



Results from Joint NASA/ESA Field Trials Simulating International Missions to a Lunar/Mars Base

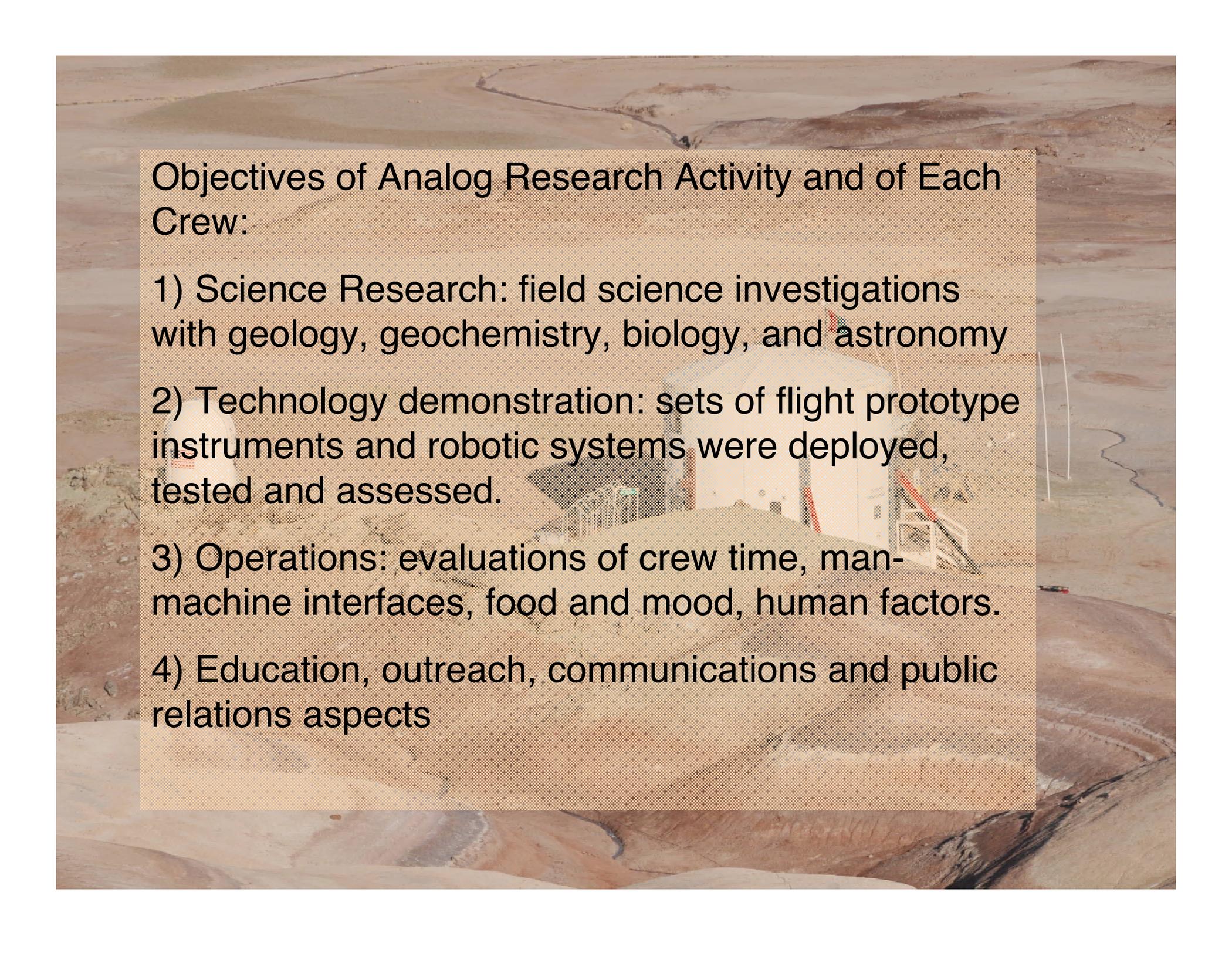
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Drilling on the Moon and Mars in human Exploration (DOMMEX) and EuroGeoMoonMars



What is it?

