SAMPLR – A Lunar Regolith Geophysical Evaluation Instrument and Development of an In Situ Calibration Method

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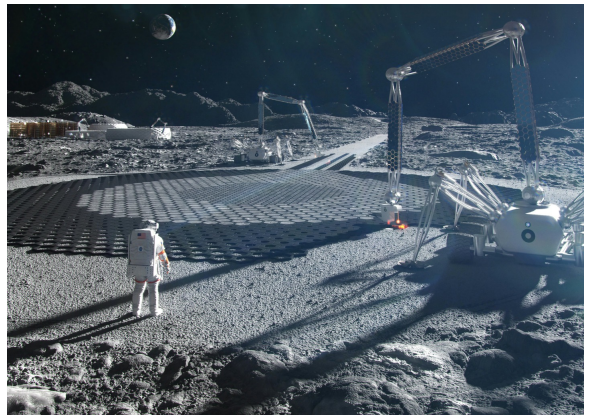
Why does Geotech on the Moon matter?



The lunar surface is not uniform

- Varies in composition, grain size distribution

- Lunar Construction
  - Site preparation, roads, pathways, foundations
- Natural Hazards
  - Slope stability
- Mobility
  - Rover traction, excavation

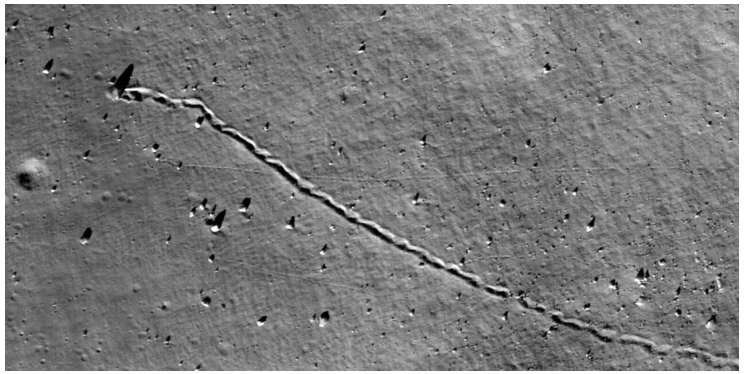
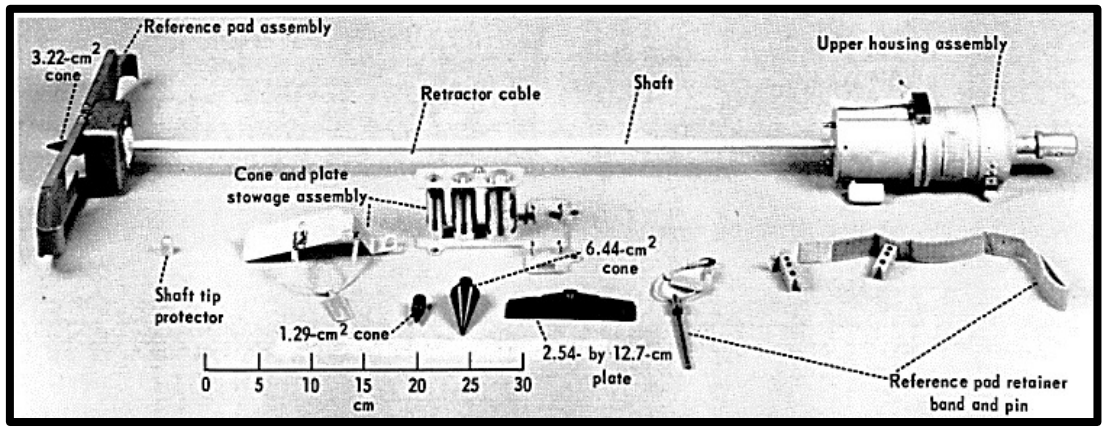


