ISRU Explorations with WINE (the World Is Not Enough)

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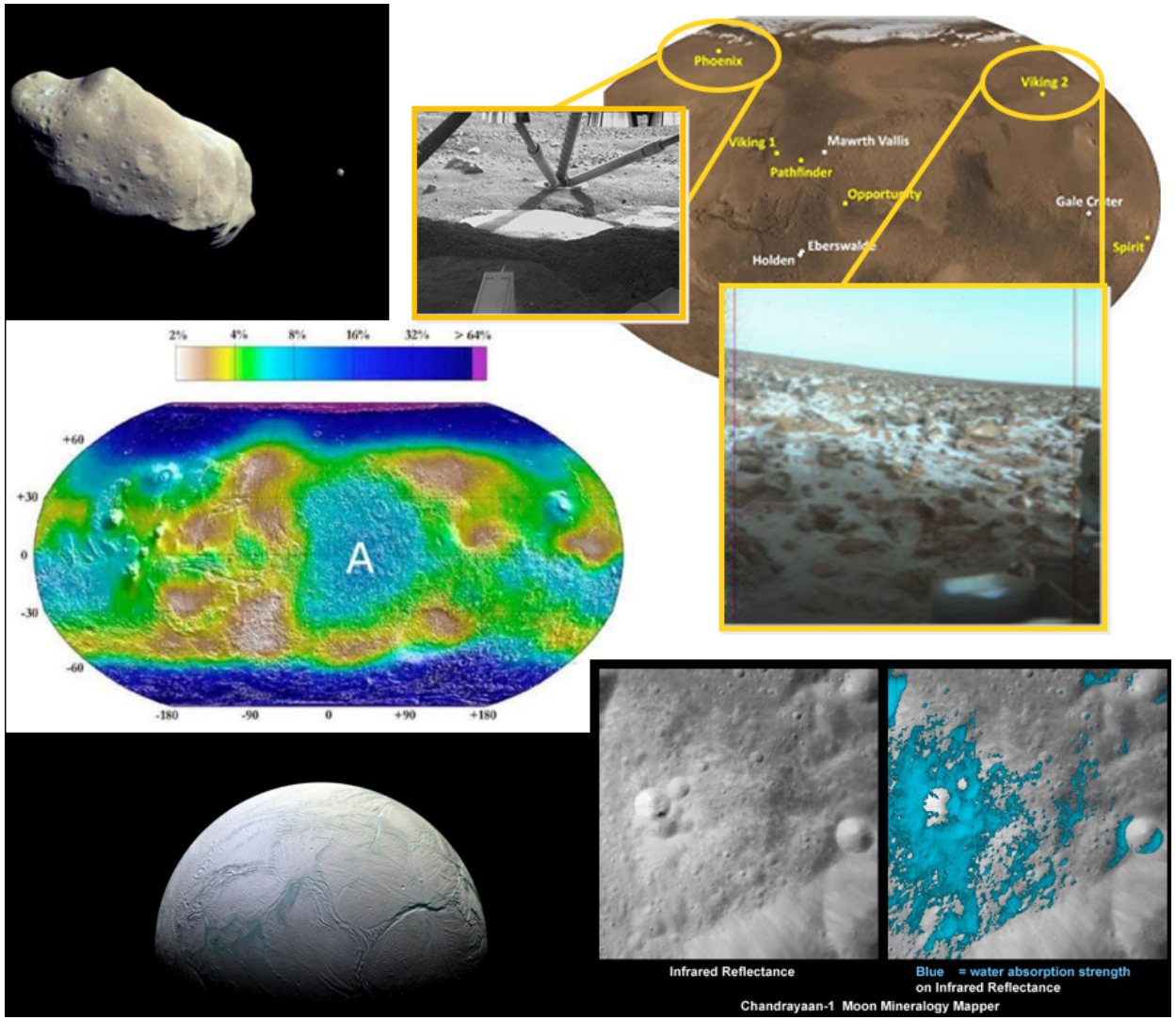
Agenda

- Background
- Design Overview
- Test Setup and Demonstration
- Acknowledgements

Water is Everywhere

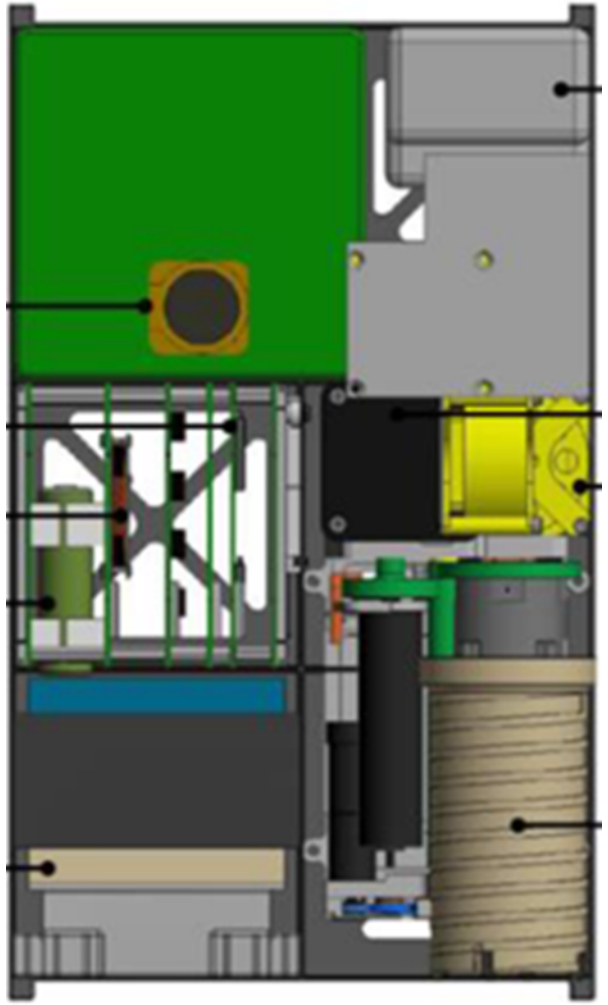
- Asteroids
  - Analysis of sunlight reflected by 24 Themis showed H_2O covering most of its surface
  - Several groups of carbonaceous chondrite asteroids are known to contain high percentages (3-22% by mass) of H_2O
- Mars
- Earth's Moon
- LCROSS provided direct evidence of ground ice (~5.6% by mass)
- Other Solar System Bodies
- Many comets, icy moons, and Kuiper belt objects are also believed to possess significant quantities of water



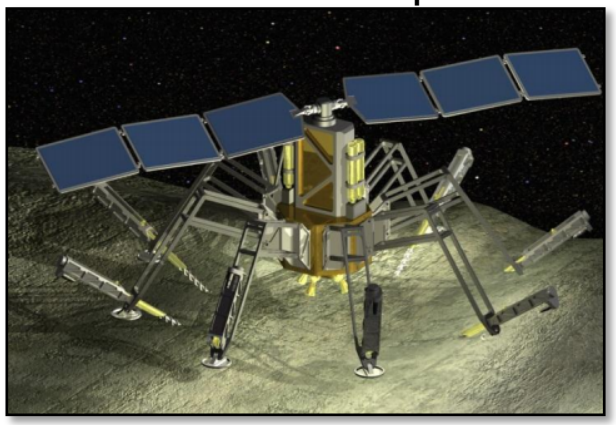
Technology Demonstration and Potential Applications

