3rd International Hawaii Analogue Field Test: Overview & Status

Preparatory Research for Optimization & Validation in Environmental Simulations (PROVES)

June 2012, Hawaii

Presentation for

PTMSS-SRR
June 20th, 2011

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NASA Johnson Space Center

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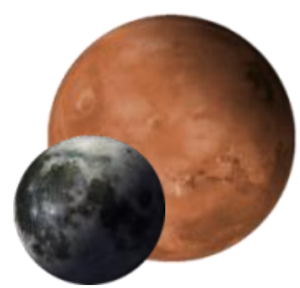


Martin Picard
Canadian Space Agency

3^{rd} International Hawaii Analogue Field Test
Purpose

Key Programmatic Analogue Field Test Purpose

1. **Expand NASA and CSA partnership; Include other International Partners in analogues**
2. **Expand integration of Science & Engineering for exploration, particularly with ISRU**
3. Utilize analog activities and operations to develop and enhance mission concepts and integrate new technologies; Improve remote operations and control
4. Evaluate parallel paths and test hardware under stressful environmental conditions to evolve TRL and improve path to flight
5. Be synergistic with other analogue test activities (past and future)
6. **Public Outreach, Education, and "Participatory Exploration"**

Key Technical Analogue Field Test Purpose

1. **Stress hardware under realistic environmental and mission operation conditions to improve path to flight**
2. Improve remote operations & control of hardware for surface exploration and science
3. Promote use of common software, interfaces, & standards for control and operation (ISECG)
4. Focus on interfaces, standards, and requirements (ISECG)
5. Focus on modularity and 'plug n play' integration (ISECG)

3rd International Hawaii Analogue Field Test
Overview

Field Dates: June, 2012 **Location: Mauna Kea , Hawaii**

Mission Key Personnel

- Jerry Sanders/Bill Larson, NASA
- Martin Picard, CSA

John Hamilton/Univ of Hawaii-Hilo

Science:

Top-Level Field Mission Objectives (Exploration Mission Capabilities):

Focus on Robotic Precursor and Pre-Deployment Missions

1. **Science/Resource Characterization**
   A. Perform robotic lunar polar ice/volatile characterization mission (*applicable to Mars and NEOs*)
   B. Perform robotic science/resource/site characterization mission with multiple rovers and control centers (*applicable to multiple destinations*)
2. **Technology Demonstrations** (*NASA Involvement Limited Pending Funding Decisions)*
   A. Mobility and human robotic systems
   B. ISRU (excavation, landing pads, oxygen/fuel production)
   C. Power & Fluid Systems(fuel cells, power management, cryogenic fluid management)

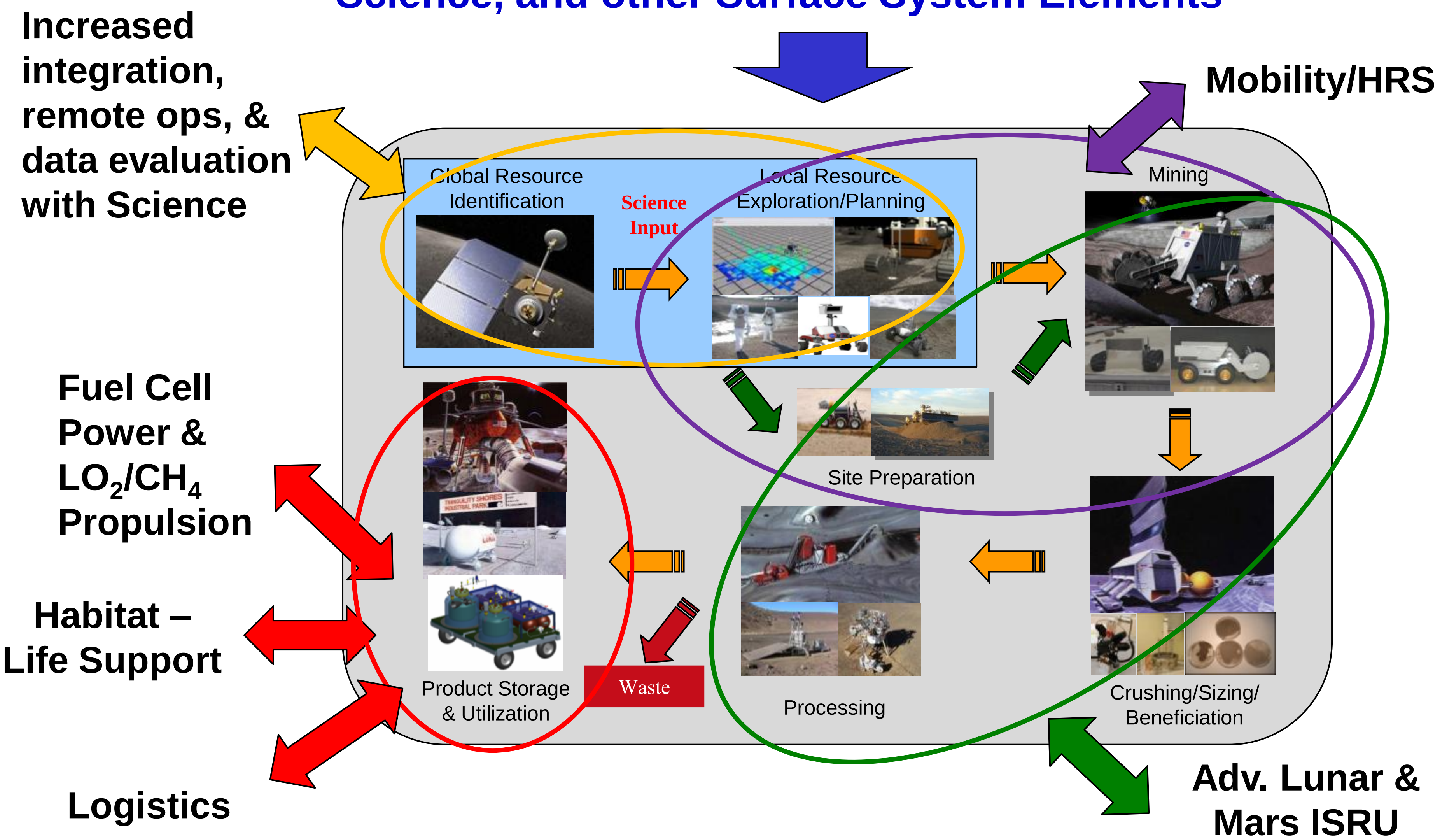
3. **Mission Support and Operations**
   1. Utilize mission representative communications infrastructure and remote operation centers and procedures
4. **Human Medical Tele-Operations**
   A. Advanced Astronaut Medical Support Concepts & Technologies (patient simulator, ultrasound …)
   B. Use combination of representative candidates at the field test with remote specialists

5. **Human Exploration Field Test Involvement**
   A. Human-capable EVA rover mobility testing
   B. Field science prospection missions humans, rovers & technologies

Public Outreach, Education, and "Participatory Exploration" is Critical to All Objectives

Science & Technology Demonstrations Centered Around Space Resource Utilization Mining Cycle

Increased integration and fidelity of ISRU, Science, and other Surface System Elements



'Apollo Valley'
Pu'u haiwahini
Communication to Allow Remote Operation
Observatory Infrastructure & Housing for Test Support
19°46'33.16" N
155°26'59.41" W
elev 10874 ft
Eye alt 28871

Analogue Sites for 3rd Int'l Hawaii Field Testing

"Apollo Valley"

11,500 ft Mauna Kea

Pu'u haiwahini

9000 ft Mauna Kea

Perform Science/Resource Characterization

- Site has terrain, rock distribution, and soil of interest to polar exploration and has geological diversity of potential interest to science instrument investigators
- Minimal test disturbance required at site
- Tests to be performed with minimum personnel and infrastructure at site; support from Hale Pohaku and Pu'u haiwahini site and remote centers

