



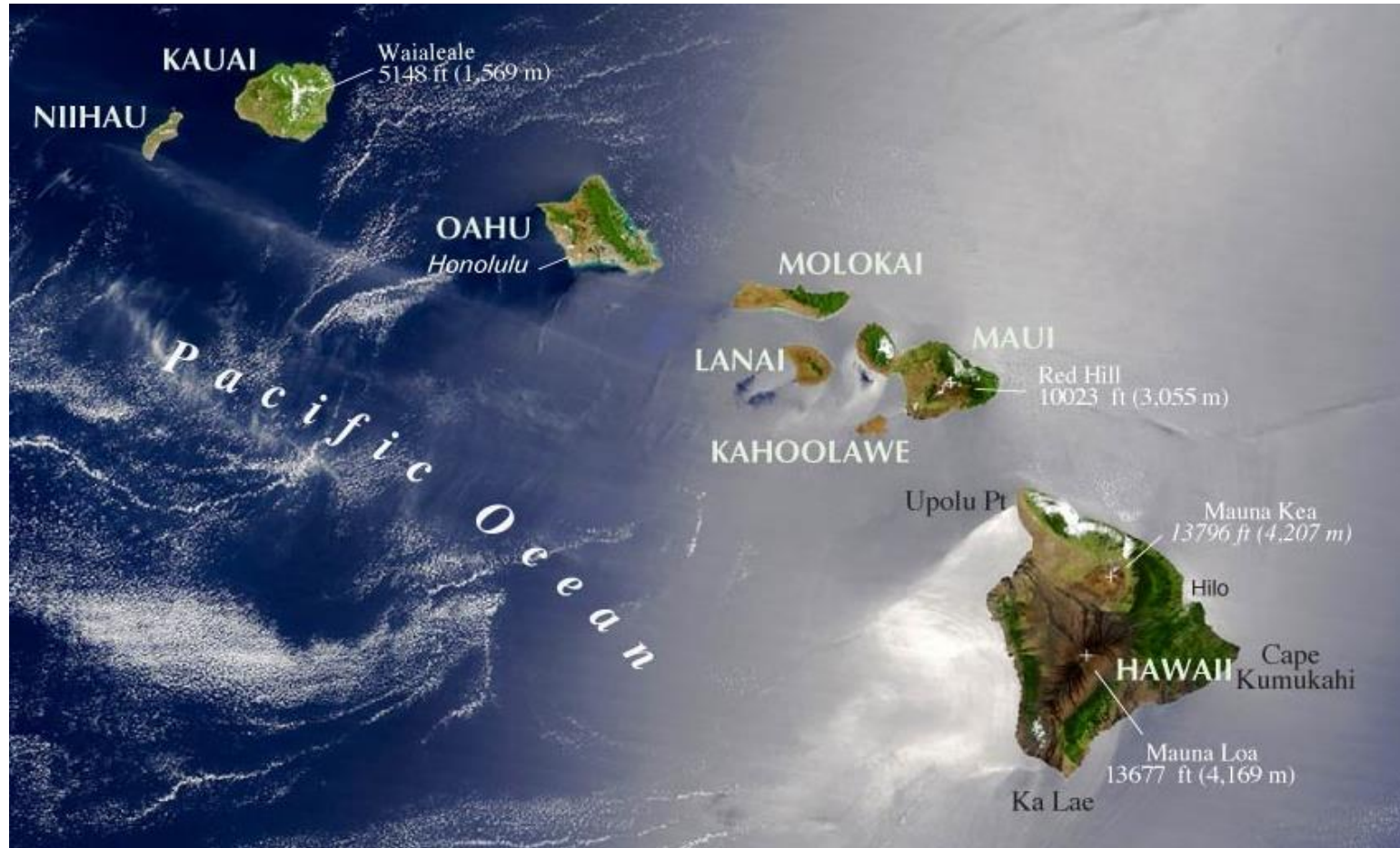
Basalt ISRU & Planetary Analog Test Sites in Hawai'i.

LSIC E&C Meeting
January 29, 2021

PISCES

State Agency under Department of Business,
Economic Development & Tourism (DBEDT)
located in Hilo, HI

Objective: To Promote the Aerospace Industry
& Foment Economic Development in the State.

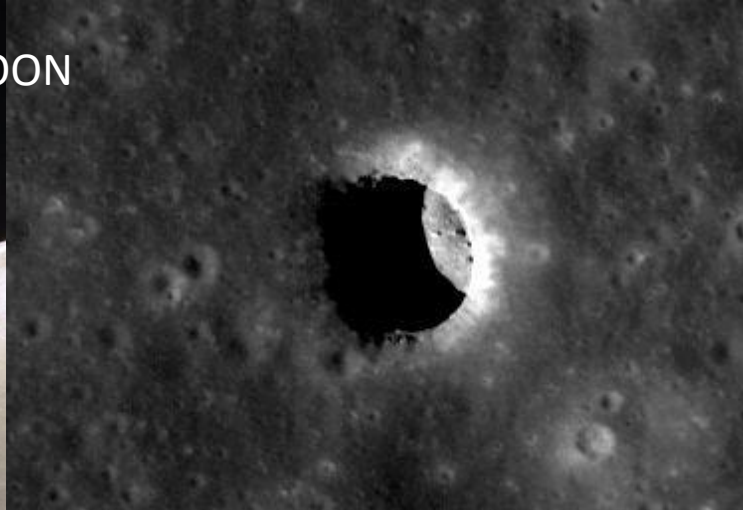


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ISRU: We've been doing it for a long time, but the real question is...