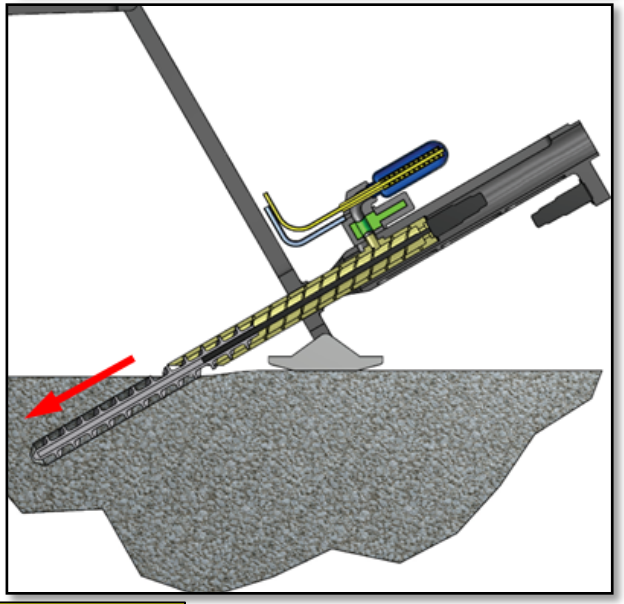
- Combine several Honeybee technologies including volatile capture and drill systems to demonstrate capability and develop hardware
- Potential NASA applications include prospecting and ground truthing
- Potential non-NASA commercial applications include targeting asteroids for ISRU for human consumption or refueling of existing satellites
- Relocate from location to location (larger gravity bodies) or from asteroid to asteroid (microgravity bodies)

Reference 6U Architecture



WINE Concept

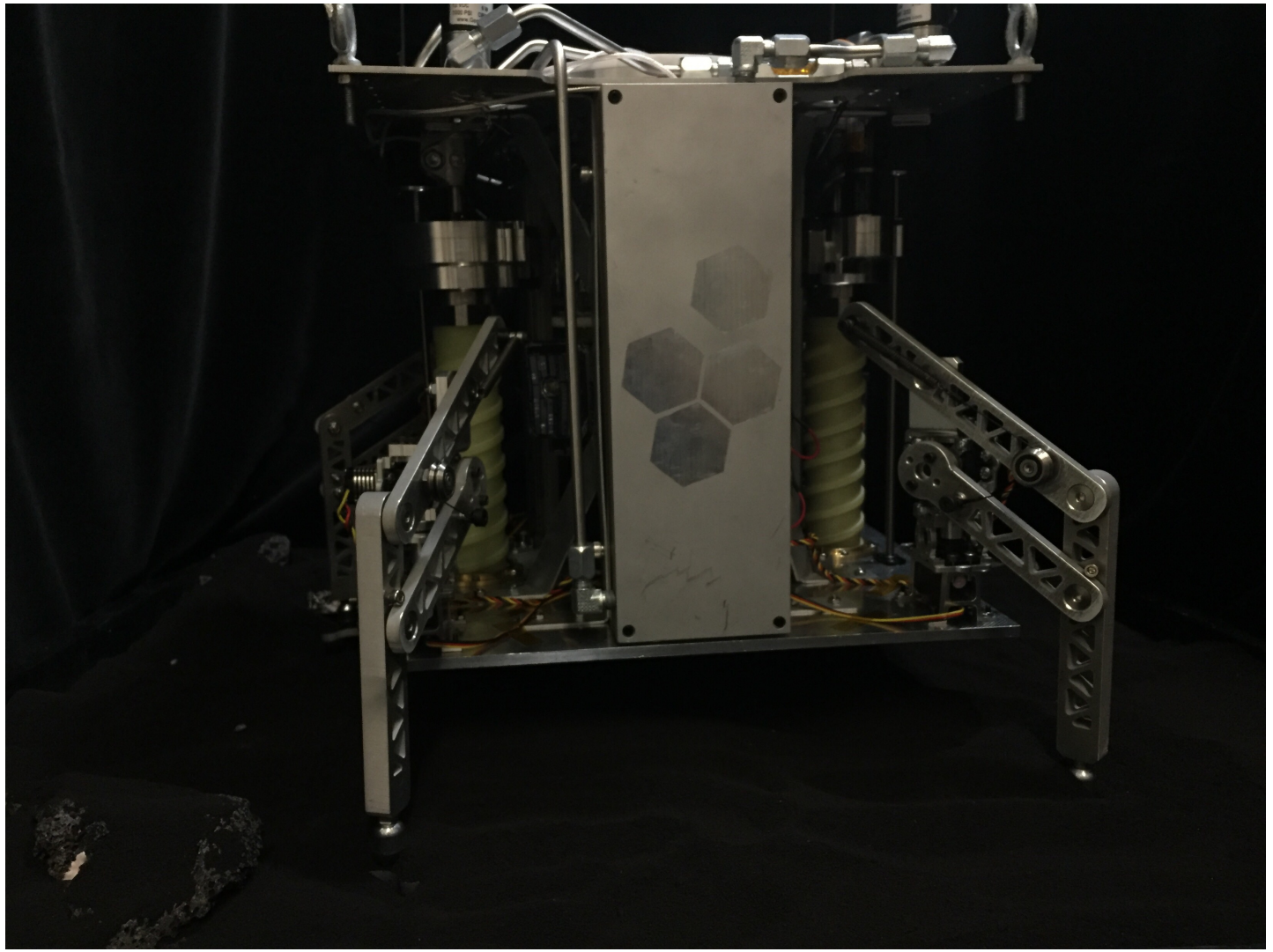




Utilize captured water for fuel which extends mission operations

WINE Overview

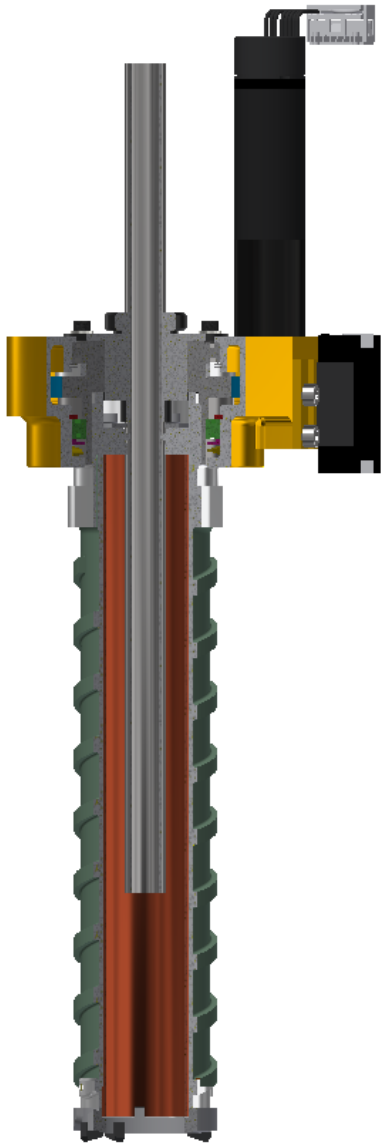
- Demonstrates on-surface operations on asteroid simulant and under vacuum conditions
- 4 Primary Subsystems:
  - Drill/Volatile Extraction
  - Cold Trap
  - Locomotion
  - Propulsion
- Tether used for electronics. 9U volume reserved on opposite side of WINE for bus/batteries/etc.
- Includes valving and sensing components
- Passive gravity-offload system used during chamber operations

