

**Pacific International Space  
Center for Exploration Systems**



**FINAL REPORT**

**Fiscal Year 2013**

**Act 273, SLH2013**

**1 July 2012 – 30 June 2013**



July 20, 2013

Aloha!

I am very pleased to introduce the final report for the Pacific International Space Center for Exploration Systems (PISCES) for fiscal year (FY) 2013. As Executive Director for this important project, it has been my pleasure to direct the operations during this transition year. I want to extend my congratulations to the excellent PISCES staff who made this first year a success in Hawaii. I also extend my sincere thanks to the many legislators, board members, academic advisors, cultural committee members and members of the business sector for their input, contributions, guidance and interest.

Within the pages of this final report, the reader will note a marked growth in the level of strategic participation from many elements in Hawaii, as well as from NASA, educational institutions and the private sector outside the State and in other countries. The inclusion of private sector, federal agencies and international entities has allowed the research collaborations to greatly grow and deepen.

Further, our partnership with Hawaii's Department of Business, Economic Development, and Tourism (DBEDT) was an important linkage into the State's aerospace initiative. We look forward to continuing this partnership as PISCES efforts within the State continue to grow.

The need for Hawaii to improve its basic science and technology infrastructure remains a strong point in the strategic development of our state's economy and educational system. Hawaii's most important resource is our people. Thus, PISCES projects and partnerships focus not only on developing technologies for planetary surfaces, but also for how these technologies can improve the sustainability of Hawaii. As such, PISCES has infused three important tenets in all of its projects: (1) growth of 21<sup>st</sup> century skills for 21<sup>st</sup> century jobs, (2) economic development and (3) workforce development.

I look forward with great anticipation to my continued role as Director as PISCES enters its first full-year of operations in FY14. The enthusiastic and widespread support for PISCES will ensure continued success during the exciting years ahead. We have only just begun to reach for new heights in continuing Hawaii's long history with the stars.

With much Aloha,

Robert M. Kelso

Executive Director, PISCES

# Pacific International Space Center for Exploration Systems

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## A. Executive Summary

The Pacific International Space Center for Exploration Systems (PISCES) in Hawaii is focused on the validation and verification of planetary surface systems and technologies. It is also compelled to apply translational technologies back within the State of Hawaii at a terrestrial level to assist in improving the sustainability of Hawaii. As such, PISCES is an important component of the State's emerging aerospace sector and is an economic driver for Hawaii in promoting 21<sup>st</sup> century skills for 21<sup>st</sup> century jobs, economic development and workforce development. Act 169, SLH 2012 removed PISCES from the University of Hawaii-Hilo and instituted it as a State project within the Department of Business, Economic Development and Tourism (DBEDT). While Act 169 took effect on 1 July 2012, authority-to expend was not approved until December, 2012. Hiring of staff was not realized until late February, 2013. Thus, the remarkable achievements and milestones were accomplished in the remaining 4 months of FY13. FY14 will be the first full year of operations. The highlights of PISCES for FY2013 are presented below.

### Overview of PISCES FY2013 Funding

- Act 169 and Act 106 provided the authoritative funding for PISCES operations for FY13. The level of funding was \$2.34M.

Total Funding Authorized	\$2.34M	
CIP	\$1.84M	Act 106 (2012)
OPS-General (G-Fund)	\$500K	Act 169 (2012)

- \$275K was allocated from CIP to the State's Department of Accounting and General Services (DAGS) to perform a site selection and environmental assessment for a future PISCES organizational building. The remaining \$1.565M of CIP is held in reserve for design and construction of the building.

### FY2013 Milestones

- 1 July 2012 – (PISCES funding bill) takes effect
  - PISCES legislatively transferred from the University of Hawai'i system into the State of Hawai'i Dept. of Business, Economic Development and Tourism (DBEDT)
- 10-23 July 2012 – 3rd International Hawaii In-Situ Resource Utilization Analogue Field Test
  - A mission simulation to locate, characterize, and map water/ice and other volatiles that may be present at the lunar poles using the Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) experiment on the Canadian Space Agency (CSA) Artemis Jr. rover.
  - Evaluation of NASA's Moon Mars Analog Mission Activity (MMAMA) instrument ability to perform science investigations associated with rover-based planetary surface (Moon or Mars) exploration
- Nov 2012 – PISCES Board of Directors formed, new PISCES Executive Director named
- Nov 2012 – PISCES Conference in Waikoloa, "Pioneering Planetary Surface Systems Technologies and Capabilities"
- Dec 2012 – DBEDT/RCUH sign project agreement for administrative services to PISCES
- Dec 2012 – Governor Abercrombie approves request to expend funds under Act 169

- 25 Feb 2013 – official start-date / hiring complete of four of PISCES staff
  - Executive Director, Office/Admin Manager, Test Manager, Logistics Manager
- Late Feb 2013 – \$275K transfer of funds to DAGS for PISCES building study
  - DAGS begins development of PDR requirements for a DBEDT-PISCES headquarters facility, plus Site Surveillance Study (SSS)
  - Effort to be completed in Dec 2013
- 10 April 2013 – PISCES, as Lead-PI, submits 5yr, \$6M proposal to NASA for research study in “Regolith, Resources and Recovery”
  - Study, to be led by PISCES, will characterize the regolith on the Moon and near-Earth asteroids to assess regolith for construction materials (e.g., concrete, reinforcements)
  - PISCES also submitted as Co-PI on proposal to assess technologies for lava tubes and pit craters
- 11 April 2013 – PISCES establishes offices at 99 Aupuni Street, Hilo
- 19 April 2013 – signed Space Act Agreement (SAA) between PISCES and NASA
- 25 April 2013 – PISCES signs six memoranda of understanding (MOU)
- 15 May 2013 – hiring complete for PISCES public information officer (PIO) position
- 31 May 2013 – hired 5 student interns for summer 2013

**Strategic Partnerships / Memorandums of Understanding (MOU)**

- The following MOUs were signed with PISCES strategic partners:

<b>Organization</b>	<b>Relationship with PISCES</b>
East Hawaii Development Corp (EHDC) / Hawaii Tech Works	Workforce Dev, C3T, Machining for Customers, 3D and Additive Manufacturing
Behrokh Khoshnevis (University of Southern California)	Contour Crafting and Sulfur Binders
Leonhard Bernold (Univ. of New South Wales) - Australia	Polymer binders and basalt casting/sintering
Planetary Power Inc. (PPI)	Portable and sustainable renewable power
Lutz Richter – International Society of Terrain Vehicle Systems (ISTVS)	Robotics M&O
Na Pua No`Eau	EPO, workforce development at the front-end (K-12), student and intern projects
Russ Ogi Inc. (Honolulu)	3D printing technology
Korea - International Space Exploration Research Institute(ISERI)	Lunar/basalt concrete
Ontario Drive Gear (ODG)	Robotic rover systems

**PISCES Projects**

- Lunar/basalt concrete – PISCES is exploring research opportunities in the area of basalt construction:
  - Basaltic concrete – under investigation by PISCES is the use of basalt material for construction, versus using traditional concrete imported from the mainland into Hawaii. To live and operate on a planetary surface (example: moon, Mars) will

require stabilizing the surface to construct landing pads, berms, shelters, etc. Hawaii, with its volcanic basalt material approaching that of moon and Mars, is a perfect location and analog for testing planetary construction techniques using basalt material, with application of specific binding agents. This to the benefit in future planetary exploration, and also to the benefit of Hawaii in its move to a more sustainable environment.

- Advanced manufacturing / 3D printing technologies – in its search for 21<sup>st</sup> skills and workforce development, PISCES is assessing opportunities for infusing more advanced manufacturing within the State starting with applications of 3D printing technology.
  - 3D laser printing – 3D printing technology has come a long way in the last few years. PISCES is investigating the use of 3D laser printers to do sintering of basalt ‘fines’ - small particles of basaltic powder produced by rock crushers in quarries. Application of this technology is instrumental to constructing small part/objects on planetary surfaces using indigenous materials. It also applies to making small parts from the stock of basalt fines located in Hawaii. It has application to generating 21st skills for 21st century jobs and creating advanced manufacturing opportunities within the State.
- Renewable energy
  - PISCES is partnering with Planetary Power Inc (PPI) on assessing high technologies in the area of renewable energy generation. PPI has made recent advances in high-tech, solar concentrator energy systems that provide high efficiency off-grid power. PISCES needs such power systems to support remote field tests at various lunar/Mars analog test sites on the Big Island. These systems also could provide off-grid power for emergency response services in event of disasters.
  - PISCES is working with PPI to assess marketing opportunities within the State, and identifying candidates for early-adopters for the technology within the State. Then, discussions are planned for options to locate PPI manufacturing and production jobs to Hawaii for their power systems.
- Aerial Tele-robotic Systems
  - PISCES is investigating opportunities to leverage its prior experience in tele-robotics into the area of unmanned aerial systems, specifically gyro-copter systems. These systems could have relevant application to search & rescue, and sensor technologies for monitoring agricultural programs on the Big Island. It also includes opportunities for establishing operator training programs with Hawaii Community College (HCC).
- NASA Laser Communication Technology Demonstration
  - NASA has approached PISCES during FY13 with interest in exploring possible opportunities to locate a state-of-the-art laser communications ground terminal above the cloud layer in Hawaii. Such a capability relates to the broadband interest of the State cited within the PISCES authorization bill. PISCES has initiated discussions with NASA to further explore this opportunity.
- PISCES Facility Users Guide
  - It is anticipated that future users of the PISCES test facilities will come from NASA, international, and the private sector. In preparation for this future testing in Hawaii, PISCES is developing a facility user’s guide which will assist users with understanding

what capabilities will be provided and how to make arrangements for travel to/from the site.

