National Aeronautics and Space Administration

Resource Prospector Instrumentation for Volatile Analysis

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LAVA Lead - Janine Captain, Ph.D., KSC

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Resource Prospector (RP) Overview

Mission:

- Characterize the nature and distribution of water/volatiles in lunar polar sub-surface materials
- Demonstrate ISRU processing of lunar regolith

Project Timeline:

- ✓ FY13: Pre-Phase A: MCR (Pre-Formulation)
- ✓ FY14: Phase A (Formulation)
- ✓ FY15: Phase A (Demonstration: RP15)
- ✓ FY16: Phase A (Risk Reduction)
- • FY17: L2 Requirement Lockdown (July 11)
- • FY18: MRD and PDR (Implementation)
- • FY19: CDR (Critical design)
- • FY20: I&T
- • FY21: RP launch

RP Specs:

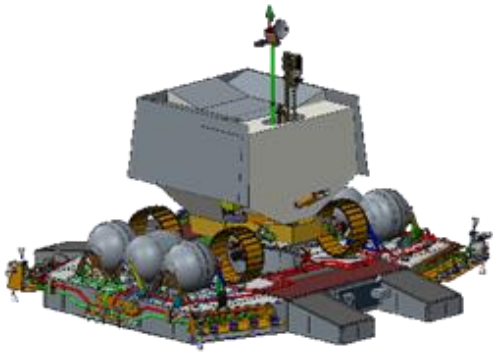
Mission Life: 6-14 earth days
(extended missions being studied)
Rover + Payload Mass: 300 kg
Total system wet mass (on LV): 5000 kg
Rover Dimensions: 1.4m x 1.4m x 2m
Rover Power (nom): 300W
Customer: HEOMD/AES
Cost: ~$250M (excl LV)
Mission Class: D-Cat3
Launch Vehicle: EM-2 or ELV

Resource Prospector – The Tool Box

Mobility

Rover

- Mobility system
- Cameras
- Surface interaction



Prospecting

Neutron Spectrometer System (NSS)

- Water-equivalent hydrogen > 0.5 wt% down to 1 meter depth

NIR Volatiles Spectrometer System (NIRVSS)

- Surface H2O/OH identification
- Near-subsurface sample characterization
- Drill site imaging
- Drill site temperatures

Sampling

Drill

- Subsurface sample acquisition
- Auger for fast subsurface assay
- Sample transfer for detailed subsurface assay

Processing & Analysis

Oxygen & Volatile Extraction Node (OVEN)

- Volatile Content/Oxygen Extraction by warming
- Total sample mass

Lunar Advanced Volatile Analysis (LAVA)

- Analytical volatile identification and quantification in delivered sample with GC/MS
- Measure water content of regolith at 0.5% (weight) or greater
- Characterize volatiles of interest below 70 AMU

Presentations:

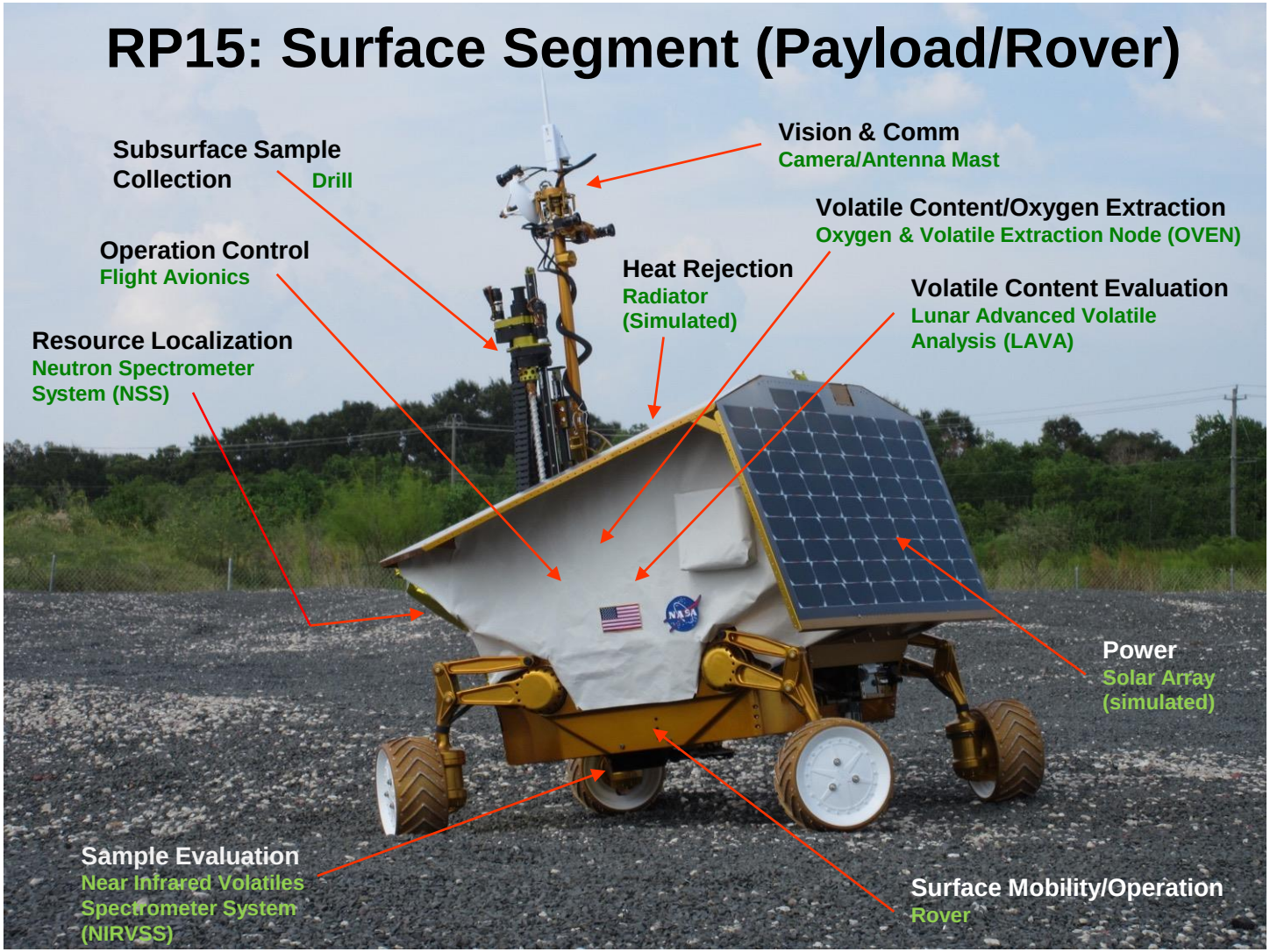
11:30 Ted Roush -- Water Ice in Lunar Simulants: NIRVSS Drilling Observations

2:35 Julie Kleinhenz -- Characterization of Volatiles Loss from Soil Samples at Lunar Environments

Posters:

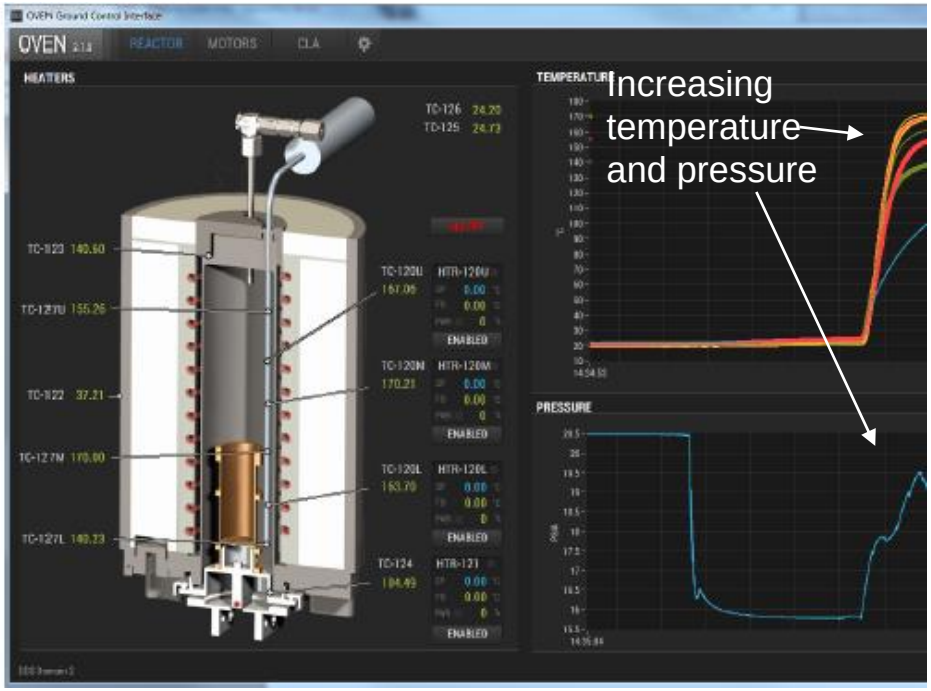
Colaprete: Traverse and Observation Planning for the Resource Prospector Mission (#66)
Cook: Testing Near-Real-Time Remote Science Operations in the Field: NIRVSS in BASALT (#68)
Elphic: The Resource Prospector Neutron Spectrometer System: RP's Bloodhound (#71)
Zacny: The Resource Prospector Drill (#79)

RP15: Surface Segment (Payload/Rover)

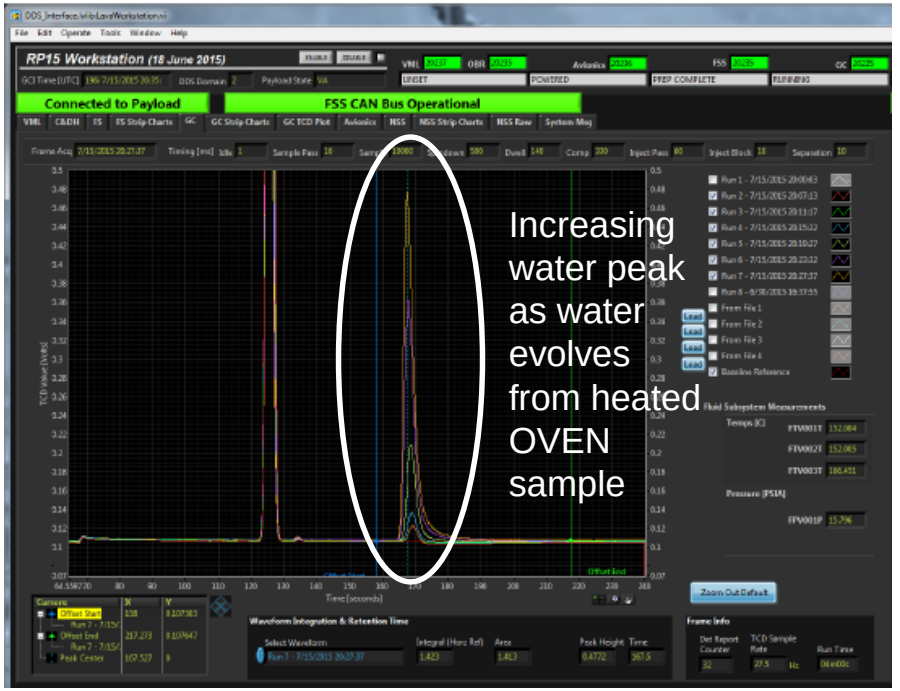


OVEN-LAVA Operation during RP-15 Volatile Analysis

Volatile analysis demonstration measured increasing water concentration as simulant sample temperature increases



