RESOLVE 2010 Field Test

ernational Lunar Surface Operations • In-Situ Resource Utilization Analog Test

Big Island, Mauna Kea
2010

REGOLITH & ENVIRONMENT SCIENCE & OXYGEN & LUNAR VOLATILE EXTRACTION

RESOLVE

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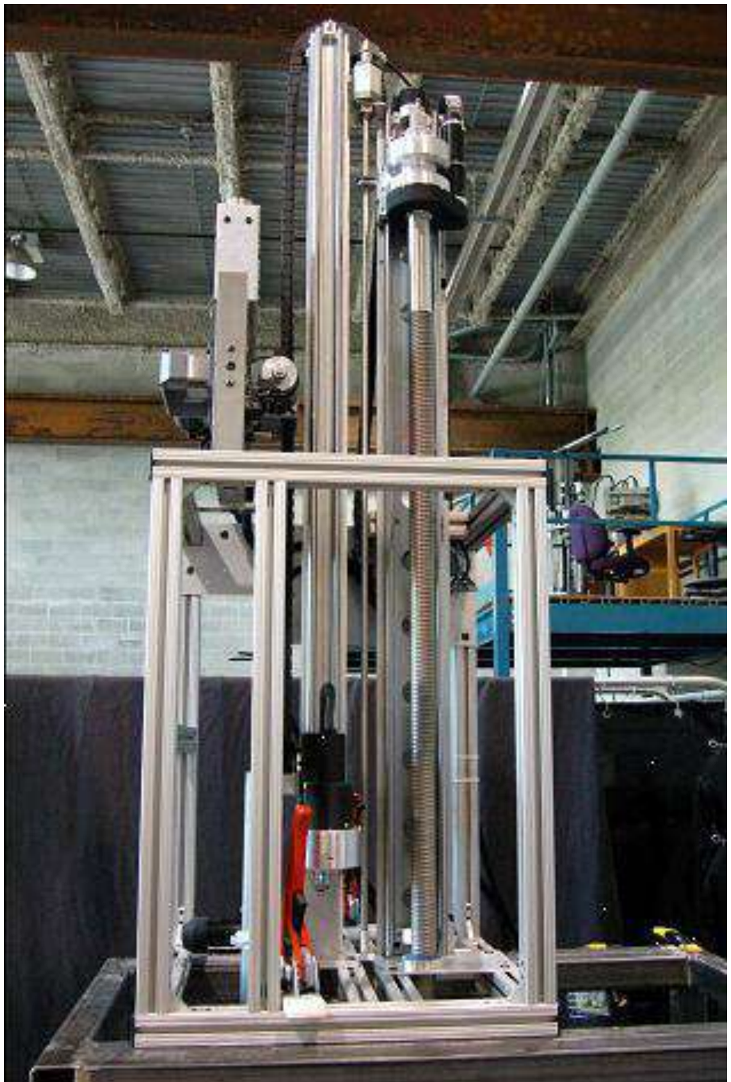
- EBRC – drill and crusher (CSA/Norcat)
- RVC – reactor and gas analysis (GRC and KSC)
- LWRD – fluid system, water and hydrogen capture (KSC)
- ROE – oxygen production (hydrogen reduction), not performed in 2010 Field Test (JSC)
- Mobility
  - Carnegie Mellon University (2008)
  - SRCan (2010)

EBRC

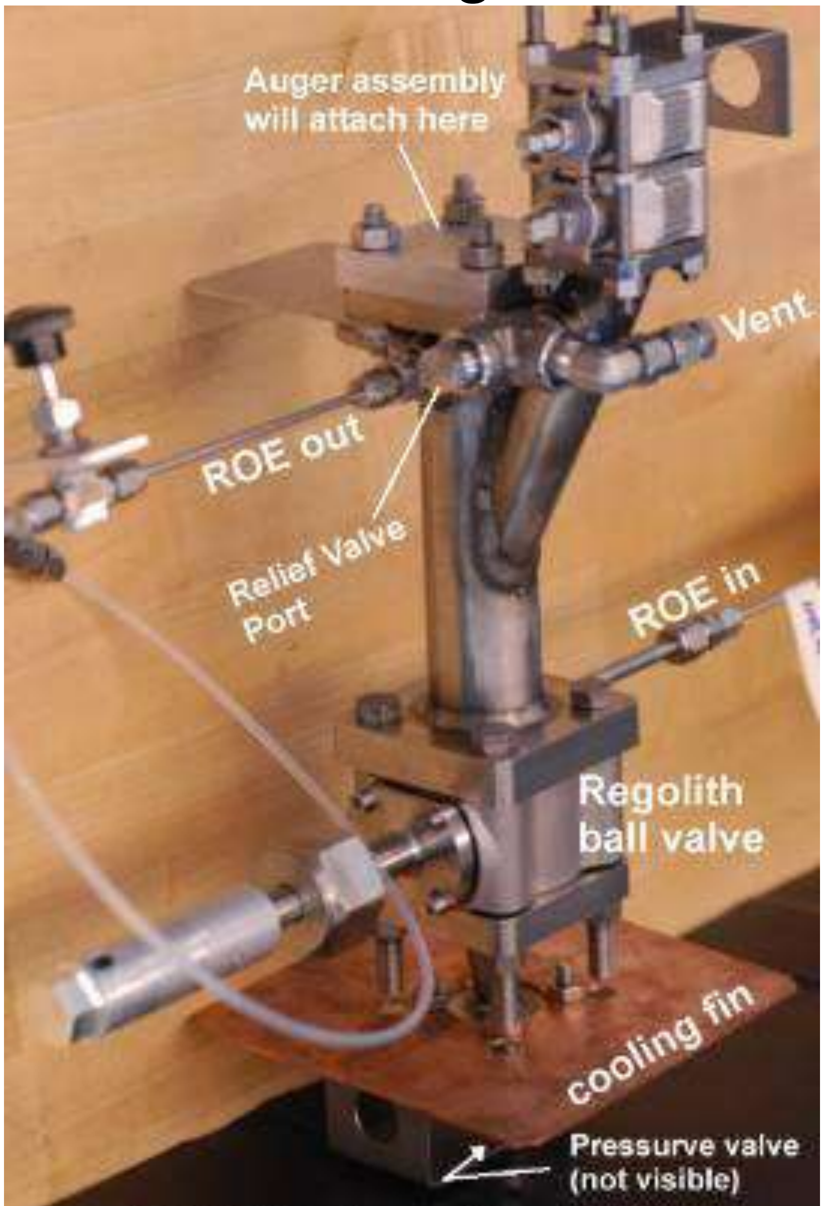
Excavation and Bulk Regolith Characterization