- Google Lunar X-Prize (GLXP) Preferred Provider Program
  - PISCES has initiated work to assess ability and options for PISCES to assist with the Google Lunar X-Prize (GLXP) organization regarding approaches within the State's local/corporate groups to assist these non-profit, GLXP teams in bringing their test hardware to Hawaii to test in the lunar analog sites of the Big Island. The idea is to assist these teams in defraying costs to make the trip more cost effective for the teams. Examples were reduced hotel rates, flying their hardware free on Hawaiian Airlines when excess capacity allows, etc.

#### **PISCES Educational and Outreach Programs**

- PISCES supported a number of EPO/outreach activities during the fiscal year, including Journey thru the Universe, Astro-Day in Hilo, hosting of the Moonbot: GLXP Lego Mind Storm Challenge winning team from Hungary, speaking to the Hui Ka Ua breakfast club, speaking at the Rotary group meeting, and outreach of rover / NASA technology at `Imiloa during the NASA/Canada field testing in July 2012.

#### **PISCES Organization**

- With the enactment of Act 169, PISCES was legislatively transferred from the University of Hawai'i system into the State of Hawai'i Dept. of Business, Economic Development and Tourism (DBEDT). Following the appointment of a Board of Directors in November 2012, the Board offered the new Executive Director position to Rob Kelso, formerly a NASA Space Shuttle Flight Director. The PISCES staff was formally hired at the end of February 2013:
  - Rob Kelso – Executive Director
  - Polly Roth – Executive Assistant, Office Administrator
  - Christian Andersen – Manager, Test Operations
  - John Hamilton – Manager, Test Logistic, EPO
  - Mari-Ela David Chock – Public Information Officer (PIO), hired mid-May 2013
- Board of Directors – a Board of Directors was established for PISCES through the legislative bill, Act 169 SLH 2012, as an executive Board. The Board convened and met with PISCES on four occasions during FY13. The Board was established with representatives from the State government, industry, University of Hawaii system, members local to Hawaii and those from the mainland. A NASA representative was assigned as a non-voting member. The Honorable George Ariyoshi was appointed as the PISCES Board Chairman.
- Cultural Advisory Committee – PISCES re-instituted a set of native Hawaiian representatives to advise the PISCES organization on cultural matters.

## **B. Introduction**

PISCES was initially established in 2007 and located within the University of Hawaii-Hilo to provide enabling services for users of high-quality planetary surface test sites unique to Hawaii. In 2012, Governor Abercrombie signed Act 169 wherein the State determined that “the PISCES, including its proposed aerospace technology research and development park project, is an economic driver for the

island of Hawaii that promotes the establishment and growth of new sustainable and green industries along with associated jobs, workforce development, internships, and science, technology, engineering and math education programs (STEM)”.

As such, Chapter 201, Hawaii Revised Statutes, was amended to administratively attach the PISCES project to the State’s Department of Business, Economic Development and tourism (DBEDT). The bill also created an associated board of directors and executive director position.

Since 2007, PISCES had been instrumental in providing test operations for the verification and validation of planetary surface systems and technologies. Under this legislative transition in 2012, PISCES expanded its portfolio in FY13 to include a broader scope of planetary tasks, and also focus to assure that each project contained elements important to the State: growth of 21<sup>st</sup> century skills for 21<sup>st</sup> century jobs, economic development and workforce development. The PISCES portfolio thus expanded to include new focal areas: advanced manufacturing, 3D printing using basalt material, tele-robotics for search & rescue and Space-Ag, assessing high efficiency planetary power/energy systems for test site operations, lunar concrete, student flight experiment opportunities, and more.

Given the delay in establishing the board of directors (Nov 2012) and processing of the approval-to-expend (Dec 2012) for PISCES, the organization was in operations for only the last 4 months of the fiscal year. However, significant contributions, progress and strategic alliances were established for the State in that shortened period of operations in FY13.

This report highlights these accomplishments, budgetary overview, project planning, and strategic partnerships so produced during the last four months of FY13.

### **C. Overview of FY13 Funding**

The State’s Act 169 and Act 106 appropriated \$2.34M to PISCES for FY13. This sum was portioned between \$1.84M (Act 106)(12) for capital improvement (CIP) and \$0.5M (Act 169)(12) of general revenues (G-fund) for operations.

- Of the \$1.84M for CIP, \$275K was allocated from PISCES to Department of Accounting and General Services (DAGS) for the planning and site survey study (SSS) for locating a new PISCES facility. This facility is required to support administrative offices for staff, workshop and highbay for test/checkout of test equipment and hardware leading to test operations. The DAGS study is due in December 2013. The remaining CIP (\$1.565M) are held in reserve for the building project. Cost estimates for the PISCES building will be provided in the December report from DAGS. The balance of the CIP required for building construction will be forwarded into the FY15 funding cycle.

The following table shows the financial data for the fiscal operations thru 30 June 2013. A more detailed report is shown in Section M.

COST CATEGORY	AWARDED	EXPENDED THRU 6/30/2013	OUTSTANDING PURCHASE ORDERS	TOTAL EXPENDED & COMMITTED	AVAILABLE BALANCE
Salaries & Fringe	337,000	147,516	-	147,516	189,484
Non-labor Operating Costs	163,000	63,874	18,198	82,072	80,928
Equipment	-	-	-	-	-
Total	500,000	211,390	18,198	229,588	270,412

The available balance of FY13 funds show in the table above will be used to cover early FY14 operations until FY14 funds are available for use. If FY14 funds are available by the end of September, it is likely that some FY13 funds can be used to purchase essential test hardware.

## D. PISCES Governance, Management & Administration

PISCES was established as a space center administratively attached to the State of Hawaii Office of Aerospace Development in the Department of Business, Economic Development and Tourism (DBEDT) through the enactment of Act 169 on July 1, 2012. The bill formally transferred all responsibilities, powers, functions, appropriations, supplies, assets, obligations, agreements from the University of Hawaii (UH) to DBEDT.

Act 169 laid the foundation for PISCES governance, management and administration, by establishing a PISCES board of directors and enumerating its powers and duties, enumerating the powers and duties of the executive director, and by providing stability for the transition from UH to DBEDT by keeping all existing administrative rules, policies, procedures and guidelines in full force and effect until they were amended or repealed by DBEDT. Here is an update of activities undertaken since the enactment of Act 169.

### Governance

In November 2012, the PISCES Board of Directors was formed following the guidelines set forth in the legislation. The Board members are:

- PISCES Board Chairman, the Honorable George R. Ariyoshi
- Henk B. Rogers, Vice Chair
- Lewis L. Peach, Jr., Board Secretary
- Hoyt Davidson, Near-Earth LLC
- Galen Ho, President Galen Enterprise
- Mary Alice Evans (representing the Director of DBEDT)
- Jim Keravala, Shackleton Energy
- Chancellor Donald Straney (representing the President of the University of Hawaii)
- Rob Kelso, Executive Director, PISCES, Ex-Officio, Voting
- Dr. Daniel J. Rasky, NASA-Ames, Ex-Officio, Non-Voting

The Board has met four times in fiscal 2013: November 1, 2012; November 11, 2012; December 14, 2012; March 12, 2013.

**Management**

The Director of DBEDT appointed Robert M. Kelso to be the Executive Director of PISCES and the Board of Directors confirmed his appointment in November 2012. He was hired through the Research Corporation of the University of Hawaii (RCUH) on February 25, 2013. The Executive Director supervises all current PISCES personnel and provides direction for all of their activities and projects. The chart below lists current PISCES positions.

Position	FTE	Incumbent	Start Date
Executive Director	1.0	Rob Kelso	02/25/2013
Executive Assistant, Office Administrator	1.0	Polly Roth	03/01/2013
Manager, Test Operations	1.0	Christian Andersen	02/20/2013
Manager, Test Logistics, EPO	1.0	John Hamilton	02/20/2013
Public Information Officer	0.5	Mari-Ela David Chock	05/20/2013

The Executive Director meets quarterly with the Deputy Director of DBEDT and the Director of the Office of Aerospace Development to provide a budget status report and an update on programmatic progress.

PISCES has continued with the previously assembled Community Cultural Advisory Committee (Papa A’oa’o) which was originally formed in 2007. This committee is composed principally of Native Hawaiian professionals and cultural practitioners and its role is to provide advice to PISCES Management and Staff on conducting operations in a culturally aware and sensitive manner. This year PISCES hosted an inaugural meeting outlining the broader mission and soliciting greater interaction between the Cultural Advisory Committee and PISCES management. The committee will meet two to three times a year. In addition, individual members may be consulted in their particular area of expertise on an ad hoc basis as issues arise or new projects are undertaken. Two new members were recruited to bring the committee membership to nine. The new members are Dr. David Sing, Director of Na Pua Noe’au and Dr. Gregory Chun, previously of Kamehameha Schools/Bishop Estate and now with Awa Kele LLC.

