Requirements and Progress Towards a Planetary Surface Simulation Facility

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Planetary Surface Simulation Facility

- ISRU project has identified need to have capability to perform integrated system tests in a thermal vacuum environment with large amounts of soil to simulate the lunar/planetary surface
- Ideally would be sufficient size to test and drive small excavator or prospecting rover with integrated ISRU hardware
- Objective is to test all components that will interact directly with the lunar or planetary surface and the abrasive, dusty regolith

Planetary Surface Simulation Facility – Previous Work

- Conducted national survey for thermal vacuum chambers
  - Experience operating with simulant/dust
  - Willing to operate with simulant/dust
- Several possible chambers both within NASA and in industry
  - No large to extra large (greater than 15 ft) chambers (operational) with experience with simulant
  - Any chamber selected will require special test equipment to prepare simulant bed to desired conditions
- Results of survey have been approved for open distribution
  - Contact author at email below to request a copy

Learning How to Prepare Simulant Bed

- Compact bed before sealing chamber and pumping down
  - Dry simulant prior to compaction at atmospheric pressure (e.g., heat, stir, etc.)
  - Control pump down speed in critical pressure range to reduce violent off-gassing
  - Cover bed with perforated plate to hold simulant in place while still providing path for volatile release
- Compact bed after pump down
  - Auger/stirring mechanism to speed up release of volatiles
  - Warm simulant bed to aid in volatile release
  - Vibration to 'fluff' simulant during drying/pump-down, then change frequencies to compact
  - Mechanical compaction (e.g., tamper)
  - Fill bed in layers with compaction in between each simulant addition

Learning How to Prepare Simulant Bed

- How do we protect the facility equipment from effects of dust clouds?
- How do the volatiles permeate out through the bed?
- If compacting after pump-down, what method(s) works best?
- How do we measure the simulant properties (compaction, cohesion, moisture content, etc.) inside the vacuum chamber?
- How do we introduce and maintain a controlled moisture content in simulant?

Facility Assessment Tests
K. Shaw, NASA GRC, 2008

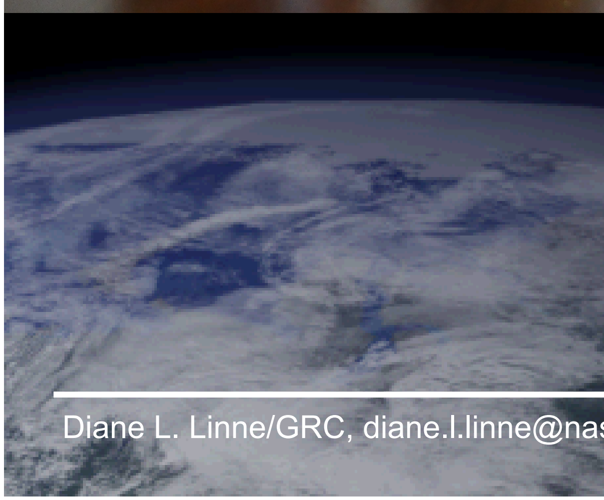
Facility Assessment Tests

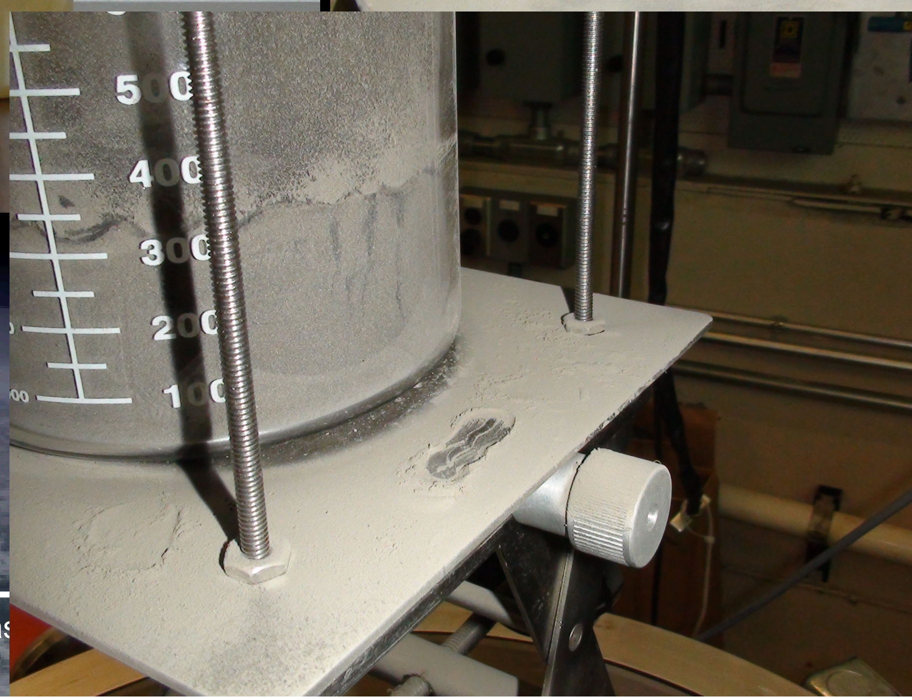
- Objective: create simulant (JSC-1A) disturbances and measure effects on facility
- Approach
  - Baseline pump-down and take ‘clean’ oil sample
  - 10 operating cycles using rough pump only
  - 10 operating cycles using holding pump though oil diffusion pump
  - Take oil samples, compare pump-down capacity, check components