MOON

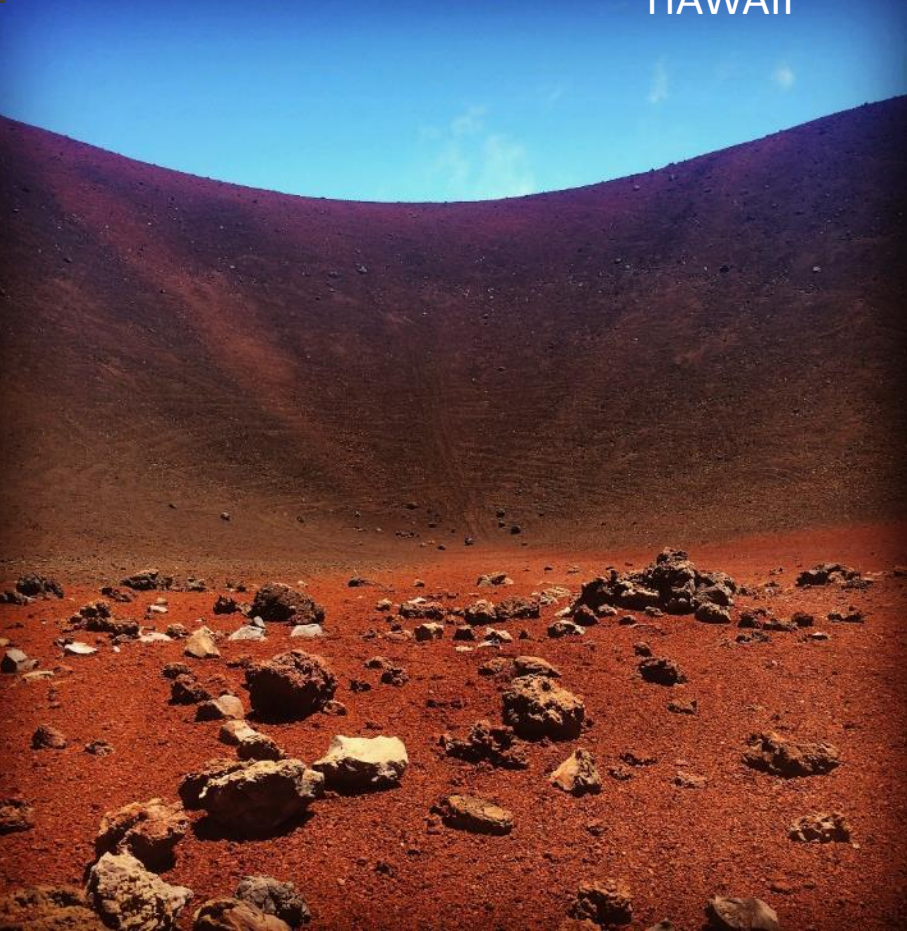


HAWAII

MARS



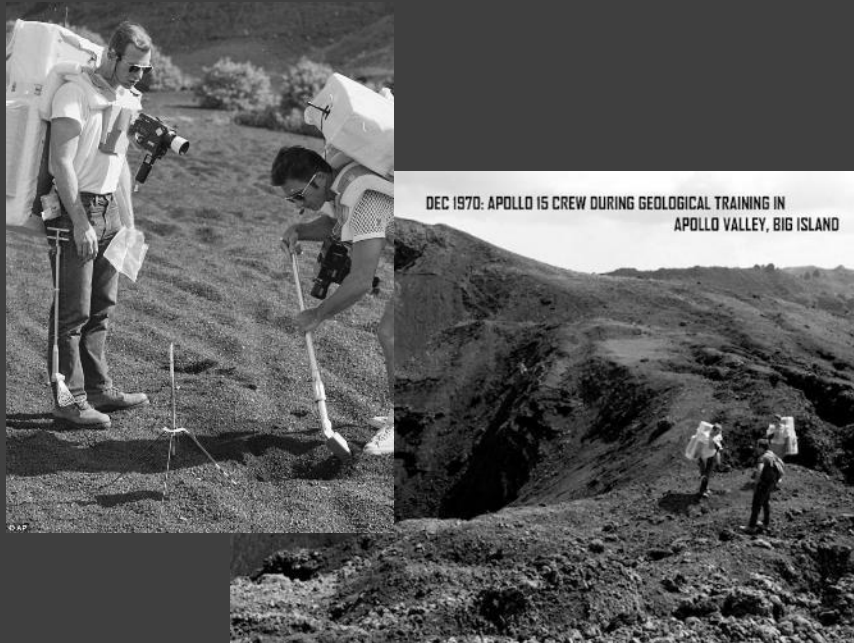
Regolith



How do we do it in another planet?

Hawai'i is a Great place to test space exploration technologies

- Terrain similar to Moon or Mars
- Composition of basalt similar to that of Moon and Mars



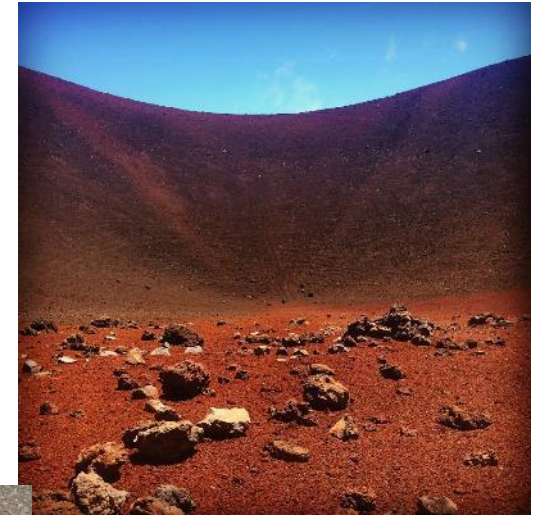
Science News from research organizations

Mars like Hawaii? NASA rover's first soil studies help fingerprint Martian minerals

Date: October 30, 2012
Source: NASA/Jet Propulsion Laboratory

MOTHERBOARD Watch ▾ Machines ▾ Discoveries ▾ Space ▾ Futures ▾ Gaming ▾ Earth ▾

Mars Is a Lot Like Hawaii, Curiosity Finds
November 6, 2012 // 04:51 PM EST

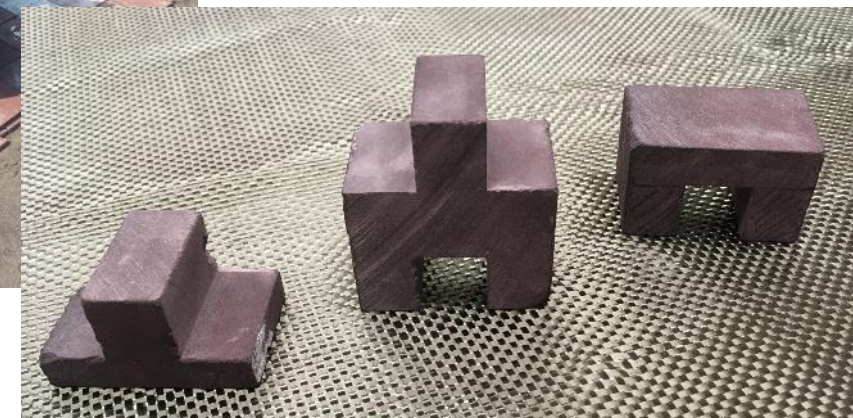
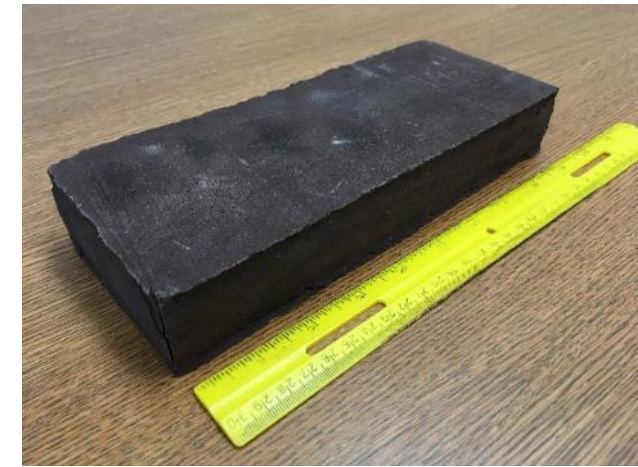


