Mauna Loa for a future laser communications ground station. One study was a telecommunications (data) infrastructure assessment and the second was a geo-technical reconnaissance study of the area.

The studies were completed before the end of the fiscal year and the resulting reports are available through PISCES and the Office of Aerospace Development.

COMMUNITY ENGAGEMENT

PISCES performed 30 speaking engagements, classroom and club visits during FY 2016.

PISCES staff spoke with several Chambers of Commerce, Rotary Clubs, the Key Club, and other business groups throughout the year. Educational outreach events included guest lecture appearances at the 'Imiloa Mauna Kea Skies talks and briefings performed at the Mauna Kea Visitor Center. PISCES Executive Director Rob Kelso was also

invited to speak at the State Capitol, the Governor's Chamber and in Hilo in recognition of the 30th anniversary of the space shuttle Challenger tragedy, an event PISCES worked on for over a year with Kea'au High School, the Hawai'i Community College and the Hilo-based Civil Air Patrol Squadron. Students from each location worked together to restore a full-scale space shuttle flight deck that was donated to PISCES by the Pacific Aviation Museum. The finished flight deck was unveiled during the special ceremony honoring Ellison Onizuka.

The staff at PISCES also assisted with other educational outreach efforts including the judging of school robotic competitions and engineering contests, participation in Journey Through the Universe, an AstroDay presentation and more.

Another outreach highlight from the past year includes PISCES STARS program. The workshop inspires high school women to pursue careers in space. Attendance more than tripled from last year.

PISCES continued to produce a stellar monthly newsletter and activity report for the State. The newsletter received much acclaim for its coverage and writing from sites around the world.

WORKFORCE DEVELOPMENT

The backbone of PISCES' workforce development initiative is our summer internship program. This year PISCES pushed that vision even further with the hiring of its first long-term intern. The University of Hawai'i at Hilo student filled the position for 4-months rather than the normal 10-week intern program.

PISCES also offered positions for 10 university students during the summer of 2015. Six of the students focused on planetary robotics and four others located, analyzed and evaluated potential planetary test sites and the geology of those sites during the internship. Four interns joined the team during the summer. All were from the island of Hawai'i.

The job training PISCES offers its interns is unparalleled and substantially impacts their future career and academic ambitions.



High school participants in the FY 2016 STARS workshop are pictured here. During the workshop they visited PISCES' headquarters, met with our engineers and learned from some of the best scientists and astronomers in the State.

PISCES FY 2016

WORKFORCE DEVELOPMENT

HOW PISCES IS EXPANDING

For the past 3 years, PISCES has trained and educated more than 30 university interns in a variety of backgrounds ranging from geology to astronomy, from engineering to mathematics.

Students from universities as far away as New York and as close as the University of Hawai'i at Hilo have been fortunate enough to join our staff and receive hands-on experience that has significantly impacted their future. Some have gone on to attend prestigious universities such as The California Institute of Technology, Vanderbilt, UH-Manoa, and Cooper Union, while others ended up working with the likes of NASA and Honeybee Robotics.



PISCES 2015-2016 INTERNS:

*ERNESTO ESPARZA, UH-MANOA

*AKIL MARSHALL

*AARON ROTH, ASU

*ARA UHR, HILO HI

*NIKI THOMAS, UH-HILO

*ETHAN PAGUIRIGAN, UH-HILO

*TEDDY DEREGO, UH-HILO

*CASEY PEARRING, UH-HILO

KARLIN YEH, COOPER UNION

COLIN MILOVSOROFF, UH-HILO

VALERIE WASSER, UH-HILO

LARISSA BELCIC, HARVARD

ERIC BOUCHER, CANADA

LEFT: Ara Uhr, a high school student from Hilo is seen here at the PISCES headquarters on the first day of her internship. In FY 2016, Ara joined the team to help with the computer programming of PISCES' robotic rover.

* Indicates local students from the Big Island.

"I THINK MY EXPERIENCE WITH PISCES HAD A HUGE IMPACT ON MY FUTURE," SAID 18-YEAR-OLD CALEB BISHOP WHO WILL BE ATTENDING CALTECH IN THE FALL OF 2016. "I'M SURE SEEING THAT I WORKED WITH A NASA FACILITY ON UNPUBLISHED RESEARCH WAS VITAL IN THEM ACCEPTING ME."