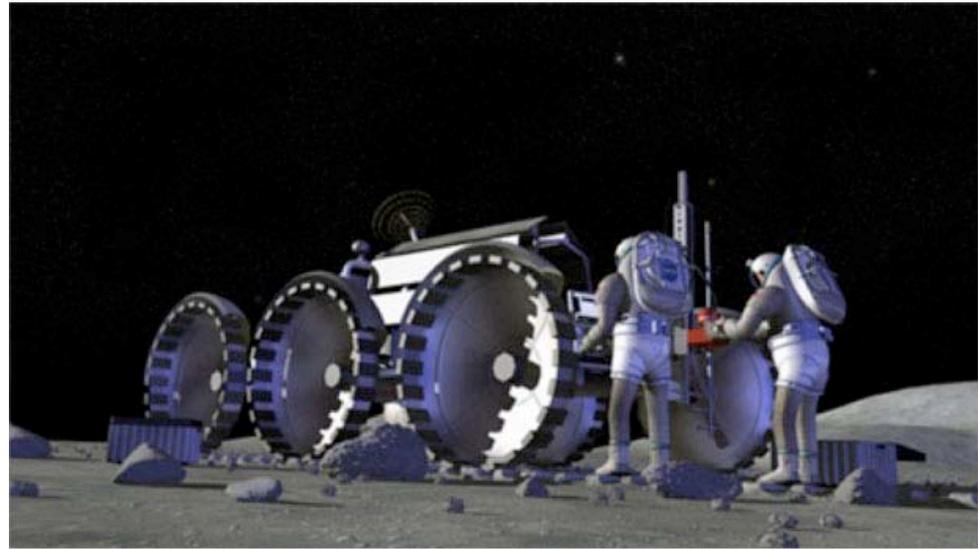
- A collaboration between NASA DOMMEX, EuroGeoMars, Intl. Mars Society
- Crew simulations of 2 week duration using Mars Desert Research Station
- 7 missions in 2009-2010 with having a mix of national origins, gender, age, & experience levels.

An aerial photograph of a desert landscape, likely a salt flat or a similar arid environment, with a semi-transparent text box overlaid in the center. The text box contains the title and a list of objectives. The background shows a wide, flat expanse of land with some darker, possibly wet or mineral-rich, areas. A small structure or vehicle is visible in the distance on the right side.

Objectives of Analog Research Activity and of Each Crew:

- 1) Science Research: field science investigations with geology, geochemistry, biology, and astronomy
- 2) Technology demonstration: sets of flight prototype instruments and robotic systems were deployed, tested and assessed.
- 3) Operations: evaluations of crew time, man-machine interfaces, food and mood, human factors.
- 4) Education, outreach, communications and public relations aspects

