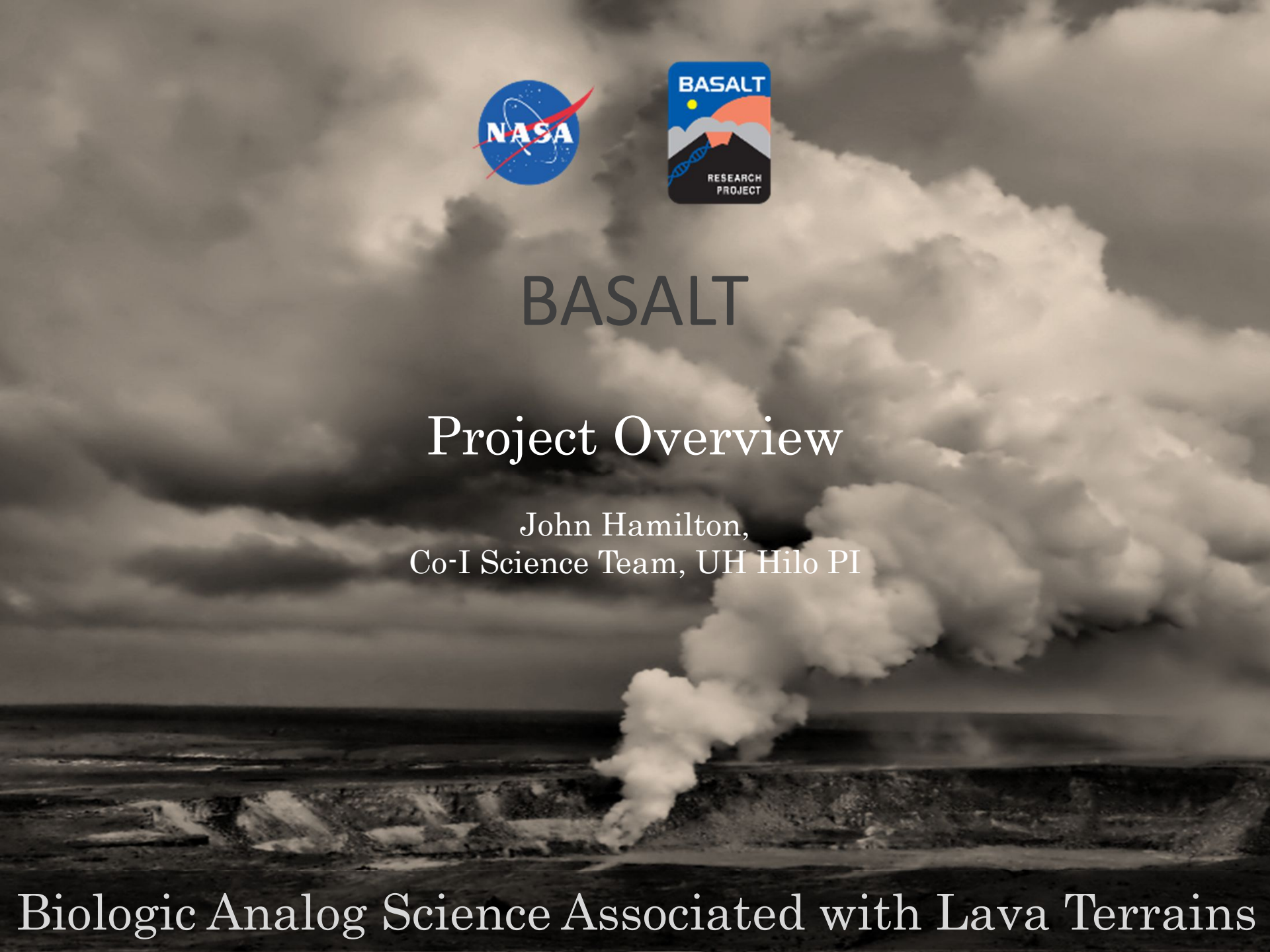


BASALT

Project Overview

John Hamilton,
Co-I Science Team, UH Hilo PI

Biologic Analog Science Associated with Lava Terrains

Biologic Analog Science Associated with Lava Terrains – Conops Development for Future Human Exploration of Mars

Planetary Science and Technology from Analog Research (PSTAR) program addresses the need for integrated interdisciplinary field experiments as an integral part of preparation for planned human and robotic missions.

- Furthermore, the program solicits proposals for investigations focused on exploring the Earth's extreme environments in order to develop a sound technical and scientific basis to conduct astrobiological research on other solar system bodies.
- The focus of this program element is on providing high-fidelity scientific investigations, scientific input, and science operations constraints in the context of planetary field campaigns.

PSTAR solicitation is a consolidation of two previous calls: Astrobiology Science and Technology for Exploring Planets (ASTEP) and Moon Mars Analogue and Mission Activities (MMAMA).

https://spacescience.arc.nasa.gov/basalt/
https://twitter.com/basalt_research?lang=en

Project Goals

Science:

The BASALT science program is focused on understanding habitability conditions of early and present-day Mars in two relevant Mars-analog locations (the Southwest Rift Zone (SWRZ) and the East Rift Zone (ERZ) flows on the Big Island of Hawai'i and the eastern Snake River Plain (ESRP) in Idaho) to characterize and compare the physical and geochemical conditions of life in these environments and to learn how to seek, identify, and characterize life and life-related chemistry in basaltic environments representing these two epochs of martian history.

Science Operations:

The BASALT team will conduct real (non-simulated) biological and geological science at two high-fidelity Mars analogs, all within simulated Mars mission conditions (including communication latencies and bandwidth constraints) that are based on current architectural assumptions for Mars exploration missions. We will identify which human-robotic ConOps and supporting capabilities enable science return and discovery.

Technology:

BASALT will incorporate and evaluate technologies in to our field operations that are directly relevant to conducting the scientific investigations regarding life and life-related chemistry in Mars-analogous terrestrial environments. BASALT technologies include the use of mobile science platforms, extravehicular informatics, display technologies, communication & navigation packages, remote sensing, advanced science mission planning tools, and scientifically-relevant instrument packages to achieve the project goals.

What ?

- BASALT is an international team of scientists, engineers, mission operators, and astronauts who are dedicated to enabling the human-robotic exploration of Mars!
- 4 NASA Centers: Ames Research Center, Goddard Space Flight Center, Kennedy Space Center, Johnson Space Center
- 4 Universities: McMaster University (Canada), Univ. of Edinburgh (UK), Idaho State Univ., Univ. of Hawai`i - Hilo

How ?

- The drive to discover and explore our Solar System will benefit from and ultimately demand the infusion of science into the operational framework and execution cadence of the mission. From an early stage in the architecture development process we are designing the "How?" in such a way that supports both the well-being of astronauts and their ability to conduct *meaningful, productive,* and *efficient* scientific exploration.
- By examining the minerology of basalts, one can determine the moisture conditions during eruptions and look for changes due to both water and microbial life (bio-alterations).

Milestones

- June 2015 – Face to Face Kickoff Meeting – Ames Research Center
- Oct 2015 – Hawai'i Recon for operations sites, HVNP
- June 2016 – The first round of BASALT field tests, at Craters of the Moon National Monument and Preserve, in Idaho. The site was an analog to present-day Mars, where most evidence for the type of volcanism studied by the project is from a more active past thousands of years ago.
- November 2016 – BASALT's second field test, on the lava flows of Mauna Ulu, on the Big Island of Hawaii. This volcanically active location was an analog environment for early Mars.
- July 2017 – Operations Readiness Test – Ames
- November 2017 – The third and final season of testing for BASALT was held at Kilauea Iki and Kilauea Caldera Region, Hawaii Volcanoes National Park – also an analog environment for early Mars.
- December 2018 – AGU Washington DC
- March 2019 – The journal Astrobiology published a special issue devoted to the science, technology and engineering of future human space exploration studied by the BASALT research program: "The BASALT Program: Analog research in support of human scientific exploration of Mars."
- December 2019 – AGU San Francisco

Face to Face Meeting @ ARC 2-4 June 2015

Rock Yards are laboratory (artificial) versions of analog sites.

K-Rex rover on Ames Rock Yard

Viewed by Astronaut Jeff Hoffman

CotM

Landsat Image

Craters of the Moon National Monument

Radio Comm Link – 22 Miles

Mars to Earth

Darlene Lim, BASALT Lead Principal Investigator.

Astrogeobiologist

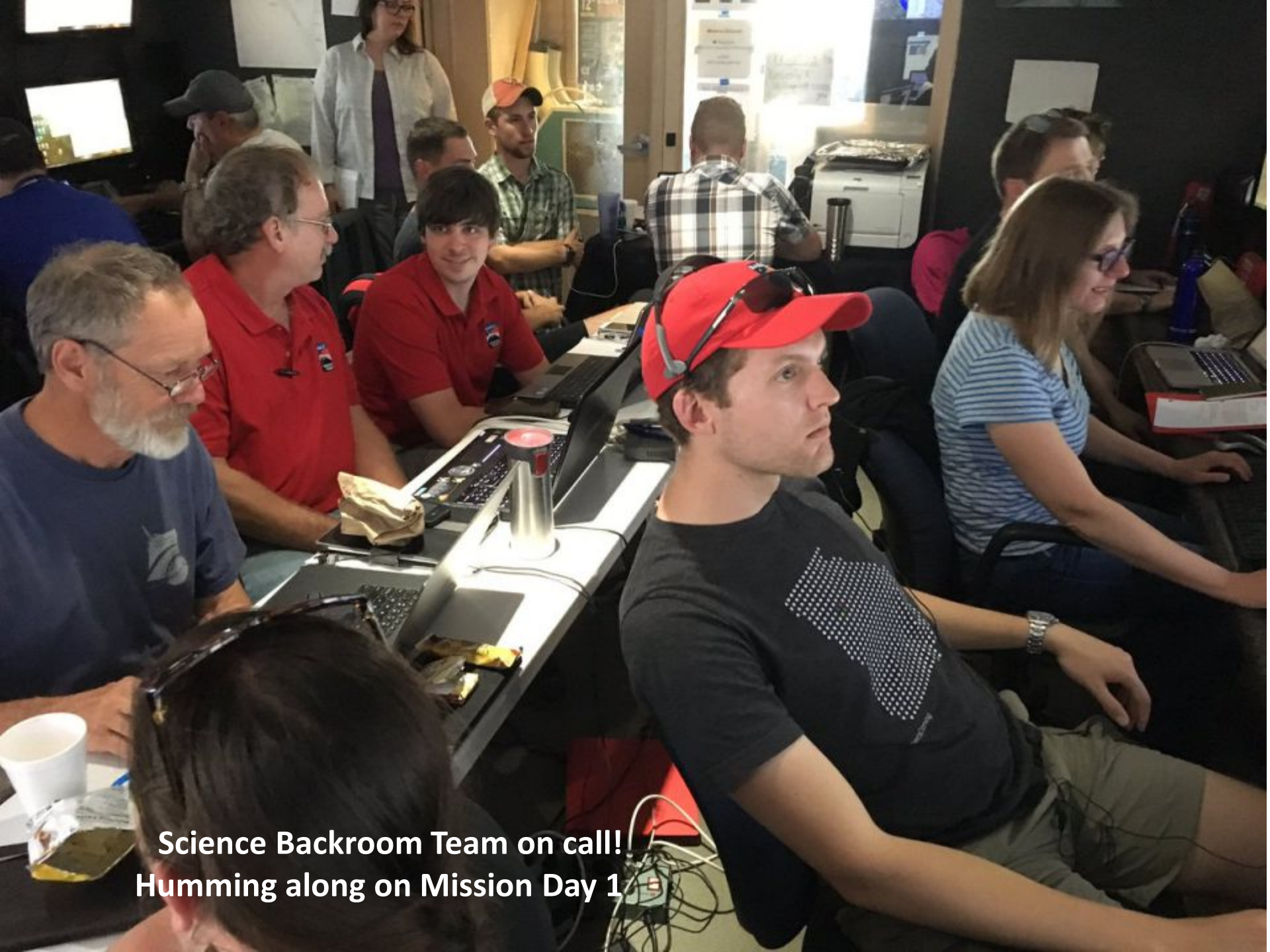
Cinders


You'll be BLOWN AWAY!