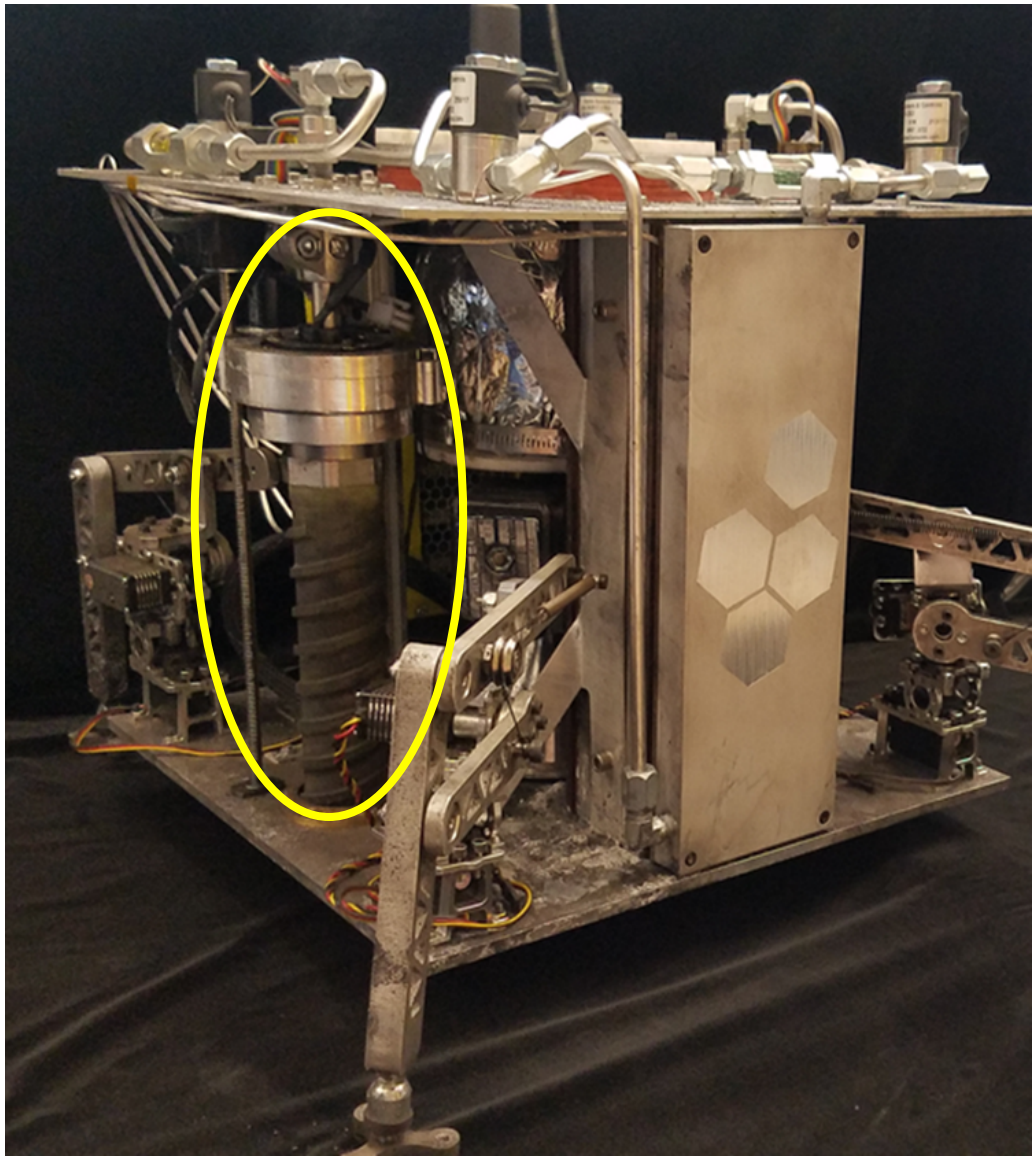


WINE incorporates many subsystems critical to development of ISRU CubeSat System

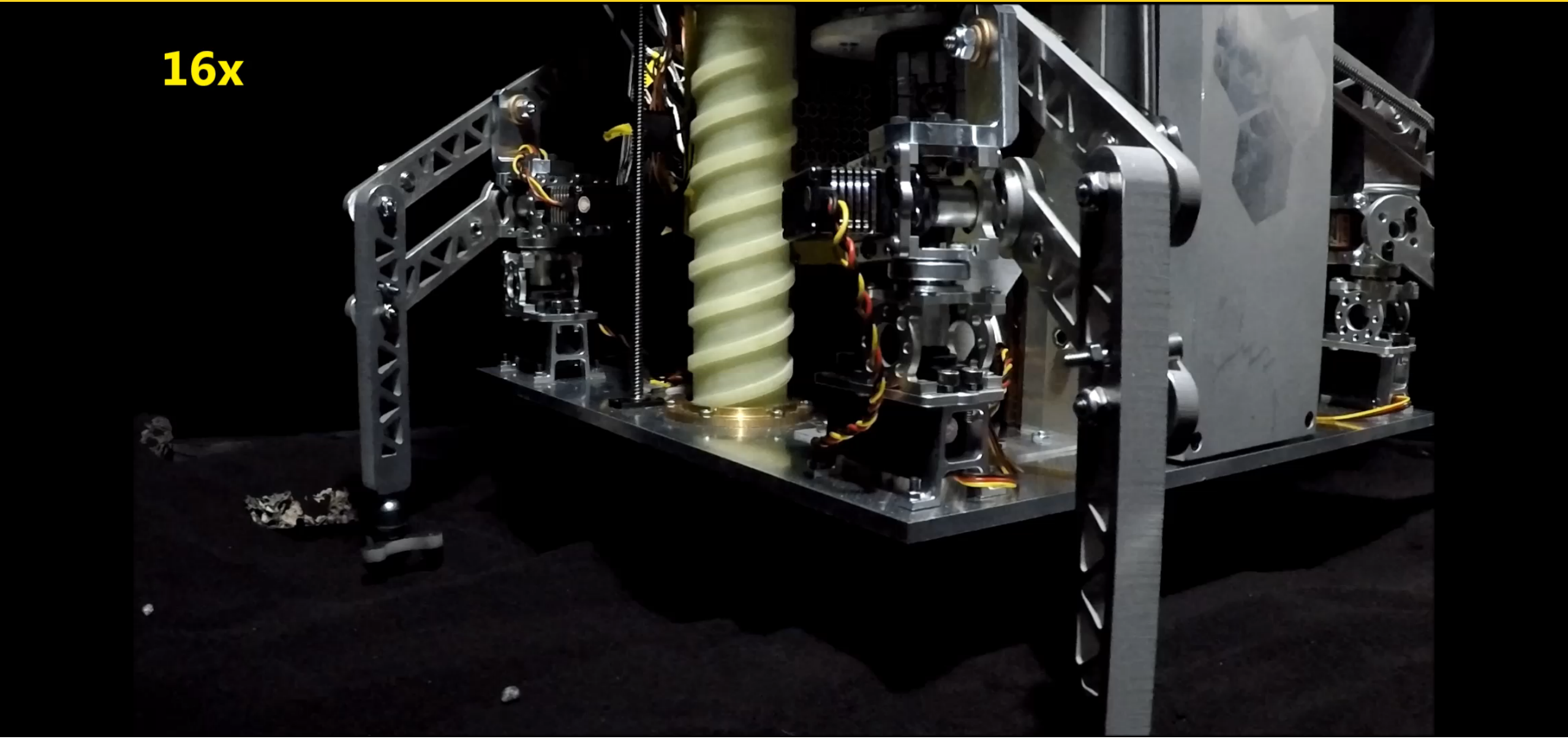
Corer and Drill Assembly

- Two 33mm diameter x 200mm long Garolite rotary augers with Z-stage and embedded 60W heater sleeve
- Garolite insulates auger and reduces waste heat into surrounding regolith
- Slip Ring is used to transfer power to rotating heater sleeve. Typically, heaters are only activated at full depth
- Sealed “trombone” tube allows for vapor to flow through center of drill to the cold trap