Facility Assessment Tests

- Disturbances consistently occurred during bell jar evacuation between 2 – 7 Torr
- Simulant samples weighed 600 – 800 gms before testing and lost 2 – 3 gms during pump down

Facility Assessment: Before/After





Facility Assessment Test Results

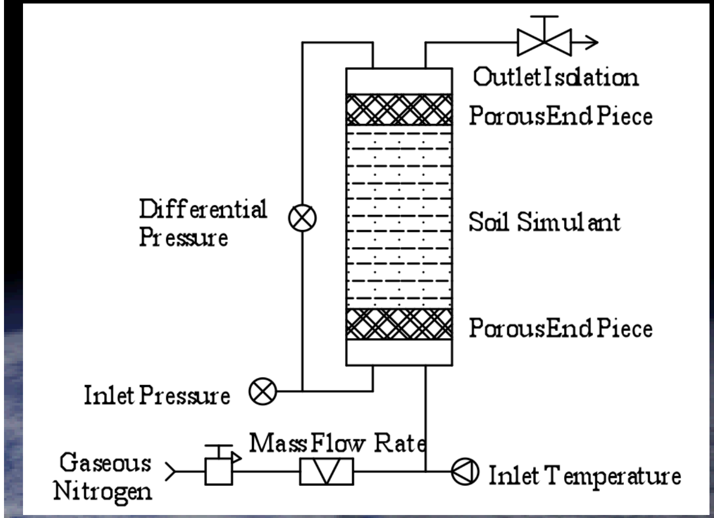
- Base Pressure
  - Before: 5.88 x 10-7 torr
  - After: 9.67 x 10-7 Torr
- Pumping Speed – Rough Pump
  - Before: 0.382 L/s
  - After: 0.379 L/s

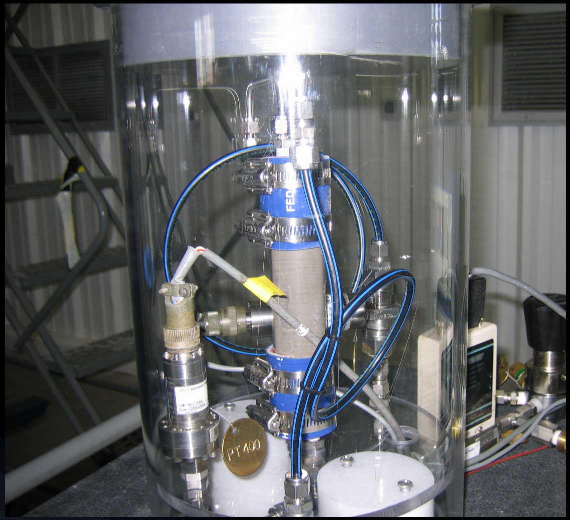
	Hours of Operation b/w Samples	Change in Particulate Counts by Size (ppm)			Change in Contaminants (ppm)
		>14.1 microns	6.1 – 14 microns	4 – 6 microns	
Roughing Pump	6.7	+382	+2257	+253	Silicon +28
Holding Pump	145.3	-382	+2712	-1338	Silicon +9
ODP	132.4	+1038	+3659	-918	Silicon +33

Gas Permeability Tests
M. McClean, NASA JSC, 2008

Gas Permeability Tests

- Objective: determine permeability of compacted simulant to aid in analysis of gas transport out of soil during evacuation
- Approach: ASTM D6539, *Standard Test Method for Measurement of Pneumatic Permeability of Partially Saturated Porous Materials by Flowing Air*