Perform Technology Demonstrations

- Site has terrain, rock distribution, and soil of interest to lunar/Mars resource processing, site preparation, and infrastructure integration.
- Site allows for tests involving excavation and material modification
- Tests to be performed with support from Hale Pohaku and remote centers

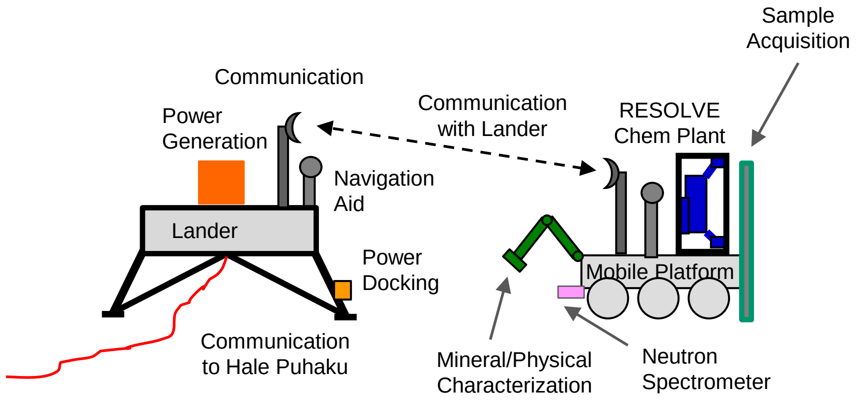
Objective 1A: Perform Dress Rehearsal for joint Lunar Science-Exploration-ISRU Mobile Precursor

Purpose: Demonstrate Integrated Mobility Platform/Science Payload for Polar Ice/Volatile Mission

- Perform 1 or more mission scenarios remotely with all hardware/capabilities required

Questions to Be Addressed

- What science & resource characterization instruments should be mounted on a single platform?
- How are operations and data collection effected by control from multiple control centers?
- How does remote scientist involvement (in the loop?) impact productivity?
- How are operations effected by Remote Operations, Power, and level of Autonomy?
- Are navigation capabilities sufficient to for mission scenarios evaluated?



Lander

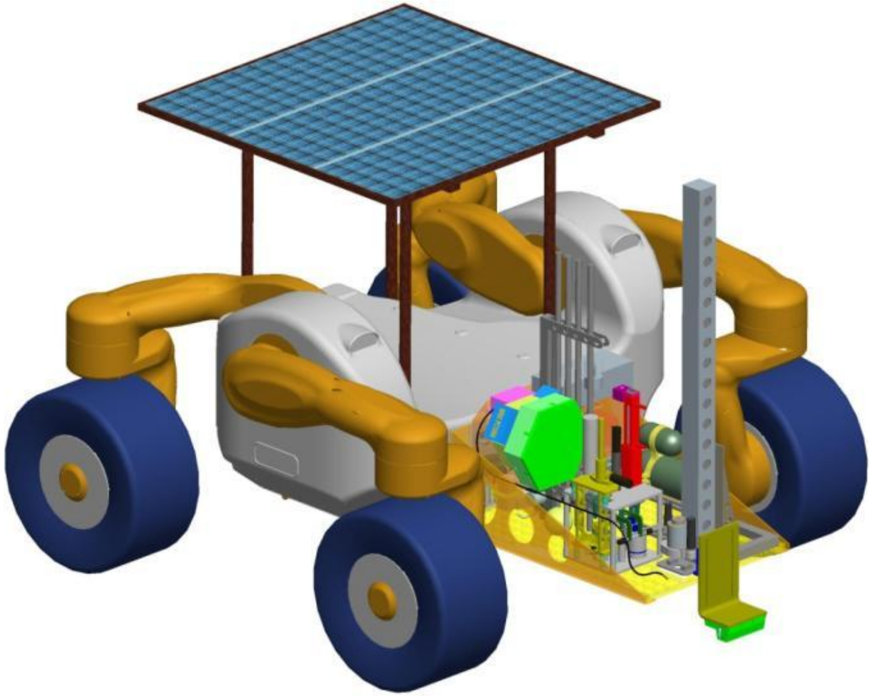
- Communication to rover and back to Hale Pohaku (through land line)
- Power for recharging (if autonomous recharge concept evaluated)

Rover/Payload

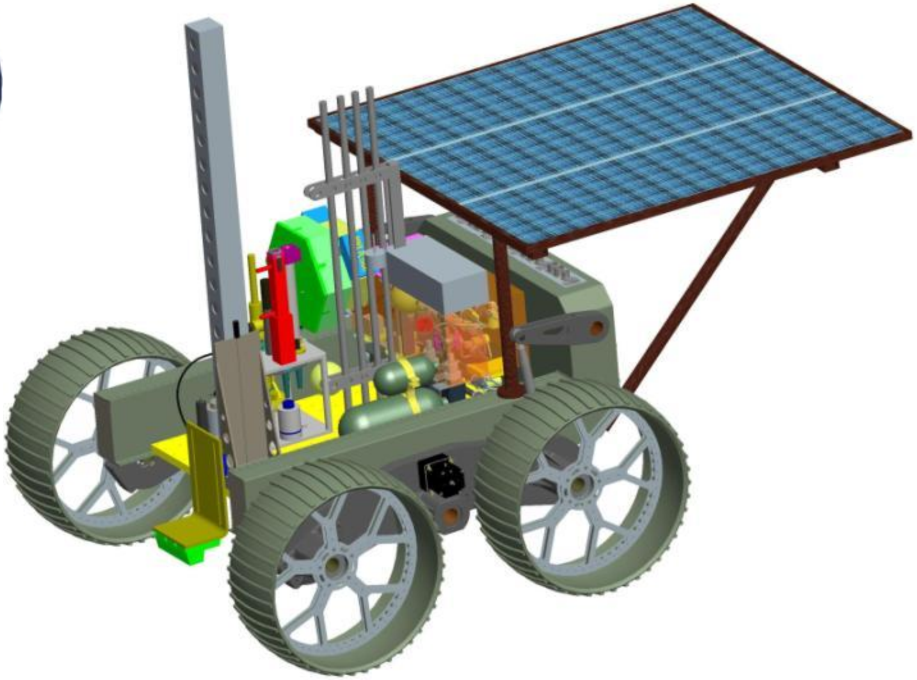
All mission critical hardware on rover

- RESOLVE Drill and Chem Plant
- Neutron Spectrometer
- Mineral characterization instruments/microscope

Latest Designs



NASA Rover Mounted



CSA Rover Mounted

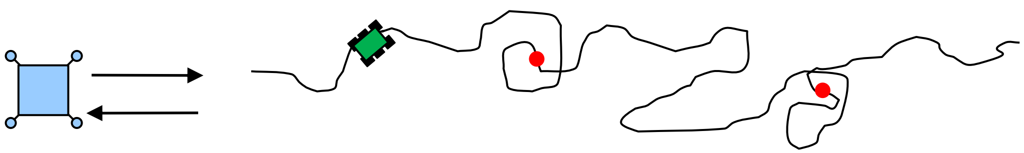
Mission Scenarios Under Consideration

Scenario 1: Scout first. Return to Sites of Interest

Use Neutron Spec to find water

Return to best spots for sample collection

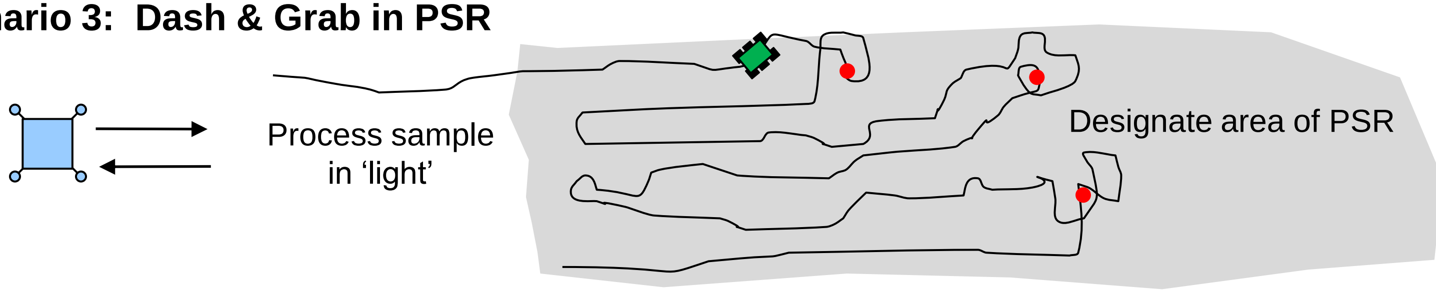
Scenario 2: Rove, Find, Process, Repeat



Evaluate mission impact if returning to Lander for recharging or processing is required

