PISCES

Pacific International Space Center for Exploration Systems

Applied Research
Workforce Development
Economic Development

FY 2017

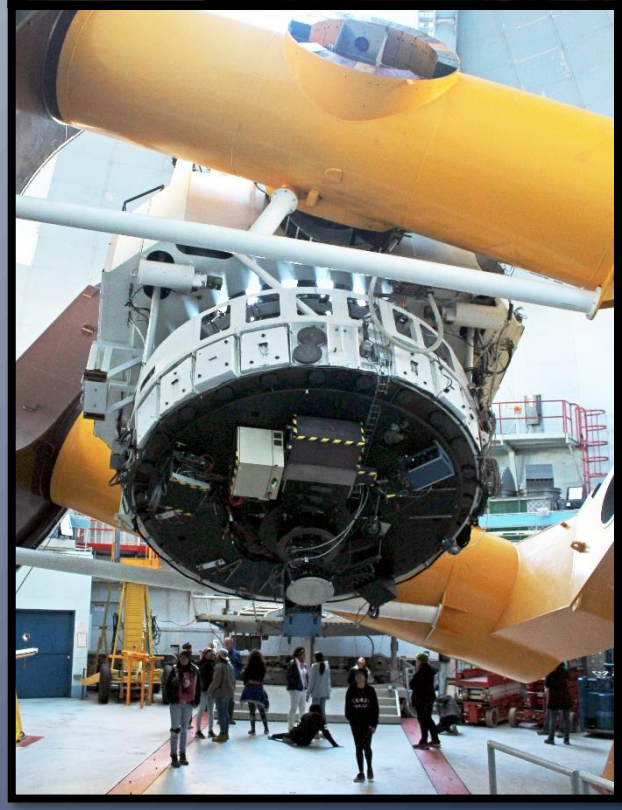
Annual Report

PISCES

The **Pacific International Space Center for Exploration Systems** (PISCES) is a Hawaii state-funded aerospace center under the Department of Business, Economic Development and Tourism (DBEDT). The Hilo-based agency is working to position the State of Hawaii as a leader in space exploration while developing sustainable products and technologies that benefit the Islands. Through Applied Research, Workforce Development, and Long-Term Business and Economic Development, PISCES provides hands-on experience to Hawaii's future scientists and engineers, preparing them to meet the demands of a highly competitive industry while improving the local economy through job diversification, innovative products and new industries.

Annual Report

July 1, 2016 – June 30, 2017



Letter from the Board Chair

Henk Rogers

Greetings friends of PISCES,

While operating under a very tight budget, PISCES has had a great year. We are getting ever closer to accomplishing our mission of bringing the business of Space Exploration to Hawaii in an economically significant way.

PISCES' continued efforts in developing "lunar concrete"—a concrete-like material derived solely from the volcanic basalt found in Hawaii—for use on Earth and in space, is bearing fruit. Our latest samples composed of sand and dust-sized particles were sintered at high temperatures to create construction material ten times the strength of residential concrete.

This notable accomplishment bodes well for the successful design and construction of a prototype Moonbase in Hawaii. PISCES is playing a key role in joining experts from around the world for the first International Moonbase Summit this October on Hawaii Island to develop a plan of action to make this science fiction dream a reality.

Building a Moonbase prototype on Hawaii Island will create a positive impact on the local economy while creating a firm foothold in the global effort towards space settlement. Humans will need to robotically build a Moonbase before establishing a long-term presence on the lunar surface. This effort will require Artificial Intelligence, Robotics, Materials Science, *in-situ* resource utilization, 3D printing, microwave sintering and a host of other specialty fields and technologies. The opportunities for partnerships and high-technology jobs in this effort are abundant. Each field will attract and produce people with skillsets that will support Hawaii's sustained economic growth into the 21st century.

Not only is this project exciting, but I believe that robotically building a prototype Moonbase on Hawaii Island will be the greatest accomplishment yet for the Space Exploration community in Hawaii.