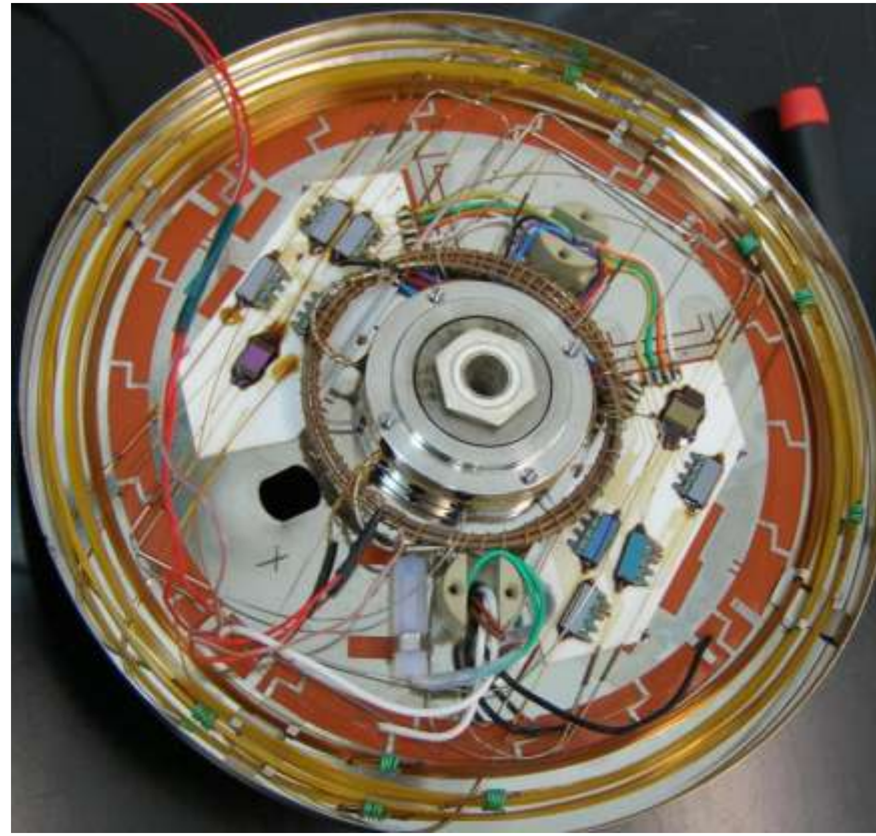


- Drill, Crusher, Metering Sample Delivery
  - Capable of 1 meter depth
  - Captures soil core and inserts sample into crusher to crush soil to <1 mm size particles
  - Crusher also weighs sample and delivers 20 grams at a time into the reactor

RVC

Regolith Volatiles Characterization





Reactor – heated 80 gram sample
auger/core heater design
performed both RVC and ROE

