Lunar Water Resource Demonstration (LWRD) Test Results

ex luna, aqua

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July 30-August 2, 2009

Coauthors

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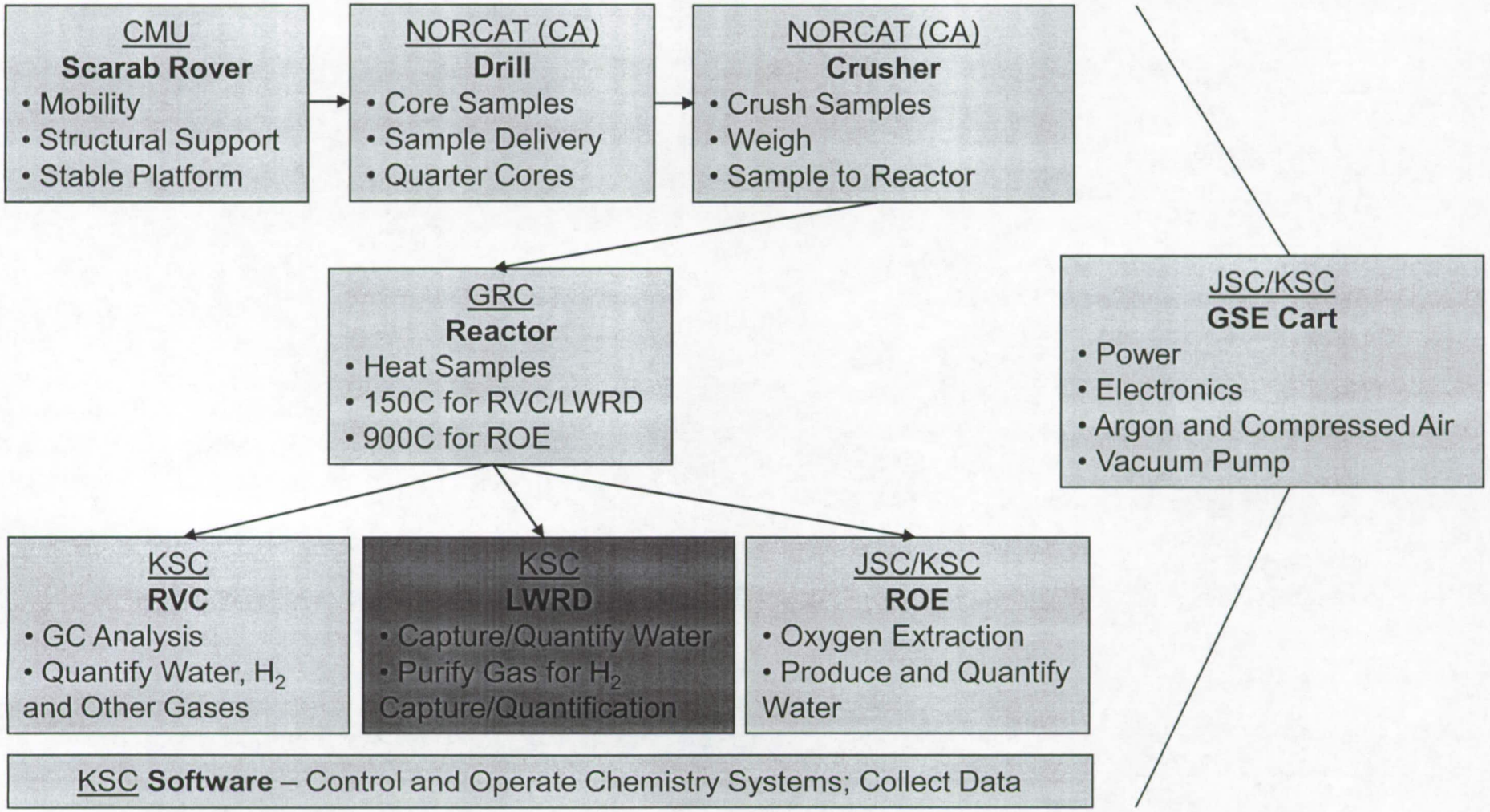
Outline

- Background
- RESOLVE Project and Field Demonstration
- LWRD Design Review
  - Fluid systems design
  - Water Bed design
  - Other component design
  - ProE 3-D model
  - Hydrogen bed calculations
  - Actual components
- Testing Plan
- Lab and Field Demonstration Results
- Hydrogen Capture/Quantification Test Results
- Summary

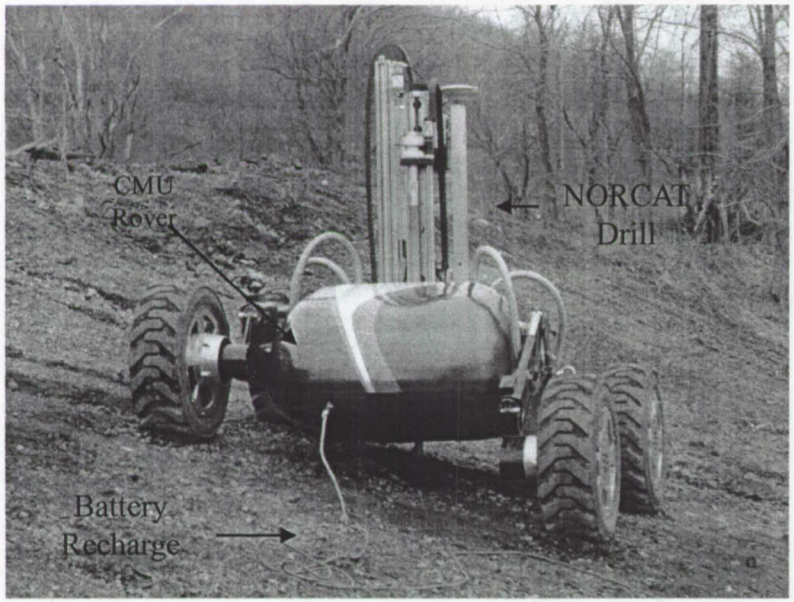
Background

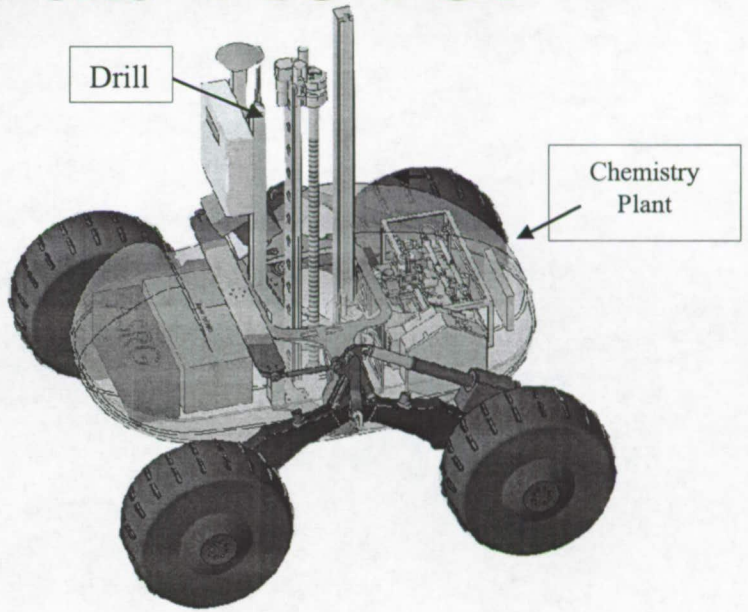
- LWRD is part of RESOLVE (Regolith and Environment Science & Oxygen and Lunar Volatile Extraction)
- RESOLVE is an ISRU ground demonstration:
  - A robotic rover to explore a permanently shadowed crater at the south or north pole of the Moon
  - Drill core samples down to 1 meter
  - Heat the core samples to 150C
  - Analyze gases and capture water and/or hydrogen evolved
  - Use hydrogen reduction to extract oxygen from regolith
- The field demo took place on Mauna Kea as an analog site for the Moon
- JSC, GRC, KSC, NORCAT, CSA and CMU involved
- The same technology is applicable to Mars