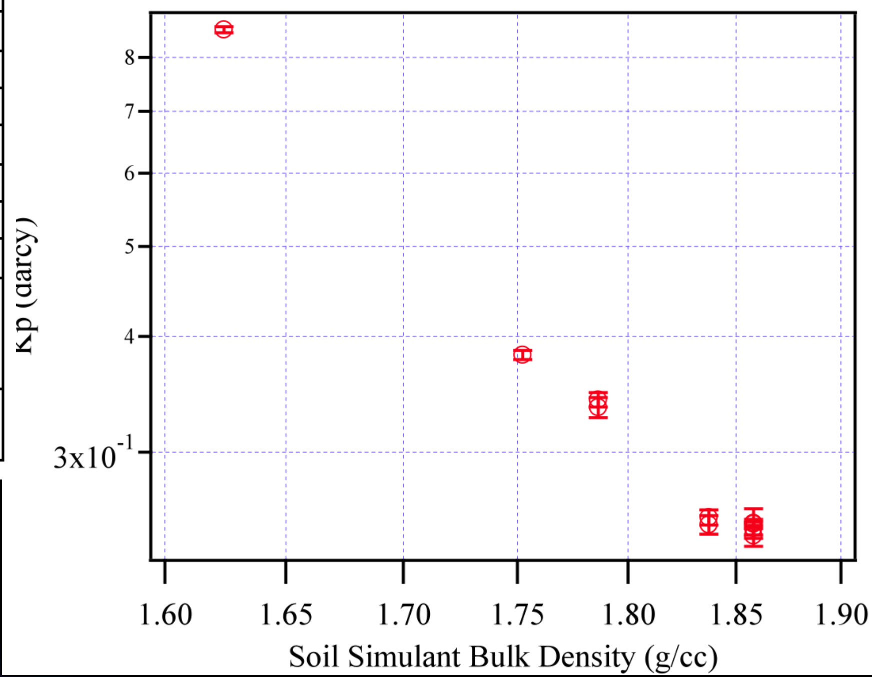


Gas Permeability Test Variables

- No compaction: spooned simulant into test cylinder
  - Gas flow created void channels (failed check for Darcy's law)
- Vibration compaction: mechanical etching tool placed against cylinder
  - some visible separation of particle sizes (finer particles migrating toward bottom of each increment of simulant)
- Mechanical compaction: tamping tool (100 gm) dropped from set height (28 cm) 1 or more times
- Two permeameter cell lengths: 9.2 and 22.2 cm
- JSC-1 simulant

Gas Permeability Test Results

Compaction Method	Density (g/cc)	Kp (darcy)	σ
None (*flow channeling lead to a violation of Darcy's Law*)	1.46	*3.491*	*0.533*
		3.129	*0.564*
Vibration to compact simulant from "A" test series and while additional simulant spooned in	1.86	0.244	0.006
		0.251	0.009
		0.251	0.003
		0.248	0.004
Five strikes of tamping tool after each of six incremental simulant additions	1.79	0.335	0.008
		0.342	0.006
Five strikes of tamping tool after each of fourteen incremental simulant additions	1.84	0.255	0.005
		0.250	0.006
One strike of tamping tool after each of nine incremental simulant additions (22.2 cm long cell)	1.62	0.857	0.007
Vibration while simulant spooned in (22.2 cm long cell)	1.75	0.382	0.004