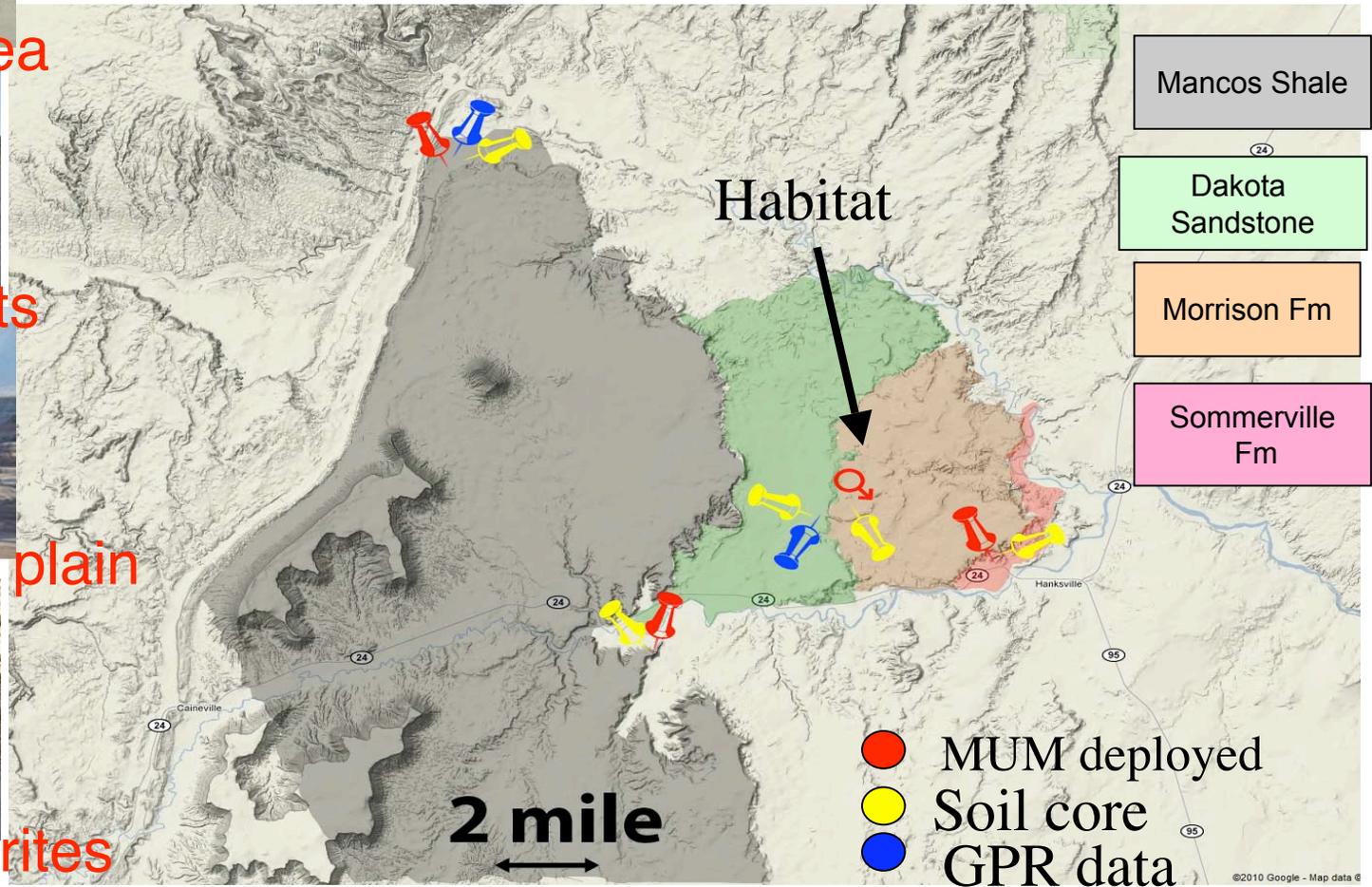
Why Drill on the Moon and Mars?



Drilling and subsurface sample acquisition is a key science activity for robotic precursor missions and human exploration on both the Moon and Mars. Regolith core samples are among the most valuable science products of Apollo. On Mars, drilling is needed to get to the most biologically interesting samples.

DOMMEX mission objectives focus on subsurface investigations and sample collection, and test subsurface access technologies

DOMMEX Activity map



Science Tasks Exploration Phase

- Explore major geologic units in the base area
- Choose and characterize candidate sites for drilling, soil sampling, and geophysics experiments

Sampling phase Activities: Soil cores collected and analyzed with TERRA field XRD

- Soil cores were collected from each geological unit using a manual impact soil corer and aseptic techniques.
- Mineral analysis was performed with TERRA (in Xitu™) portable XRD instrument, a commercial grade prototype of the MSL CHEMIN instrument.
- Biological analysis (DNA extraction) was also performed in the habitat and samples were prepared for subsequent analysis upon return to “earth”.