Use Neutron Spec to find water, process, than continue on

Scenario 3: Dash & Grab in PSR



Scenario 4: Lander-based Progressive Search

Perform searches farther from lander with each sample

Objective 1B: Perform Robotic Resource and Terrain Site Characterization

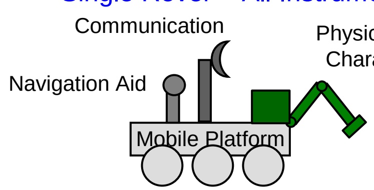
Purpose: Demonstrate instruments and operations associated with performing terrain and resource site characterization before crew arrive

- To evaluate operation concepts and instrument effectiveness with characterizing physical/mineral resources and site terrain; Single vs Multiple Rovers (International)
- Extend Science/Site Characterization operations and instruments from Objective 1A

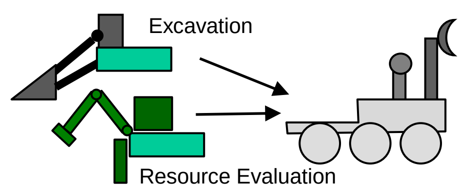
Questions to Be Addressed

- How do science and resource prospecting site characterization differ? Instruments & Ops
- Can multiple rover/instrument operations be coordinated remotely? By Multiple Ops centers in different time zones
- How does rover size (micros) or number of instruments on each rover impact science performed over specified time?
- How does remote scientist involvement (in the loop?) impact productivity? Multiple Ops centers
- How are operations effected by Communications (time delays) and Level of Autonomy

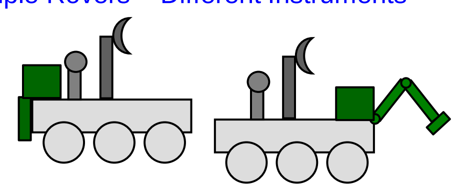
Single Rover – All Instruments

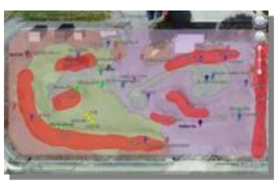


Single Rover – Exchangeable Instruments

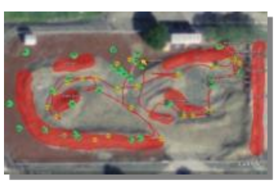


Multiple Rovers – Different Instruments

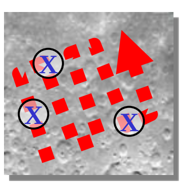




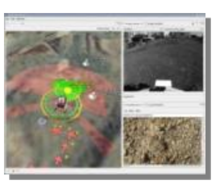
Initial Site Planning



Site Operations and Control



Survey Ops



Data Integration & Visualization

Data Interpretation

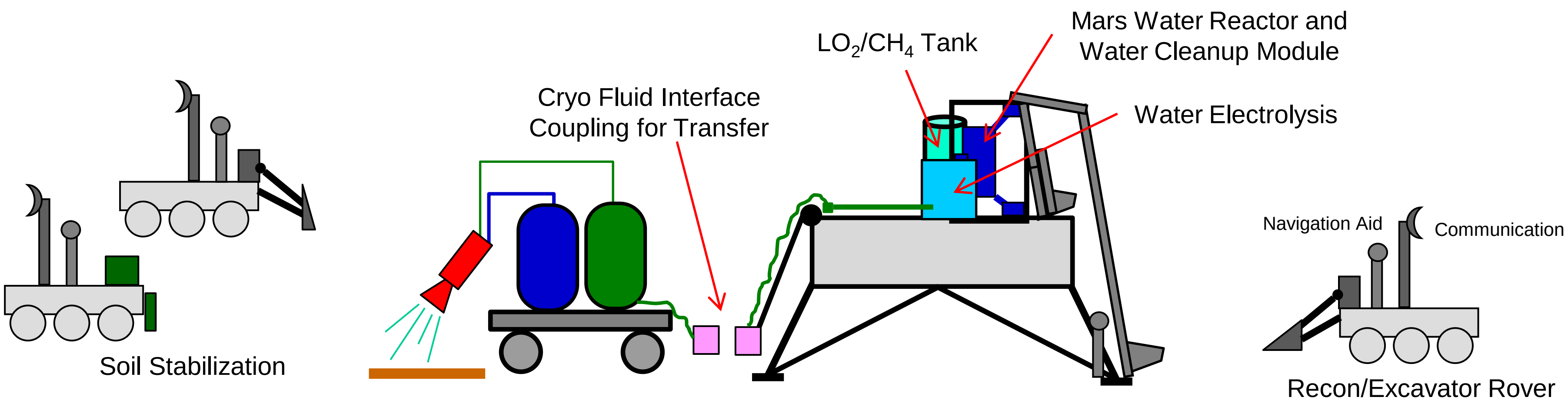
Finalize Site Operation Planning

Apollo Valley

Objective 2: Technology Demonstrations
(NASA Involvement Limited Pending Funding Decisions)

Objectives of Interest

- Demonstrate all aspects associated with Mars soil and atmospheric processing at relevant scale for demonstration mission
- Build and expand off of previously demonstrated capabilities and operations for missions requiring multiple landings (Robotic Village)
- Demonstrate technologies and options associated with converting crew trash and waste into usable fuel for Power/Propulsion
- Demonstrate advanced power system capabilities and operations integrated with ISRU products
- Demonstrate cryogenic fluid management storage and transfer capabilities in dusty surface environments