**Administration**

DBEDT’s decision to contract with the RCUH for fiscal and human resources services was key to effecting a smooth transition for PISCES administrative operations. DBEDT and RCUH entered into an agreement on December 6, 2012 that would assure the provision of these services through December 31, 2013, with the possibility of extending the agreement, one year at a time, through December 31, 2015.

RCUH was established by the legislature in 1965. They are an effective administrative organization. In FY 2012, their volume of business was \$484M. RCUH has mature and tested procurement, accounting and human resources policies, procedures and forms. They have secure on-line financial and human resources portals for entering and approving purchases, payments and personnel actions. Up-to-date financial and human resources information can be viewed on line and downloaded for customized reports.

By contracting with RCUH, DBEDT assured that all funds provided to PISCES would be governed by, and would follow, all RCUH policies and procedures, thereby conforming to relevant laws and regulations. There is a system of checks and balances in place. Purchasing and hiring actions are initiated at the project level, they are approved by a Fiscal Officer at RCUH and by the Principle Investigator on the account (Deputy Director of DBEDT) or a Co-PI (PISCES Executive Director or Office Administrator).

There are few administrative situations that are not covered by RCUH policies, procedures and guidelines. As we discover areas that need to be clarified or expanded to cover PISCES operations, we develop PISCES-specific policies and procedures. Examples of PISCES-specific policies are those covering volunteer operations and use of the PISCES vehicle.

In addition to establishing governance, management and administrative functions during Fiscal 2013, PISCES staff located, leased and furnished an off-campus office near the State and County offices in Hilo. The facility has a private office, an administrative area, a conference room and general space with four desks that can be used by PISCES staff, interns and visitors.

## **E. Updated business plan for the aerospace technology research and development park project**

The critical pieces that PISCES must understand and consider for the successful implementation of an Aerospace Technology Park are: location, land & infrastructure; park management; and anchor tenants.

### Location

To be desirable to potential tenants, the location of the park is critical. The choice of location should derive from a number of factors that contribute and facilitate commercial activities.

- Labor Skill: Available labor needs to have adequate skills to perform desired work and an adequate workforce training program in the community.
- Cost of Living: The cost of living needs to be reasonable enough to minimize expenses to the business and employees.
- Accessible Distribution Points: Shipping facilities (ports, freight, and airports) must be easy to access and preferably underutilized (to accommodate increased traffic with minimal infrastructure improvements).
- Business Incentives: Any County, State and Federal business incentives should be attainable. In Hawaii this can mean Enterprise Zones, Federal Trade Zones, and qualifiers for grants (e.g. rural for USDA grants).

PISCES has been working with Hawaii Community College, Hawaii TechWorks, County of Hawaii Research and Development, University of Hawaii at Hilo and others to identify and quantify these factors.

### Land & Infrastructure

PISCES will need to develop the Aerospace Technology Park on either public land, private land, or a combination of both. Factors that need to be considered in land choices for the park are:

- Cost of Development: High cost to develop the infrastructure needed for a tech park (roads, water, sewage, electric, fiber optics, etc.) makes it difficult for PISCES to develop the park on undeveloped State lands. The most cost- and time-efficient route will be to leverage pre-existing public and/or private business/industrial/research parks with emplaced infrastructure.
- Lease-Hold or Fee Simple
- Ease of access/building/zoning

PISCES has consulted, and will continue to consult, with the County of Hawaii, the State of Hawaii, NELHA, W.H. Shipman, University of Hawaii at Hilo, Maui Research & Technology Park and others to understand the options available.

### Park Management

To better understand how PISCES will structure the park management and the models for cash flow, PISCES is consulting with: NASA AMES and studying their AMES Research Park model; Google and their Google Campus in Sunnyvale; Maui Research & Technology Park; and the NELHA model. PISCES has met with the Directors of the High Technology Development Corporation and the Director of the Hawaii Strategic Development Corporation to understand what roles they may be able to fulfill in a planned park. Specifics being studied are:

- Cash Flow Models
  - Sales or Rentals
  - Membership Fees
- Overhead Costs
- Methods to Receive Payment
- Incubators

PISCES is continuing to collect the various parameters for a DAGS Site Selection Survey and the information needed to develop the Aerospace Technology Park business plan. PISCES plans to have both finished by the end of 2013.

## **F. Progress made toward the development of a world-class space center for Hawaii**

### **Executive Summary of July 2012 ISRU Testing**

- PISCES conducted a 3 week Analog Field Test with NASA and the Canadian Space Agency. It was the most ambitious test to date, with operations at one site (Pu`u Haihawine) focused on a Lunar Polar Mission operations scenario conducted by a Mission Control situated a mile away. This was for the NASA Resolve program (tested twice before here in 2008 and 2010) along with the CSA Artemis Jr. robotic rover. The test was an overwhelming success and now the program has been slated for a Lunar Mission in November 2017 (Lunar Prospector). Operations were also performed simultaneously at a second higher elevation site ("Apollo Valley") conducting simulations with a Canadian contractor Juno robotic rover and astro-geologists as part of the Moon-Mars Analog Missions Analog (MMAMA) program of NASA.

### **Acquisition of PISCES rover from ODG**

- Collaborations with Ontario Drive Gear (producers of the rover platforms for the last 2 field tests) have resulted in an extended lead agreement for PISCES use of the Juno robotic rover. We expect delivery in late summer/early fall. This rover will play a central role in further PISCES research, activities and tests.

### **PISCES Facility Users Guide**

- PISCES Form 100 - PISCES is producing a Facility Users Guide to aid future researchers on our capabilities and test sites, later to include our projected base support facilities. Central to this is the Form 100 survey detailing test parameters with customers. PISCES has completed the product development of the Form 100 and has already initiated the form to upcoming customers for test coordination.

### **Field Site Characterization Summary**

To better serve a diverse customer base with varied testing needs, PISCES started a detailed inventory of potential analog test sites in Hawai'i. The site inventories capture geographic, biologic, geologic, logistic, visual, cultural, and land management information for incorporation into a GIS accessible database.

Some specifics that we are capturing are:

- Geographic
  - slopes and inclines of topographic features
  - Degrees of vegetation
  - GPS waypoints
- Biologic
  - Native and invasive flora and fauna identification
    - Photographic cataloging of flora and fauna
    - Identification of endangered and threatened flora and fauna
    - Identification of critical habitats
- Geologic
  - Flow ages
  - Soil types via USDA satellite imagery and visual survey
  - Soil composition
  - Soil size distribution
  - Flow rates (in lava tubes)
- Logistic
  - Degree of ingress and egress to site
  - Proximity to food, gas, and lodging
  - Site ownership and permitting to be required
  - Maximum supportable field test size
- Visual
  - High resolution 3D, panoramic, and geotagged photos of site and points of interest.
  - Establishing ground truth of aerial and satellite imagery
- Cultural
  - Surveyors are to be aware of, and record, any potential areas of cultural history.

- Management
  - Information on ownership of land, Ahupua`a, land use designation, etc

The site surveys started in June of 2013 with 3 PISCES' student interns and 1 PIPES intern. The interns were upper classmen and graduates of UH Hilo with strong backgrounds in geology, geography, GIS, and environmental science. Due to the comprehensive nature of the site surveys, PISCES has been engaged by Bishop Estates and Kamehameha Schools for possible collaboration assessing sites on their lands. Their interest has highlighted the benefit these surveys may offer to private landowners and the role PISCES can play.

#### **News release - "Mars Dirt Similar to Hawaiian Volcanic Soil"**

- On October 30, 2012, NASA held a press conference to release exciting results from the CHEMEN instrument onboard the Mars Science Laboratory – Curiosity Lander/Rover. The CHEMEN instrument had been tested in 2008 in a PISCES Mars analog site on the slopes of Mauna Kea in preparing for flight. Incredibly, the CHEMEN instrument sampled the volcanic material at Gale Crater on Mars and found the soil/basalt to be identical to the slopes of Mauna Kea. The following day, November 1<sup>st</sup> 2012, the world-wide press carried headlines of the vast similarities between the basalt materials on Mars and those of Hawaii. This scientific evidence further validates that the planetary analogue test sites in Hawaii are among the world's finest!
- <http://www.space.com/18286-mars-rover-curiosity-soil-analysis-chemin.html>

#### **Manifest of upcoming user testing in planetary analogue sites**

- Team Puli – Fall 2013
  - PISCES has embarked on a campaign to attract all of the 23 international Google Lunar X-Prize competitor teams to perform high fidelity tests in Hawaii. This began with the participation of White Label Space team during our conference in November 2012 with a one day mini-test with their rover prototype. Results were encouraging, so we are planning a Summer 2014 field test of their flight hardware. In March 2013, the GLXP Moonbot Hungarian high school grand prize winners accompanied by the GLXP Hungarian sponsor members of Team Puli arrived in Hawaii to use a PISCES test site. They were pleased enough with our test site to plan a November 2013 field test. Another GLXP team (US based Astrobotics) are collaborating with PISCES for future testing of their rover for initial and follow up missions. (see grants)
- NASA collaborative projects (preliminary phase): JPL – AXEL 2015
  - Multiple opportunities exist for robotics testing with NASA. One such opportunity is further testing with the JPL AXEL rover system, a novel modular robot that can access challenging terrain such as cliffs and craters. Another prospect is from JSC, a game changing Development Program of deploying mini science payloads from a single lander via a catapult mechanism. Two more potential opportunities involving NASA Ames are the testing of robotic deployment of a radio telescope array planned for the lunar far-side and well as teleoperation of rovers in Hawaii from the orbiting International Space Station.
- Astrobotics -2014
  - The Google Lunar X-Prize (GLXP) team Astrobotics is considering several visits in 2014 for analog field testing of their robotic lander and exploration rover. Astrobotics is a team comprised of Carnegie Mellon University and their Robotics Institute. The exploration rover is designed to enter and explore sub-surface voids found recently on the moon. Analogs here in Hawaii suitable for testing such hardware include lava tubes and their skylights, volcanic pit craters and also large

volcanic cracks such as the Great Crack in Ka`u. PISCES is a collaborator on a NASA research grant proposal with Astrobotics for supplemental funding of these tests.