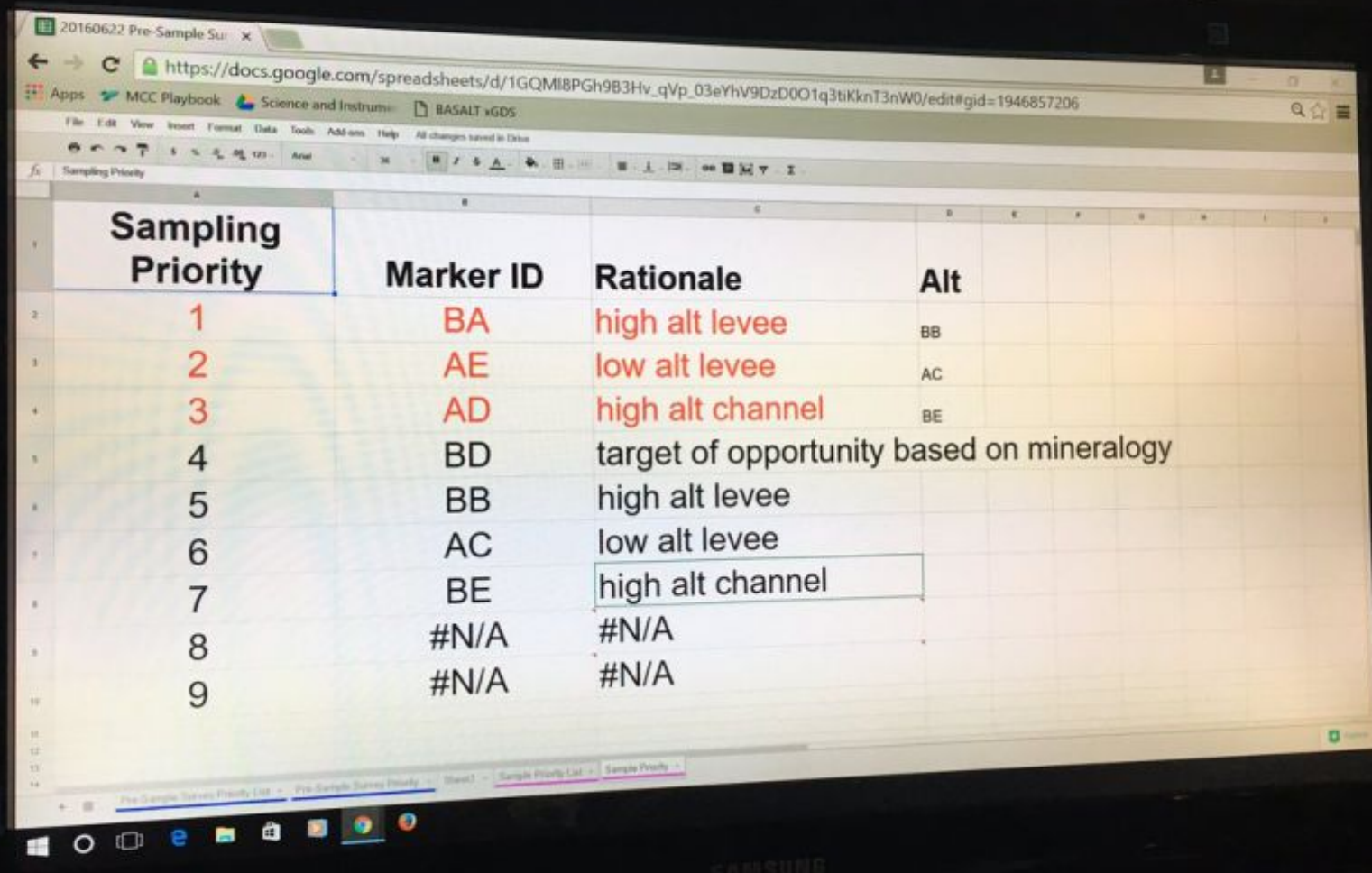
LIDAR mapping

MMC - Mobile Mission Control
Arco Mountain View RV Park


NASA


Science Backroom Team on call!
Humming along on Mission Day 1

Leader Board



Sampling Priority	Marker ID	Rationale	Alt
1	BA	high alt levee	BB
2	AE	low alt levee	AC
3	AD	high alt channel	BE
4	BD	target of opportunity based on mineralogy	
5	BB	high alt levee	
6	AC	low alt levee	
7	BE	high alt channel	
8	#N/A	#N/A	
9	#N/A	#N/A	

BASALT FINESSE xGDS

Map EVA Notes Sample Se

Photo Sample ASD FTIR Notes

Search: Display 10

Previous 1 2 3 4 5 … 24 Next

Acquisition	TZ	Name	Description	
06/22/16 13:00:32	MDT	P6220067.JPG	MD3 Sample Location BA Station 7	
06/22/16 12:59:48	MDT	P6220066.JPG	MD3 Sample Location BA Station 7	
06/22/16 12:23:32	MDT	P6220065.JPG	MD3 Sample Location BD Station 7 ASD Scan 19 Spectrum	
06/22/16 12:22:58	MDT	P6220064.JPG	MD3 Sample Location BD Station 7 ASD Scan 19 Minerals	
06/22/16 12:22:05	MDT	P6220063.JPG	MD3 Sample Location BD Station 7 ASD Scan 18 Spectrum	
06/22/16 12:21:55	MDT	P6220062.JPG	MD3 Sample Location BD Station 7 ASD Scan 18 Minerals	
06/22/16 12:21:01	MDT	P6220061.JPG	MD3 Sample Location BD Station 7 ASD Scan 17 Spectrum	
06/22/16 12:20:54	MDT	P6220060.JPG	MD3 Sample Location BD Station 7 ASD Scan 17 Minerals	

Daily Mission Management Team
meeting/ritual 20 Jun 2016

Traverse Planning & Evaluation (live GPS tracking)


2016-06-20 17:51:55
MARS-PET
EARTH-PET
04:07:57.3
04:02:56.9
Stop
Stop

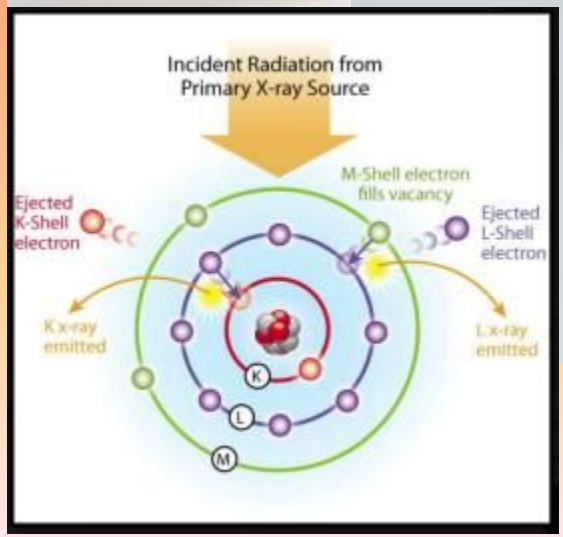
Tools of the Trade (a la Star Trek)

TerraSpec Halo
Portable Vis-NIR Spectrometer

Range:
350-2500 nm

Resolution:
3 nm @ 700 nm
9.8 nm @ 1400 nm
8.1 nm @ 2100 nm

Thermo X-Ray Fluorescence
Spectrometer (XRF)

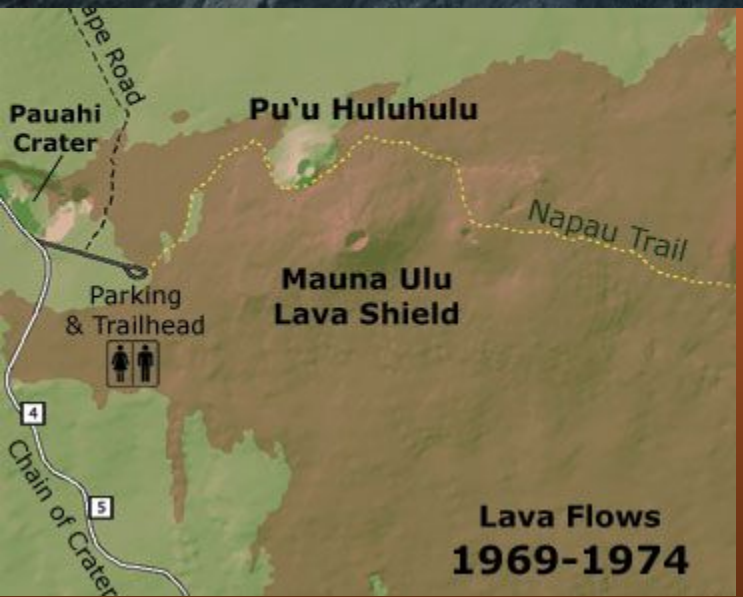


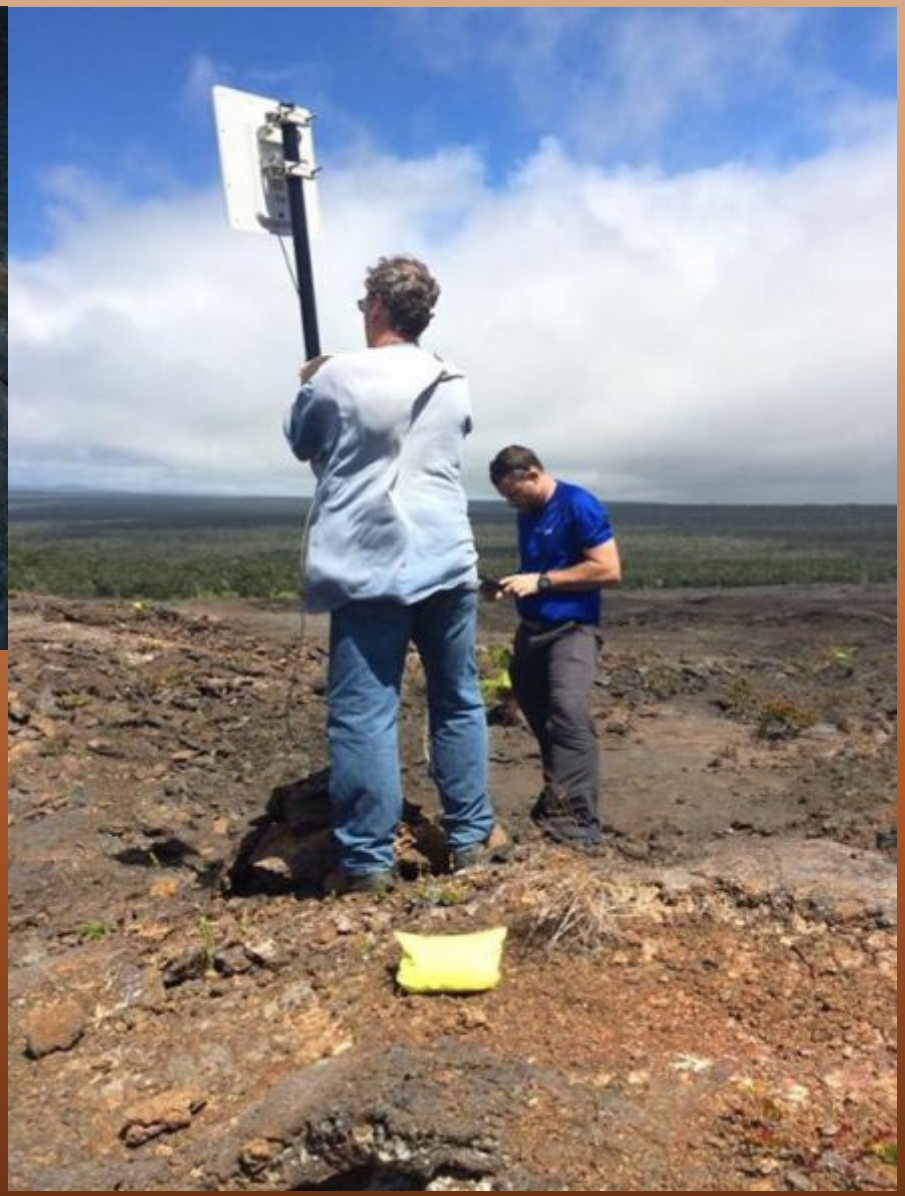
~ $30,000

Chris and Shannon w/ UHH support

Comms Recon at Mauna Ulu

NASA KSC and UHH fix line-of-sight radio to HVO then relay to Kilauea Military Camp