- Results can be used to estimate evacuation times for packed simulant beds

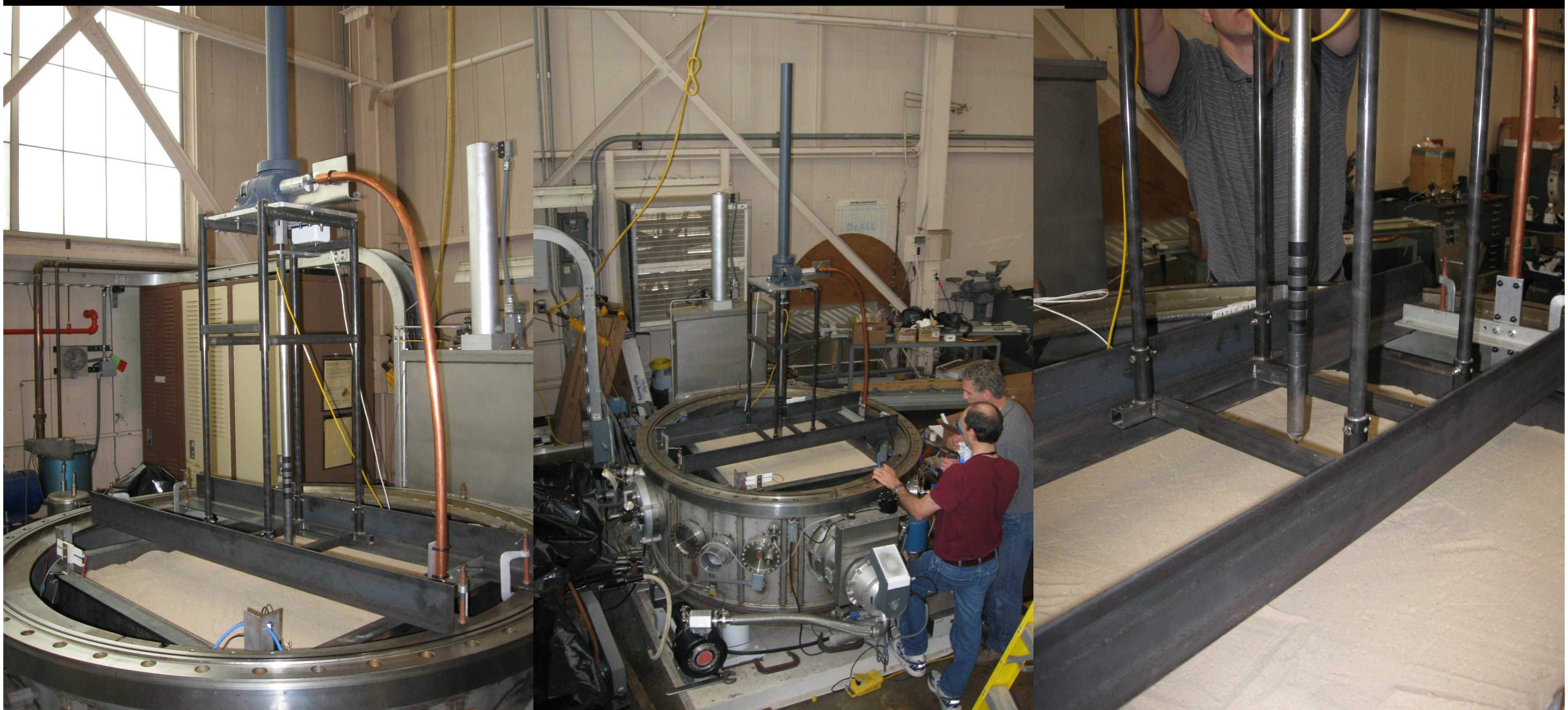
Soil Compaction Tests

A. Wilkinson, J. Kleinhenz, NASA GRC, In-progress

Soil Compaction Tests

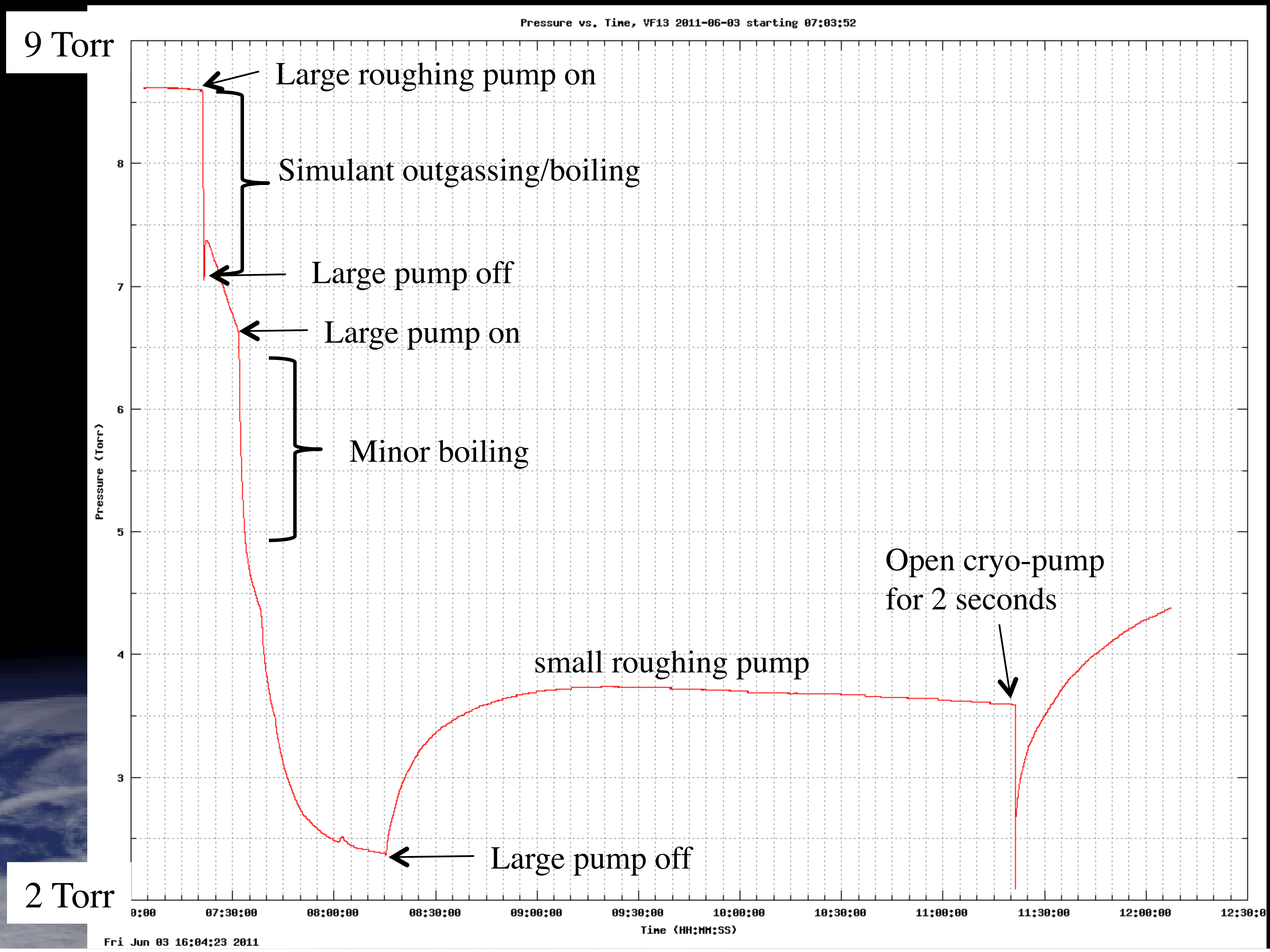
- Objective: Develop methods to compact and measure simulant bed
- Approach (Phase I)
  - 3’ x 3’ x 2.25’ deep simulant bed installed in vacuum chamber
  - Control pump-down speed/time to minimize disturbances
  - Measure properties with cone penetrometer
- Soil Prep methods (Phase II/III)
  - Tamper (2-axis)
  - Fill bed from hopper after pump-down
  - Soil ‘aeration’ during pump-down

Soil Compaction Tests



Soil bin filled with GRC-3 and installed in chamber with cone penetrometer (Phase I)