- Japan / White Label Space – summer of 2014
  - Another GLXP team, White Label, is also considering field testing of their flight hardware systems in the timeframe of 18 months. The White Label team is a consortium of European and Japanese collaborators, with the robotics element being led by Tohoku University in Japan. A prototype rover was brought to Hawaii and exhibited at our PISCES conference. This rover performed a one-day trial excursion at our analog test site on the slopes of Mauna Kea. Results were encouraging and highlighted the value of field testing at such a high fidelity lunar test site.

## **G. Development of technologies for basaltic concrete composition**

### **Regolith, Resources and Recovery (R<sup>3</sup>)**

- In April of 2013, PISCES led and submitted (through UH Hilo) a grant proposal for \$6,000,000 over 5-years to NASA. The proposal outlines a detailed characterization of lunar regolith and meteorites on Earth, which are samples of near-Earth asteroids, to address fundamental science problems and to set the stage for a series of materials science and engineering experiments. The engineering data gathered from the proposal will provide much of the research and development needed to move PISCES' sustainable basalt concrete forward in the State of Hawai'i. The proposal's Co-Investigators are leaders in their respective fields and contribute to an impressive consortium of universities and research institutions. Contributing to the consortium are: University of Hawaii, Manoa; University of Hawaii, Hilo; Notre Dame; Missouri University of Science and Technology; Hanyang University; NASA Kennedy Space Center Swampworks; NASA Marshall Space Flight Center; The Institute for Structure and Nuclear Astrophysics (ISNAP); and the International Space Exploration Research Institute (ISERI).

### **3-D laser printing with basalt fines**

- There is a need in space exploration for in-situ methods for parts fabrication on the Moon, Mars, and Asteroids. This need is driven by cost and time. The European Space Agency (ESA) and NASA have begun actively investigating 3D additive manufacturing methods using fine basalt dust. In Hawai'i, this fine basalt dust is presently a waste product of quarries.

PISCES is pursuing opportunities to purchase a Selective Laser Sintering (SLS) 3D printer. SLS printers form objects out of metallic and ceramic powders and have high potential for use of basalt fine dust. PISCES is discussing with Hawaii Community College the shared use of a PISCES acquired printer for course development and student training on an advanced manufacturing test bed.

### **KSC basalt bricks with Mauna Kea fines**

- Early testing of manufacturing building material components ("bricks") was successful. Hawaiian tephra fines from our field test site were sent to KSC for use in their labs where they

successfully produced 3 cube samples with a polymer binder and well as a sample bonded by heat sintering. Results are encouraging for further research.

#### **Basalt for sidewalk construction / ISERI**

- PISCES is working with the County of Hawaii (through Hawaii County R & D) and Hanyang University (Korea) to prototype a non-cement portion of a sidewalk. We are working with the County of Hawaii to identify a suitable location. This prototype sidewalk will provide PISCES with data on durability and structural integrity.

### **H. Status of all working relationships with educational and research institutions, federal agencies, and local industries; to include the use of existing basalt resources in the State to identify, verify and validate sustainable and in-situ concrete binders**

#### **PISCES/NASA Space Act Agreement (SAA) Overview**

- A fully reimbursable Space Act Agreement between PISCES and NASA Kennedy Space Center (KSC) went into effect in April of 2013. Under the SAA, PISCES will reimburse NASA for the costs associated with the help it receives. KSC will provide technical support of PISCES projects that involve developing advanced-human robotic systems and other technologies required for space exploration beyond low orbit Earth when such support is not available from commercial sources. Projects may include technical services related to the Hawaii Space Exploration Analog and Simulation (HI-SEAS) Mission Operations, advanced architecture concepts, development for interconnecting PISCES communications systems with other partner sites, advance regolith manipulation techniques, and advanced habitation systems and technology development. The SAA is for five years. PISCES is now seeking a non-reimbursable SAA with NASA.

#### **Regolith, Resources and Recovery (R<sup>3</sup>)**

- R<sup>3</sup> notice of intent (NOI) was submitted in February of 2013 and the full proposal was submitted in April of 2013. Selection/Announcement of the proposals will be made at the Division for Planetary Sciences conference in early October. If awarded, funding is anticipated to begin in January of 2014.

#### **CAVES**

- PISCES is a co-investigators in a NASA research proposal collaborating with Carnegie-Mellon University Institute of Robotics and the GLXP team Astrobotics for investigating, access and survey methods of recently discovered lunar features of subsurface openings that resemble lava tube skylights. Analog testing on the Big Island at similar geologic sites (lava tubes, volcanic pit craters, cracks) will be very valuable.

#### **ISTVS**

- Discussions are underway with the International Society of Terrain-Vehicle Systems (ISTVS) to identify opportunities for future collaborations and equipment loans. PISCES will participate in the annual ISTVS meeting in November 2013.

## **UNSW**

- PISCES and the University of New South Wales (Australia) entered into a MOU to explore mutual interests in sustainable concretes and to work towards student intern exchanges.

## **USC Contour Crafting**

- PISCES and the University of Southern California have entered into a MOU to work together on applying USC's Contour Crafting (3D printing on a construction scale) technology in Hawai'i using sustainable binders (non-portland cement) in the concrete mixtures.

## **Korea ISERI**

- PISCES and the International Space Exploration Research Institute (ISERI) entered into a MOU in November of 2012. This MOU was to work on shared interest and research into lunar concretes. As a result of the MOU: ISERI is part of PISCES' "Regolith, Resource and Recovery" proposal; ISERI and PISCES are working together to install a prototype sidewalk; ISERI has invited PISCES researchers to work in a researcher exchange in South Korea.

## **LADEE intern program**

- PISCES is continuing to support the ground based data collection of optical lunar impact events with our high-speed data cameras. This continues with support of an Akamai Workforce Development Program intern for a 7-week program. The Lunar Atmosphere and Dust Environment Explorer (LADEE) is a robotic mission that will orbit the moon to gather detailed information about the lunar atmosphere, conditions near the surface and environmental influences on lunar dust. Our internship program (in collaboration with the Akamai Workforce Program) will assist with the collection of ground based observations of meteor impacts on the lunar surface, which are known to be contributors to the dust environment. A global effort before, during and after the LADEE mission is an important calibrator for this mission in order to help determine the causes of this temporary lunar exo-sphere. Understanding of the nature and movement of dust will be critical for any future lunar exploration or commercial development, manned or robotic.

## **Field Site Characterization intern program**

- For ten weeks during the summer of 2013, PISCES had 4 University of Hawaii at Hilo interns. Of these, 3 were hired by PISCES and 1 by the Pacific Internship Programs for Exploring Science (PIPES) program. The interns were upper classmen and graduates of UH Hilo with strong backgrounds in geology, geography, GIS, and environmental science. They performed site surveys, constructed a GIS database, and presented at various venues.

## **Pacific Astronomy and Engineering Education Summit**

- The Pacific Astronomy and Engineering Education Summit will be held in Hilo July 22-26, 2013 and is sponsored by the Thirty Meter Telescope (TMT). PISCES is preparing to present a student design brief on methods for mining asteroids. The student design

brief is a team-oriented exercise that has students solving real-world challenges through hands-on interaction. PISCES has been preparing the design brief content and focus to address the challenges NASA and commercial interests will face with activities on low gravity bodies like asteroids and the moons of Mars.

## **LUNABOTICS**

- PISCES served as an invited judge for the 4th annual Lunabotics Competition held at KSC. This university-level event is the culmination of a year-long process in which student teams design, build and demonstrate a robotic system that can navigate and excavate regolith material and return it for off-loading. This is a critical component of future In-Situ Resource Utilization (ISRU) methodology which has now become the cornerstone of all future lunar and planetary exploration and development. Use of native resources for survival (oxygen, water) and for commercial applications (rocket fuel, precious metals) is essential for mission planning. The centrality and viability of ISRU technology has been the focus of the past three PISCES field tests held here. PISCES is exploring the concept of extending this competition to use our analog field test sites as part of an international grand challenge. This concept was validated when the 2012 Lunabotics winners (University of Alabama) tested their robot at our test site during last year's PISCES conference.

### **I. Development of robotics operator training and certification program and curriculum development**

PISCES is developing an operator's course for Search and Rescue robotics systems along with facilitating acquisition of pilot systems (ground system rovers, aerial systems like quad-copters, and marine systems). Future applications for government agencies and public-private partnerships are plentiful, and the need for trained workforce is coming.

