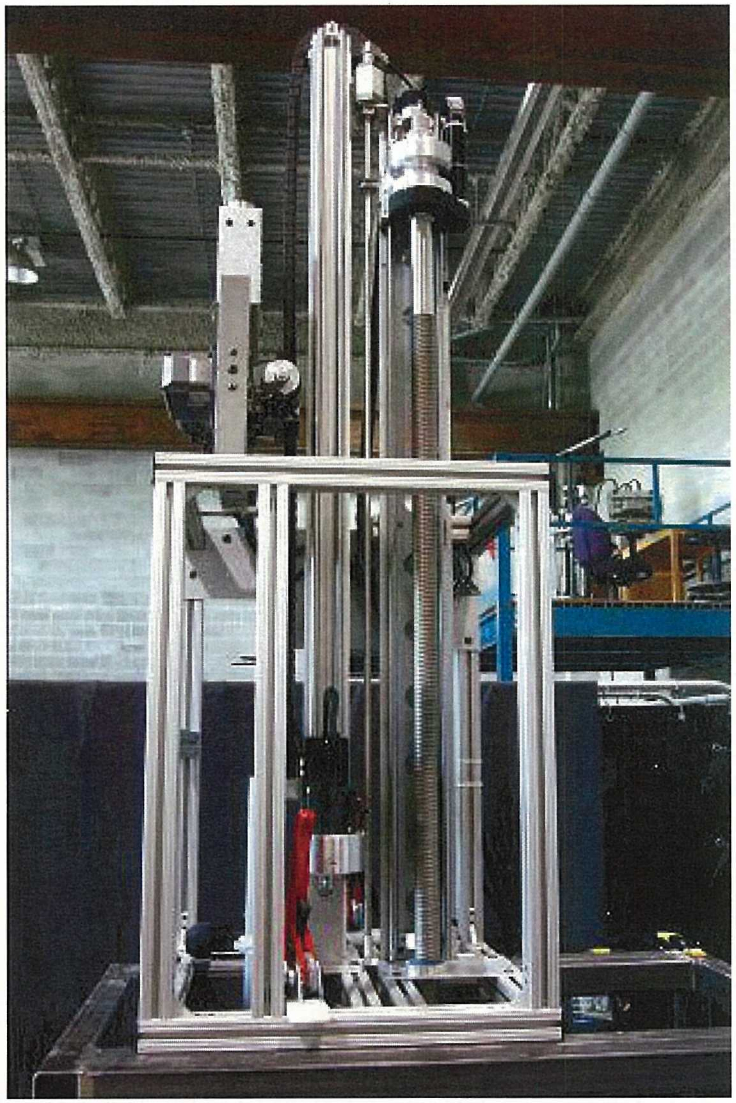
RESOLVE 2010 Field Test

RESOLVE

- EBRC – drill and crusher (CSA/Norcat)
- RVC – reactor and gas analysis (GRC and KSC)
- LWRD – fluid system, water and hydrogen capture (KSC)
- ROE – oxygen production (hydrogen reduction), not performed in 2010 Field Test (JSC)
- Mobility
    - Carnegie Mellon University (2008)
    - SRCan (2010)

EBRC

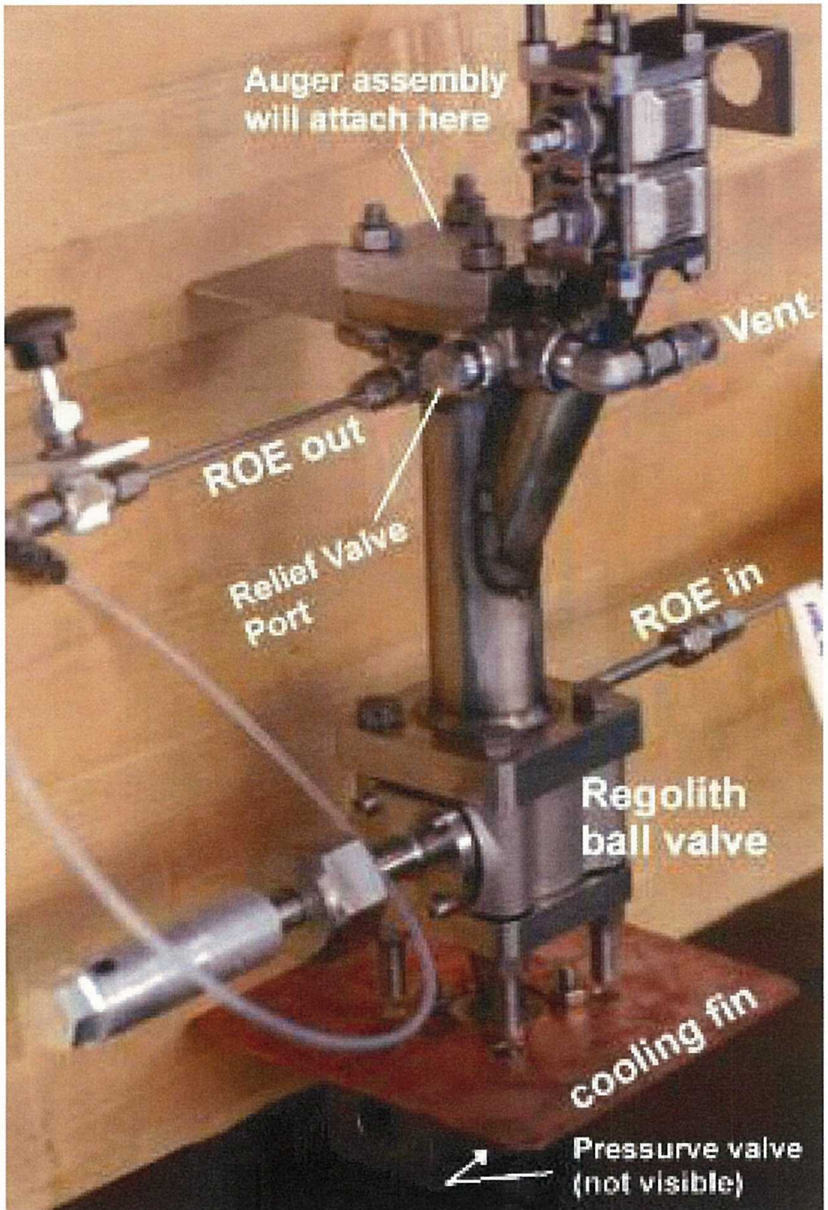
Excavation and Bulk Regolith Characterization

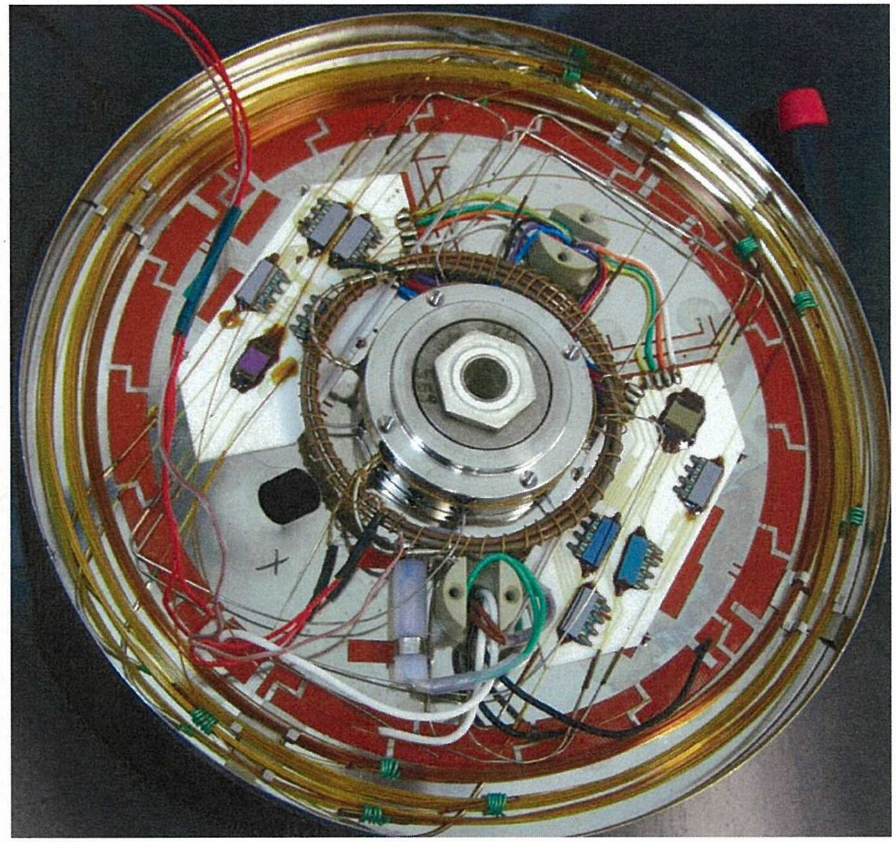


- Drill, Crusher, Metering Sample Delivery
  - Capable of 1 meter depth
  - Captures soil core and inserts sample into crusher to crush soil to <1 mm size particles
  - Crusher also weighs sample and delivers 20 grams at a time into the reactor

