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# Lunar Water Resource Demonstration (LWRD) Test Results

ex luna, aqua

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July 30-August 2, 2009



# Coauthors

- **ASRC Aerospace: Tracy Gibson, Steve Perusich, Steve Parks, and Kyle Weis**
- **NASA: Jeremy Parr, Mark Nurge, Dale Lueck, Janine Captain, Curtis Ihlefeld, Tom Moss, Jackie Quinn, and Bill Larson**



# 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**

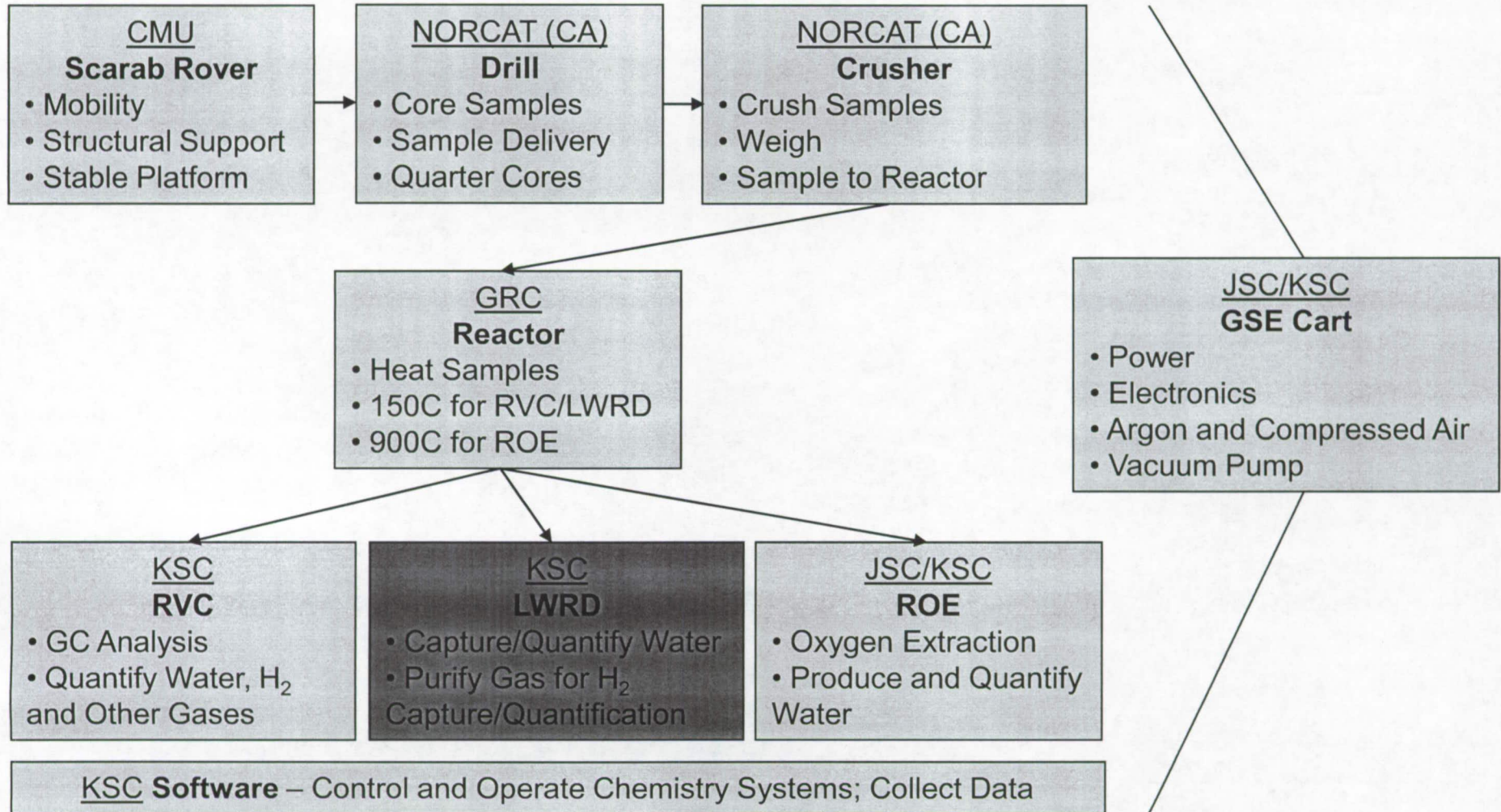


# Background

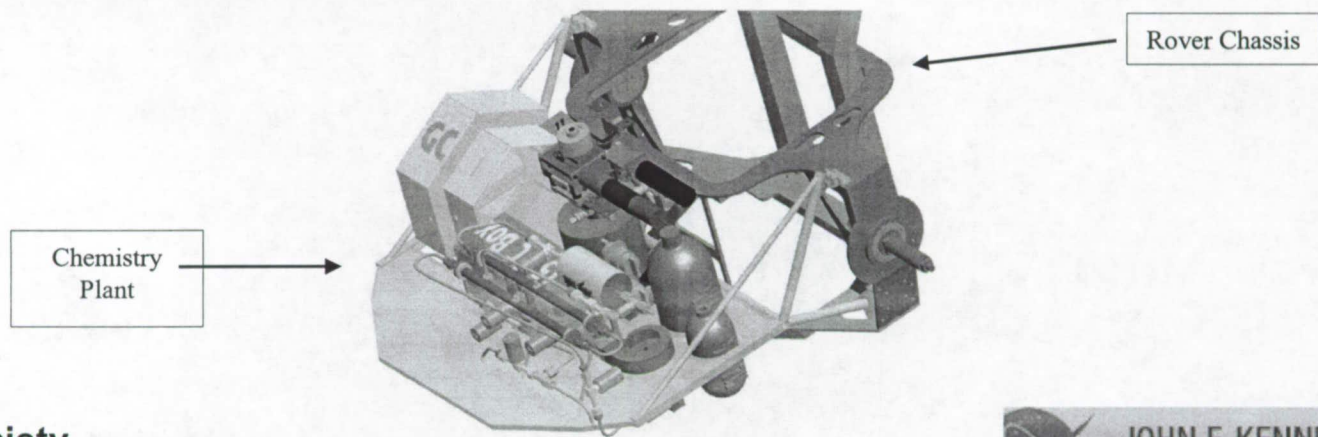
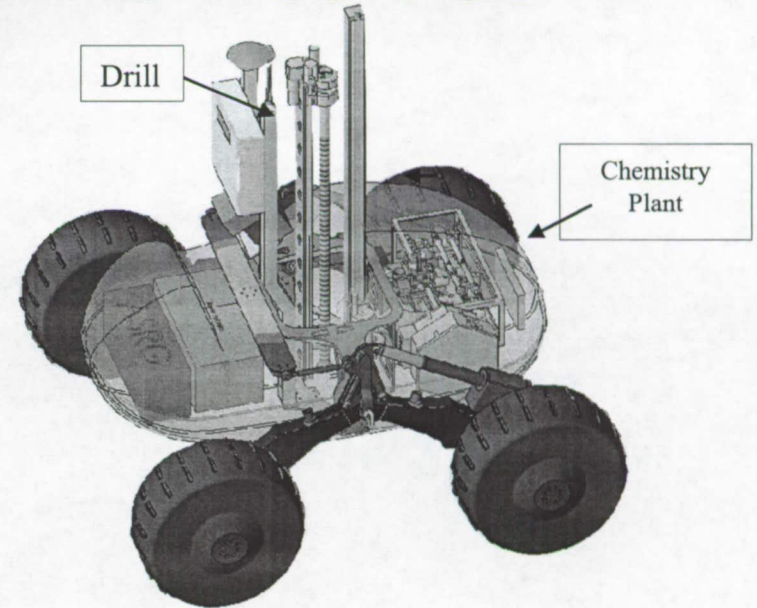
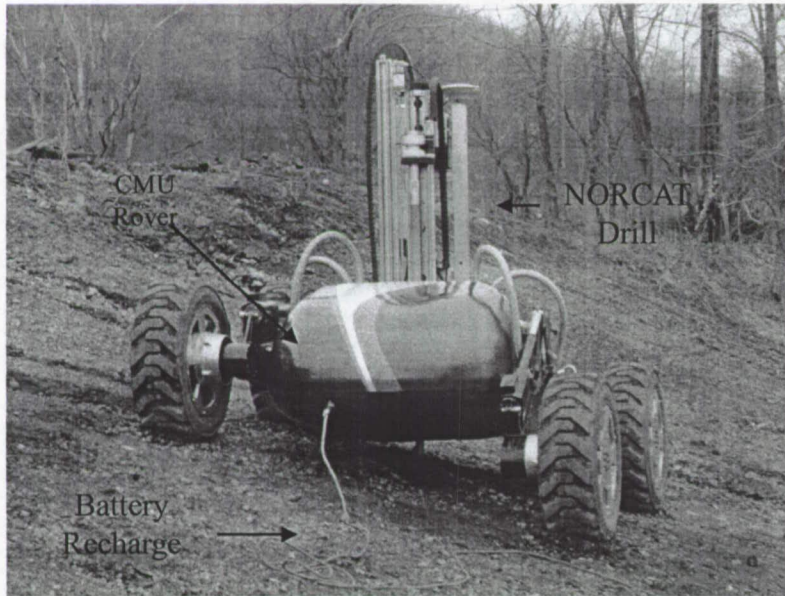
- **LWRD is part of RESOLVE (Regolith and Environment Science & Oxygen and Lunar Volatile Extraction)**
- **RESOLVE is an ISRU ground demonstration:**
  - **A robotic rover to explore a permanently shadowed crater at the south or north pole of the Moon**
  - **Drill core samples down to 1 meter**
  - **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**



