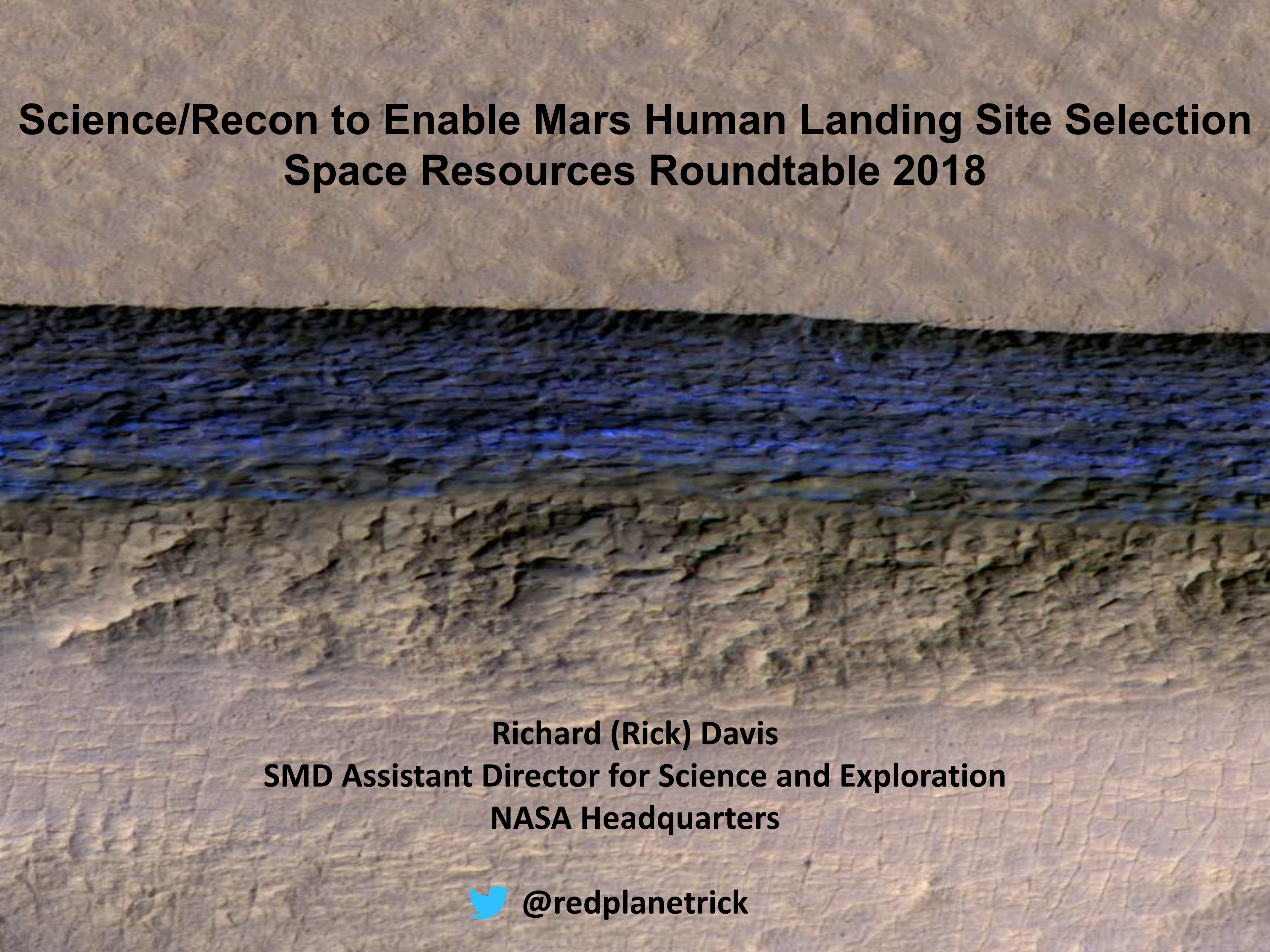
# Science/Recon to Enable Mars Human Landing Site Selection
## Space Resources Roundtable 2018

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**@redplanetrick**

# The Real Mars

Gale Crater, Mars

The panorama to the left is from Curiosity, and sometimes makes Mars seem like the deserts on Earth

We must not be fooled into thinking it is easy- Mars is closer to the extreme heights of the Himalayas than it is to the peaceful (if hot) deserts of the American Southwest.