RVC

Regolith Volatiles Characterization



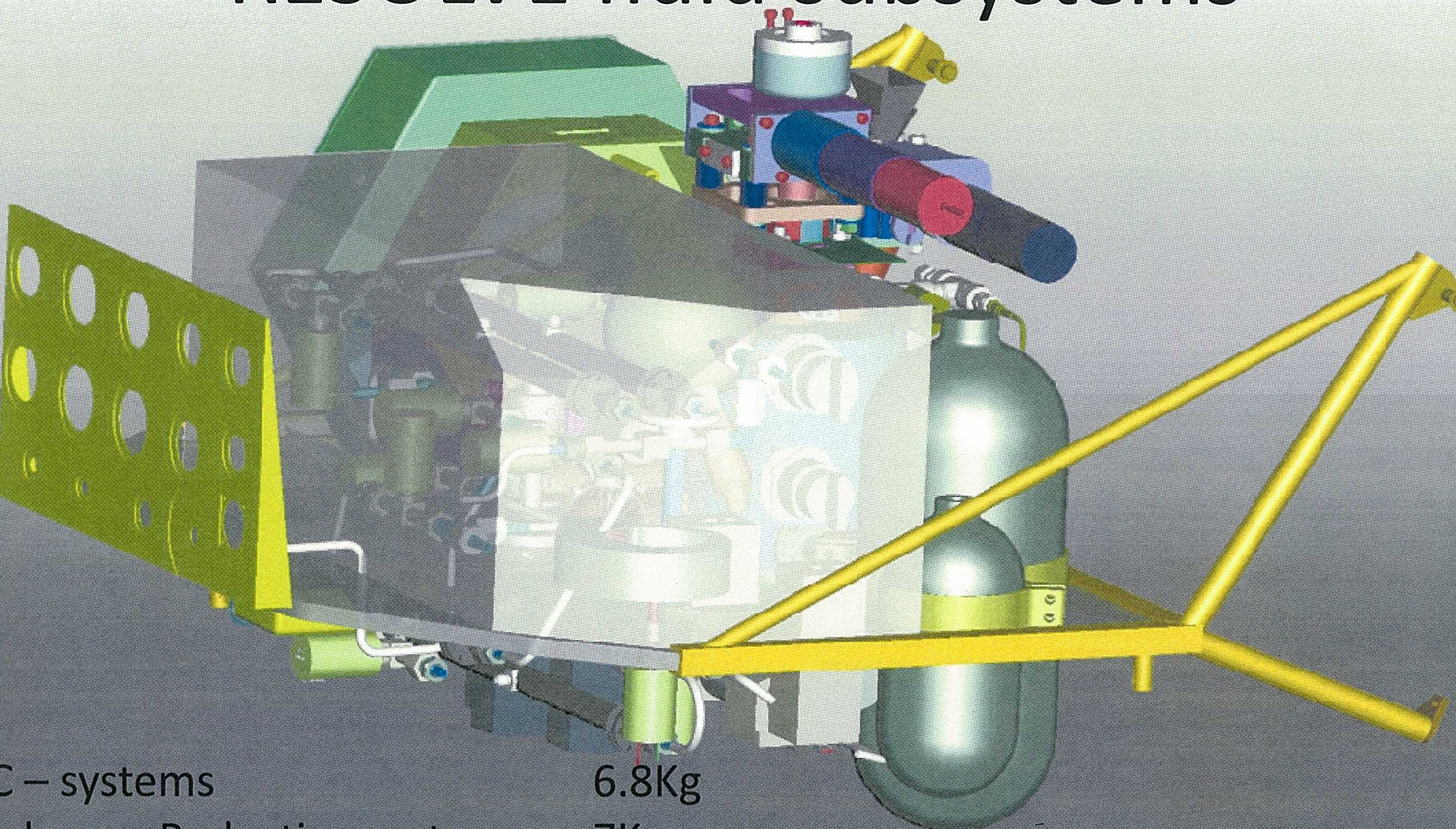


Reactor – heated 80 gram sample
auger/core heater design
performed both RVC and ROE
Gas Chromatograph – analyzed volatiles
MEMS technology

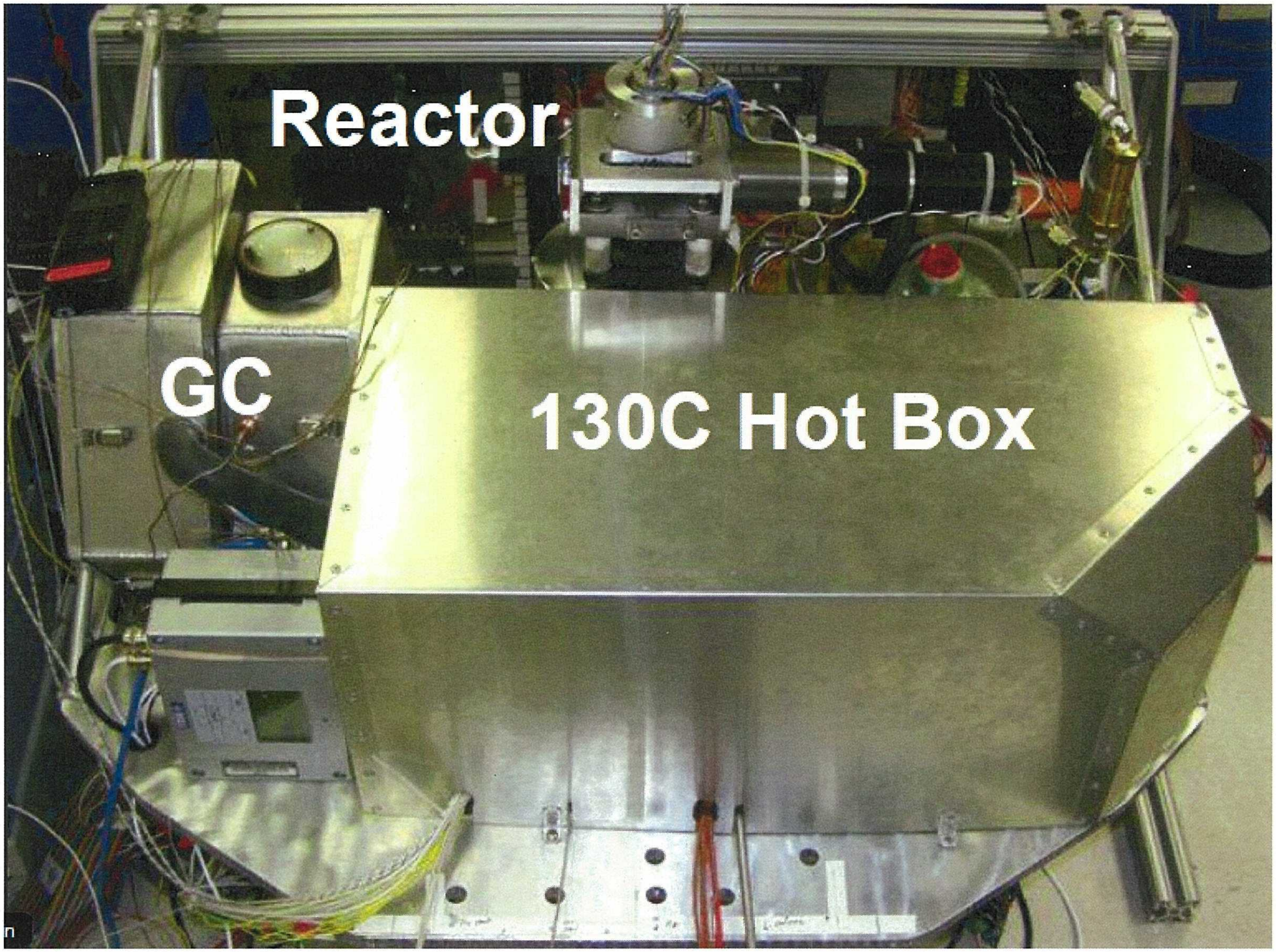
LWRD
Lunar Water Resources Demonstration