### **J. Level of private sector investment in aerospace and related partnerships with industry to facilitate state-based manufacturing, and operations in green energy**

- Hawaii Tech Works
  - PISCES has been working closely with Hawaii TechWorks to coordinate joint efforts in bringing needed manufacturing skills and technology to Hawai'i Island. Additionally we have begun talks to have Hawaii TechWorks work on the design and conversion of a shipping container for mobile ground support operations (command and control, situational awareness, and electronics repair)
- Planetary Power Inc. (PPI)
  - Planetary Power Inc. (PPI) is a manufacturer of portable and stationary renewable energy power systems. Their primary concentration is on biodiesel generators with thermodynamic capture of waste heat and solar concentrator units. PISCES has been working with PPI since November of 2012 to bring their units to Hawaii for testing. In April 2013 PPI installed one of their units on Mauna Loa at the HI-SEAS Mars analog habitat and their Chief Technical Officer

had the opportunity to meet with PISCES and discuss the potential for PPI to locate manufacturing and distribution for their Pacific Rim operations. This meeting was followed up by a series of meetings in mid-July between their COO & President and local groups. They met with County of Hawai'i R & D, W.H. Shipman, Hawaii County Council members, Hawaii TechWorks, and others to assess opportunities in Hawai'i.

### **K. PISCES 2013 Summer Intern Program**

PISCES established a formal intern program for summer 2013, hiring five interns. Three of the interns were hired as temporary RCUH employees, one is sponsored by the University of Hawaii's Pacific Internship Programs for Exploring Science (PIPES), and the fifth comes to us through the Akamai Workforce Initiative (partnering with the UH Institute for Astronomy, Center for Adaptive Optics and UH-Maui College). The internships provide valuable work experience for the students, enhance PISCES relationships with University and workforce resources, and produce valuable information for future operations.

Four interns with backgrounds in geology, environmental science and database development are working on a site characterization project that includes both the design and population of a database that catalogs key characteristics of several potential analog sites on the island of Hawaii. This is the first year of a multi-year project that will result in a searchable database that will aid future analog site users in identifying the perfect site for their project.

The Akamai intern is working with John Hamilton gathering data for NASA's Lunar Atmosphere and Dust Environmental Explorer Mission that will be departing for the Moon on August 12<sup>th</sup>. They will be using two 11" telescopes and high speed video cameras to measure the impact and frequency of meteor strikes on the far side of the moon. This data will be used by NASA to help quantify possible dangers inherent in living on the lunar surface.

### **L. Memorandums of Understanding (MOU) regarding cultivation of skilled local workforce to support planned manufacturing operations**

A skilled workforce is a crucial need when introducing high technology jobs and equipment. To this end PISCES has entered into Memorandums of Understanding with Na Pua No`eau, Planetary Power Inc., and Hawaii TechWorks. PISCES also meets and updates Hawaii Community College, the University of Hawaii at Hilo, the County of Hawaii, the County Councils for the State of Hawaii, the Hawai'i Aerospace Advisory Committee, educators like Art Kimura, Na Pua No`eau, the Chamber of Commerce, the Rotary Club, and Tech Tuesdays (Hawaii TechWorks public talks) to share our vision forward and the skills needed to achieve that mission.

**M. Detailed statement of assets, liabilities, revenues,  
and expenses for FY13 ending June 30**

Act 169 formally transferred all assets and obligations associated with PISCES from the University of Hawaii to DBEDT effective June 30<sup>th</sup>, 2012. The only capital asset (value of \$5K or more) assigned to PISCES was a 2006 Chevrolet Silverado K1500 pick-up truck. For practical reasons, this truck remains assigned to the University of Hawaii for use by PISCES. PISCES pays for the operation, maintenance and care of this truck.

The first expenditure of Act 169 funds did not begin until the engagement of staff in late February. There have been, to date, no purchases of capital assets. Non-labor liabilities as of June 30, 2013 are low, with outstanding invoices already encumbered and totaling less than \$500. June 2013 payroll expenses to be paid in July are \$21.8K. The table shows the budget, expenditures, encumbrances and the balance of funds remaining as of June 30, 2013.

COST CATEGORY	AWARDED	EXPENDED THRU 6/30/2013	OUTSTANDING PURCHASE ORDERS	TOTAL EXPENDED & COMMITTED	AVAILABLE BALANCE
Salaries & Fringe	\$341,000	\$143,219	\$0	\$143,219	\$197,781
Controlled Property	\$18,000	\$8,776	\$0	\$8,776	\$9,224
Materials & Supplies	\$11,000	\$2,873	\$1,433	\$4,306	\$6,694
Travel	\$52,000	\$19,382	\$1,000	\$20,382	\$31,618
Consultant/Fee for Service	\$24,000	\$14,021	\$10,000	\$24,021	(\$21)
Printing/Publication	\$1,000	\$229	\$0	\$229	\$771
Communication	\$5,000	\$1,965	\$0	\$1,965	\$3,035
Equipment	\$0	\$0	\$0	\$0	\$0
Repairs & Maintenance	\$3,000	\$1,344	\$139	\$1,483	\$1,517
Rental-Space	\$20,000	\$8,841	\$5,626	\$14,467	\$5,533
Other Current Expenditures	\$10,437	\$4,582	\$0	\$4,582	\$5,855
Direct Costs Total	\$485,437	\$205,233	\$18,198	\$223,431	\$262,006
Indirect Costs	\$14,563	\$6,157	\$0	\$6,157	\$8,406
Grand Total	\$500,000	\$211,390	\$18,198	\$229,588	\$270,412

PISCES will not have access to FY14 funds until late August or early September due to the time required to complete normal administrative steps within the state system. Some of the FY13 funds remaining as of June 30, 2013 can be used to cover PISCES operations costs until the FY14 funds are available. The remainder will be used to purchase essential test hardware for future PISCES operations. The following table below shows the plans for funds remaining as of June 30, 2013. These funds will be fully expended before December 31, 2013.

COST CATEGORY	AWARDED	TOTAL EXPENDED & COMMITTED THUR 6/30/2013	AVAILABLE BALANCE AS OF 6/30/2013	PROJECTED OPERATING COSTS JUL 1 - SEP 30	REMAINING FOR TEST HARDWARE PURCHASES	TOTAL PROJECTED EXPENSES THRU 12/31/2013	PROJECTED VARIANCE FROM BUDGET
Salaries & Fringe	341,000	143,219	197,781	156,337		299,557	41,443
Controlled Property	18,000	8,776	9,224	5,000		13,776	4,224
Materials & Supplies	11,000	4,306	6,694	3,150		7,456	3,544
Travel	52,000	20,382	31,618	18,464		38,846	13,154
Consultant/Fee for Service	24,000	24,021	(21)	12,300		36,321	(12,321)
Printing/Publication	1,000	229	771	-		229	771
Communication	5,000	1,965	3,035	1,530		3,495	1,505
Equipment	-	-	-	-	58,820	58,820	(58,820)
Repairs & Maintenance	3,000	1,483	1,517	500		1,983	1,017
Rental-Space	20,000	14,467	5,533	1,610		16,077	3,923
Other Current Expenditures	10,437	4,582	5,855	1,950		6,532	3,905
Direct Costs Total	485,437	223,431	262,006	200,841	58,820	483,092	2,345
Indirect Costs	14,563	6,157	8,406	8,693	2,059	16,908	(2,345)
Grand Total	500,000	229,588	270,412	209,534	60,879	500,000	0

The delay in availability of FY13 funds until December 2012 resulted in a delay in hiring PISCES staff. This delay produced a \$41K underspend in the salaries and fringe budgets. There were corresponding underspends in the rental, supplies and communications line items. Travel plans were curtailed in order to reserve budget for strategic consulting expenses which include redesigning the website, research park business model consulting services and the initial expenses for the Mare Volcanism Conference to be held in Houston in the coming year. Smaller variances from the other line items were added to the savings in the salaries & fringe in order to create a budget to begin to purchase essential test and design equipment.

## **N. Appendices**

**Appendix 1: Final Report – Lunar analog Field Demonstrations of In-Situ Resource Utilization & Human Robotic Systems**

**Appendix 2: Media outreach, website development, branding, newsletter - 2013**

**Appendix 3: Education/Public Outreach**

## **Appendix 1: Final Report – Lunar analog Field Demonstrations of In-Situ Resource Utilization & Human Robotic Systems**

### **Technical Progress Report Two Year Report**

#### **ISRU ANALOG FIELD DEMONSTRATIONS OF IN-SITU RESOURCE UTILIZATION AND HUMAN ROBOTIC SYSTEMS**

**Performed under  
NASA Cooperative Agreement NNX11AH92A**

Submitted by  
John Hamilton (PI) and Christian Andersen (Co-I)  
University of Hawai`i-Hilo, Dept. of Physics & Astronomy

### **Introduction**

The Cooperative Agreement began on March 3, 2011 with the initial award for preliminary preparations associated with the upcoming summer 2012 test on Hawaii Island, Hawai`i. The 3rd International In-Situ Resource Utilization (ISRU) Analogue Field Test was conducted July 10th to the 23rd, 2012. All project close-down activities were completed by December 31, 2012.

This report summarizes the activities completed under the requirements and scope of work (SOW) of the subject cooperative agreement.