Soil Compaction Tests

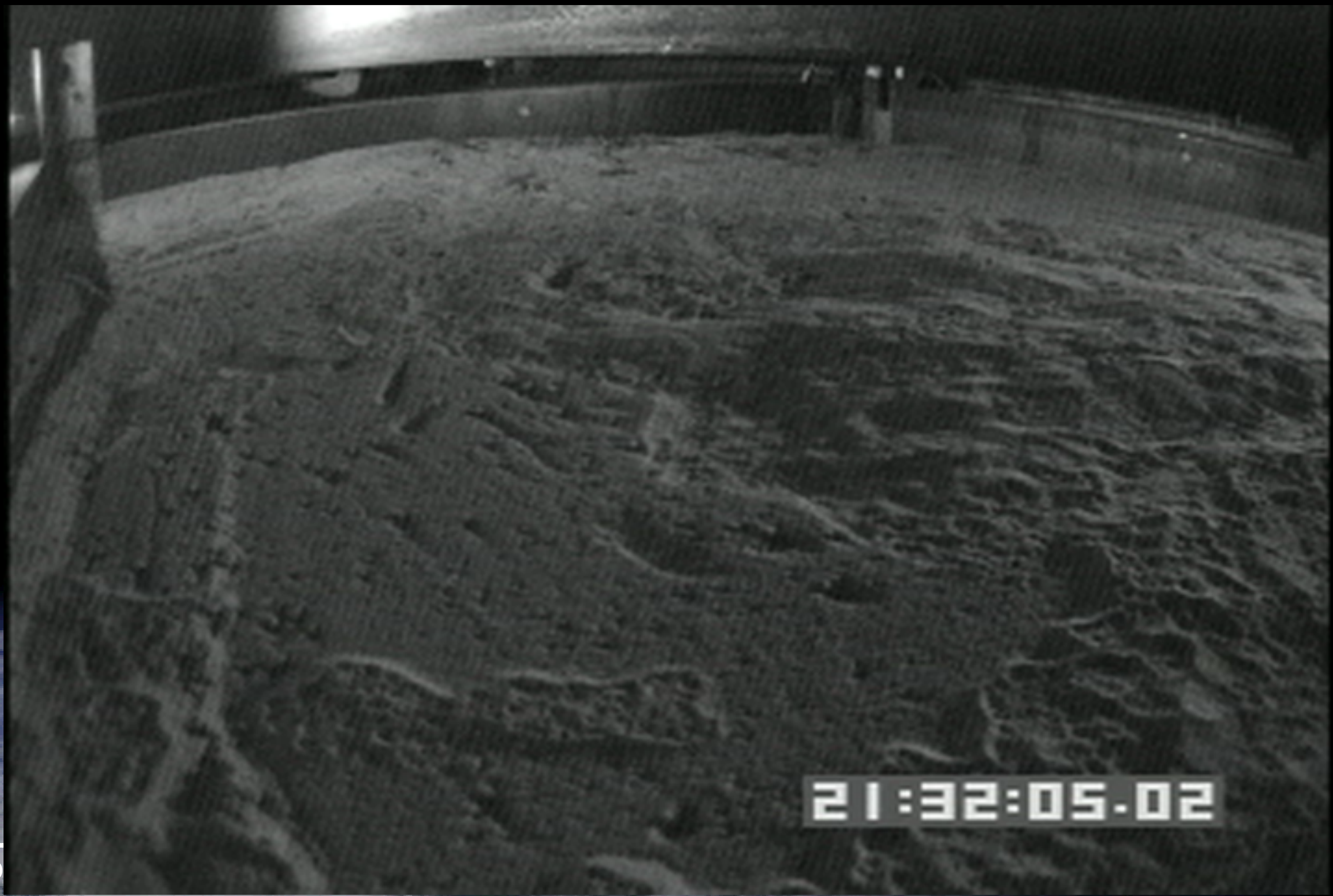


Soil Compaction Tests – Roughing Pump

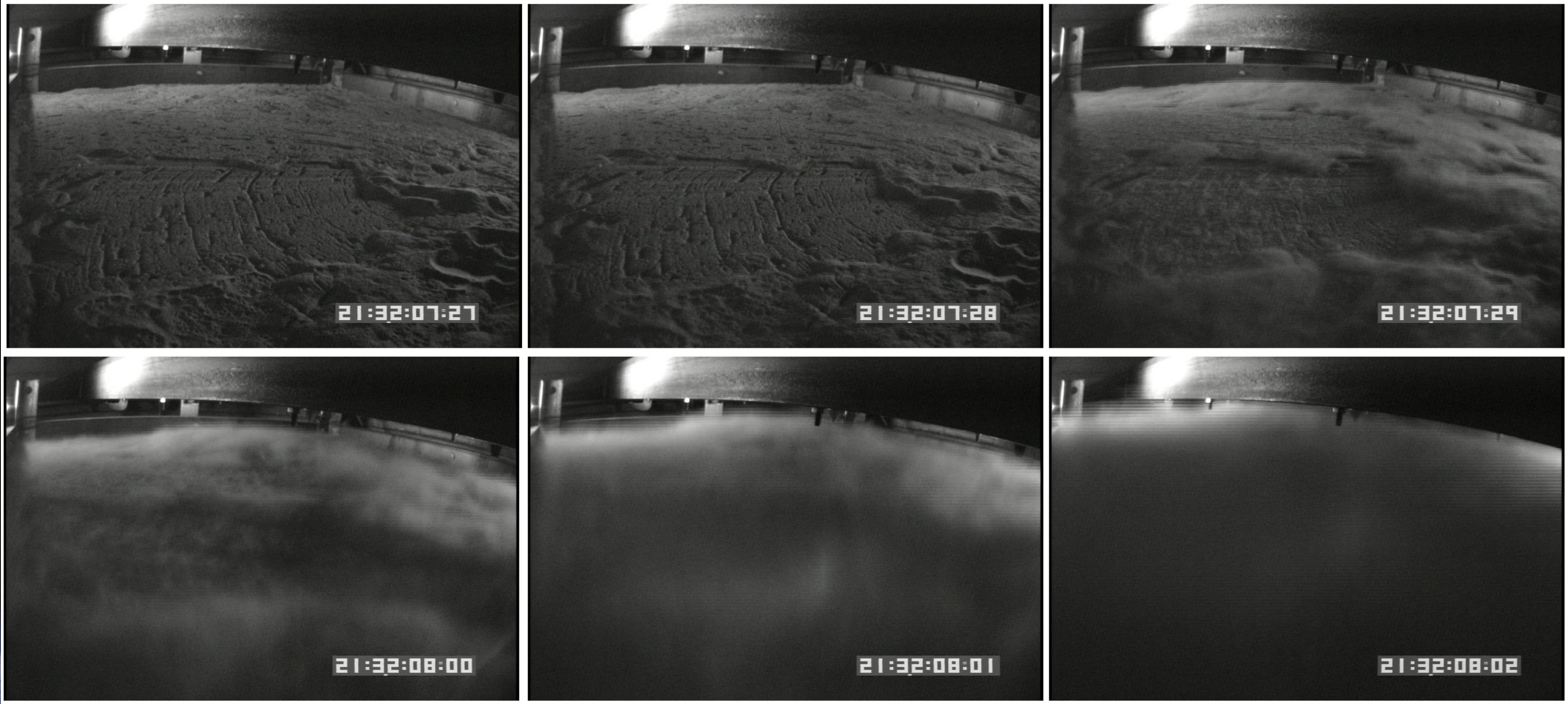
A. Wilkinson, J. Kleinhenz, NASA GRC, Current