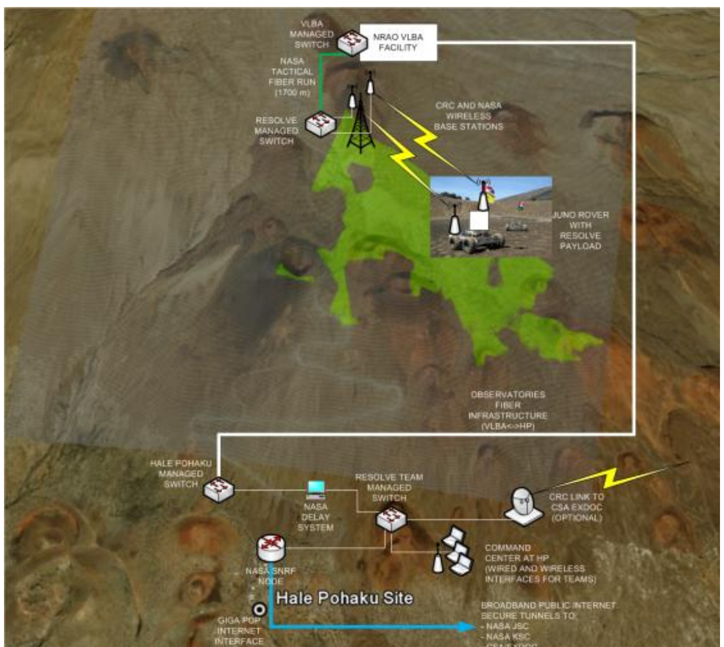


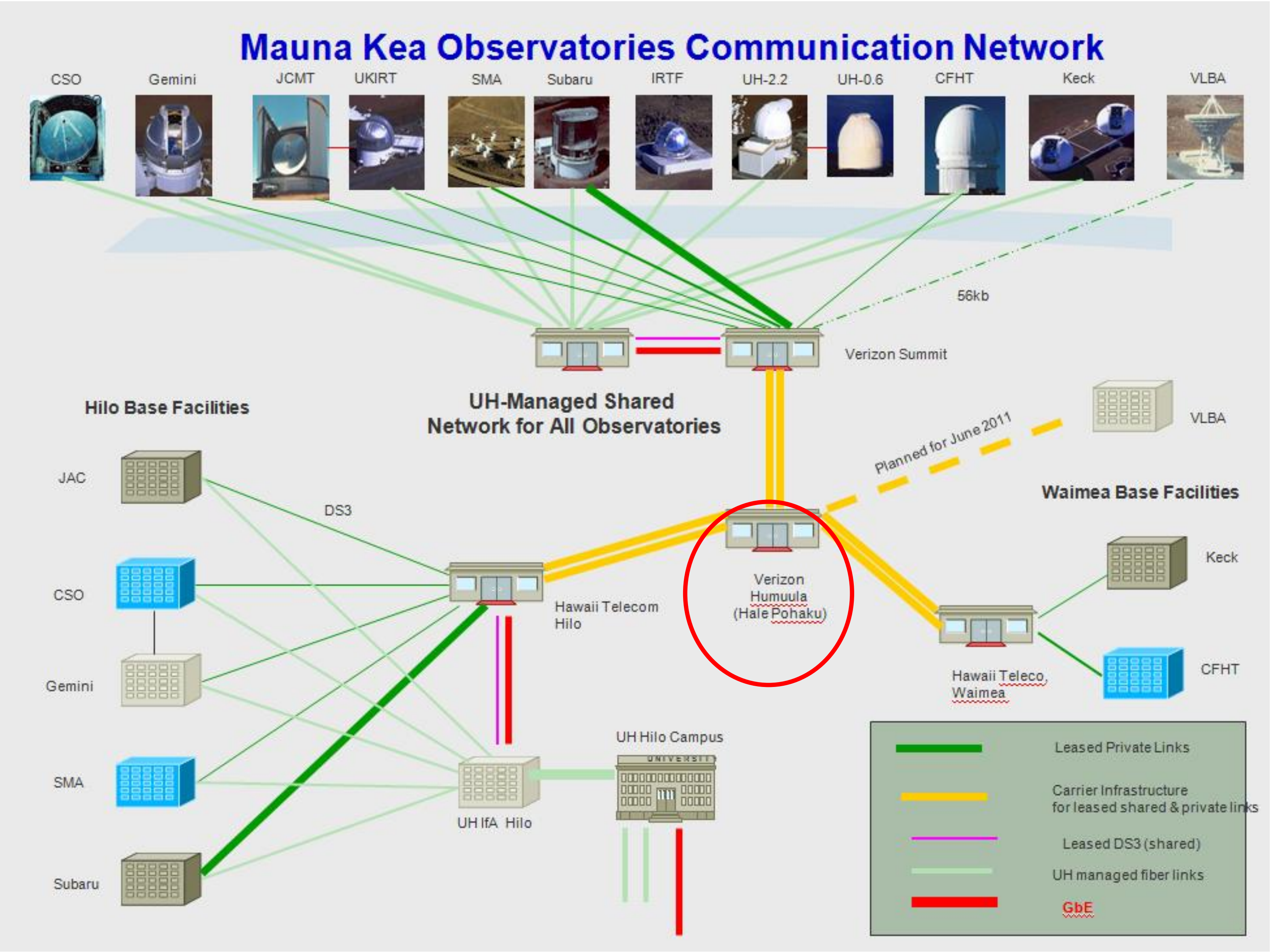
Clear Landing Pad — Plume-Soil Interaction Test — Lunar/Mars Propellant Production

Objective 3: Mission Support and Operations

Purpose: Utilize mission representative communications infrastructure and remote operation centers and procedures

- Control and limit bandwidth and introduce communication delays and noise for rover and payload to simulate communication challenges for lunar polar mission
- Utilize remote operations centers at CSA Headquarters, NASA (ex Shuttle control rooms) and other participants for field test operations (after initial operations performed near test site)
- Utilize Shuttle/ISS communication architecture between centers to minimize firewall issues
- Utilize Shuttle/ISS planning tool (SCORE) and establish remote operations teams for hardware and science (linked to Obj 1A & B)

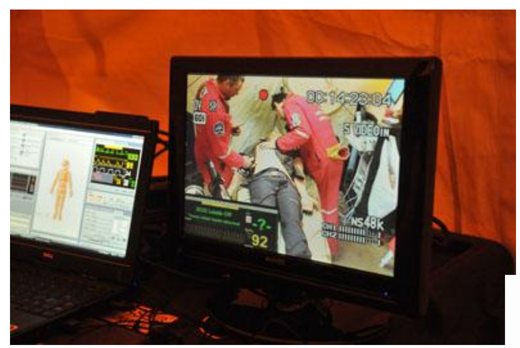



Mauna Kea Observatories Communication Network
CSO
Gemini
JCMT
UKIRT
SMA
Subaru
IRTF
UH-2.2
UH-0.6
CFHT
Keck
VLBA
56kb
Verizon Summit
UH-Managed Shared Network for All Observatories
Hilo Base Facilities
JAC
CSO
Gemini
SMA
Subaru
DS3
Hawaii Telecom Hilo
Verizon Humuula (Hale Pohaku)
Planned for June 2011
VLBA
Waimea Base Facilities
Keck
CFHT
Hawaii Teleco, Waimea
UH IfA Hilo
UH Hilo Campus
UNIVERSITY
Leased Private Links
Carrier Infrastructure for leased shared & private links
Leased DS3 (shared)
UH managed fiber links
GbE

Objective 4: Human Medical Tele-Operations

Purpose: Advanced Astronaut Medical Support Concepts & Technologies (patient simulator, ultrasound …) & Use combination of representative candidates at the field test with remote specialists

- Experiment tele-medicine interaction between non-specialist in the field and remote specialist for diagnose and perform interventions on patients.
- Usage of technologies such as remote ultrasound, patient monitoring systems, patient simulator, Data Redistribution System (DRS)
- Follow-up to the experiments and lessons learned from the Hawaii 2010 deployment and HMP researches.
- Possibility of linking to Objective 5.
- *Detailed objectives in work*



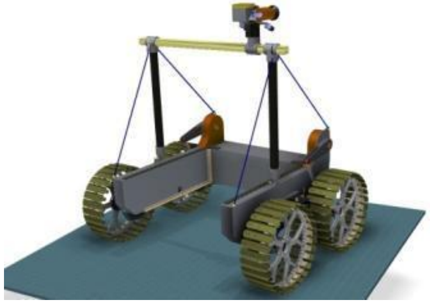
Objective 5: Human Exploration Field Test Involvement

Purpose: Human-capable EVA rover mobility testing & field science prospection missions involving humans, rovers & technologies:

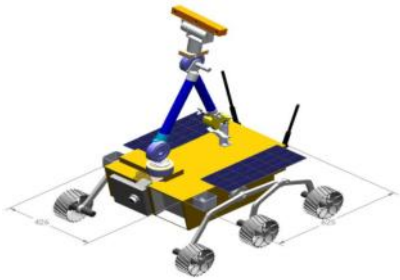
- Experiment usage and collaboration between human and tele-operated rovers and payloads.
- Operations concept and demonstration of human capable vehicles equipped with advanced navigation (E-commander)
- Demonstrate science prospection with human versus tele-operated robots.
- Interactions in the field and with a remote control location.
- Detailed objectives in work

Potential CSA Supplied Hardware

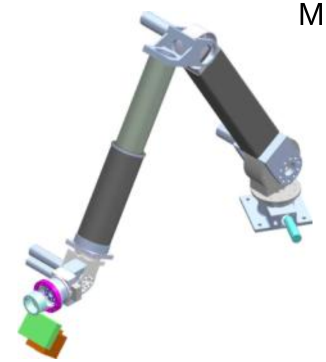
Artemis Jr Rover(<190 kg)



