Building a Vertical Take Off and Landing Pad using *in situ* Materials

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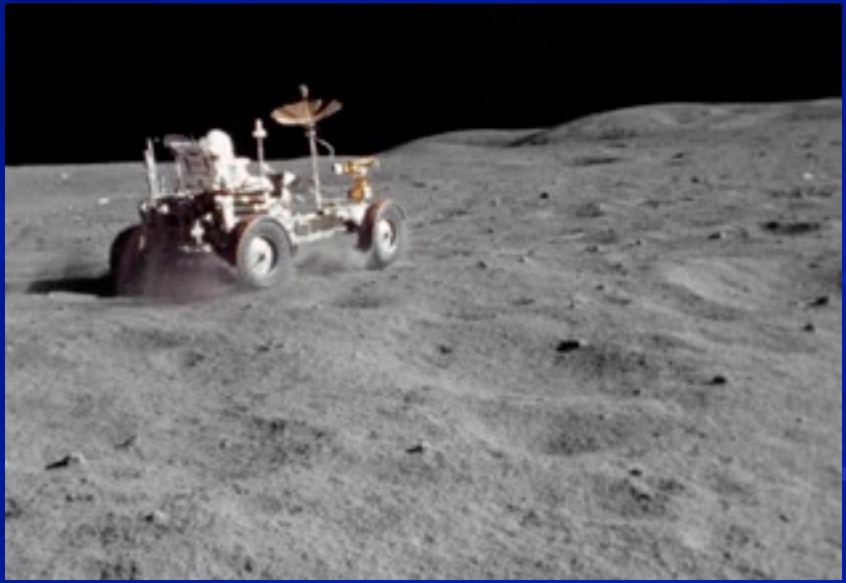
Overview

- Why do we need a landing pad?
- Other applications
- Regolith Stabilization Methods
- Demonstrations
- Future

Photo-s78_23252

Dust and surface stabilization

- Dust ejecta during lunar launch/landing can affect visibility, erode nearby coated surfaces and get into mechanical assemblies of in-place infrastructure
- Dust mitigation will be necessary for certain areas of the lunar habitat
- Surface stabilization be used for roads, launch pads and other dust free areas



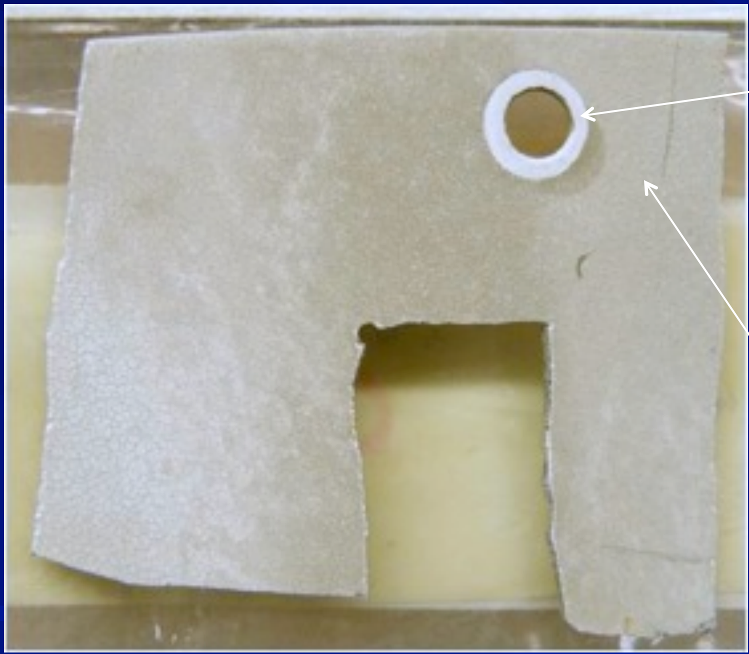
John Young, Photo S72_37002

Surveyor III

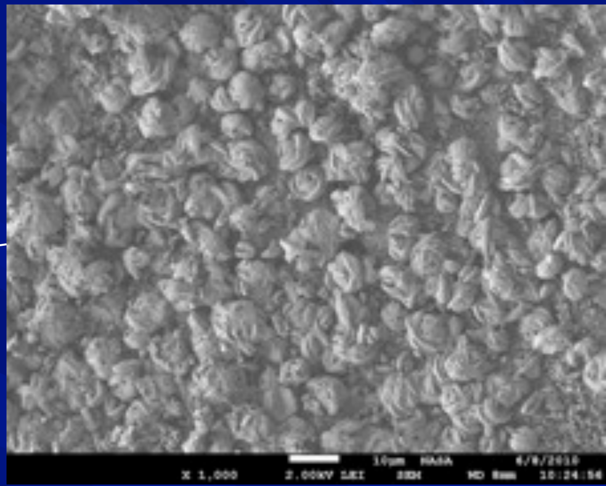
- Apollo 12 LM landed 155m from the Surveyor III craft
- NASA-SP-284: Analysis of Surveyor 3 material and photographs returned by Apollo 12 – found “sandblasting” with shadows showing that the blast came from the LM