KARLIN YEH

Currently attending Cooper Union in NYC
PISCES robotics summer intern 2015

"Karlin has been recommended by PISCES for the summer internship at Honeybee. Thanks to his combination of problem solving skills, hands-on approach as well as mechanical and controls background he quickly became an invaluable member of the Honeybee team and has been involved in several projects for NASA and Google. " - Kris Zacny; Director of Exploration Technology Group at Honeybee Robotics



MELISSA ADAMS

Former Sally Ride intern with NASA
PISCES geology intern 2013-2014

After graduating from the University of Hawai'i at Hilo in December 2014, NASA offered Adams an opportunity to return to Johnson Space Center to perform contract work for Jacob's Technology. Adams plans to earn a doctorate in geology specializing in volcanology and/or planetary geology. She says the ripple effect of these opportunities all started with being a PISCES intern.



VALERIE WASSER

University of Hawai'i at Hilo student
PISCES geology intern 2015

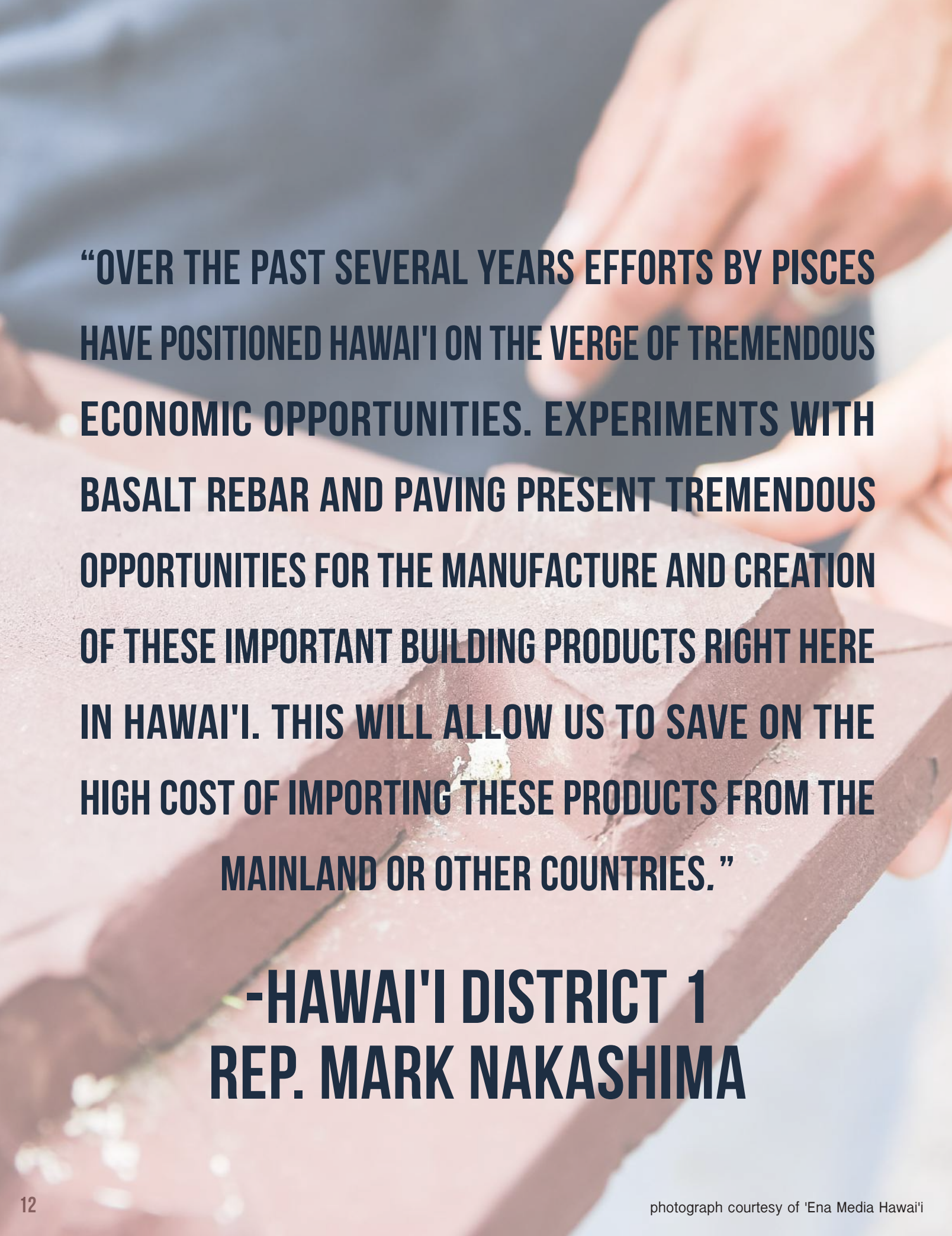
"My tasks as an intern included: finding potential analog sites; measuring and estimating the extensions of those sites; taking samples as well as chemically analyzing them; taking pictures of important features on the sites; and finally writing reports of those field trips. This summer internship was a very valuable experience for me. I got to see parts of the island I hadn't visited before, and at the same time I learned a lot about the geology of the Big Island and about potential Mars and Moon analog sites."