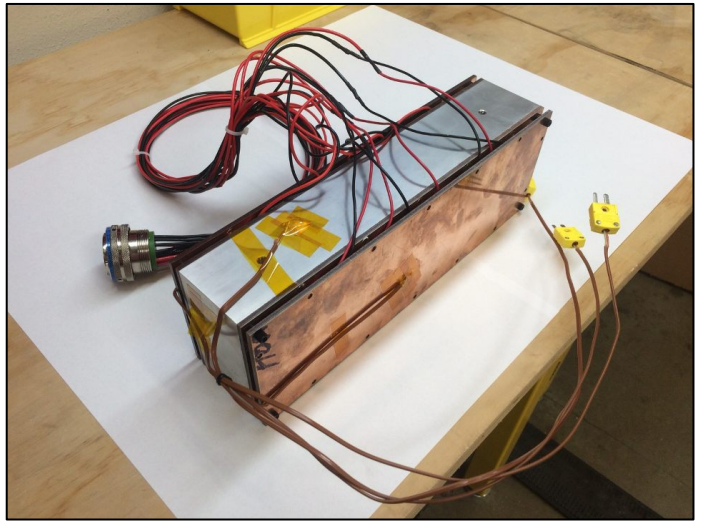


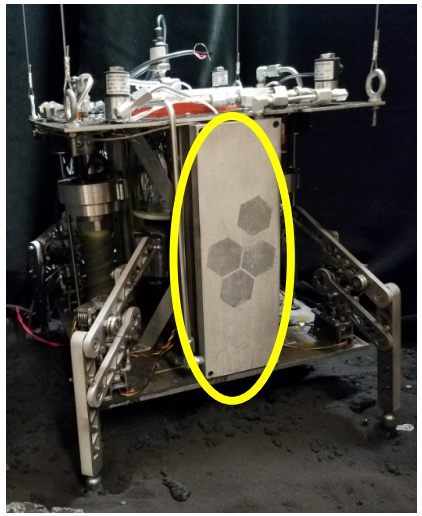
Drilling Video

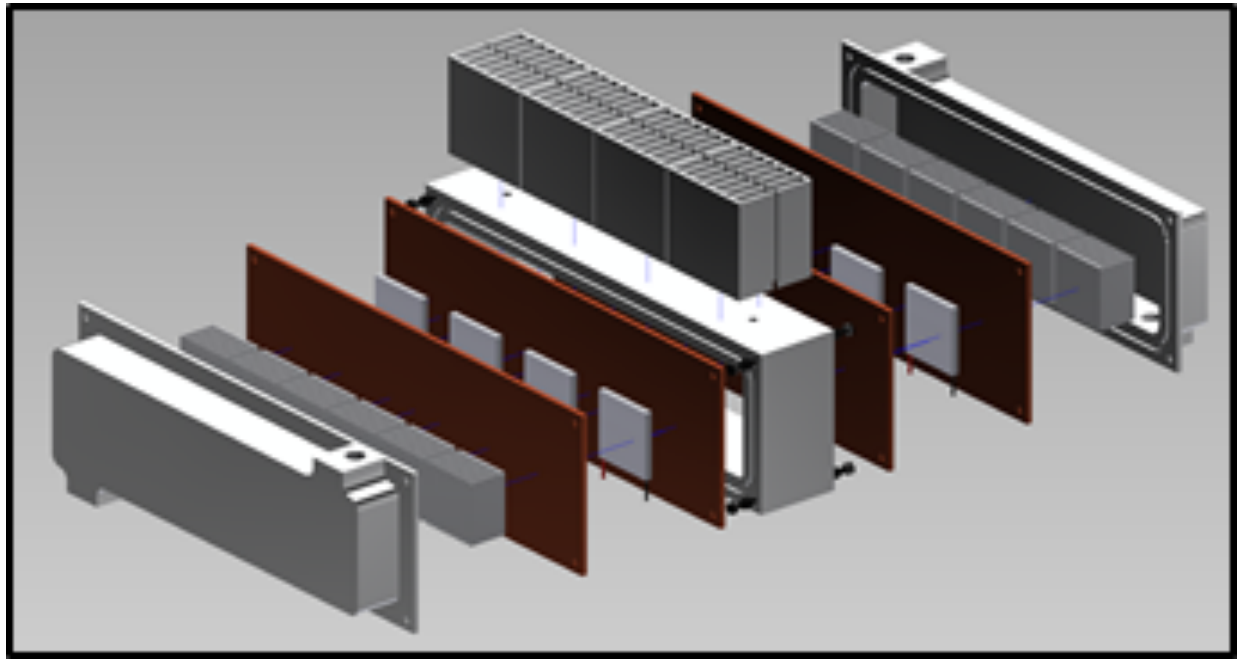


Cold Trap

- Dual cold trap (condenser) chambers are separated by phase change material
- Thermo-electric coolers (Peltier) cool condensing chamber and reject heat into phase change material
- Flow is controlled by valves (not shown). The captured ice is re-vaporized by reversing the polarity of the TECs and move water into propulsion tank