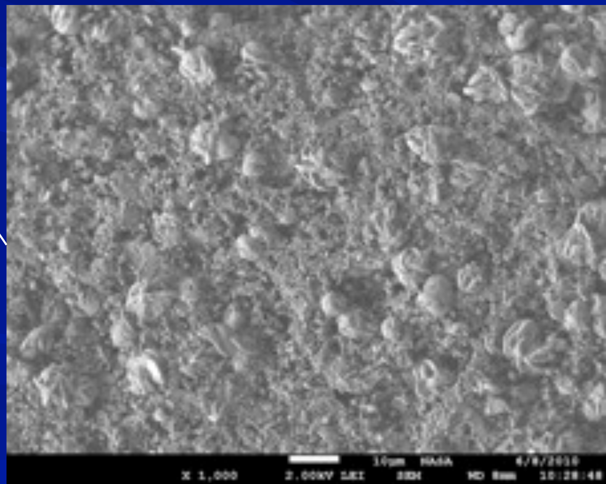
Charles Conrad Jr. and Surveyor III

Surveyor III

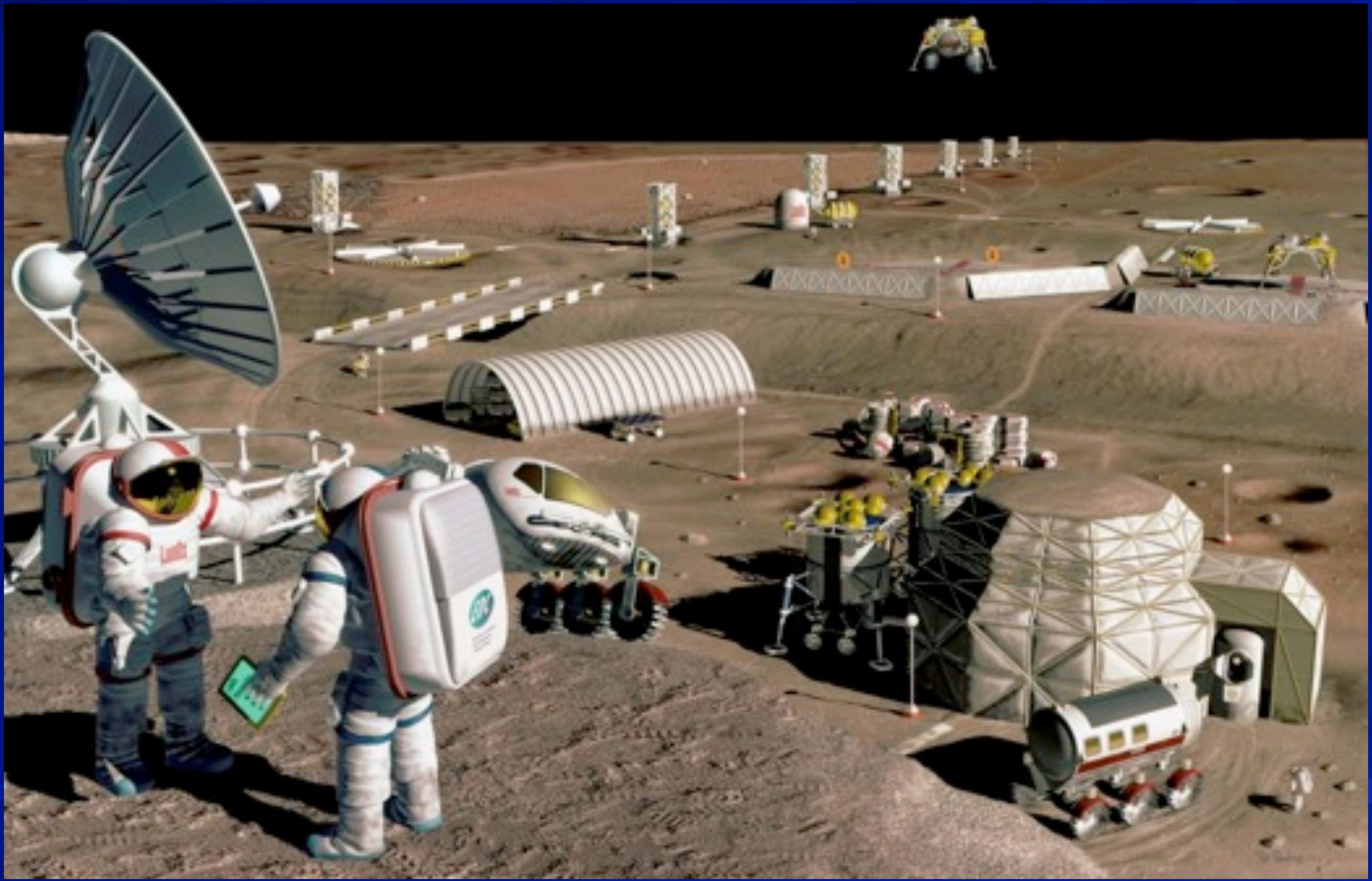


Part from lower shroud





Applications



- Roads and Landing Pads
- Dust Free areas for habitation or science
- Berm/trench stabilization
- Habitation structures

Stabilization Methods

- Polymer Composites
- Sintering/melting regolith
- Others…

Polymer Palliatives

- Technology successfully used in military applications for helicopter pads and roads
- Polymer is sprayed with water as the solvent
- Technology required very little development

