MoonRIDERS – PISCES and Hawai'i High School's Lunar Surface Flight Experiment

Executive Summary

Recently, a unique flight technology project was formed for the design, development, testing and flight operation of a lunar surface flight experiment jointly developed between Hawaii's Pacific International Space Center for Exploration Systems (PISCES), NASA-Kennedy Space Center (KSC), and two Hawaii High Schools. While the Google Lunar X-PRIZE is "designed to inspire pioneers to do robotic space transport on a budget", the Moon-RIDERS project seeks to inspire this generation of Hawaii high school students in a first-ever student–participation involving a lunar surface experiment project with emphasis on STEM. In a similar fashion, this project allows for critical flight testing/validation of spacecraft systems technology on the surface of the moon…something NASA is unable to do, up to this point, on its own.

Over the last 4-5 years, NASA-KSC has been actively working to advance dust-removal technologies which could be critical in future spacecraft systems operating on planetary surfaces…referred to as the Electrodynamic Dust Shield (EDS). As has been seen with lunar surface operations during Apollo and more recently with the experiences with dust on lander/rover systems on Mars, dust is a major problem affecting: mechanisms, ability to negatively impact thermal characteristics of space suit materials, lowering efficiencies of radiators and solar arrays, and more. The problem is….NASA is developing these technologies but is unable achieve flight-testing in the lunar environment to further advance the respective technical readiness level (TRL). Likewise, PISCES, given its legislative direction in advancing planetary surface systems, saw this collaboration as an opportunity to uniquely involve Hawaii high school students in a joint engineering project with NASA KSC…then flying as a hosted-payload/secondary on an upcoming GLXP mission under NASA's recently announced Lunar CATALYST program (Lunar Cargo Transportation and Landing by Soft Touchdown) through which NASA selected three U.S. commercial lunar lander partners.

Since the spring of 2014, NASA-KSC and PISCES have initiated a "program-start" on this project and have recently added two participating Hawaii high schools within the engineering project to flight test EDS on the lunar surface. Project costs are being handled individually within each organization/school…funding their own activities in the strategic partnership.

Introduction - An Unprecedented Opportunity for Education and Space Exploration

Space is the last great uncharted frontier. And the journey into its great unknown is just beginning for the human race. Providing the education, technology, and expertise to venture its depths are the foundations for humankind's continuing endeavor in this new adventure. The Pacific International Space Center for Exploration Systems (PISCES) – a state-funded aerospace agency strategically located in Hilo, Hawai'i, is working at the forefront of this incredible journey by initiating 'Moon RIDERS' (Research Investigating Dust Emulsion Removal Systems) - a one-of-a-kind STEM (Science, Technology, Education, Math) project in partnership with NASA's Kennedy Space Center (KSC) and two Hawai`i high schools. In the spirit of discovery and education, this program is designed to immerse and inspire Hawai`i high school students in the development and execution of a real-life lunar surface flight experiment, while simultaneously conducting critical flight testing and validation of a NASA-developed spacecraft systems technology. This project is the first of its kind to give high school students an opportunity in participating

in an experiment conducted on the surface of the Moon. Since the spring of 2014, NASA-KSC and PISCES have initiated a "program-start" on this project, adding two participating Hawai`i high schools within the engineering project to flight test NASA's spacecraft technology called the 'Electrodynamic Dust Shield' (EDS) – a system designed to address the problematic surface dust found on places like Mars and the moon. Moon RIDERS is fully-funded to design, develop, test, evaluate, (DDTE) and deliver a certified flight unit for a lunar landing. PISCES believes that this program has a significant value for STEM education and planetary surface technology advancement, and thus for the greater human endeavor of space exploration. The following paper will provide a detailed description of the logistics, technology, partnership roles and relationships, cost model, DDTE/testing for flight, STEM value, and all-important contributions being made by two Hawai`i high schools within the Moon RIDERS project. By shooting for the moon, we here at PISCES hope to inspire the next generation of scientists and explorers alike.