Soil Compaction Tests – Cryo Pump

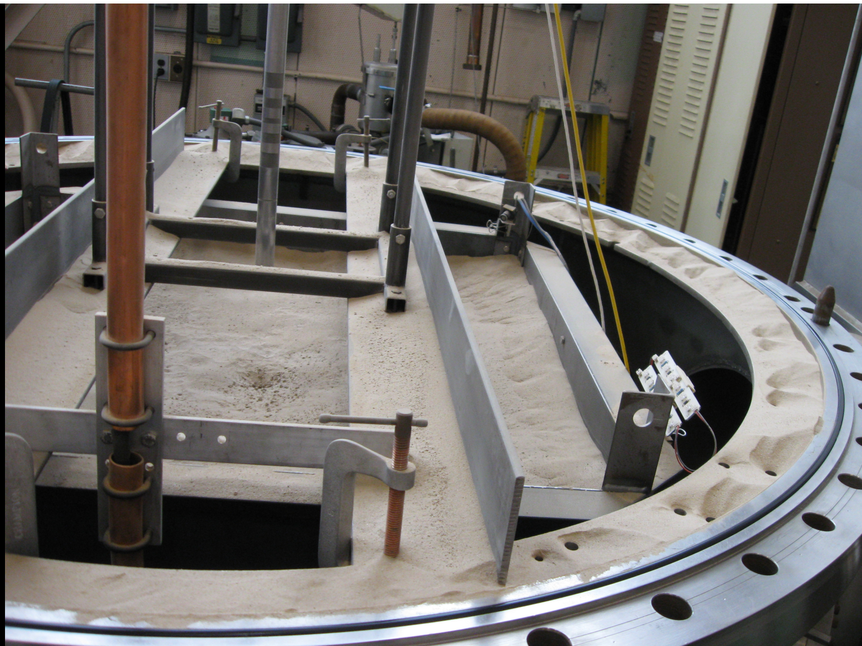
A. Wilkinson, J. Kleinhenz, NASA GRC, Current



Soil Compaction Tests



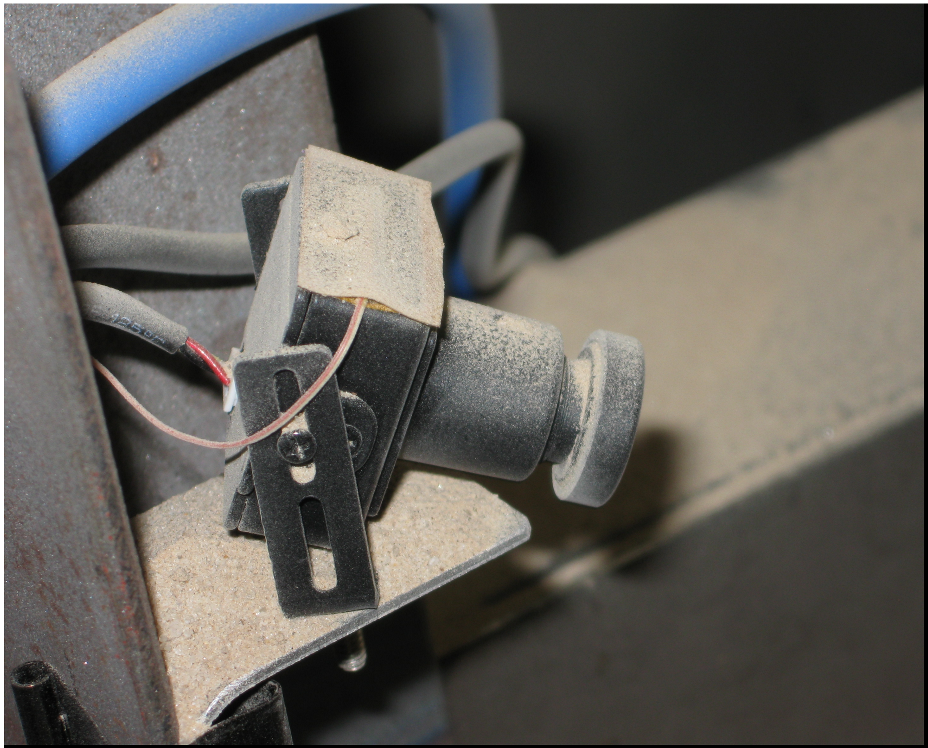
Soil burst when Cyropump activated at ~4torr. Image sequence from video.