### **Description of Performing Organization**

The University of Hawai`i – Hilo (UHH) is the UH system outer island campus situated with a rural setting in close proximity to available analog site while the flagship campus (University of Hawai`i – Mānoa) is situated in urban Honolulu. The UHH Department of Physics and Astronomy has participated in two previous analog field demonstrations that were performed at a 9,200 foot elevation test site in November 2008 and January/February 2010. Expertise and experience was gained during prior work as staff with Pacific International Space Center for Exploration Systems (PISCES). For these tests PISCES was the lead local organization that provided logistical support for the organizations that came to Hawai`i to utilize the close similarity of soil, geology, geochemistry and terrain to that found on the Moon and Mars. On July 1, 2012 PISCES was legislatively transferred from the University of Hawai`i system into the State of Hawai`i Dept. of Business, Economic Development and Tourism (DBEDT) as an attached agency reporting to the Office of Aerospace Development (OAD).

### **Description of Test**

The technical purpose of the 3rd International Hawaii In-Situ Resource Utilization (ISRU) analogue field test is to perform robotic mission simulations of resource prospecting and science before human crew arrive. The analogue test includes two mission simulations:

1. A mission simulation to locate, characterize, and map water/ice and other volatiles that may be present at the lunar poles using the Regolith & Environment Science and Oxygen & Lunar Volatile Extraction (RESOLVE) experiment on the Canadian Space Agency (CSA) Artemis Jr. rover.

2. Evaluation of Moon Mars Analog Mission Activity (MMAMA) instrument ability to perform science investigations associated with rover-based planetary surface (Moon or Mars) exploration using fixed instruments and instruments mounted on a CSA Juno II rover.

3. Perform rover mobility characterization activities.

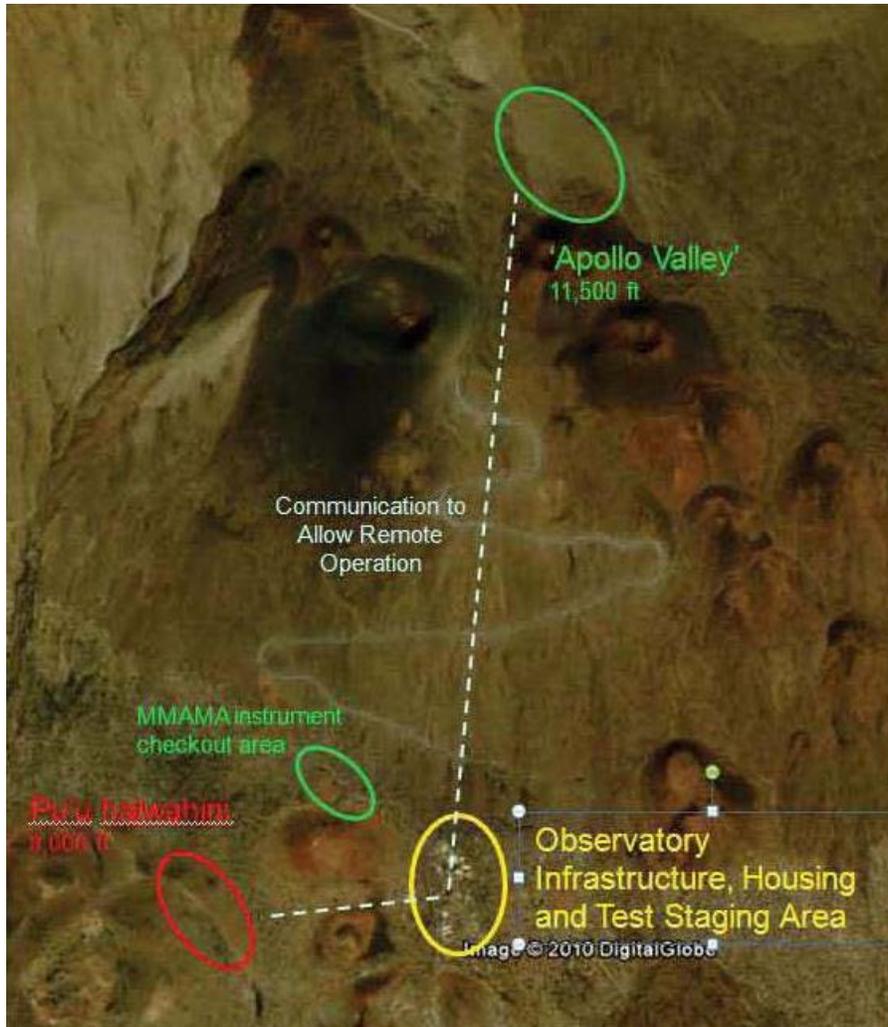


Figure 1 Overview map of Operations Area

### Description of Test Sites

To support the technical objectives of the test, multiple analogue sites were selected and incorporated into a unified program.

The RESOLVE simulation was performed at the Pu`u Haiwahine valley test site (9,000 feet elevation) previously used in the 2008 and 2010 tests. The fine volcanic tephra and ash found here is an excellent lunar regolith simulant and the terrain of the valley lent itself well for multiple traverses. A support camp was created here for repair and maintenance and supplies.

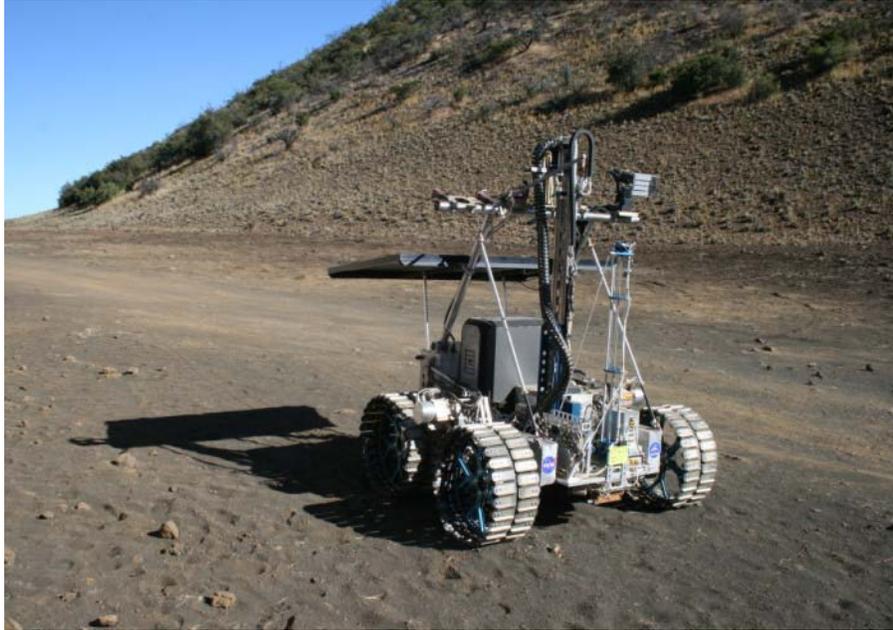


Figure 2 Artemis Jr. with RESOLVE and Norcat drill in Pu'u Haiwahine Valley.



Figure 3 Support camp behind Artemis Jr. sans drill package.

The MMAMA activities were conducted at a site near 11,500 feet elevation in an area below the Mauna Kea ice-age glacial terminus called "Apollo Valley". This area lies on the tri-border between the Mauna Kea Science Reserve, the Mauna Kea Ice Age Natural Area Reserve and the State Forestry lands. A MMAMA instrument and rover check-out area was also supported near the Mauna Kea summit access road and Hale Pohaku on the upper Pu'u Haiwahine access 4wd road.

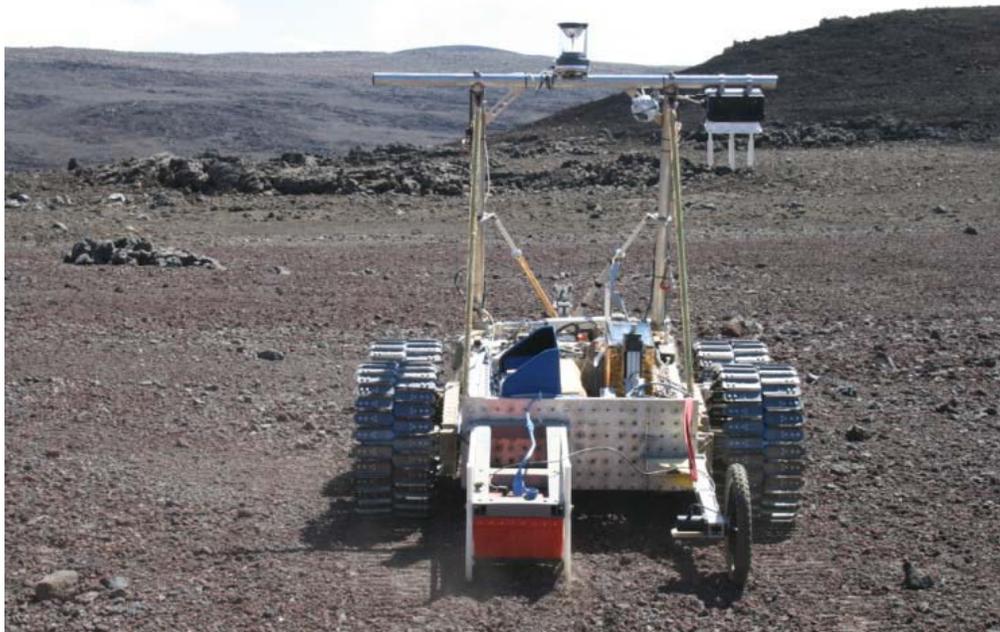


Figure 4 Juno II rover with MMAMA instruments at Apollo Valley.