Wadi Rum, Jordan

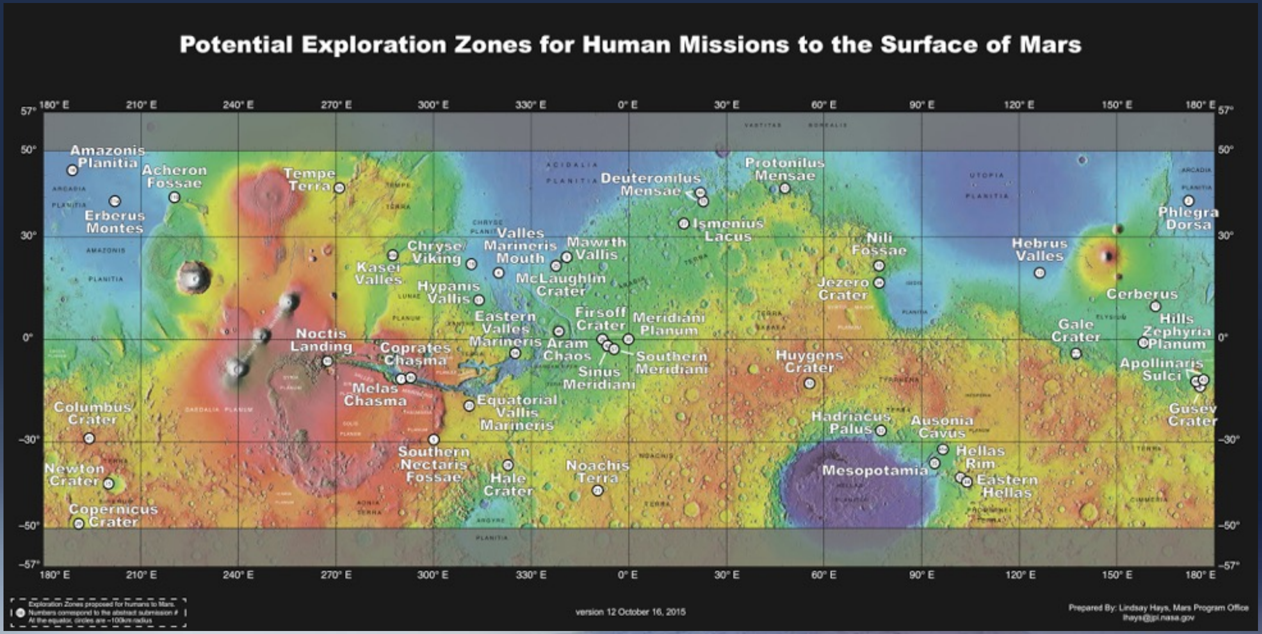
K2, Himalayas

MARS

# Water and the Human Landing Sites Study (HLS2)

Goal of Study: Identify landing sites for human surface exploration of Mars.

- These landing sites provide access to Exploration Zones (EZs) which are regions on Mars that contain multiple sites of scientific interest as well as satisfying engineering and human constraints for human exploration.
- Leverage Mars Reconnaissance Orbiter (MRO) data collection capabilities to acquire data of potential prioritized human Mars landing sites within the exploration zones
- Establish a database of high interest sites—science and resources, which can easily be updated as we learn more about Mars and what is needed to support humans on the planet
- Inform future reconnaissance needs (particularly water) at Mars—orbital and landed missions




This effort is a joint Human Exploration and Operations Mission Directorate (HEOMD) / Science Mission Directorate (SMD) study

# Workshop Significantly Increased Awareness of Importance of Water

- Workshop significantly increased the Agency’s awareness of the availability of water on Mars and the potential of water resources there to enhance human surface operations.
- HLS2 work has also increased the understanding that water reconnaissance and ISRU technology development are integrally tied. Since the workshop, two studies have been completed to better understand potential of water feedstocks and what it takes in the form of ISRU equipment to produce water from those feedstocks.
  - https://www.nasa.gov/sites/default/files/atoms/files/mars_ice_drilling_assessment_v6_for_public_release.pdf
  - https://mepag.jpl.nasa.gov/reports/Mars_Water_ISRU_Study.pdf
- Reassessing mission architectures assuming a water rich environment.