RICHARD KERR

Attending Vanderbilt University
Former PISCES technician intern

"My experience with PISCES was overwhelmingly positive. Coming into the project, I was definitely under-prepared for the technical challenges that would be posed by such a complex system. However, with help from the incredible teams at PISCES, NASA, and Argo, the first iteration of the project was a success. The experience I gained at PISCES has been absolutely invaluable in both my education and my other work."



**“OVER THE PAST SEVERAL YEARS EFFORTS BY PISCES
HAVE POSITIONED HAWAI'I ON THE VERGE OF TREMENDOUS
ECONOMIC OPPORTUNITIES. EXPERIMENTS WITH
BASALT REBAR AND PAVING PRESENT TREMENDOUS
OPPORTUNITIES FOR THE MANUFACTURE AND CREATION
OF THESE IMPORTANT BUILDING PRODUCTS RIGHT HERE
IN HAWAI'I. THIS WILL ALLOW US TO SAVE ON THE
HIGH COST OF IMPORTING THESE PRODUCTS FROM THE
MAINLAND OR OTHER COUNTRIES.”**

**-HAWAI'I DISTRICT 1
REP. MARK NAKASHIMA**

LONG-TERM

ECONOMIC DEVELOPMENT

PISCES CONTINUES TO FOCUS ON LONG-TERM ECONOMIC DEVELOPMENT FOR THE STATE OF HAWAI'I

While PISCES works hard to ensure opportunities in the short-term, our team is also evaluating economic options for the future. Here are some projects we have in the works for the next few years:

HIGH BANDWIDTH COMMUNICATIONS

During FY 2016, PISCES procured and oversaw two engineering studies (geologic and telecommunications) at a Mauna Loa location that shows promise as one of the possible sites for a future NASA laser communications ground station.

BASALT REBAR & SINTERING

As part of PISCES' lunar sidewalk initiative with the County of Hawai'i, PISCES incorporated a commercially available rebar made from basalt. Basalt rebar has twice the tensile strength of steel rebar, but a quarter of the weight, and because of its exceptional physical characteristics (including its resistance to rust), basalt rebar appears to be an invaluable building material for use in Hawai'i. Commercial production of basalt fiber used in basalt rebar currently occurs outside of the U.S. This could change with the help of PISCES.

Research completed during the construction of the Vertical Take-Off/Vertical Landing pad produced a high quality basalt paver with physical characteristics that surpass those of residential concrete. This process has the potential to be applied in the fabrication of construction blocks, similar to cinder blocks, to be used in Hawai'i and in this way reduce the dependency of Hawai'i for construction materials that need to be imported from overseas.



PISCES Executive Director Rob Kelso is seen here laying out the lunar concrete at our test site in downtown Hilo, Hawai'i.

SPACEPORT ON HAWAI'I ISLAND

PISCES is providing support for groups studying a proposed spaceport on the Big Island that would provide commercial space flights and create new jobs for Hawai'i Island as well as increase tourism dollars in the State.

The Kona airport, if approved, would join 10 other locations that would have active launch site operator licenses and become a viable economic driver for Hawai'i.

MULTIPURPOSE PROCESSING FACILITY

The proposed multipurpose processing facility (MPPF) will act as a catalyst for workforce, education and economic opportunities and provide space training and services needed to manufacture and tend to high-tech equipment. MPPF aims to provide infrastructure to supplement presently out-sourced services from the user communities of Hawai'i. The concept is to have a full-service, state-of-the-art facility to serve a variety of high-tech projects here in Hawai'i.