- Fluid system
  - Backup measurement of water and hydrogen
  - Capture/release water and hydrogen

RESOLVE fluid subsystems



GC – systems	6.8Kg
Hydrogen Reduction systems	7Kg
Water Capture systems	22.2kg
Frame & mounting hardware	4kg
Reactor	18.1Kg
Total	**58.1Kg**

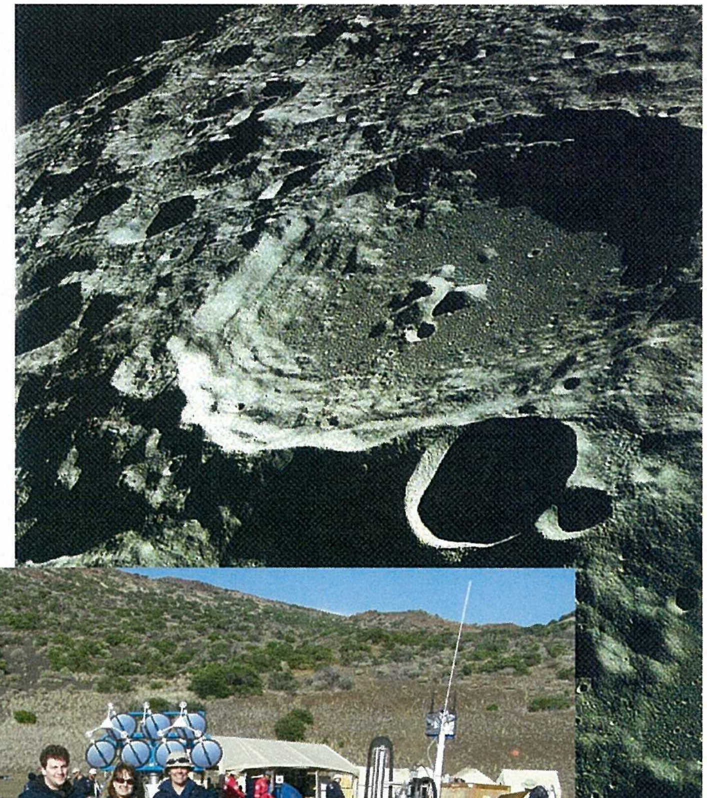

Reactor
GC
130C Hot Box

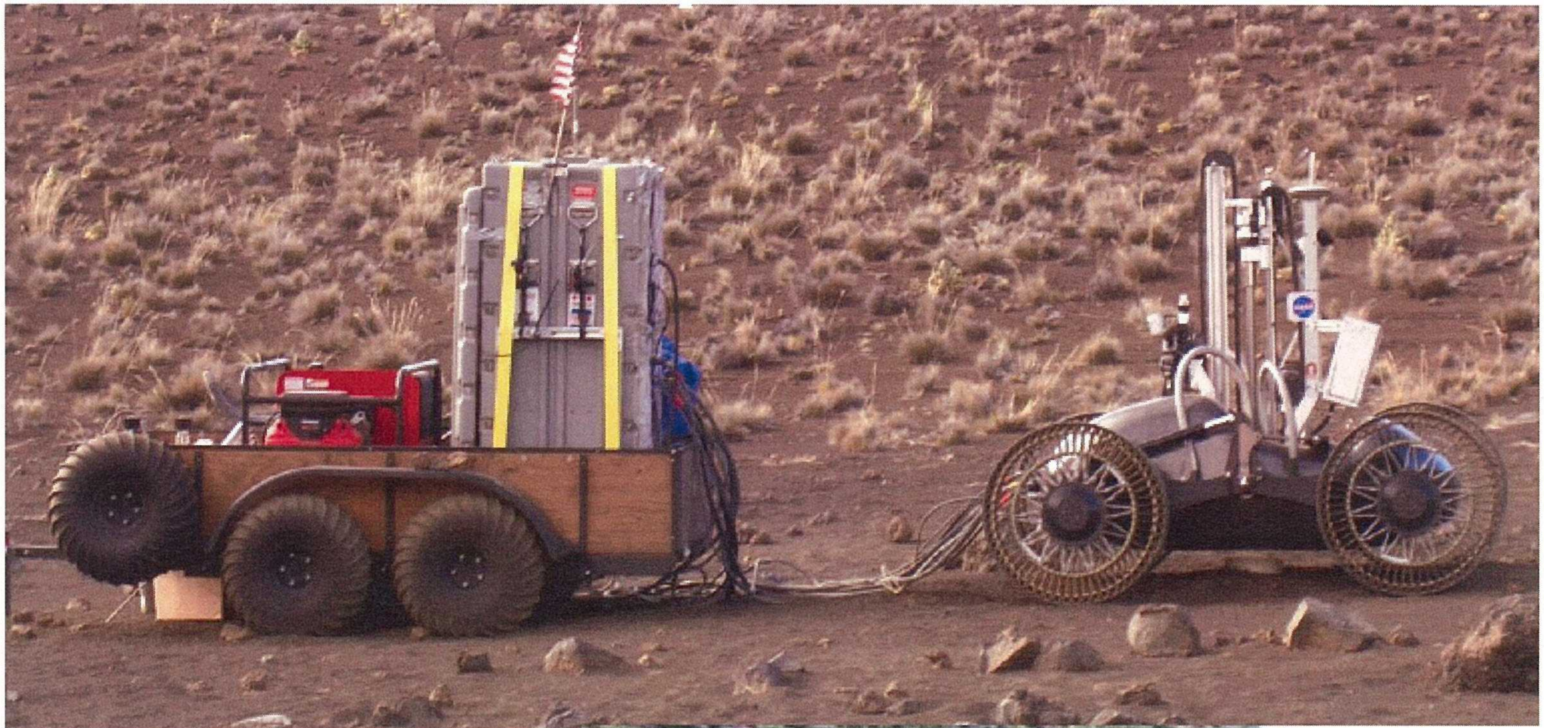
2008 Field Test

- Integration onto Scarab Rover (CMU) with GSE cart for power, electronics, vacuum pump, gas commodities
- Local command/ control
- Volatile characterization with water doping
- Oxygen production
- First field test of integrated system

2010 Field Test Goals

- Scientific goal
  - demonstrate evolution of low levels of hydrogen and water as a function of temperature
- Engineering goals
  - Integration onto new rover (CSA)
  - Miniaturization of electronics rack
  - Operation from battery packs (elimination of generator)
  - Remote command/control
  - Operation while roving