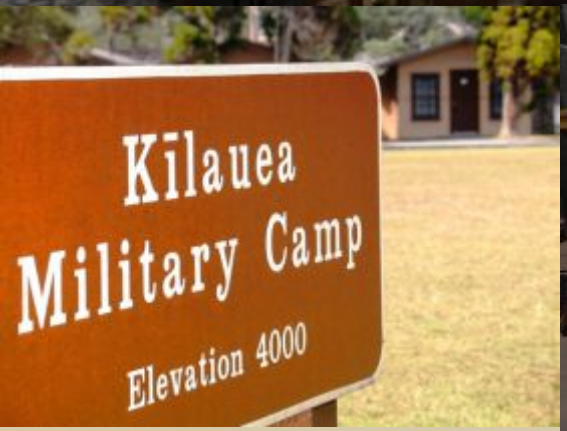





Kilauea Military Camp
Volcano
Kīlauea Visitor Center
1.4 miles
Hawaii Volcanoes National Park
Jaggar Museum HVO
Nāhuku - Thurston Lava Tube
Kilauea
~8 Miles
Hawaii Volcanoes National Park
Mauna Ulu Summit

Kilauea Military Camp aka “Earth”

- Science Backroom



MOUNTAIN COTTAGES & RESORT
KILAUEA MILITARY CAMP
www.KilaueaMilitaryCamp.com
808.967.8333

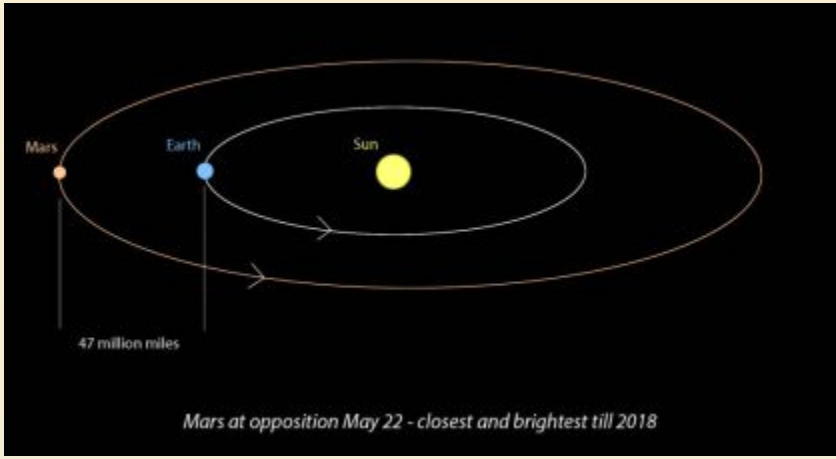
The Software Support behind the Science Team

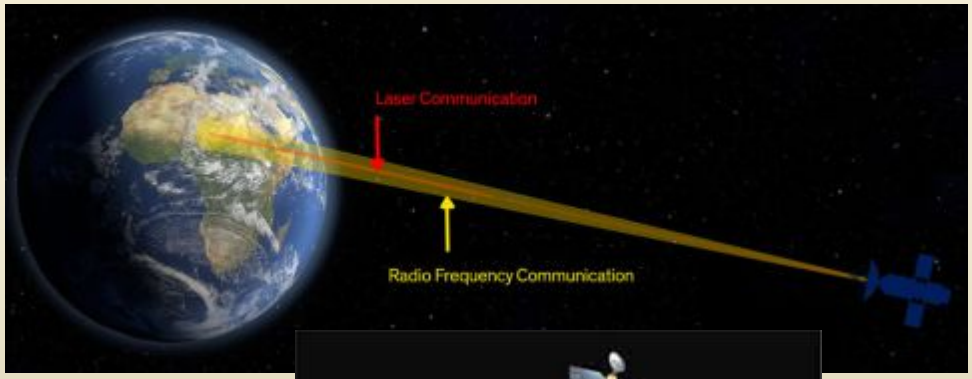
Image and Location

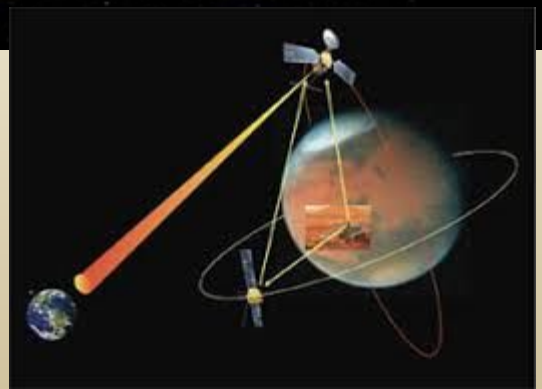
Leader Board

OWLT and BW

- Communication latency will occur between Mars and Earth, ranging from 4 to 22 min one-way light time (OWLT) (8–44 min round trip). The question remains as to when and how Earth-based support could assist during EVAs.







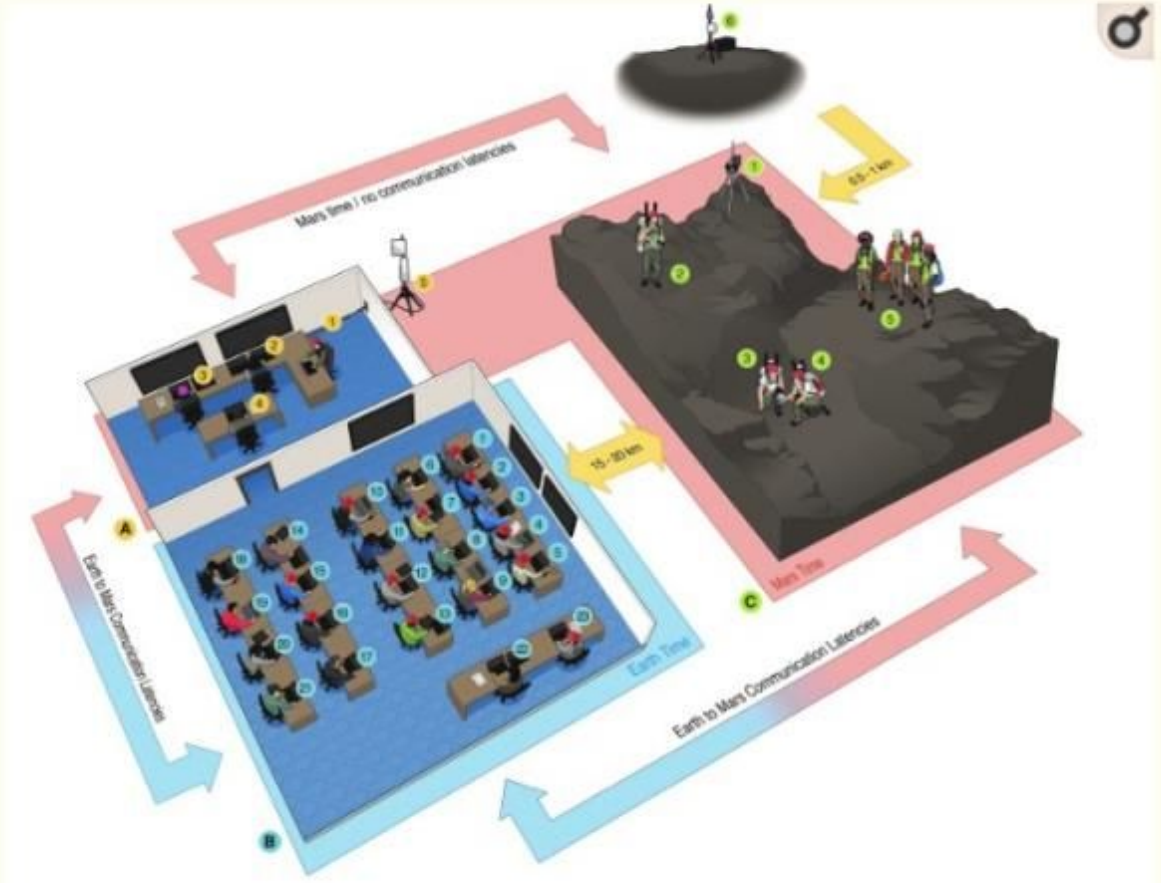
Radio vs Laser: Bandwidth afforded by communications architecture will impact the ability to share data products and other communications between space and ground during EVA.

Timeline


MARS PET
2h 03m 09s
EARTH PET
1h 48m 09s
Playbook for BASALT - Ground
Playbook for BASALT - Ground

Timeline Managers - Playbook

Mission Architecture



A Intra-Vehicular Workstation

1. Stenographer
2. IV Crewmember - Science
3. IV Crewmember - Operations
4. X-Sim Playbook
5. Base Camp Relay Node

B Mission Support Center

1. Leaderboard Lead
2. Science Lead
3. Sci-Comm
4. CapCom
5. EVA Timeliner/Planner
6. Situational Awareness
7. Image Tagging
8. Instrument Lead
9. Science Tactical (Geo)
10 & 11. Situational Awareness/ Image Management/ Science Tactical
12. Ethnographer
13. Science Tactical (Bio)
14 & 15. xGDS Members
16. SEXTANT
17. VR/AR Support
18 & 19. Additional Support
20 & 21. Communications/Networking Support
22. Bio Lead
23. Geo Lead

C Field

1. Situational Awareness Camera / Mobile Instrument Platform (MIP)
2. In-Field Communications Leader / MIP
3. EV Crewmember - Operations
4. EV Crewmember - Science
5. Field Support Team (FST) / MIP
6. Central Relay Node

OPS LAYOUT

Simulation
Astronauts
Mars Surface
EVA

Mauna Ulu
and Kilauea

Realtime

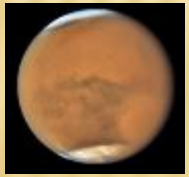
Mars Base
support
Astronauts

KMC
(Quarantined)

Time Delay
(5 and 20min)