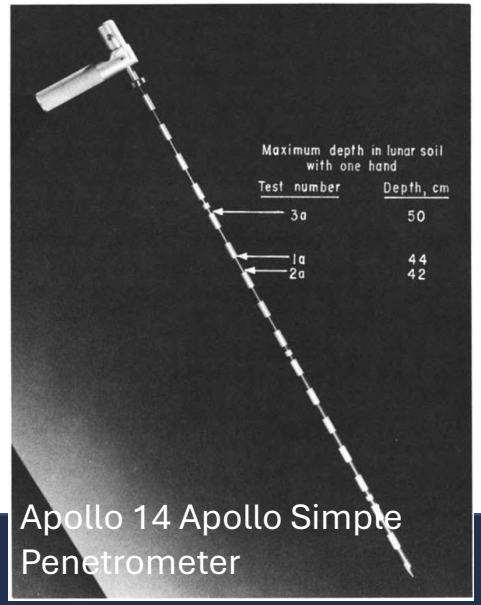
Image Credit NASA

Measurements have been done, we need more

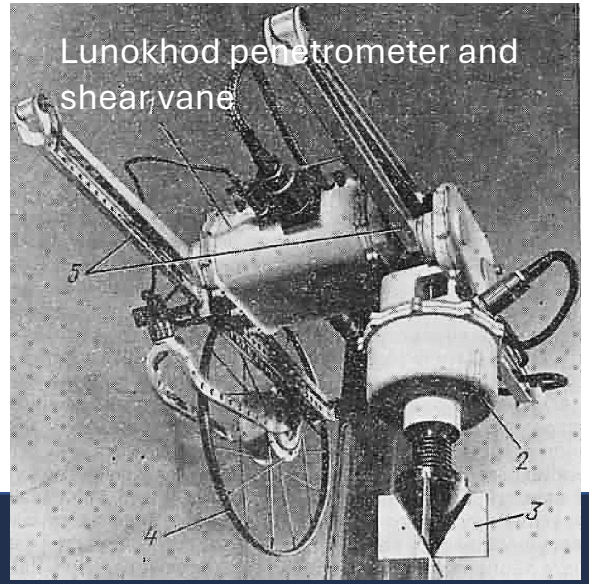
- Penetrometers have been used on the Moon
  - Apollo 14, 15, and 16
  - Lunokhod 1 and 2

Apollo 15 and 16 Self Recording Penetrometer





Apollo 14 Apollo Simple Penetrometer



Lunokhod penetrometer and shear vane

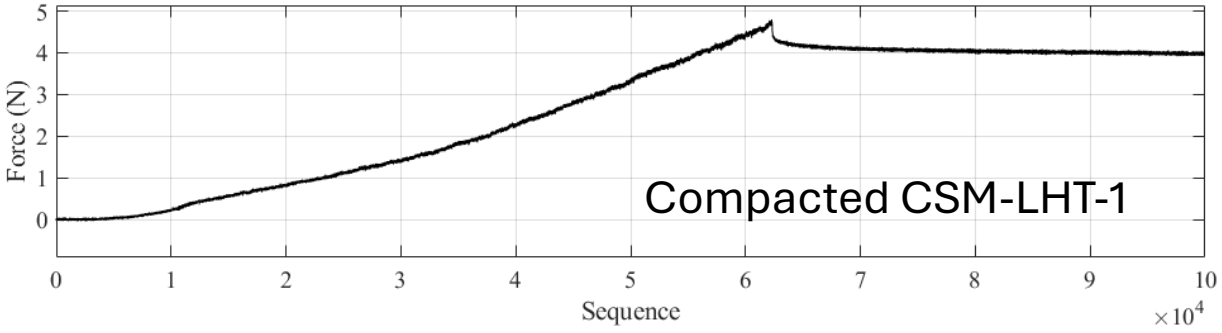
SAMPLR

Sample **A**cquisition, **M**orphology filtering, and **P**robing of **L**unar **R**egolith

- Robotic arm deployed
- Penetrometer
- Scoop
- Workspace cameras
- Heimdall cameras