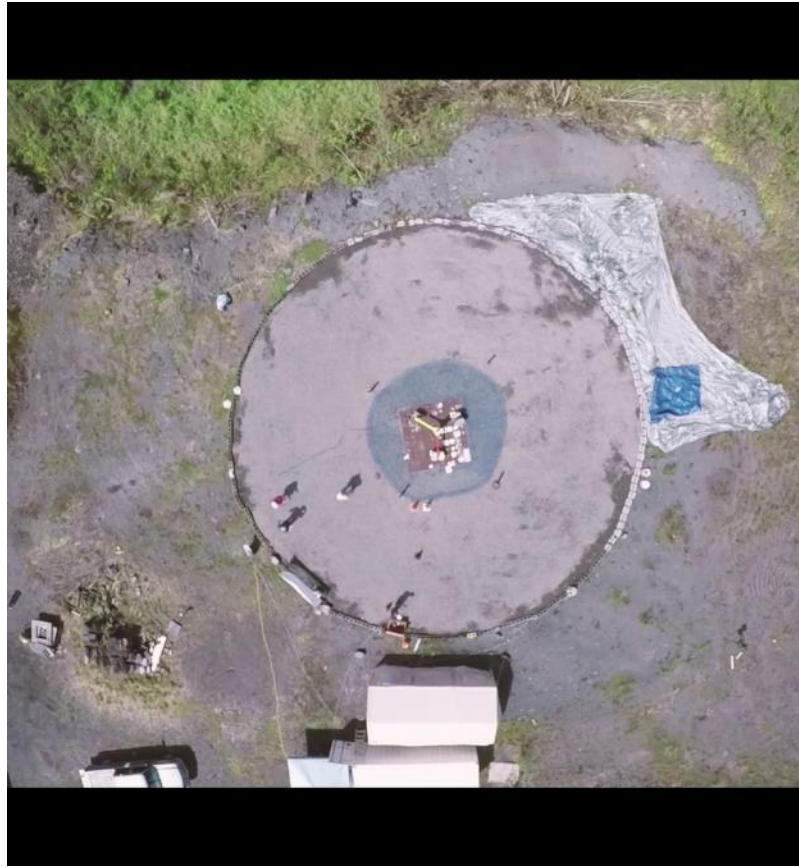
Sample	MnO ppm	Fe %	Na ₂ O %	MgO %	Al ₂ O ₃ %	SiO ₂ %	K ₂ O %	CaO %	TiO ₂ %
HI-Glover*	1672.517	8.176	2.404	6.781	13.007	50.504	0.353	10.132	1.777
JSC-1A	1800	10.79	2.7	9.01	15.02	47.71	0.82	10.42	1.59
LS 14163	1000	10.5	0.7	9.6	17.8	47.3	0.6	11.4	1.6
Spirit	2500	17	3	8.7	10.2	45	0.3	6.1	1
Opportunity	3000	18	2.1	7.5	9.1	44	0.4	6.9	1.1

PISCES FOCUS: *Sintering of basalt to produce a feedstock for construction & manufacturing*

Potential Applications

- Launch Pads
- Paver manufacturing for Thermal Wadis
- Reentry Thermal Heat Shields
- Radiation Shields.
- Indoor/Outdoor Flooring Tiles
- Tools & Parts
- Construction Blocks
- Thermal insulation
- Paved surfaces for dust mitigation





2015-2016 VTVL Project
PISCES, Swamp Works & Honeybee Robotics



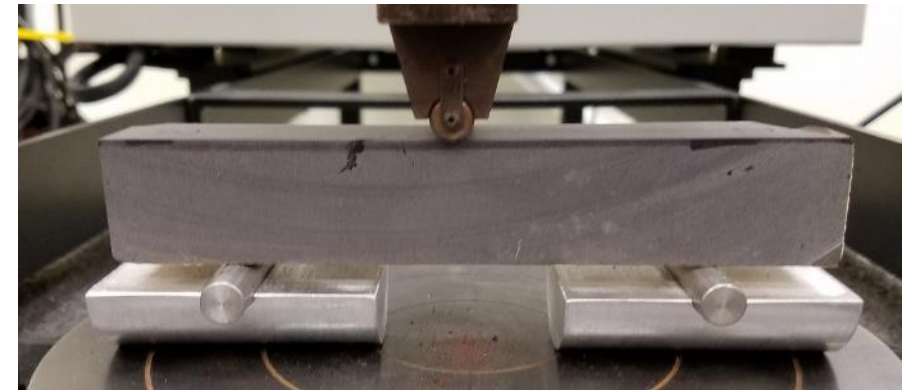
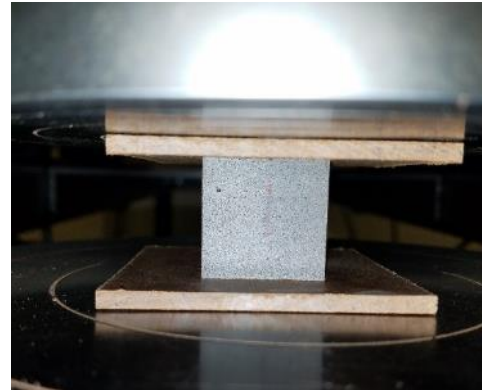
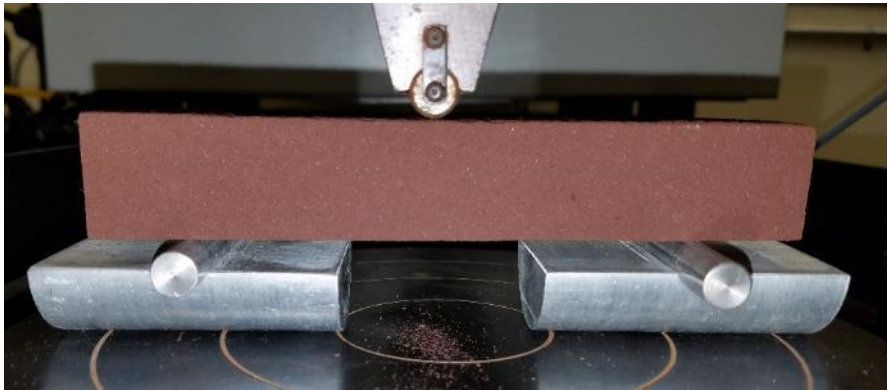
• Rocket Motor Test Firing