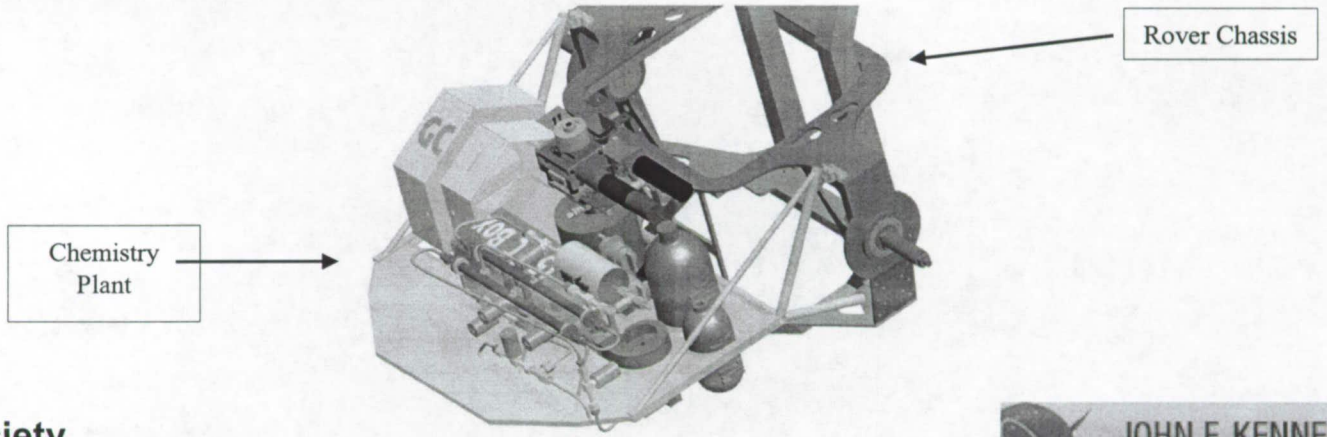
RESOLVE Block Diagram



RESOLVE/Scarab Rover







12th Mars Society Convention

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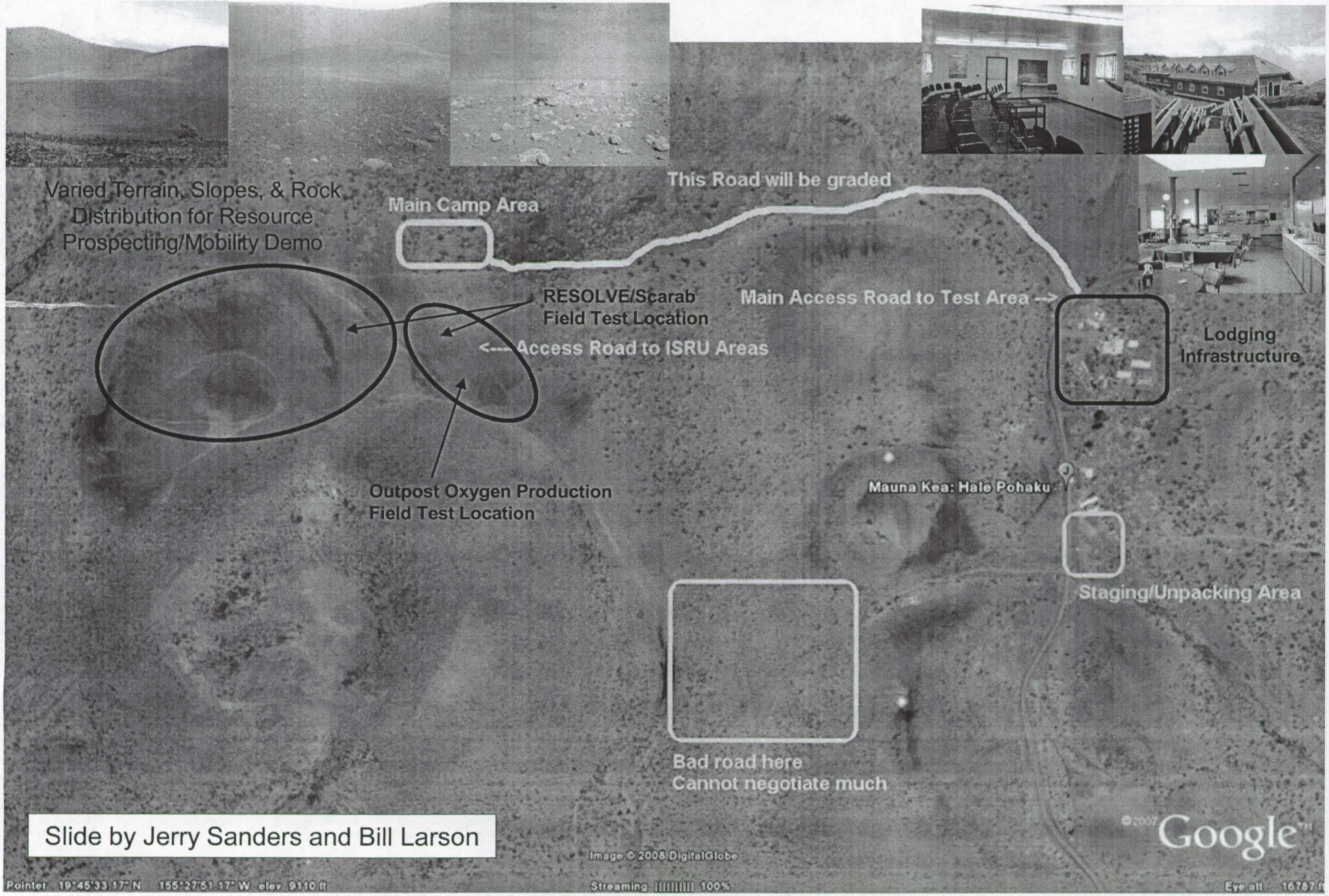
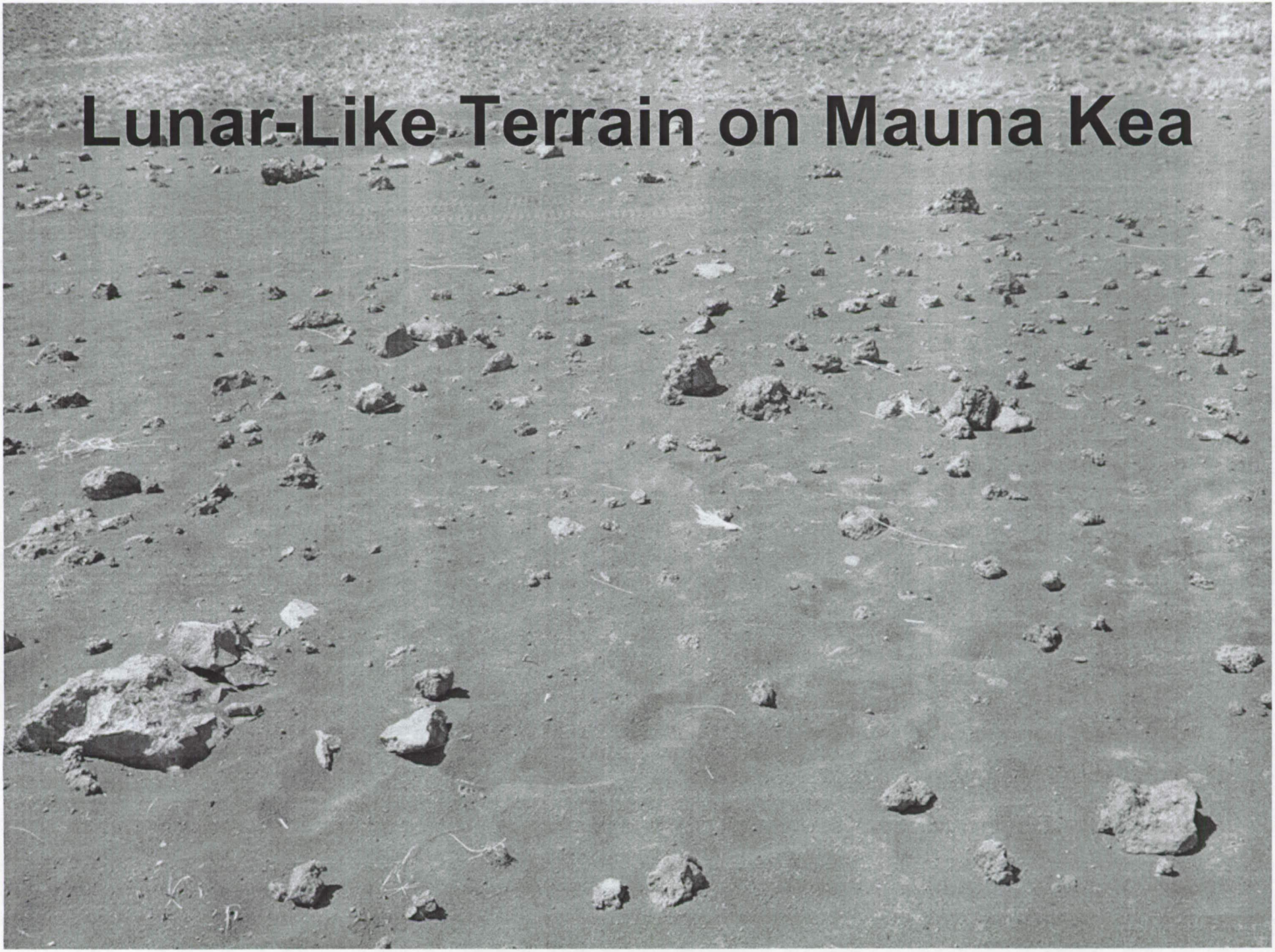
Nov. 2008 ISRU Field Test Infrastructure and Test Layout




Lunar-Like Terrain on Mauna Kea

Purpose of LWRD

- Capture up to 6 g of water per regolith/soil core sample and quantify up to 20 g of water (backup to GC measurements)
- Capture and quantify up to 0.10 g of hydrogen from same core sample (backup to GC measurements)
- Quantify within 20% accuracy

Design Review

- Prevent water condensation
  - Operate in 150C/130C Hot Boxes
  - Heated head recirculation pump
  - Heat trace Reactor gas lines
- Minimize number of transfers
  - 500 cc Surge Tank
- Absorb water at 130C
  - "Moisture Gone" zeolite absorbent
- Have sufficient water absorption capacity
- Quantify water
  - Desorption of MG is too slow; use RH probe, P, V, and T

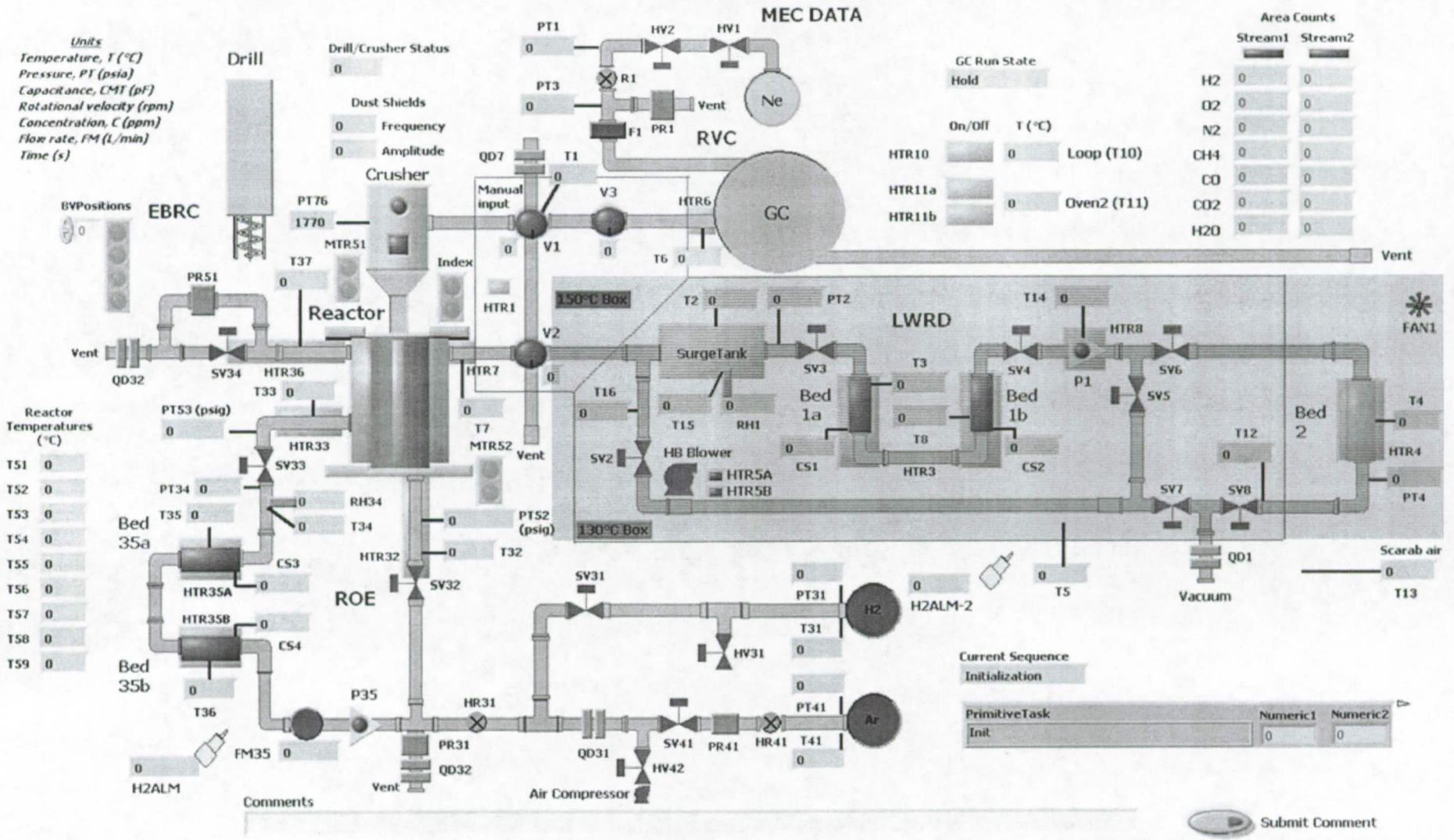
Design Review (Cont.)