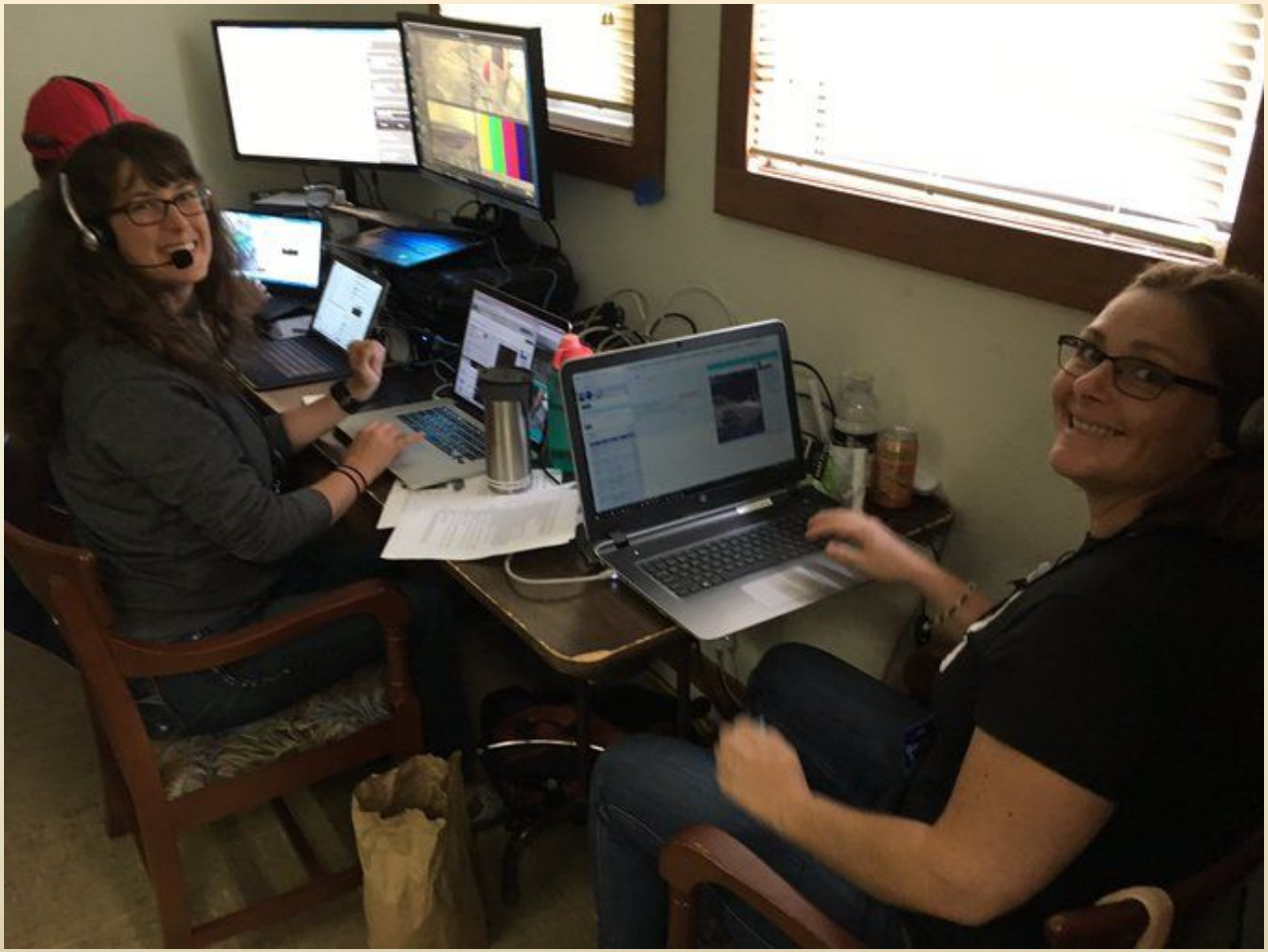
Earth Science
Backroom
support

Kilauea
Military
Camp

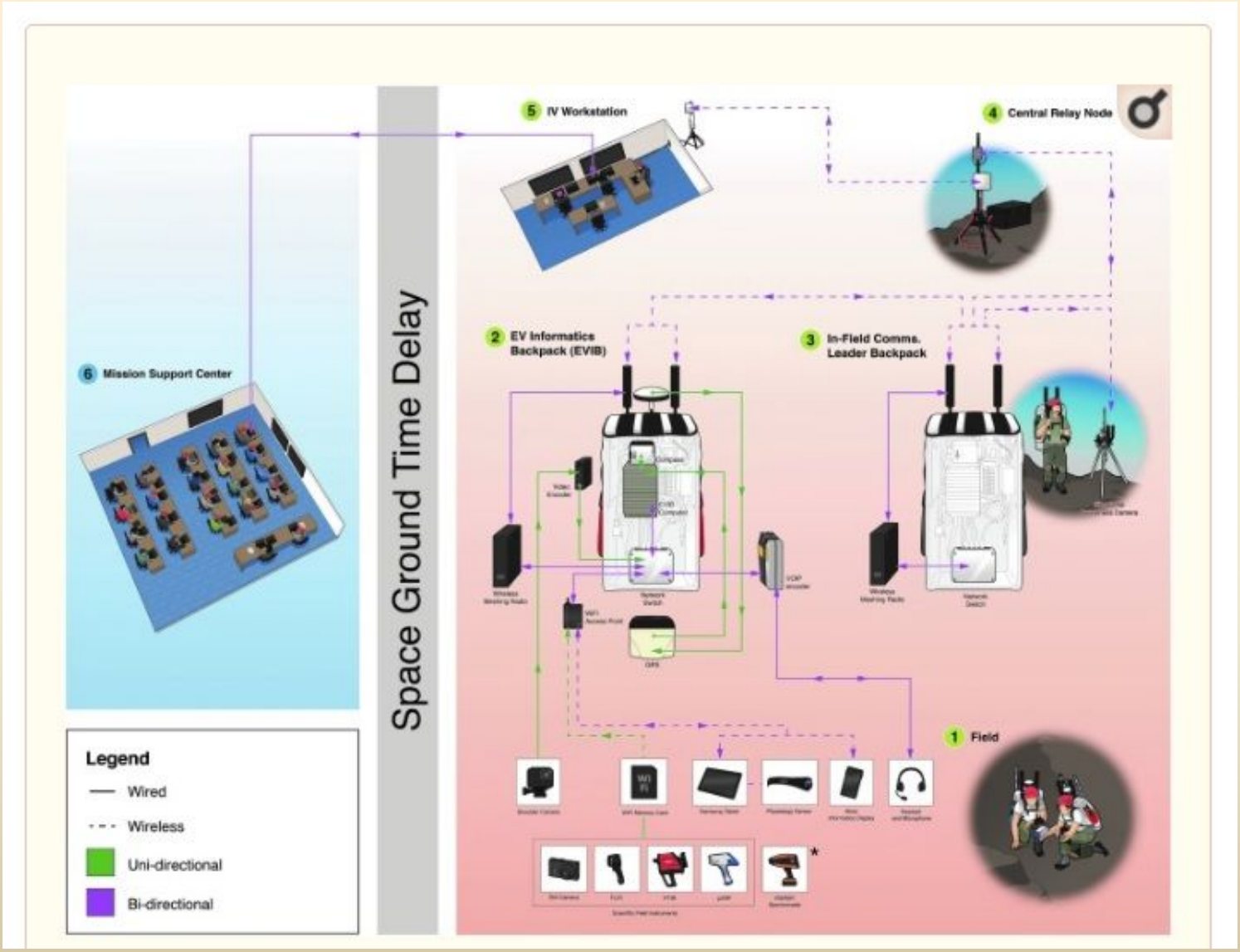


Another Day back on Earth

Mars Base

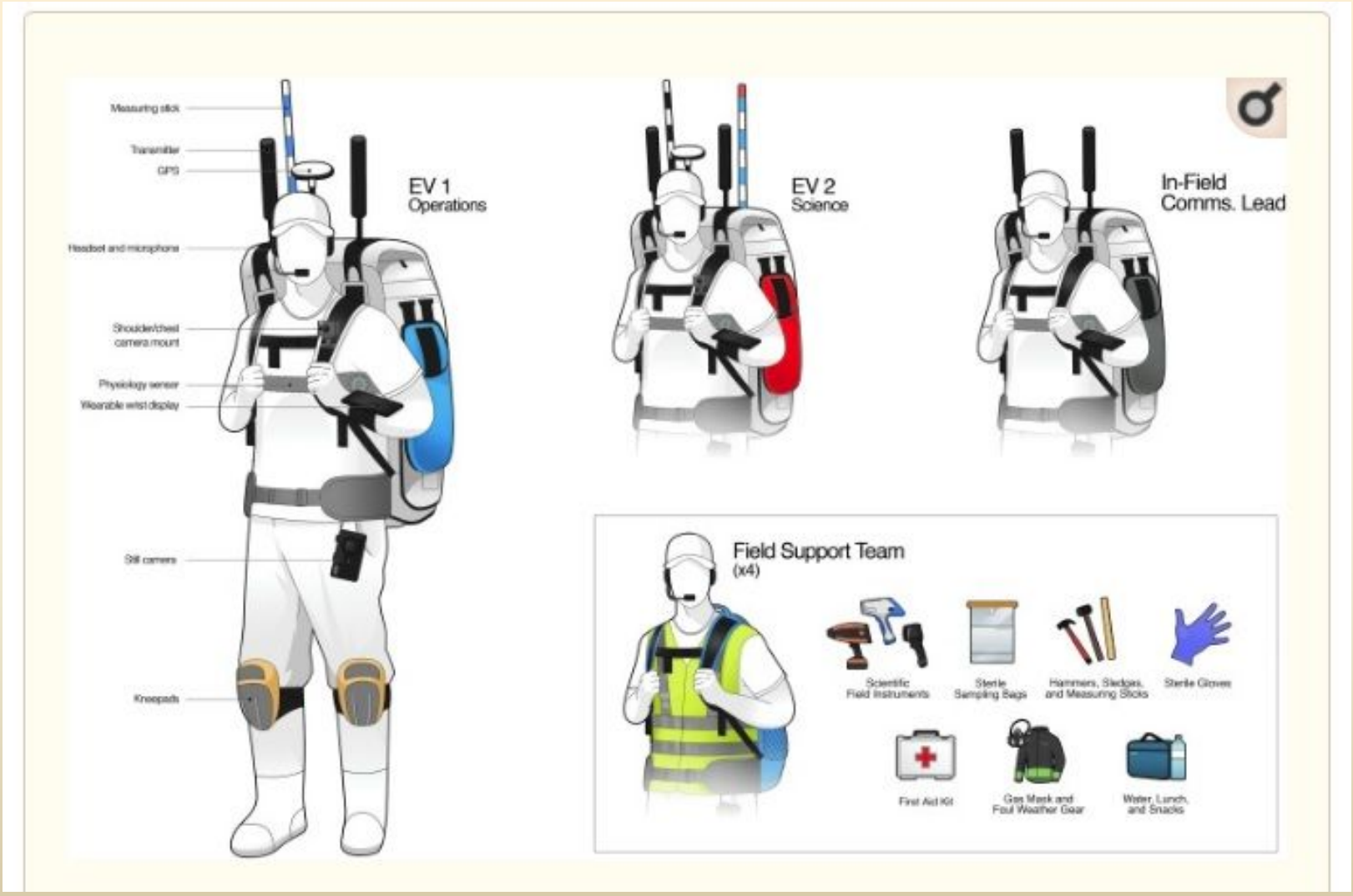


Communications Architecture



Mike Miller - KSC

EV backpacks



High Bandwidth video stream


BASALT FIELD SUPPORT TEAM
WE SIT, WE STAND, WE HAND
imgflip.com

Group Photo Time

Not every day is sunny

December 2016

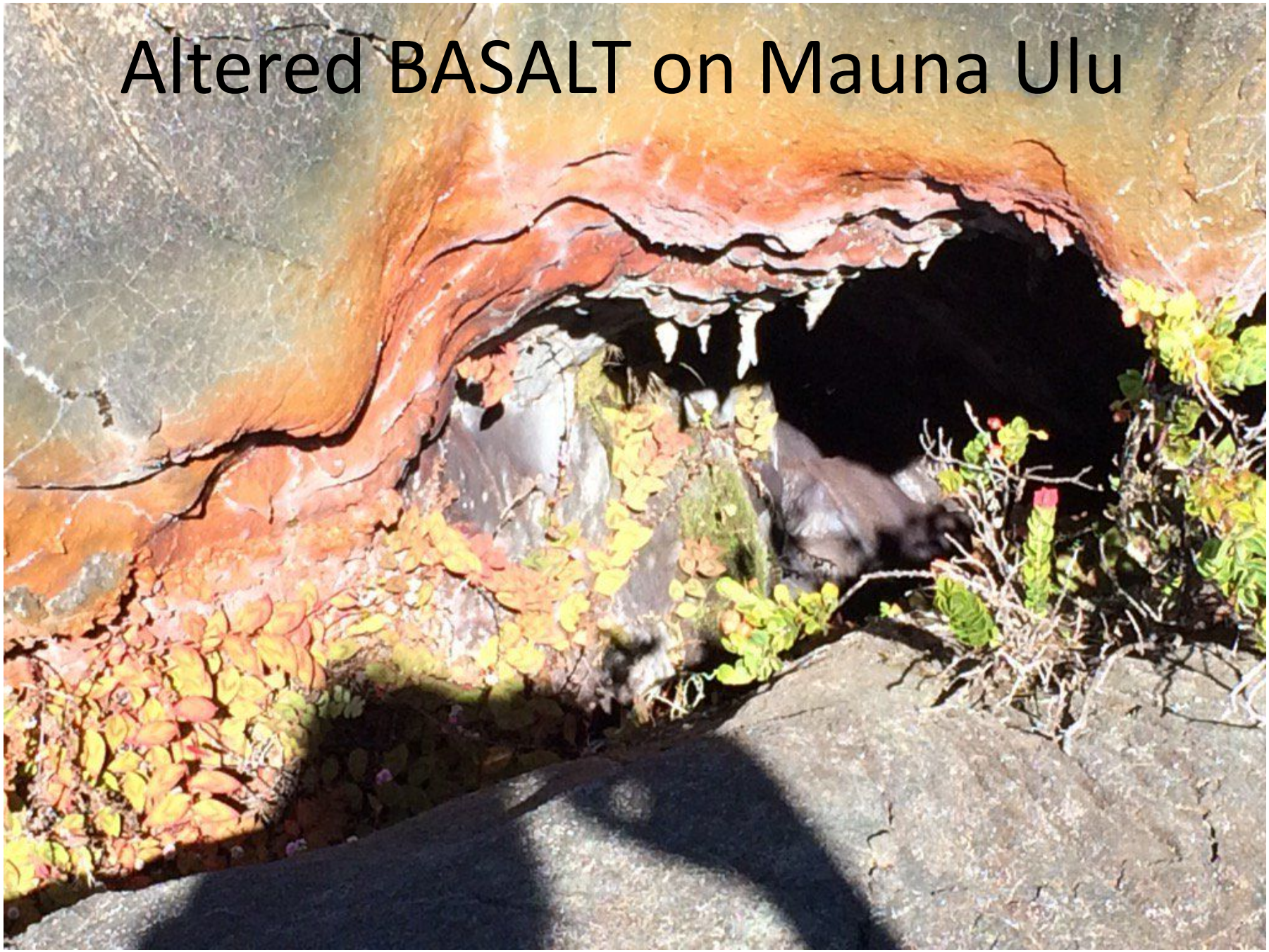

Science team members discussing tactical sampling priorities for today's EVA.