Soil cores collected with penetrometer to 1m depth

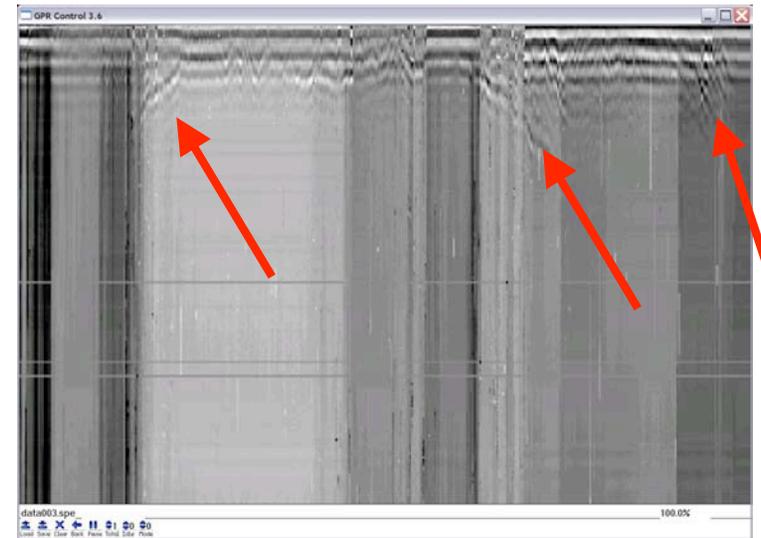


XRD analysis in field and hab with Terra XRD



Biological sample analysis in the habitat

Activity: Geophysical survey of buried inverted channel with CRUX Experimental GPR System



Human explorers are far superior to robots for drilling

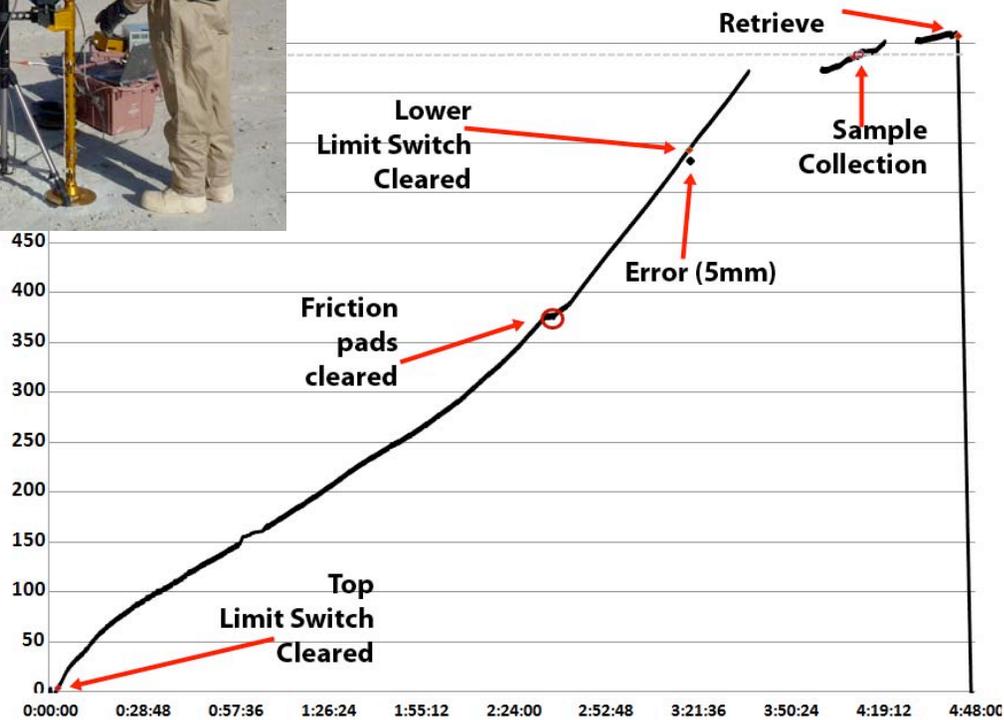
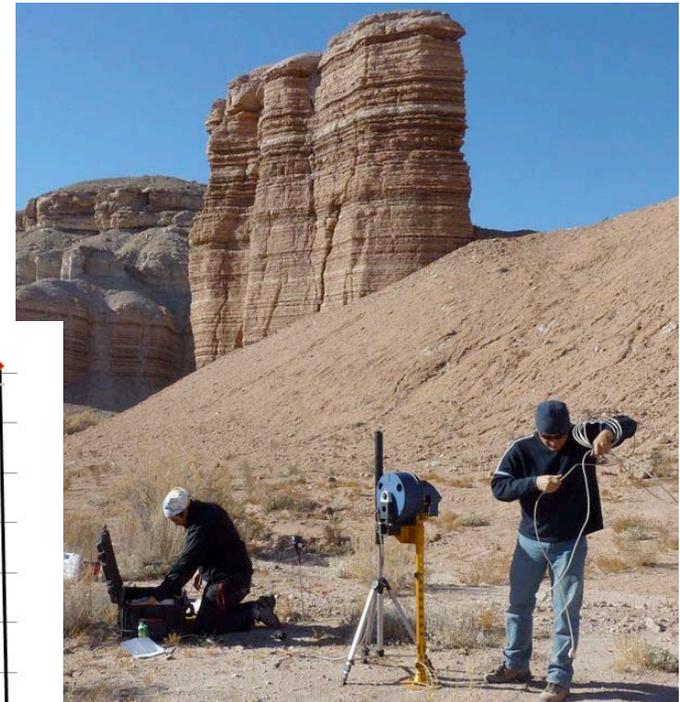