- **Absorb/desorb hydrogen efficiently**
  - FSEC developed new hydride former; works at room temp.
- **Operate during 8-12 hr workday**
  - Desorb water beds overnight (or during ROE)
  - Split full RESOLVE ops over two days
- **Stay under 60 kg mass limit**
  - Minimized masses of individual components
  - Transferred Ar, vacuum pump and electronics to GSE
- **Demonstration on Mauna Kea in November 2008**
  - Keep close track of schedule; fix issues quickly
- **Limited budget**
  - Work efficiently; minimize equipment costs

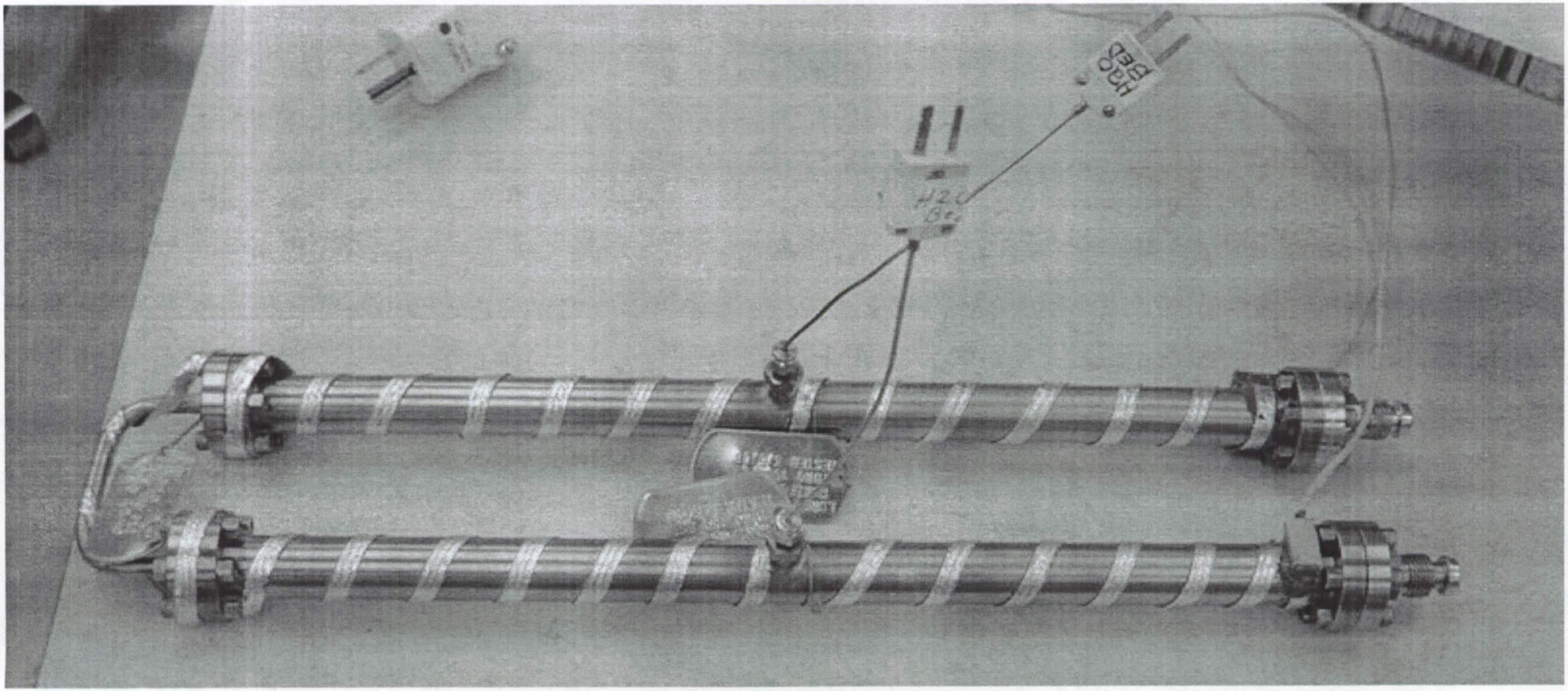
LWRD Process Summary

- At 150C in the Reactor, transfer gases to Surge Tank; measure RH, P, & T; and transfer to Water Beds two times (up to ~1.5 g water)
- Transfer residual gases to Hydrogen Bed, vent unabsorbed gases, heat to 300C and measure P & T of desorbed gas in Surge Tank and H_2 Bed (skipped this step in Hawaii demo)
- Subsequent transfers: measure RH, P, & T in Surge Tank since gases will consist of >90% water vapor; and vent
- Repeat sequence for each quarter core

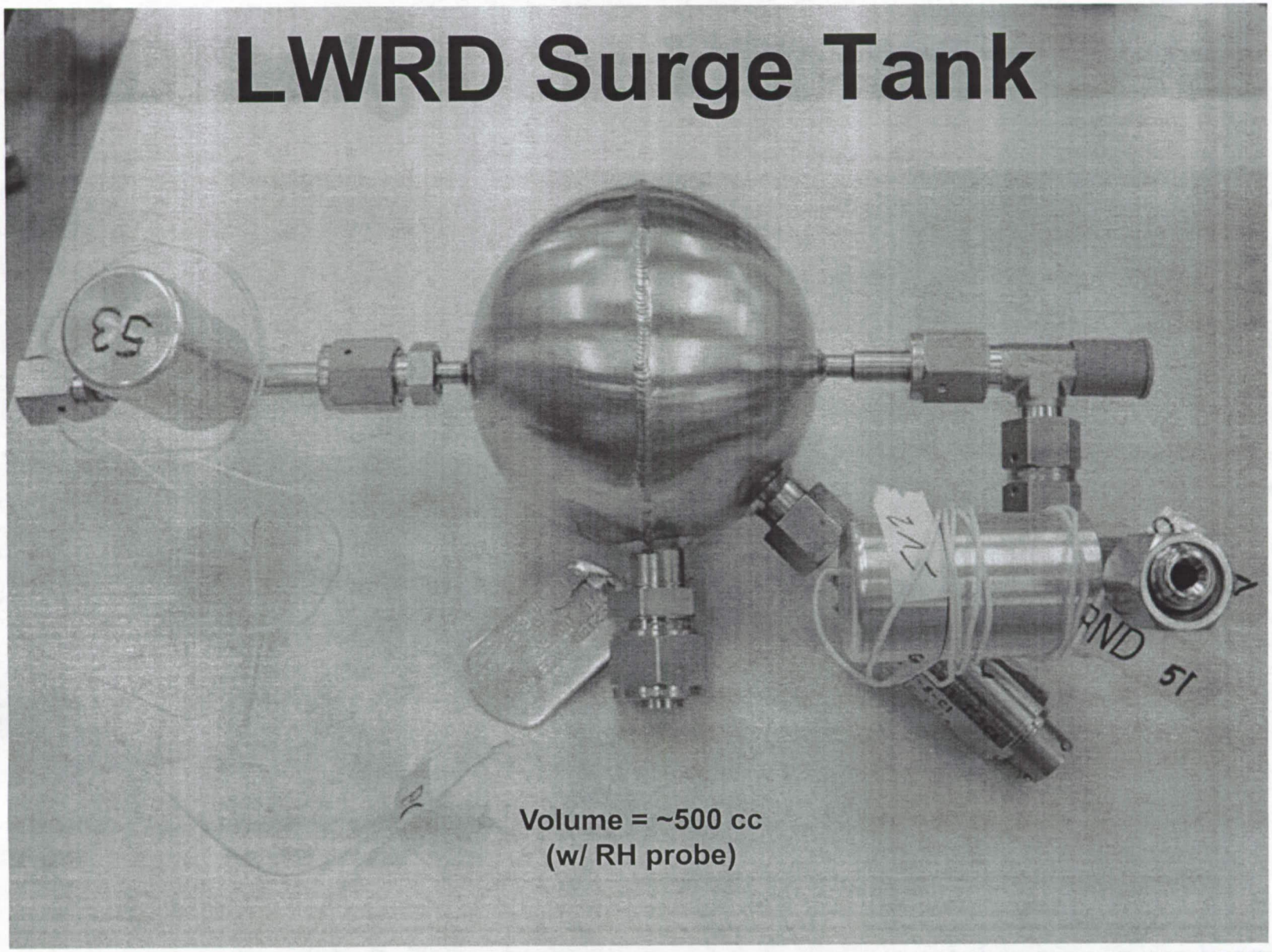
MEC LabVIEW Screen



Water Beds

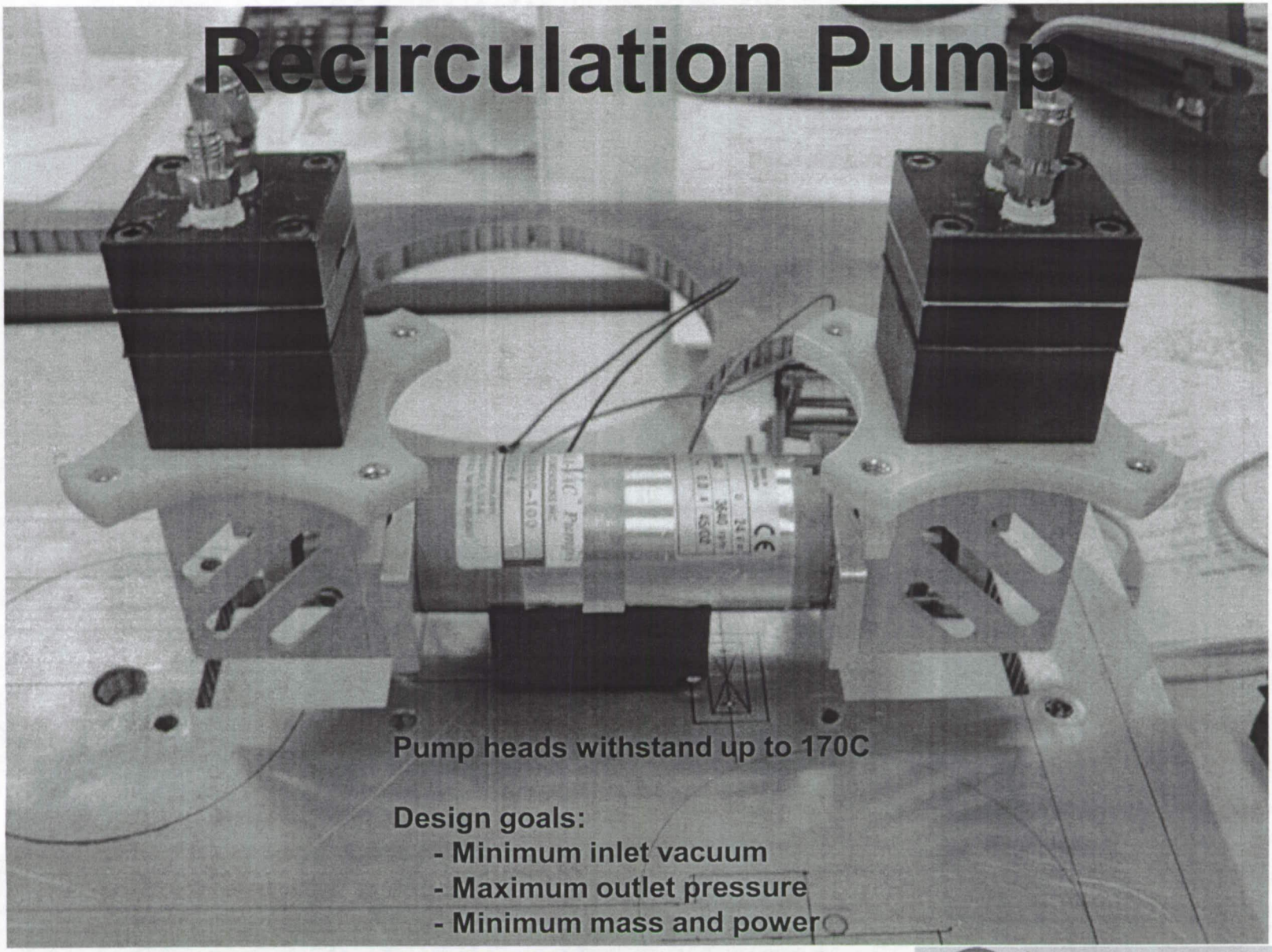


LWRD Surge Tank



Volume = ~500 cc
(w/ RH probe)