Learning Experimental Instrument Samples (LEIS)

Examples & Frozen Samples

Last day of Operations – Science Team

Altered BASALT on Mauna Ulu




Tartigrade outcrop.

Astronaut in Training - summit of Mauna Ulu

Stan Love – in the field and The Martian commentator

EARTH SCIENCE PICTURE OF THE DAY

A SERVICE OF UNIVERSITIES SPACE RESEARCH ASSOCIATION

BASALT is developing the geology and biology sampling protocols for future Mars astronauts as well as concepts of operations involving traverse planning and execution under time-delay and high/low communication bandwidth conditions.

Simulating Mars Exploration

November 21, 2016

Photographer: Andrew Hara (ENA Media)

Astronaut Jeff Hoffman and crew


xGDS
Map
EVA
Notes
Sample
Search
Import
Status
Feedback
Photo
Sample
ASD
FTIR
pXRF
Notes
Today
Search:
Display
Previous 1 2 3 4 Next
Time
TZ
Name
Description
11/11/16 11:42:52 HST PB110029.JPG Sample location BA still
11/11/16 11:42:28 HST PB110028.JPG Sample location BA Context
11/11/16 11:28:39 HST PB110026.JPG Context shot Station 20 "B"
11/11/16 11:28:32 HST PB110027.JPG Context shot Station 20 "B"
11/11/16 11:28:11 HST PB110025.JPG Context shot Station 20 "B"
11/11/16 11:19:02 HST PB110024.JPG Sample location AE still
11/11/16 HST PB110023.JPG Sample location AE context
BA
Add Note
DELL

New Window

PB110050.JPG

EV ONE 11/11/16 12:56:22 HST

Download Edit

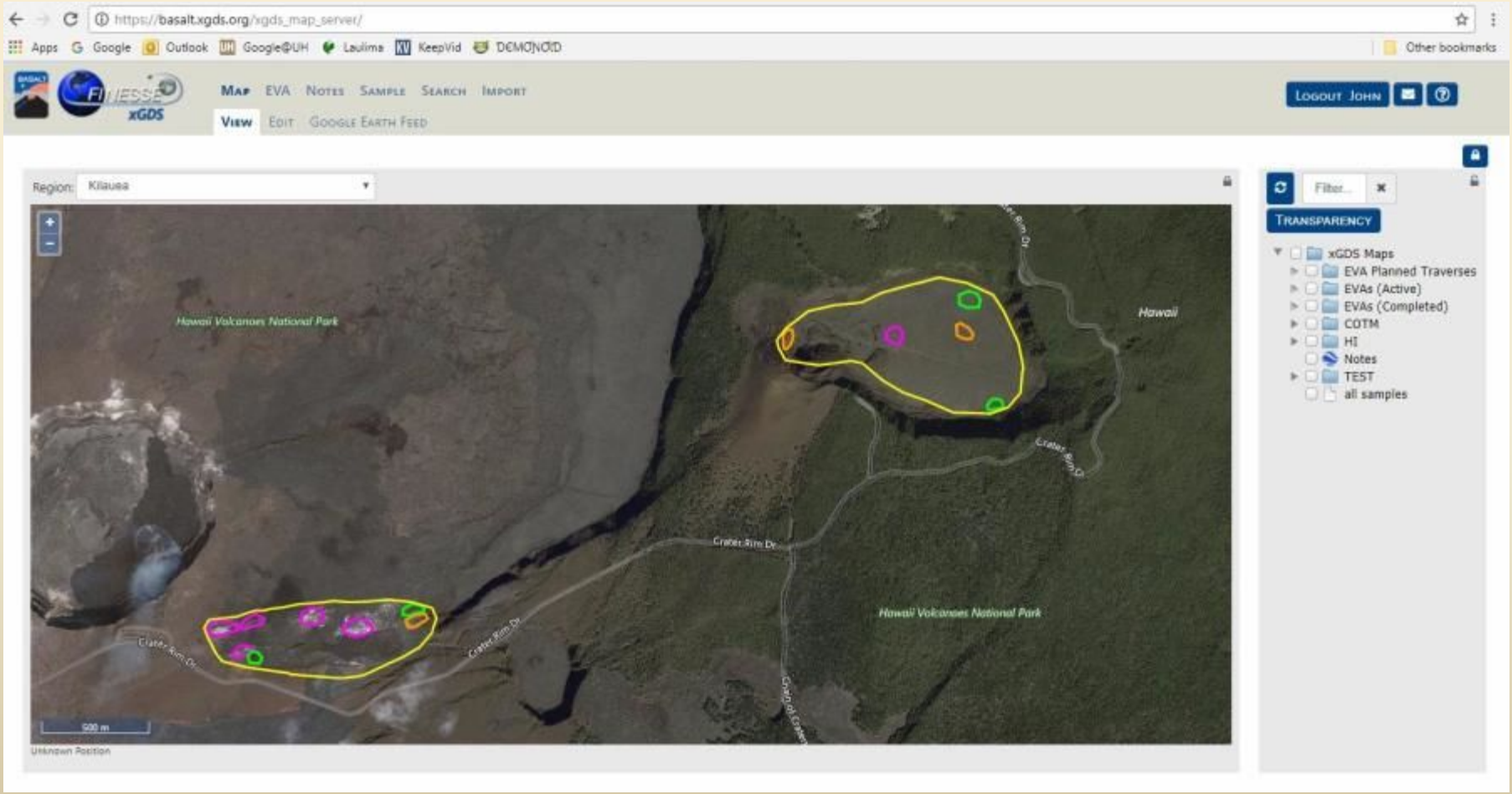
Heading: 123° Resolution: 1920 x 1440 | 2.76 MP | 0.58 MB