APPLIED RESEARCH & TECHNOLOGY



Helelani on the partially-built bullseye for the lunar landing pad

Appplied research is one of PISCES main pillars and it has played a key role in developing a recognized name in the space exploration community. Through diverse areas of applied research, PISCES creates technologies, processes and products that not only have a direct application for space exploration but can also benefit Hawai'i directly and have the potential to create derivative industries to diversify the State's economy. This has resulted in peer reviewed papers presented and published in prestigious conferences such as

the Lunar Exploration Analysis Group (LEAG), the ASCE Earth and Space Conference, and in collaborative work with NASA and other institutions and organizations.

This past year, PISCES' planetary rover Helelani made news around the world for its accomplishments during the construction of the Vertical Take-Off/Vertical Landing Pad (VTVL), a project developed in collaboration with NASA Kennedy Space Center, Honeybee Robotics, Hawai'i County Research and Development and ODG Canada. This was the world's first-ever telerobotically built lunar landing pad.

APPLIED RESEARCH AND TECHNOLOGY DEVELOPMENT IN THE AEROSPACE FIELD HAS ALLOWED PISCES:

- To demonstrate that "aerospace happens in Hawai'i." Success in applied research can act as a magnet to draw more aerospace activity to Hawai'i. It also shows that Hawai'i has a supportive government and a skilled workforce that can conduct innovative aerospace research activity - both of which are necessary ingredients to attract new investment.
- To provide STEM workforce training activities for Hawai'i students. Students from local high schools and colleges work on all of PISCES applied research projects. This hands-on experience with "real world" projects will translate, ultimately, into a trained high-technology workforce.
- To develop new technologies that may be manufactured and used in Hawai'i. This can mean new products, additional jobs and possibly even less imports and/or more exports.
- To leverage aerospace research investment outside of Hawai'i to benefit Hawai'i. This stretches Hawai'i investment dollars.

APPLIED RESEARCH & TECHNOLOGY

ROBOTICS

Robotics in Hawai'i's high schools is a growing area producing outstanding teams that produce top-level performances at national and international competitions. Many of these students move to the mainland to continue with their university studies and some remain in the state. The University of Hawai'i at Hilo's computer science department has provided PISCES with students who either through paid internships, volunteer work or hired as technicians have developed an advanced and sophisticated communications, navigation and control system for PISCES' planetary rover, Helelani.

Starting in the summer of 2015, four university students were involved with the development of the control systems, imaging systems, navigation and mechanical interface systems to prepare Helelani for the ambitious task of telerobotically constructing a landing pad using only local resources.

These four students came from the University of Hawai'i at Hilo, University of Hawai'i Manoa and Cooper Union University in New York. Two students were computer science majors and the other two were majoring in mechanical engineering. Their experience assisting with such a vital piece of the project provided them with real-life job training that transformed their abilities to meet the demands of the high-tech industry in the State and elsewhere. As a result of this experience, one of the summer interns has secured an internship with Honeybee Robotics, another was hired by Google, and a third began exploring different job opportunities in Space, IT and banking industries.

Other upgrades needed to prepare the rover for the experiment included a mechanical interface that allowed the exchange of two different end effectors (a heavy duty levelling blade, and a roller compactor) that were used during the first two phases of the ACME project. Later, a robotic arm designed by Honeybee Robotics and an end effector designed by NASA were mounted on Helelani and used for the third phase of the project (the deployment of the sintered basalt pavers to form the bullseye of the landing pad).

Another key aspect of the project involved the Graphic

User Interface (GUI) systems needed for the teleoperation of Helelani. The GUIs were designed and built by the UH-Hilo students and allowed for real-time operations or a "time delay" to emulate lunar or Mars communications. These systems allowed NASA engineers to operate the rover and deploy pavers from NASA Kennedy Space Center in Florida.

One of the lessons learned during the VTVL project was that Helelani's control systems had been pushed to their limits with regard to computing power and memory. Having identified this issue, performing major upgrades to Helelani's avionics became a priority in preparation for the Summer's Design Reference Mission. Work was led by the same two UH-Hilo computer science students that participated in the VTVL project. Their project included a complete upgrade that required the replacement of an Arduino based control system with an on-board computer with higher computing and memory capabilities. Part of the project required reprogramming the code in the GUIs' to accommodate the new system.