Gas Chromatograph – analyzed volatiles
MEMS technology

GRC and KSC

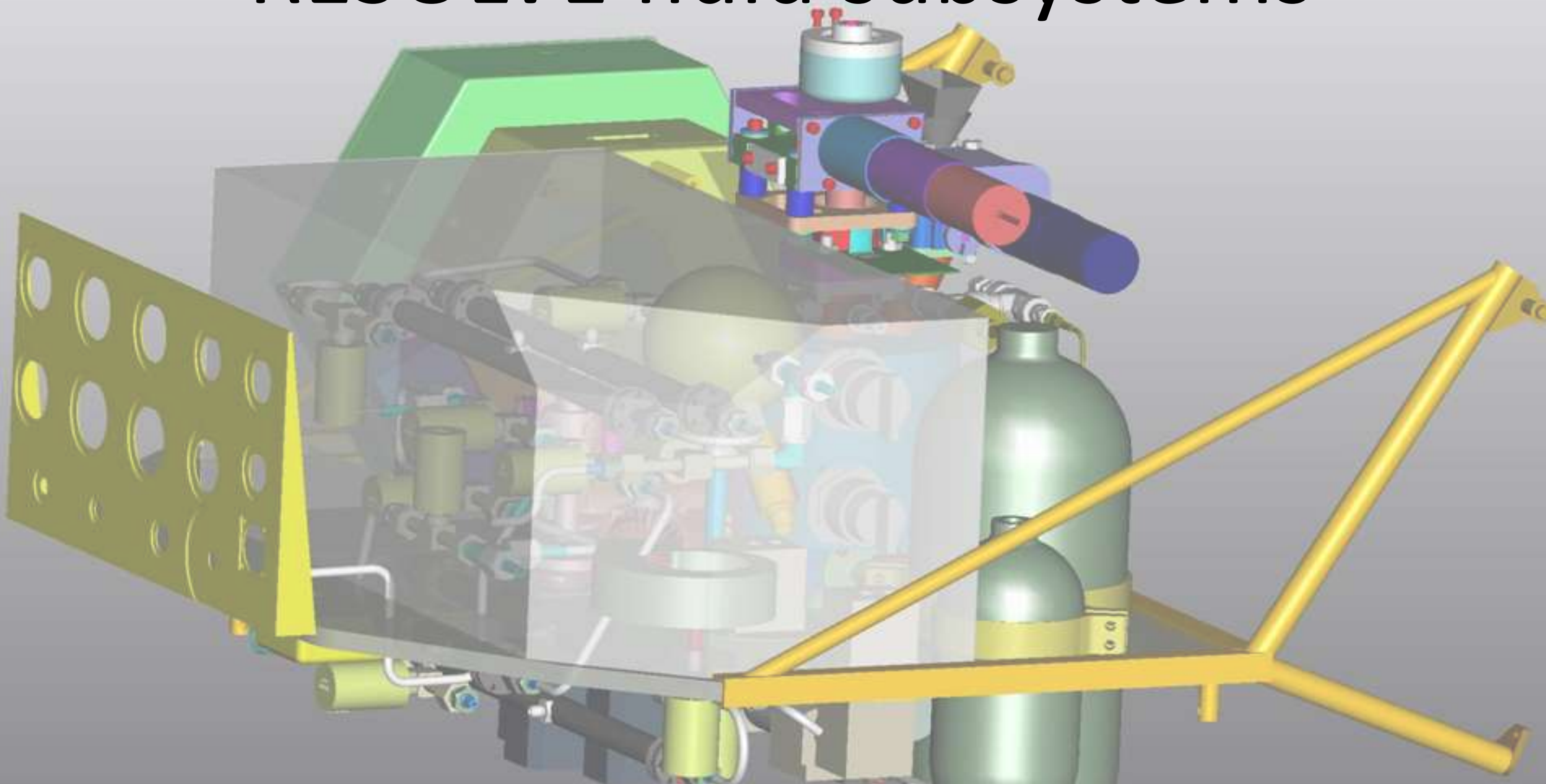
LWRD

Lunar Water Resources Demonstration

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

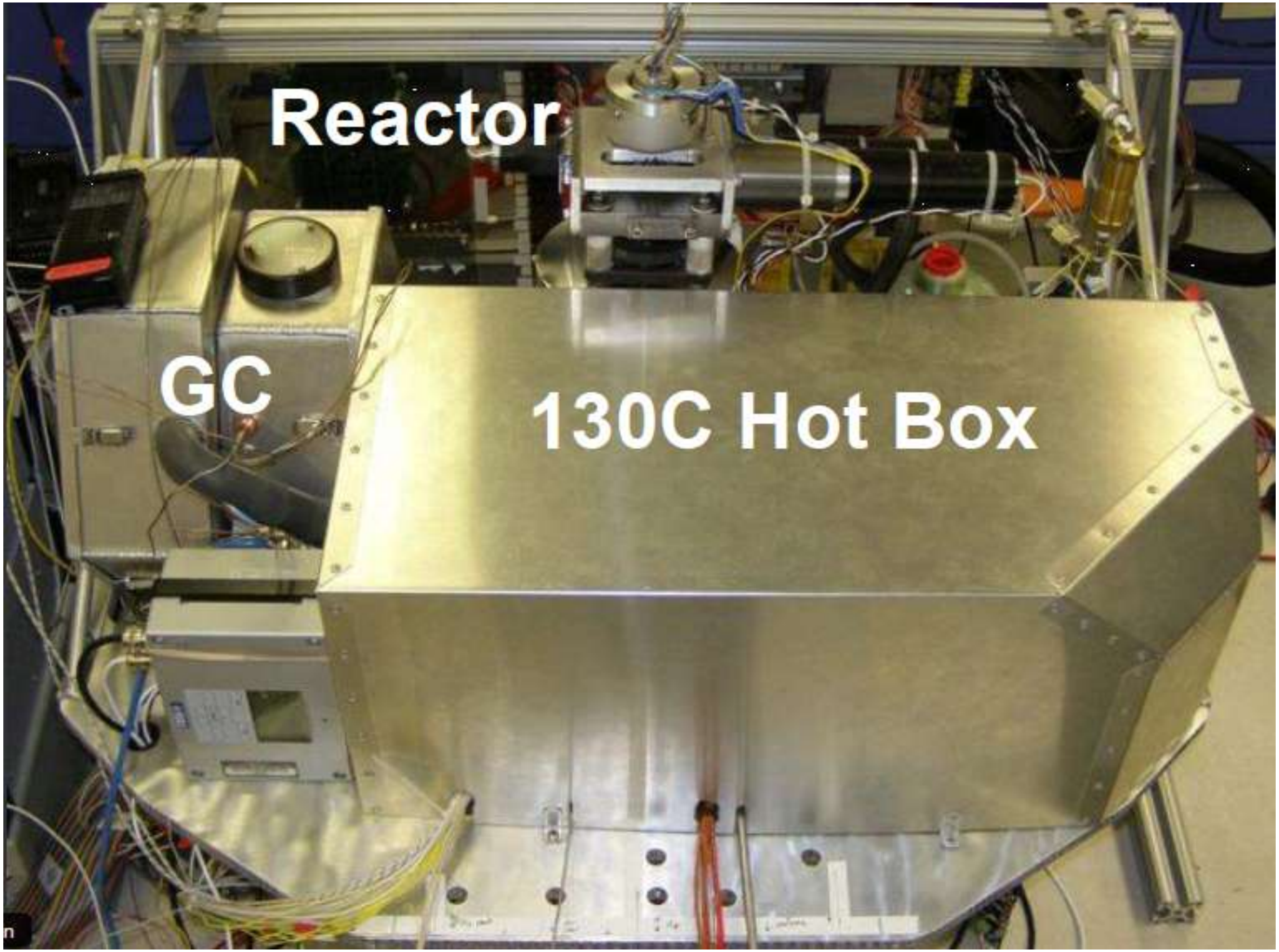
KSC

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**

LWRD Hardware Assembly



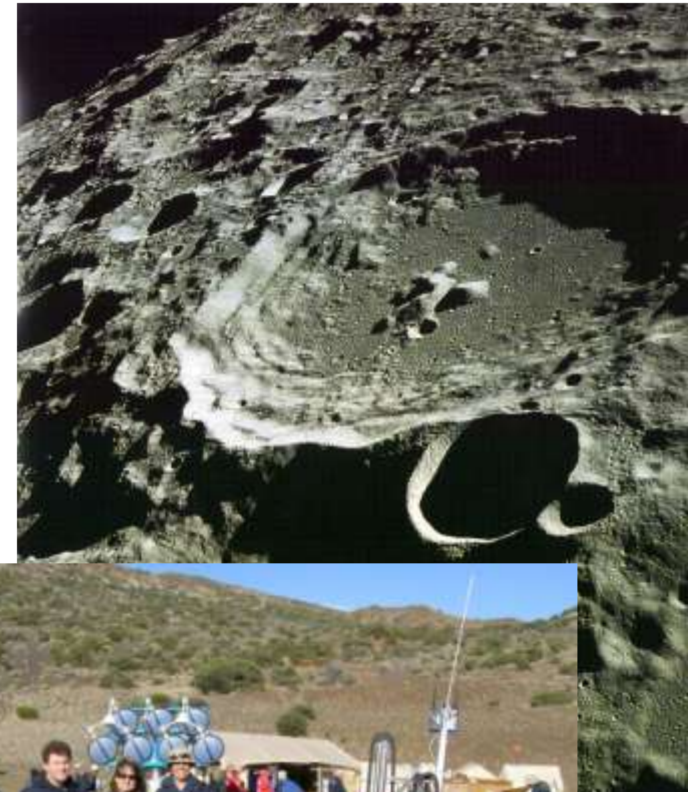
2008 Field Test

- 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 – NSPIRES Grant

- Scientific goal
  – demonstrate evolution of low levels of ***hydrogen*** and water as a function of temperature