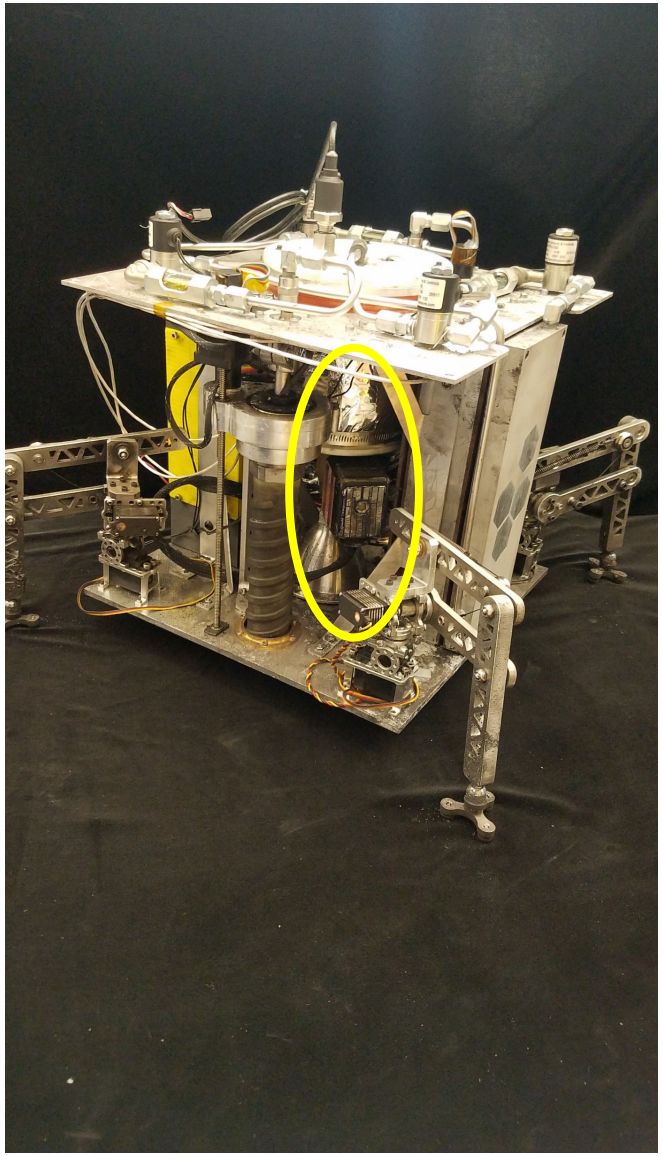






Propulsion

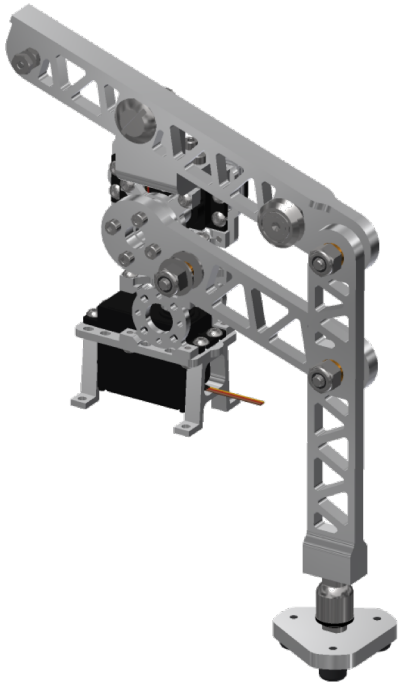
- Consists of static tank, steam valve, and nozzle
- Nozzle is placed in center of craft. Attitude control system would be required for flight-like system (not developed)
- Nichrome ribbon wrapped around tank heats propellant. Insulation surrounds the tank
- Thrust values as high as 10lbf were measured in thrust stand