OVEN User Interface

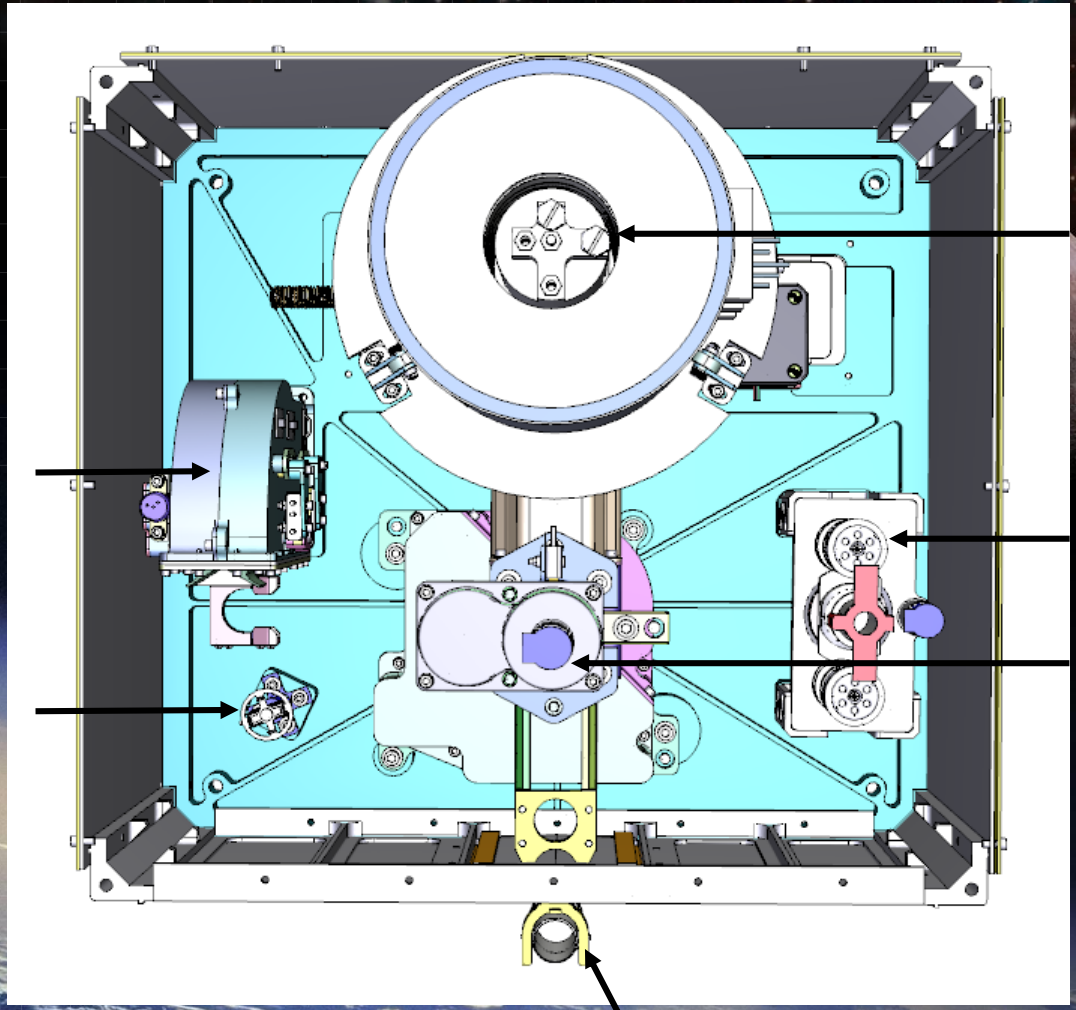


LAVA GC User Interface

OVEN (Oxygen and Volatile Extraction Node)