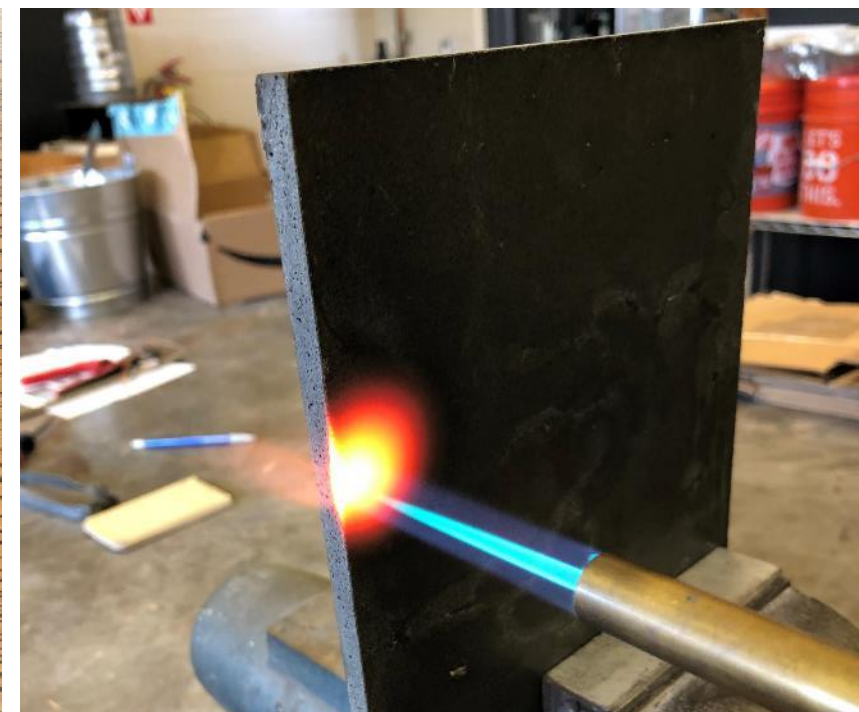
- AEROTECH N3300: 960 lb (f) Class M Rocket Motor (12 kg of ammonium perchlorate propellant)
- Plume temp: 1,926°C
- Total impulse 13,410 N/s
- Static Motor Test
- Motor Nozzle to be placed 16" above Impact Paver.

Improving the Sintering Process (2016-2020)

High temperature sintering of Hawaiian Basalt Fines

Test	Residential Portland Cement Concrete (typical)	2100	Commercial Portland Cement Concrete (typical)	Specialty Portland Cement Concrete (typical)	2150
Flexural Strength (psi)	500	716	800	2,000	5,852
Compressive Strength (psi)	2,500	3,116	4,000	10,000	30,825
Density (g/cm ³)		1.699			2.64

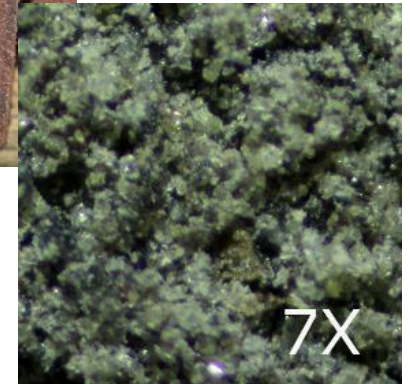




Effects that variations in mineralogy have on sintering process (2017-2020)

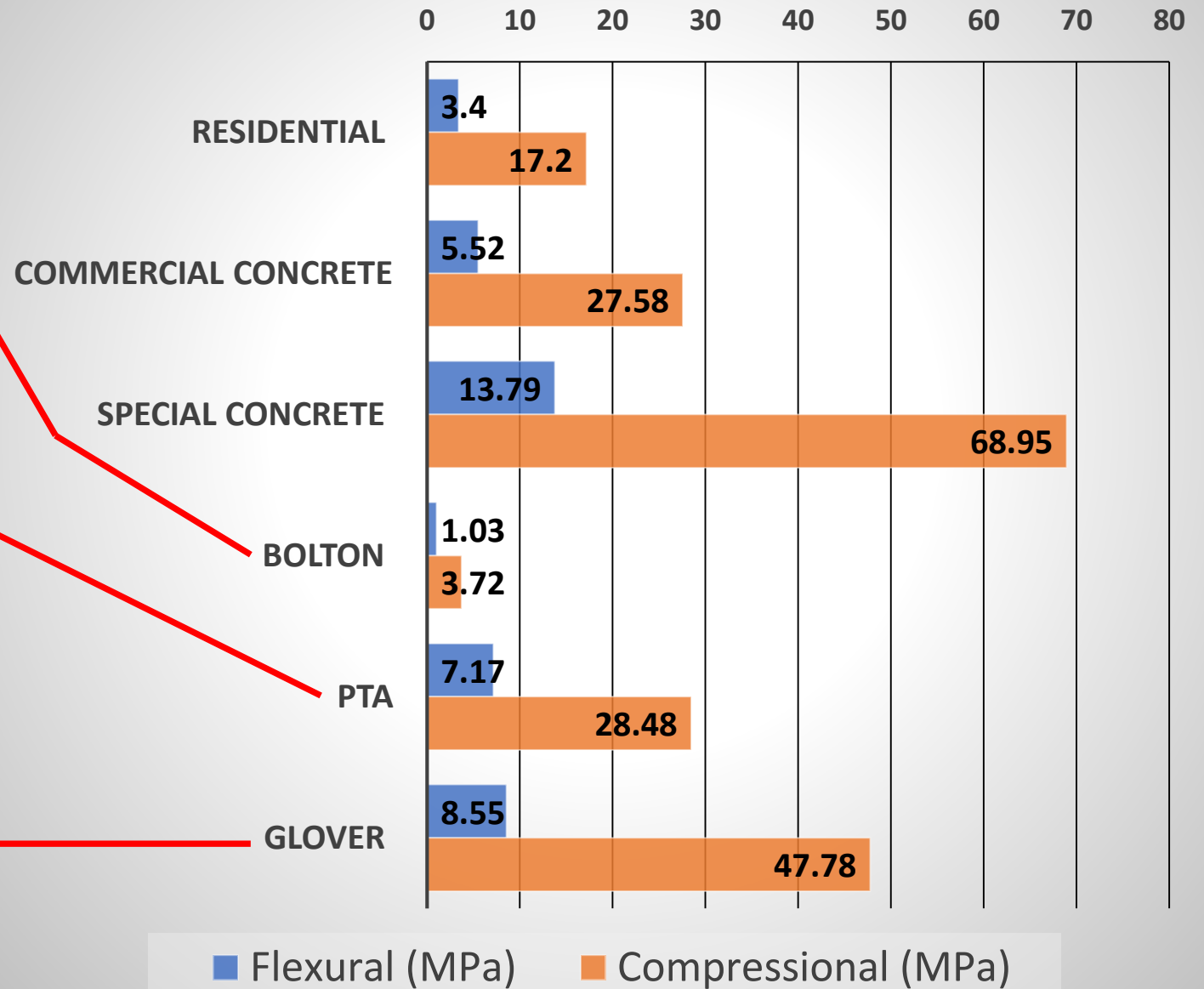
Hawaii-Lunar-Mars Basalt/Regolith Characterization (EDXRF)

Sample	MnO ppm	Fe %	Na ₂ O %	MgO %	Al ₂ O ₃ %	SiO ₂ %	K ₂ O %	CaO %	TiO ₂ %	Source
HI-Glover*	1672.517	8.176	2.404	6.781	13.007	50.504	0.353	10.132	1.777	Mauna Loa
HI-Puna	1677.425	8.54	2.392	9.109	12.552	50.69	0.347	9.938	1.755	Mauna Loa (?)
HI-Puna-b	1773.913	9.606	1.758	19.127	9.027	47.513	0.223	6.941	1.259	Kilauea
HI-PTA	1639.78	8.23	2.45	5.574	13.664	52.119	0.411	10.808	1.977	Mauna Loa
HI-Kona	1712.953	9.41	2.284	14.067	11.804	50.152	0.293	8.304	1.577	Hualalai