Henk Rogers
PISCES Board Chair

Letter from the Program Manager

Rodrigo Romo

Aloha Kakou,

Fiscal Year 2017 (FY17) was a challenging year at PISCES. The funds available to us were significantly reduced compared with previous years. This forced us to make some difficult decisions, reduce our workforce and redefine our objectives to continue operating and ensure future success.

Working closely with our staff, we identified three core areas that facilitate PISCES' mission of advancing the aerospace industry in Hawaii: Applied Research, Workforce Development and Long-term Economic Development. These three objectives feed and reinforce one another, with Applied Research as the critical foundation.

With these objectives in mind, we resolved to cover our basic operating costs using state-appropriated funds and to raise supplemental funding through research grants and private contracts.

I am proud to say that our staff rose to the occasion and made this goal a reality. Operating under budget constraints and a new focus during FY17, we successfully raised $94,260 through four separate grant awards. These supplemental funds will support PISCES' Materials Science basalt research, our Summer Internship Program for university students, and our Women's STARS (STem Aerospace Research Scholars) Program, as well as an upcoming UAV project in partnership with the County of Hawaii.

With strong support from several legislators, we also secured funding to perform a feasibility study on a potential basalt fiber/rebar manufacturing operation in Hawaii. We also participated as part of a team evaluating the implementation of a Multi-Purpose Processing Facility to service the Astronomy, Aerospace, and other Technology Industries and sectors in East Hawaii.

We still face additional challenges ahead, but the staff at PISCES is determined to continue moving forward to position Hawaii as a forerunner in the global aerospace industry. With continued vision, perseverance and collaboration, I believe we can position Hawaii as a global leader in the quickly-evolving aerospace and space exploration industry in the years to come.

R. Romo

Rodrigo Romo

PISCES Program Manager

PISCES

EXECUTIVE SUMMARY

In FY2017, PISCES refocused its mission and core objectives to utilize its limited resources and staff toward maximum successful outcomes. Overcoming budget challenges, PISCES staff successfully forged new public and private sector relationships, raised nearly $100,000 in supplemental funds to support Workforce Development and Applied Research initiatives, and attended numerous education and outreach events in the community.

Budget

Total State funding allocated to PISCES in FY2017:

$405,000

Staff

No. of Staff:

5

- **2 FT employees**
- **3 PT employees**

Awards

$94,260 in **Supplemental funds** raised through 4 grant awards

Global Partnerships

New Partnerships

- Hawaii CC
- RedWorks

Total MOUs with private/public Organizations: 20

Workforce Development

9 **Interns employed** in technical positions

90% of **STARS** students report a positive impact

Outreach & Education

Supported & Attended 30 community outreach & education events, conferences

CORE OBJECTIVES

PISCES refocused its core objectives in FY17 to three key areas which support and reinforce one another: **Applied Research, Workforce Development** and **Long-Term Economic Development**. These core objectives facilitate PISCES' mission to develop a sustainable aerospace industry in the State of Hawaii through innovative technologies, workforce development, education and outreach initiatives, and new business and industry opportunities benefiting the State of Hawaii.

Applied Research

Applied Research is at the heart of PISCES' work and drives the parallel objectives of Workforce Development and Long-term Economic Development. Through Applied Research projects and partnerships, PISCES has become a noteworthy name in the global aerospace community. These projects are a continuing source of supplemental funds through state and federal funding organizations to benefit the State of Hawaii.

FY17 Research Grants

Early on in FY17, PISCES focused on securing supplemental funding sources through grants and sponsorships from county, state and federal agencies to continue Applied Research projects. Despite the highly competitive nature of many of these programs, PISCES successfully raised a total of $62,860. The table below displays a complete listing of grant proposals solicited by PISCES.