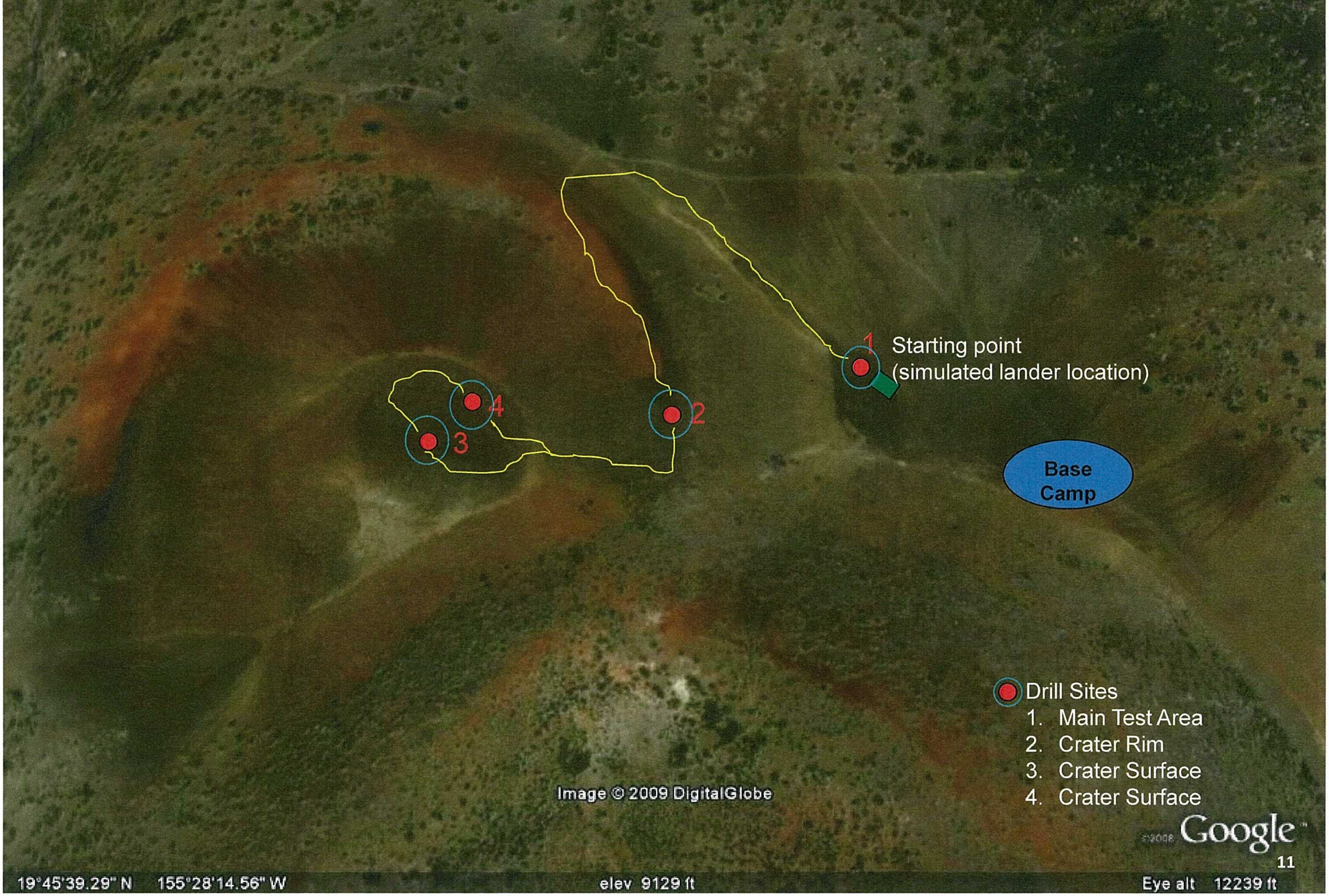
2008

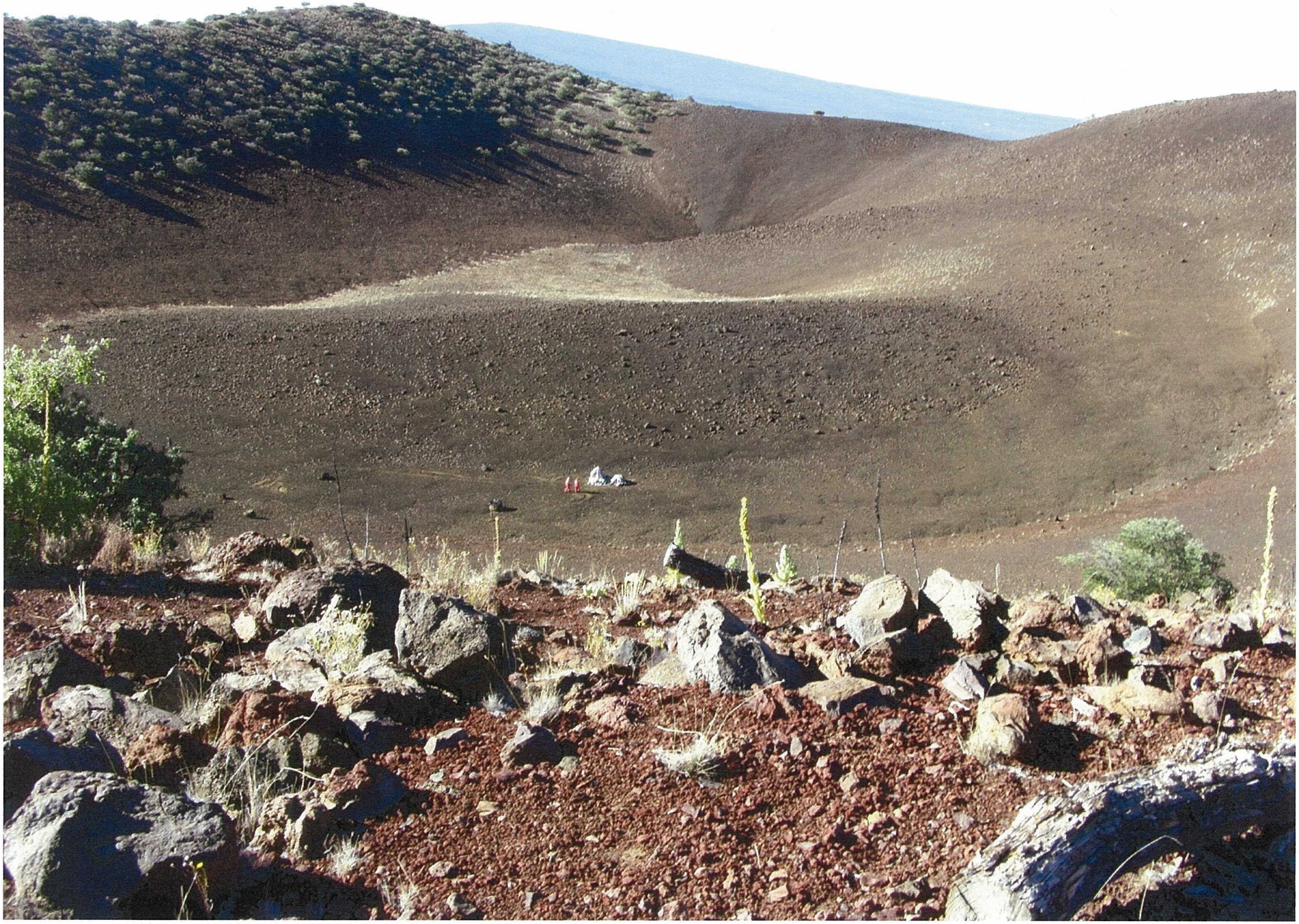
Scarab rover and GSE cart with generator