Compressional & Flexural Strength Testing on 1,149 °C Materials





Present Work: Use of a
mineral based binder in
aqueous solution

Benefits:

- Reduce mold deterioration
- Reduce sintering temperature
- Curing in lunar/Mars environment
- Potential for additive manufacturing through extrusion
- Binder has the potential to be synthesized from Martian regolith (lunar regolith less likely)

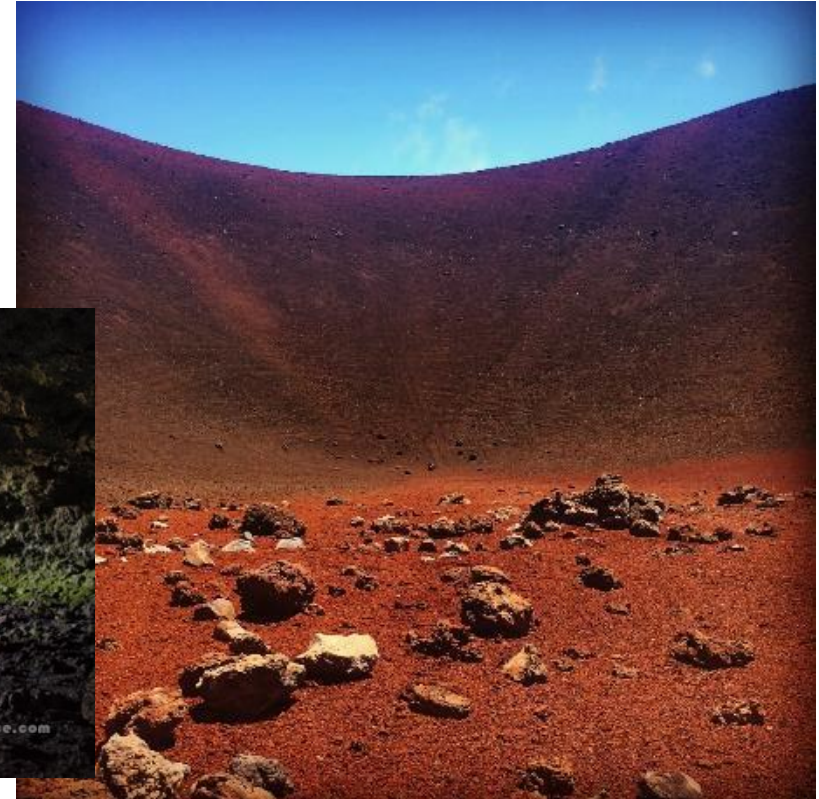


HALO
Hawaii Analogs for Lunar Operations



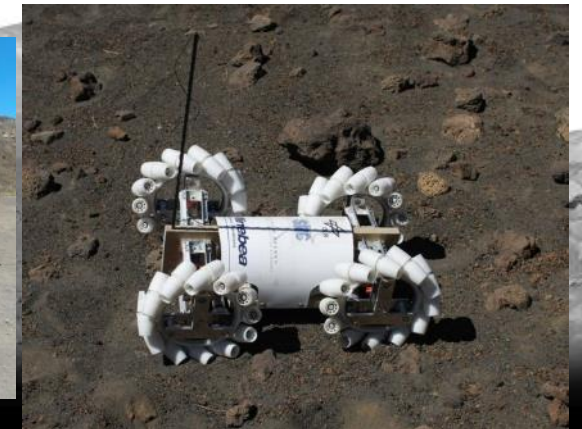
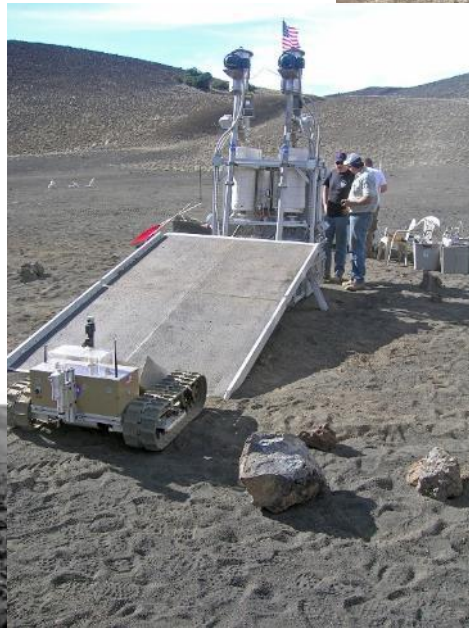
Hawai'i Island

- Formed by 5 Volcanoes
- Multiple lava fields with wide range of characteristics
- Pristine lava fields with no significant vegetation
- Multiple lava tubes
- Wide range of climates (Sea Level – 4,200 m ASL)
- Two major airports (Kona, Hilo)
- Deep Sea Water Port (Hilo)
- University & Community College
- Ideal infrastructure for testing



Recent Analog Testing under PISCES

- 2008 ISRU Analog Demo – NASA
- 2010 ISLO Analog Field Test – NASA
- 2012 Resolve Field Test – NASA, CSA
- 2013 Team Puli Field Test – GLXP team
- 2014: Helelani DRM-1 (PISCES)
- 2014: PRISM (Robotic Mining Competition)
- 2015: MoonRIDERS, (I‘olani, Kealakehe, PISCES, NASA) EDS Test
- 2015: Helelani DRM-2 (PISCES) @ Pu‘u Nene
- 2015-Spring 2016: ACME VTVL (PISCES, NASA & Honeybee Robotics)
- 2016: Helelani DRM-3n & Resource Prospector Remote Driving Test, (PISCES & NASA Ames)
- 2017: Helelani DRM-4 (PISCES)
- 2020: Helelani at HI-SEAS EMMIHS-III, HI-SEAS