Now manifested on CP-21 to Gruithuisen Domes

The need for in situ calibration

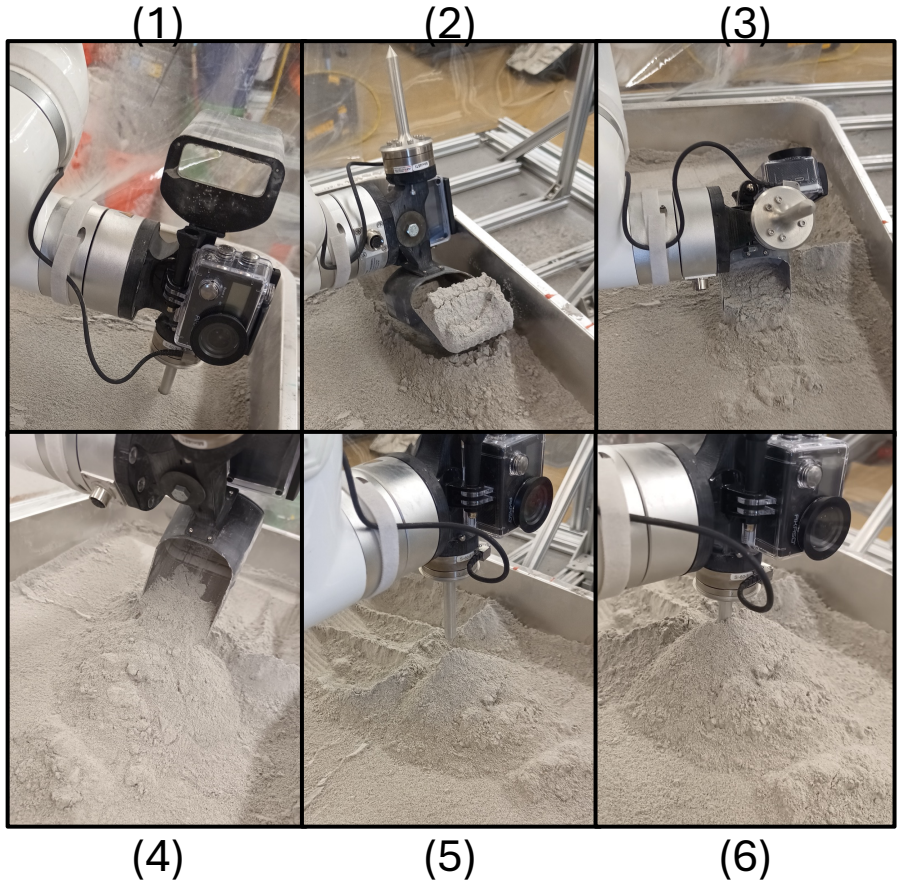


- A calibration relates penetrometer response to known regolith properties.
- Can a penetrometer be calibrated on Earth?
  - Only partially and not accurately
  - ➢ Gravity dependence of penetrometer response
  - ➢ Variability of regolith on the Moon
  - ➢ Simulants are not real lunar regolith