Recirculation Pump

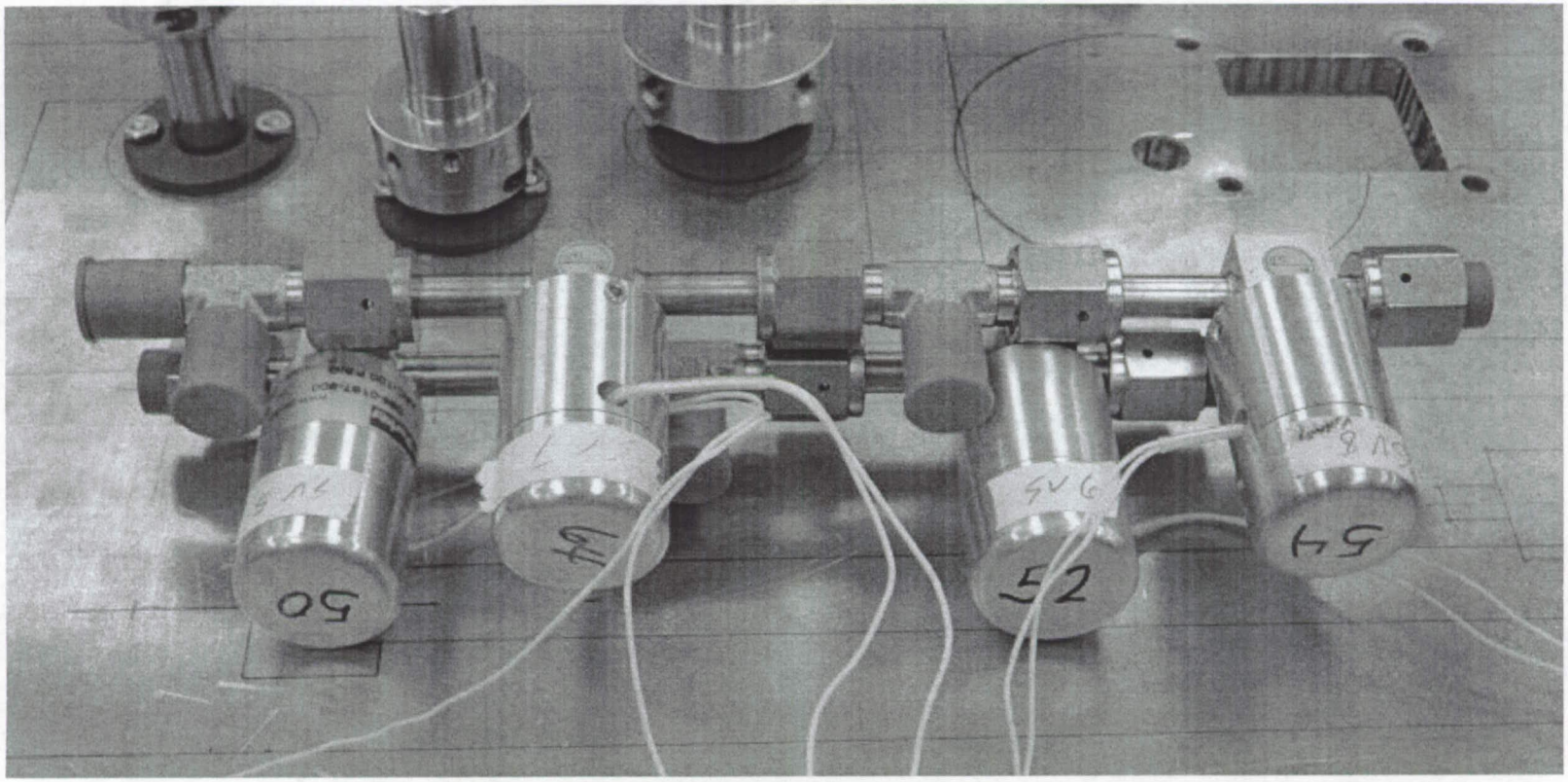


Pump heads withstand up to 170C

Design goals:

- Minimum inlet vacuum
- Maximum outlet pressure
- Minimum mass and power

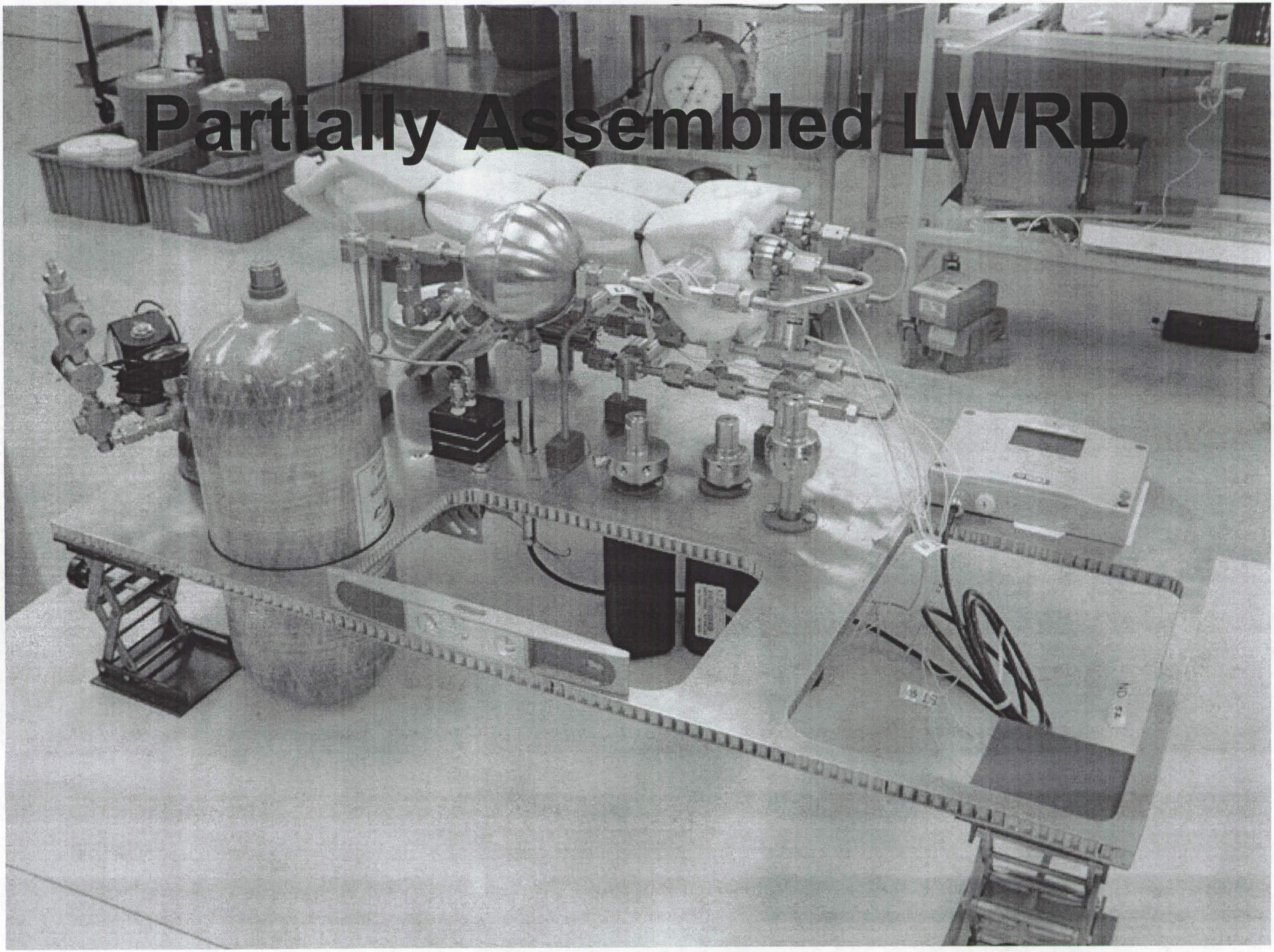
High Temperature Latching Solenoid Valves



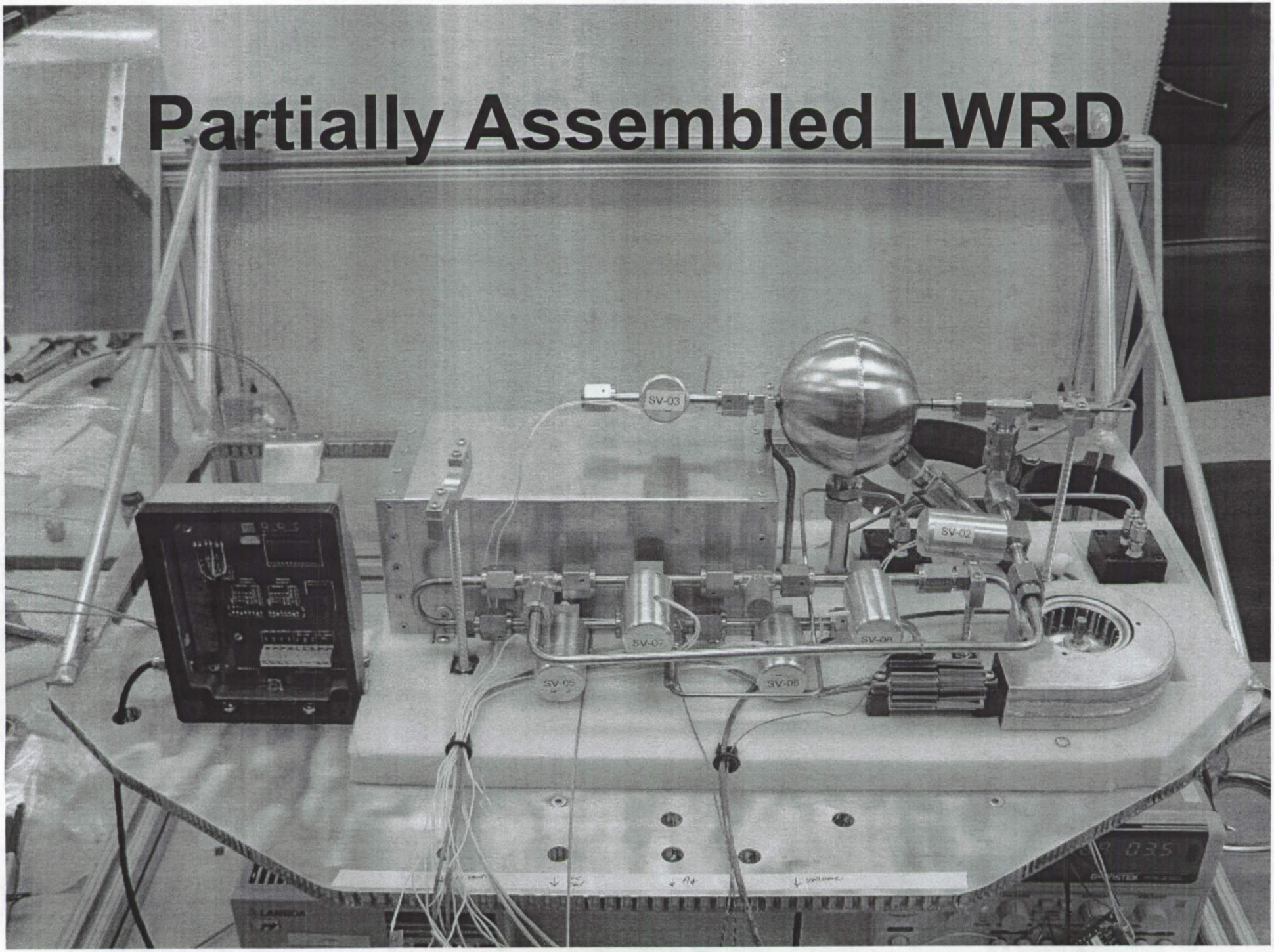
Modified standard solenoid valves at KSC