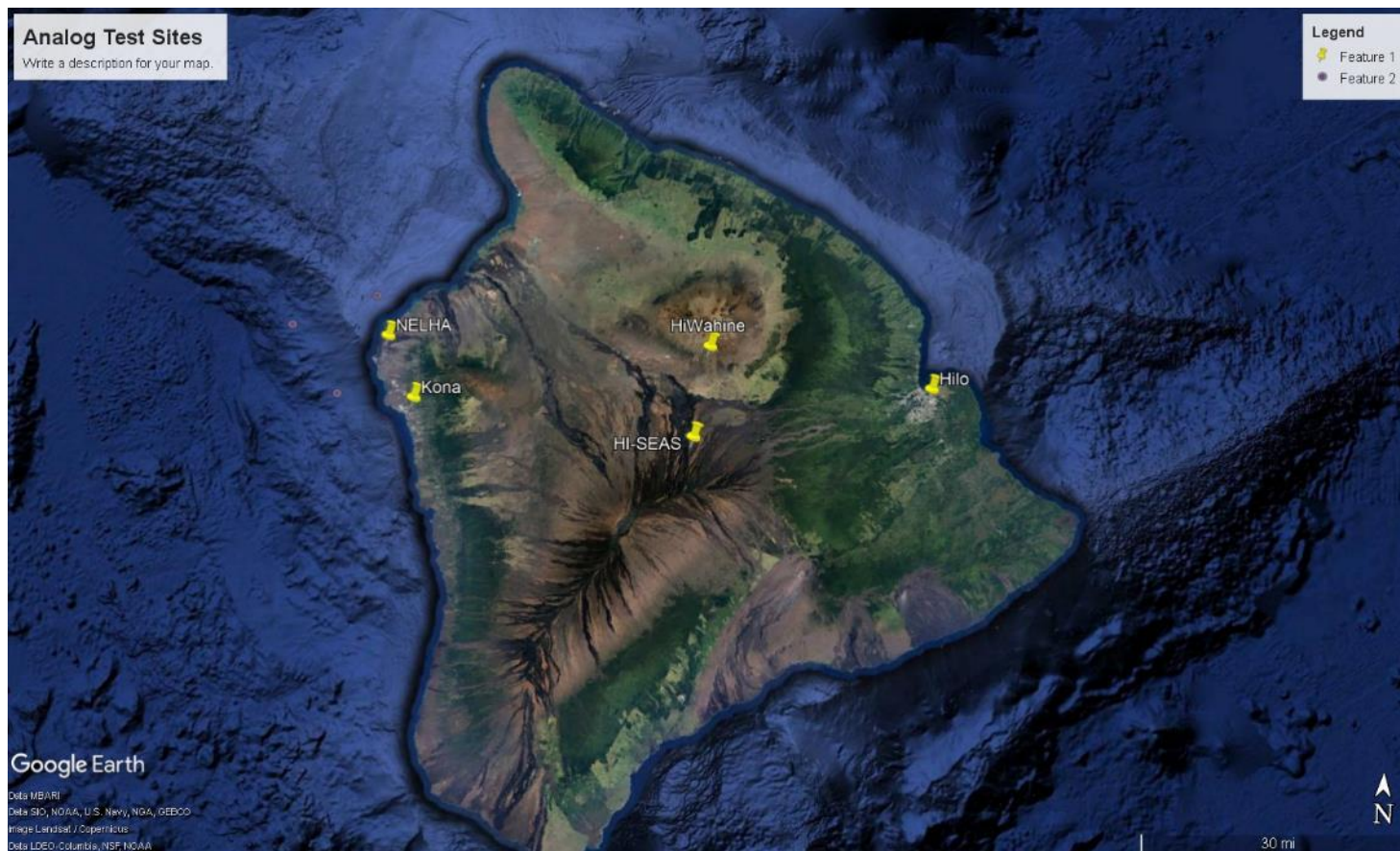


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Overview of Three Analog Sites

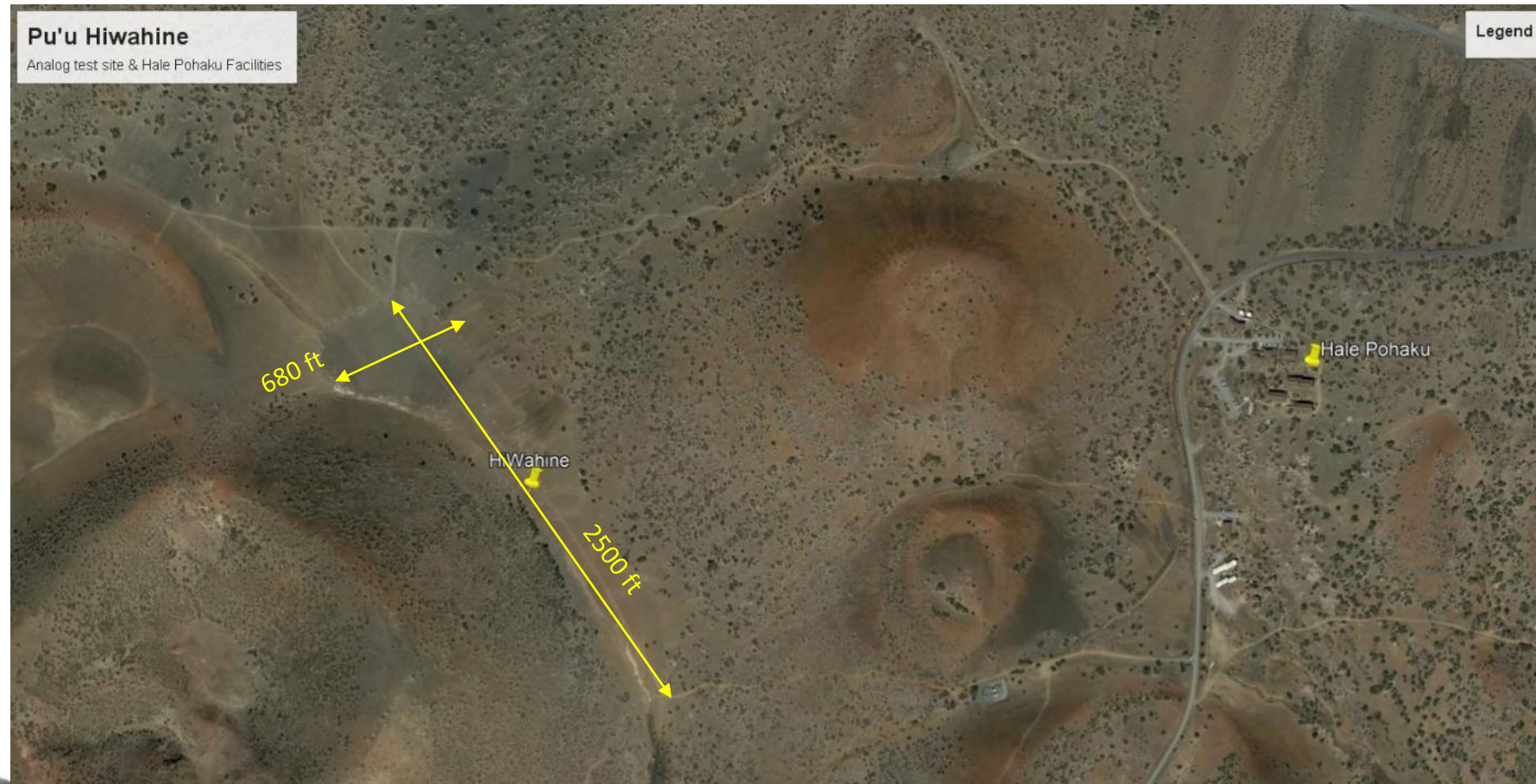
- Pu'u Hiwahine
- NELHA
- HI-SEAS



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Pu'u Hiwahine (2,750 m /9,000 ft ASL)

- High Elevation
- Full facilities close by
- Easy access (4x4 to valley)
- Requires DLNR Permit
- Communications Available
- Low Probability for Precipitation
- Site for many previous tests
- Wide range of terrain and surface.