Horizontal drilling



Angled drilling

Technology Testing Activities



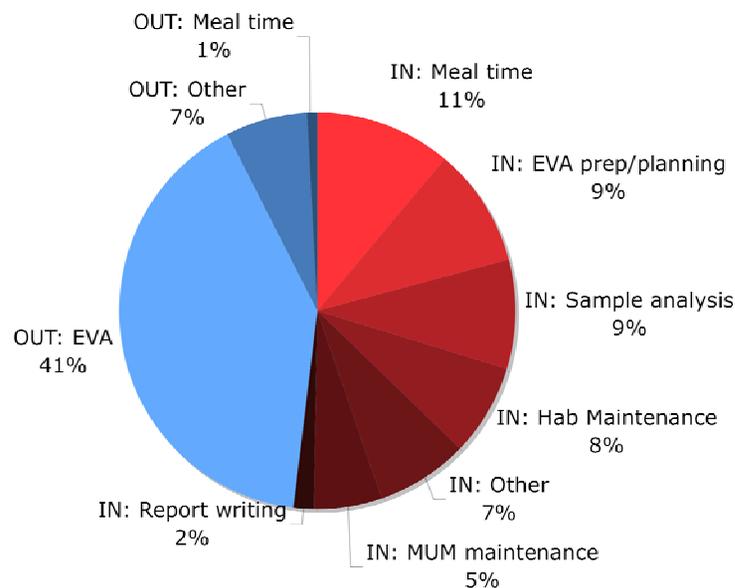
- Deploy and test MUM prototype soil penetrometer and sample collection system in 4 different types of soils

Operational Assessment

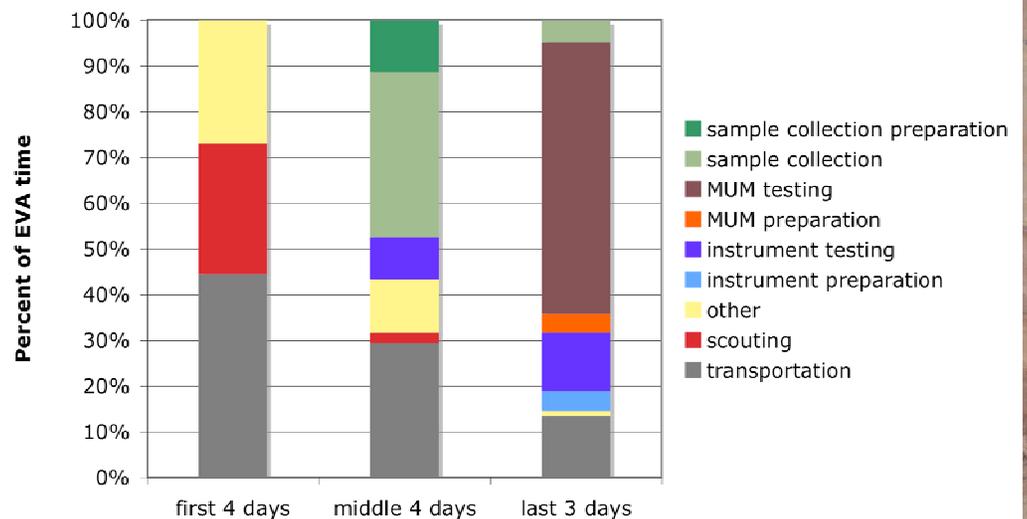
Detailed time records kept of all activities performed
Analysis shows time allocation for different activities and phases of mission