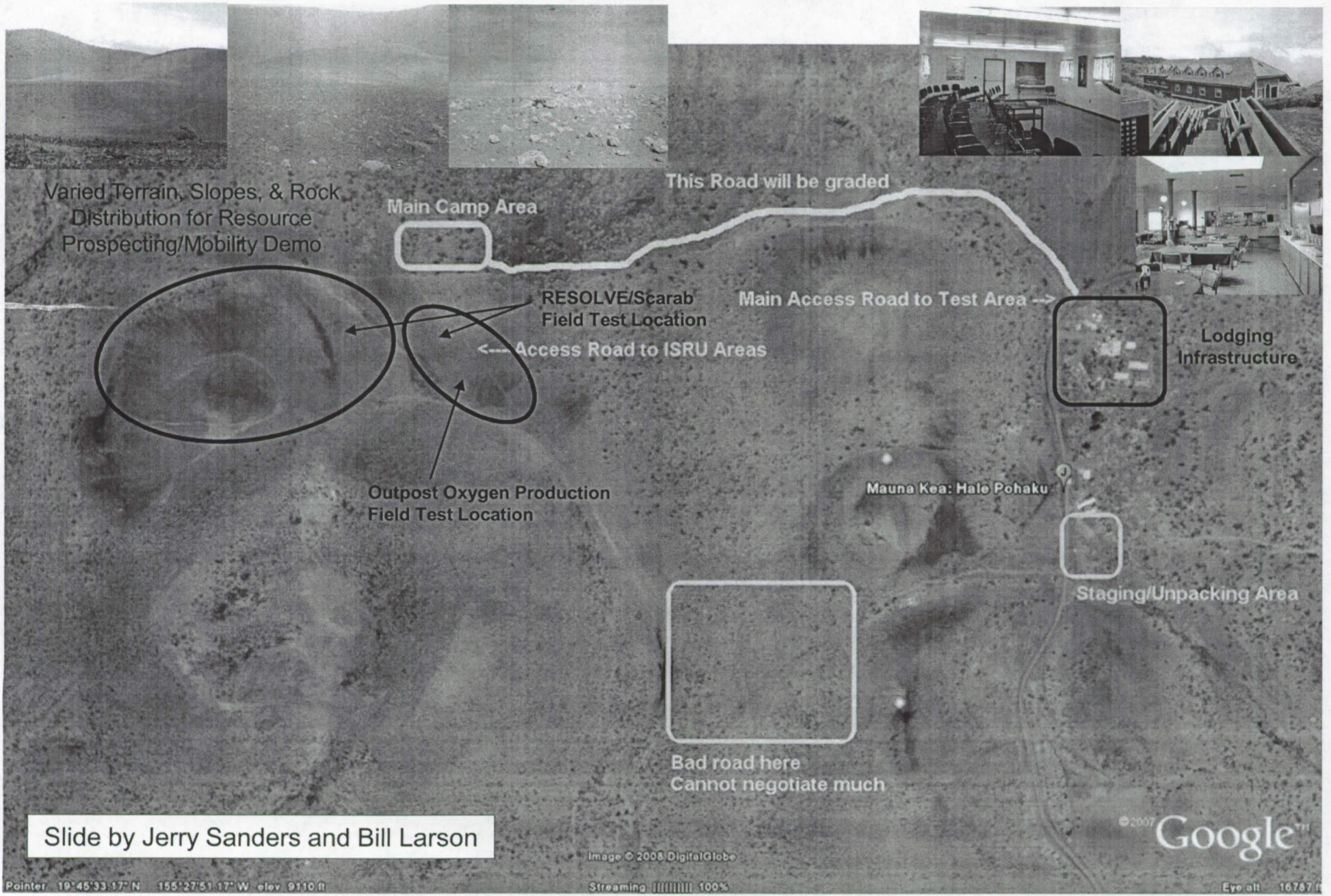
# RESOLVE Block Diagram



# RESOLVE/Scarab Rover



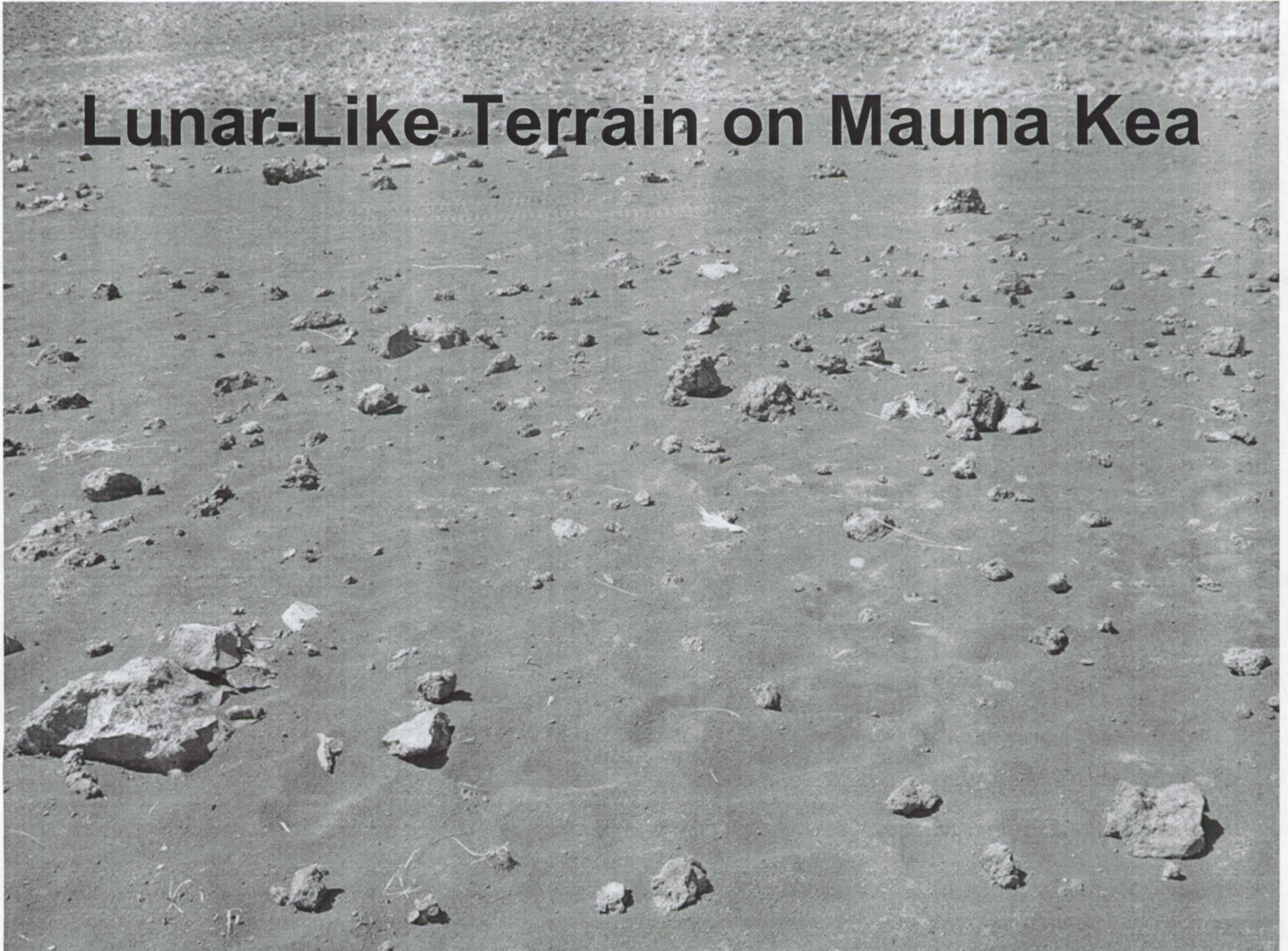
# Nov. 2008 ISRU Field Test Infrastructure and Test Layout



Slide by Jerry Sanders and Bill Larson



# 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



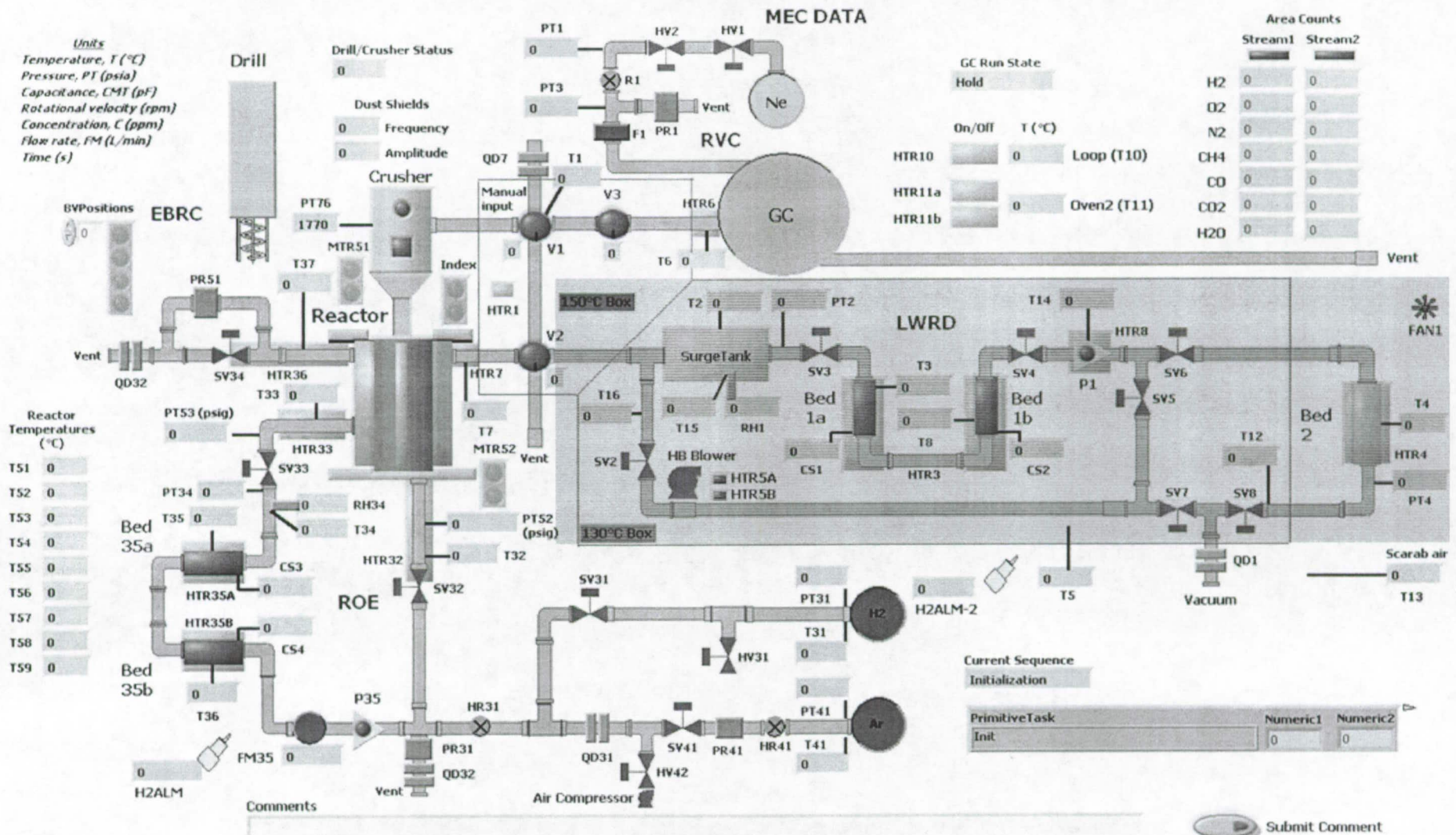
# Design Review (Cont.)