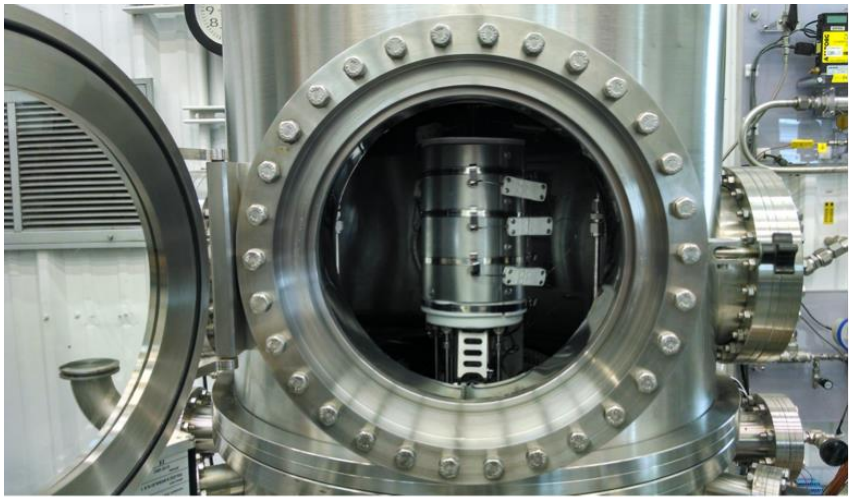
Multiple functions

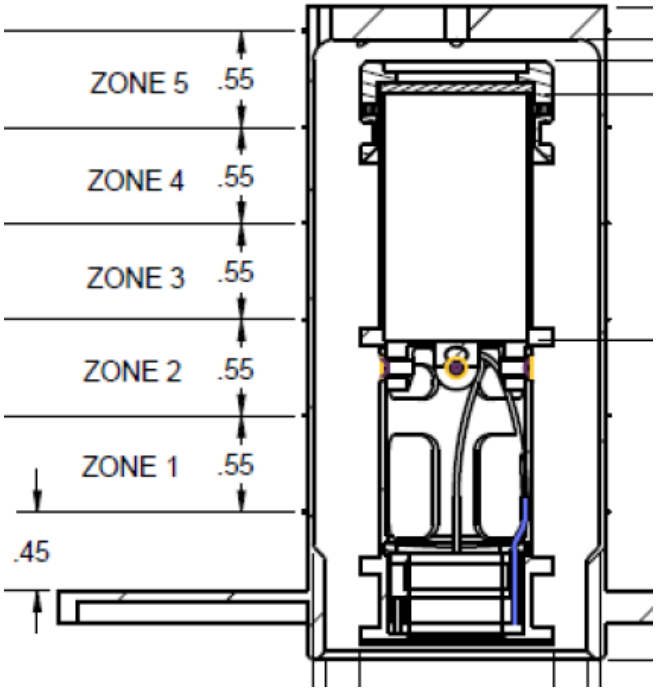
- Receive sample from drill
- Confine sample to a known volume
- Weigh sample
- Heat sample, build pressure from volatiles
- Transfer volatile sample to LAVA Subsystem
- Discard sample



OVEN Subsystem

- Completed testing to understand temperature distribution of regolith during heating profiles to compare to modeling results
- Completed testing of required sealing forces and dust tolerance of seals to minimize volatile loss during heating