See poster by Messeri and Stoker for more details

12 Mission Days; 864 People Hours



Breakdown of EVA activities over mission duration



Multicultural and Educational Aspects



Denmark
Grad Student

France
Airforce
Cadets

Australia
professor

NASA/US
researcher



- Education: These mission simulations are an important way to train and engage students. In addition to students in this crew, 4 follow up missions with student crews performed in this field season at MDRS. These included 1 US student crew, 1 European student crew, and 2 mixed US+ Euro crews.

All student crew members were required to present papers at technical meetings. See Student poster session ([here](#)) for some of the results, including Messeri and Stoker, Shiro and Stoker, and Wilhelm et al. European students are presenting at COSPAR, ILEWG, and EGU.

Activities from a base naturally allows for iteration and refinement

Iterative Science Strategy on Analog Geophysical EVAs



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MARS DESERT RESEARCH STATION MISSION PLANNER



Summary

We carried out a series of ground-penetrating radar (GPR) and active seismic experiments at the Mars Desert Research Station (MDRS) in southeastern Utah in order to better understand the approach to conducting subsurface studies on the Moon and Mars via astronauts.

During November 2009, a crew led by Stoker collected exploratory ground penetrating radar (GPR) data using the miniature CRUX (Construction and Resource Utilization Explorer) prototype instrument and discovered a possible channel deposit.

In January-February 2010, a subsequent crew led by Shiro conducted an active seismic survey along a 109-meter profile to further investigate the feature using 12 vertical geophones mounted on a land streamer that was towed behind a rover.

Later in March 2010, another crew collected a complete GPR transect along the exact profile as the seismic study. Combined, the GPR and seismic data provide a more complete picture of the subsurface structure than either method alone can provide.

The evolution of planning experiments in this sequence illustrates the utility of building flexibility in missions so that crews can modify subsequent experiments based on results collected in previous ones. We recommend crews employ such a strategy when exploring the Moon and Mars.

About MDRS



The Mars Desert Research Station (MDRS) is a simulated Mars surface habitat built by The Mars Society in the remote Utah desert. Since it's founding in 2002, MDRS has hosted over 500 people on 100 crews and served as an effective testbed for field operations studies. Crews are diverse ranging from students to seasoned researchers from all over the world. Areas of study have included field exploration strategies, tools, technologies, and crew selection protocols to help optimize the productive exploration of Mars by humans.

Fyi



Inverted river channels on Earth preserve fossilized life and organic material. They have been identified on Mars too, such as this example at Miyamoto Crater (Mars image PSP_009965_1770).

EVA Log

Crew 83 @Nov 2009

Goal - CRUX GPR Field Testing¹

Nov 20 - Carol and Josh
Collected Track 7 data up on Radio Ridge where Kissing Camel Range intersects with the ridge. See a reflector on the northern edge of the profile. Perhaps the ridge is a buried paleochannel.

Nov 26 - Josh and Carol
Collected Track 15 data along a profile closer to the edge of the ridge, but the reflector still only shows up on the northernmost edge of the track. No time left in the mission to return for further investigation.

Crew 89 @Jan-Feb 2010

Goal - Active Seismic Survey²

Jan 30 - Brian and Luis (15:57-18:07):
Scouted the route up to Radio Ridge in the snow and took GPR waypoints of the proposed survey. We had to deviate from the GPR Track 7 and 15 lines to find a flatter surface for towing the land streamer.