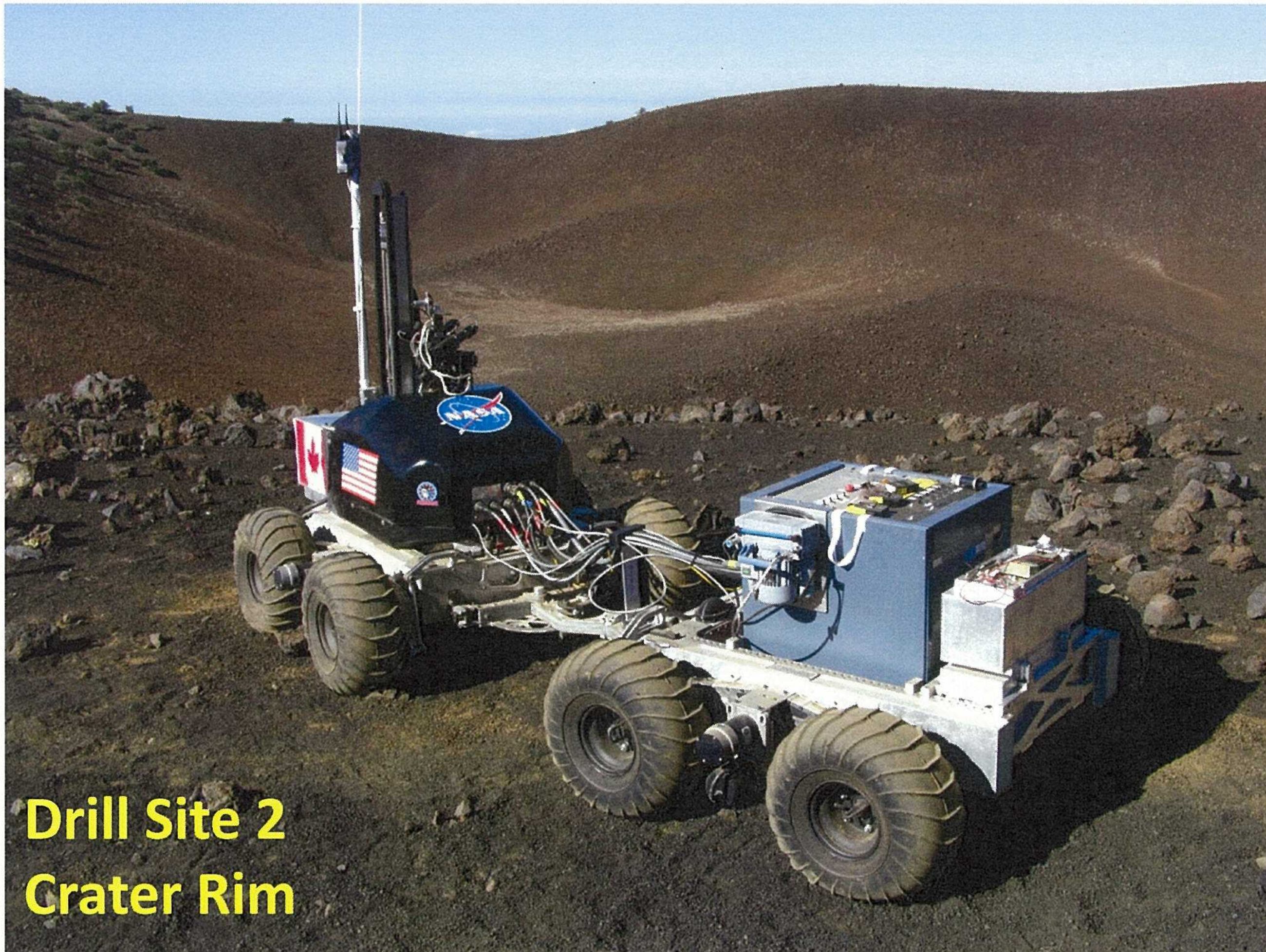
2010

Juno tandem rover

Notional RLEP-2 Mission Path



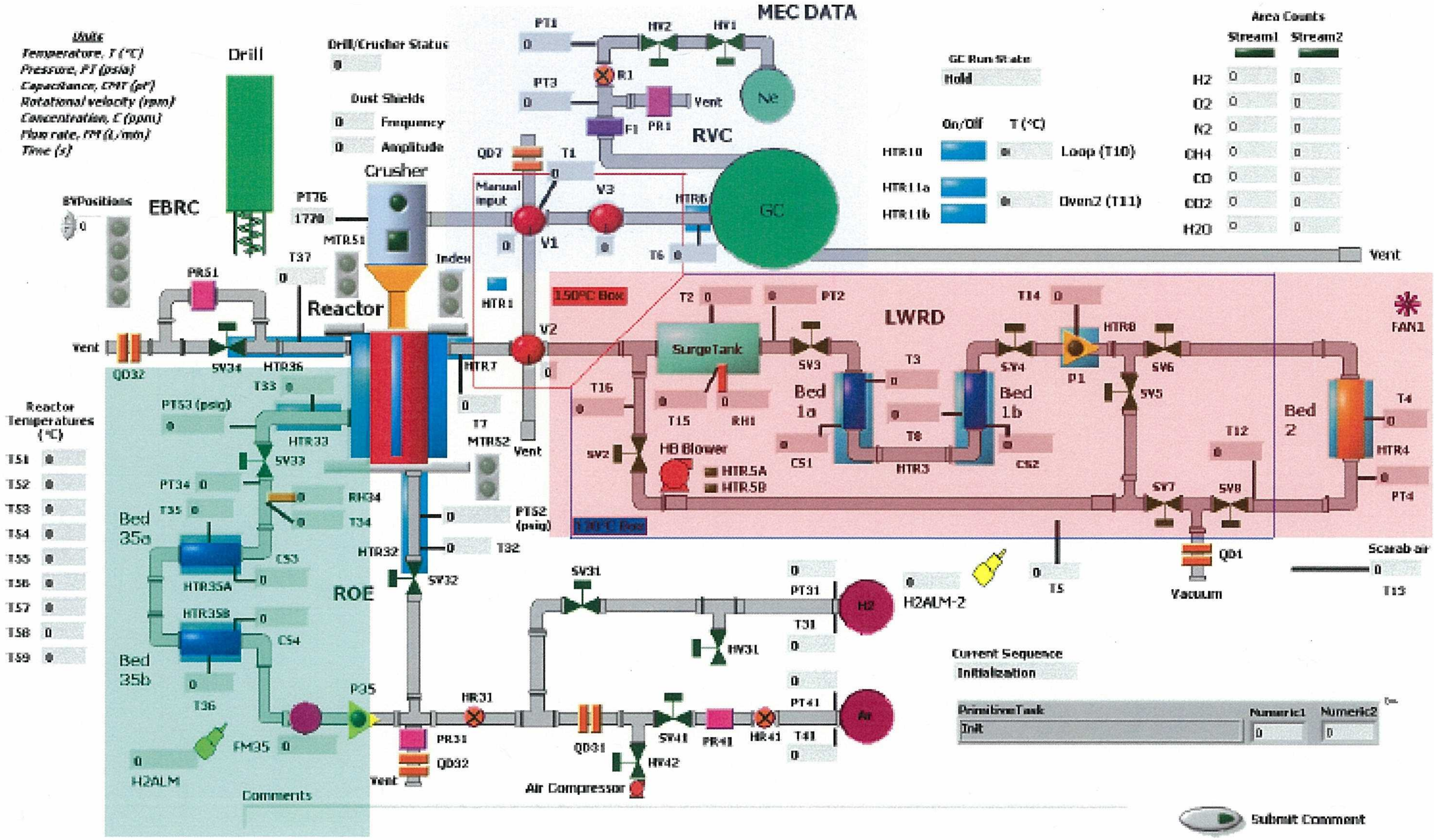


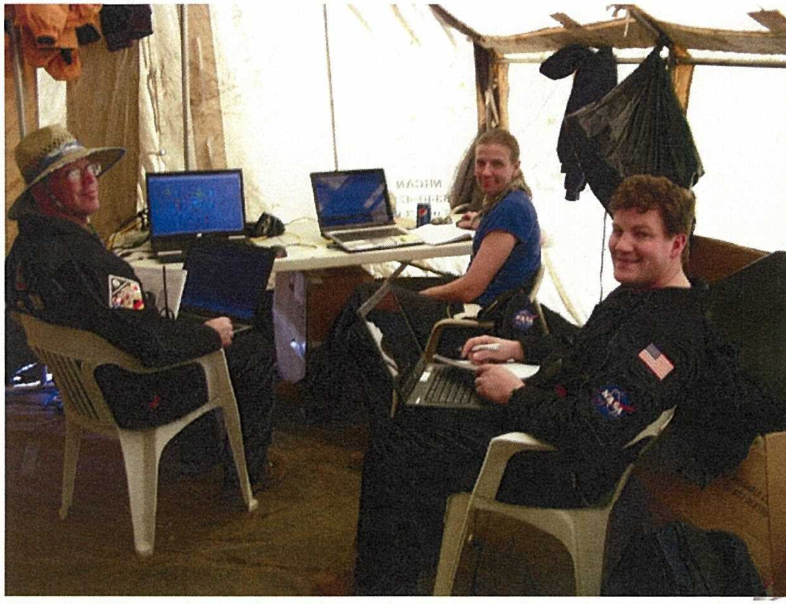

NASA
Drill Site 2
Crater Rim

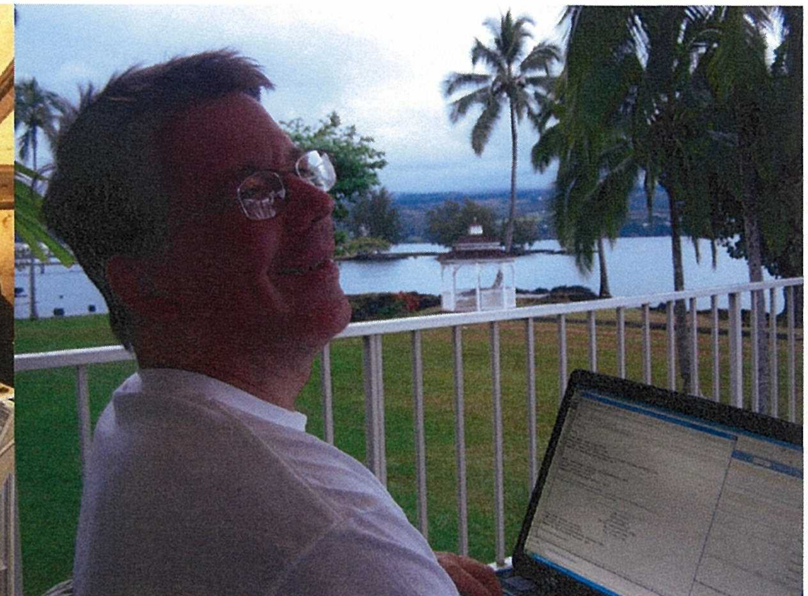

Drill Site 3
Crater Basin

MEC GUI

Master Events Controller Graphical User Interface



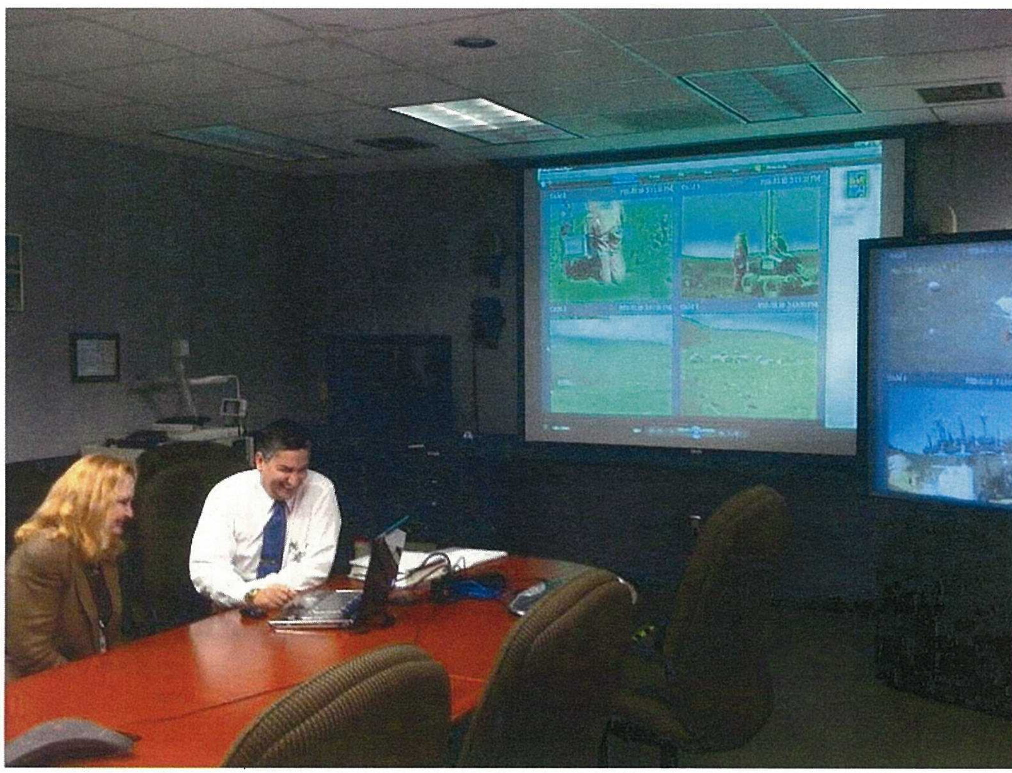




RESOLVE FIELD TEAM

Remote Command/Control from KSC

- LabView webserver published to internet
- Satellite connection → ExDOC (CSA) → KSC
- Streaming video for situational awareness



Current GC System

- Current weight
  - GC – 4.5 kg
  - Neon carrier gas - 2.2 kg
  - Valves - 1.8kg (2 Valco selector valves)
- Current time for analysis (3-4 minutes with valve purge)
- Analyze samples up to 150C
- Analytes tested for last field test
  - N_2, O_2/Ar, H_2, He, CH_4, CO, CO_2, water (H_2S and NH_3 tested for previous field test)
- Challenges
  - Water calibration at wide range
  - Limit of detection for water
  - Unknown components can be difficult to identify
  - GC required its own laptop computer to talk to Labview
  - Require 2-7psid to sample (prevented sampling from ST)

Operational Procedure

- Drill
- Crush
- Deliver tephra to reactor
- Add dosed tephra and metal hydride to reactor
- Purge reactor with Argon (inert atmosphere for hydrogen release)
- Seal reactor and heat to 150C, recording GC measurements every 3-4 minutes
- Cool reactor
- Dump analyzed tephra