MARS

# How Would a Mars Mission Use Abundant Water?

*20 tons of water (plus $CO_2$) provides ascent fuel and oxidizer for one MAV*

| Subsystem | Mass (kg) | |
|---|---|---|
| | MDM Payload | Mars Liftoff |
| **Crew Cabin** | **3,427** | **4,122** |
| Structures | 881 | 881 |
| Power | 377 | 377 |
| Avionics | 407 | 407 |
| Thermal | 542 | 542 |
| ECLS | 502 | 502 |
| Cargo | 422 | 1,117 |
| Non-Prop. Fluids | 295 | 295 |
| **1st Stage** | **9,913** | **31,432** |
| Dry Mass | 3,605 | 3,605 |
| LO2 | 0 | 21,519 |
| LCH4 | 6,308 | 6,308 |
| **2nd Stage** | **5,006** | **13,245** |
| Dry Mass | 2,566 | 2,566 |
| LO2 | 0 | 8,239 |
| LCH4 | 2,440 | 2,440 |
| **TOTALS** | **18,345** | **48,799** |

*23 tons of water provides rover reactants for robust surface mobility*

| | |
|---|---|
| TRIP DURATION | 14 sols |
| NO. OF DAYS DRIVING | 9 sols |
| CREW | 2 |
| ROVER DRIVE TIME/DAY | 9 hours |
| TOTAL ENERGY NEEDED | 1564 kW-hrs |
| TOTAL O2 NEEDED | 841 kg |
| TOTAL CH4 NEEDED | 276 kg |
| EXCESS H2O PRODUCED | 621 kg |

Power

Martian Water: $2H_2O$

**Electrolysis:** $4H_2O + power = 4H_2 + 2O_2$

$2O_2$

$2H_2O$ $4H_2$

$O_2:CH_4$ 4:1

Martian Atmosphere: $CO_2$

**Sabatier:** $CO_2 + 4H_2 = CH_4 + 2H_2O + heat$

$CH_4$

**Production Plant NET Reaction:** $2H_2O + CO_2 + power = 2O_2 + CH_4 + heat$

$O2:CH_4$ 3.4:1

$O_2$

$3O_2$

**Fuel Cell:** $3O_2 + 6H_2 = 6H_2O + power$

$4H_2O$ (crew metabolic)

Power

$O_2:CH_4$ 3:1

$6H_2$ $2H_2O$

$2CH_4$

**Methane Reformer:** $2CH_4 + 2H_2O + heat + catalyst = 6H_2 + 2CO$

2CO

**Rover NET Reaction:** $2CH_4 + 3O_2 + heat + catalyst = 2CO + 4H_2O + power$

$H_2O$

| | CLOSED-LOOP $H_2O$, $O_2$ | OPEN-LOOP $H_2O$, $O_2$ | OPEN-LOOP + LAUNDRY |
|---|---|---|---|
| $H_2O$ CLOSED-LOOP MAKEUP | 970 | 0 | 0 |
| $O_2$ CLOSED-LOOP MAKEUP | 2480 | 0 | 0 |
| LAUNDRY | 0 | 0 | 14660 |
| EVA | 0 | 3072 | 3072 |
| FOOD REHYDRATION | 0 | 1070 | 1070 |
| MEDICAL | 0 | 107 | 107 |
| DRINK | 0 | 4280 | 4280 |
| FLUSH | 0 | 134 | 134 |
| HYGIENE | 0 | 856 | 856 |
| TOTAL | 3450 kg | 9519 kg | 24379 kg |

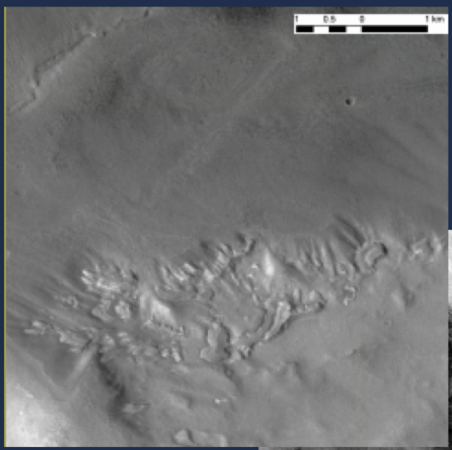
*25 tons of water provides robust open-loop life support for 4 crew of four for 500 days*

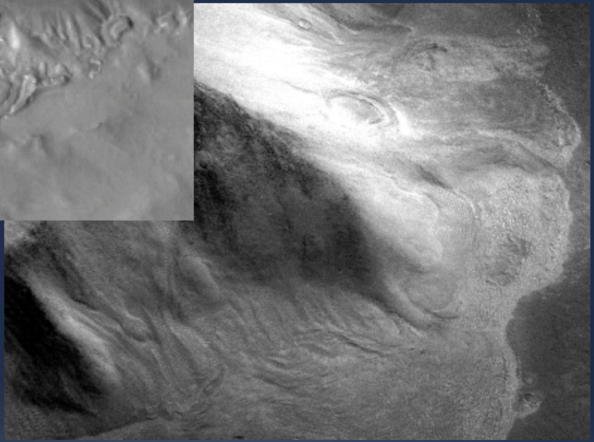
***A total of 68 tons of water supports one crew of 4 during a 500 day mission***