Work with the interns continued into the summer of 2016. PISCES added two new interns to work on our robotics, one is a Waiakea High School graduate attending Arizona State University and studying computer science, and the other is a Hilo High School student involved in the robotics team. They're charged with developing a stereoscopic imaging system for Helelani. The interns will be working closely with engineers at NASA AMES and with Dr. Jim Bell from ASU who has designed some of the imaging systems currently on the rovers Spirit, Opportunity and Curiosity. The opportunity of working with leaders in planetary exploration under real-life conditions will significantly improve these interns' qualifications for future employment. Our intern from ASU has already secured a position in Dr. Jim Bell's laboratory for the fall 2016 semester.

In retrospect, Helelani continued to be a key member of the PISCES family that provides a unique job training tool to Hawai'i's younger generations by exposing them to real life work situations and leaders in the space technology industry. One of the primary goals of Helelani is to give PISCES interns an advantage in their careers.

APPLIED RESEARCH & TECHNOLOGY

THE VERTICAL TAKE-OFF/ VERTICAL LANDING PAD PROJECT



ABOVE: Partners and supporters of the VTVL project are seen here following PISCES/NASA's rocket engine firing test. Photograph courtesy of 'Ena Media Hawai'i.

The Vertical Take-Off/Vertical Landing Pad project was a highly ambitious endeavour successfully completed in collaboration with NASA Kennedy Space Center's Swampworks, Hawai'i County Research and Development, Honeybee Robotics and ODG Canada. The project was conducted under NASA's Advanced Construction with Mobile Emplacement (ACME) umbrella.

As a proof of concept, there were two main objectives to the project in regard to technicality and materials:

Can a landing pad which is capable of withstanding multiple landings and takeoffs from a 960 lb(f) engine be constructed using only the materials that would be available on the Moon or Mars? In this case, Hawaiian basalt was used as an analog material due to its similar characteristics, both physical and chemical, to lunar and Mars regolith. Secondly, can the entire project be done robotically and through teleoperations without human labor directly applied to the construction process?

Plenty of theoretical work has been done proposing the construction of basic infrastructure on the Moon or Mars using robots, but no actual fieldwork to prove this concept was explored prior to PISCES' involvement.

The project was a tremendous triumph with regard to the construction of the pad through teleoperations and the information gathered about the physical properties found in the sintered basalt pavers. Helelani was the linchpin for the construction project, performing surface preparation including the grading, levelling and compacting of the site and for the deployment and placement of the basalt pavers.

The pad was put to a test on March 20th under the direct impact of a 960lb(f) rocket engine. NASA chose that engine to make it similar to the engine it's using for the Morpheus lander. The center paver was able to withstand the velocity and the temperature of the rocket engine's plume; however, the interlocking design of the pavers allowed some of the engine's hot gas to penetrate underneath causing them to be aero-lifted and ejected. After the test, a structural analysis of the pavers showed they had higher strength than residential concrete.

While the analysis on the VTVL pad is not complete, results from the sintered basalt pavers have opened doors for business development opportunities in the area of construction. PISCES will continue to explore the characteristics of local basalt and its potential applications for the construction industry. PISCES would like to thank the University of Hawai'i at Hilo Astronomy and Physics Department for the use of their facilities and help in this project.

APPLIED RESEARCH & TECHNOLOGY



ABOVE: Prior to building the lunar landing pad, our robotic rover Helelani leveled, compacted and graded the soil. Soil compaction analyses were later performed of the bullseye site prior to and post compaction. A sample of the basalt fines were sent to a lab to be used as the reference standard. BELOW: Helelani is seen here placing down the 100th paver using an “arm” apparatus from Honeybee robotics. The aerial image in the bottom right shows the completed lunar landing pad before our rocket engine firing test. Atop of the pad is the PISCES’ constructed gantry that held the rocket engine.



photo courtesy of 'Ena Media Hawai'i

PISCES FY 2016

COMMUNITY ENGAGEMENT

Public outreach and engagement was a high priority for the PISCES during FY 2016...



The image above shows members of the Hawai'i Island community checking out the reconstructed space shuttle cockpit at Kea'au High School.