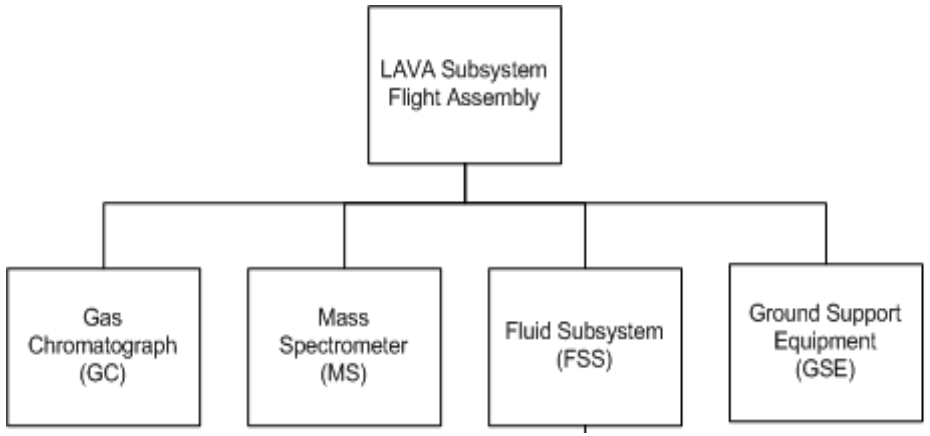


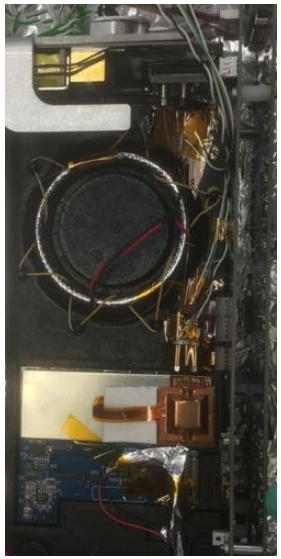
Trade Studies

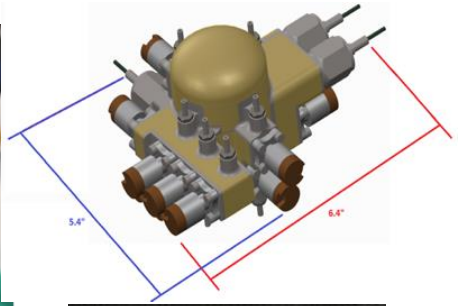
- Crucible chiller – To reduce sublimation losses
- Weigh and Dump Stations – May be removed
- Integrated RTD in crucible- Provides sample temperature but adds complexity
- Active vs passive gripper

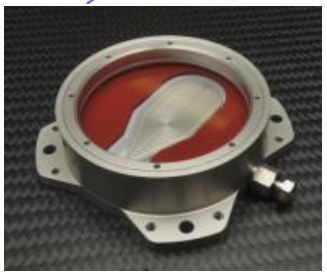
Lunar Advanced Volatile Analysis (LAVA)

- Purpose: Identify and quantify water as well as other low molecular weight species of interest to ISRU and Science community
  - Volatiles are transferred from the OVEN reactor to the LAVA Surge Tank where the pressure & temperature are measured
  - Gas sample is diluted and analyzed by GC-MS to identify and quantify constituents.
  - Gases of interest are H_2O, CO, CO_2, H_2, H_2S, NH_3, SO_2, CH_4, and C_2H_4 (1-70 amu)
  - Water that is evolved will be condensed and photographed, demonstration of resource storage (as well as public engagement).





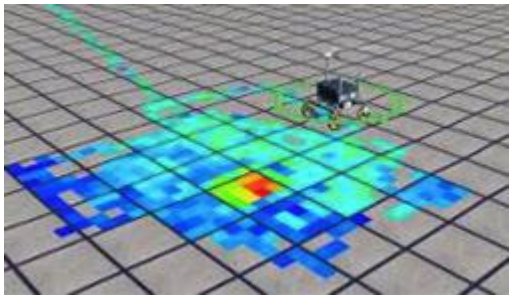




Volatile Identification and Quantification

Drill and Regolith Transfer

- Near Surface Assay located sample of interest
- Regolith from depth captured on drill flutes and transferred into OVEN crucible

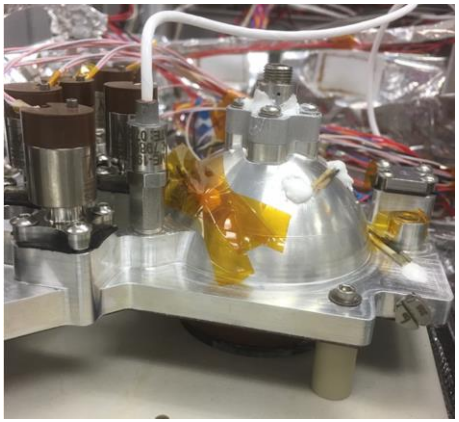


Seal and Heat

- Regolith filled crucible manipulated in OVEN and sealed in reactor station
- Crucible is heated to user defined setpoints to drive volatiles into gas phase

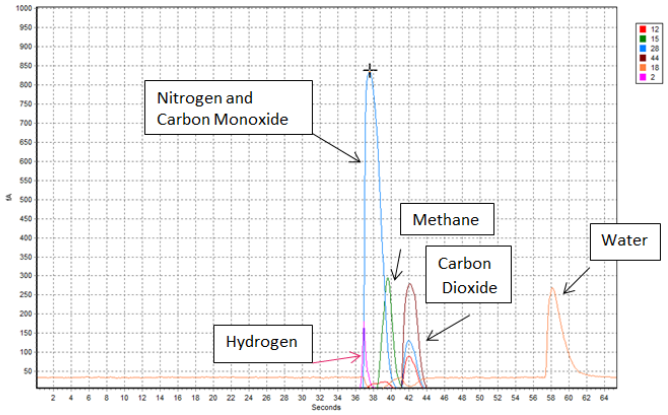
Quantify and Identify

- Gas phase volatiles transferred to known volume held at temperature to prevent condensation, number of moles calculated with ideal gas law
- Gas sample diluted and analyzed with GC-MS for species identification and quantification