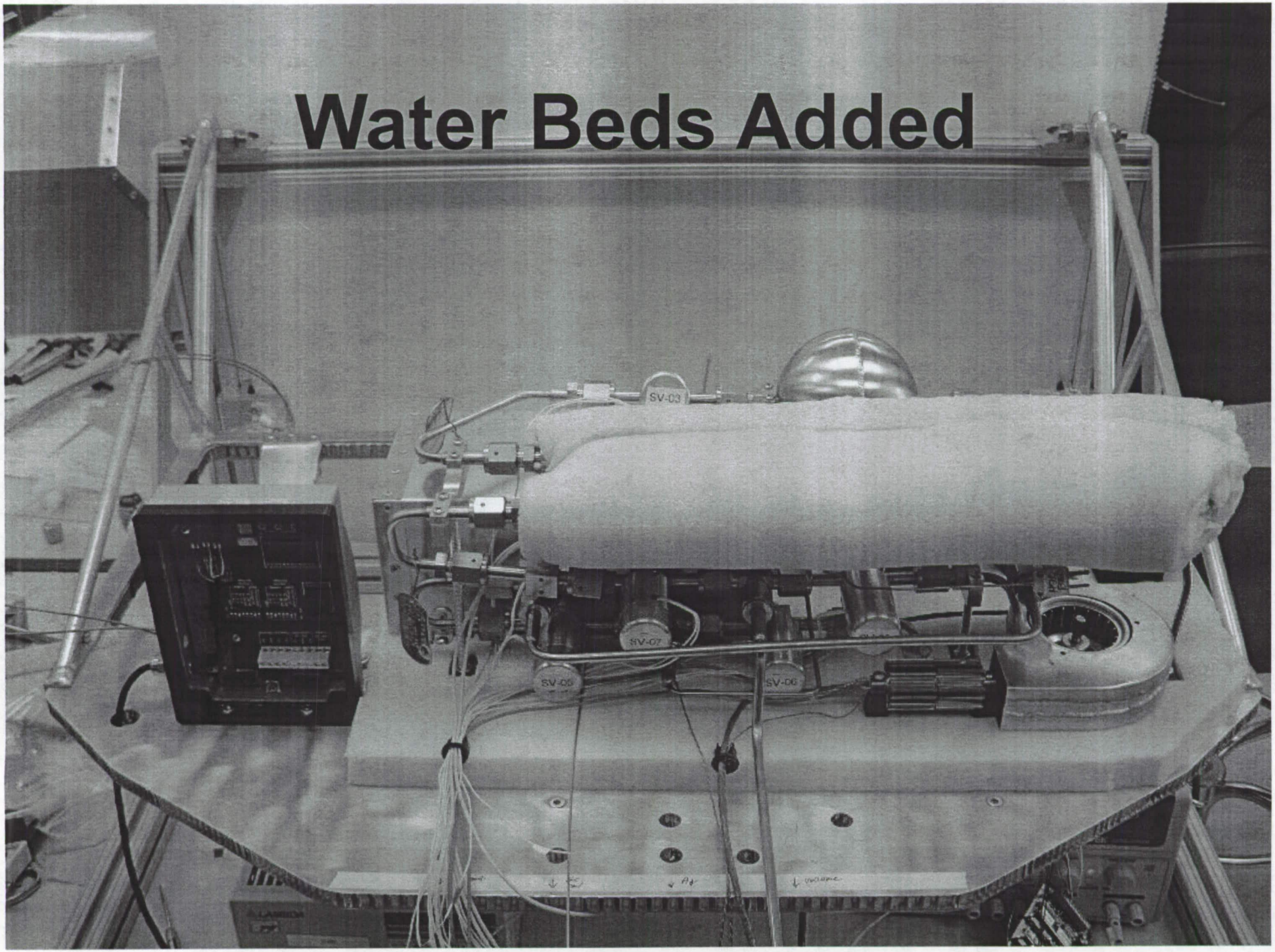
Hydrogen Desorption

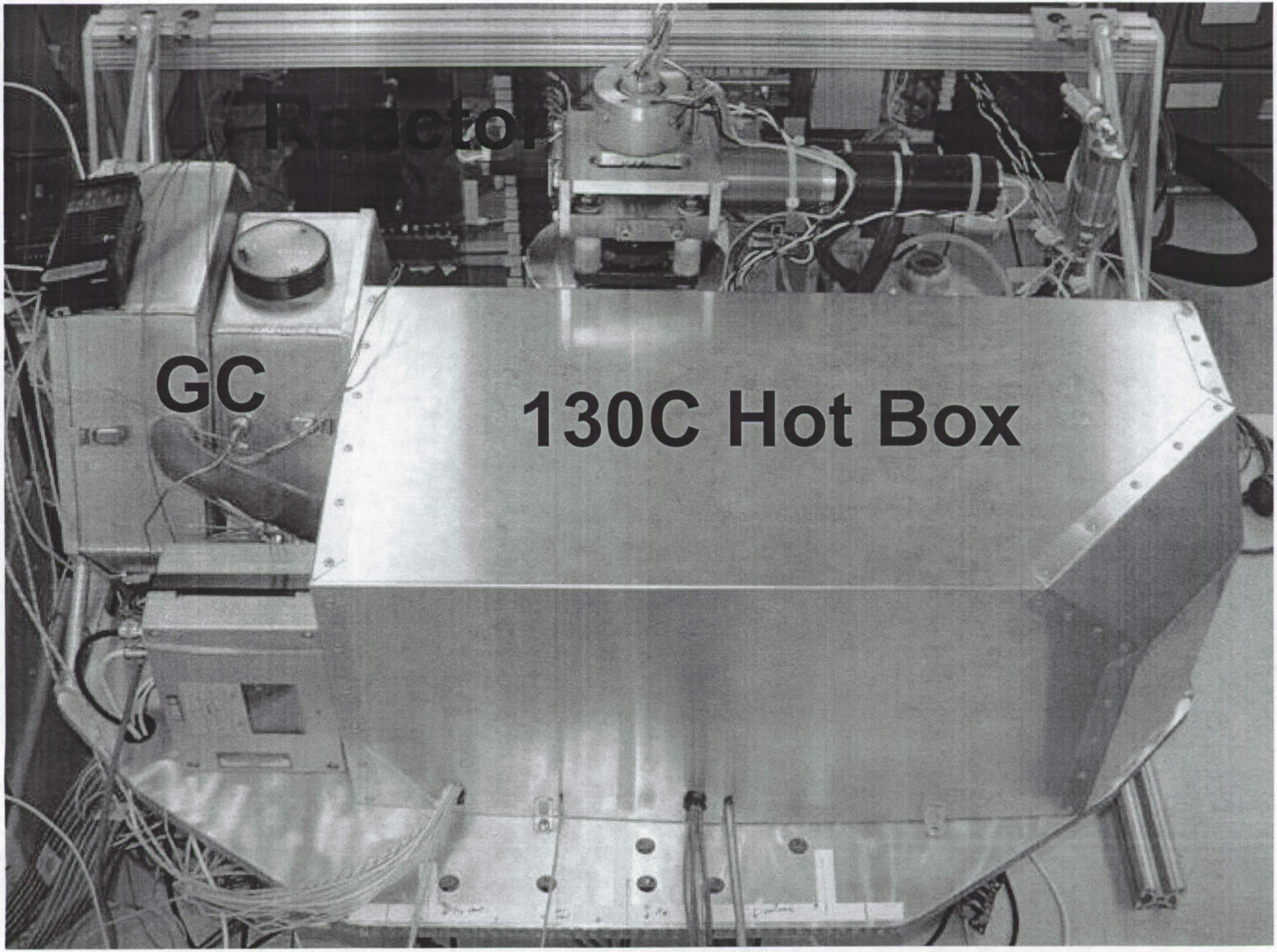
- H_2 Bed size = 50 g of new absorber
- Absorber H_2 capacity = 0.10 g (0.2%)
- Average lunar H_2 expected = 0.088 g per ¼ core (0.11% H_2) if all elemental hydrogen
- Free bed volume = 25.3 cc
- ΔP at 300C = 1200 psi (rated at 150 psi) minus equilibrium as with water bed desorption
- Therefore, use Surge Tank; ΔP = 32 psi
- Encourages dehydriding to completion