PISCES had a busy year engaging in 30 public and classroom outreach programs in our community. In January of 2016, PISCES coordinated a Challenger Remembrance Day ceremony in honor of Hawai'i astronaut Ellison Onizuka. Kea'au High School hosted the event. A full scale model of a space shuttle flight deck, given to PISCES by the Pacific Aviation Museum, was also unveiled the same day. For months dozens of students from the high school, Hawai'i Community College and Civil Air Patrol Squadron worked to restore the module. The replica included a brand new flight simulation deck that was unveiled the day of the event. This day of recognition attracted a large crowd from people all over Hawai'i Island and was certainly a day to remember.

On top of our usual outreach efforts, PISCES attended many more events including the annual AstroDay in Hilo, Hawai'i that featured more than 40 exhibits, demonstrations, and activity areas at the local mall. PISCES brought out their robotic rover and taught interested students about their on-going projects and how they are helping to further mankind's understanding of the space exploration.

Another highlight for FY 2016 included work with the University of Hawai'i at Hilo's robotics team that travelled to NASA Kennedy Space Center for their inaugural appearance at the annual robotics competition. The team placed 21st out of 45 teams.

**PISCES ATTENDED MORE THAN 30 EVENTS,
SPEAKING ENGAGEMENTS, CLASSROOM
AND SCHOOL CLUB VISITS DURING THE
FISCAL YEAR 2016**



**PISCES MENTORED UH-HILO STUDENTS FOR
THEIR FIRST NASA ROBOTICS COMPETITION**

**PISCES HIGH SCHOOL STARS PARTICIPANTS
MORE THAN TRIPLED FROM
FY2015 TO FY2016**



PISCES FY2016

MOONRIDERS



Members of the FY 2016 MoonRIDERS program

In FY 2016, PISCES continued to lead the collaborations with NASA Kennedy Space Center (KSC) and two Hawai'i high schools (Kealahou High School in Kailua-Kona, and 'Iolani High School in Honolulu).

The project is called MoonRIDERS and involves innovative technology for the Research Investigating Dust Expulsion Removal Systems (RIDERS).

There were two major accomplishments in the development of the lunar surface flight experiment:

1. Fabrication of upgraded support brackets- In Fall 2015, both high schools fabricated and provided upgraded support brackets for the electrodynamic dust shield to the NASA-KSC. These brackets were attached and tested at KSC for the latest version of the dust shield.
2. Vacuum chamber testing at Kennedy Space Center- In Spring 2016, each high school flew to Florida to perform vacuum

chamber testing at the NASA KSC to evaluate further the imaging options and camera configurations associated with the lunar surface dust shield (EDS) experiment. The results were analyzed and presented to both the PISCES staff and NASA-KSC in post-test briefings. Objectives for the vacuum chamber testing were:

- * To identify and test optimal EDS shim angle and complimentary GoPro angle using a second GoPro to observe camera angle within a vacuum chamber.
- * To test effectiveness of GoPros in a vacuum.
- * To test fisheye and 25mm lenses to create a recommendation of lens types.
- * To find the maximum and minimum angles at which the camera and EDS can be positioned.
- * To test the effects of the sun at estimated angles on cameras and image processing.
- * To find the optimal resolutions for processing of images.

PISCES GRANT-FUNDING REVISIONS FOR MOONRIDERS

In 2015, PISCES was honored to receive a \$25,000 grant from Hawai'i County / Department of Research and Development (R&D) and a \$10,000 grant from the Hawai'i Community Foundation (HCF) for the MoonRIDERS' Lunar Surface Flight Experiment involving both the NASA Kennedy Space Center and the two Hawai'i high schools.

Since the planned launch date for the flight experiment had been delayed into 2017, PISCES requested and received approval during FY 2016 for grant extensions of these monies into spring 2017.

PISCES

PARTNERS

DURING FY 16, PISCES EXECUTED AND SIGNED TWO NEW SPACE ACT AGREEMENTS (SAA) WITH NASA KENNEDY SPACE CENTER (KSC) AND ADDED NEW MEMORANDA OF UNDERSTANDING (MOU) WITH ENA MEDIA HAWAI'I AND SOLVI ENERGY, BRINGING OUR MOU TOTAL TO 18. HERE IS INFORMATION ON EACH OF THE NEW AGREEMENTS.