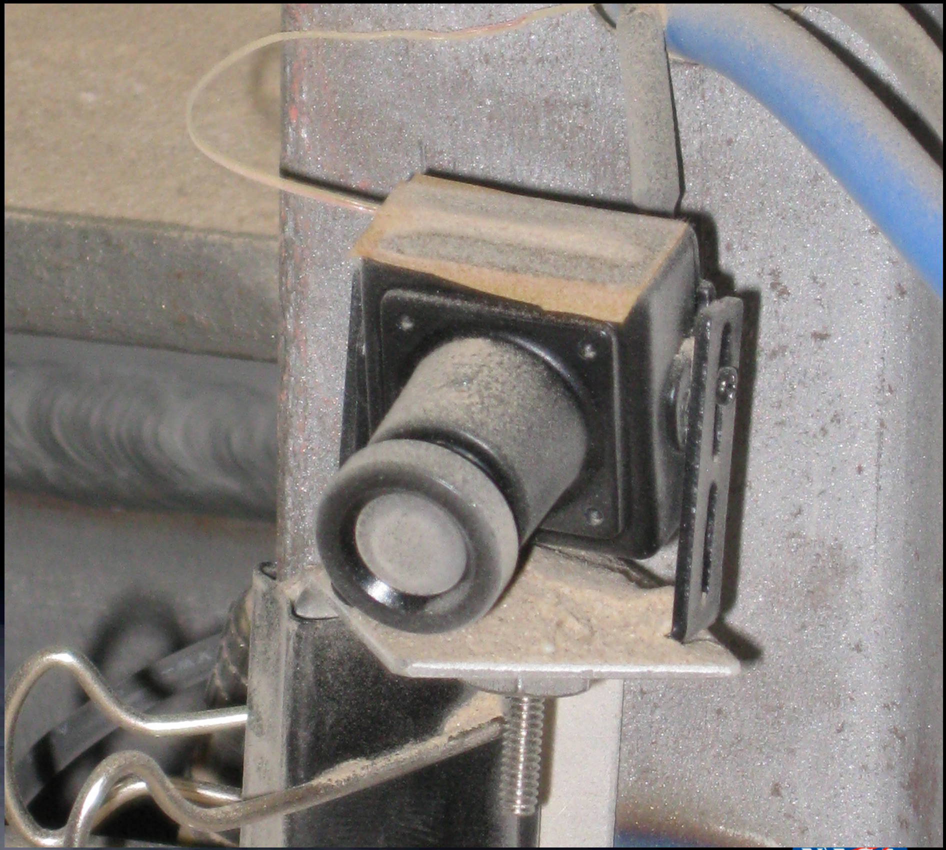


Interior of chamber post-test

Bottom of chamber under soil bed

Location of cone penetrometer test





Camera coated with dust after cryopump burst

Remaining Work

- How to prepare icy dirt (or dirty ice) and maintain conditions in chamber?
- Drill tubes (one concept)
  - Prepare simulant with proper moisture content in drill tube
  - Attach tube to bottom of simulant bed
  - Chill tube to cryogenic temperatures (possibly cap off)
  - Pump down chamber and remove cap
- Icy regolith preparation (e.g., for Mars regolith excavation)
  - ???
- Measure moisture content inside vacuum chamber

Facility Requirements and Selection

- Facility Requirements Document draft (almost) complete
  - Based on RESOLVE Hardware
  - Some specifications still need work
  - Sufficient detail to make a tentative facility selection
- Call to interested NASA facilities (coming soon)
  - Will work call through NASA Space Environment Test Alliance Group (SETAG) out of NASA HQ
  - Facilities to outline their capabilities, plans and costs for upgrades, and projected operating costs
- Continue to advocate need for such a facility capability and look for funding source