Goal

The goal of MoonRIDERS is to develop, launch, fly, and land on the moon a Hawai`i High School student-built lunar surface experiment, in concert with technology from the NASA Kennedy Space Center (KSC) as a hosted payload on one of the upcoming Google Lunar X-PRIZE (GLXP) lunar missions.

This project has established four unique strategic partners:

1. Academia/STEM Education - Two Hawaii High Schools: `Iolani High School – Oahu, HI and Kealakehe High School - Big Island, HI. Both of these high schools will develop complementary components for the experiment (like an experiment frame, full-scale mockup, remote activation system, etc. and analyze prototype performance utilizing school funding.

2. State: Pacific International Space Center for Exploration Systems (PISCES). PISCES provides overall program integration between NASA, Hawai`i high schools and commercial lander spacecraft. PISCES additionally provides a lunar analogue test site and necessary infrastructure.

3. Federal: NASA-KSC – KSC will provide overall project responsibility for technical concept, design and test of the EDS hardware using internal center funds

4. Industry/Commercial Space: Several Google Lunar XPRIZE (GLXP) Teams are participating in the flight project by: providing engineering data for their lander for high school student teams to construct mockups, and provide an engineering camera for assessing particle sizes on the EDS.

Thus, this joint flight test program between Hawai`i high school students and NASA-KSC is s[ecifically designed for the testing of critical dust removal technologies on the lunar surface. Students will be involved in component development, testing at a PISCES lunar analogue test site, mockup fabrication, as well as designing mission control procedures and operations under mentorship from NASA-KSC. The technology will be sourced from NASA KSC in Florida; student-built hardware will come from Hawai`i; integrated testing will occur on the slopes of Mauna Kea on the Big Island of Hawai`i; launch is likely to occur from Florida. Mission Operations Control Center location is yet to be determined. PISCES targets to support a flight/launch opportunity for lunar landing on upcoming GLXP launch for late 2016.

Value Proposition – a WIN/WIN Strategy

This unique flight project provides some compelling value proposition:

First, the Science Technology Engineering and Math (STEM) program includes participation by two high schools in Hawaii to produce supporting hardware such as scale models of competitor's landers and conduct field testing of the EDS using Hawaiian tephra as lunar regolith simulant. This will allow the students to learn about Computer Aided Design (CAD) tools, manufacturing, and construction. The testing will allow the students to prepare test plans and conduct testing in coordination with the NASA team. The NASA team will obtain valuable field test data. The NASA team provides mentoring such as training in lessons learned in systems engineering and project management. Next, flight testing of the EDS allows for all hardware and software to be space flight certified and can lead to design improvements and applications on future missions. Thirdly, the EDS is being developed by NASA using internal funding and it to be made available to all GLXP teams as Government Furnished Equipment (GFE) through the Lunar CArgo Transportation And Landing bY Soft Touchdown (CATALYST) program. Support of the NASA team will be provided at no cost through leveraging of the Lunar CATALYST program.

Multi-Discipline, Hands-On Learning

MoonRIDERS covers multiple disciplines, with a core curriculum in physics, geology, chemistry, soil mechanics, space weather, astronomy, as well as creative engineering design. Mentors from NASA, academia, and PISCES provide the real-world complement to traditional student instruction as well as project-specific teacher training. Prototype design, construction, and testing are involved with a crucial element that is often overlooked in traditional curricula: Systems Engineering. The understanding of how components tie together, interact via command and control software, as well as the design and delivery schedules from multiple distributed partners, gives students a foundational grasp of project management. This is a skill applicable over all STEM disciplines and even into non-STEM areas such as finance, politics, social sciences, and health care. Finally, the Lunar Flight Experiment provides a college level learning experience for high school students in a unique and historic initiative. Never before in human history have students placed an experiment on the surface of another heavenly body!