Figure 5 Juno II egress into Apollo Valley with support team

Mission Control was established at a third location, allowing simultaneous command and control for both sites. This was housed at the nearby Ellison S. Onizuka Center for International Astronomy (aka Hale Pohaku) at 9,200 feet (2800m) elevation. The library was transformed into the control center, along with several support offices (including a devoted MMAMA control center in the downstairs Exercise Room).



Figure 6 Hale Pohaku Facilities.



Figure 7 Mission Control at Hale Pohaku library.

## Implementation of Operations

### A. Permits and permissions (cultural and legal)

Prior to formal permit applications, presentations were made to the PISCES Cultural Advisory Committee to establish proper protocols for access, use and restoration. A cultural and environmental awareness program was performed (via internet) with all participating staff prior to arrival. Permissions and blessings were conducted with an appropriate Hawaiian elder (kupuna) and kahuna on all test sites.

Permits were received from the Division of Forestry and Wildlife (DoFaR), Department of Land and Natural Resources (DLNR) for the operations in Pu'u Haiwahine valley for the month of July, allowing site preparation, camp and infrastructure deployment as well as survey of planned traverse routes. Permits for the Apollo Valley use was also obtained from DoFaR. Access to the valley is from the paved Mauna Kea access road (Gov. John Burns Way) which connects the Hale Pohaku facilities with the summit (a designated Science Reserve). The University of Hawai'i Office of Mauna Kea Management (OMKM) manages access on these areas overseeing a mixed use of science research, environmental preservation, historic site stewardship and commercial tour activities. This necessitated close attention to

interagency overlap and varying restrictions and regulations. Presentations were made to the OMKM Cultural Committee (Kahu Ku Mauna) as well as the Mauna Kea Management Board. Due to locations of historical sites, an archaeological survey by a certified expert was conducted and a "Letter of No Impact" solicited from the State Historic Preservation Department. OMKM regulations required the rediscovery on potentially impacted sites and onsite availability of our archeologist. Daily traverse maps (planned and actual) were reviewed each night to avoid proximity operations.

## **B. Researcher and Support Staff accommodations**

Meals and lodging were provided at the mess hall and dormitories of the Mid-Level Support Facilities (Hale Pohaku). These were originally built to support operations of the multiple Mauna Kea Observatories at the 13,805 feet (4207m) elevation summit, but have become available for associated uses due to the increasing vacancies resulting from remote observing and remote control of the observatories. Co-location at Hale Pohaku (9,200 ft, 2800m) allowed acclimating to high altitude conditions and also allowed a full work day since the commute was quite short. Rapid after-hours response was also aided by this. Approximately 45 personnel were housed at the facility. A few personnel (23) elected to commute (~1 hour) to hotels in Hilo or Waikoloa areas.

UHH undergraduates (~40 total) were employed as laborers, drivers, field and (in some cases) research assistants. They commuted due to the varying daily availability (summer school) and projected tasking (as well as expense). This aspect was also an integrated portion of our EPO, as all had some quality time with researchers. Enthusiasm level was high.

Private security was contracted for nocturnal monitoring in the Pu`u Haiwahine valley. Security for Juno II/MMAMA was provided by the locked trailer inside the locked and fenced VLBI compound.

## **C. Communications Infrastructure**

Operations at Apollo valley were facilitated by a communications loop that was wireless between the Juno II rover and an access point positioned above the valley on the overlooking cinder cones. This WiFi equipment was connected via a fibre optic and ethernet cable to the Very Large Baseline Interferometer (VLBI) facility managed by the National Radio Astronomy Observatory (NRAO). The VLBI sits at an altitude of 12,256 feet (3736m). The com link then connected to the Mauna Kea Fibre Optic Ring which connects all the observatories to the Hale Pohaku offices (and further to the Hilo and Waimea observatory headquarters). Because the VLBI is in the Mauna Kea Science Reserve and the WiFi link entailed a deployment across the terrain, not only was an archeology survey and monitoring required (due to possible burial sites in the cinder cones) but also the presence of the OMKM staff biologist since this area is within the rare wekiu bug habitat. All conditions were met and complied with for a successful operation.

Operations at Pu`u Haiwahine valley were facilitated by a Wireless Area Network established in the valley proper. This WAN was connected to the Hale Pohaku facilities by a repeater hop over the intervening cinder cone. This permitted operations in the valley as well as command and control from the MC at Hale Pohaku. Communications from MC to XDoc in Canada and JSC and KSC were provided over the existing high bandwidth fibre optic internet connection.

## Resolve Mission Simulation Support at Pu'u Haiwahine valley

Access to the valley is supplied by two public 4WD hunter roads from the north and south. The valley is approximately one mile from Hale Pohaku facilities. Both roads were prepared prior to the test, an upper (north) road for ingress and a lower (south) road for egress. This was done to minimize 2-way traffic, as both roads are fairly narrow. Prior to test start road conditions were assessed and improved by filling large ruts with rocks and coarse base and then with surface stabilizing mats composed of fabric and chain link fencing allowing traction on the loose surfaces. Steep grades and sandy stretches were covered with a combination of anchored and tensioned chain-link and burlap (to prevent the chain link from sinking into sand). The road was patrolled and patched (as needed) by our student road crew daily to maintain safety and drivability.

Tents were successfully erected and stabilized against wind at the planned locations. Plastic tarps were initially placed as tent flooring for dust mitigation, but static discharge concerns resulted in the use plywood flooring. The tents were supplied with multiple Honda 2000i (2kW) generators and a Winco Big Dog generator for an available 16kW continuous power. The lander mockup was supplied with one 2kW generator to support its coms assets. These generators were fueled at the end of each day, and were checked at least 3 times throughout each day. Combustibles (gasoline, diesel and reserve propane tanks) were safely stored at a clearly designated spot about 0.5 kilometers from activities.

A rough terrain forklift was present in at all times in the valley with a licensed operator during the work day. Additionally a Case skid steer was also present at the site with a front loader and auger. A second rough terrain forklift was kept at the staging area below Hale Pohaku to accommodate incoming and outgoing road cargo.

16 drill sites were identified by NASA personnel prior to operations along with corresponding traverses and a mock lander. Clearing vegetation from the traverses and target sites began one month prior to testing and was completed shortly after testing began. Vegetation removed was non-native and considered an invasive pest (primarily California Needle Grass). This aspect of the site preparation was deemed beneficial to the mission of DNLR by reducing competing species for the indigenous native species. Removal was by hand as heavy equipment grading was not permitted. Also performed manually to aide plant identification. Grading would also remove the surface fines which accumulate around the vegetation due to aeolian processes. This task came in behind schedule due to an underestimate of labor performance at altitude.

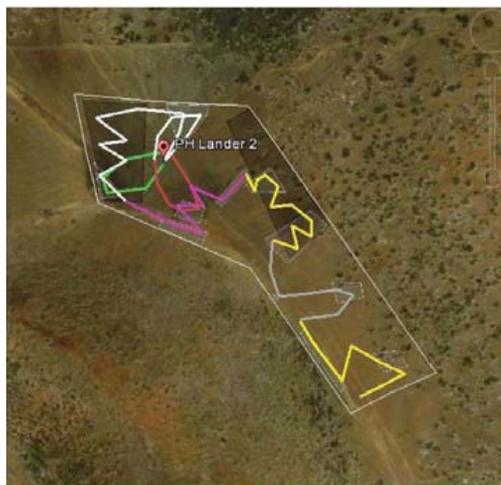


Figure 8 Resolve Traverse Path

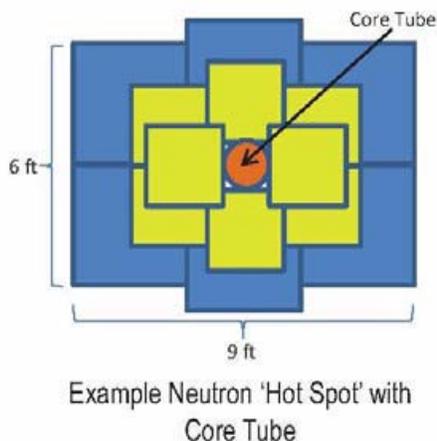


Figure 9 Subsurface poly sheet target pattern

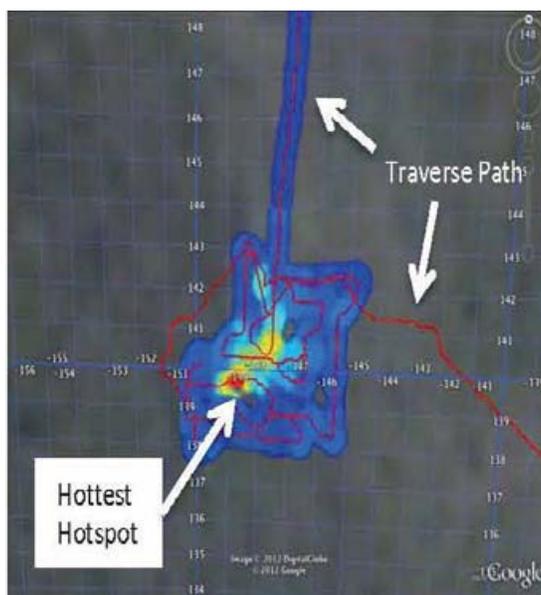


Figure 10 Neutron Spectrometer data

The identified target sites were excavated to accommodate 4 foot long, 8 inch diameter “drill tubes” which were later filled with sieved native material to remove large rocks. This material (tephra from the site) was previously dried to remove any moisture. Excavation was accomplished using a skid steer equipped with an 8 inch diameter auger bit after the two person hand power auger proved insufficient. After emplacement, different tubes were filled with material that was stratified according to moisture content. Each drill tube was buried an inch below surface level and surrounded by buried polyethylene sheets of varying diameter and thickness to emulate a H<sub>2</sub>O signal for the Artemis Jr. onboard neutron spectrometer.