Feb 3 - Brian, Darrel, Luis (13:07-17:26)
Hauled seismic equipment up to Radio Ridge, staked out the survey shot points and geophone positions at 5-foot intervals for a 145-meter total nominal profile. Took first shot gather data set and moved geophone spread to next position. Laptop fell off the ATV and the ethernet connector was damaged. Have to return to the Hab and fix it tonight.

Feb 4 - Brian, Luis, Kirr (12:40-18:45)
Lost data from yesterday when the computer dropped so have to start over. Conducted the active seismic survey consisting of 6 geophone spreads with 12 geophones at 5-ft spacing on a towed land streamer. We used a sledgehammer as the source for the 36 shots with 30 stacking at each of the 47 shot locations across the 145-meter profile, up analysis problematic, but MASH inversion shows Vs velocity profile and the possible buried inverted channel!

Crew 92 @March 2010

Goal - Take new GPR track along full seismic profile

Mar 16 - Carol, Jon, Lindsay
Collected GPR Track 3 data S-N and Track 4 N-S along the same waypoints as the Crew 89 seismic profile. Track 4 data is noisier than the Track 3 data but shows the same reflectors. The reflectors seem to correlate to structure seen with the seismic study. We used the new wheeled GPR cart and it was much easier than the old sled we pulled on Crew 83.

We found a concretions-rich deposit on the northern flank of Kissing Camel near its intersection with Radio Ridge. These deposits are found in other Morrison Formation channel fills in the area. Evidence that Kissing Camel is an inverted channel.

Study Area

profile center
38.4°N, 110.8°W

Kissing Camel Range is a 100m high arcing structure that intersects with the Cretaceous Dakota sandstone-capped ridge line called Radio Ridge. It is elevated due to a cap rock that is gravel cemented by silica and therefore harder than the surrounding Jurassic era Morrison Formation deposits. We hypothesize that Kissing Camel extends subsurface beyond the intersection.



Acknowledgements

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JPL & Ulmer Systems, Inc.

Seismic equipment provided by:²

SeisImager/2D³ analysis support provided by:³

Other seismic survey advice provided by:
- Jim Hadzrook (Hadzrook Geophysics),
- Rob Stewart (U. of Houston), Chris Gifford (JHU-APL), and Drew Feustel (NASA).

Special thanks to everyone on the MDRS 83, 89, and 92 Crews and to the Mars Society Mission Support team of volunteers.

- References
1. CRUX GPR background: Kim, et al. (2006) IEEEAC Paper #1365.
 2. Land streamer background: - van der Ween, et al. (2001) Geophysics, 66: 482-500.
 3. MASW technique: - Park, et al. (1999) Geophysics, 64: 800-808.
- This work previously presented in part by:
- Shiro, et al. (2010) LPSC, Abstract #2052.
- Stoker, et al. (2010) LPSC, Abstract #2697.



See poster by Shiro and Stoker for illustrative example

Conclusions

- Mission simulations at MDRS is a highly cost effective way to simulate mission scenarios end-to-end.
- International crew mix was successful and no interpersonal or communication problems resulted. Instead, it was bonding experience.
- Mixing students with senior scientists worked well on many levels. Analog mission activity has high value for training and inspiring the next generation.
- Astronaut towed Ground Penetrating Radar successfully identified a subsurface channel deposit. Previous attempts to use this instrument towed by a robot were unsuccessful due to electronic noise interference.
- Astronaut operated drill was highly portable, light, and speedy compared to any comparable robotic system. Even though this is not a flight prototype, it is representative of the type of field portable drilling systems envisioned for astronauts.

Acknowledgements:

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- European student participants in DOMMEX field campaigns and other missions were organized and funded by the ILEWG EuroMoonMars mission activity led by Dr. Bernard Foing.
- NASA Spaceward bound supported student participants at MDRS.
- The CRUX GPR was provided by Sam Kim(JPL) and colleagues. For further information on this instrument see S.S. Kim et al., IEEEAC paper #1365, Version 2, Updated Nov. 10, 2005.
- The Terra XRD and assistance interpreting the results are provided by David Blake (NASA ARC).
- The Mars Desert Research Station is provided by the Mars Society. Logistics for this campaign were supported by Artemis Westinberg and a dedicated team of Mars Society volunteers.