In-Situ Calibration Method for Density

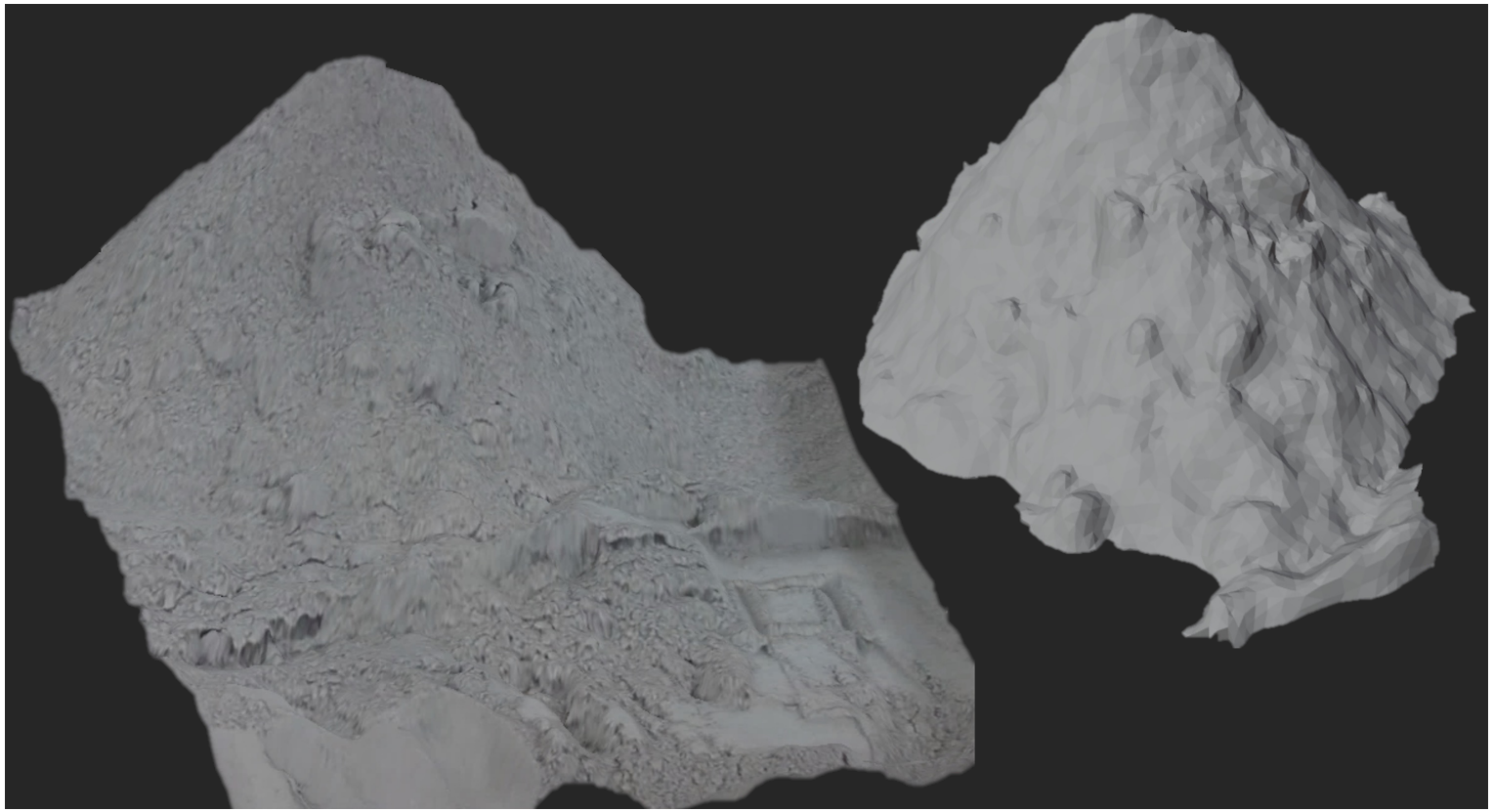
1. Produce penetrometer measurements of a low-density reference

2. Produce penetrometer measurements of a high-density reference



Low Density Reference - Photogrammetry

- Imagery is used to produce 3D render of loose-poured reference pile for volume estimations
- Scoop and arm data used to generate mass estimate of loose-poured reference pile
  - Instrumented scoop
  - Sensitive joint reaction currents



Photogrammetry

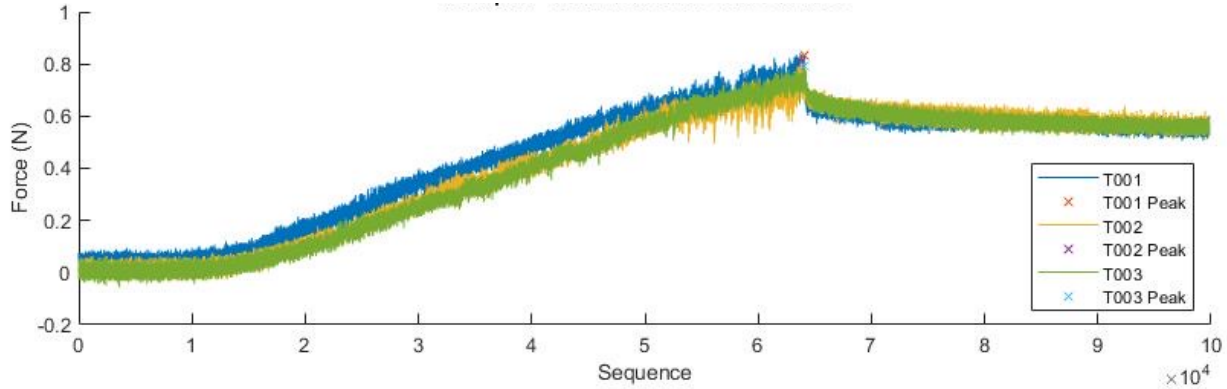
- Fiducial marks can be made in a surface to scale images
- Scoop used to flatten area
- Probe used to draw fiducial mark
  - Size known from arm trajectory
- Mark should have geometry that is tolerant of obfuscation
  - Square mark – opposing sides or corners
  - Circle – arc radius or circle diameter