### MMAMA Mission Support at Apollo Valley

The Juno II rover and science packages were initially field tested on the upper (north) access road to Pu`u Haiwahine valley. This area simulated native terrain but was adjacent to the Hale Pohaku facilities and just west of the Mauna Kea Access Road (Gov. John Burns Way).

On Day One of operations, the rover was transported to the Apollo Valley at a road maintenance pulloff which had a small ramp provided by the Mauna Kea Support Services road crew. Transport was via a custom covered trailer pulled by a 4WD pickup truck. After rover delivery, the trailer was then taken to the VLBI fenced compound. Upon completion of the day's activities, the rover would be picked up by the trailer and returned to the VLBI for overnight storage and battery recharge.

This scenario was necessitated by the requirement by OMKM that prohibited off-road parking in the area, as well as a safety precaution for the numerous tourist traffic. This procedure was beneficial in that operations did not attract any unauthorized and unpermitted visitors. (Nor distract tourists on the steep unpaved portion of the summit road). At the conclusion of the MMAMA operations, trailer and rover were returned to the Hale Pohaku staging area.



Figure 11 Juno II with Com Link on background cinder cone



Figure 12 Juno II / MMAMA traverse path



Figure 13 Rock climb

### Community and Public Outreach

Pursuant to permit requirements and community "give-back", multiple EPO activities were conducted on island. Classroom visits to the Hilo (east) side were performed with the Ames Research Center Exploration Uplink educational internet controlled mini-rovers were conducted with PISCES and Ames personnel. While at Hale Pohaku, an EPO activity was conducted at the Mauna Kea Visitor Information Station (VIS) for the staff and general public visiting the observatories. Following accepted local protocol, a community and cultural "Mahalo" function was conducted on the Kona (west) side of the island at Pu`u Waa Waa ranch. A press day was conducted at the test site with coverage from print (Honolulu Star Advertiser, Hawaii Tribune Herald and West Hawai`i Today) and broadcast media (Big Island Video with feeds to the Honolulu news stations).



Figure 14 Juno II



Figure 15 ARC EU mini rover



Figure 16 Artemis Jr.

Due to the remote location and 4WD access to the sites (as well as restricted personnel at Apollo Valley), our keystone public education and outreach was conducted in Hilo. The culmination event was a public outreach day at the `Imiloa Astronomy Science Center at the University of Hawai`i-Hilo campus. A large visitor count ensued with the rovers and hardware on display and demonstration in the parking lot. Science and Mission presentations were conducted in the Planetarium. Ames EU rovers were popular with the keikis (youth). A live AM radio broadcast was held which carried interviews of team along with local dignitaries such as State Senator Gil Kahele and County Councilmember Dennis Onishi.

### **Post Test Activities**

After the `Imiloa event, equipment was returned to the staging area below Hale Pohaku. The covered trailer that was used in the support for the MMAMA team was used for roundtrip transport of both Artemis Jr. and Juno II. Research equipment was re-crated and removed via commercial transport. Communication lines removed from the VLBI area and the WiFi hop for Pu`u Haiwahine. All camp equipment removed along with rented luas (porta-potties). Final notifications to the permitting agencies were performed.

### **Site Mitigation**

All buried poly sheets and drill tubes were removed and holes filled. Vehicle tracks and operations/encampment area were hand raked to restore area to a visual state of non-use. Lastly the fencing and underlying mats were removed from both 4WD roads that access Pu`u Haiwahine valley. A final cultural protocol was also performed, concluding the use of the land.

## Appendix 2: Media outreach, website development, branding, newsletter - 2013

### MEDIA OUTREACH

#### Press Releases:

Since April, PISCES has issued two press releases. The first release, issued on April 18<sup>th</sup>, was on the Memoranda of Understandings (MOU's) that PISCES signed with six agencies around the world. The agreements are the first MOU's in five years for PISCES. The second release, issued on June 25<sup>th</sup>, announced the Space Act Agreement between NASA and Kennedy Space Center. Media coverage followed in both cases, from outlets such as the Hawaii Tribune-Herald, NBC News, KITV, the San Francisco Chronicle's SFGate, New York's Times Union, and more. The next round of pressers scheduled for release in July will be about the interns hired, the PISCES bill that takes effect on July 1<sup>st</sup>, and the new MOU's signed since the first six were announced.

#### Social Media:

PISCES is now on Facebook and Twitter. "PISCES Hawaii" is the profile name for both the Facebook and Twitter accounts, with @PISCES\_Hawaii as the username for Twitter. The accounts became active in mid-June.

#### Other Outreach:

April 18: Executive Director Rob Kelso was the guest speaker at Hui Ka Ua's Breakfast Conversation at the Hilo Hawaiian Hotel. His presentation aired on Na Leo O Hawaii community television.

Join The Breakfast Conversation!

**SPACE, SPORTS & SCIENCE**  
Thursday, April 18, 2013

**Introducing: Rob Kelso**

- New Director of Pacific International Space Center for Exploration Systems (PISCES)
- Recipient of NASA Outstanding Leadership Medal

**Hilo Hawaiian Hotel, Moku'aha Room**  
7:30am - Continental Breakfast  
8:00 - 9:00am - Presentation with Rob Kelso  
RSVP by Sunday, April 14

\$10.00 per person, Continental Breakfast

**PISCES Initiatives**

- Workforce Development & Skill Level Training
- Education Initiatives
- Technology Champions & Robotics Training for First Responders (BRIEF/Research)
- Testing Planetary Systems Technologies for Living on the Moon (3)
- Building Research in Business & Economy through Science and Technology (Get it on the GROUND LIFE!)

Do you remember the TCM HANES movie "Apollo 13" and the Mission Control Specialist who said "EAGLE IS NOT AN OPTION?" This is the same person as Flight Director Rob Kelso was in for 12 years.

Please submit your reservations to: Fred Yamashiro  
E-mail: fred.yamashiro@gmail.com or ph: 935.3721 ext. 510

June 21<sup>st</sup>: Dr. David Livingston invited Kelso to be a guest on The Space Show. The 90 minute interview aired live via webcast.

August: Discovery Channel Canada will send a producer during the first week of the month to produce a segment on PISCES for the Daily Planet, a science magazine show



### **WEBSITE DEVELOPMENT**

PISCES is setting up two websites: PISCES.hawaii.gov as well as an independent website (domain name TBD). DBEDT is currently working on constructing the shell of the Hawaii.gov website. Once complete, PISCES's PIO will be trained in Honolulu by DBEDT's IT team, on how to develop the site using WordPress, a Content Management System. The independent website will be developed professionally. An RFP was sent the first week of June to eight prospective web designers. All proposals are in, and PISCES is now in the process of choosing the winning bidder. Due to the pressing need for a website, the winning web developer will immediately put up a splash/temporary home page with essential PISCES information (i.e. contact) until the full site is complete. Estimated time of completion is between six weeks to two months.

### **BRANDING**

PISCES will undergo a marketing make-over consisting of a new logo, identity and brand. Once a decision is reached by the Board of Directors on whether or not to keep the PISCES name, PISCES will send prospective design firms a RFP for re-branding.

### **NEWSLETTER**

In an effort to keep legislators, the media, constituents, and the community informed of all the projects PISCES is working on, the PIO has developed a monthly e-newsletter, with the launch date of the inaugural issue set for July 1<sup>st</sup>. A newsletter featuring an annual report will also be published at the end of the year.

### **Appendix 3: Education/Public Outreach**

#### PISCES EPO (Education/Public Outreach) Activities - 2013

As part and parcel of any effective workforce development, education and sharing of future technologies and developments to the public is important. PISCES EPO performs that function by engaging students at many levels; science, culture and employment.

PISCES has provided Cultural and Environmental Awareness training for our staff, the HI-SEAS project staff and the GLXP Moonbots team. All visiting researchers experience these activities to enhance productivity and bestow appreciation of the unique and fragile environment that many of our research projects utilize.

PISCES taught a Space Sciences Seminar class at the University of Hawaii - Hilo campus during the Spring of 2013. We also mentored several students on individual projects and have 5 student interns involved in two projects.

PISCES participated with numerous public events this past year such as the Onizuka Space Day at UHH, Hawaii Science and Engineering Fair (with a PISCES Aerospace Award), Journey Through the Universe classroom visitation program, Merrie Monarch Parade and AstroDay in Hilo at the Prince Kuhio Mall.

PISCES leverages its small staff and multi-faceted projects by participating in established events along with other island groups (such as USGS HVNP, NELHA, UHH-HCC, `Imiloa and the astronomical observatories). PISCES is an active member of the Mauna Kea Astronomy Outreach Committee. PISCES also collaborates with the NASA centers EPO programs, enabling use of greater resources and access.