GRANT	AWARD & TERM	SUBJECT	GRANTOR	TEAM	OUTCOME
NASA Innovative Advanced Concepts (NIAC)	Phase I: $125,000 for up to 9 mos.	Rock-based Energy Storage Systems for space farms	NASA	PISCES and NASA SwampWorks	Not Awarded
Small Business Technology Transfer (STTR)	Phase I: $125,000 for up to 12 mos.	Planetary Lego	NASA	Honeybee Robotics and PISCES	$118,690 contract in June 2017; **$54,860** for PISCES
Hawaii County Dept. of Research & Development	$8,000 for up to 12 mos.	Little Fire Ant UAV Bait Dispersion System	Hawaii County R&D	PISCES and UH Hawaii Ant Lab	**$8,000** awarded to PISCES
Space Technology Research Grants Program, Early Stage Innovations	$500,000 for up to 3 years	Extraction of Water from Hard Extraterrestrial Soils	NASA	HI-SEAS and PISCES	Proposal submitted at end of June 2017; PISCES eligible for up to 30% of Grant
				Total	**$62,860.00**

Applied Research

FY17 Research Topics

Materials Science: Basalt-derived Feedstock for Manufacturing

Sintered basalt pavers produced during PISCES' Vertical Take-off/Vertical Landing pad construction project in FY16 generated significant interest in the space exploration community, particularly within NASA. Building upon this work, PISCES partnered with Honeybee Robotics to submit a Phase I NASA Small Business Technology Transfer (STTR) proposal that was awarded in partnership with Michigan Technological University. PISCES will solicit a Phase II proposal with Honeybee Robotics in the first quarter of FY18 to apply for funding up to $1 million over two years to continue basalt materials research and development.

ISRU: Water Extraction from Regolith

PISCES is partnering with HI-SEAS on a three-year grant to investigate methods of extracting water from hard extraterrestrial soils. With combined experience in microwaves, robotics, analog test site field work and water extraction, PISCES and HI-SEAS make a strong collaborative team. The grant proposal in June 2017 and has the potential to bring up to $150,000 in funds to PISCES over three years.

NASA BASALT Project

PISCES is collaborating with NASA on a Planetary Science and Technology Through Analog Research (PSTAR) grant called BASALT (Biologic Analog Science Associated with Lava Terrains). PISCES Operations Manager Christian Andersen and Education & Public Outreach Manager John Hamilton are Co-Investigators on this human Mars mission analog simulation. Led by geobiologist Darlene Lim of NASA Ames Research Center, the five-year program is exploring how usable geology and biology samples can be identified and collected on Mars by future astronauts. So far, the BASALT Project has deployed a mission at the Craters of the Moon National Monument in Idaho (June 2016) that serves as an analog for the late Mars period. The second deployment was conducted on Hawaii Island at Hawaii Volcanoes National Park (November 2016) which is similar to early Mars conditions when water was more abundant. Simulation astronauts were placed in the field with 5- and 15-minute communication delays as well as low- and high-data bandwidth conditions while a supporting team coordinated the mission from a remote location representing a control center on Earth.

Robotics

PISCES' planetary rover Helelani continues to generate interest from agencies like NASA Ames, NASA Glenn and NASA Kennedy Space Center (KSC). During the summer of 2016, the NASA Ames Resource Prospector team used Helelani to hone their remote piloting skills for an upcoming lunar mission. ODG, Helelani's Canadian manufacturer, learned of the test and has initiated discussions for future testing with a second long-term rover for PISCES to continue robotic technology development.

Near the end of FY17, PISCES was approached by a company interested in developing an innovative new wheel design for planetary rovers. The proposal, brought forward by California-based company Shark Wheels, may result in an STTR grant solicitation with NASA.

FY17 Conferences

Space-related conferences are ideal venues for PISCES to present and partner with other industry-related organizations on new and existing projects. Most networking and future collaborative research agreements happen at annual conference events, and they play a critical role in PISCES' ongoing success.

AMOS Surveillance Technologies Conference: September 2016 - Hawaii, USA

Organized by Maui Economic Development Board, the Advanced Maui Optical and Space (AMOS) Surveillance Technologies Conference is considered the premier technical conference in the nation devoted to space surveillance. Personnel from military, government, private industry and academia attend AMOS annually. During the September 2016 meeting, PISCES met with various members of the Space Industry, including companies interested in small satellite launch facilities in Hawaii and autonomous and remotely controlled rover systems.