- **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

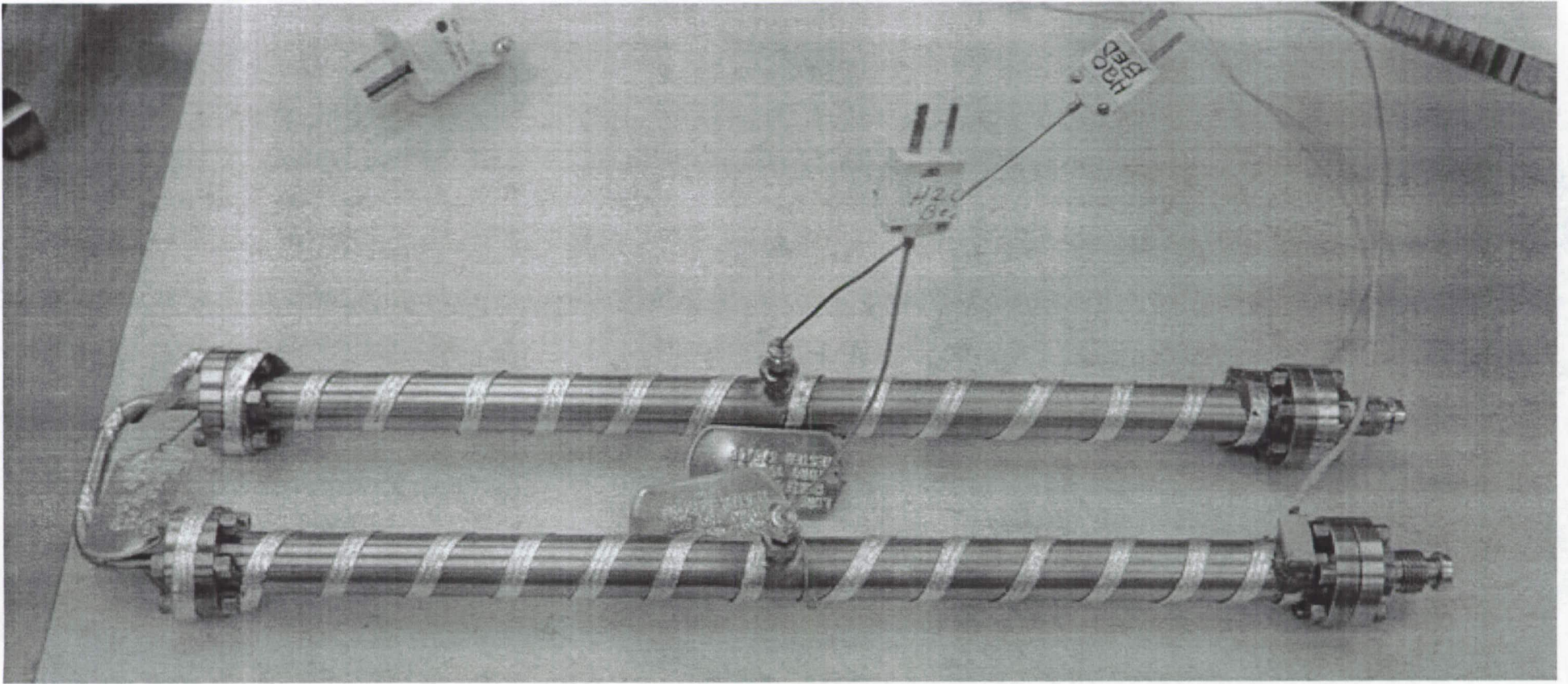
# LWRD Process Summary

- 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<sub>2</sub> 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

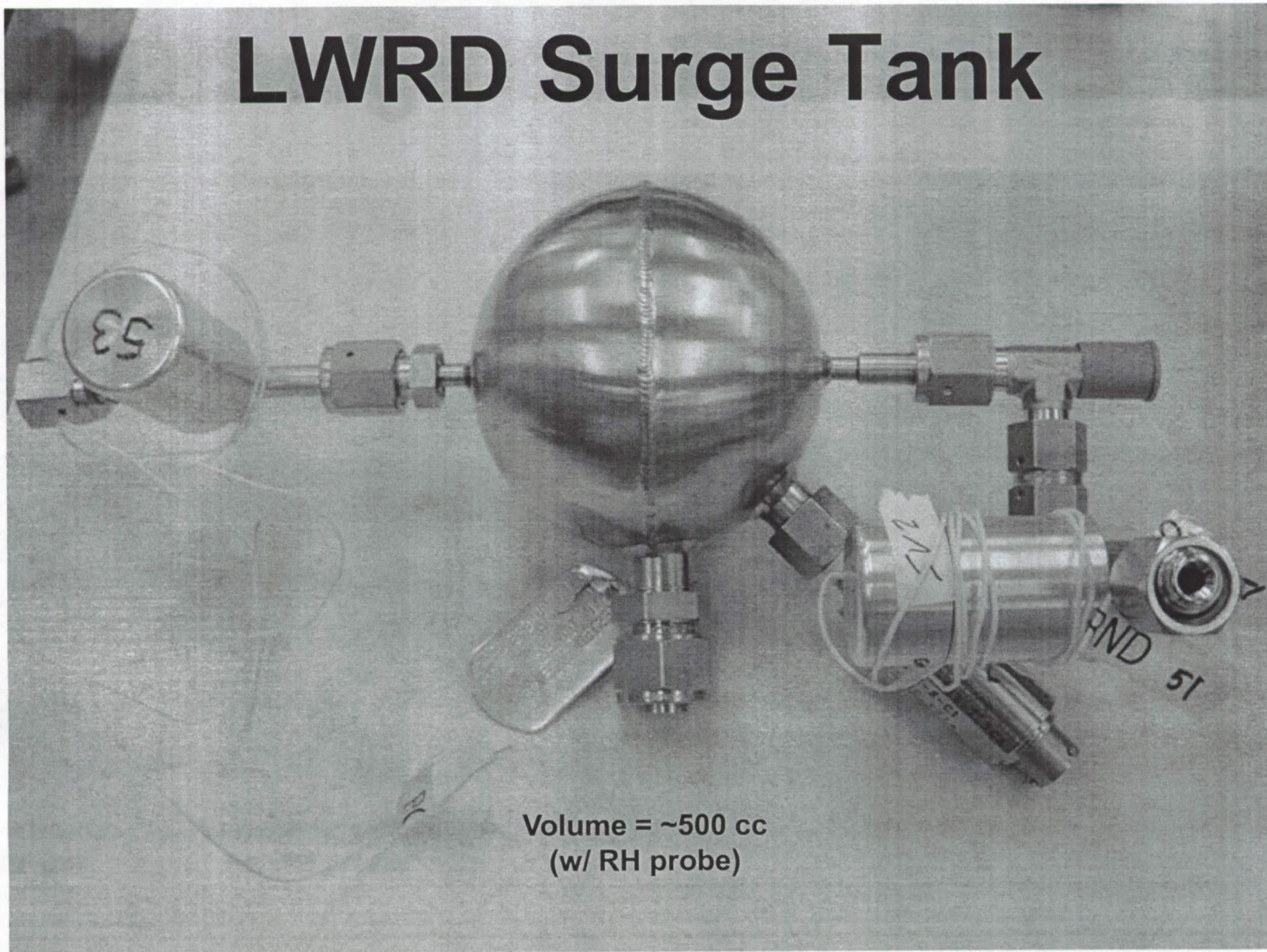
# MEC LabVIEW Screen



# Water Beds



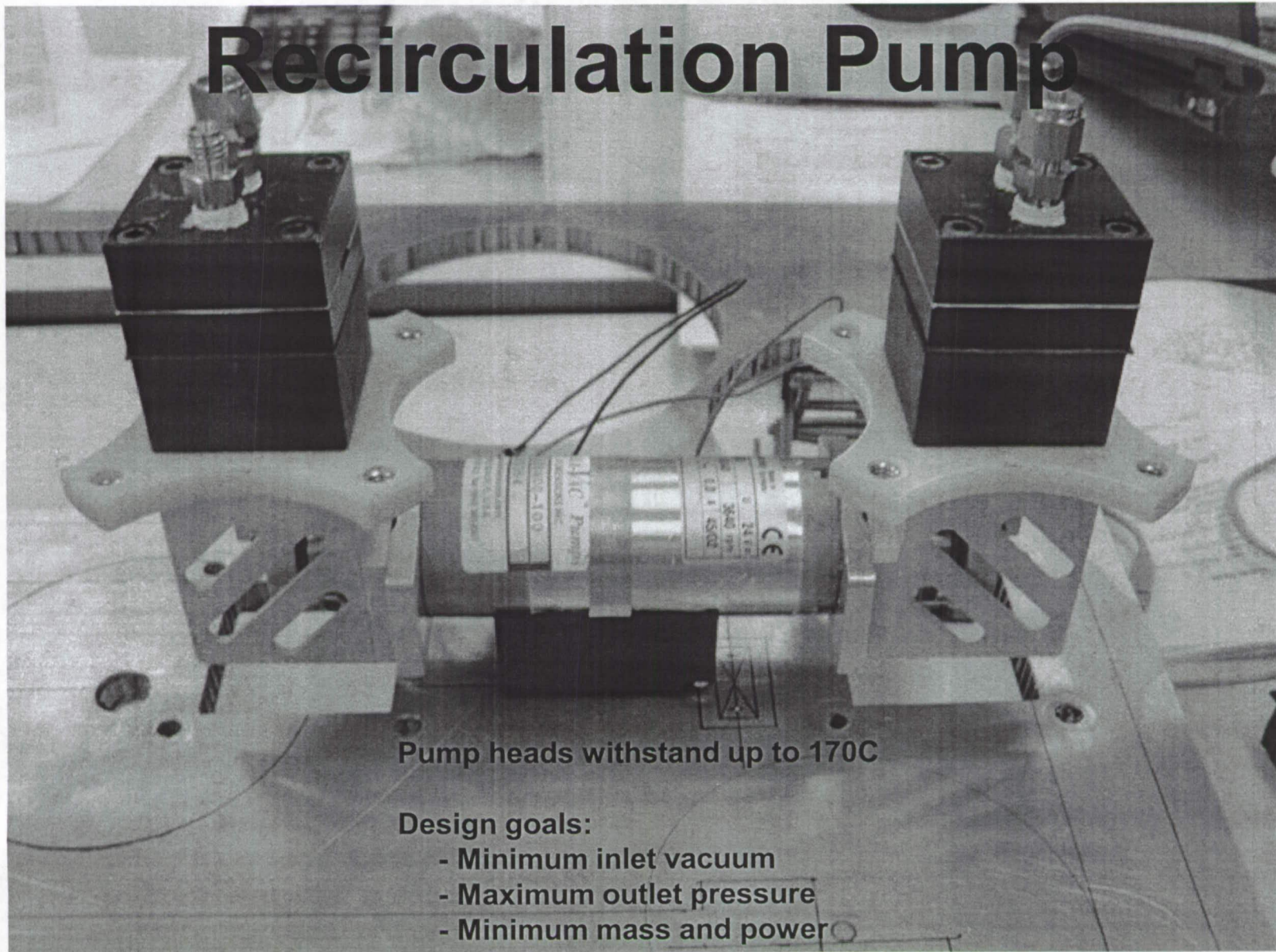
# LWRD Surge Tank



Volume = ~500 cc  
(w/ RH probe)