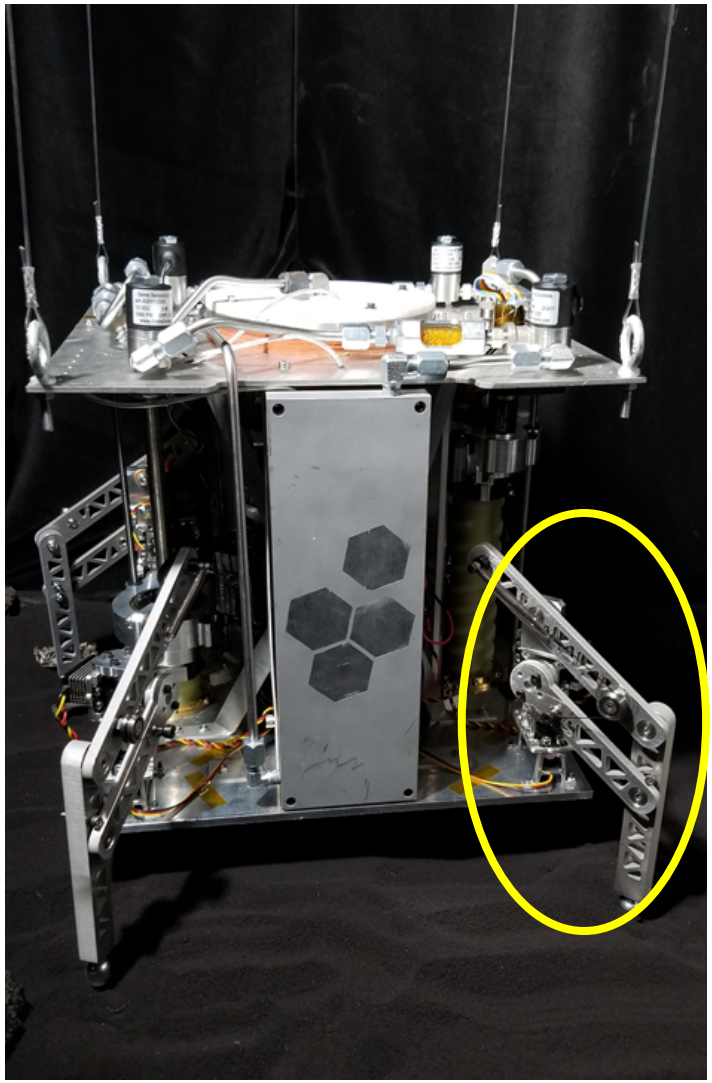


Locomotion

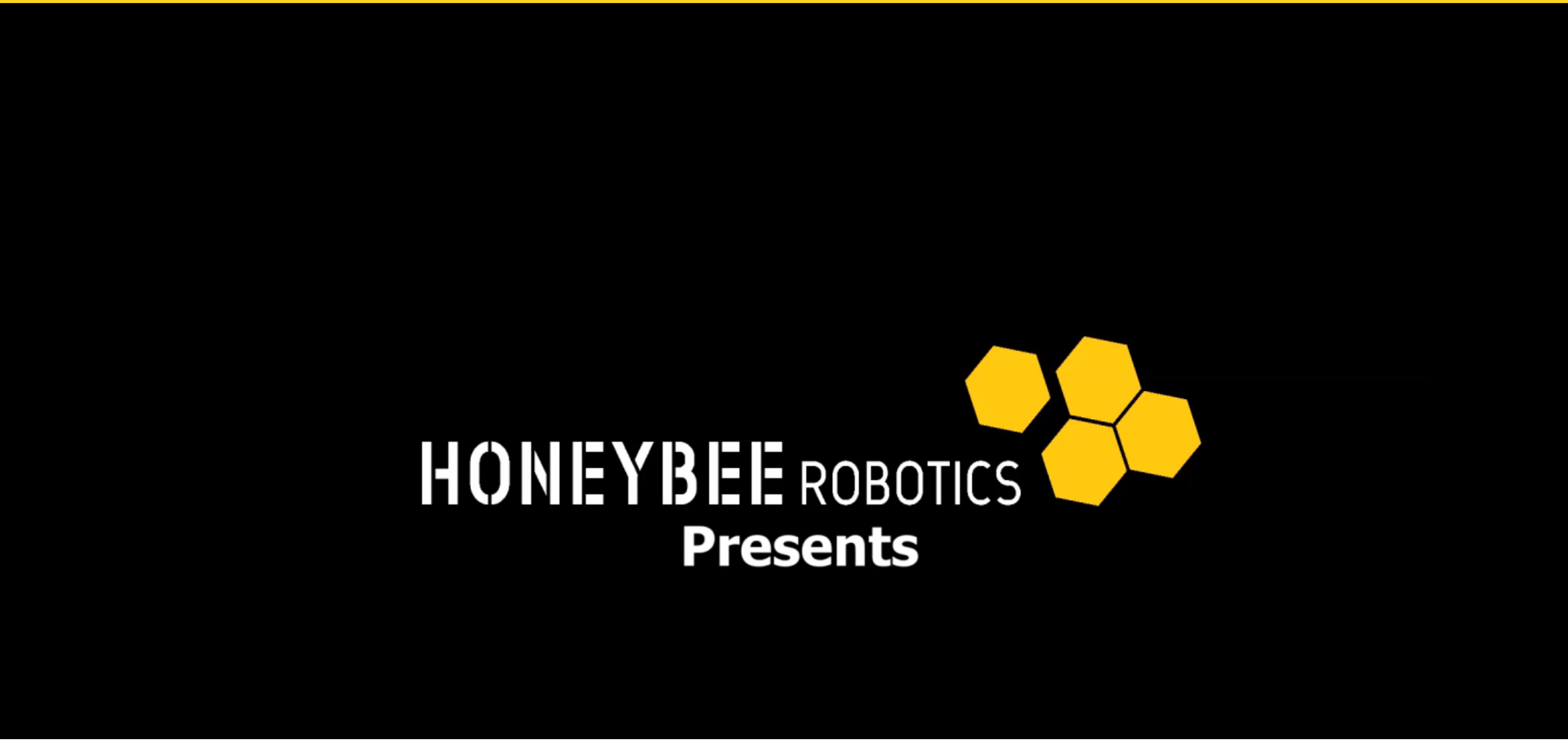
- Simple four-bar linkage with spring offload was prototyped and tested

- Legs allowed for several capabilities:
  - Reposition drill to new hole location without expending water captured (at 8% water by weight, ~68 drill operations would be required per launch)
  - Dampen landing
  - Pitch-over to direct launch angle (azimuth and inclination)