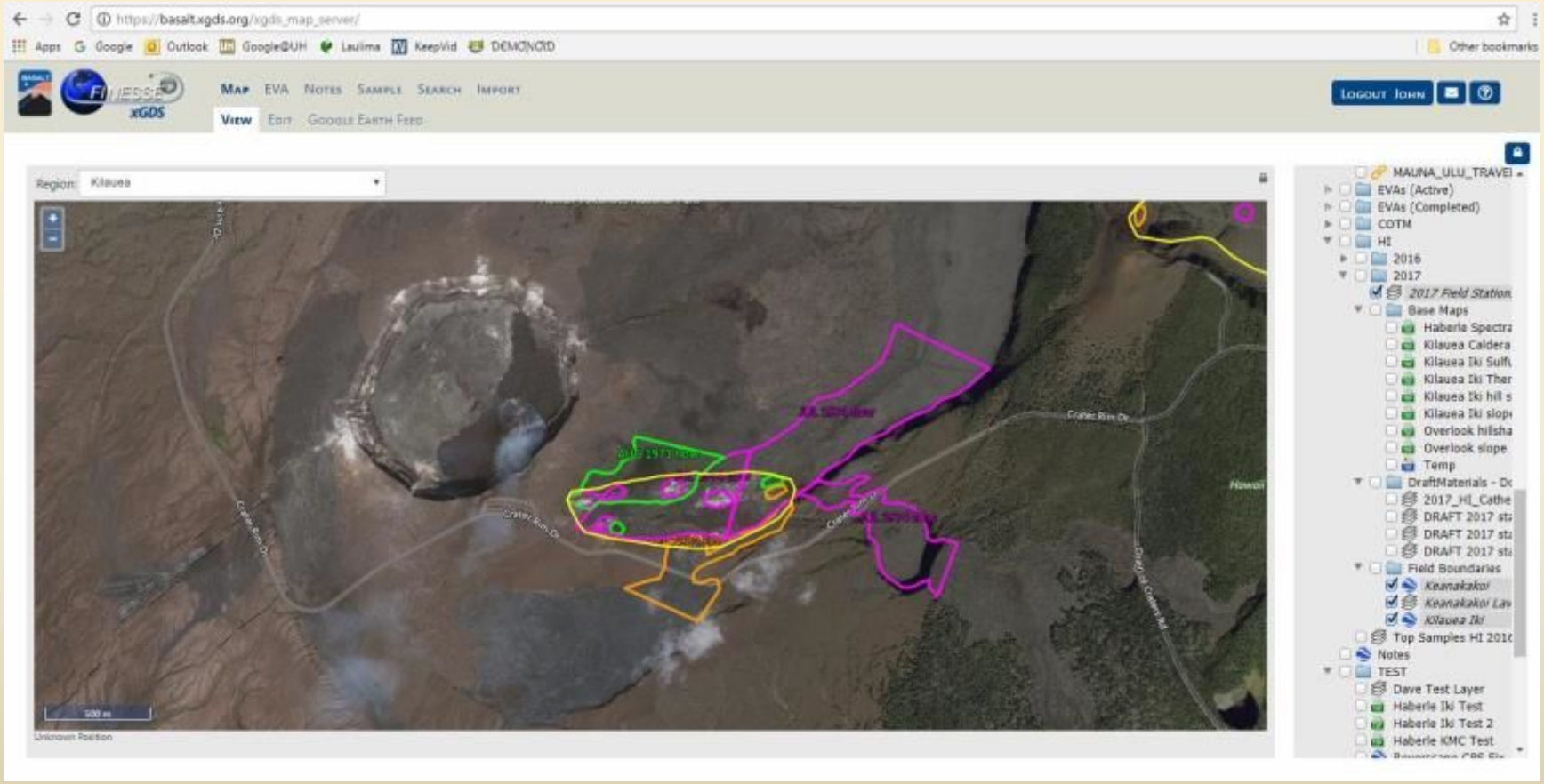
Add Note

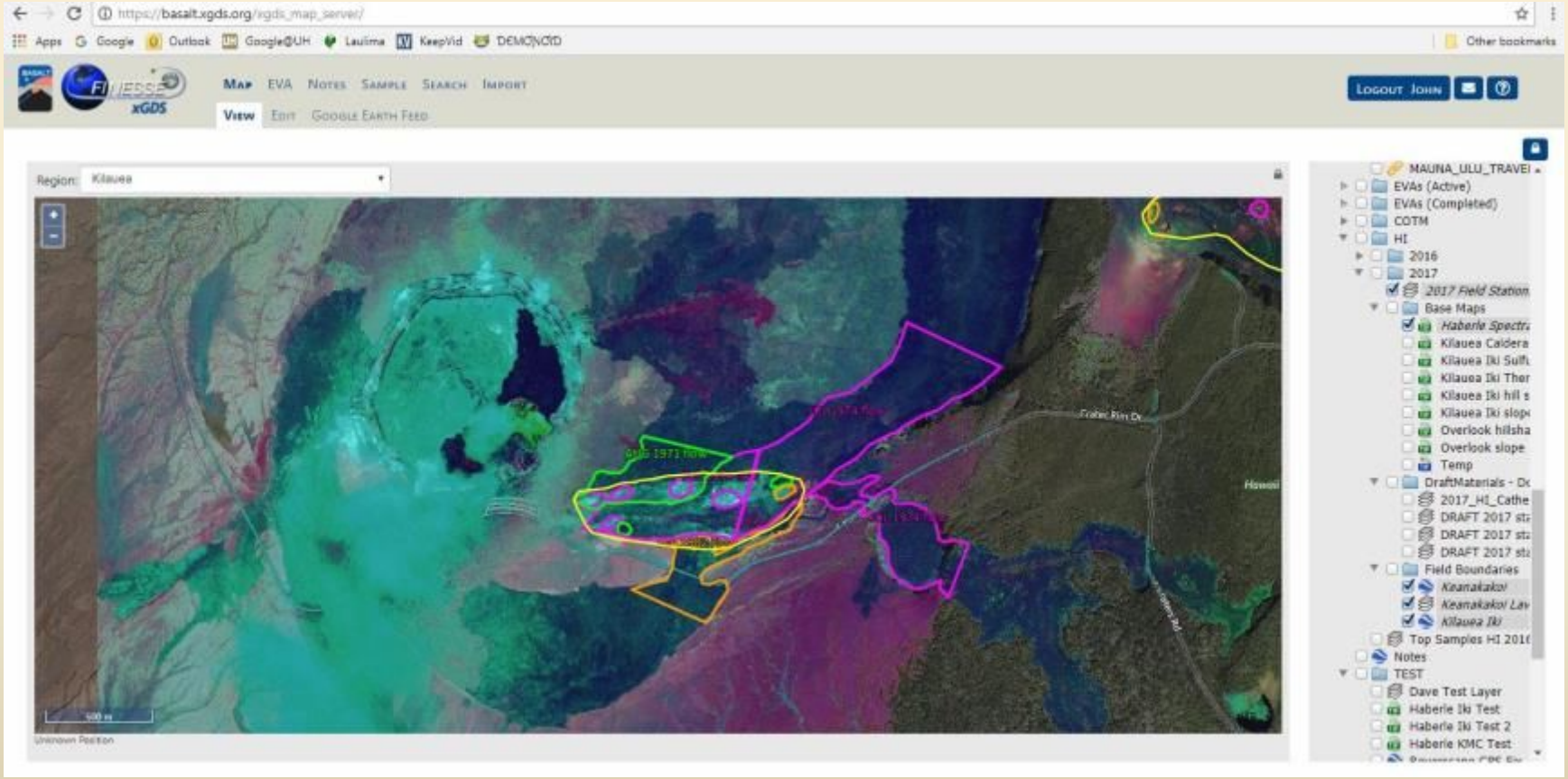

Live View
Playback
102 EV2 Backpack sensor
EV2
2016-11-09 14:56:04:02
100089
x1.18
PTZ Panel
Monitor#1, View: All Cameras (12 contents invisible)

Kilauea Military Camp
Science Backroom, Earth

Hawai`i 2017
Science Deployment areas
Keanakekoi and Kilauea Iki




https://basalt.xgds.org/xgds_map_server/
Apps
Google
Outlook
Google@UH
Laulima
KeepVid
DEMO|NOYD
Other bookmarks
xGDS
Map
EVA
Notes
Sample
Search
Import
View
Edit
Google Earth Feed
Logout John
Region:
Kilauea
Crater Rim Dr
Hawaii
Unknown Position
MAUNA_ULU_TRAVEL
EVAs (Active)
EVAs (Completed)
COTM
HI
2016
2017
2017 Field Station
Base Maps
Haberle Spectra
Kilauea Caldera
Overlook slope
Temp
DraftMaterials - Dc
Field Boundaries
Keanakakoi
Kilauea Iki
Top Samples HI 2016
Notes
TEST
Dave Test Layer
Haberle Iki Test
Haberle Iki Test 2
Haberle KMC Test


https://basalt.xgds.org/xgds_map_server/
Apps
Google
Outlook
Google@UH
Laulima
KeepVid
DEMO|NCID
Other bookmarks
xGDS
Map
EVA
Notes
Sample
Search
Import
View
Edit
Google Earth Feed
Logout John
Region:
Kilauea
MAUNA_ULU_TRAVEL
EVAs (Active)
EVAs (Completed)
COTM
HI
2016
2017
2017 Field Station
Base Maps
Haberle Spectra
Kilauea Caldera
Kilauea Iki Sulfi
Kilauea Iki Ther
Kilauea Iki hill s
Kilauea Iki slope
Overlook hillsha
Overlook slope
Temp
DraftMaterials - Dc
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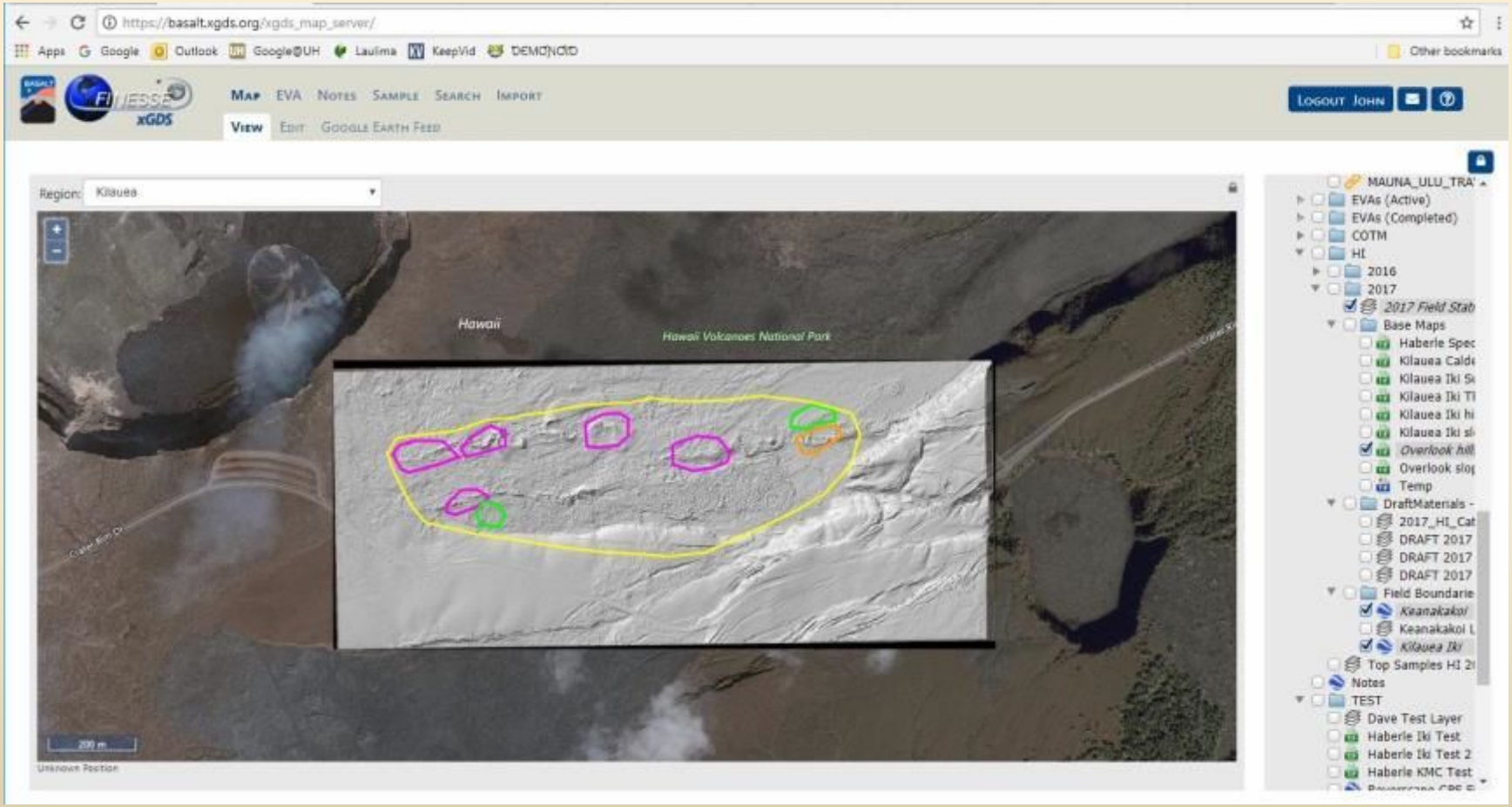
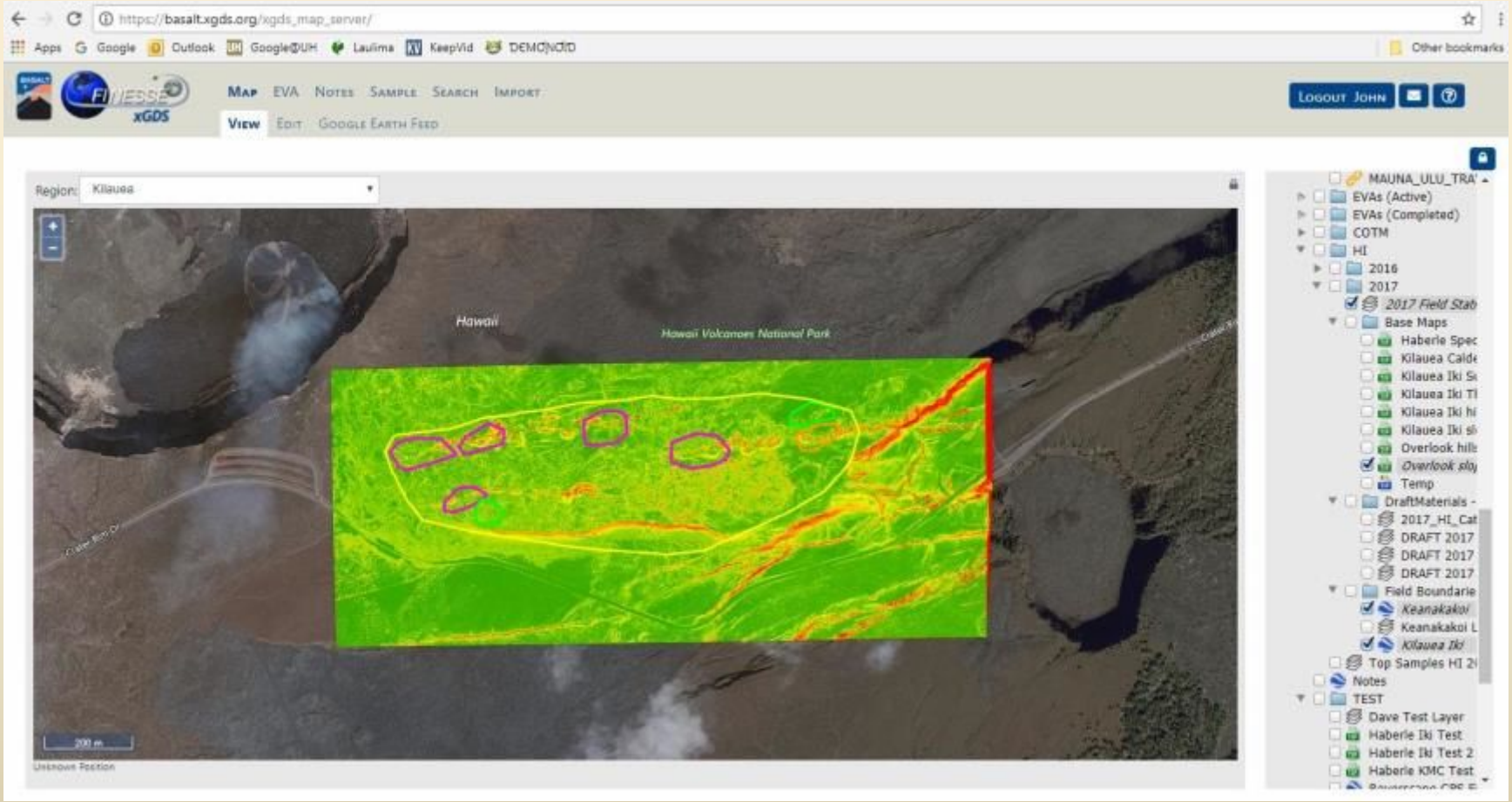
DRAFT 2017 sta
DRAFT 2017 sta
DRAFT 2017 sta
Field Boundaries
Keanakakoi
Keanakakoi Lav
Kilauea Iki
Top Samples HI 2016
Notes
TEST
Dave Test Layer
Haberle Iki Test
Haberle Iki Test 2
Haberle KMC Test
Crater Rim Dr
Unknown Region