# Recirculation Pump

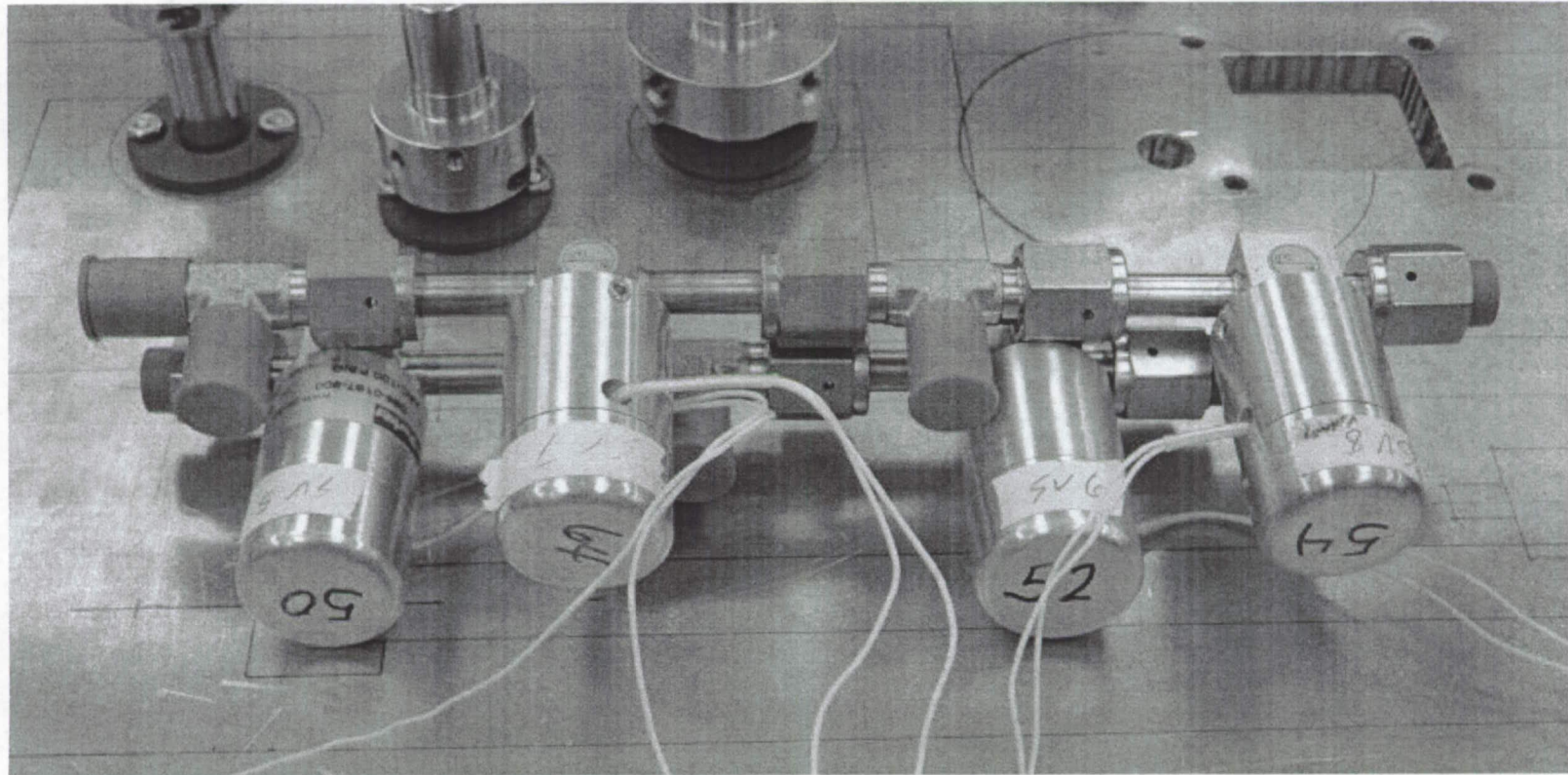


Pump heads withstand up to 170C

Design goals:

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

# High Temperature Latching Solenoid Valves

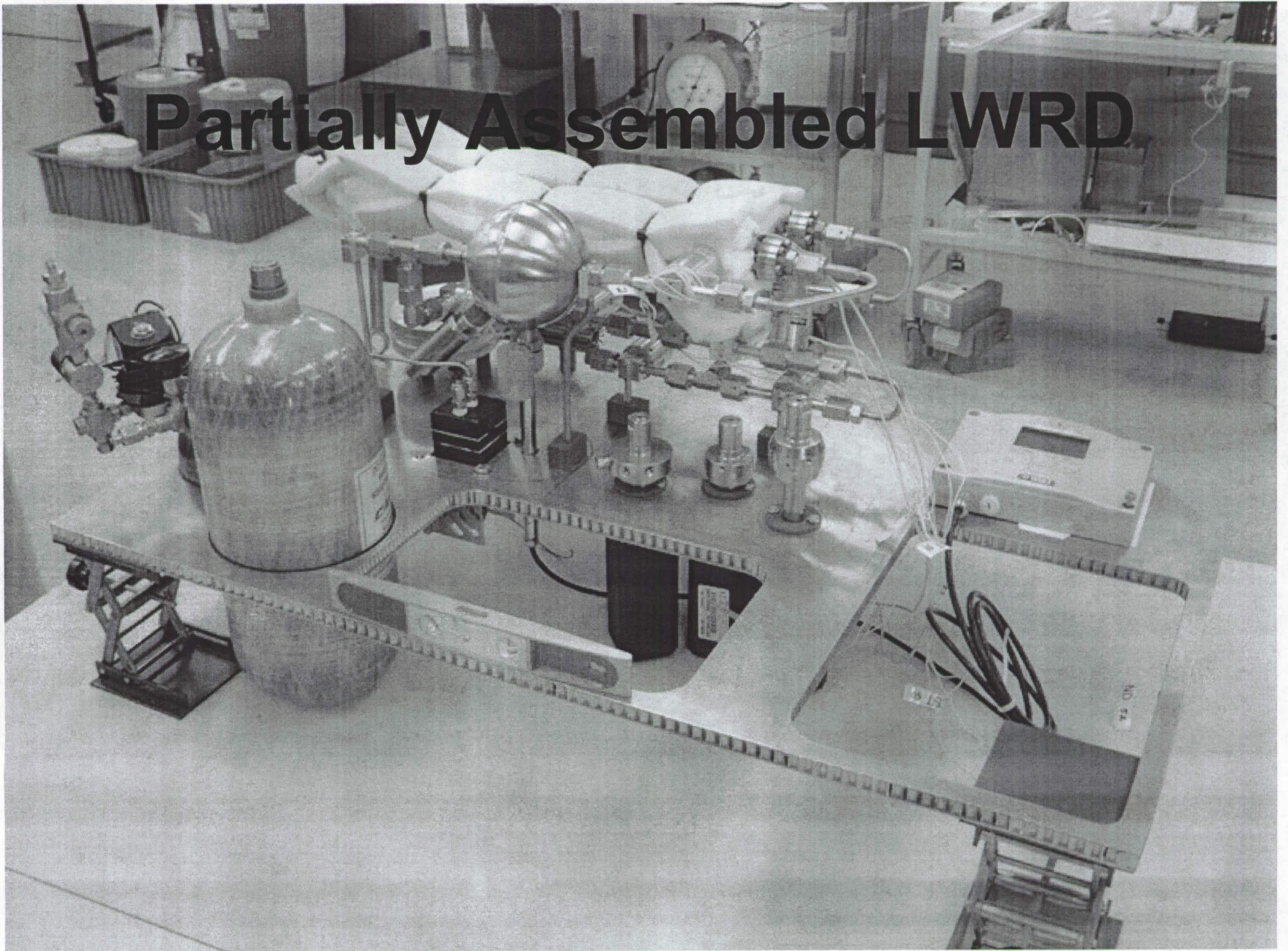


Modified standard solenoid valves at KSC

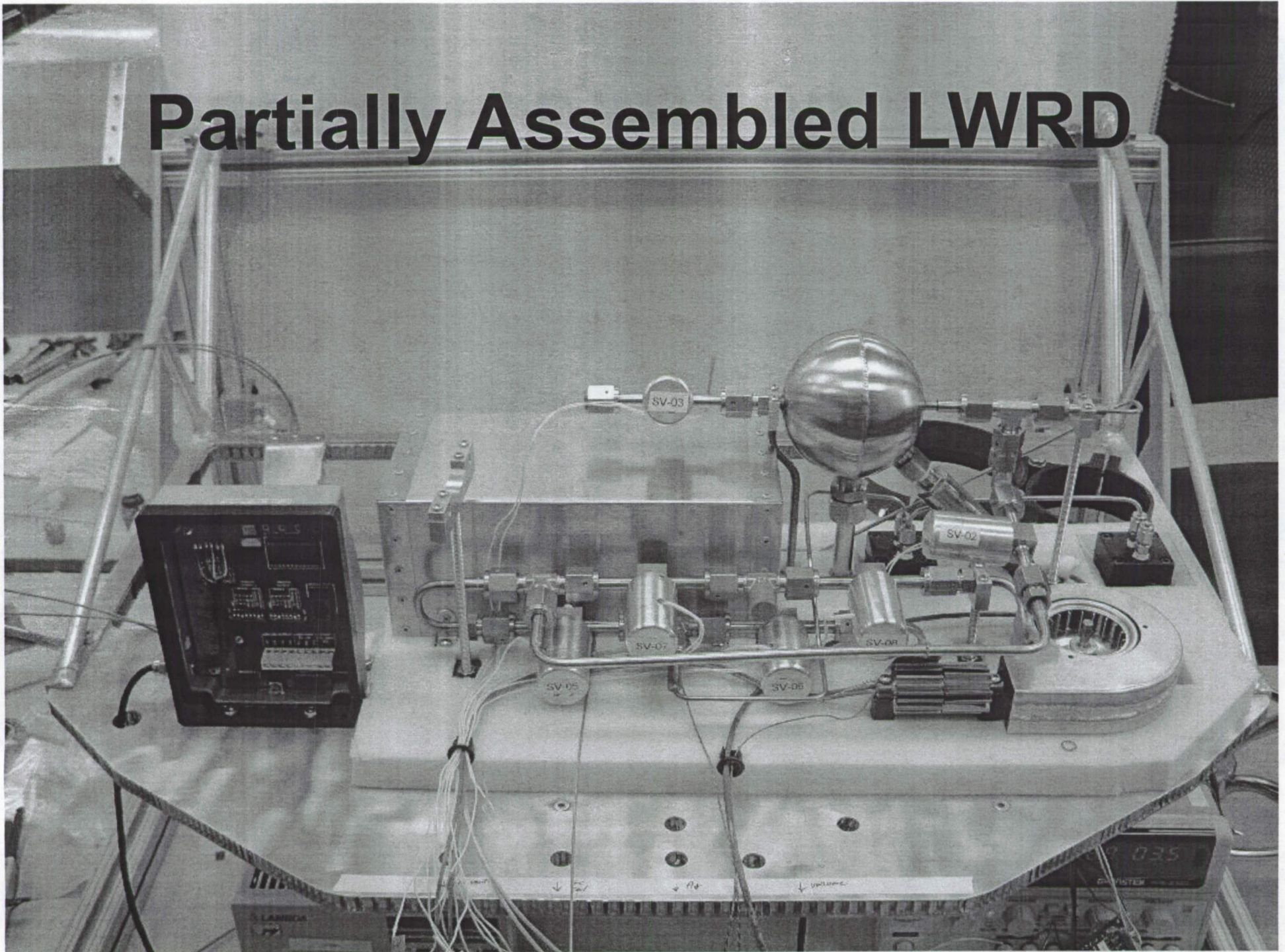
# Hydrogen Desorption

- **H<sub>2</sub> Bed size = 50 g of new absorber**
- **Absorber H<sub>2</sub> capacity = 0.10 g (0.2%)**
- **Average lunar H<sub>2</sub> expected = 0.088 g per ¼ core (0.11% H<sub>2</sub>) 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 dehydrating to completion**