NASA-Built Technology Addressing the Challenges of Planetary Surface Dust

Planetary dust has proved no small problem to planetary surface missions. Our best understanding of the interaction between lunar dust and exploration activities comes from the Apollo missions. As astronauts walked on the moon and drove the lunar rover along the surface, dust began covering spacesuits and equipment. It scratched lenses and eroded every rock box seal used over the course of six Apollo missions. Dust sullied spacesuits, jammed suit joints, and ate away at boots. Apollo astronaut Harrison Schmidt said the invasive nature of lunar dust is more challenging to future lunar mission astronauts than dose radiation [Schmidt 2006].

The Electrodynamic Dust Shield

To address the problem of planetary surface dust, NASA-KSC Swamp Works Laboratory is developing the Electrodynamic Dust Shield (EDS), a dust-mitigating technology which has proven extremely efficient at

clearing dust in simulated lunar and martian environments. Based on the electric curtain concept developed at NASA in 1967 (and later by the University of Tokyo), the EDS has successfully been implemented on solar panels, optical instruments, viewports, visors, thermal radiators, as well as on flexible materials and fabrics. For applications requiring transparent EDS coatings (solar panels, optical instruments, habitat viewports, and astronaut visors), indium tin oxide (ITO) film (the transparent film used in touchscreen computers and tablets) has been successfully developed and tested under simulated martian and lunar environmental conditions. The EDS coating can be applied to both metallic and electrically insulated surfaces.

How It Works

The surface of the moon is composed of rocks and granular material expected to be electrostatically charged due to ultraviolet (UV) light from the sun which releases photoelectrons from the surface of the material. EDS utilizes the opportunity presented by this electrostatically charged dust (also anticipated on the surface of Mars), by generating an electric field wave that propagates outward like the ripples on a pond [Calle et al., 2009, 2011, 2013]. Charged dust particles are carried off the surface of an EDS-equipped surface with the electric wave.

The EDS system itself is composed of sets of independent electrodes sandwiched between two dielectric layers, forming a multi-layer coating that generates the non-uniform electric fields that move across the surface when out of phase signals are applied to the electrodes. Charged dust particles on the surface are carried along with the traveling field.

Field Testing Experiential Education for Students

The participating Hawai`i high school students will build full-scale models of selected GLXP lunar landers from designs provided by the GLXP teams involved for field testing and integration of NASA's EDS technology. Students will assess various spacecraft camera locations, attachment of the EDS, and identify methods to measure dust deposits and their removal, gaining valuable test/engineering data for flight configuration. Students will also write test reports on the engineering data evaluation, and present their findings with a technical briefing to both NASA KSC and the associated GLXP lander teams. Pre-Flight Preparation and Testing Student teams will deliver their hardware and lunar lander models to a PISCES test facility to integrate hardware, the EDS, flight-engineering cameras, and command and control systems into their mockup lander, followed by preliminary testing. Once the landers have been equipped and tested, they will be transported to a lunar analogue site at Pu`u Haiwahine valley on Mauna Kea volcano for field-testing. The valley is a high-fidelity analogue test site located 9,000 feet above sea level. NASA and other space agencies have utilized it for several space exploration tests and exercises. The valley plain is composed of a fine basaltic sand that closely mimics lunar regolith. PISCES also provides a superfine basalt dust to supplement the existing regolith in case it is not fine enough for the purposes of the test.

Pre-Flight Preparation and Testing

Testing will consist of placing the lunar lander models at different heights (to simulate the lander's approach to the lunar surface) and discharging a high velocity burst of high pressure gas to simulate the engine's nozzle exhaust. PISCES will design, build, and operate the high pressure gas system (HPGS) and oversee the integration of hardware into the lunar lander models to ensure proper safety protocols.

After each burst, the dust-shield system will be tested for efficiency. Measurements will be taken prior to the HGPS expulsion, after the expulsion, and after the dust control system has been activated.