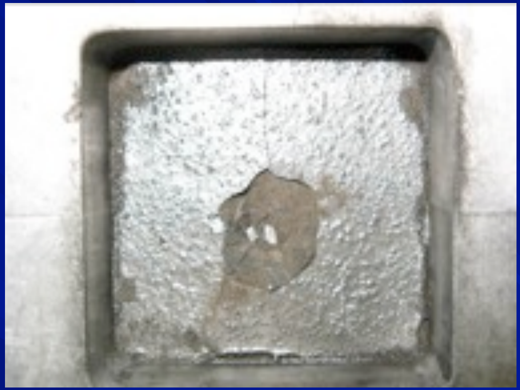
Rhinosnot.com

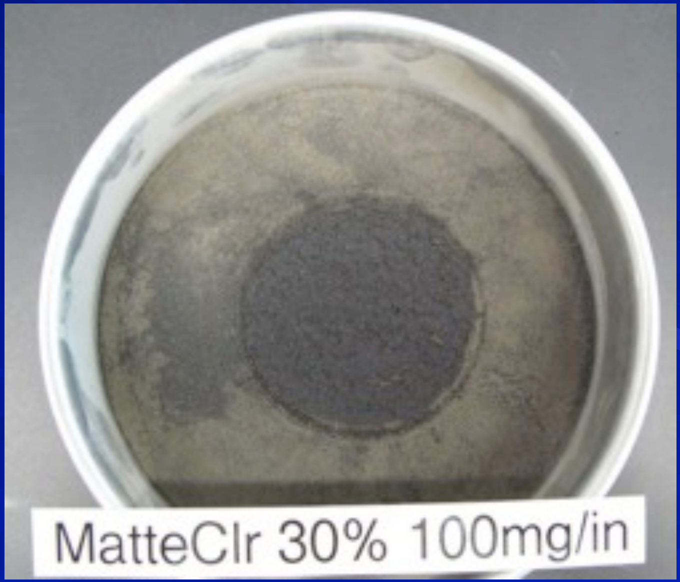
Polymer Palliatives

- Advantages
  - Ease of use: heat (200 C), UV or ambient curing
  - Many commercially available products (solvent free solids or liquids) with different desirable properties: High temperature resistance, abrasion resistance, flexibility
- Disadvantages
  - Mass
  - Consumable
  - Can be vacuum sensitive

Polymer Palliatives

- Evaluated 4 commercially available powders and 1 developed at KSC
  - Abrasion, UV resistance, high temperature resistance
- Demonstrated stabilization in the lab and in the field using our solar concentrator
- Investigated different spreading ratios, mixing ratios and application methods
- Polymers do not begin thermal degradation until 260 – 290 C
- Coverage rates ranged from 0.08 to 0.31 kg/m^2



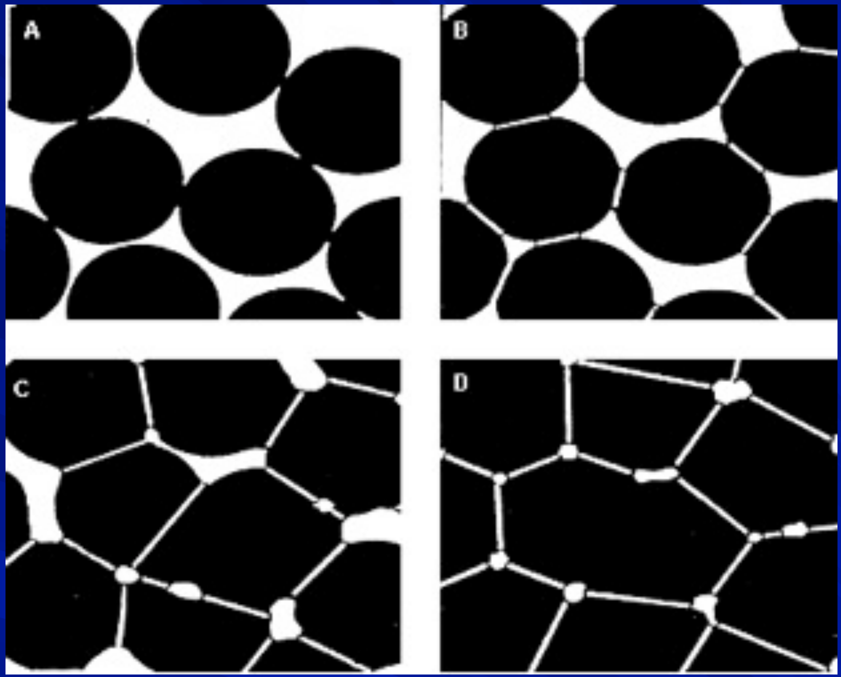


Polymer Palliatives

- Adherent Technologies Inc., Albuquerque, NM, has Phase I, II SBIR to develop polymers for spraying and making blocks.
- Identified spray nozzle for vacuum use.
- Made blocks with 5 wt% resin (185 psi) and sprayed resin at a rate of 25 g/m^2