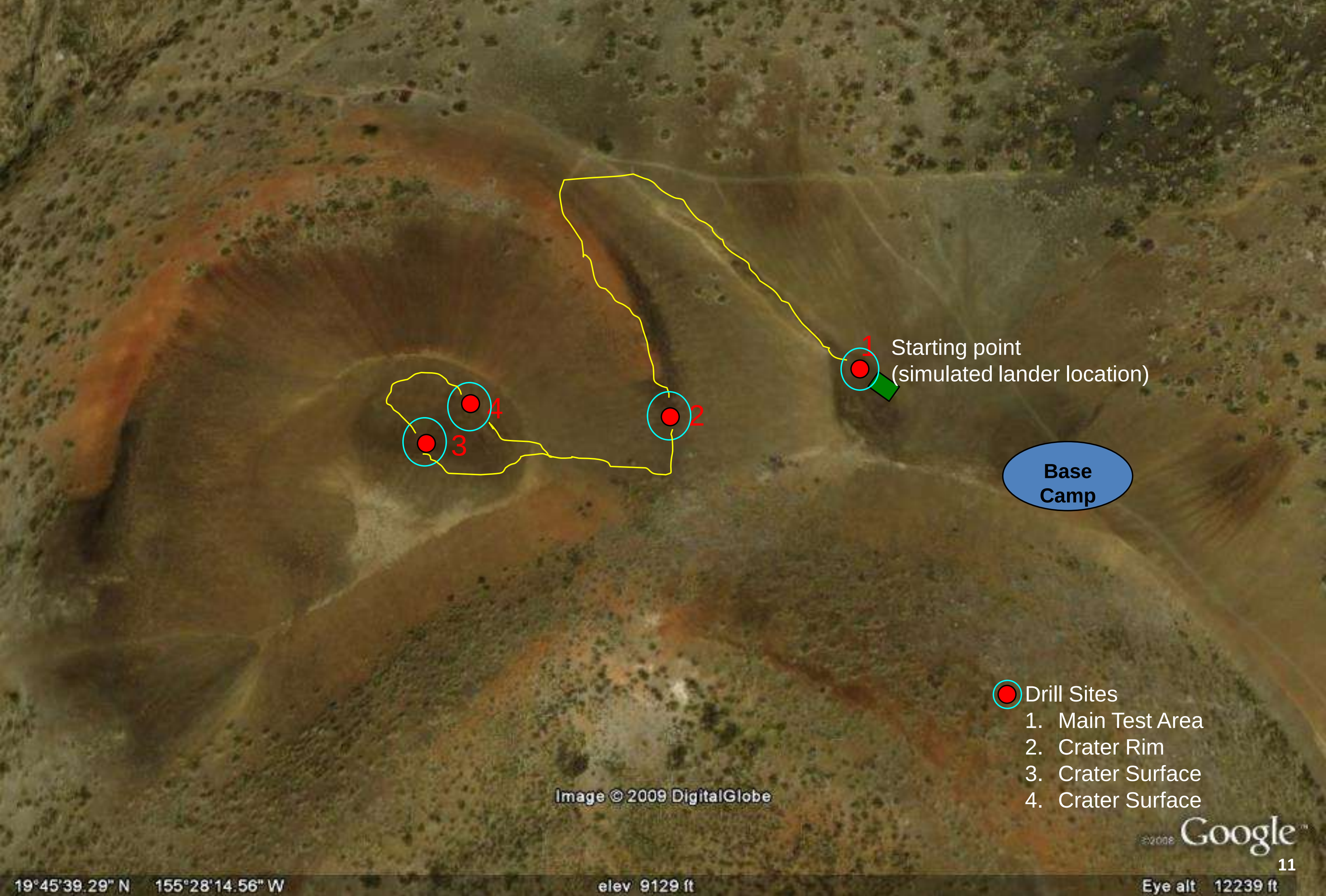
- Engineering goals
  – Upgrade control hardware
  – Integration onto new rover (CSA-SRCan)
  – Miniaturization of electronics rack
  – Operation from battery packs (elimination of generator)
  – Remote command/control
  – Operations while roving