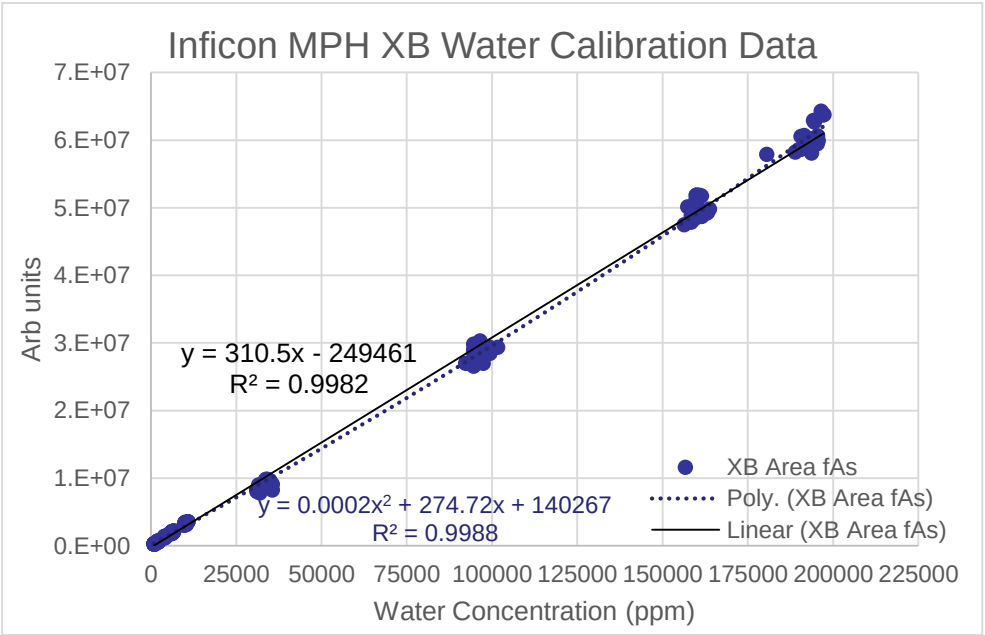


RP LAVA GC-MS Summary

- Inficon Fusion MicroGC module
  - Single Plot-Q column (8m), separate inert components from CO_2 and H_2O
  - Isothermal operation, ~2min runtime
  - microTCD with auto-ranging capability



- Inficon Transpector MPH
  - Quadrupole mass spectrometer
  - Open ion source and cross beam ion source configurations
  - ~3.5kg, ~20W