Hawaii Aerospace Summit: October 2016 - Hawaii, USA

Organized by the Office of Aerospace Development (OAD), the Hawaii Aerospace Summit joined entrepreneurs, state legislators, academics and members from NASA, private launch facilities and private aerospace companies to discuss a wide variety of aerospace initiatives. PISCES was invited to present its work in Materials Science on the Planetary Sustainability and Space Economy panel. PISCES also interacted with the public to share the agency's projects and mission. Several meetings were held with members of NASA Ames, Hawaii Spaceflight Lab, Alaska Aerospace and other private companies to explore opportunities for collaboration.

New Worlds Symposium: November 2016 - Texas, USA

New Worlds Symposium organized a series of dynamic talks presented in eight-minute segments. PISCES submitted "ISRU: The Basalt Economy," a paper outlining the agency's research and development with sintered basalt and the many potential applications it has in space and on Earth. Private companies and educational institutions expressed strong interest in the technology and an MOU was established with RedWorks to collaboratively develop 3D printing capabilities using basalt. Other meetings led to the invitation to submit a proposal that led to the recent NASA STTR grant award for PISCES and Honeybee Robotics.

33RD Space Symposium: April 2017 - Colorado, USA

The Space Symposium is considered the single most important event in the Space Industry for both domestic and international public and private sector organizations. Companies from around the world come together to present their latest technologies and innovations. The week-long symposium hosted technical tracks and provided a unique opportunity to network with a wide variety of peers in the Space Industry. PISCES was invited to participate in a panel called "Living and Working on Mars," aimed toward aspiring young engineers and scientists. Several meetings yielded new collaboration opportunities with academic organizations and private companies.

Planetary & Terrestrial Mining Sciences Symposium (PTMSS): May 2017 - Quebec, Canada

The PTMSS was held in conjunction with the Canadian Institute of Mining (CIM) annual meeting to link terrestrial mining sciences and space mining for ISRU. PISCES presented two talks illustrating the uses of volcanic basalt for ISRU manufacturing and highlighted Hawaii's value as a high-fidelity lunar and Martian analog.

Workforce Development

Programs

Due to budget constraints, PISCES' workforce development programs were put at risk of being discontinued. Following a new approach of focused core objectives, PISCES secured supplemental funding through two grants in 2017 to continue its Summer Internship Program and Women's STARS (STem Aerospace Research Scholars) Program.

Grantor	Program	Amount
Hawaii Technology Development Corporation (HTDC)	Women's STARS Program	$5,000
State Department of Labor & Industrial Relations (DLIR)	Summer Student Internship	$26,400
	Total	$31,400

Women's STARS Program

The annual summer STARS Program is a free week-long STEM workshop designed to encourage more of Hawaii's young women to pursue studies and careers in science, technology, engineering, math (STEM) and related fields. STARS takes participating high school women on an engaging journey through the career worlds of engineering, science, technology and astronomy. Students hear from local scientists, engineers and educators to understand the real-world application of STEM and inspire them to follow their dreams.

Now in its fourth consecutive year, the program has expanded in participants and partnering organizations, offering a fun, enriching and educational experience. The 2017 program was made possible by a generous $5,000 sponsorship from HTDC. The following organizations supported the program with presentations, activities, tours, staff and in-kind support:

- HTDC
- Canada-France-Hawaii Telescope
- UH Hilo Robotics Team "Vulcan"
- JCMT/East Asian Observatory
- Caterpillar, Inc.
- Hawaii Volcanoes Observatory
- Subaru Telescope
- Onizuka Center for International Astronomy
- Pacific Aviation Museum

Photo: STARS students toured Subaru Telescope headquarters in Hilo, HI during the 2017 summer program.

The 2017 STARS Program hosted 11 high school women from schools across Hawaii Island including Honokaa High School, Keaau High School, Kealakehe High School, West Hawaii Exploration Academy and Waiakea High School.