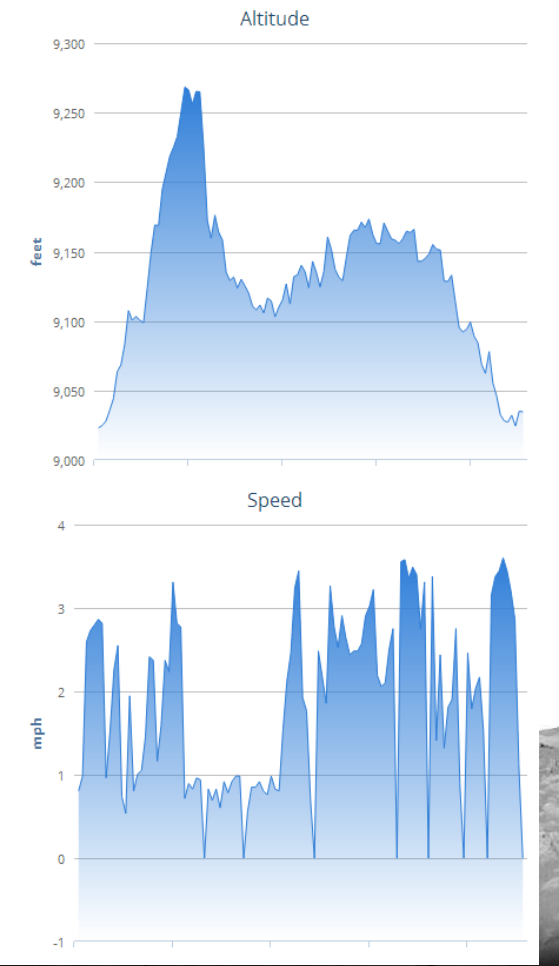
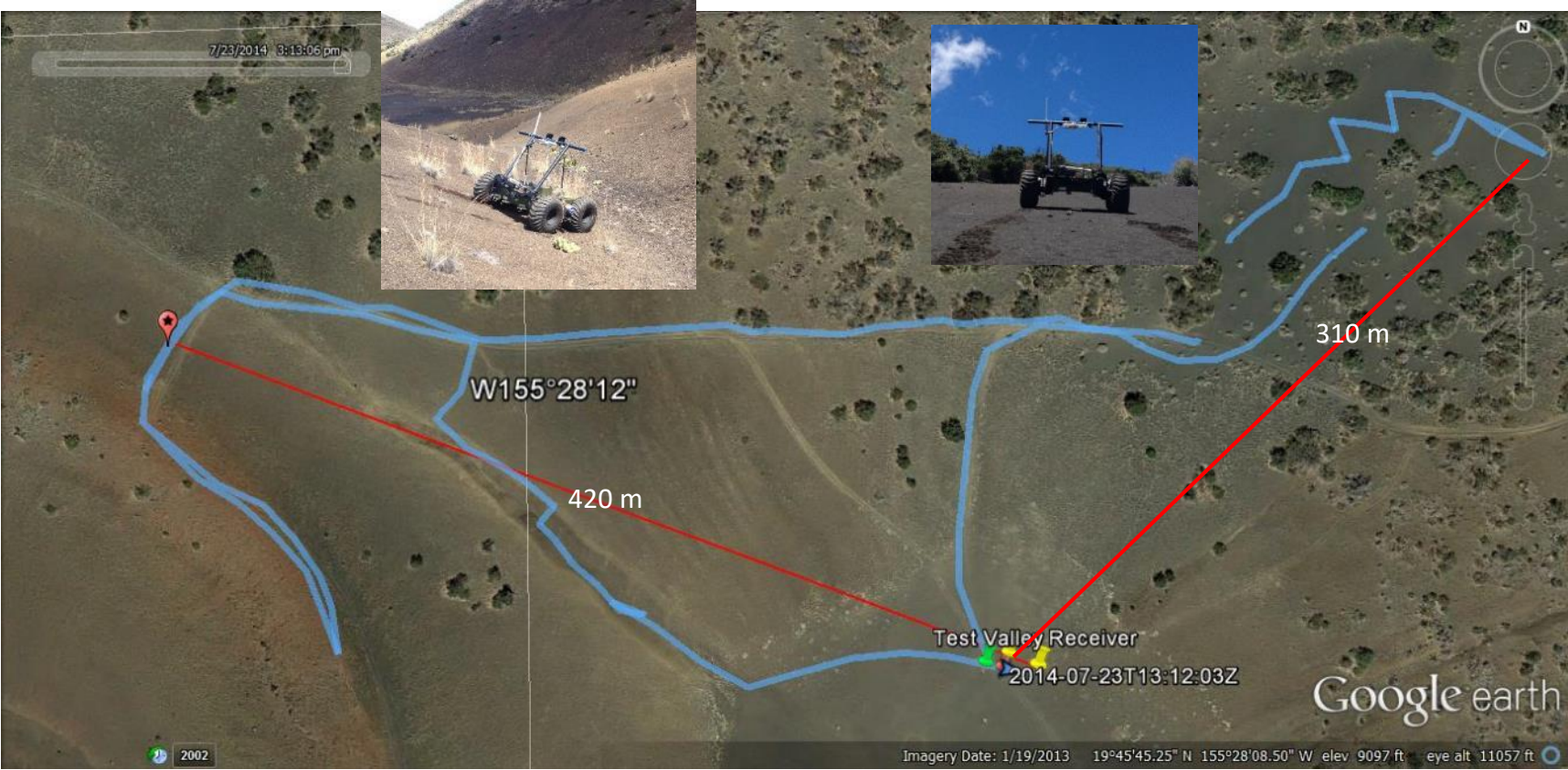


Test Run 3 (7/23/2014) – Steep Climb | Controlled from Base Camp

Trip Maps Statistics

July 23, 2014, 7:10 p.m. - July 23, 2014, 8:36 p.m.	
Traveled:	1958.30319908
Travel Time:	July 23, 2014, 8:36 p.m.
Speed:	1.61000001431
Altitude:	2824.74418259
Downhill:	954.319812286
Uphill:	1003.9833868
Vertical Drop:	126.173828125
Vertical Climb:	145.650634766

[Download KML](#)



Facilities: Hale Pohaku

- ~1hr from Hilo/Kona
- Paved Road Access
- Full cafeteria service
- Bedrooms
- Conference Center
- Rec Center
- Comms