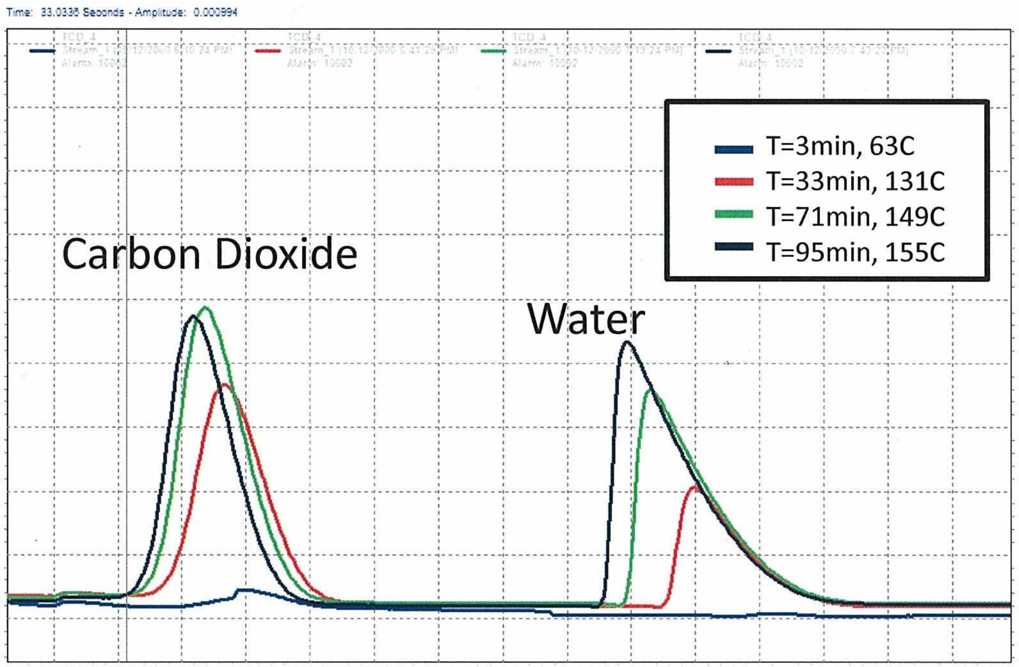
Water and Hydrogen Doping of Tephra

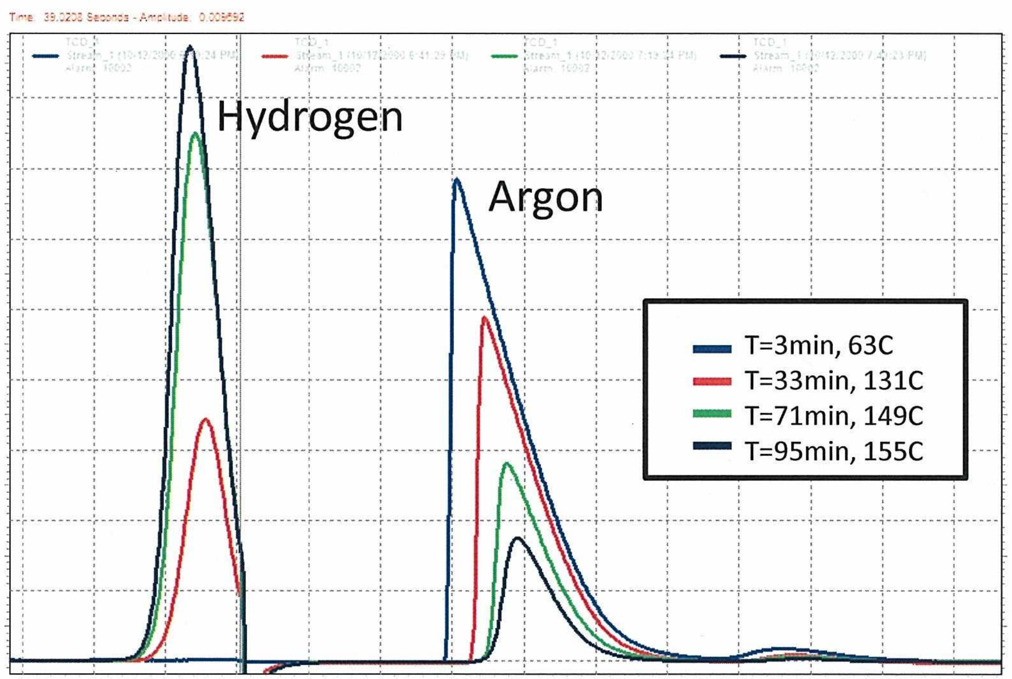
Water Doping

- Residual absorbed water on dried tephra (water contained ~1% by weight)
- Various amounts of liquid water was added to tephra
- Wet tephra was added to reactor after crushed sample was delivered

Hydrogen Doping

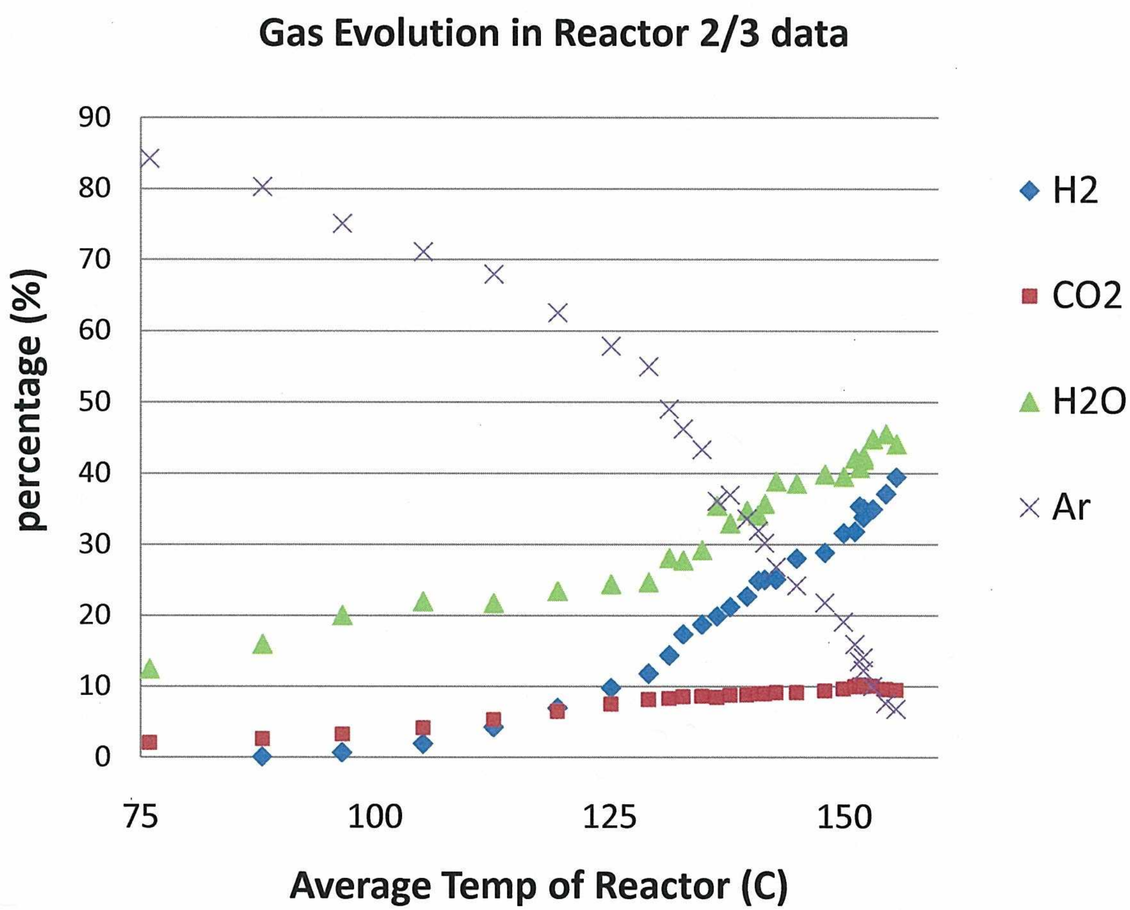
- Metal hydride (Hy-Stor 207) used as a hydrogen source
- Metal hydride made and passivated on site
- Metal hydride added to reactor after crushed sample was delivered


T=3min, 63C
T=33min, 131C
T=71min, 149C
T=95min, 155C
Carbon Dioxide
Water


Hydrogen
Argon
T=3min, 63C
T=33min, 131C
T=71min, 149C
T=95min, 155C

Gas evolution in Reactor

- Argon was used as purge gas
- Hydrogen, water, carbon dioxide were evolved during the run



	g tephra	g MH	mL water added	total g	% water
3-Feb	72.0	10.0	0.3	82.3	0.4
4-Feb	75.0	5.0	0.1	80.1	0.1
5-Feb		>12.6	ads only	73.5	
5-Feb	55.0	19.4	0.5	74.9	0.7
5-Jan	83.3	3.08	0.25	86.63	0.3
12-Jan A	80.23	4.08	0.2	84.51	0.2
12-Jan B total	80.28	3.15	0.5	83.93	0.6

Table 1 Sample composition of field samples (Feb) and lab samples (Jan) during integrated testing

Wt Percent H2, H2O and CO2 generated

	g H2	g H2O	g CO2	H2 wt %	H2O wt %	CO2 wt %
3-Feb	0.00369	0.03710	0.01959	0.00448	0.04508	0.02381
4-Feb	0.00005	0.02486	0.00392	0.00006	0.03104	0.00490
5-Feb	0.00235	0.02215	0.01258	0.00319	0.03014	0.01711
5-Feb	0.00380	0.01938	0.00825	0.00507	0.02587	0.01101
5-Jan	0.00024	0.02358	0.00870	0.00028	0.02722	0.01004
12-Jan A	0.01011	0.01261	0.00582	0.01197	0.01493	0.00689
12-Jan B 1st xfer	0.00766	0.05324	0.01378	0.00913	0.06343	0.01642
12-Jan B 2nd xfer	0.00544	0.04528	0.02769	0.00648	0.05396	0.03299
12-Jan B total	0.00842	0.06599	0.03305			