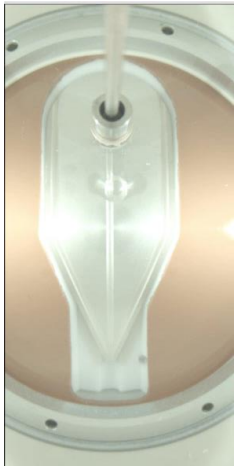


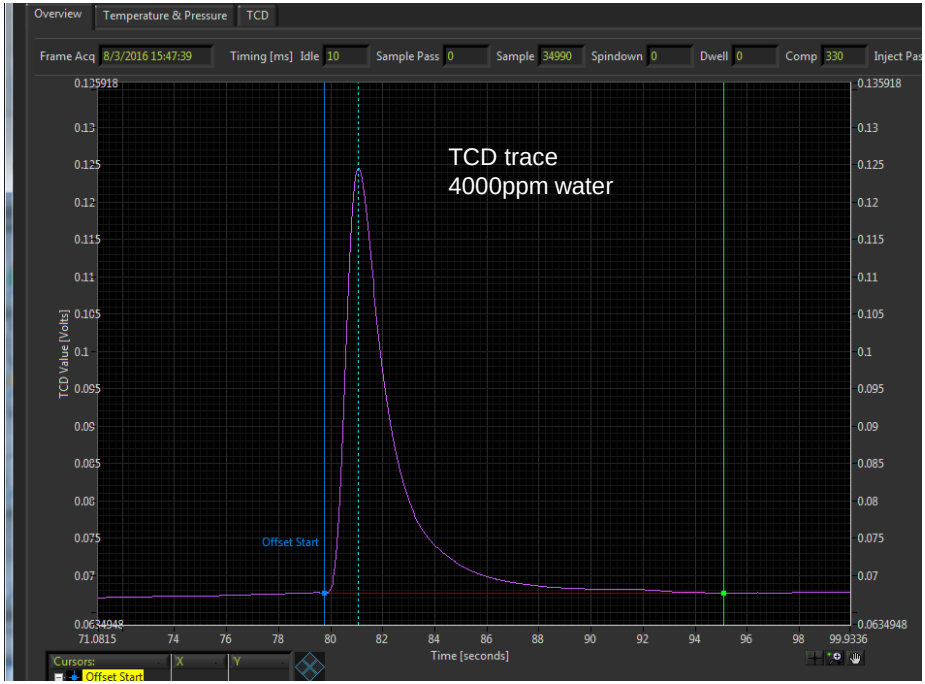
	Factor	Requirement
1.1	Scan rate	Collect 1-70 amu at 6Hz
1.2	Water detection limit	1000ppm at above scan rate

	Integrated System
Low water range average uncertainty	70 ppm
High water range average uncertainty	1725 ppm

Detection Limits for Water

- Detection limit for water with worst case assumptions is 1.3% water in the vapor phase
- Instruments have demonstrated detection limits of 1000ppm
- Lower limit of detection required for isotope analysis, this work is still in progress





Assumptions

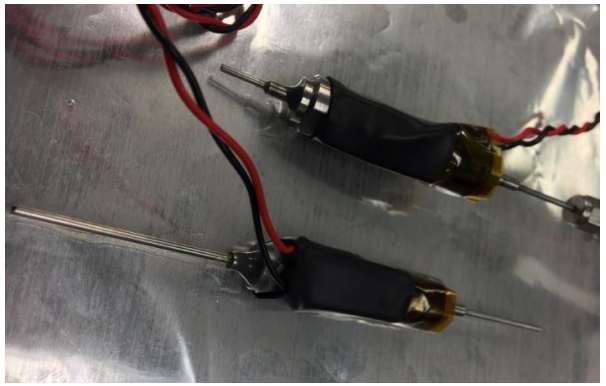
- 12g lunar regolith sample (lowest density sample)
- 50% loss of water ice due to sublimation during drilling
- OVEN and LAVA volumes were volatiles are generated are 100cc each
- SDS dilution is 1:5 (sample to helium diluent) based on the assumption that the sample is all water (worst case assumption)
- Total pressure generated by water and other volatiles is 65psia (max operational pressure with current concept of operations)
- All of the water present in the sample is in the vapor phase
- Gas temperature is 150C (423K), i.e. the temperature of the LAVA system

Flight forward design – modified Commercial Off the Shelf (COTS)

- Modification areas for flight driven by environment
  - Thermal considerations
  - Vibration considerations
  - Radiation considerations
  - Command/control interface

- Utilize components from other missions where possible within schedule/cost (valves, port connectors)

- Testing in thermal vacuum chamber and radiation testing of avionics



Current Status and Future Work

LAVA

- Instruments developed in partnership with Small Business Innovative Research (SBIR) at NASA - Creare, LLC has history of flight hardware development and delivery
- Software development in concert with hardware development – new command and control flight compatible software is under development
- ETU hardware build in progress for manifold and water droplet demonstration

OVEN

- Continue to investigate trade space and contribute to payload investigation on volatile loss
- ETU hardware build in progress for testing with avionics

Payload

- Continue to work towards understanding integrated set of measurements
- Requirements development