Kapvik Micro-Rover (30 kg)

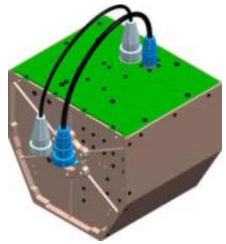


Mini Corer



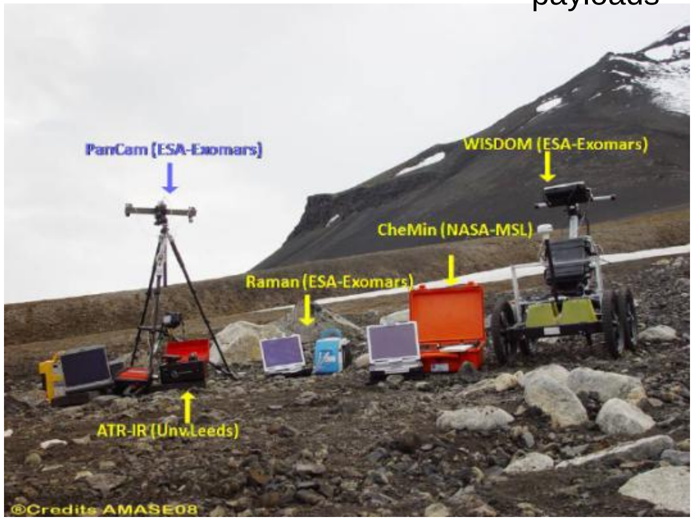
Small Manipulator Arm (1 m, 6 DoF)

Three-D Exploration Multispectral Microscope Imager (TEMMI)



MRPTA Micro-Rover (30 Kg)

Juno Rover(s) with related ISRU payloads



E-Commander

RESOLVE 1 m Core Drill & Sample Transfer

Generic Payload Interface

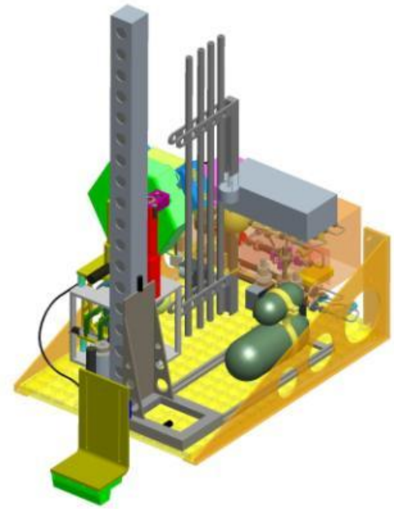
Tele-medicine patient simulator

Potential NASA Supplied Hardware

Centaur 2 Rover

K-10 Rover

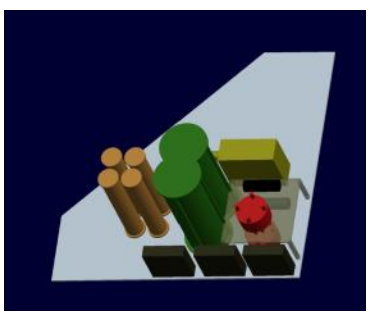
RESOLVE



Neutron Spectrometer

Near Infra-Red Spectrometer

Mars ISRU – Power Lander Demo



Moderate Pressure Water Electrolysis

Fuel Cell Module (10 KWe)

Surface Stabilization (Sprayer & Brick Maker)

Moon-Mars Analog Mission Activity (MMAMA) Instruments

Analog Field Test Planning Status

- Top-level field test purpose, goals, and objectives approved by NASA and CSA (Dec. 2010)
- A trip to Apollo Valley on Mauna Kea was performed to understand communication impacts and limitations for performing analogue testing for the polar ice/volatile mission scenario near the VLBI antenna. (Mar. 2011)
- NASA and CSA have initiated discussions on communication architecture and roles/responsibilities (Apr. 2011)
- Agreement reached with NASA Science Mission Directorate (SMD) to provide addendum to Moon Mars Analog Mission Activity (MMAMA) ROSES solicitation (May, 2011)
- Grant with University of Hawaii – Hilo awarded to support field test (May, 2011)
- A NASA proposal covering the joint NASA-CSA field test in June 2012, was selected but asked to merge into all NASA analog planning with direction focus on performing a lunar polar ice/volatile characterization and site/resource prospecting mission scenarios with CSA (May, 2011)
- CSA Science provided initial inputs for science objectives and activities to occur at the field test (May, 2011)
- CSA Tele-medicine group provided initial objectives at the field test (May 2011)
- *Tentative sites selected for field test activities: Follow-up trip for final review planned for end of summer/fall 2011*
- *Discussion with ESA and DLR on field test involvement planned for Sept., 2011*

Other Potential Participants

- ESA
  - ESTEC interest in field testing of Eurobot
- Germany
  - DLR (Bremen & Cologne) interest in Exploration-Science Objectives for robotic terrain and resource site characterization
- Japan
  - University (Kyushu, Tokyo Institute of Tech.) and industry (Shimizu) interest in robotic exploration and technology demonstration (similar to recent Osaka Univ. field test on volcano at Izu-Oshima in Japan)
- South Korea
  - University (Hanyang Univ.) interest in mobility evaluation and demonstration of automated pad construction with concrete

3rd International Hawaii Analogue Field Test
Milestone Schedule

- **Pre-Test activity or milestone (use T-xx months format)**
  - 12/10 (T-18) NASA and CSA to agree to 'core' field test purpose, goals, and objectives. Identify initial roles and responsibilities, and list of potential hardware for field test
  - **6/11 (T-12)** Complete process to ensure agreement to utilize Apollo Valley
    Review and update field test purpose, goals, objectives, participants, and hardware status (during PTMSS)
  - **6/11 (T-12)** Work with NASA SMD and CSA Science to have agreement on Science instrument involvement (MMAMA, FSAT, etc.) as well as Data Collection and Integration
  - 11/11 (T-7) Final reconnaissance of field test site and ensure agreements are in place for site and Hale Pohaku usage (during JUSTSAP)
  - **12/11 (T-6) Finalize participant list and hardware to be tested**
  - 1/12 (T-5) Finalize logistic needs for field test; Field Test Communication Architecture Review
  - 3/12 (T-3) Finalize checkout of field test hardware; begin preparation for shipment
  - 4/12 (T-2) Finalize analog field test timeline of operations

- **Test activity timeline**
  - Setup test infrastructure at Hale Pohaku and Pu'u haiwahini for checkout, maintenance, and ops
  - Setup & checkout hardware and communications links at both sites; Perform initial operations
    - Setup Lander mockup and Science/Exploration Rovers at Apollo Valley for Objectives 1A & 1B. Minimum invasive impact to site required
    - Setup Object 2 thru 5 hardware at Pu'u haiwahini
  - Move operations to Hale Pohaku and remote operation centers as quickly as possible