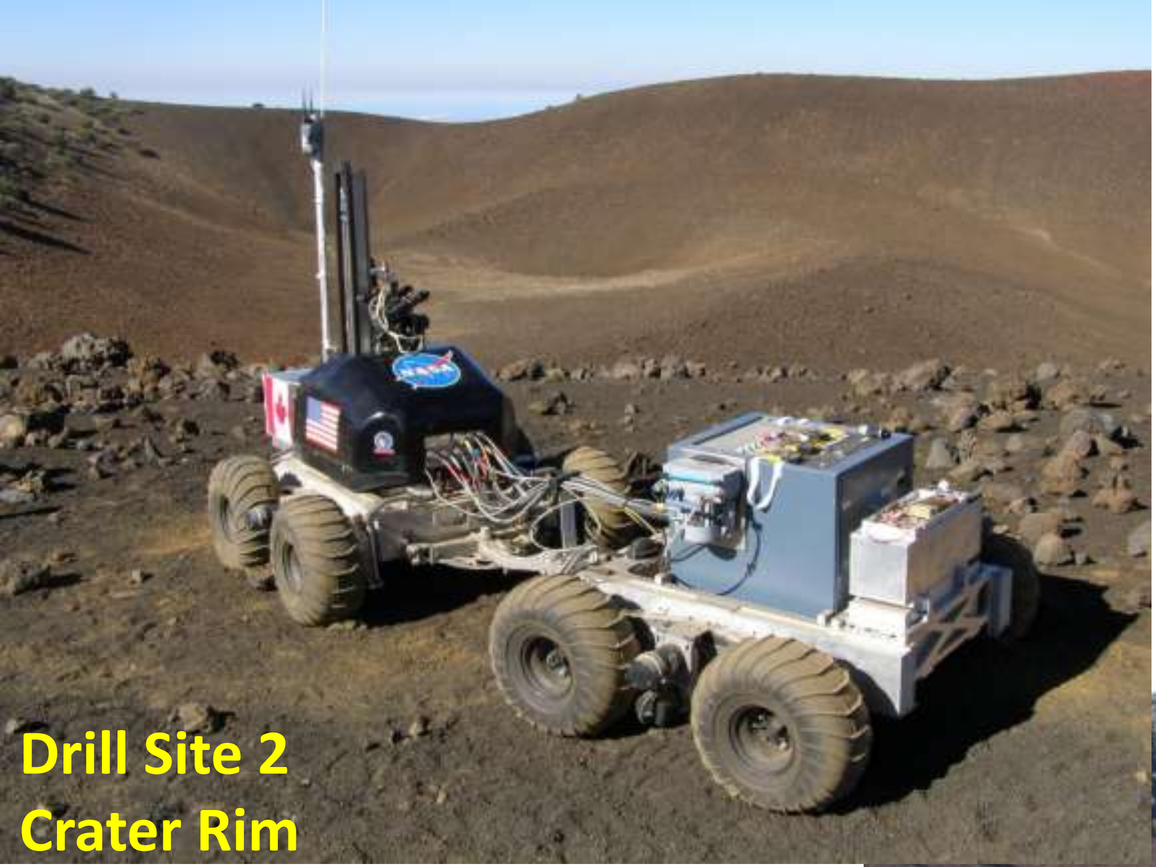


2008
Scarab rover and GSE cart with generator

2010
Juno tandem rover

Notional RLEP-2 Mission Path




Drill Site 2
Crater Rim


Drill Site 3
Crater Basin

RESOLVE FIELD TEAM

Jackie Quinn, Tom Moss,
Kyle Weis, Janine Captain

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

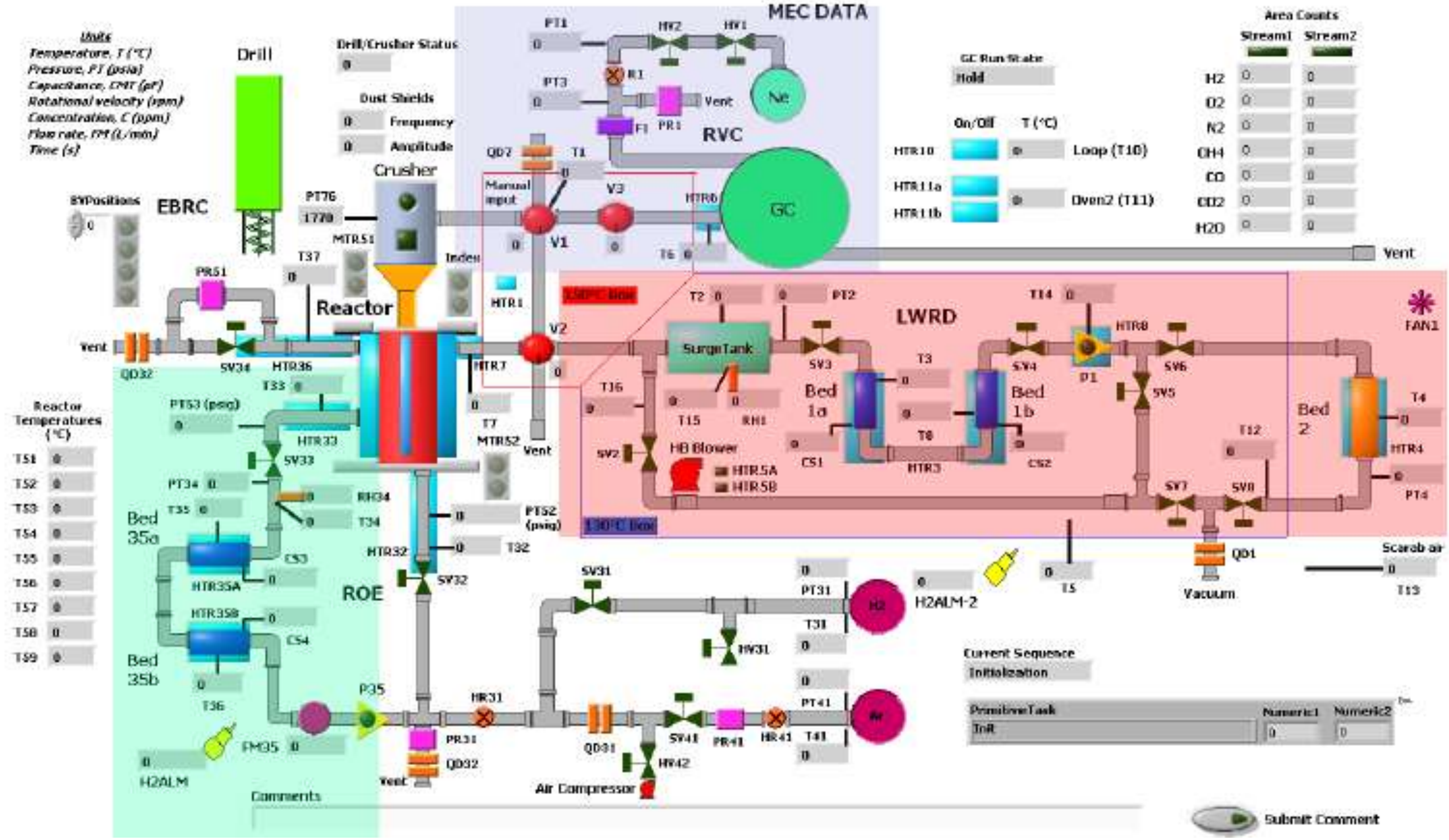
Operational Procedure

A Day in the Life of RESOLVE

- 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
- Transfer to surge tank, capture water and evacuate inert species
- Dump analyzed tephra
- Cool reactor