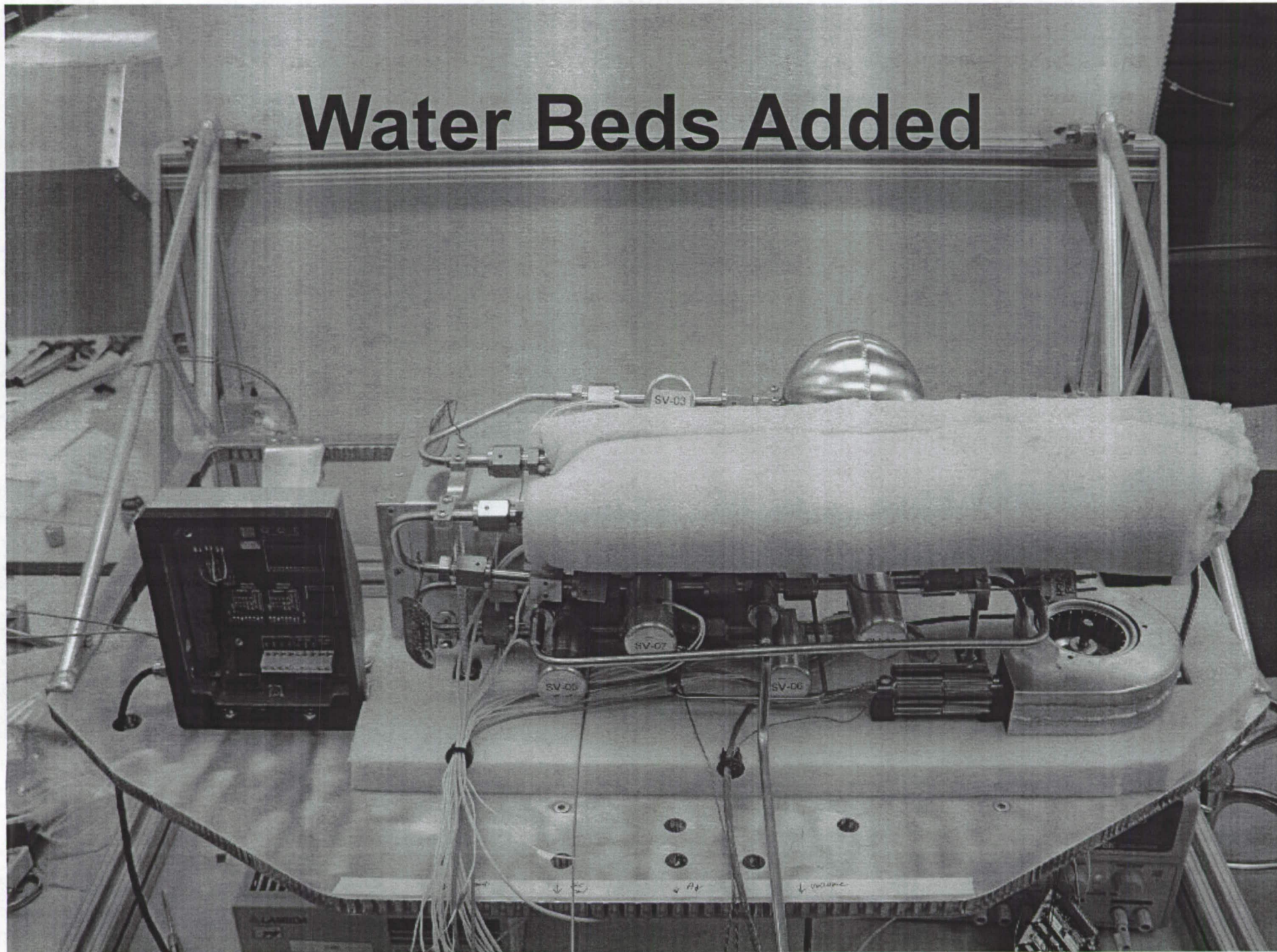
# Partially Assembled LWRD

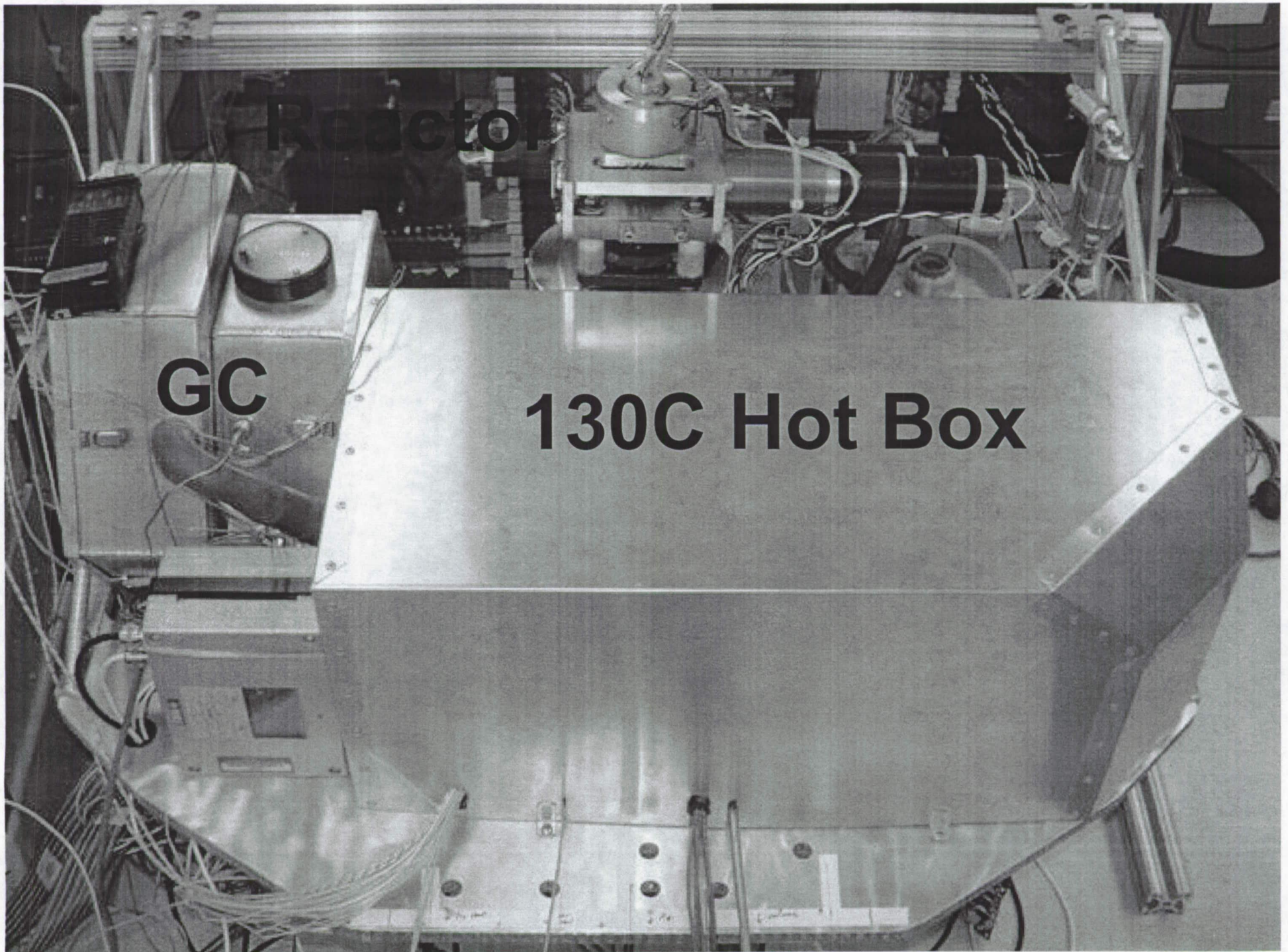


# Partially Assembled LWRD

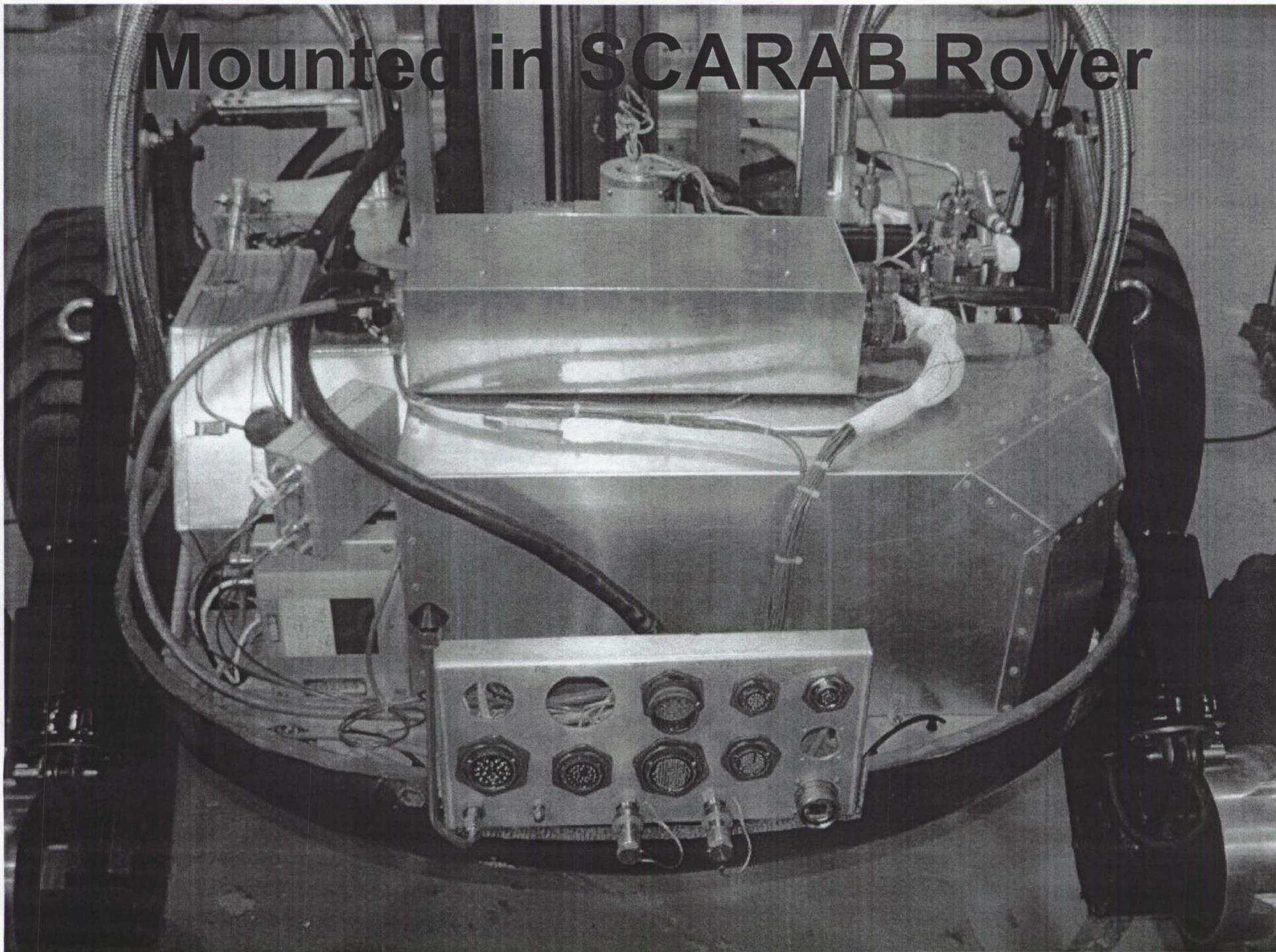


# Water Beds Added



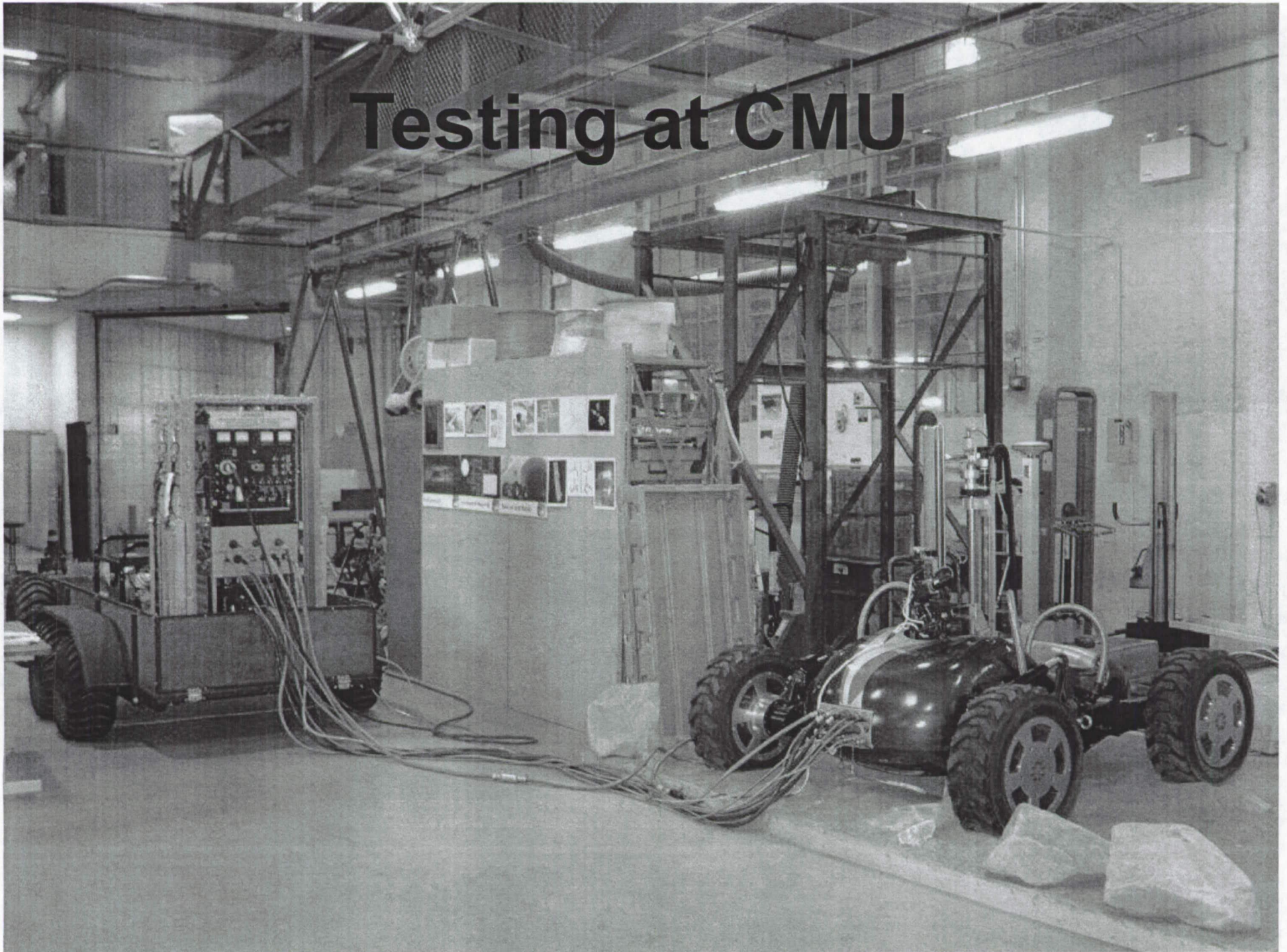