Table 2 GC analysis of evolved gases in the reactor during heating of reactor to 150C

		g H_2	g H_2O	g CO_2	H_2 wt %	H_2O wt %	CO_2 wt %	total g	g tephra	g MH	mL H_2O
Field	3-Feb	0.00369	0.03710	0.01959	0.0045	0.0451	0.0238	82.3	72.0	10.0	0.3
Test	4-Feb	0.00005	0.02486	0.00392	0.0001	0.0310	0.0049	80.1	75.0	5.0	0.1
Data	5-Feb	0.00235	0.02215	0.01258	0.0032	0.0301	0.0171	73.5		>12.6	ads only
	5-Feb	0.00380	0.01938	0.00825	0.0051	0.0259	0.0110	74.9	55.0	19.4	0.5
	5-Jan	0.00024	0.02358	0.00870	0.0003	0.0272	0.0100	86.63	83.3	3.08	0.25
Lab	12-Jan A	0.01011	0.01261	0.00582	0.0120	0.0149	0.0069	84.51	80.23	4.08	0.2
Data	12-Jan B(1)	0.00766	0.05324	0.01378	0.0091	0.0634	0.0164	83.93	80.28	3.15	0.5
	12-Jan B(2)	0.00544	0.04528	0.02769	0.0065	0.0540	0.0330				
	12-Jan B total	0.00842	0.06599	0.03305	0.0065	0.0540	0.0330				

Hydrogen, water, carbon dioxide and argon were measured in the reactor. Argon was used as the purge gas prior to heating the sample. Data is from the last GC sample prior to transfer with the amount of each species calculated based on the GC data, temperature, volume, and temperature of the reactor.

			GC water in reactor (g)	GC data xfer water (g) using H2/H2O ratio	Capacitance Water (g)	% difference Cap vs GC calc
Field	Feb 3 2010		0.0371	0.0616	0.0186	-69.9
Test	Feb 4 2010		0.0249	0.0487	0.0100	-79.5
Data	Feb 5 2010	run1	0.0222	0.0229	0.0513	124.4
	Feb 5 2010	run2	0.0194	0.0205	0.0006	-97.1
Lab	Jan 5 2010		0.0236	0.0431	-0.0075	-117.4
Data	Jan 12 2010	run 1	0.0126	0.0120	0.0082	-31.6
	Jan 12 2010	run 2	0.0660	0.1434	0.1791	24.9

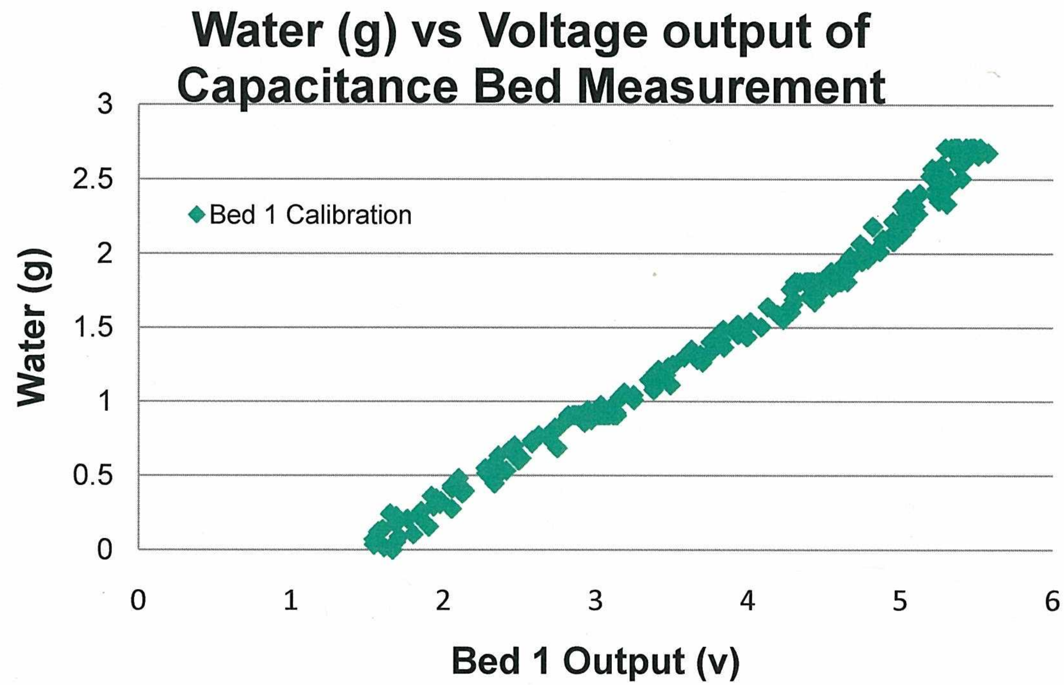
Water and hydrogen were generated during the transfer of the gas to the surge tank, quantifying excess will require sampling the surge tank after transfer

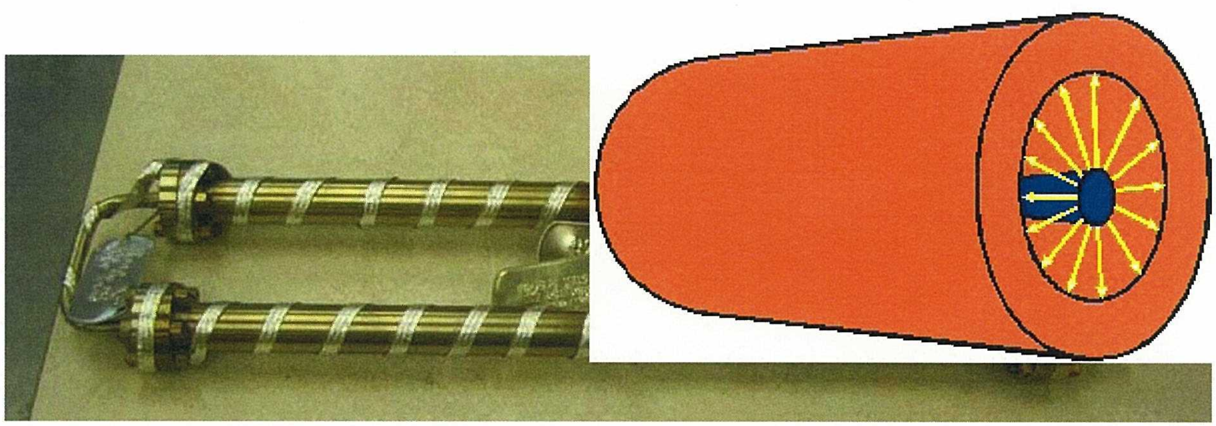
The capacitance beds used for this field test were larger than the previous system, the amount of water transferred was below the detection limit of the system (shown by standard deviations). Repeated heating and cooling of the beds also caused water migration and affected results

		Water (g)	Standard Deviation
Feb 3 2010		0.01855	0.0305
Feb 4 2010		0.01	0.0251
Feb 5 2010	run1	0.0513	0.0483
Feb 5 2010	run2	0.0006	0.0327
Jan 5 2010		-0.0075	0.1257
Jan 12 2010	run 1	0.00819	0.0896
Jan 12 2010	run 2	0.1791	0.1072

Capacitance Water Capture Beds

- Bed capacity was designed for hydrogen reduction
- Water transferred during RVC ops were much too low to quantitate using these capacitance beds
- Change in size or geometry can increase sensitivity of this technique





Future Direction

- GC-MS
  - Additional capability to identify unknowns
  - Increased accuracy of MS compared to standalone analysis
  - Ability to detect isotopes of interest
- Additional Instrumentation
  - Neutron spectrometer
- Fluid system
  - Manifold design with smaller valves
  - Complete integration of recirculation loops for volatile analysis and oxygen production
- Electronics
  - Miniturization and move towards space rated platform