Sintering or Melting

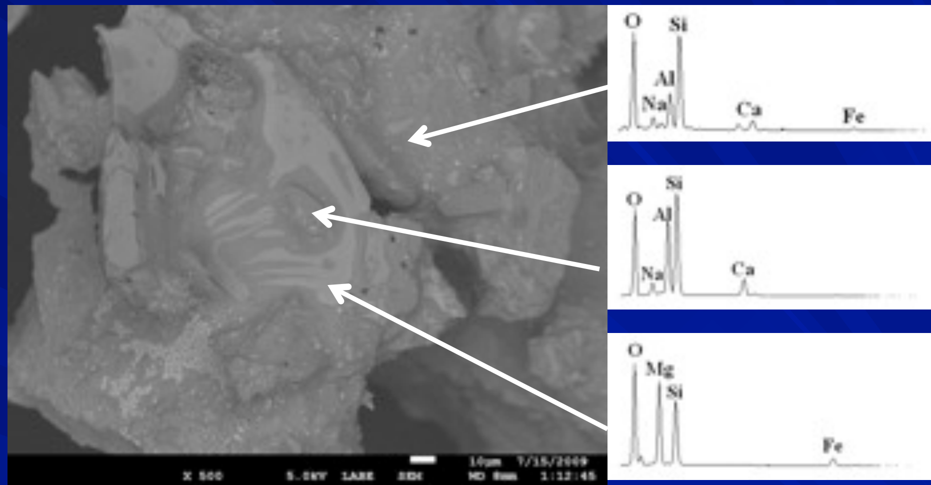
- Sintering is a method for making solid objects from a powder by heating the material (below its melting point) until its particles adhere to each other
- Particle size, density and packing of regolith are ideal for sintering
- Use *in situ* materials; need heat source



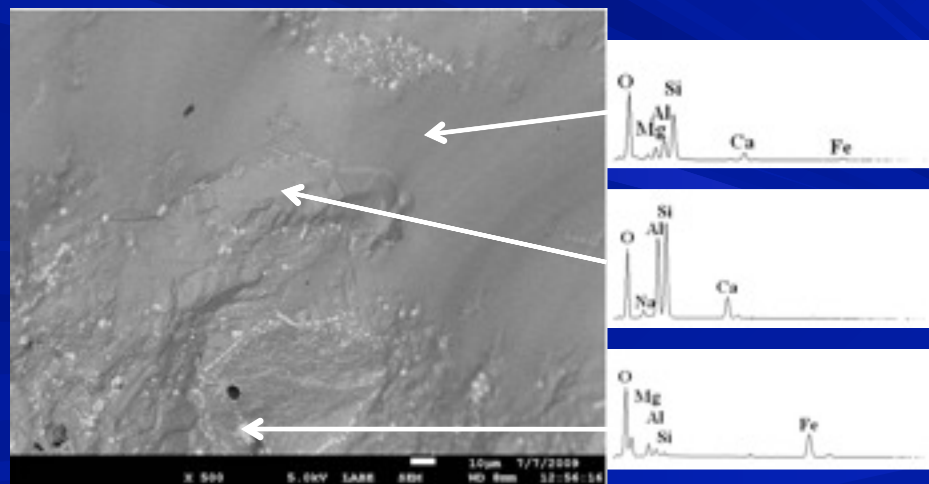
A. Loose powder (start of bond growth).
B. Initial stage (the pore volume shrinks).
C. Intermediate stage (grain boundaries form at the contacts).
D. Final stage (pores become smoother).

Sintering or Melting

- One or all phases can melt
- Depending on cooling rate, re-crystallization will occur



JSC-1A, 1100 °C

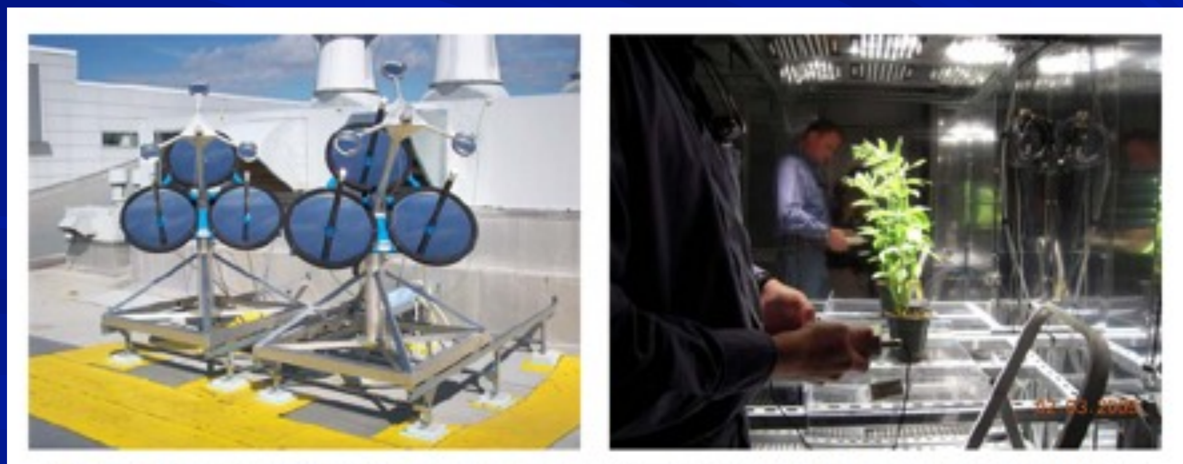


JSC-1A, 1200 °C

Solar Concentrator

1st generation solar concentrator

- Sunlight gives 1.3 kW/m^2 of energy
- Solar heating used for cooking, water purification, plant growth and other uses