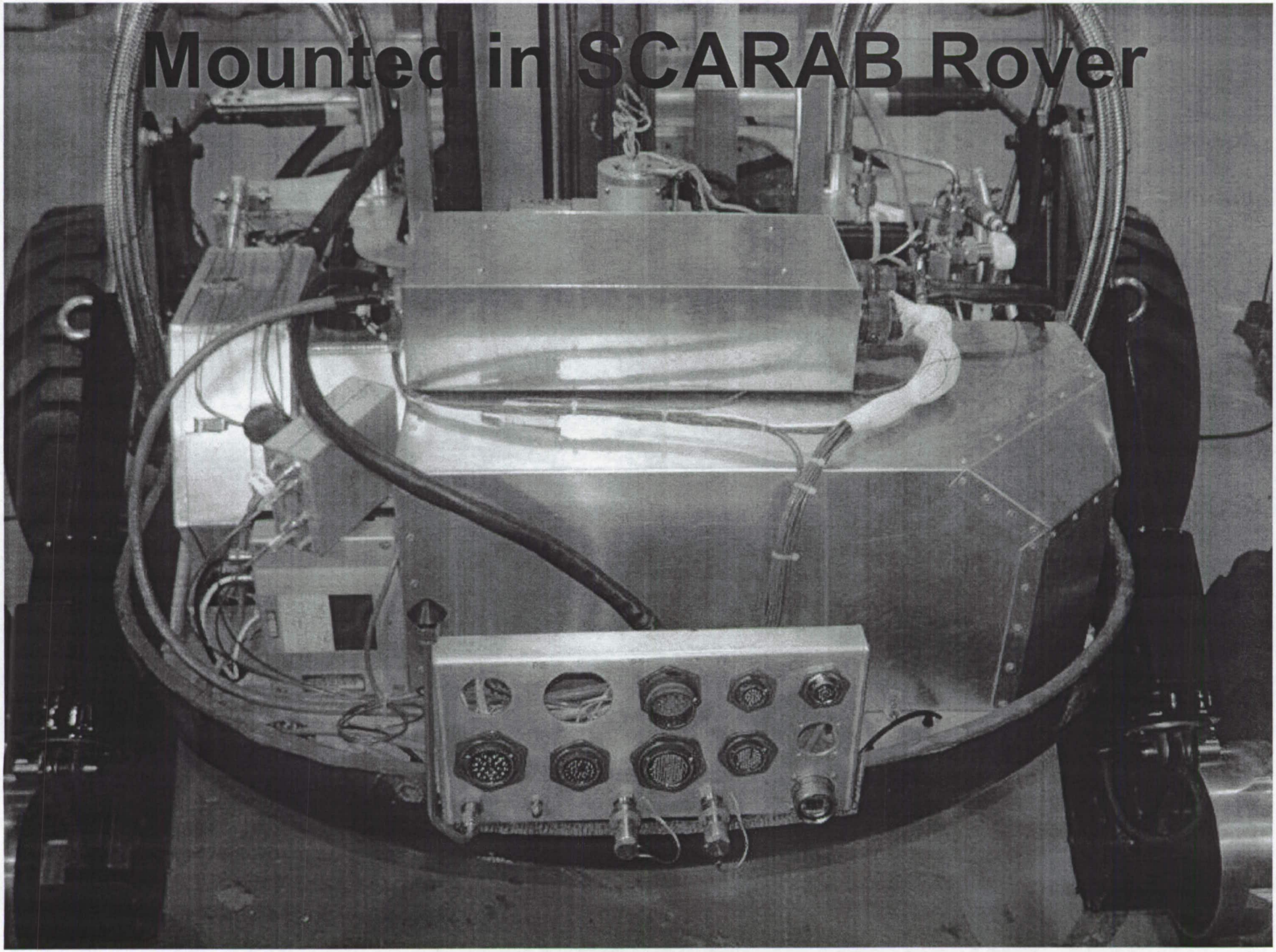

Partially Assembled LWRD

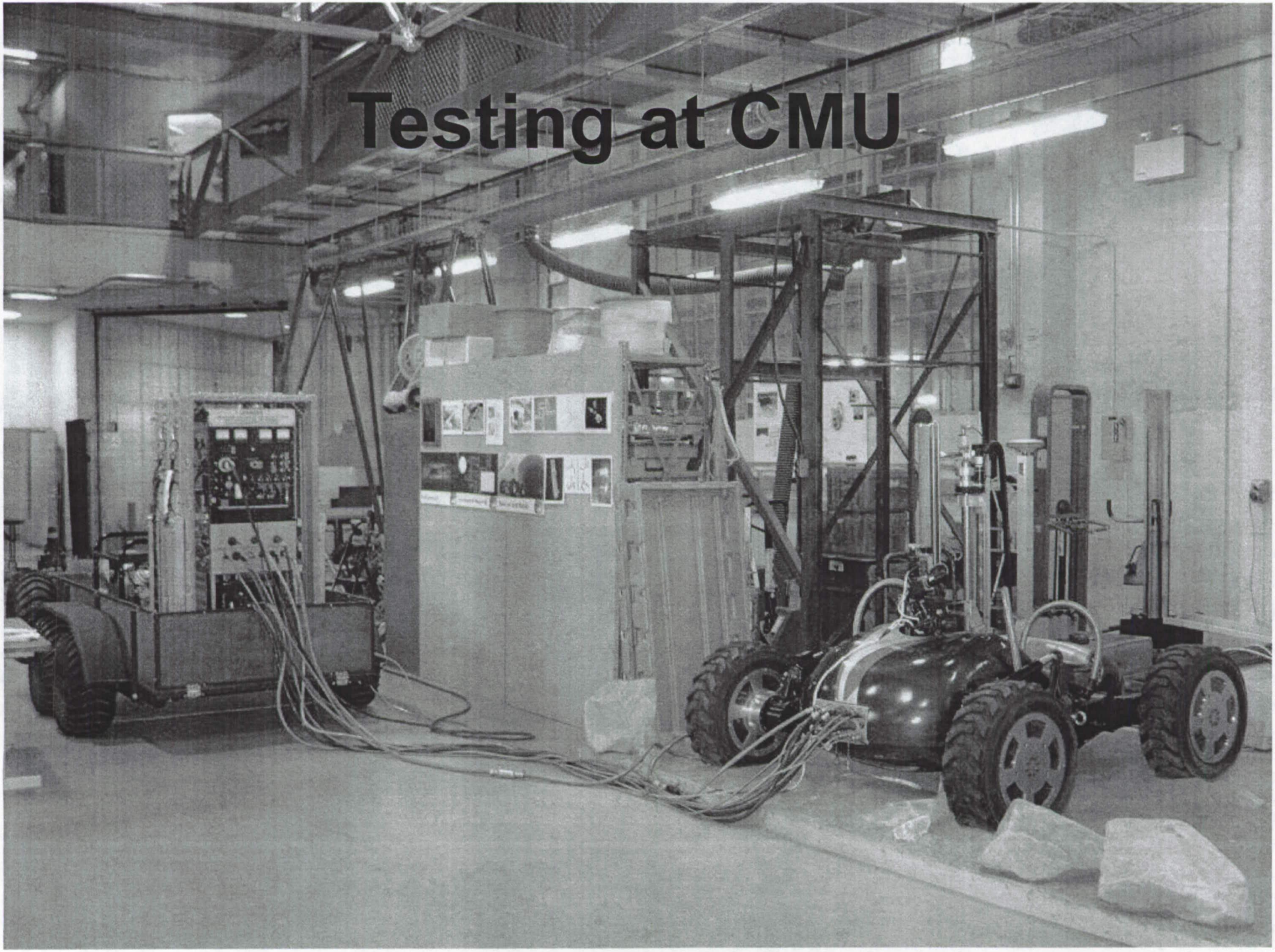
Partially Assembled LWRD




Water Beds Added
SV-03
SV-07
SV-05
SV-06

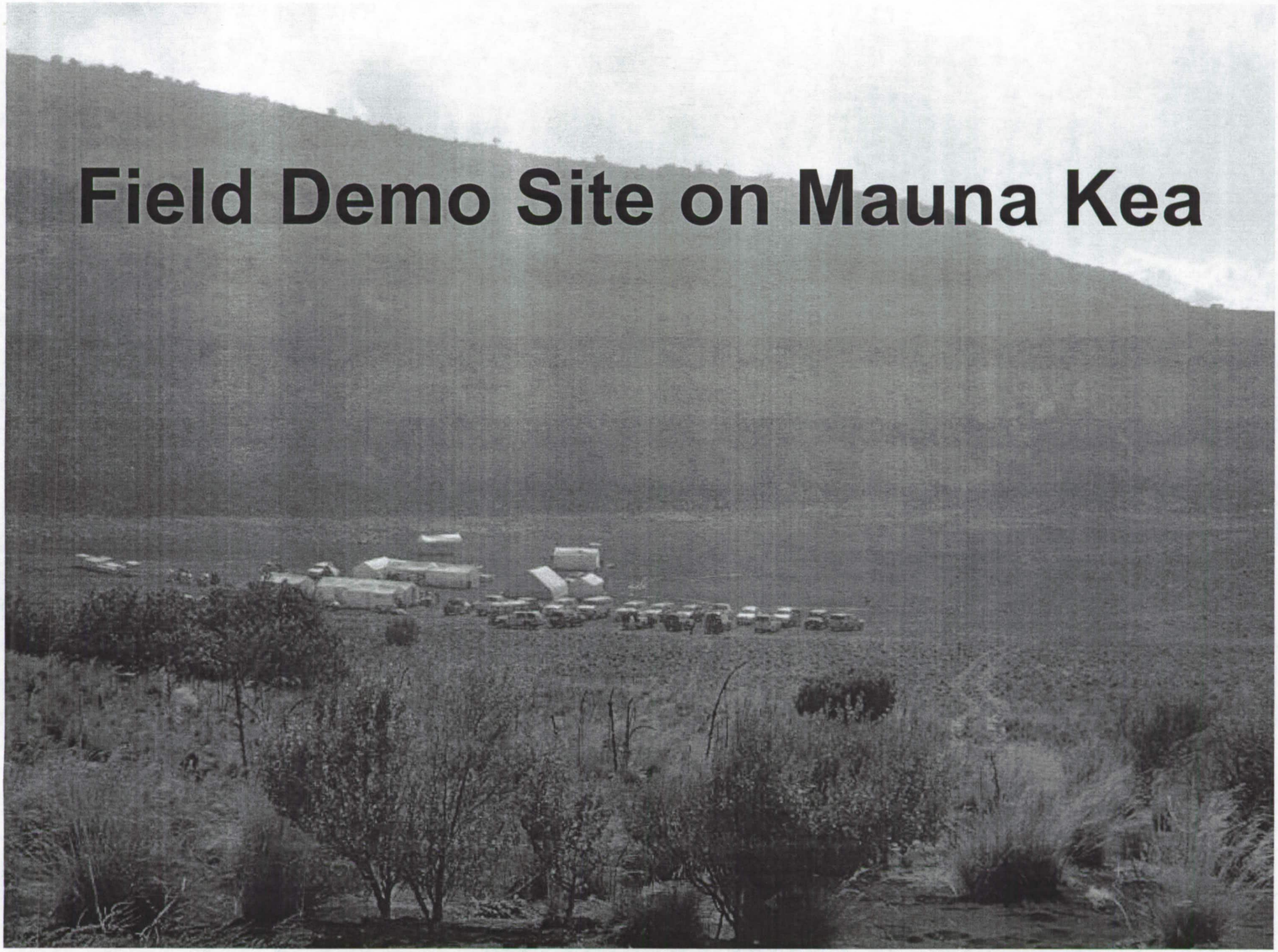

Reactor
GC
130C Hot Box

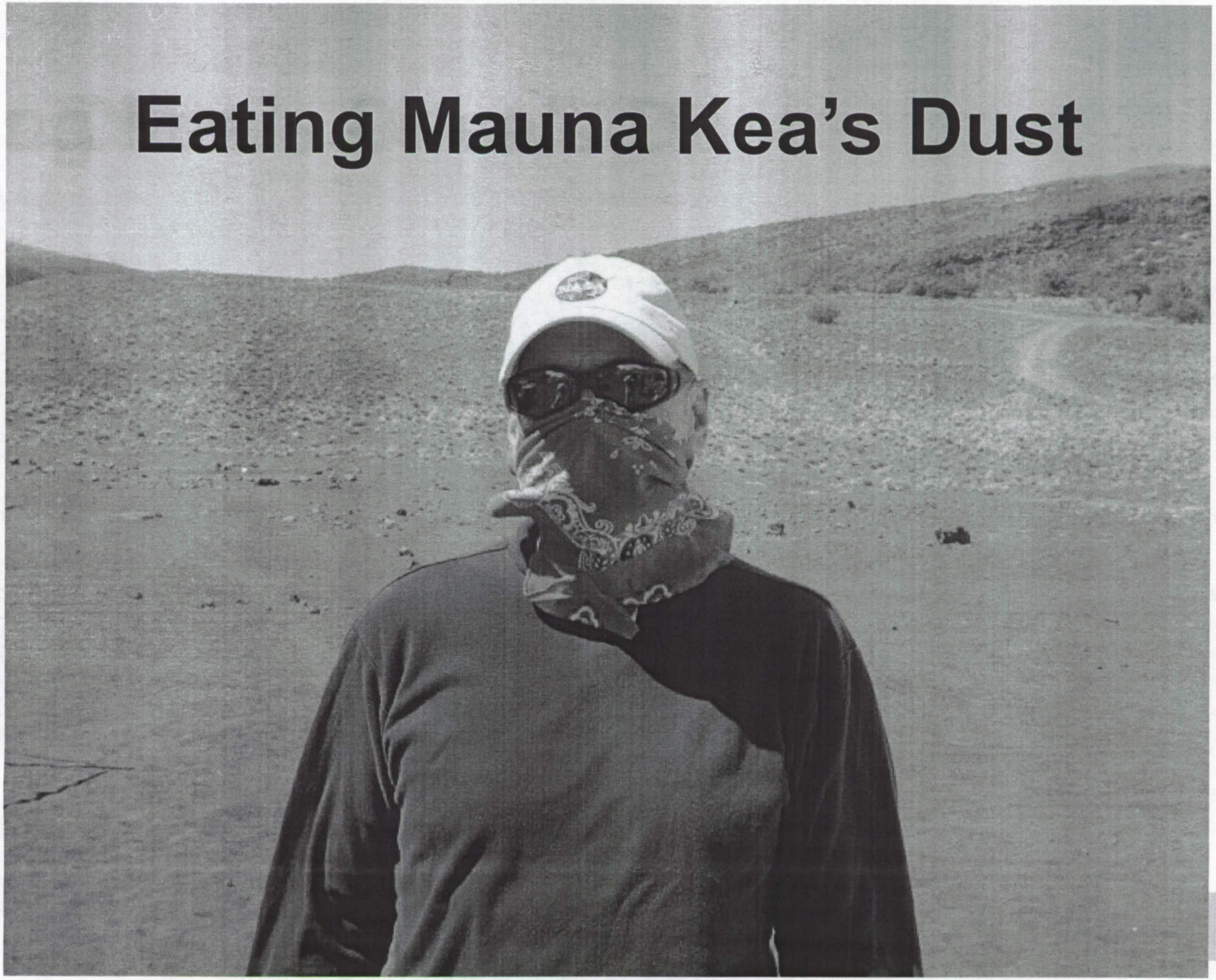