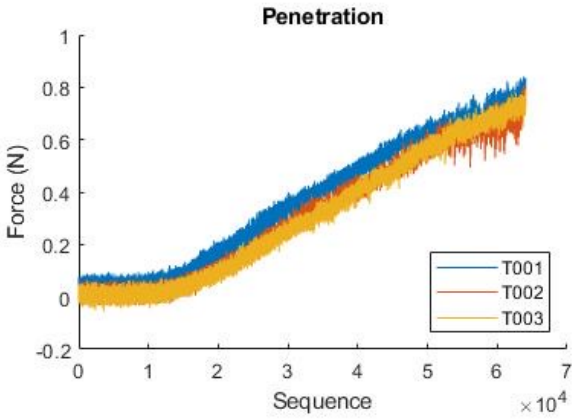
High Density Reference

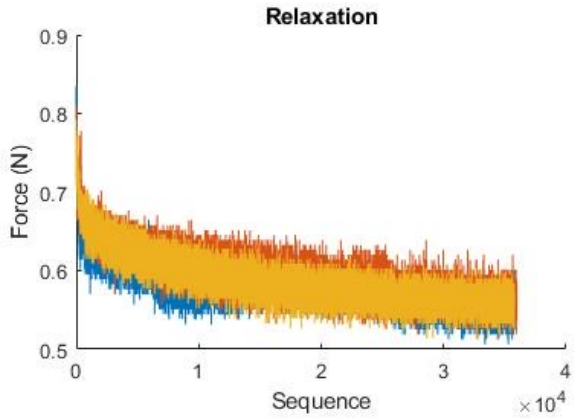
1. The natural surface at depth is high density
   - Use scoop to excavate to depth and assume a reasonable high density
2. Photogrammetry
   - Penetrometer measurement in natural subsurface of high density
   - Scoop excavates the penetrometer site
   - Density determined from:
     - Photogrammetry of the hole for volume
     - Arm response for mass in scoop

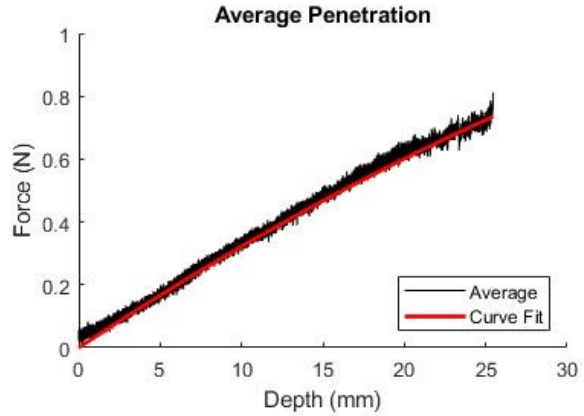
Penetration

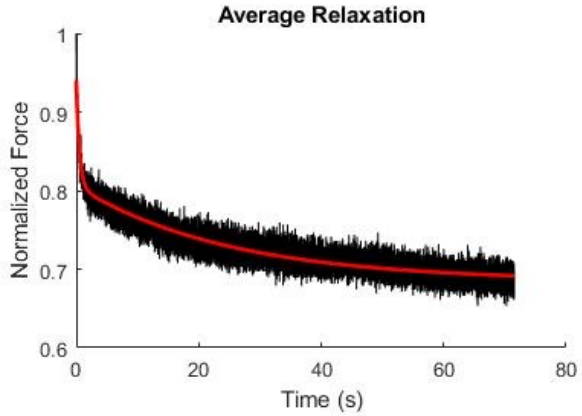
- Function of Depth
  - $F(z) = \alpha z + \beta z^2$
  - $F(z)$ – Force at depth
  - α – First-order coefficient = Slope
  - β – Second-order coefficient = Curvature
- α sensitive to density
- β sensitive to compressibility