"Taking part in the STARS program was such an enlightening and empowering experience for me. I met like-minded individuals that share my interests. I was also able to network with industry professionals, gaining future help for my science fair project, senior project and internships." – Hope Kudo, 2017 STARS Program student

Summer Internship Program

PISCES' internships provide college-level students with unique, hands-on work opportunities in applied research projects. Students work alongside PISCES staff and researchers in the fields of robotics, programming, engineering, geology, planetary science, ISRU and more. The program is limited to Hawaii-based students—either those who study at the University of Hawaii or those who return home from an out-of-state university for the summer.

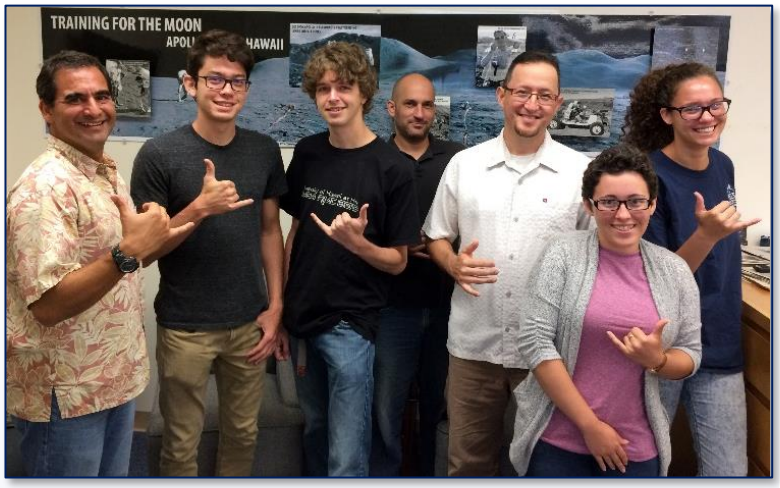


Photo: 2017 PISCES summer interns are working in robotics, programming development and planetary science tracks.

In FY17, former PISCES interns who earned undergraduate degrees went on to work for companies like Google, Apple, Microsoft and Taos. Those who remain in college have been offered internships and fellowships with space industry organizations like Honeybee Robotics and NASA. One 2016 PISCES intern was invited to work at an advanced imaging systems lab at Arizona State University under Dr. Jim Bell to develop imaging systems for future Mars rover missions.

During the last four years, PISCES has mentored a total of 30 student interns. Past summer internship programs were funded through PISCES' operations budget in addition to programs like AKAMAI and PIPES. Faced with a funding shortage in FY17, PISCES applied for a grant through DLIR to continue the program. DLIR awarded PISCES with funding to provide salaries for five full-time interns during the 10-week summer program.

FY17 PISCES interns worked on Applied Research projects in the fields of:

Robotics: Three interns (two from Hawai'i Community College in Hilo and one from Arizona State University) upgraded PISCES' planetary rover by developing its on-board computer system, retrieving lost telemetry data from the CAN Bus system, optimizing avionics and power systems, and designing and integrating two new imaging systems to enable 3D camera images and autonomous navigation.

Materials Science: Two interns (a University of Hawaii at Hilo graduate and Waiakea High School graduate) studied basalt sintering processes supported by a NASA STTR grant award. They collected and characterized basalt samples from various locations on Hawaii Island, testing different sintering thermal profiles to determine the optimal temperature to create a basalt-derived feedstock for ISRU manufacturing.

Collaboration with Hawaii Community College

To provide local students with opportunities to participate in science and technology projects, PISCES met with the chancellor of Hawaii Community College in Hilo (HawCC) to discuss the creation of a credit-based internship through the school's service learning program. As a result, HawCC and PISCES established a Memorandum of Understanding (MOU) and two HawCC students joined the 2017 Summer Internship Program's robotics track.

Workforce Development

Education & Outreach

MoonRIDERS Student Flight Experiment

PISCES launched the MoonRIDERS (Research Investigating Dust Expulsion Removal Systems) program in 2014 to engage Hawaii high school students in a real-life, lunar flight experiment in partnership with NASA's Kennedy Space Center (KSC). Participating students from Kealakehe High School and 'Iolani High School built mock spacecrafts and conducted field tests with a NASA-built technology called the Electrodynamic Dust Shield (EDS).