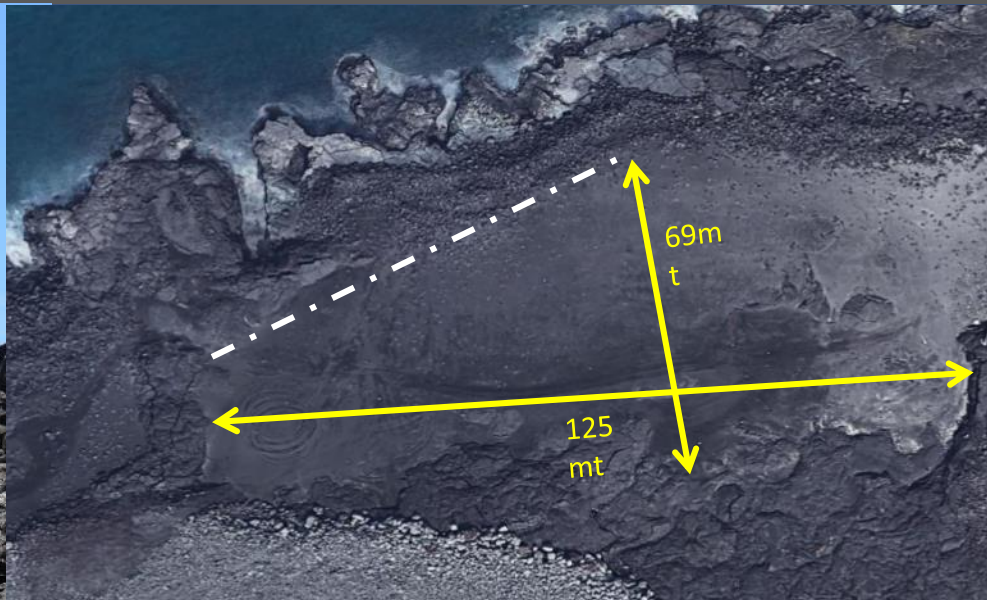


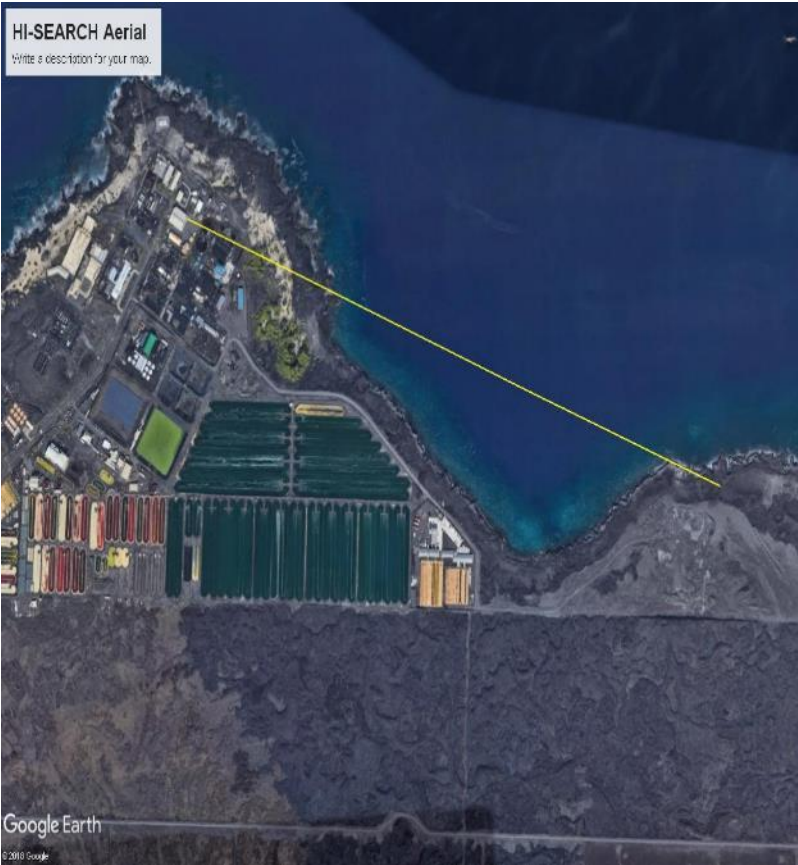
NELHA (Sea Level)

- Full facilities close by
- Easy access
- No Permit Required
- Communications Available
- Low Probability for Precipitation
- Lunar Analog
- Flat surface with sandy terrain & lava outcrops
- Good site for surface mobility tests



NELHA (Sea Level)





NELHA (Facilities)

Hawaii Space Exploration And Simulation (HI-SEAS)



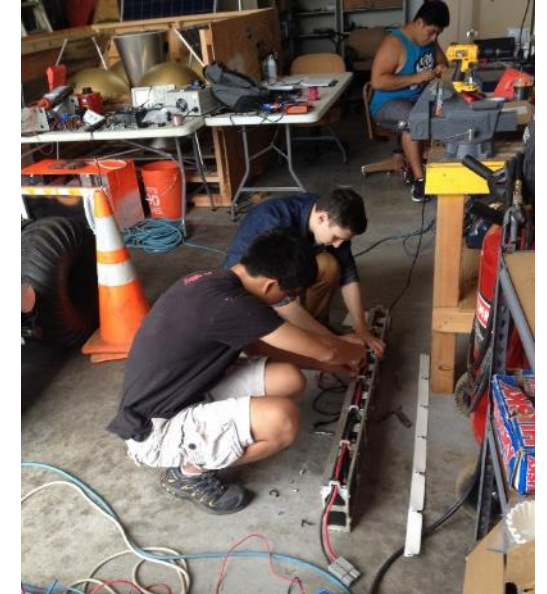
PISCES Support Capabilities

Field Test Equipment:

- Tents
- Charis & Tables
- Generators & power hardware
- Local Comm Network
- Remote Comms
- Analog Rover

Logistics:

- Land permit
- Reservations
- High Bay / shop
- Interns/volunteers
- Secured Trailer
- Third Party Equipment Rentals
- Control Room Settings



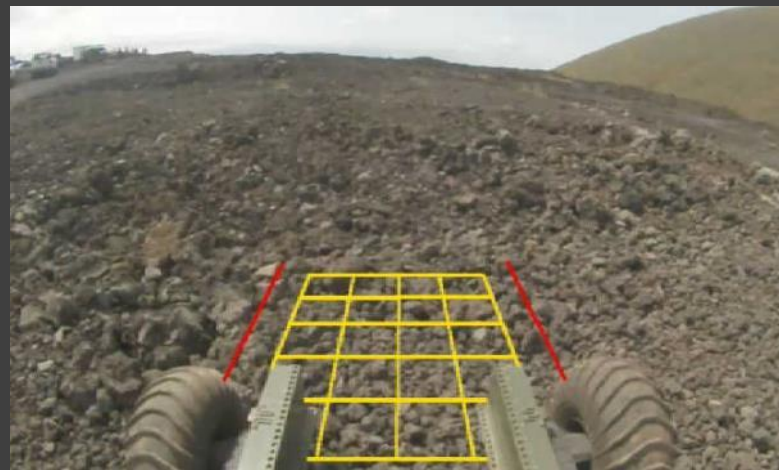
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HELELANI

ODG ARGO Rover

- Open Payload Deck Design
- Handheld or GUI control
- Up to 200lbs payload on deck 100lb on mast
- 3 Sit cams
- GPS, IMU
- 12V, 24V & 48V DC





MOKU (Island)

(Mobile Operations Kommand Unit)

- Trailer equipped with power (gas generator)
- Serves as relay station to connect Hale Iako to Test Site or to create a local LAN for rover operations.
- Work stations and tool area.
- AC equipped.

Mahalo