**Mounted in SCARAB Rover**





# Testing at CMU

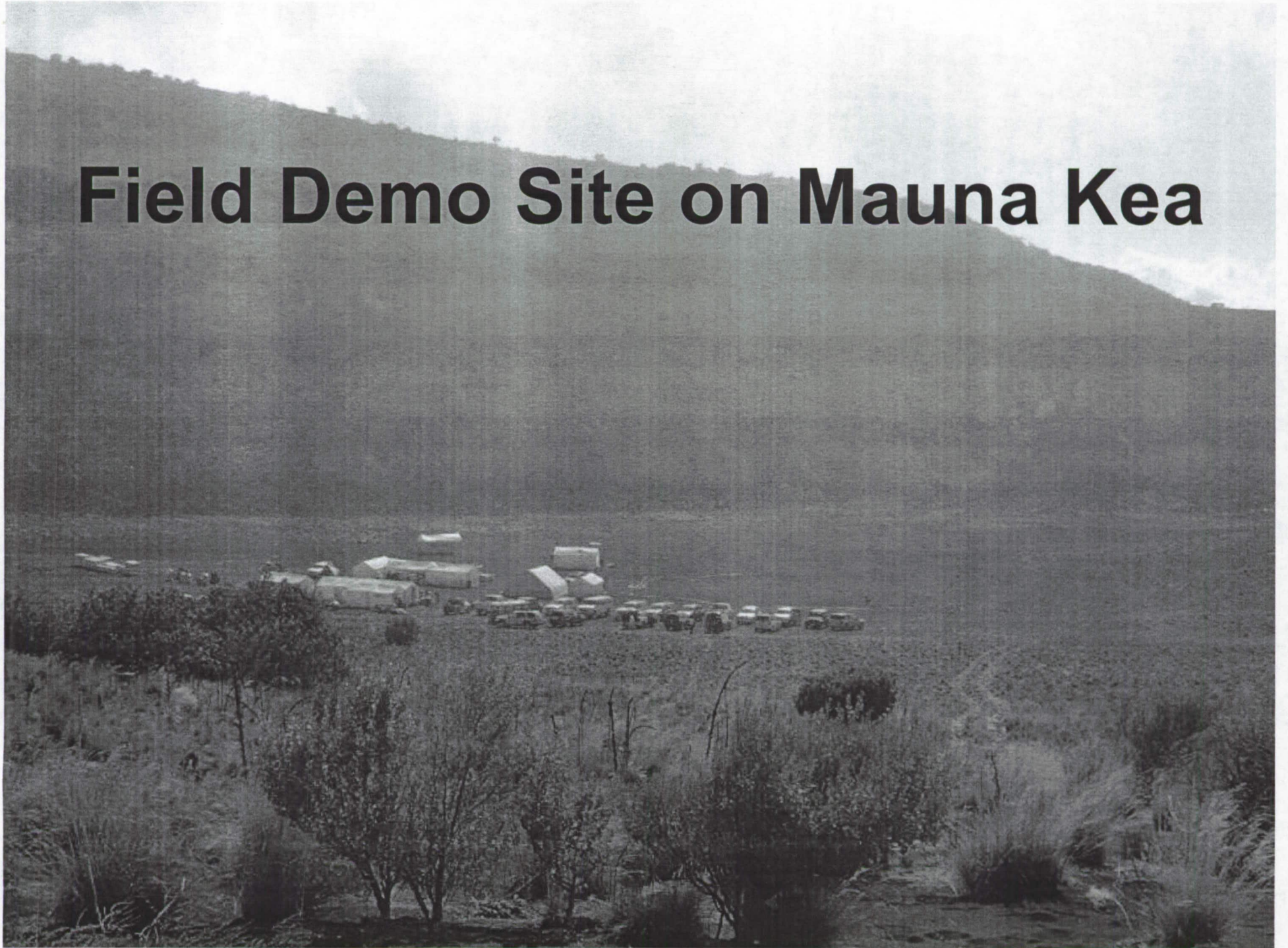


# Field Test Plan

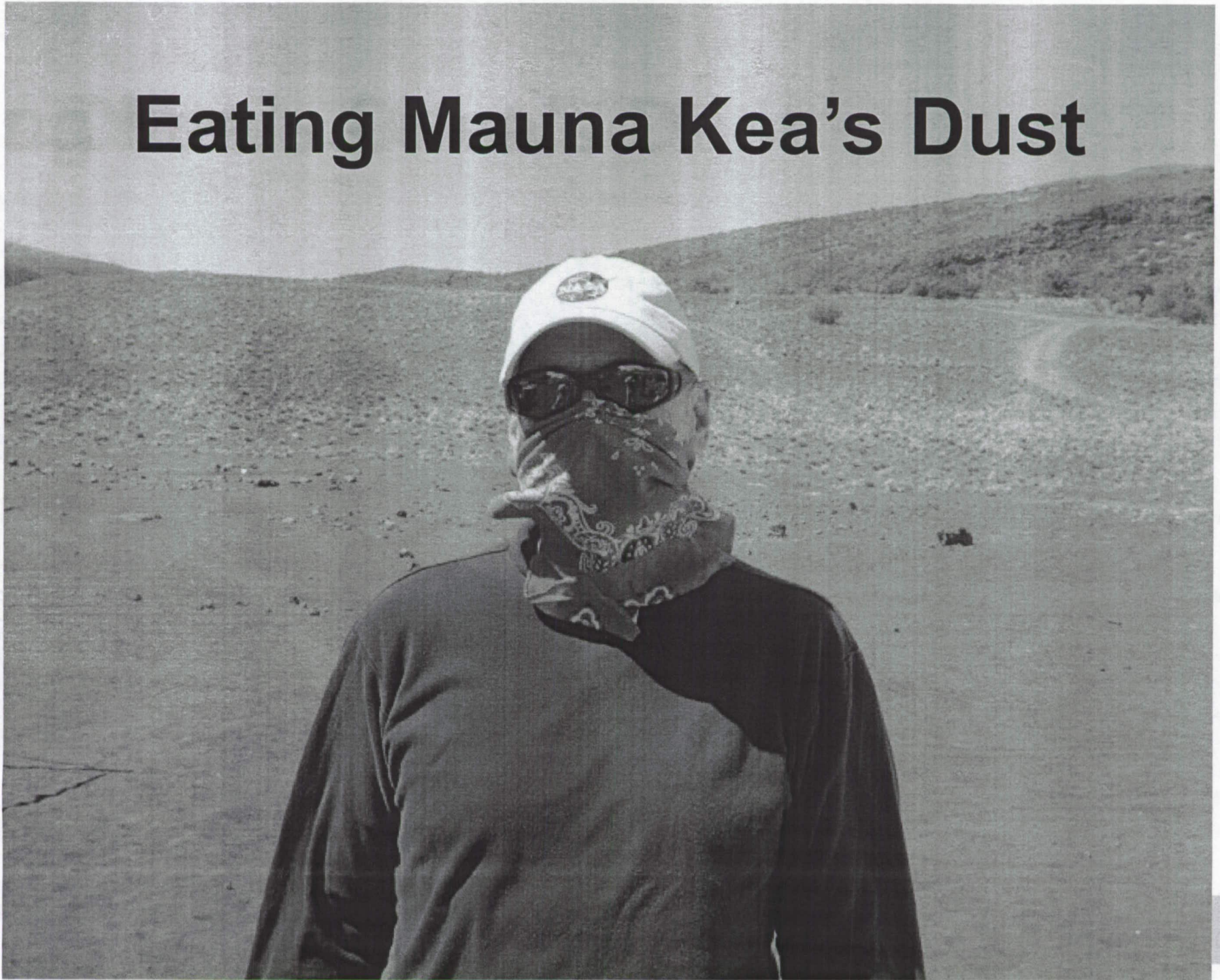
- **Lab – full capabilities demonstration**
- **Hawaii – no hydrogen absorption/  
desorption/quantification  
demonstration (run in lab at KSC after  
Field Demo)**