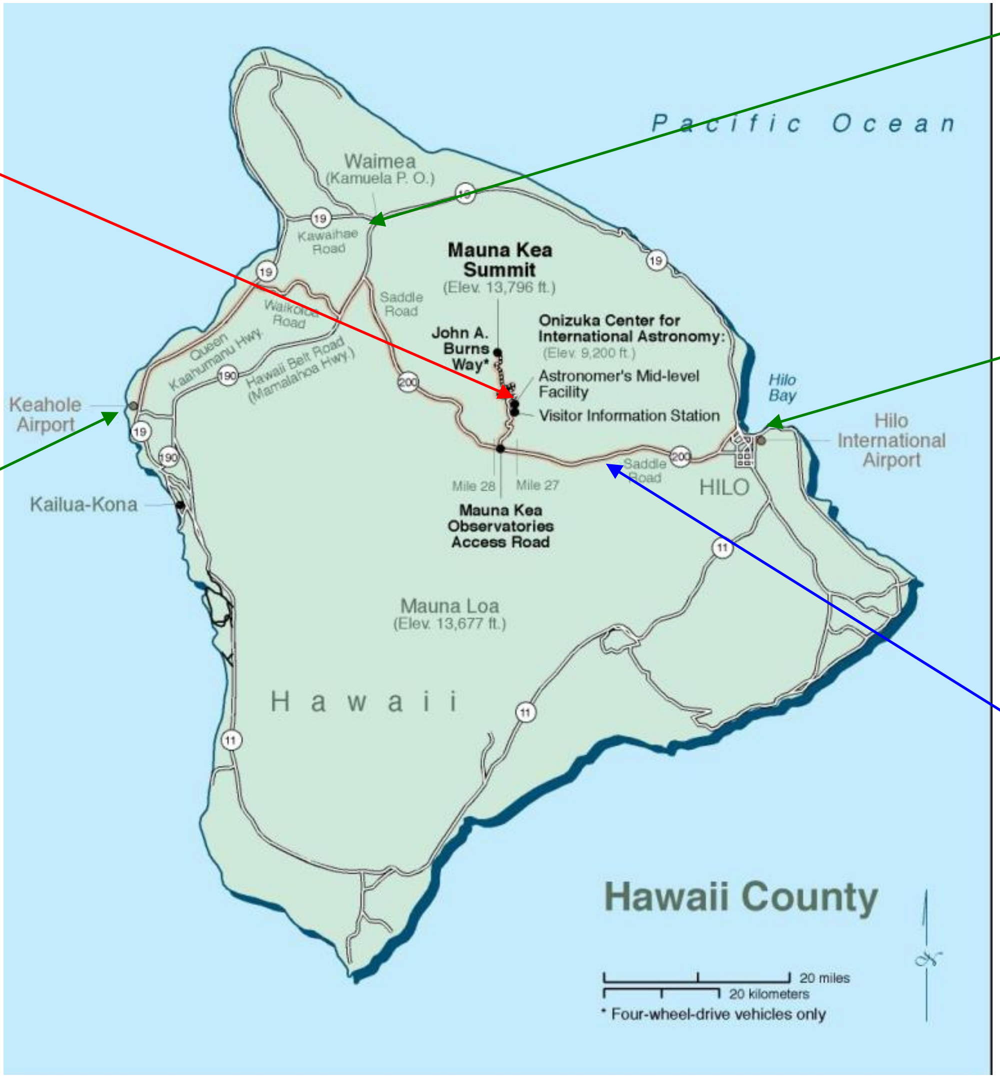
- **Post-Test activity or milestone (use T+xx months format)**
  - 7;12 (T+1) Field Test preliminary results and lessons learned presentation
  - 9/12 (T+3) Full technical reports on hardware tested; Present results at Space 2012

Backup Information on Hawaii Analog Site

Where on Hawaii?

Mauna Kea
- Astronomer's dorm & facilities
- Machine Shops
- Test sites

Kona Airport



Waimea
- Hotels
- Food

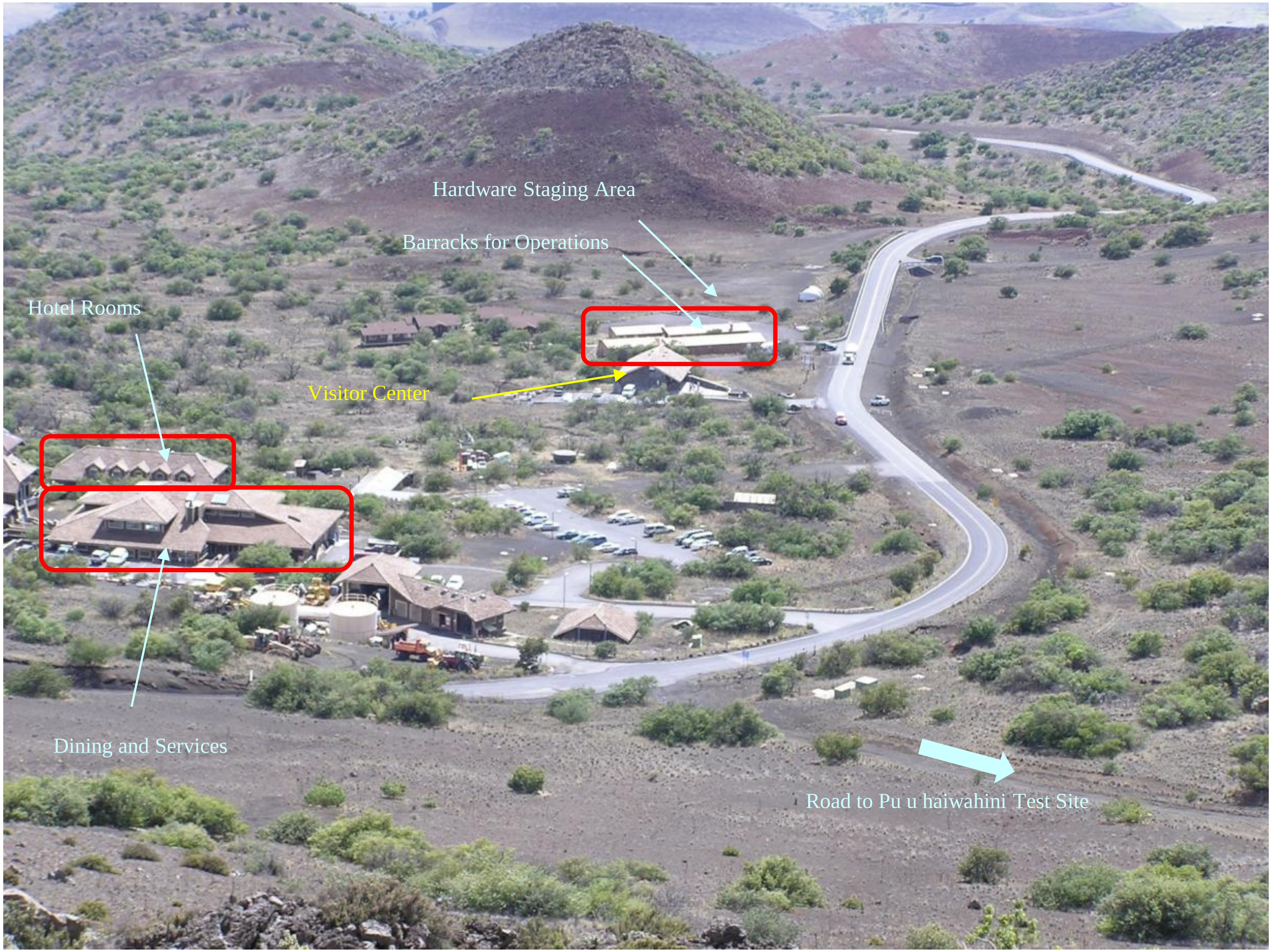
Hilo
- Hotels
- Airport
- Home Depot/Walmart

~1 hour drive from sea level to 9000+ ft

Hawaii Mauna Kea Analog Test Site Summary

- **Test Site Infrastructure**:
  - Hale Pohaku – Dorms, Cafeteria, Local Ops facilities (1 km from site)
  - On-site: Tents, portapotties, snacks/drinks
  - Paved roads to Hale Pohaku. Unpaved, 4 wheel drive to site(s)
- **Lodging/Food**:
  - Hale Pohaku (1 km from site)
  - Hilo (~1 hr drive)
  - Waimea (~1 hr drive)
- **Medical**
  - On-site (Dr. Lou Morino)
  - Hilo (emergency helicopter)
- **Weather/Environment**
  - High UV, lower oxygen (altitude sickness possible)
  - Dusty, can be windy
  - Temperatures vary from hot to freezing in 24 hr cycle (summit is cold)
- **Maintenance**
  - On Site: Tents will be available. Must bring all tools and equipment to site in 4 wheel drive vehicle. Dusty
  - At Hale Pohaku or telescope facilities: Garage and machine shops available
  - At Univ. of Hawaii – Hilo.; Machine and electronics shops. Reasonably clean. Walmart, Home Depot, and stores available

Infrastructure At Hale Pohaku



Typical Field Test Site Infrastructure

Tents for Maintenance and temporary operations until Hale Pohaku and remote operations can take over