MEC GUI

Master Events Controller Graphical User Interface

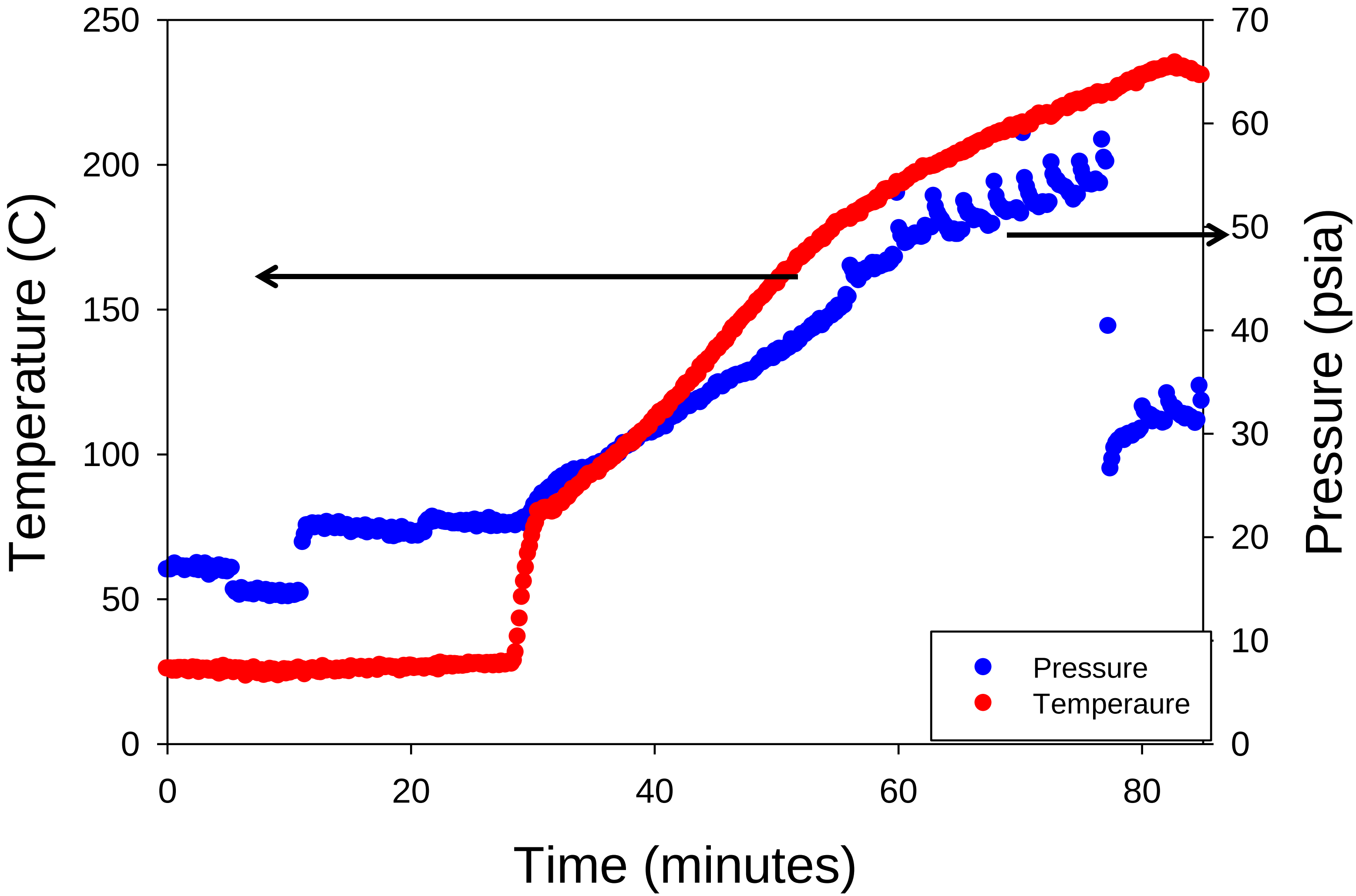


Remote Command/Control from KSC

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

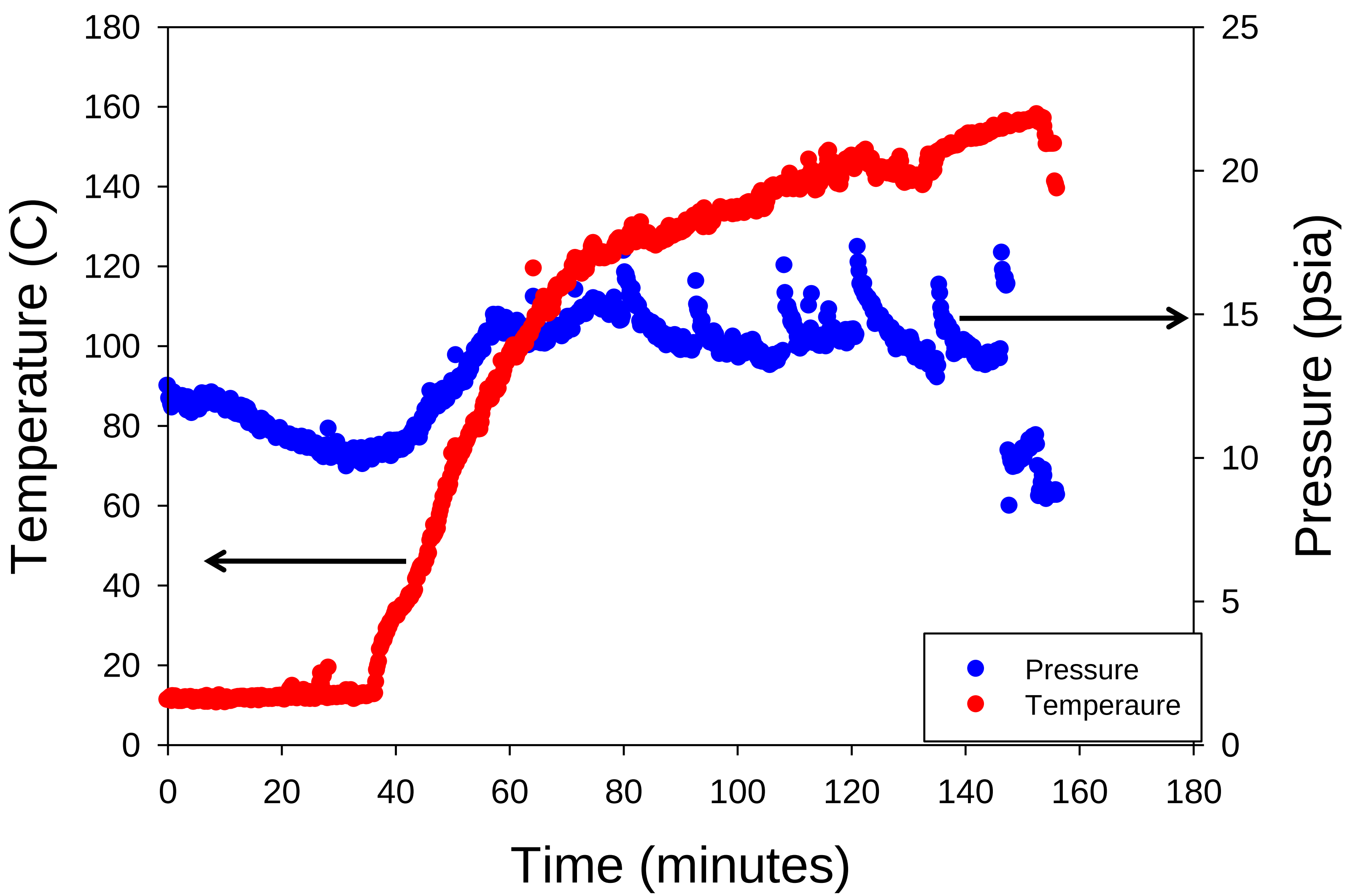
Laboratory Run 12/30/10

Temperaure and Pressure during RVC analysis

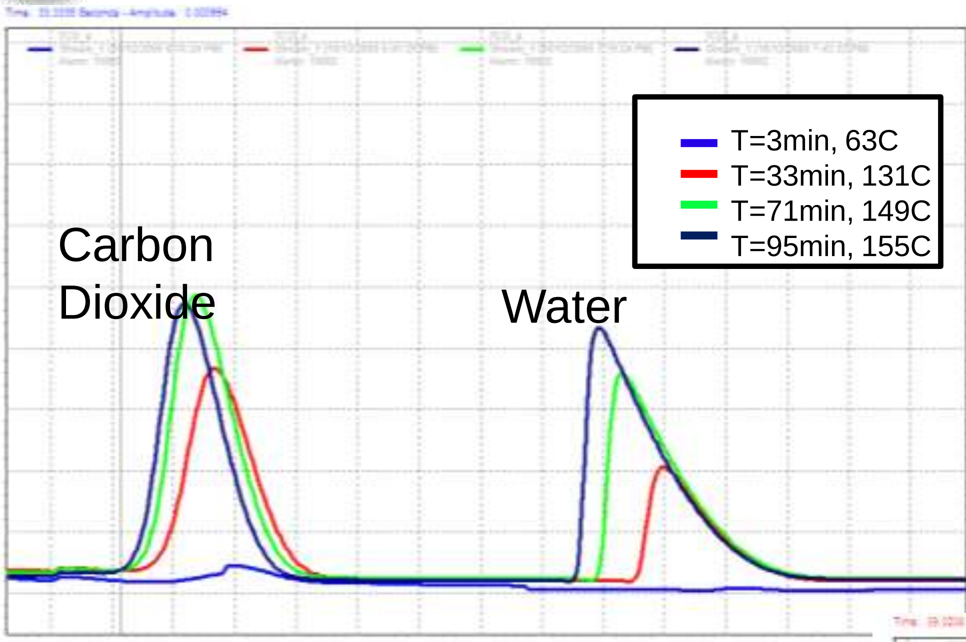


Field Test Run 2/3/10