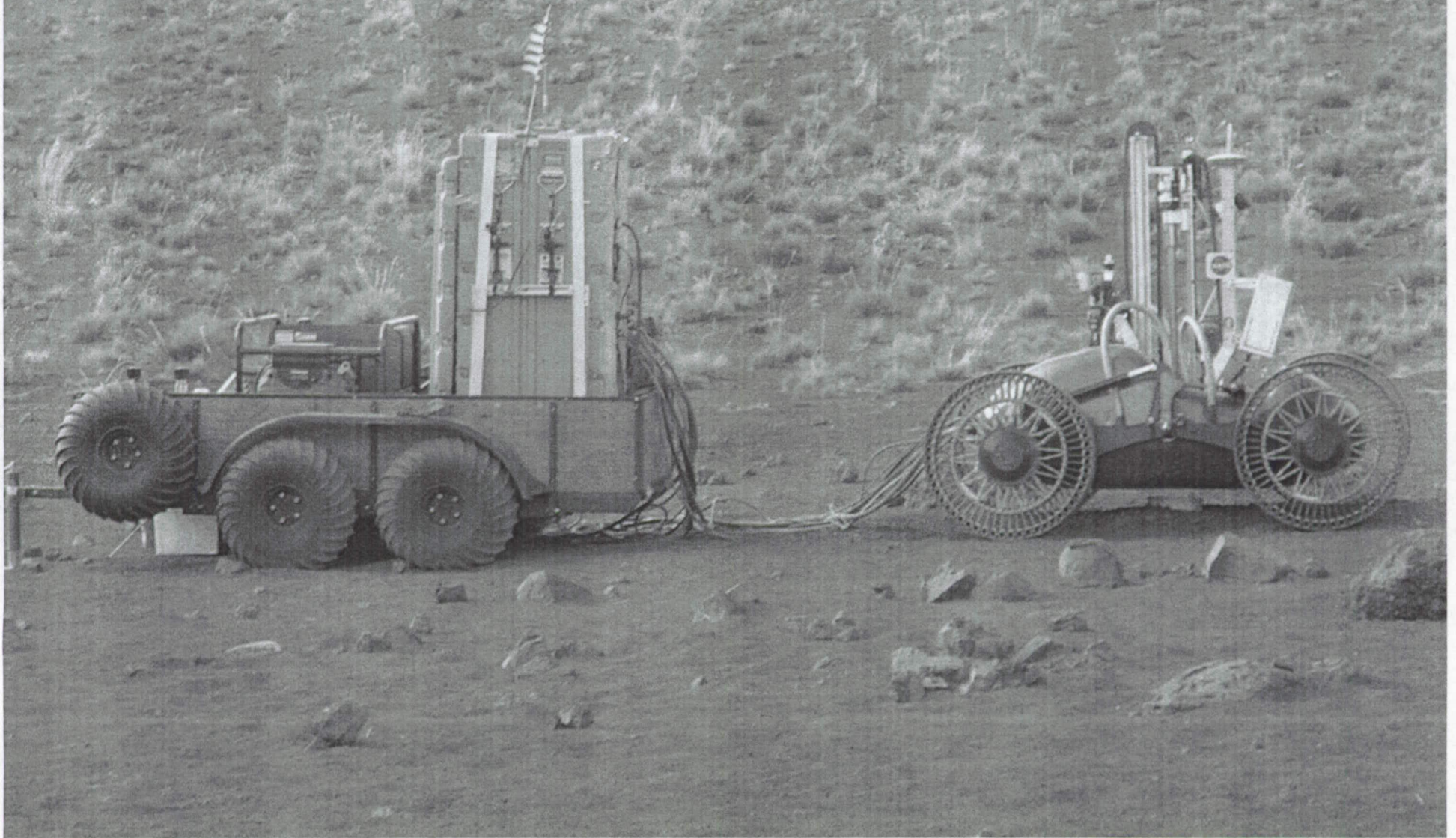
# Field Demo Site on Mauna Kea



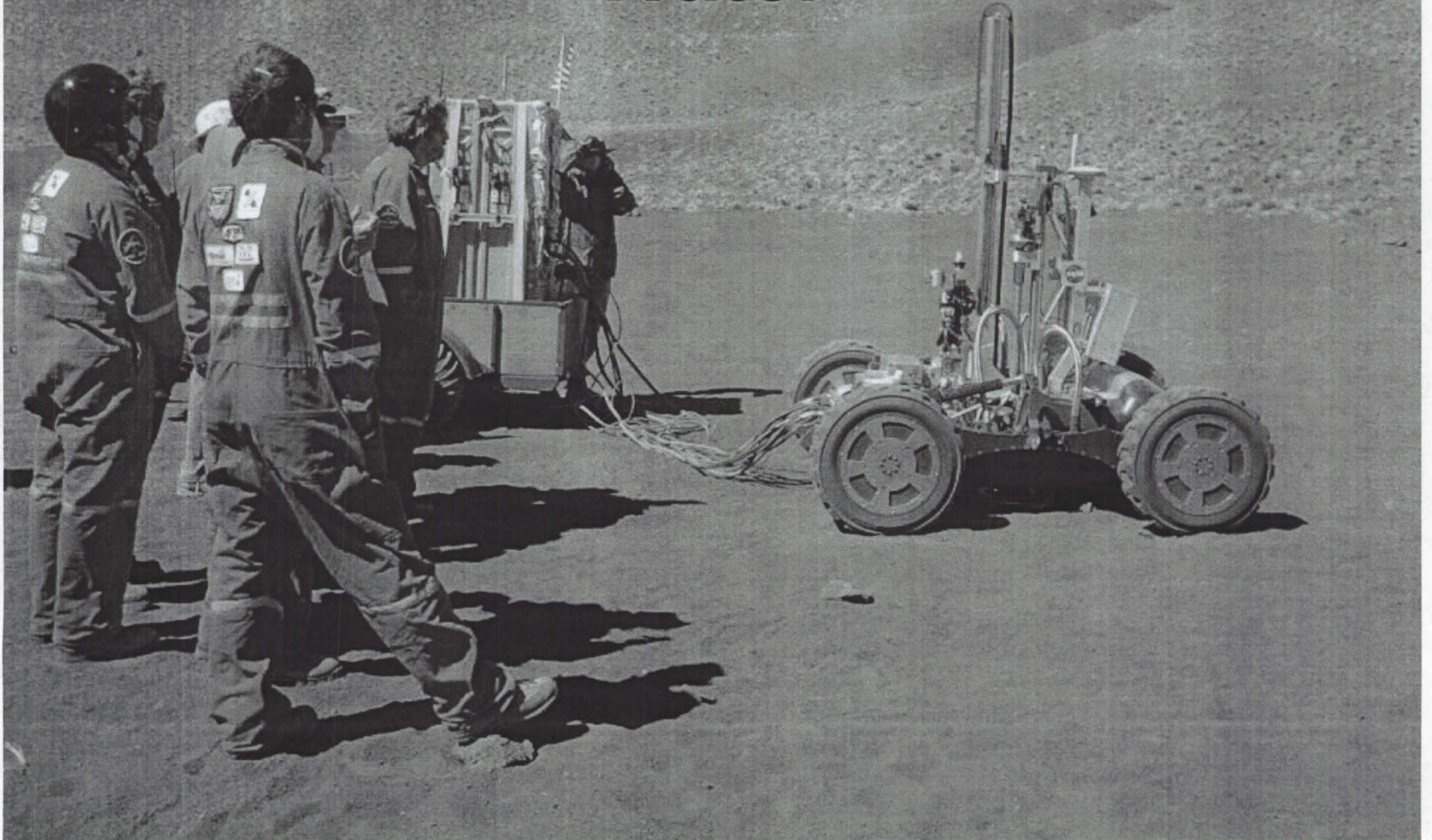
# Eating Mauna Kea's Dust



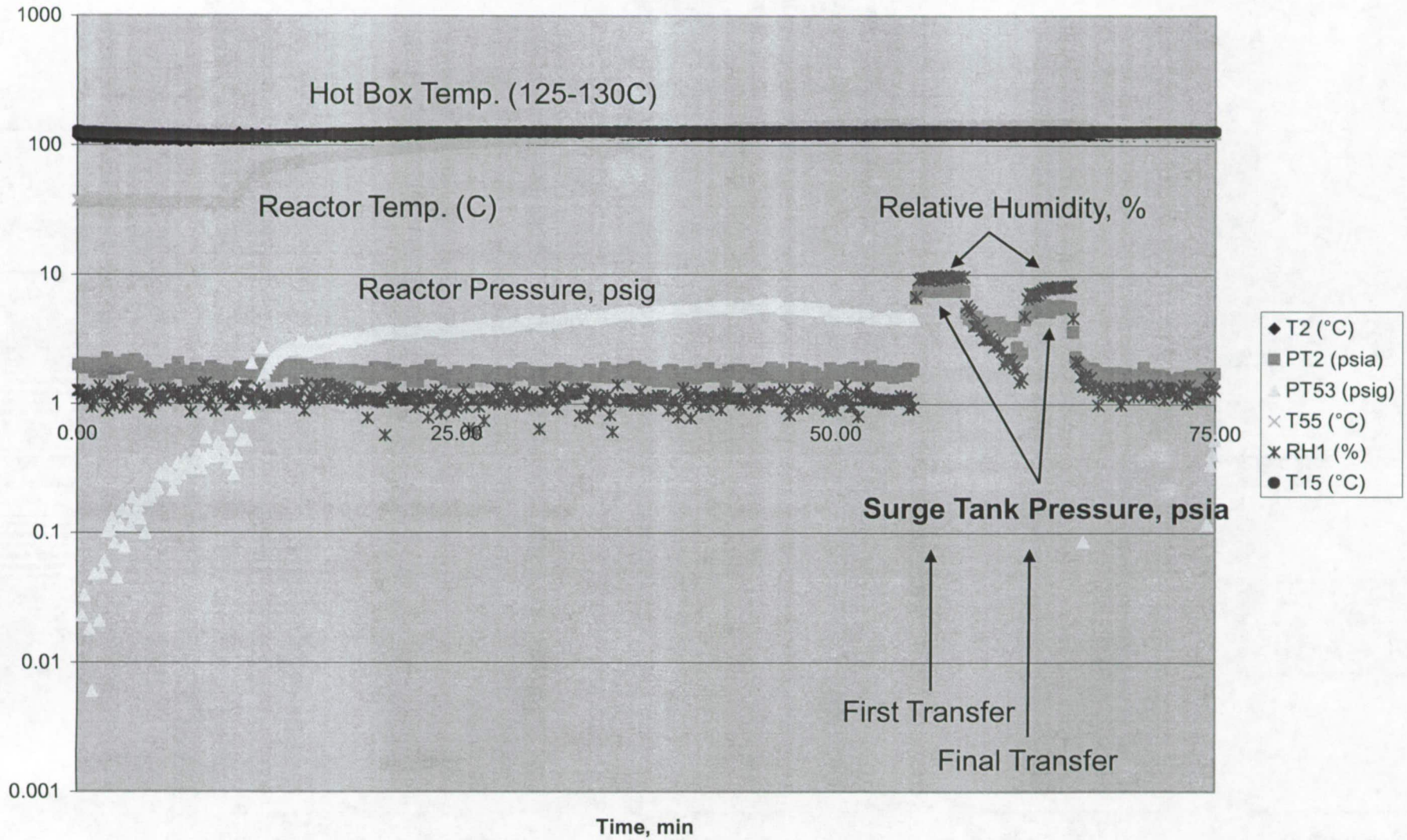
# GSE Cart and Rover Ready to Operate



# 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 <sub>2</sub> )	