Mounted in SCARAB Rover


Testing at CMU

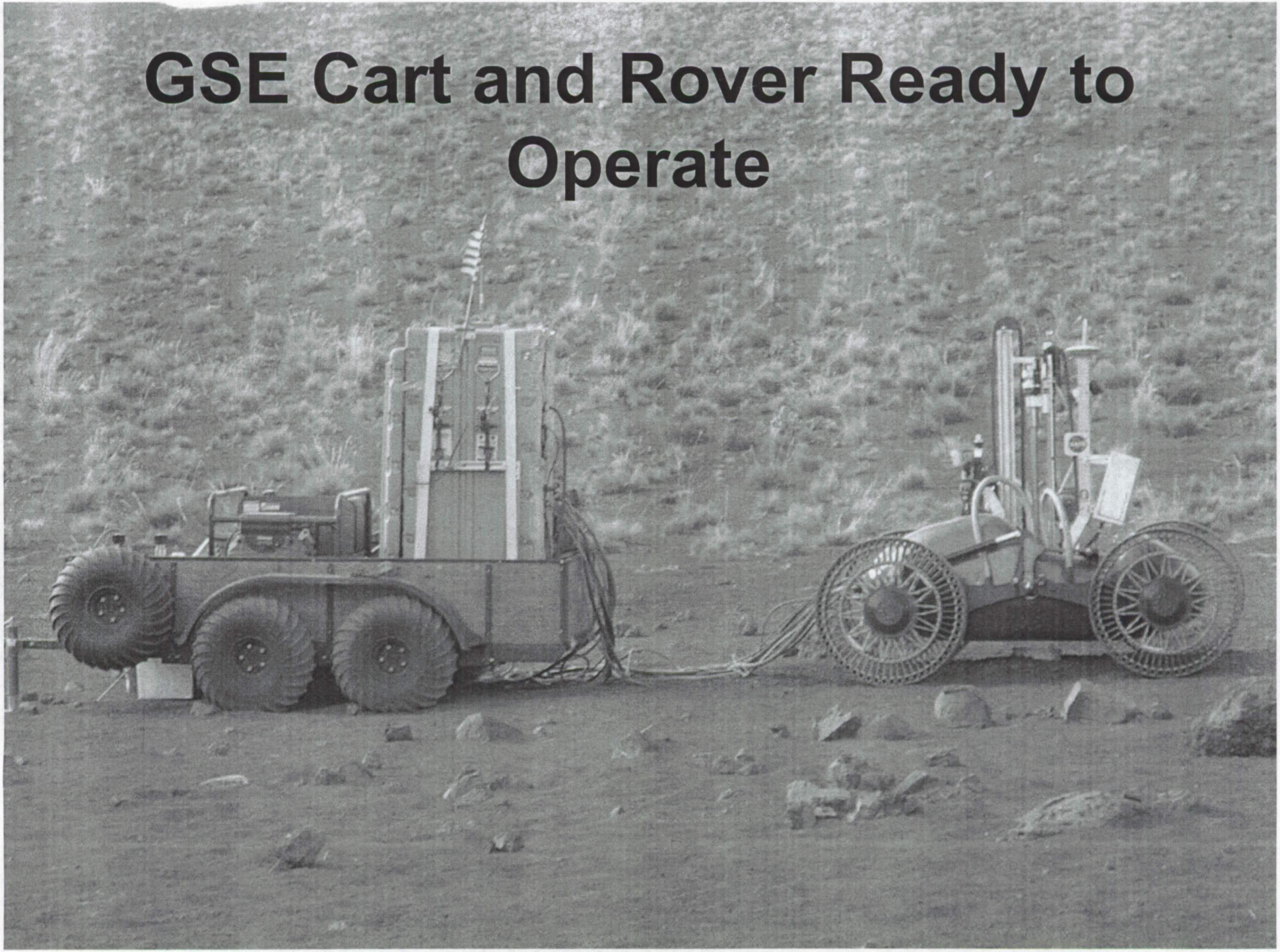
Field Test Plan

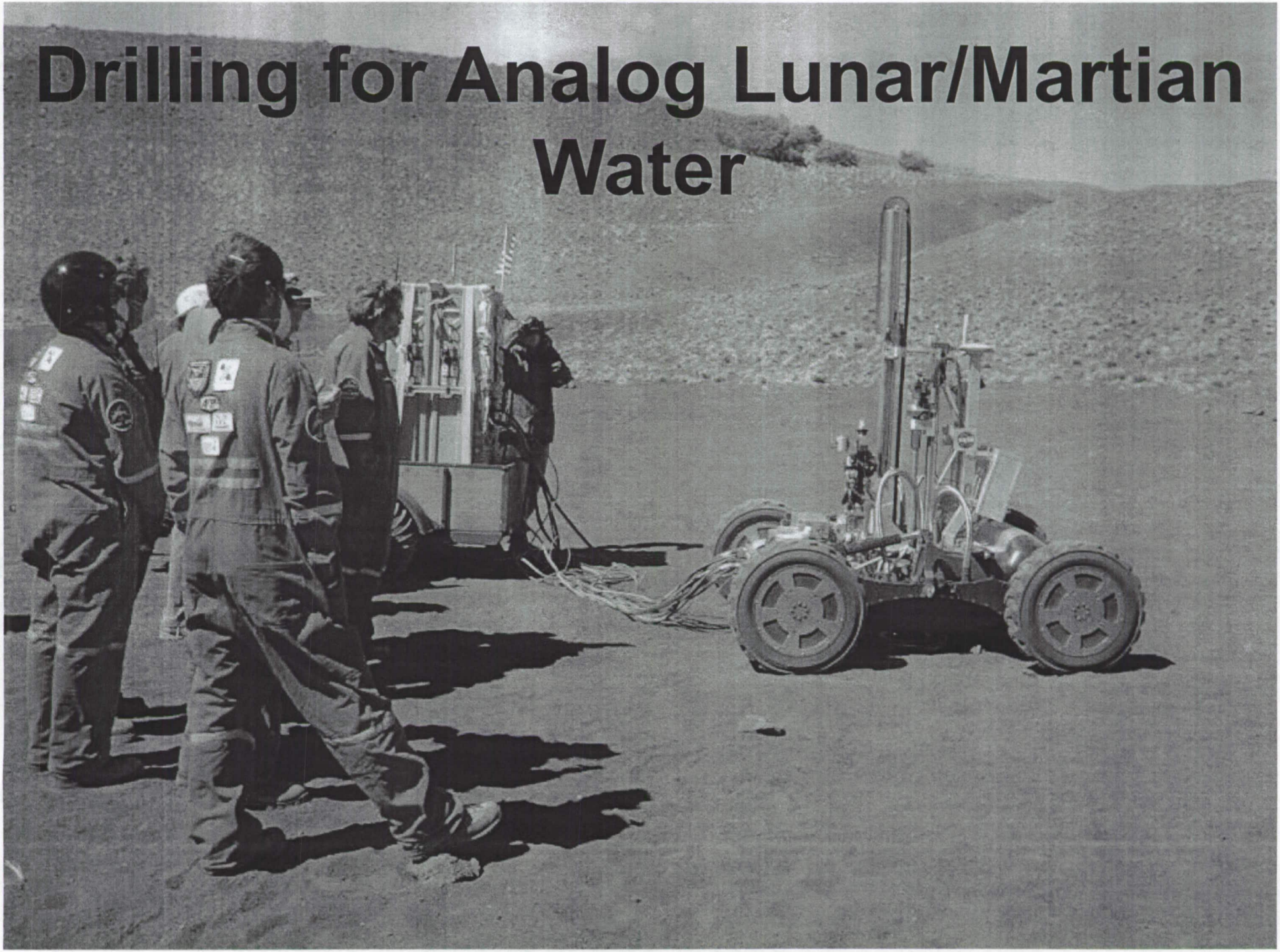
- Lab – full capabilities demonstration
- Hawaii – no hydrogen absorption/ desorption/quantification demonstration (run in lab at KSC after Field Demo)