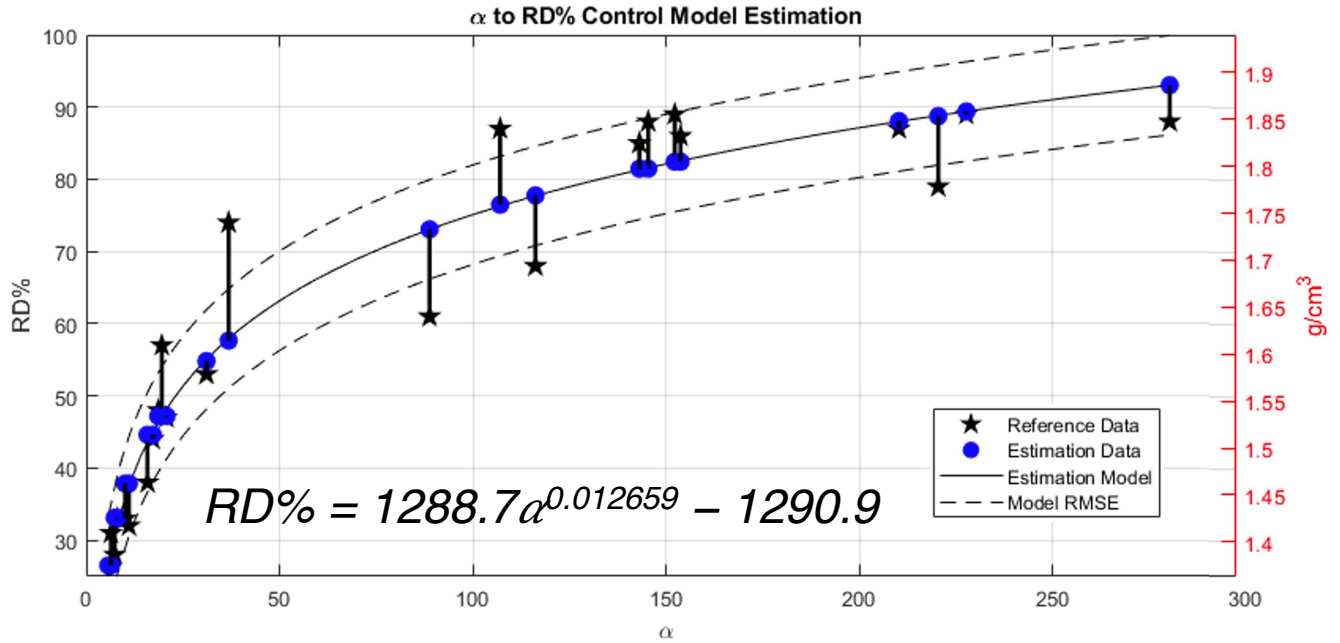


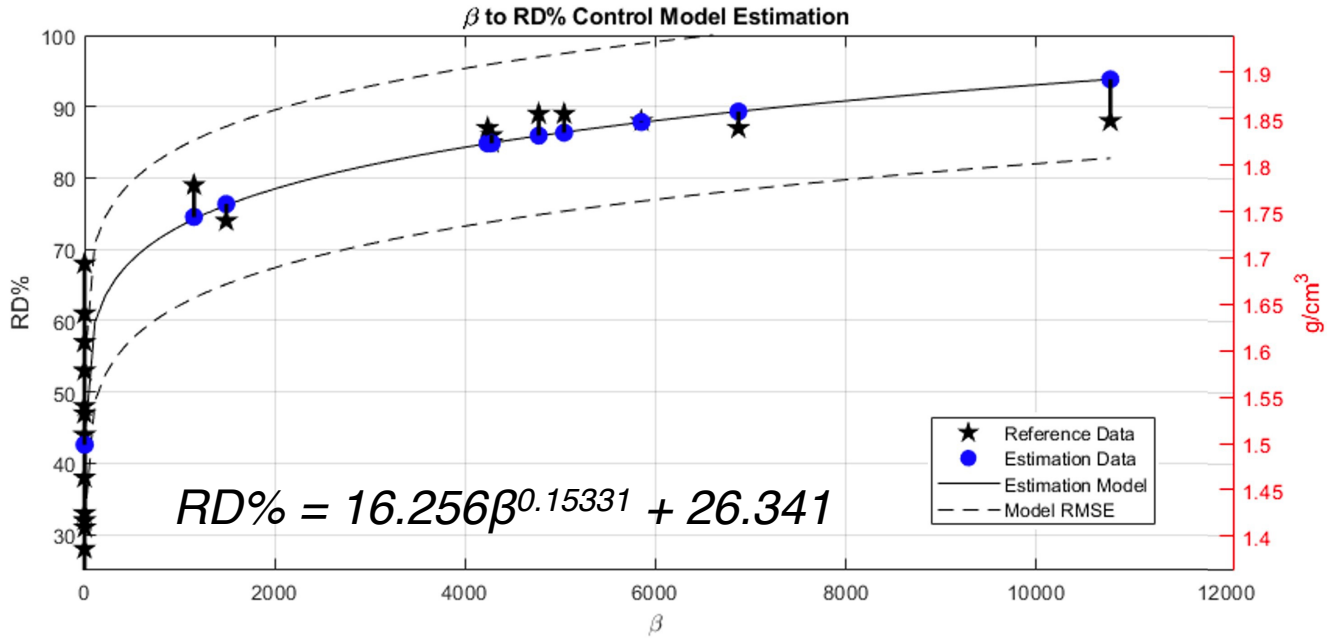




In-Situ Calibration with Known density

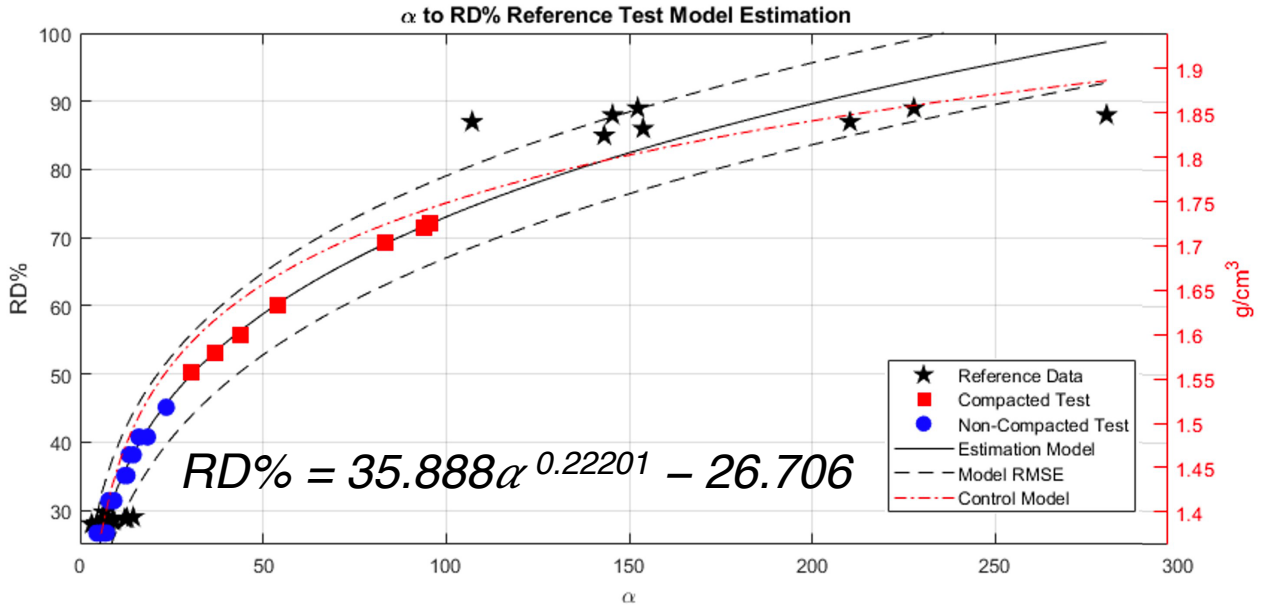
- Full measured RD%
  - Lab calibration
  - Model Check
- α model better throughout range
- β model good at high RD%, but poor at low and medium RD%