The program is now awaiting a launch vehicle to transport the student designed EDS configuration to the surface of the Moon for lunar testing. Negotiations are underway with NASA and a Google Lunar XPRIZE competition team to secure payload space aboard a Moon-bound spacecraft. Grant awards by the County of Hawaii Department of R&D and Thirty Meter Telescope's Think Fund for MoonRIDERS have been extended for an additional year to accommodate the launch negotiations.

Fourteen Kealakehe students involved in the program have received scholarships and fellowships for universities nationwide. Twelve students from participating schools have tested their designs at NASA KSC. Roughly 85 Hawaii students have participated in MoonRIDERS since the program began.

NASA's Robotic Mining Competition (RMC)

PISCES Logistics/EPO Manager John Hamilton regularly serves as a judge at the annual NASA RMC held at KSC. Fifty colleges compete in the competition each year with open-designed robots to prove various mining and traction designs made for *in-situ* resource utilization. Hawaii sent a team for the third year in a row for the 2017 RMC with students from UH-Hilo and Hawai`i Community College. The team placed in the top 50 percent of teams who competed.

Outreach Events

PISCES maintains an active presence in the community through education and outreach events to raise awareness on Space Exploration and Aerospace industry initiatives in Hawaii, and to encourage youth in STEM and related fields. During FY17, PISCES participated in 30 education and outreach events including:

- Astroday
- `Imiloa Astronomy Center Anniversary Event
- Hilo High School Career Fair
- Solar System Walk
- Statewide High School VEX Robotics Competition
- Ellison Onizuka Day at UH Hilo
- Journey Through the Universe Week
- Co-sponsored NASA talks at UHH & other schools
- UH Manoa Astrobiology Seminar
- Hawaii District Science Fair

Photo: PISCES' John Hamilton shares NASA's BASALT mission with sixth-graders at the Volcano School of Arts & Sciences.

Economic Development

Aerospace & Technology Initiatives

PISCES is legislatively mandated under DBEDT to develop, promote and advance the Aerospace Industry in the State of Hawaii through long-term economic development projects. PISCES is involved in five aerospace and technology initiatives in this effort to establish a sustainable industry in Hawaii with strong economic benefits:

Small Satellite Launch Facility (SSLF)

PISCES is part of a team evaluating the possibility of establishing a small satellite launch facility in East Hawaii. The team includes the Hawaii Spaceflight Lab (HSFL), Hawaii Economic Development Board (HI-EDB), University of Hawaii at Hilo, Rep. Mark Nakashima and Alaska Aerospace Corporation. The project is currently in progress with private land sites identified as possible locations. Community outreach efforts are also in the works.

The State of Hawaii has appropriated $250,000 to conduct an Environmental Assessment for the SSLF. Alaska Aerospace committed $250,000 in matching funds for the assessment (and any additional required studies) and is committed to raising funds to build the facility once the EA is approved and an FAA license is granted.

PISCES and its partners aim to have an SSLF operational by late 2018 to serve the small satellite industry. This project strongly benefits Hawaii's economy by creating high paying jobs. An SSLF could also create education and career training track opportunities for college students. Several small satellite launch vehicle companies have expressed interest in sending rockets to space from a Hawaii-based SSLF.

Multi-Purpose Processing Facility (MPPF)

As one of PISCES' original goals, an MPPF would support and provide services to various industries in Hawaii including: astronomy, satellite processing, payload processing, robotics, 3D Printing, unmanned aerial vehicle systems and others. PISCES is part of a team that selected Facility Logix to conduct a feasibility study for an MPPF. The study was completed in June 2017.

Basalt Rebar/Fiber Manufacturing

PISCES is exploring various applications for basalt as a construction material in space and in Hawaii, and developing a new manufacturing industry in the Islands. Basalt fiber and derivative products, as well as basalt rebar show promise and have generated a significant amount of interest.