Solar concentrator (PSI Corp) on top of Space Life Sciences Lab at NASA KSC

Solar Concentrator

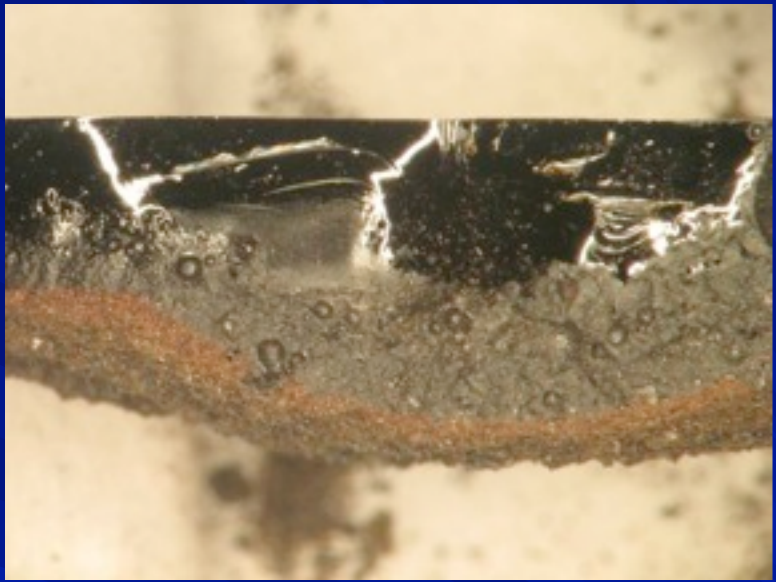
- Advantages
  - No power
  - Lightweight
  - Inexpensive
- Disadvantages
  - Direct heating only heats the surface
  - Uneven heating can cause problems
  - Must follow the sun

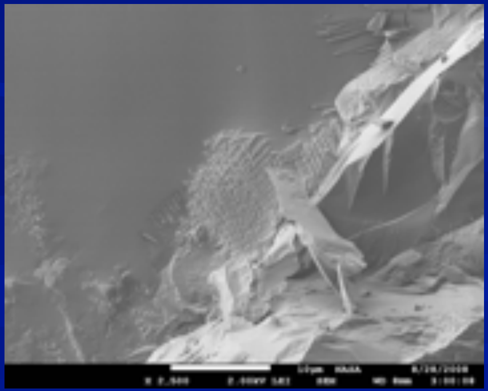
Solar Concentrator

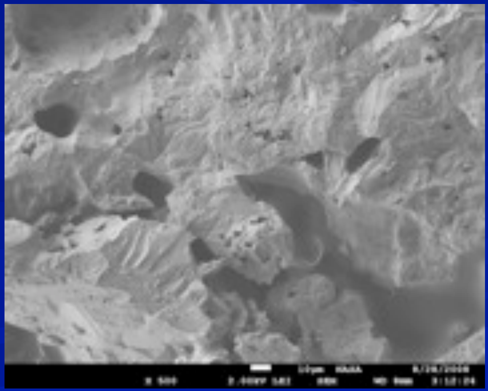
- It would take 27 days to sinter a 100 m^2 area 2.5 cm deep with a 1m^2 collector assuming 100% efficiency

Solar Concentrator

- You need good control to sinter, without melting
- Melted areas can be brittle; sintered areas might not have abrasion resistance