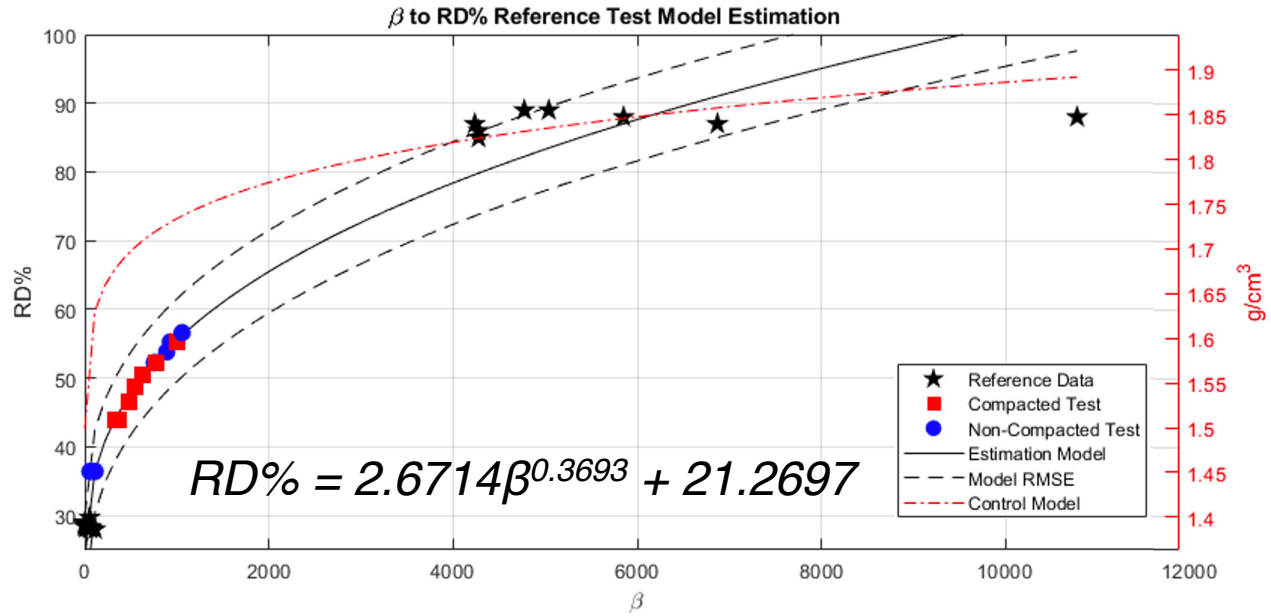




In-Situ Calibration with lunar surface method

- Low and high density produced by arm
- α model agrees well with control model
- β model has poor agreement with control model





Conclusions

- Have shown an in situ density calibration can be deployed on the lunar surface with SAMPLR – improves interpretation of penetrometer response
- More is needed
  - Additional calibrations – friction angle, cohesion, bearing capacity, etc…
  - Need addition Geotech tools – penetrometers, shear vane, plates, deflectometers, bevameter
  - Lab bench on the Moon – triaxial, direct shear, shaker table, low and max density measurement, etc…

Since you are here, also see…

Talks

- Thursday, 10:20 am, MAGMA - Molten Regolith Electrolysis, Ben Schneiderman
- Thursday, 2:00 pm, Mineralogy of Cast Simulants, Kyla Edison
- Friday, 8:40 am, Moon Quakes, Nerma Caluk (SOM)

Posters, Tuesday

- Water electrolysis, David Dickson with Oxeon
- MASON – Site Preparation with Redwire
- ASPECT – Site Preparation, Mines and MTU

Posters, Thursday

- Regolith flow in vacuum and lunar gravity – Anastasia Stepanova with Outward Tech
- Regolith simulants for high temperatures – Kyla Edison
- Regolith deflection measurements including the Trident footpad – Ian Jehn

Erin McMurchie
Director of Research

Christopher Dreyer, Ph.D.
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Ian Jehn, S.E., P.E.
Director of Engineering

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