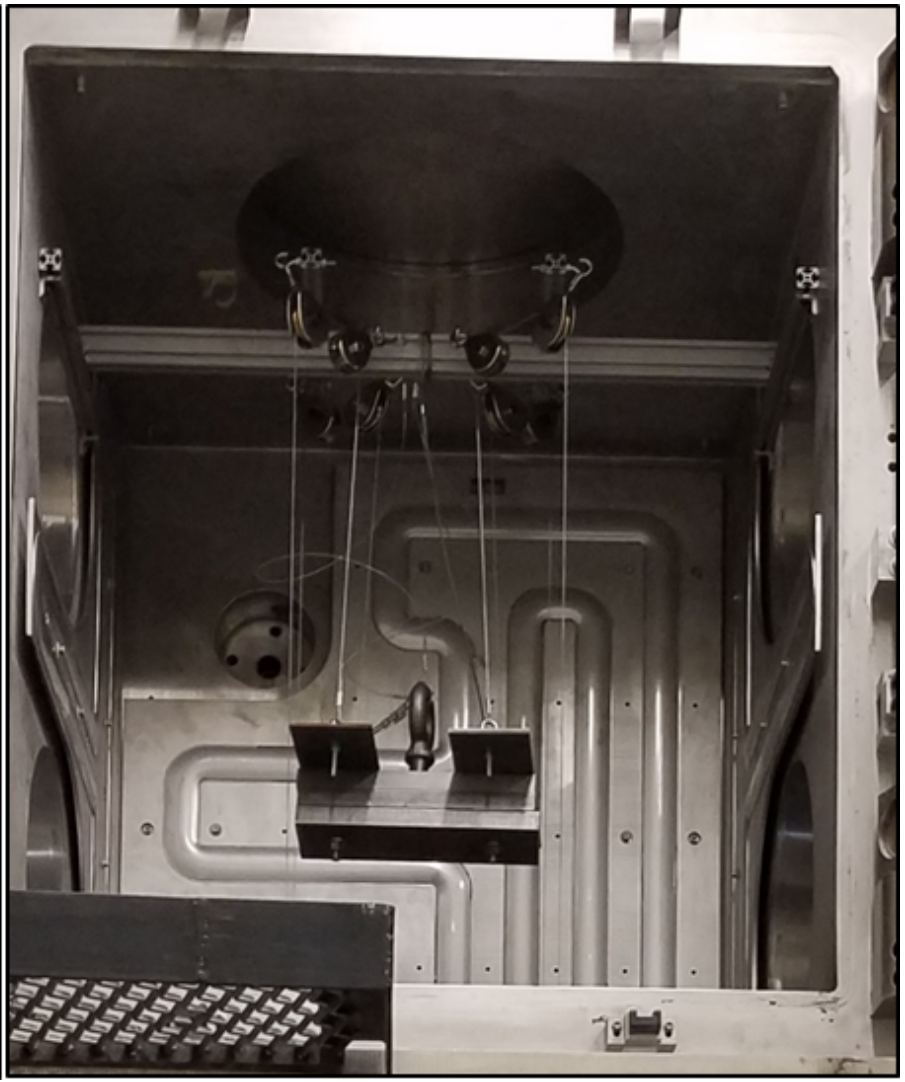


Locomotion Video

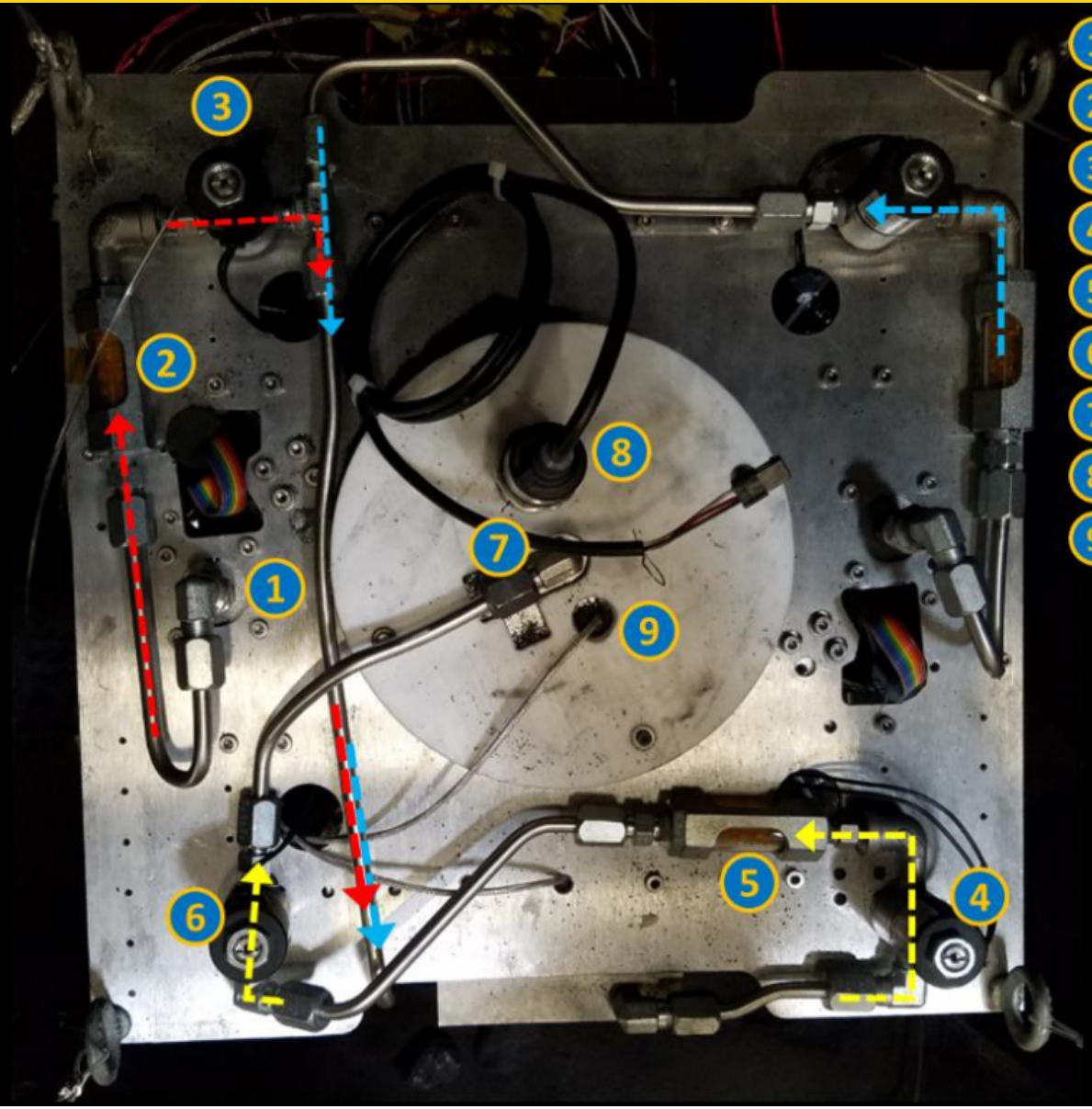


Test Setup

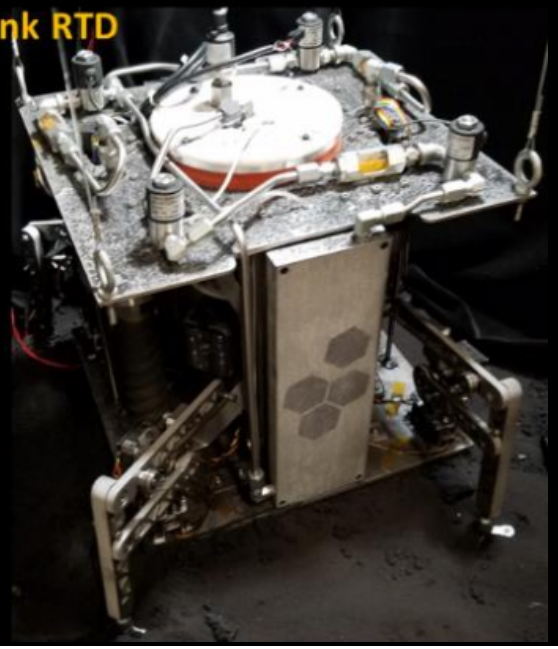
- Honeybee Large Vacuum Chamber (1m x 1m x 3m) at 6 Torr, 20C
- Asteroid simulant tray with extended depth for drilling operations
- Mass offload system (~99%) stabilizes vehicles against rotation
- Electrical tether for heaters and sensors



Flow Control of Demonstration Vehicle



1. Outlet from Drill Trombone
2. Sight Glass: Flow from Drill to Cold Trap
3. Low-Pressure Solenoid Valve to Cold Trap
4. Low-Pressure Solenoid Valve from Cold Trap
5. Sight Glass: Flow from Cold Trap to Tank
6. High-Pressure Solenoid Valve to Tank
7. Inlet to Propellant Tank
8. Propellant Tank Pressure Sensor
9. Propellant Tank RTD