Field Demo Site on Mauna Kea

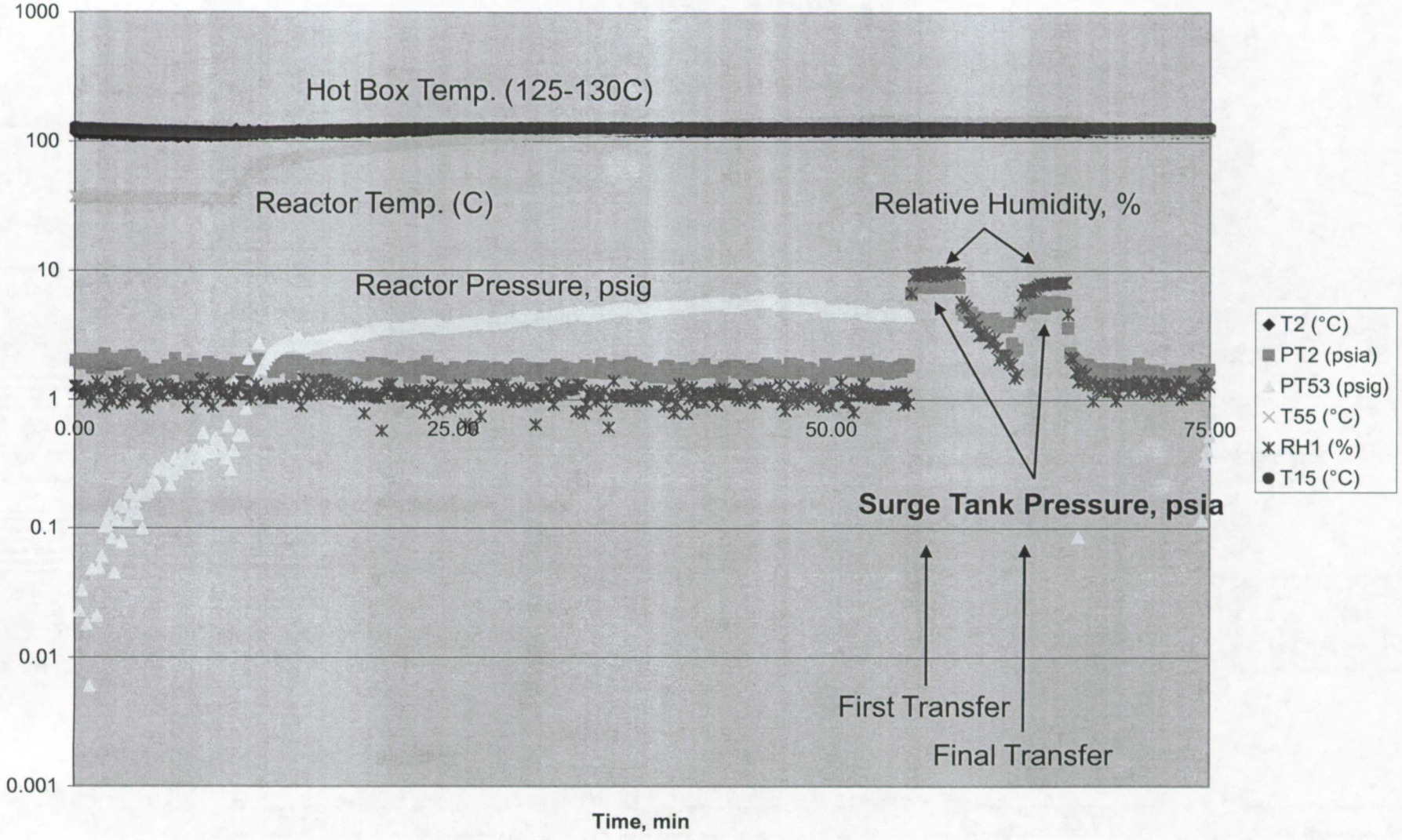

Eating Mauna Kea's Dust

GSE Cart and Rover Ready to Operate




Drilling for Analog Lunar/Martian
Water

Hawaii Demo, 11/4/08

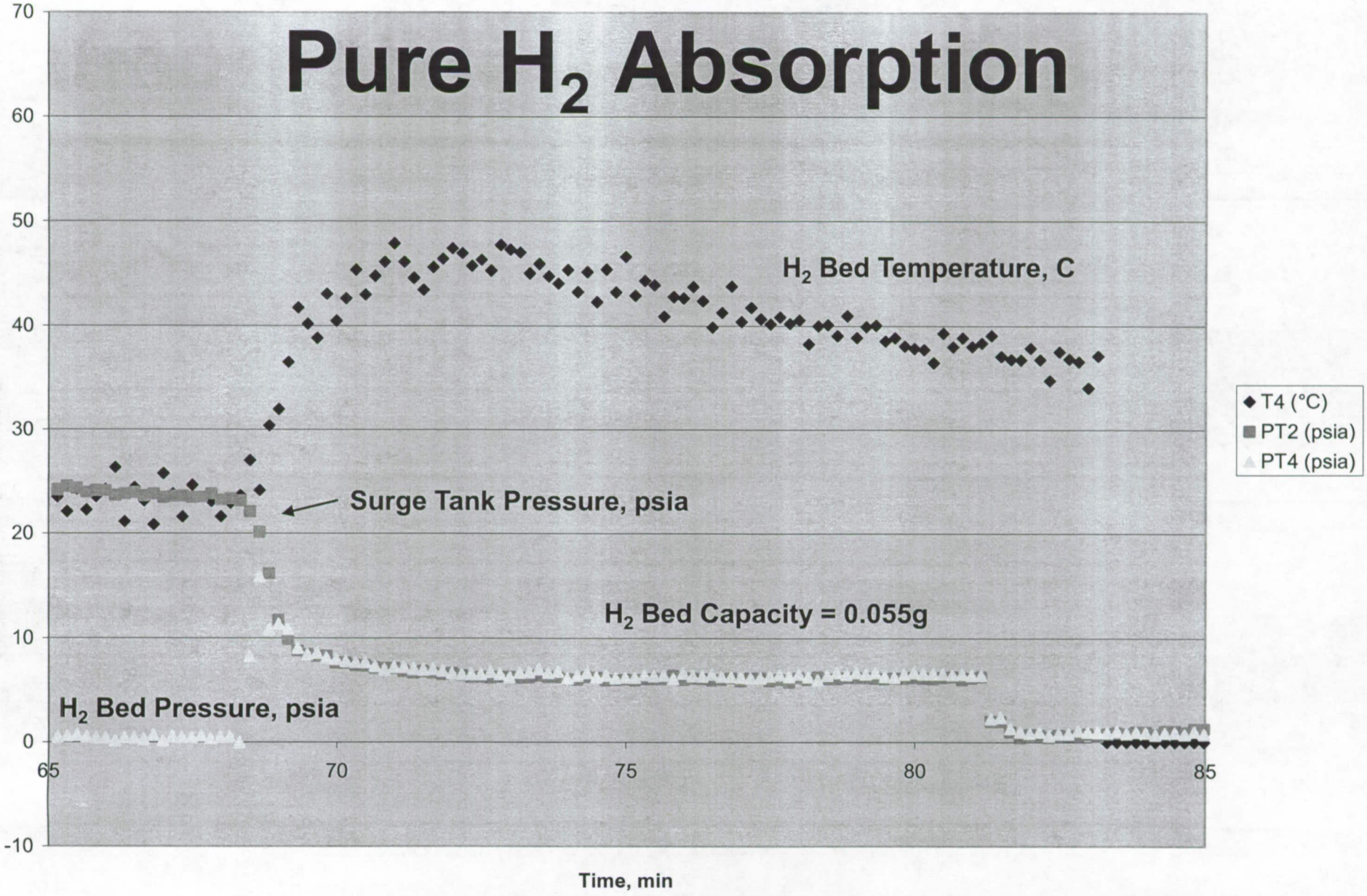


Lab/Field Demonstration Results

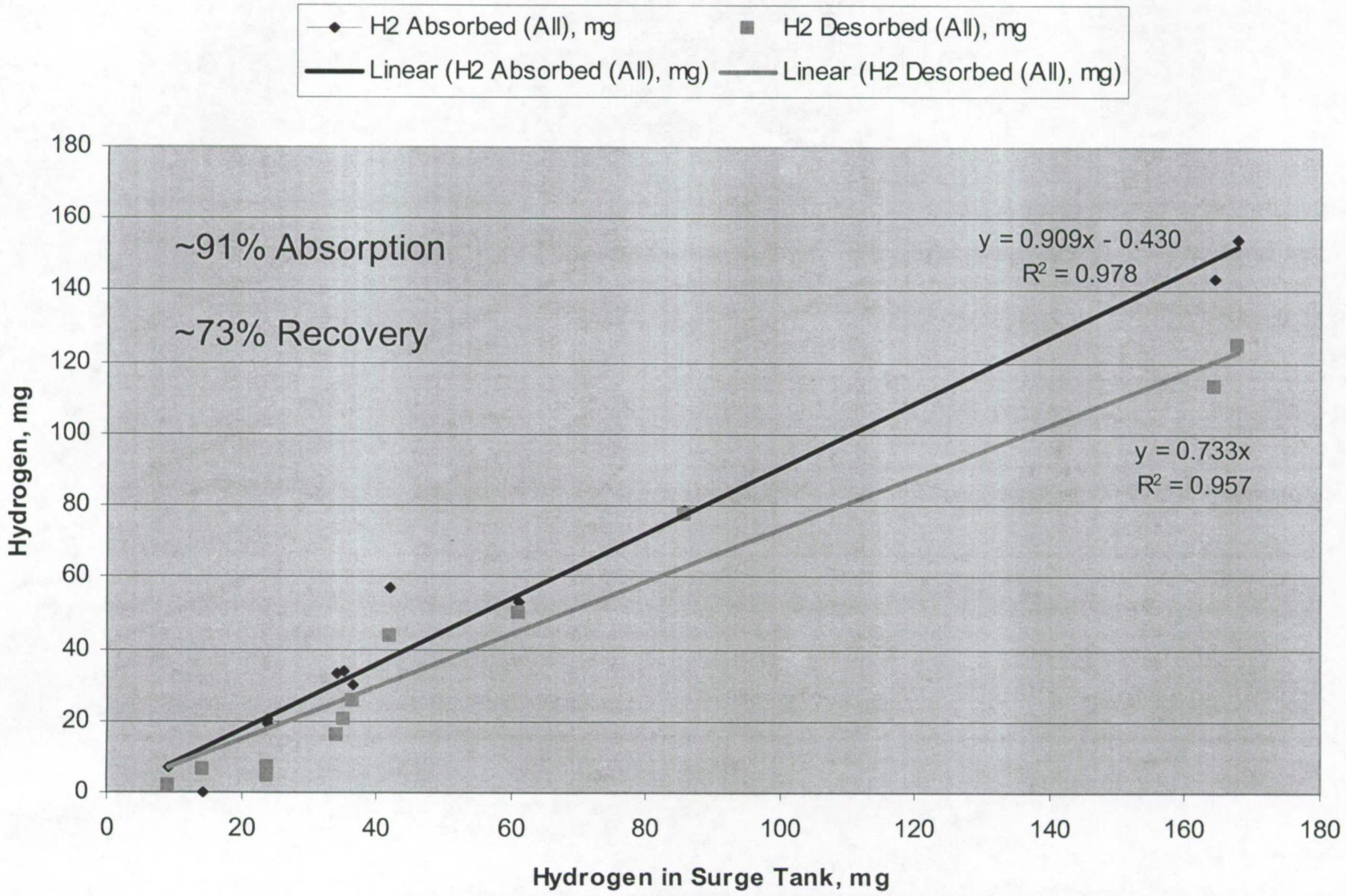
Date	Total Water Transferred	Mass of Tephra	% Water
9/24/08	0.27g	85g	0.31
9/24/08	0.08g	90g	0.09
9/24/08	0.35g	85g	0.41
9/25/08	0.33g	85g	0.39
9/25/08	0.29g	85g	0.34
11/4/08	0.11g	66g	0.17
11/5/08	0.13g	72g	0.18
11/6/08	0.16g	92g	0.17
11/8/08	0.13g	71g	0.19
11/9/08	0.11g	76g	0.15
11/10/08	0.19g	90g (LN_2)	0.22*

Field Demonstration Results

Date	RVC GC results (corrected)	LWRD results (corrected)	% difference
11/5/08	48mg	39mg	-18%
11/6/08	47mg	57mg	21%
11/8/08	46mg	47mg	3%
11/9/08	45mg	34mg	-24%
11/10/08	52mg	65mg	24%
		Average difference	18%


Pure H_2 Absorption
70
60
50
40
30
20
10
0
-10
65
70
75
80
85
H_2 Bed Temperature, C
Surge Tank Pressure, psia
H_2 Bed Capacity = 0.055g
H_2 Bed Pressure, psia
T4 (°C)
PT2 (psia)
PT4 (psia)
Time, min

Hydrogen Absorption and Desorption by LWRD



Summary

- LWRD Team has accomplished all major goals in design, construction, and testing
- Successfully completed November field demo on Mauna Kea in Hawaii
- Achieved acceptable agreement with GC results for water and hydrogen as a backup system
- Returning to Mauna Kea in February 2010 for further testing with CSA