Pu’u Haiwahini

Craters with varied slopes & rocks

'Polar crater'

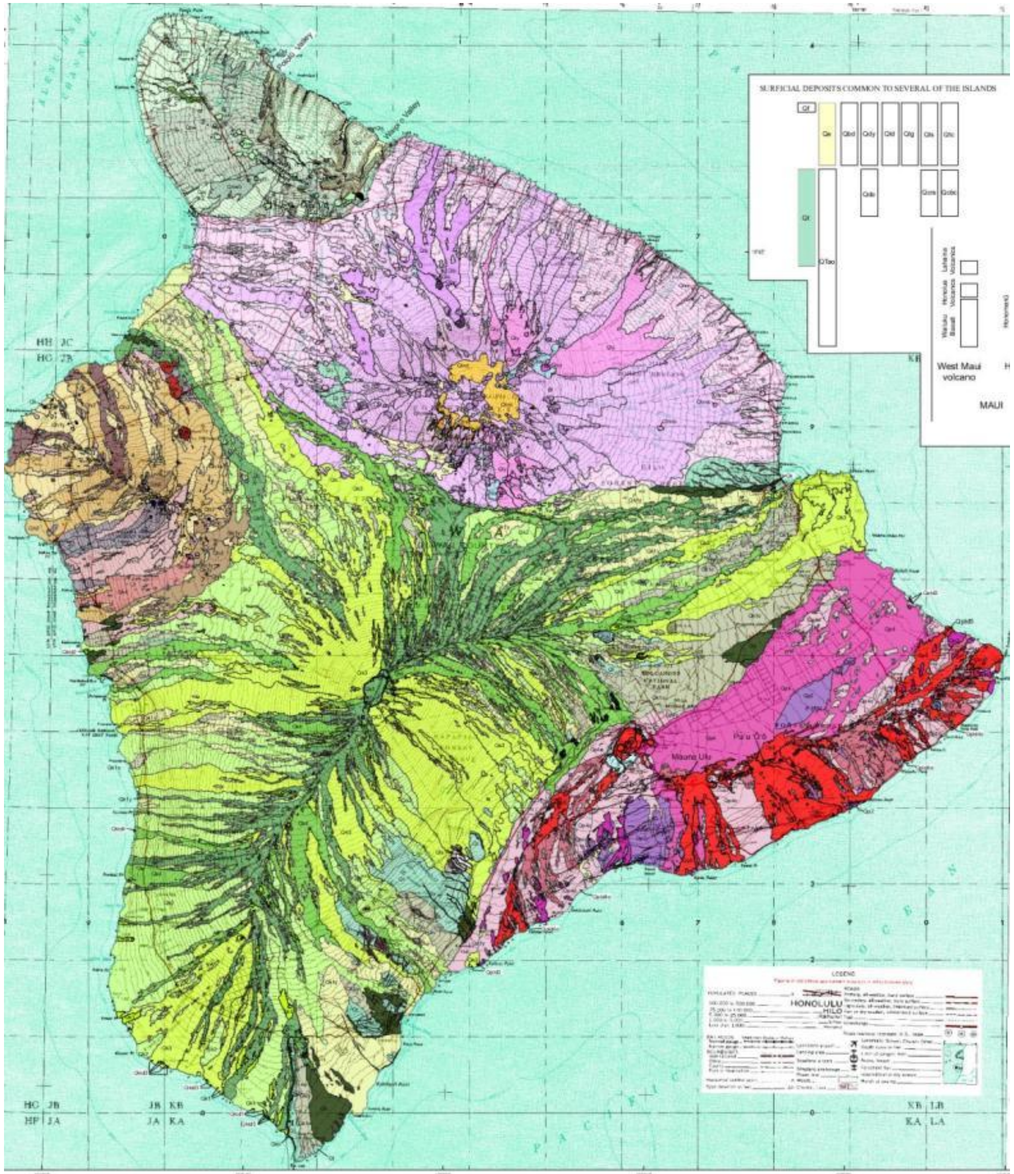

Lunar/Mars-Like Terrain & Soil

Apollo Valley Access Options

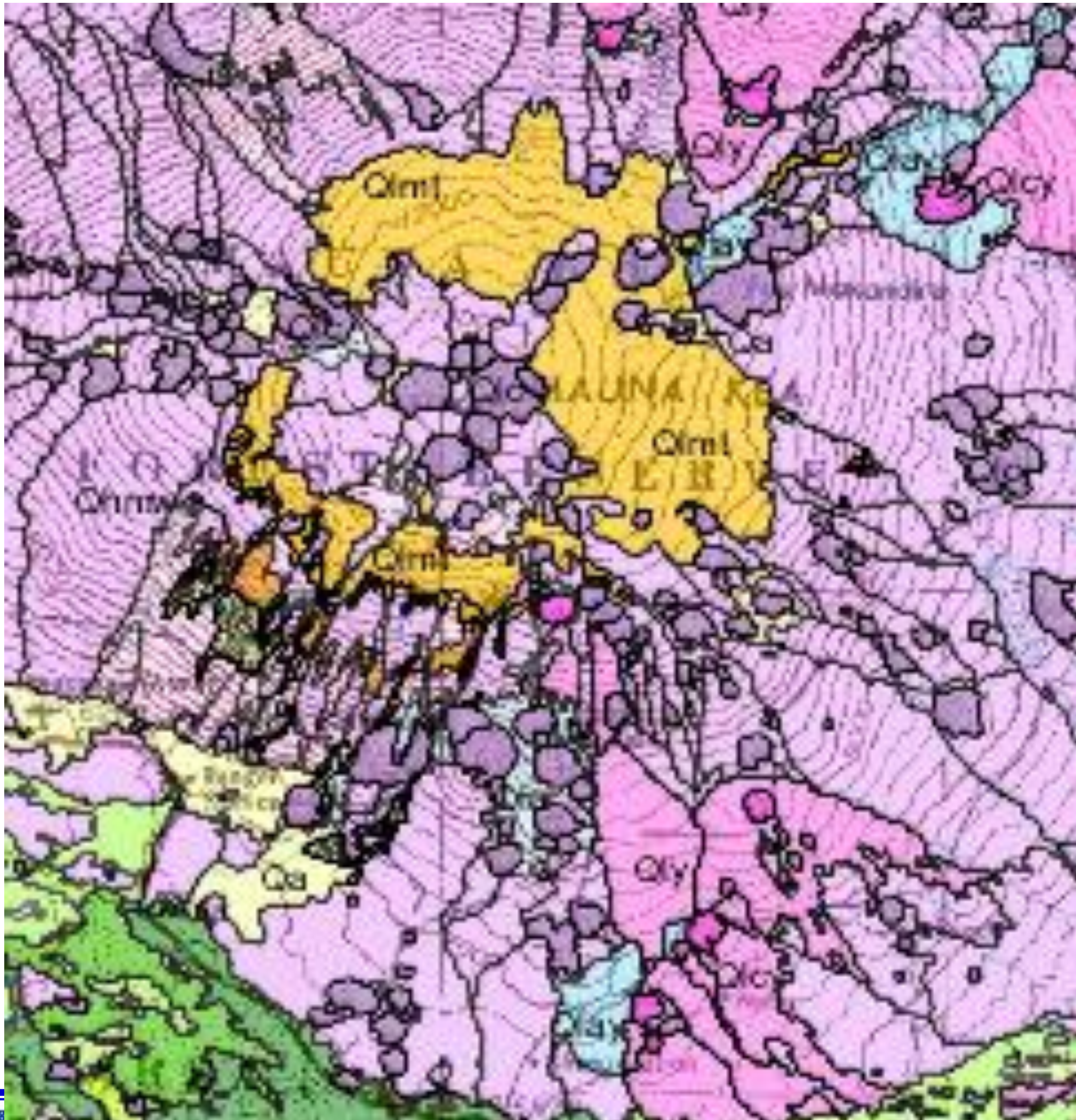
Apollo Valley Terrain (1)