ROI – Keanakekoi DEM

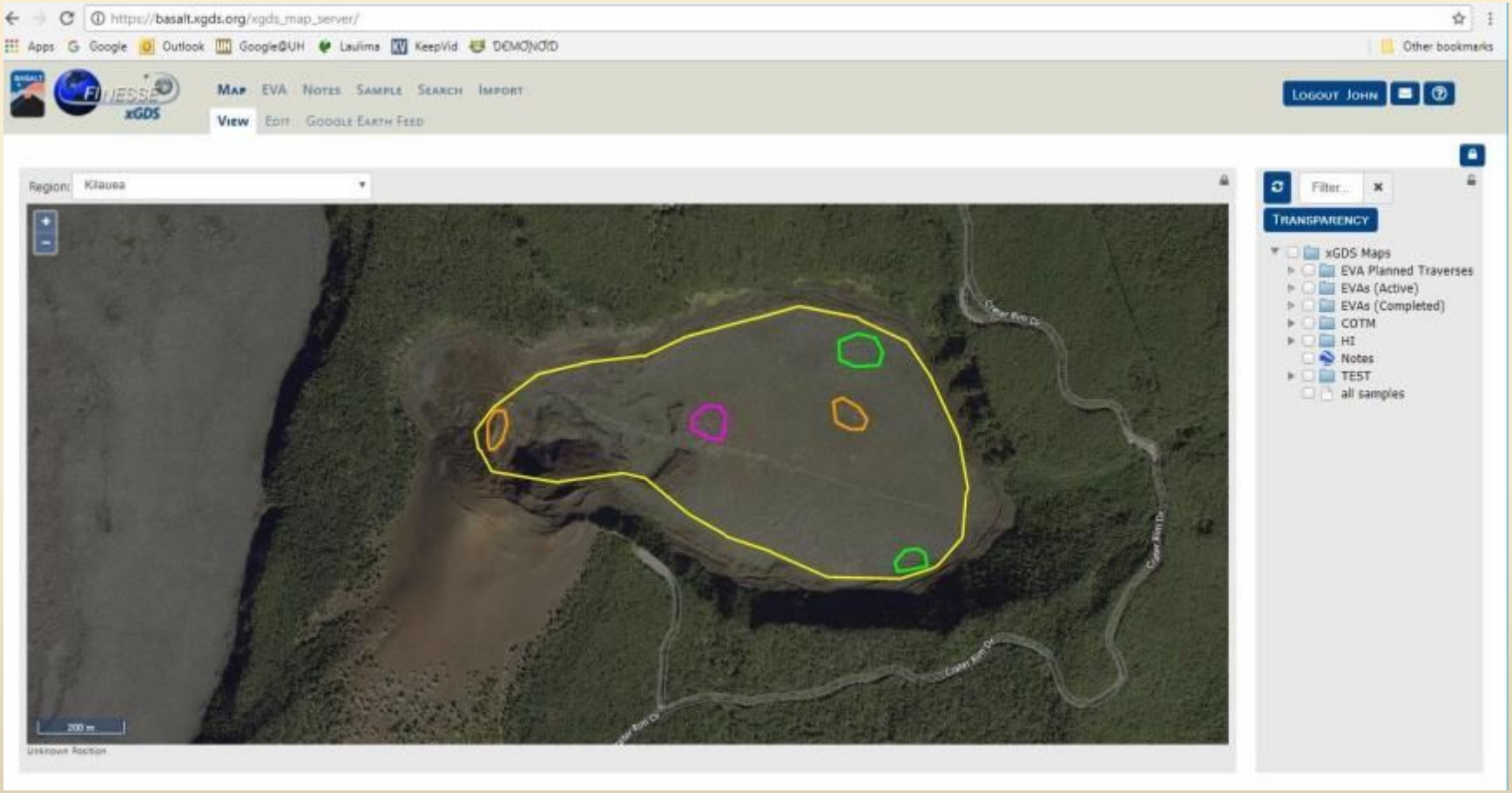


Keanakekoi - Slopes



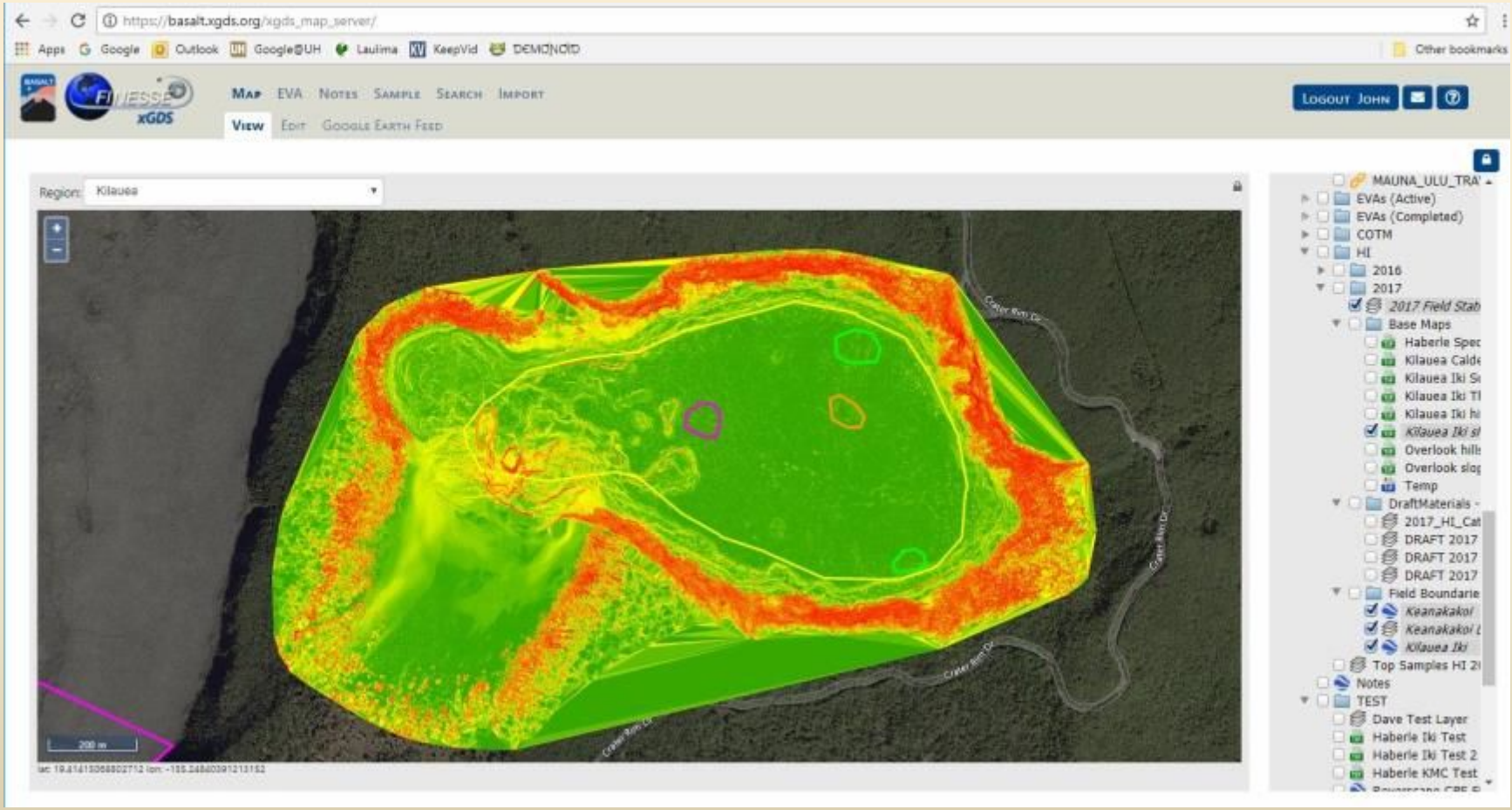

https://basalt.xgds.org/xgds_map_server/
Apps
Google
Outlook
Google@UH
Laulima
KeepVid
DEMONOID
Other bookmarks
FIELDSS
xGDS
MAP
EVA
NOTES
SAMPLE
SEARCH
IMPORT
VIEW
EDIT
GOOGLE EARTH FEED
LOGOUT JOHN
Region:
Kilauea
Crater Rim Dr
Hawaii
Hawaii Volcanoes National Park
Crater Rim Dr
Crater Rim Dr
Crater Rim Dr
Hawaii
100 m
Unknown Position
Filter...
TRANSPARENCY
xGDS Maps
EVA Planned Traverses
EVAs (Active)
EVAs (Completed)
COTM
HI
Notes
TEST
all samples