SPACE ACT AGREEMENTS:

SAA FOR MOONRIDERS

During the fall of 2015, PISCES and NASA's Kennedy Space Center signed an extension to the MoonRIDERS nonreimbursable Space Act Agreement. This agreement is the formal framework for the collaboration between NASA's KSC, PISCES and the two Hawai'i high schools who are working together on an electrodynamic dust shield (EDS) technology experiment bound for the surface of the moon. The extension to the agreement not only added a year to the existing SAA, but it also added technical requirements that will enrich the students' overall experience, such as: the involvement in two rounds of field tests on the EDS in Hawai'i; the addition of data reduction and analysis activities, and; completion of lab tests for EDS imaging analysis.

SAA FOR ADVANCED CONSTRUCTION USING ROBOTIC EQUIPMENT

PISCES signed a second major contract agreement with NASA KSC for "Development of Technologies for Remotely Operated Robotic Construction of an IN-SITU Vertical Take-Off/Vertical Landing (VTVL) Pad." Under this agreement, KSC and PISCES began a process for the technical engineering and robotic construction of a basalt VTVL in the State. This type of engineering construction had never been tried before on such a large scale. The landing pad was successfully completed and tested by the Spring of 2016. PISCES met all its defined contract milestones on schedule.

MEMORANDA OF UNDERSTANDING:

MOU WITH ENA MEDIA HAWAI'I

'Ena Media Hawai'i is a digital media company based in Hilo, Hawai'i. PISCES and 'Ena Media Hawai'i entered a MOU which established a cooperative relationship where PISCES would provide access to current and future scientific projects and 'Ena Media Hawai'i would provide their expertise in aerial, HD, high-speed photography and other types of image capturing. The first project PISCES and 'Ena Media Hawai'i collaborated on was the rocket test of the Vertical Take-Off/Vertical Landing pad on March 20, 2016. 'Ena Media Hawai'i provided aerial, high-speed and high definition media, which provided valuable scientific data.

MOU WITH SOLVI ENERGY

Solvi Energy S.A. de C.V. is a renewable energy company based in Cancun, Mexico. PISCES and Solvi entered into a MOU in Spring 2016 in order to establish cooperative relations to explore mutually beneficial opportunities in renewable and sustainable energy technologies, which offer great potential for workforce development, jobs, and advanced manufacturing in aerospace and other sectors in Hawai'i.

PISCES FY 2016

FINANCIALS

OVERVIEW OF FY16 STATE OF HAWAI'I FUNDING

FY16 Budget Request	\$1.97 M
FY16 Funds Appropriated	\$400K
FY16 Funds Allocated	\$370K

SOURCE OF STATE FUNDS FOR OPERATIONS IN FY16

FY16 Funds Allocated	\$370.0K
FY15 Funds carried into FY16:	\$468.9K
FY15 Funds for	
Laser Communication	
Engineering Assessment:	\$237.5K
Total Funds available:	\$1,076.4K

PISCES OPERATING COSTS IN FY16

Cost Category	Amount	% of Total
Labor:	\$551.1K	65.1%
Facilities:	\$46.8K	5.5%
Consulting Contracts:	\$189.2K	22.4%
Other *	\$ 59.1K	7.0%
Total Costs:	\$846.2K	100.0%

*AN ADDITIONAL \$13.8K IN "OTHER" EXPENDITURES WERE PAID WITH COUNTY OF
HAWAI'I FUNDS.



photo courtesy of 'Ena Media Hawai'i

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Rodrigo Romo, Program Manager

Polly Roth, Executive Administrator

Christian Andersen, Operations Manager

John Hamilton, Logistics and EPO Manager

Megan Moseley, Public Information Officer

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Robert Kelso, Vice Chair Ex-Officio

Hoyt Davidson, Near-Earth LLC

Galen Ho, President Galen Enterprise

Chancellor Donald Straney (representing
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Ex-Officio

Luis Salaveria, Director of DBEDT (or
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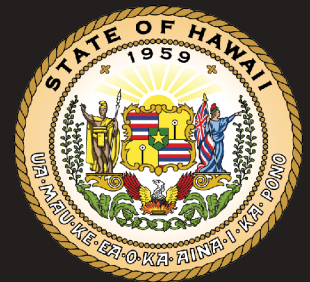
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