Temperaure and Pressure during RVC analysis



Example spectra from GC analysis of volatiles

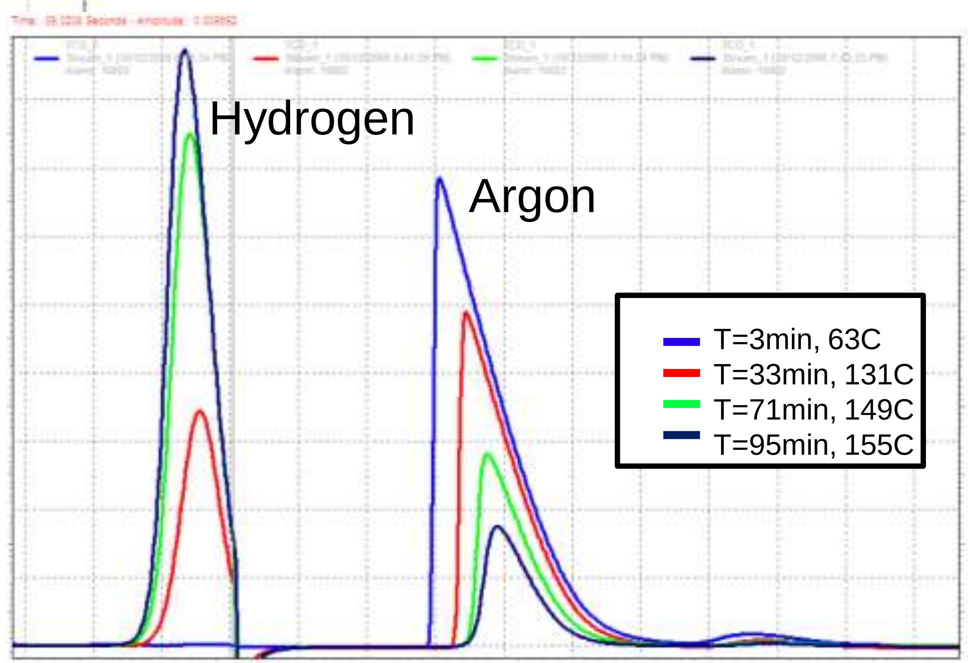


Carbon dioxide, water and hydrogen increased over time

Argon decreased as other volatiles evolved

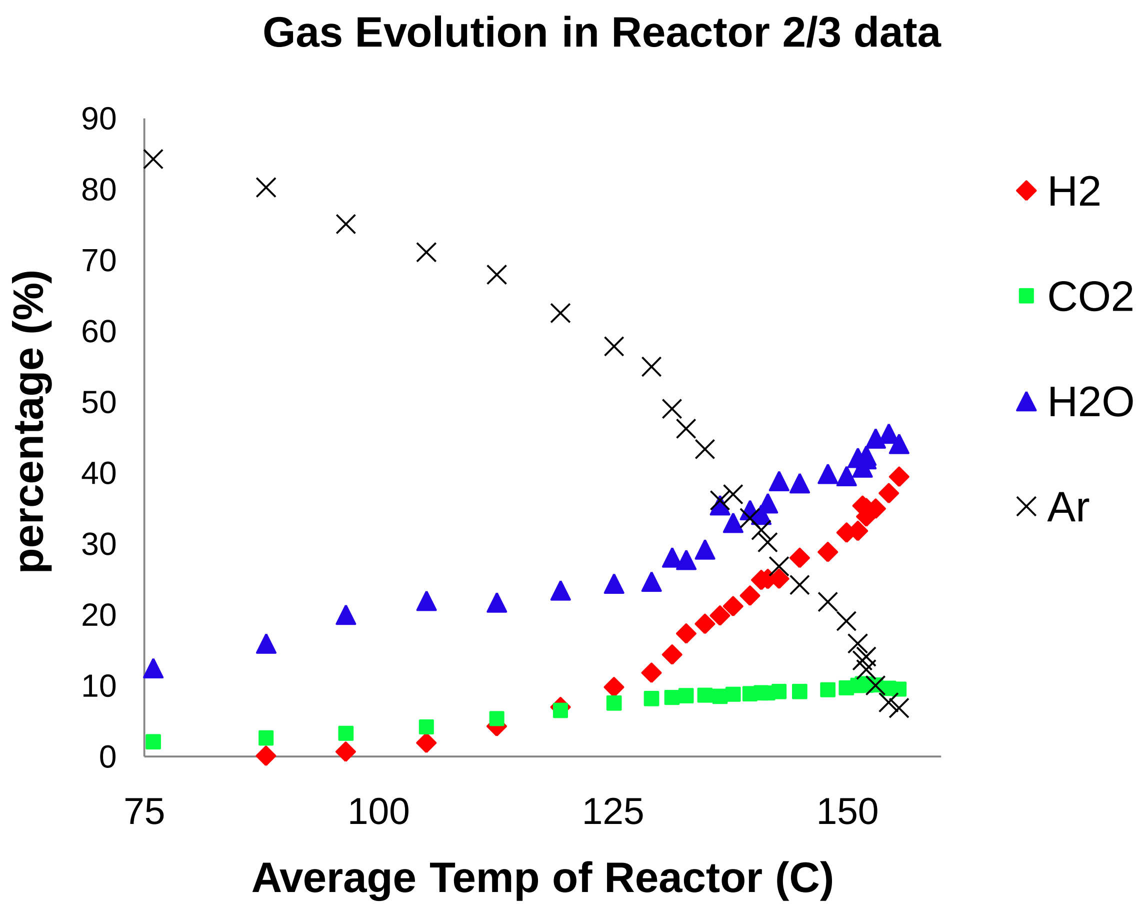
GC analysis provides the composition (ppm or %) of volatiles in the reactor