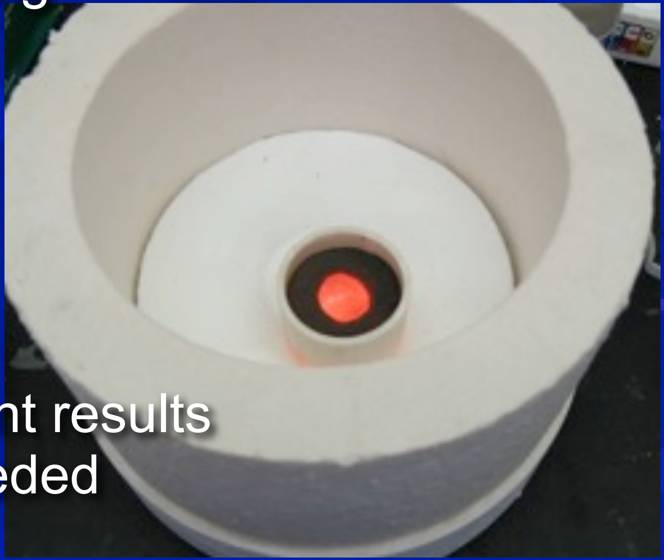






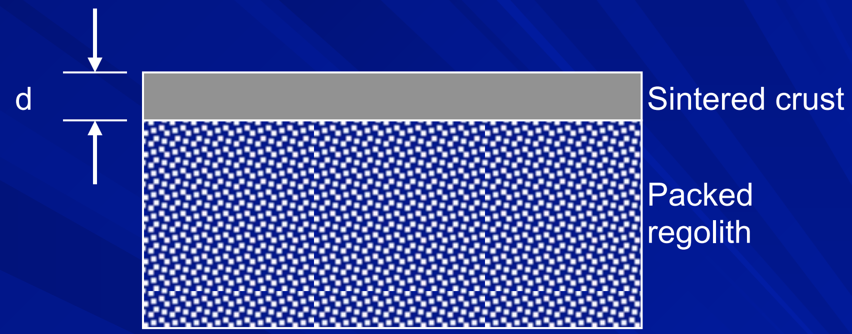
Microwave sintering

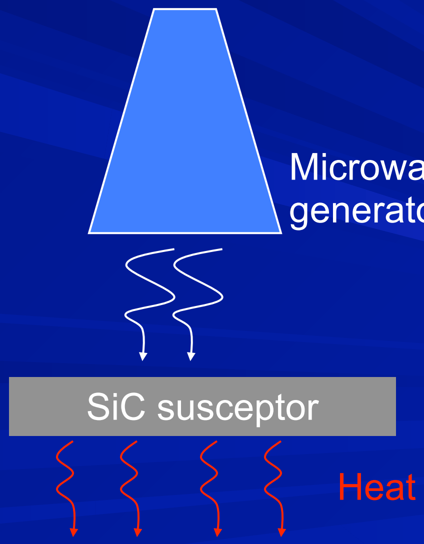
- Technology has been proposed for sintering a surface (Taylor et. al.) as well as other heating uses
- Most materials absorb microwave energy to some degree, especially at higher temperatures
- Advantages:
  - Much more efficient than electrical heating
  - Moderate Mass
  - Inexpensive technology
  - Heats the bulk of material
- Disadvantages
  - Power consumption (1 – 10 kW?)
  - Magnetron requires cooling
  - Thermal runaway can lead to inconsistent results
  - Energy might penetrate deeper than needed



Microwave Sintering

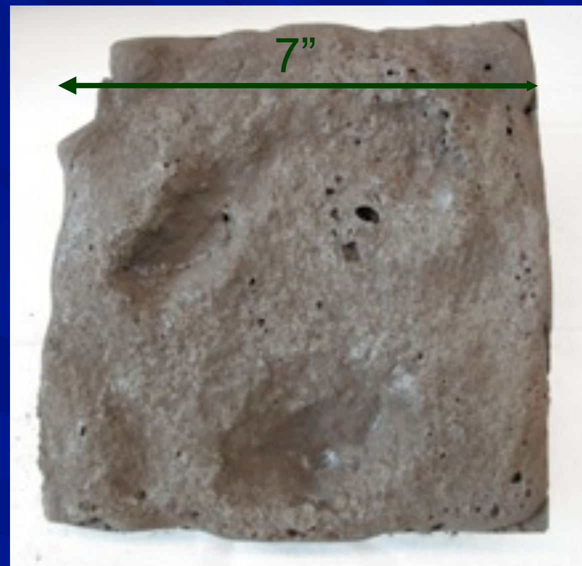
- It would take a 1000W microwave 31 days to sinter a 100m^2 area to a depth of 2.5 cm assuming 100% efficiency, 8-12 months is more realistic
- Microwaves would penetrate deeper into the surface
- Susceptors can be used to localize heating

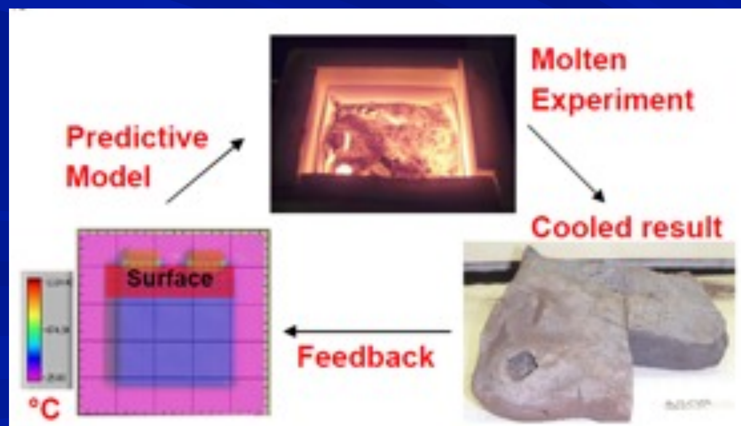




Microwave

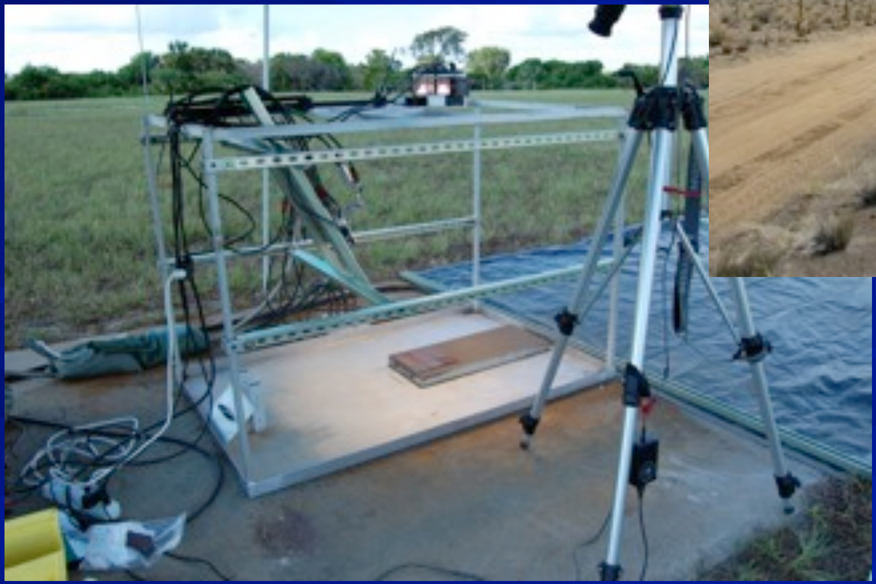
- Phase I SBIR: Automated Hybrid Microwave Heating for Lunar Surface Solidification, Ceralink Inc. Troy NY
- First demonstration of sintering a lunar simulant (JSC-1A) with microwaves coming from the top only
- Modulus of rupture ranging from 1700 to 3200 psi (ASTM C1161)
- Successfully modeled heating to account for differences in simulants