Kilauea Iki - ROI

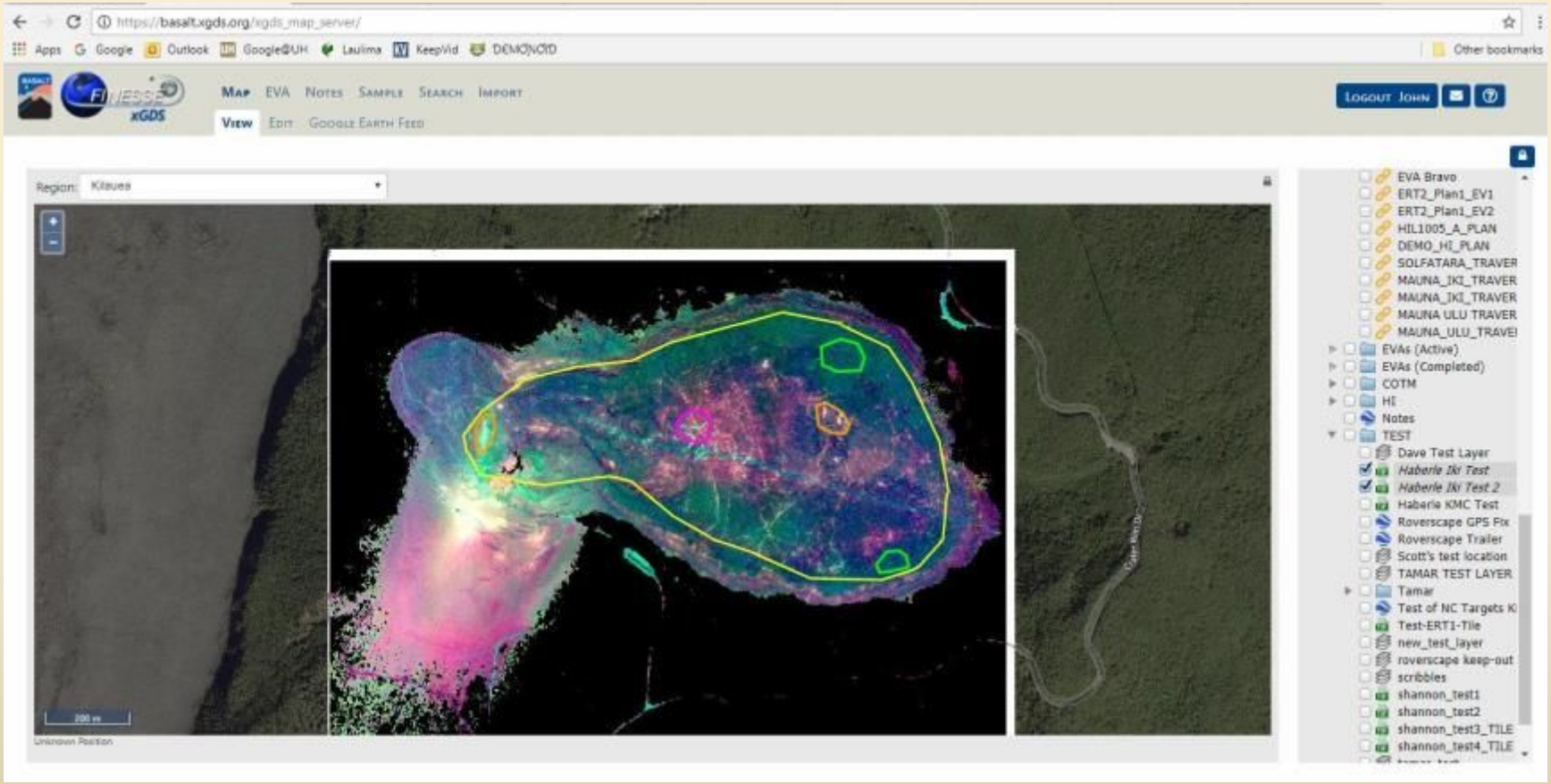


Kilauea Iki - DEM

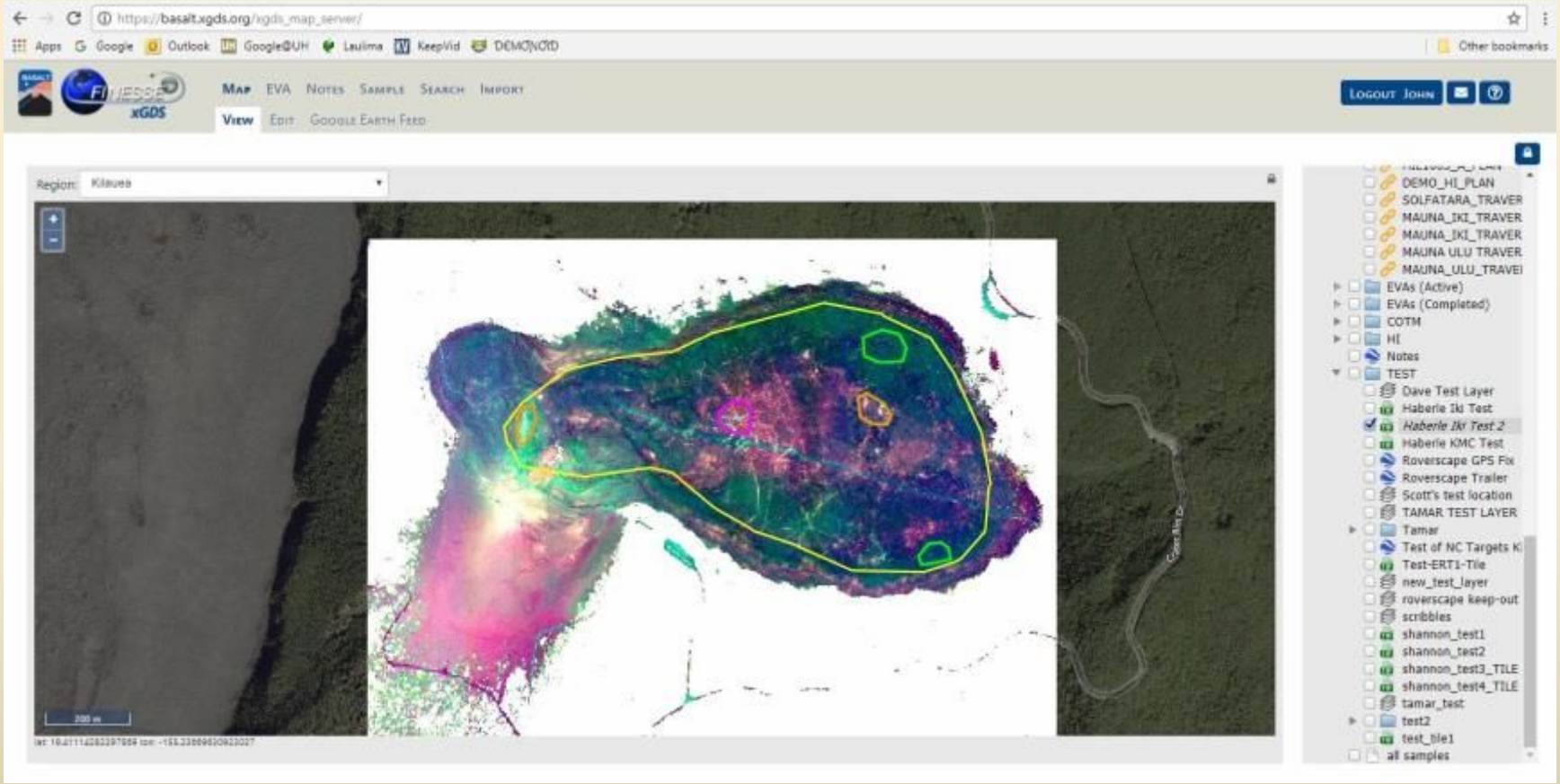
Kilauea Iki - Slopes



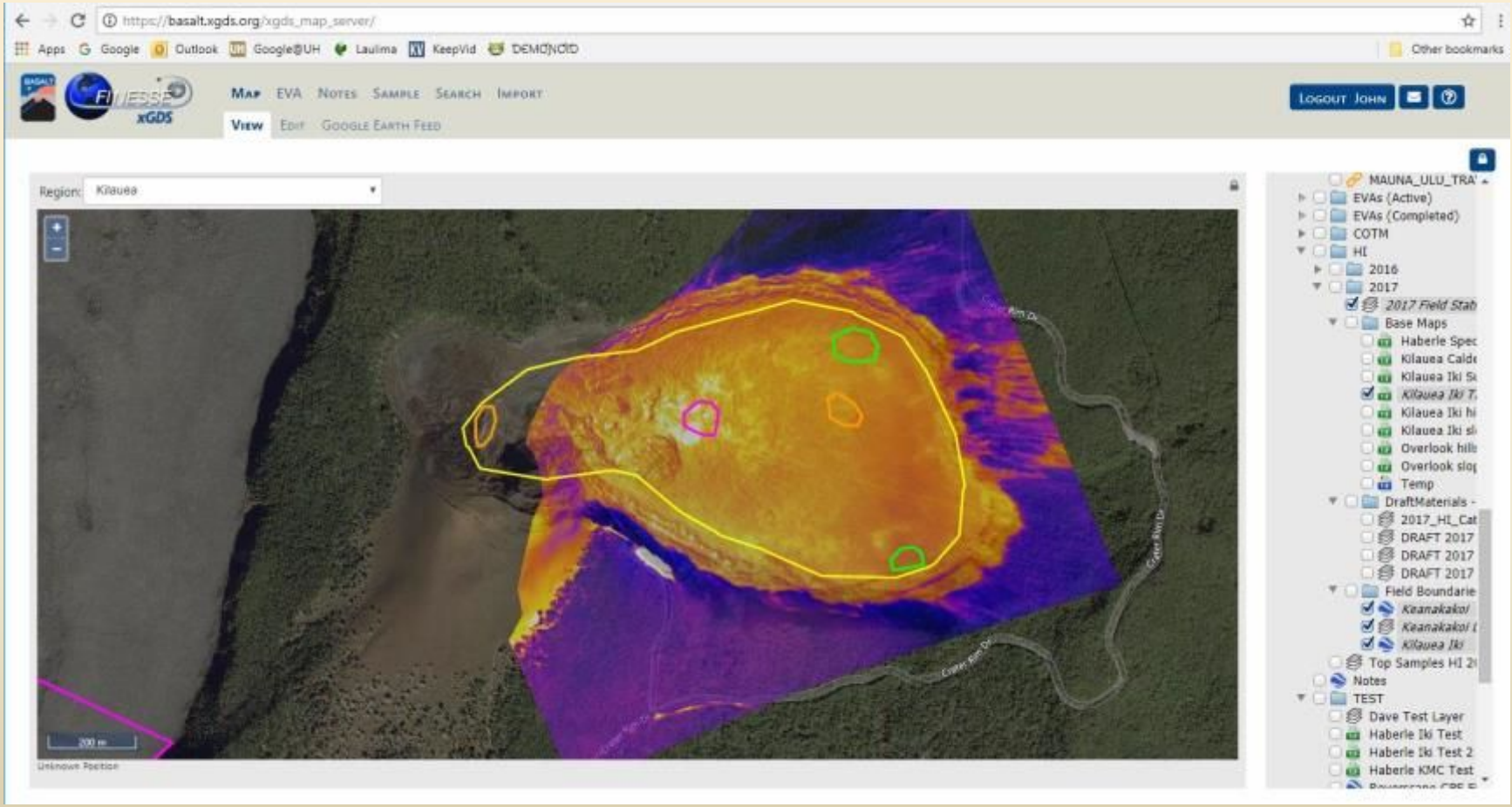
Kilauea Iki – Minerology 1



Kilauea Iki – Minerology 2

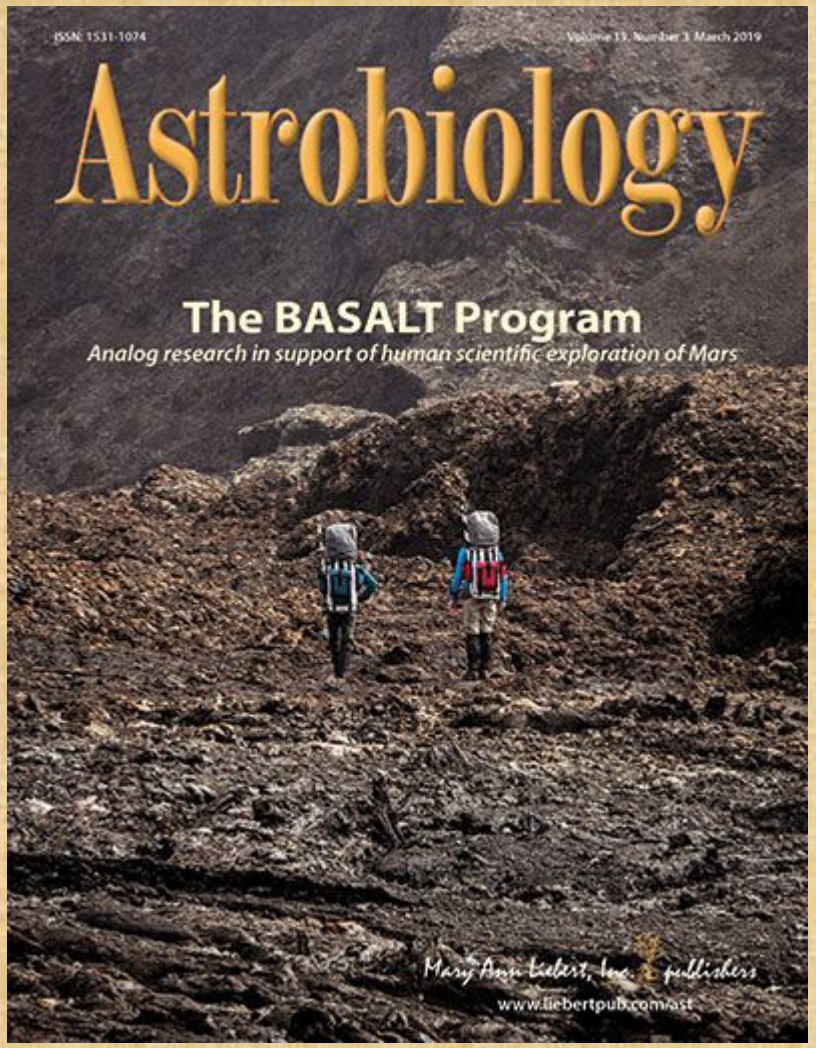


Kilauea Iki - Thermal



Special Issue of Astrobiology

VOLUME 19, ISSUE 3 / MARCH 2019



https://www.liebertpub.com/toc/ast/19/3

1. **BASALT: The Future of Mars, on Earth Today - Stanley G. Love**
2. **The BASALT Research Program: Designing and Developing Mission Elements in Support of Human ScientificExploration of Mars**
3. **Basaltic Terrains in Idaho and Hawai'i as Planetary Analogs for Mars Geology and Astrobiology**
4. **A Low-Diversity Microbiota Inhabits Extreme Terrestrial Basaltic Terrains and Their Fumaroles: Implications for the Exploration of Mars**
5. **Using Science-Driven Analog Research to Investigate Extravehicular Activity Science Operations Concepts and Capabilities for Human Planetary Exploration**
6. **Assessing the Acceptability of Science Operations Concepts and the Level of Mission Enhancement of Capabilities for Human Mars Exploration Extravehicular Activity**
7. **Strategic Planning Insights for Future Science-Driven Extravehicular Activity on Mars**
8. **Tactical Scientific Decision-Making during Crewed Astrobiology Mars Missions**
9. **Developing Intra-EVA Science Support Team Practices for a Human Mission to Mars**
10. **Requirements for Portable Instrument Suites during Human Scientific Exploration of Mars**
11. **Opportunities and Challenges of Promoting Scientific Dialog throughout Execution of Future Science-Driven Extravehicular Activity**
12. **Future Needs for Science-Driven Geospatial and Temporal Extravehicular Activity Planning and Execution**
13. **Developing Future Deep-Space Telecommunication Architectures: A Historical Look at the Benefits of Analog Research on the Development of Solar System Internetworking for Future Human Spaceflight**
14. **A Flexible Telecommunication Architecture for Human Planetary Exploration Based on the BASALT Science-Driven Mars Analog**