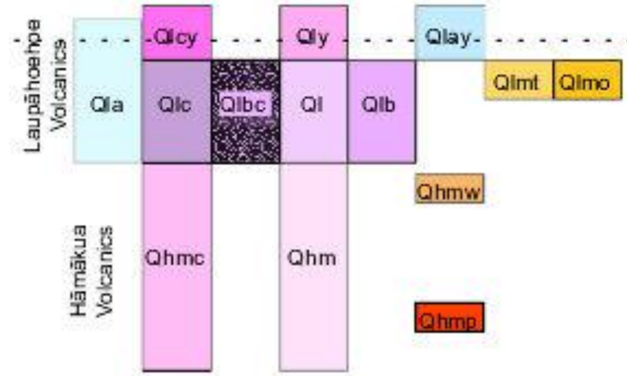
‘Apollo’ Valley

Geology of Hawaii



Geology of Mauna Kea
(USGS Map)





MAUNA KEA VOLCANO

Laupāhoehoe Volcanics (Holocene and Pleistocene)—Divided into two informally named volcanic members and an intervening formally named glacial member, thusly:

Younger volcanic rocks member (Holocene and Pleistocene)—Divided into:

Qlcy	**Scoria cones**
Qly	**Lava flows**
Qlay	**Tephra-fall deposits**

Older volcanic rocks member (Holocene and Pleistocene)—Divided into:

Qla	**Tephra-fall deposits (Holocene and Pleistocene)**
Qlc, Qlbc	**Scoria cones (Pleistocene)**
Ql, Qlb	**Lava flows (Pleistocene)**

Mākanaka Glacial Member (Pleistocene)—Divided into:

Qlmt	**Till**
Qlmo	**Outwash**

Hāmākua Volcanics (Pleistocene)—Consists of

Basalt—Divided into:

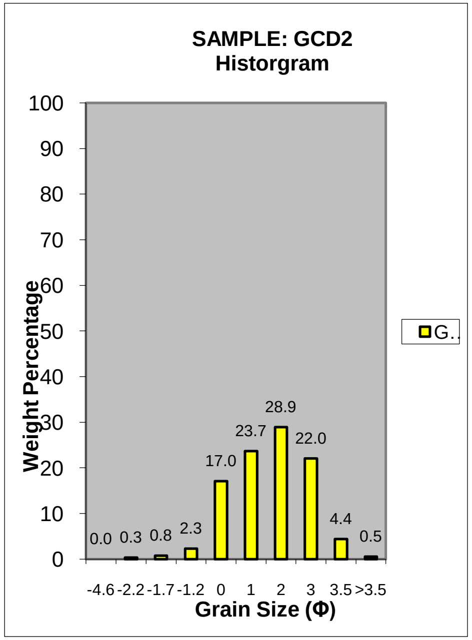
Qhm	**Lava flows**
Qhmc	**Vent deposits**
Qhmw	**Waihū Glacial Member**
Qhmp	**Pōhakuloa Glacial Member**

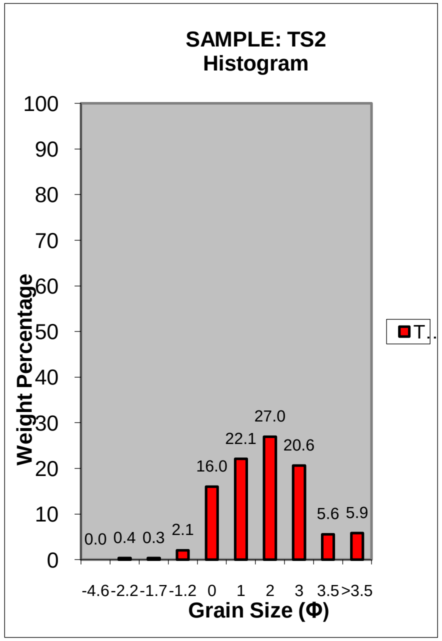
Pu'u Haiwahini Site Geology (1)

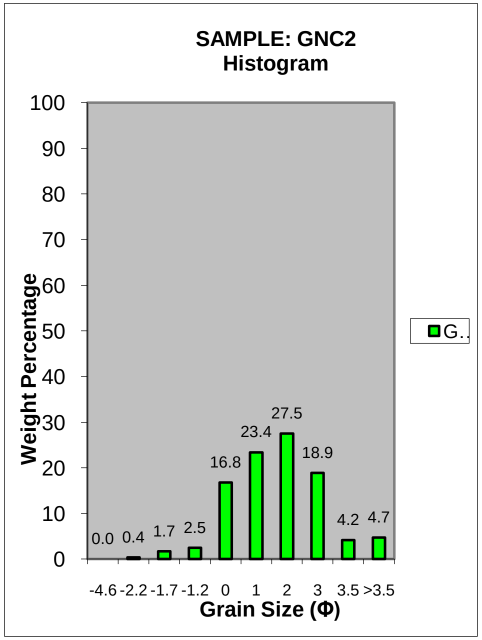
- The predominant species in the soil are anorthosite (Based on X-Ray diffraction (XRD) analyses performed in November 2008)
  - Calcium rich plagioclase feldspar, chemical formula (Ca,Na) ($[Al,Si]_4O_8$) and olivine (chemical formula $[Mg,Fe]_2SiO_4$), both common on the moon.
  - The silicon in anorthosite is bound as SiO_2 and the silicon in olivine is bound as SiO_4.
- There is approximately 31% (by mass) SiO_2 and approximately 1.1% (by mass) SiO_4. Assuming the olivine is magnesium rich, there is approximately 2% (by mass) in the sample. (Based on X-ray photoelectron spectroscopy)
- The tephra is weakly magnetic, brown to grey in colour, vesicular (contains small cavities formed by gas expansion during cooling) and abrasive. The vesicular structure of the particles increases the material's abrasiveness, partially due to sharp outer edges of the vesicles. The individual particles are resilient to crushing by hand, but exhibit friability when crushed against other particles.
- Surface material down to ~10 cm is dry; water content can increase to ~20 wt% below powdery surface material
- Laboratory testing indicates the density of the tephra ranges from 1.6 g/cm^3 to 1.9 g/cm^3. The size of the particle, the quantity of vesicles and any material which may be present in the vesicles (air, water, sediment) will impact its density.

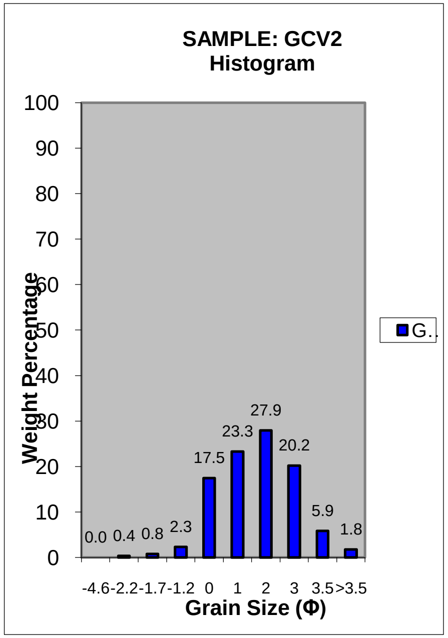
Pu'u Haiwahini Site Geology (2)

- Fragments founds are ash (less then 2 mm), lapilli (between 2 and 64 mm) and bombs (larger than 64 mm)   http://www.geo.mtu.edu/volcanoes/hazards/primer/tephra.html
- Particle size distribution was performed on four samples taken from within the 2010 field test site by Jacob Smith of the University of Hilo Hawaii









Field Testing in Hawaii is NOT Paradise

Analogue Test Conditions Stress Hardware and Personnel

- Fine magnetic dust and wind
- Varied temperatures - >27 C (>80 F) during the day & freezing overnight
- High altitude (low oxygen and high UV radiation)
- Long test days – 10 hours on site (+2 hours driving for some); 2 days off in 3 weeks
- Mist and rain is still possible
- Operations from tents (will be minimized)