Field Demonstrations

- Hawaii field demo
- Thruster Firings at KSC



Mauna Kea, Feb. 2010

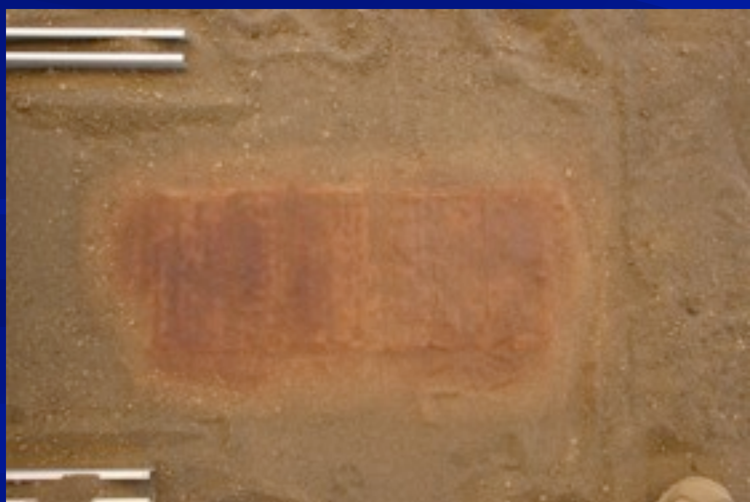
- Large Area Surface Sintering System (LASSS)
- Uses resistive heater
- Incorporates layered sintering and temperature feedback
- Mounted on NORCAT rover

LASSS

Heater

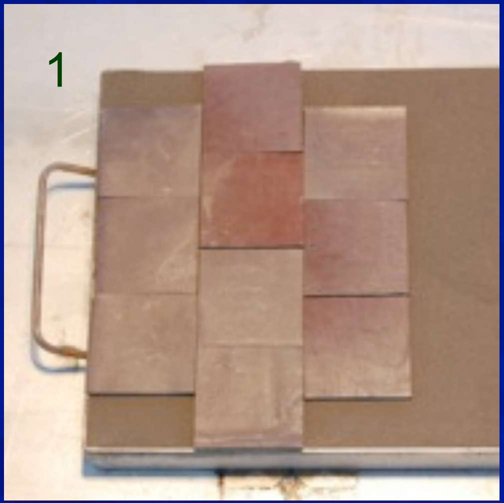
Mauna Kea, Feb. 2010

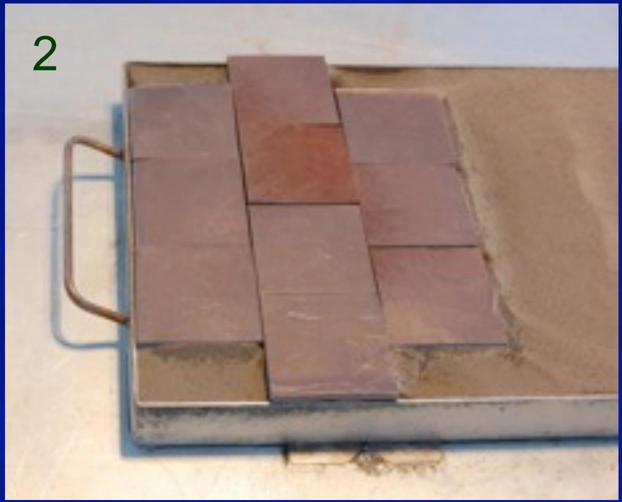
- Able to layer tephra and connect sintered areas
- Strengths from 30 – 240 psi
- Fired thruster on sintered area
- Environmental conditions caused issues