# Mars has Several Water Feedstock Options:

## Subsurface Ice

“Sheet” Ice

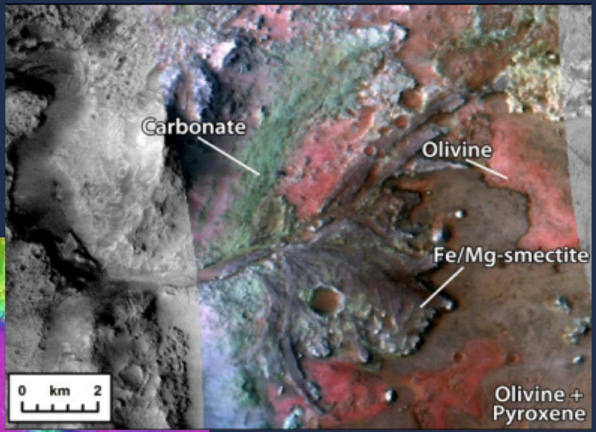


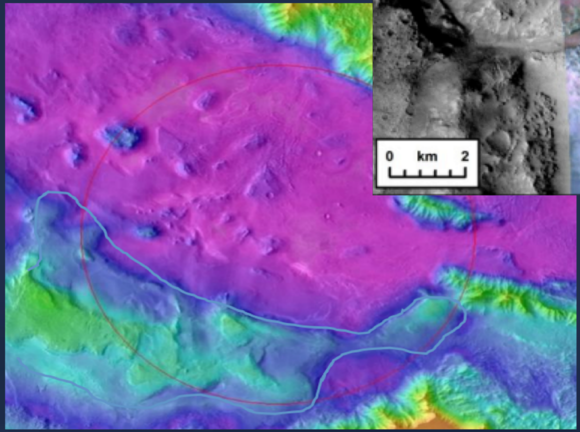


Debris-Covered Glaciers

## Hydrated Minerals

Other Hydrated Minerals



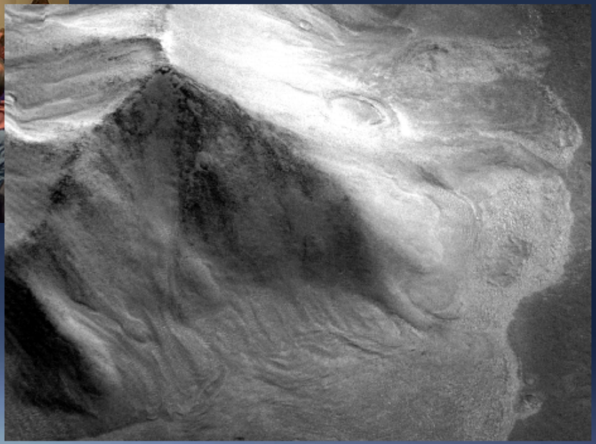



Poly-hydrated Sulfates

Many EZs have multiple water feedstock types

# How do you choose the feedstock? Answer will not be clean!

- Four Major Questions:
  - Is it really there?
  - Can you really produce it economically?
  - How much water do you need?
  - If the feedstock drives location, what does that mean for landing, launching to go home, and living there?