The State Legislature has appropriated $200,000 in funds to conduct a feasibility study for a basalt fiber and/or basalt rebar manufacturing operation in Hawaii.

Basalt fiber is currently manufactured in only a few locations worldwide: Russia, Ukraine, China and Korea. It can be made into durable fabrics, mesh, rope and rebar. Basalt rebar does not corrode, and is lighter and stronger than its steel counterpart.

Basalt rebar

Economic Development

Collaboration with RedWorks

During the 2016 New Worlds Symposium, PISCES met with one of the founders of RedWorks, a California-based startup involved in 3D manufacturing using locally sourced resources. RedWorks initially focused on applications for construction on Mars. However, the company is now expanding its work to terrestrial applications on Earth. PISCES' expertise in basalt sintering and ISRU made for a win-win partnership with RedWorks, and the two have signed an MOU to explore opportunities for collaboration.

Financial Report

Overview of Fiscal Year 2017 State Funding

FY17 Budget Request	$650K
FY17 Funds Appropriated	$400K
FY17 Funds Allocated	$405K*

Source of State Funds for Operations in FY16

FY17 Funds Allocated	$405.0K
FY16 State Funds carried into FY17	$229.2K
Total Funds available	$634.2K

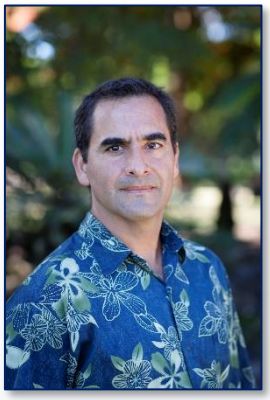
PISCES Operating Costs in FY17

Cost Category	Amount	% of Total
Labor	$331.3K	80.9%
Facilities	$46.7K	11.4%
Other	$31.5K	7.7%
Total Costs	$409.5K	100.0%

*PISCES' core operating funds in addition to the specified PISCES allocation were provided by the Office of Aerospace Development's general allocation.

Staff

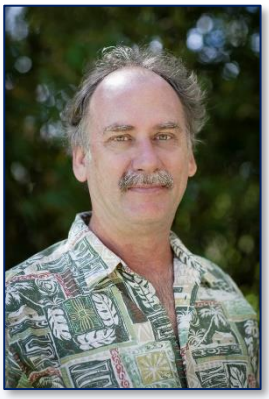
PISCES employs five staff members including a Program Manager, Administration Specialist, Operations Manager, Test Logistics/Education & Public Outreach Manager and Public Information Associate.



Rodrigo Romo
Program Manager
Full-time

Polly Roth
Admin. Specialist
Part-time

Christian Andersen
Ops. Manager
Full-time



John Hamilton
Logistics/EPO Mgr.
Part-time

Chris Yoakum
Public Info Assoc.
Part-time

Board of Directors

Henk Rogers, Chair
Founder, Blue Planet Foundation
Senate Nominee
Term: 2014 – 2018

Vacant
Ex-Officio, Executive Director, PISCES
Term: 2013 –

Kim Binsted
Principle Investigator, HI-SEAS
Professor, University of Hawaii at Manoa
Senate Nominee
Term: 2016 – 2020

Luke Flynn
Director, Hawaii Space Flight Laboratory
Governor Nominee
Term: 2016 – 2019

Galen Ho
President, Galen Enterprise LLC
Governor Nominee
Term: 2013 – 2017

David Lassner
Ex-Officio, President, University of Hawaii
Donald Straney, Designated Alternate
Chancellor, University of Hawai'i at Hilo
Term: 2013 – TBD

Luis Salaveria
Ex-Officio, Director, DBEDT
Mary Alice Evans, Designated Alternate
Deputy Director, DBEDT
Term: 2015 – 2018

Patrick Sullivan
Founder and CEO, Oceanit
House Nominee
Term: 2014 – 2018

Vacant
House Nominee
Term: 2015 – 2019

Bringing the Future to Hawaii

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