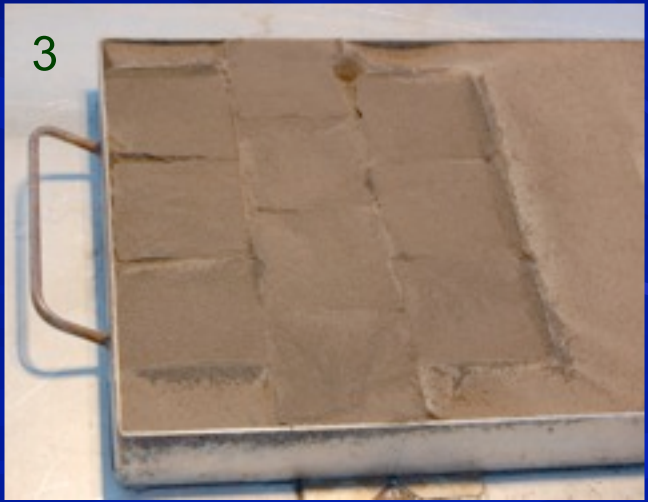


KSC Thruster Firings

- Sintered Tiles
- Polymers
- Gravel
- Textiles



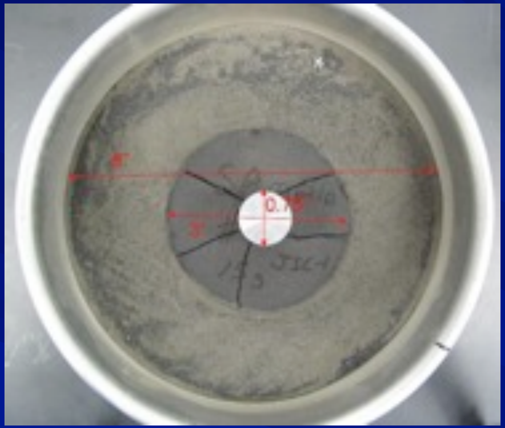




Physical Properties and Lab Testing

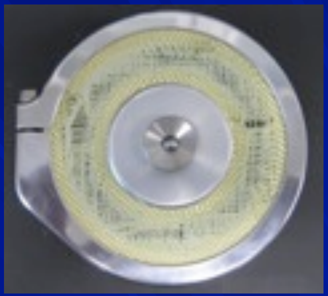
- Compression strength and modulus of rupture
- Load strength
- Abrasion Resistance (Taber Abraser)
- Abrasive blast resistance

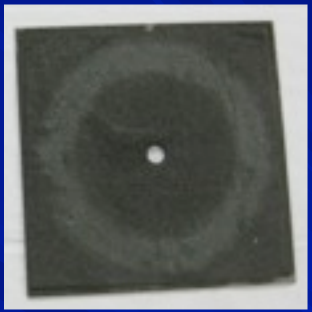
Load Bearing Strength

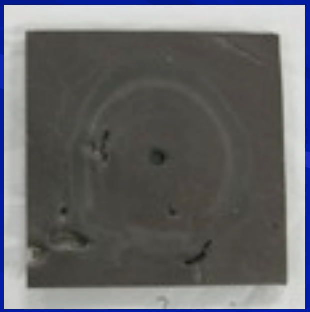


At $0.31 kg/m^2$, there would be about 200 microns thickness of polymer if it were not mixed with regolith

Abrasion Resistance



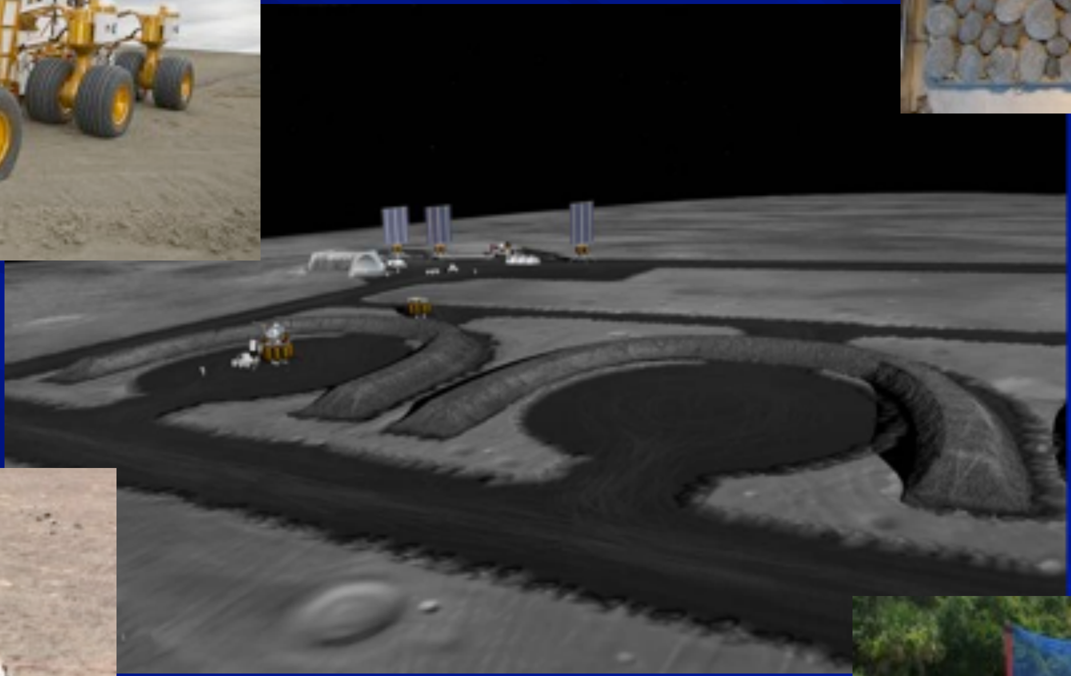




Future Work/Lessons Learned

- Identify which methods work best for which applications
- Try to find commonalities between methods used for different applications
- You always learn something on a field demo
- May need to employ multiple methods

Multiple Methods



Acknowledgements

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