MARS

# What we are doing to Precisely Locate the Water:

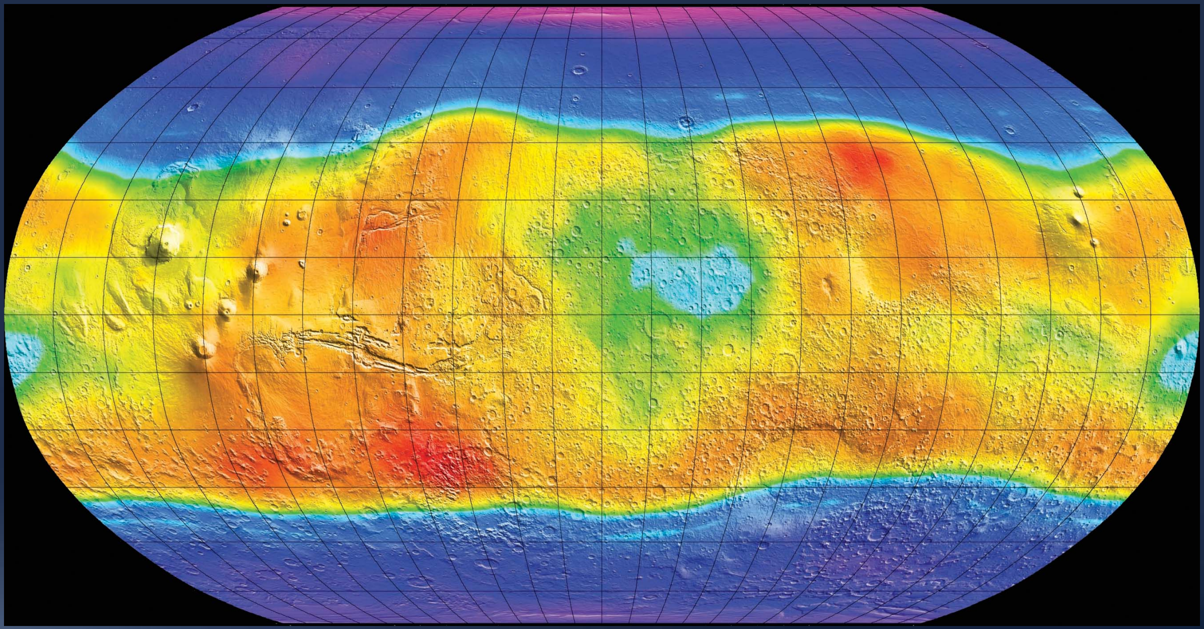
- Finding water on Mars has long been a major focus of Mars Exploration. In the search for life, following the water has always been critical.
- Four contracts recently released by NASA to build better water maps at Mars using existing data sets for Mars in new and creative ways.
- Eventually a new orbiter with a Synthetic Aperture Rader will be needed
- Ground Truthing will then be needed to study and verify feedstocks

MARS

# Potentially Needed Future Missions

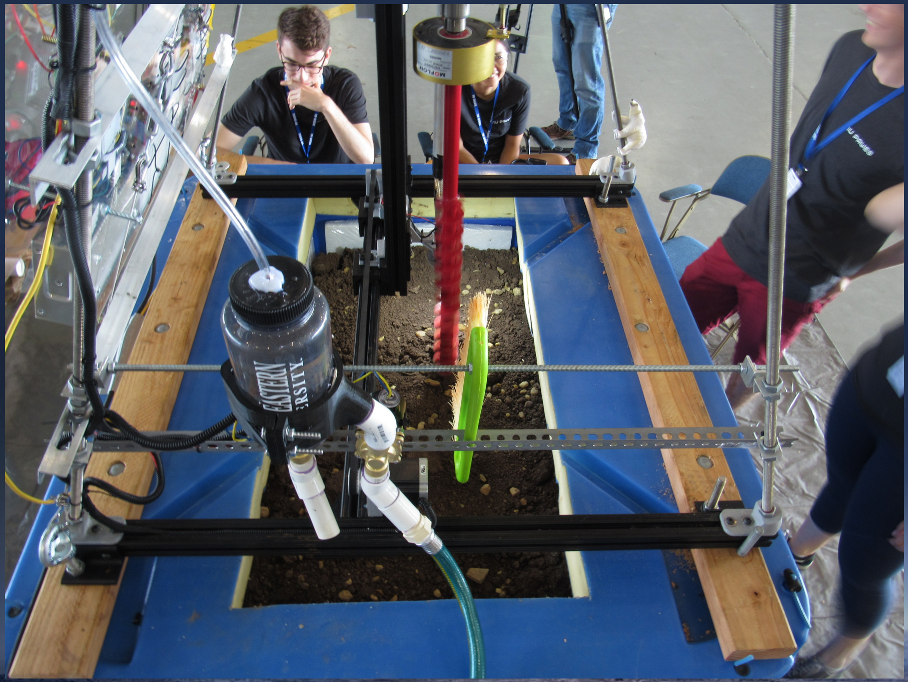
## From International Mars Exploration Working Group

- Mars Sample Return
  - Accomplish Decadal Science Priorities
  - In addition, MSR is probably needed to confirm the mechanical properties of the regolith/dust (abrasiveness, oxidizing potential particle size, etc.), how it will interact with surface systems (e.g., suits, rovers, habitats, etc.), and potential human health hazards (toxicity, respiratory, potential extant life, etc.).
- Water Recon
  - Identify near surface ice
  - Assess Potential of Hydrated Minerals
  - Ground Truthing
  - Ease of access
- Special Regions Drill
  - Search for life
  - Characterize the water
    - For ISRU
    - For potential human use
- Next-Gen Weather Capabilities (Orbital and Surface)
  - Density Profiles
    - (EDL)
  - Winds Aloft
  - Potential Microbial Transport
- Improved Communications
  - Increased data rate



# Creatively Using the Tools Available to Us

- Micro-Missions
- STEM Programs and Competitions
- Integrated Analog Missions
- Others??



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