CONOPs

1. Land at site

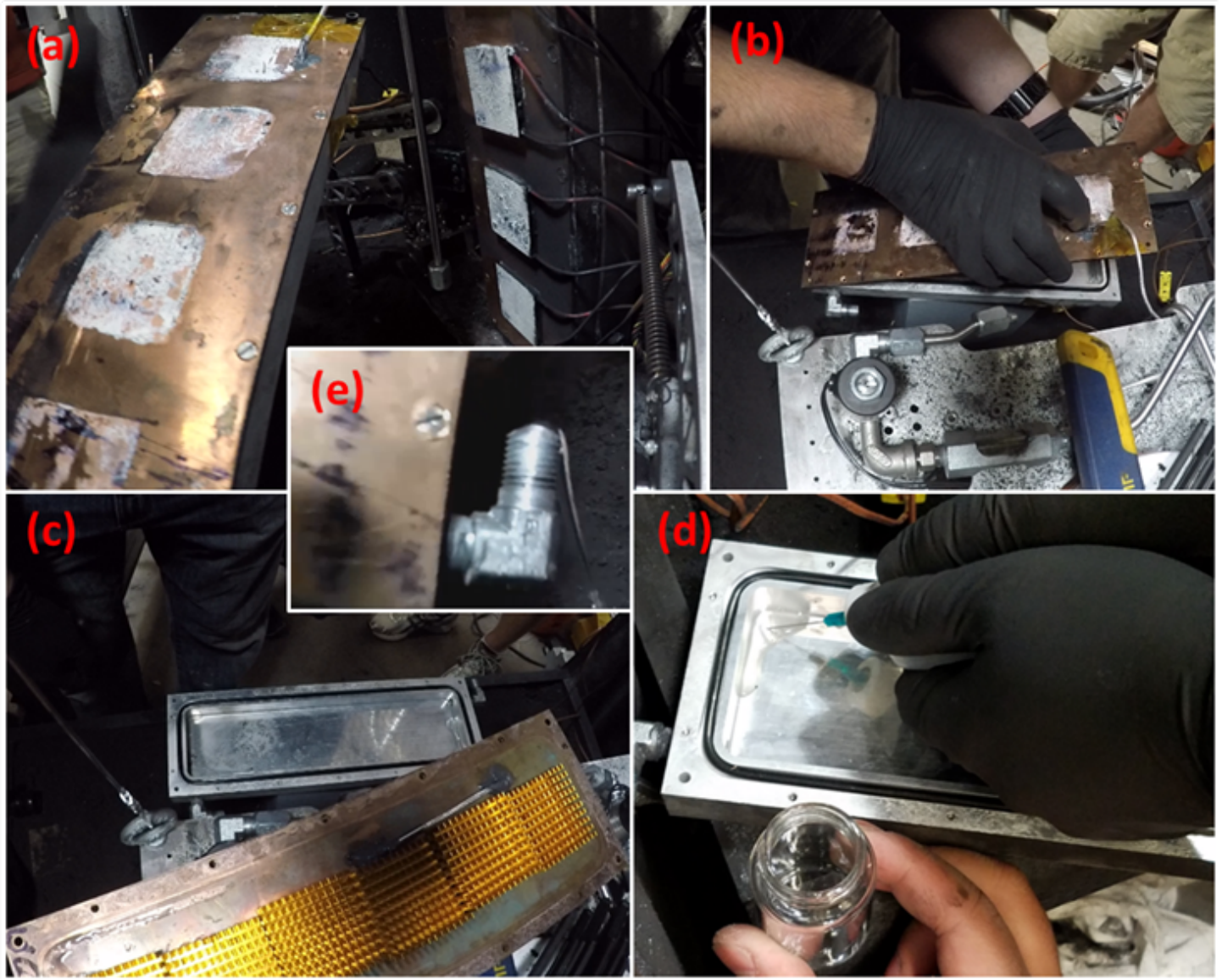
2. Drill and Capture Water

3. Reposition and continue drill operations

4. Push collected water into propellant tank

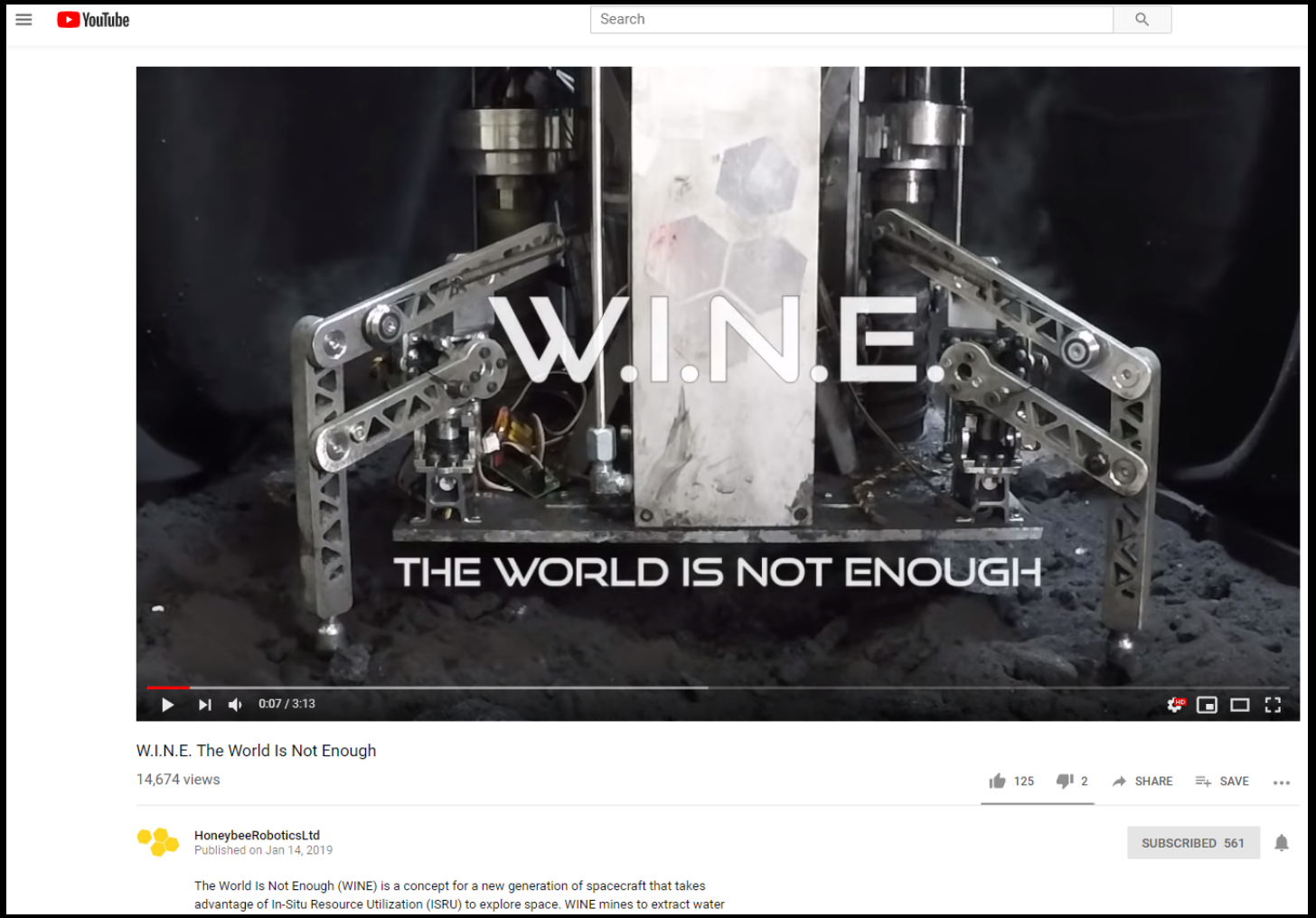
5. Launch to new site

6. Repeat at next site of operations



Launch!

Complete Video



https://www.youtube.com/watch?v=-BhnL1GqhxM

Acknowledgements

SBIR/STTR

Small Business Innovation Research / Small Business Technology Transfer

Questions

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