0.22*

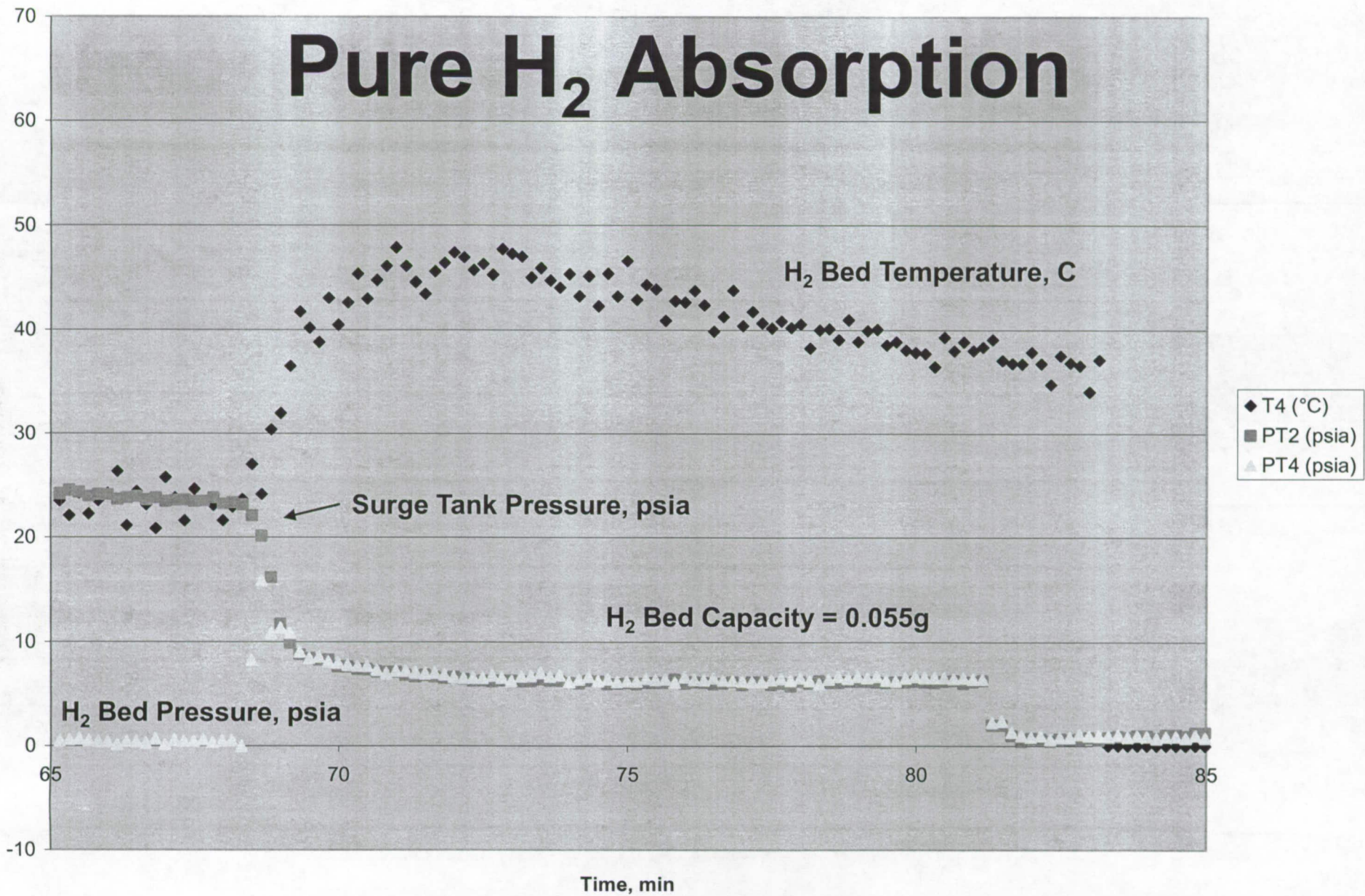




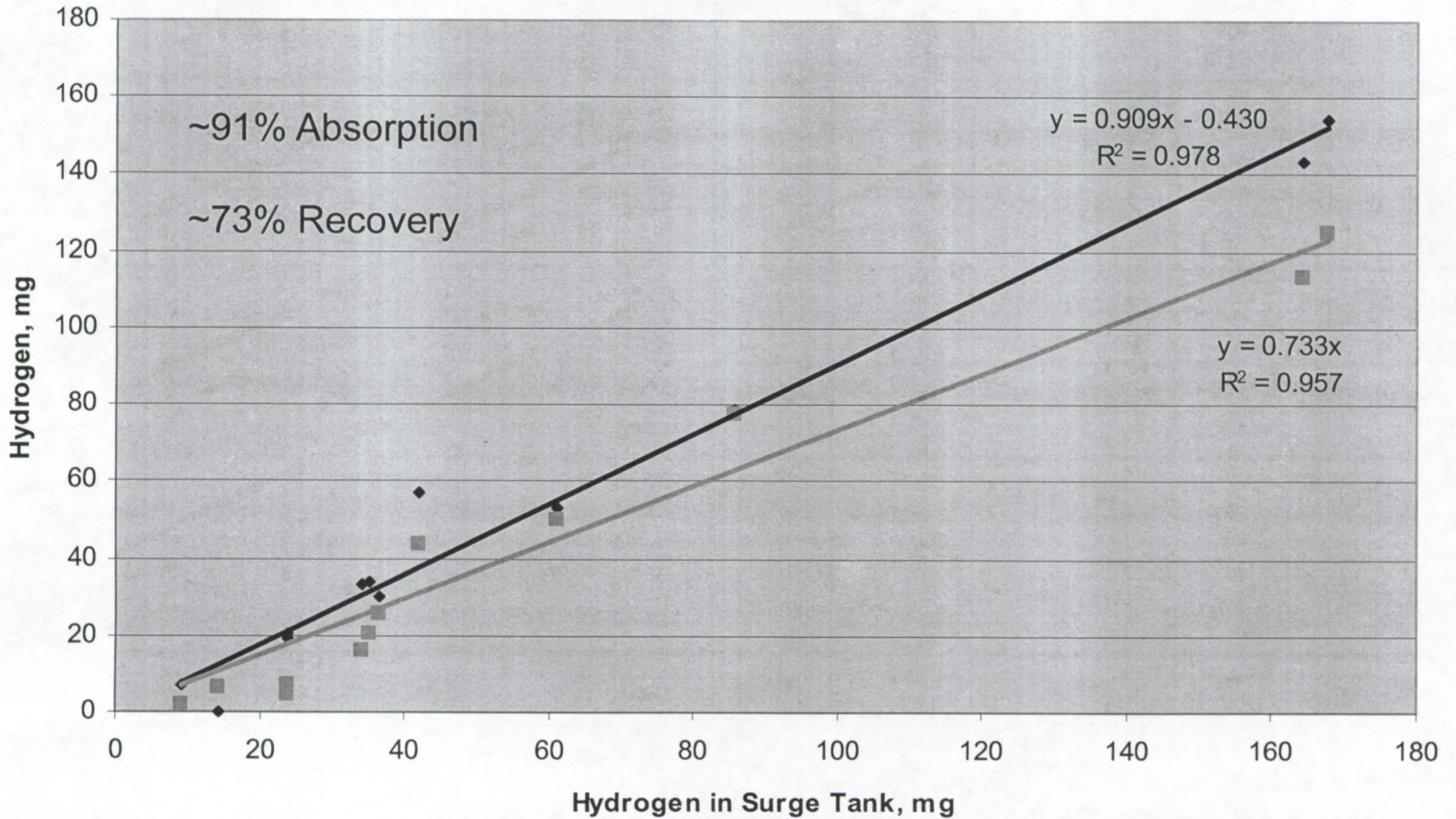
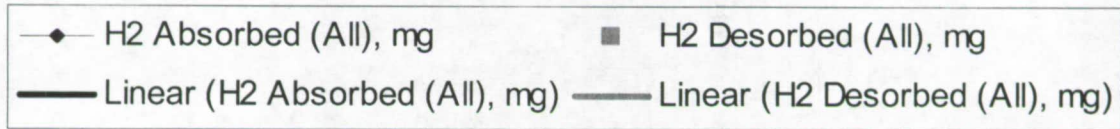
# Field Demonstration Results

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<sub>2</sub> Absorption



# 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**