Pressure, temperature, and volume of the reactor are used to determine the quantity of gas evolved from the sample



Gas evolution in Reactor

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



Sample Composition

- Sample compositions varied to demonstrate unique hydrogen/water combinations

		g tephra	g MH	mL water added	total g sample in reactor	% water added
Field Test	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
Lab Test	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

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

H_2, H_2O and CO_2

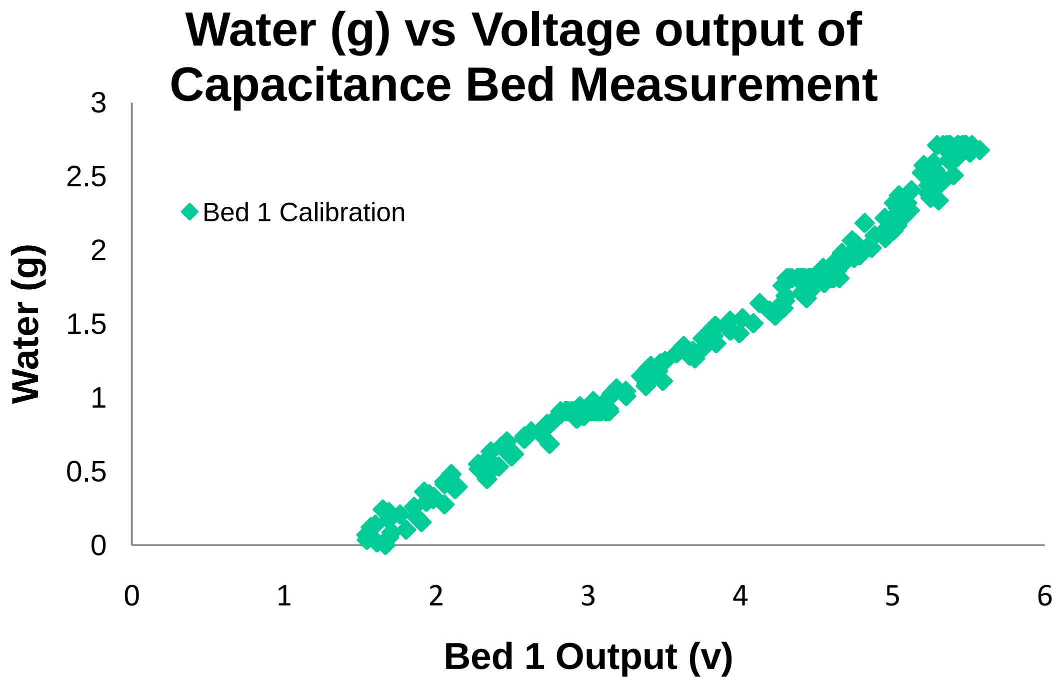
- Grams and weight percent of hydrogen, water and carbon dioxide evolved in reactor

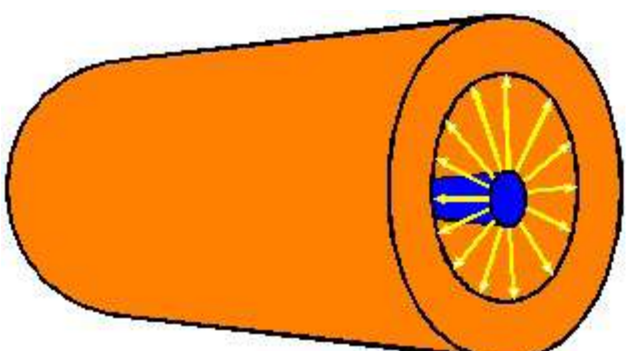
		g H2	g H2O	g CO2	H2 wt %	H2O wt %	CO2 wt %
Field Test	3-Feb	0.0037	0.0371	0.0196	0.0045	0.0451	0.0238
	4-Feb	0.0001	0.0249	0.0039	0.0001	0.0310	0.0049
	5-Feb	0.0023	0.0222	0.0126	0.0032	0.0301	0.0171
	5-Feb	0.0038	0.0194	0.0082	0.0051	0.0259	0.0110
	5-Jan	0.0002	0.0236	0.0087	0.0003	0.0272	0.0100
Lab Test	12-Jan A	0.0101	0.0126	0.0058	0.0120	0.0149	0.0069
	12-Jan B 1st xfer	0.0077	0.0532	0.0138	0.0091	0.0634	0.0164
	12-Jan B 2nd xfer	0.0054	0.0453	0.0277	0.0065	0.0540	0.0330
	12-Jan B total	0.0084	0.0660	0.0330			

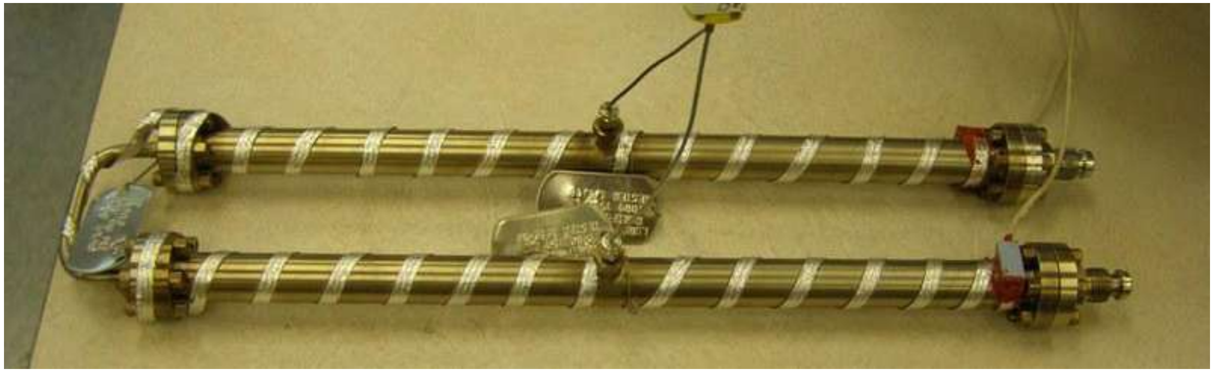
GC analysis of evolved gases in the reactor during heating of reactor to 150C

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







GC comparison to Capacitance Sensor

			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, accurately quantifying excess will require sampling the surge tank after transfer

- The capacitance beds used for this field test were designed for the ROE system
- The amount of water transferred was below the detection limit of the system
- 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

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
  – Miniaturization and move towards space rated platform