Extruded Lunar Concrete for Truss Structures

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Lunar Concrete for In-Space Construction

Modular Building Blocks for Fast Space Deployment

- The only economical way to construct large, long-term lunar bases and mega-scale orbital constructs such as solar-power satellites is by relying heavily on lunar materials.
- But what materials exactly?
- While there is a wealth of studies on the raw materials available in lunar regolith, relatively little has been written on the optimal material for large scale construction.
- Here we propose a major role for Lunar Concrete
  - The primary advantage of concrete is its low cost and high durability
  - Its main limitation will be its density and the mass of realistic structures.

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- **Space Initiatives proposes a simple solution for both lunar and orbital construction:**
  - **extruded concrete pipes and slabs that can be mass-produced on the lunar surface, transported either into orbit or across the lunar surface, and then assembled to form most required structures.**

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Calcium Aluminate Concrete: A Lunar resource

Making Concrete from Lunar Materials

- While most terrestrial concrete depends on gypsum (calcium sulfate dihydrate) cement, that is not commonly available on the Moon.
- Calcium aluminate cement is used on Earth for situations requiring rapid hardening, resistance to high temperatures, and resistance to water (Fishwick, 1982).
  - On Earth, calcium aluminate is manufactured from bauxite and limestone.
- On the Moon, the mineral Anorthite (CaAl2Si2O8) is relatively common.
  - Lin, Love, & Stark (1992) successfully made and tested calcium aluminate concrete using 40 g of lunar soil returned by Apollo 16, albeit using a commercial calcium aluminate cement. They did note, however, that it is relatively simple to produce calcium aluminate from Anorthite by baking - see also Lin, Concrete for Lunar Base Construction (1985)
- Calcium aluminate cement is also desirable for lunar uses because it needs relatively little water, tolerates high temperatures, and may be used with liquids (one of its primary uses on Earth).

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Extrusion of Lunar Concrete

Making Modular Building Blocks for Space Deployment

- Pre-fabricated concrete tubes can be used to form geodesic domes, pilings, and frameworks.
- With the addition of concrete slabs, almost any shape required can be fabricated either on the surface or in orbit, including habitats, landing pads, lunar wadis (Burgess, Wegeng, & Matyáš, 2009), solar power platforms, and large antennas.
- Pipes can also be used for water, air, and fuel transport across the lunar surface and for routing wires within an orbital structure for protection.
- There are several key concepts in play here:
  - The development of concrete extrusion most recently for 3-D printing of structures (Mechtcherine, et al., 2020).
  - Many shapes can be extruded; on Earth, the most extruded concrete elements are concrete wall slabs and road curbs.
- The transport and curing of concrete in the high-vacuum conditions on the lunar surface introduces difficulties that have to be addressed.

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Concrete Extrusion has a Long History

- **Concrete Extrusion Machine likely in Morgantown, W. Va (https://wvhistoryonview.org/catalog/052429)**

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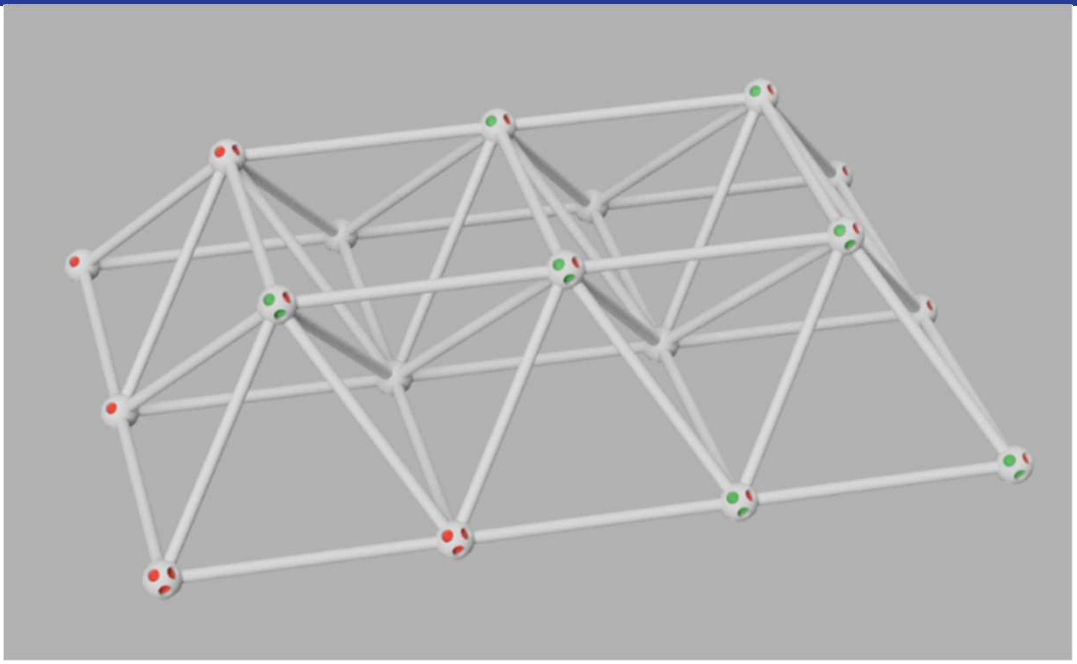
The Truss: A Basic Element for Lunar Construction



- A standard truss made from 2 meter concrete tubes having an outer diameter of 10 cm and a wall thickness of 1 cm. The pipes are joined by identical spherical concrete nodes into which the pipes are set and cemented.

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Infrastructure for Concrete Component Manufacture.

- The manufacturing plant would be located in an area containing Anorthite and near a water-drilling site
  - e.g. Clavius Crater (58.4°S 14.4°W).
- Anorthite-bearing regolith would be mined, sifted, crushed, and separated and fed to a cement-fabrication facility.
- The Anorthite would be roasted in a solar furnace attached to a high-temperature distillation column, leaving only the calcium aluminate; other materials would be condensed and used in other processes or even sold commercially.
- The calcium aluminate would then be mixed with regolith sand and aggregate and extruded in the desired form into a tight-fitting curing container.
- Truss nodes and other special shapes would be cast. Once cured, the extrusions could be shipped to lunar construction facilities or launched with a mass driver for orbital use.

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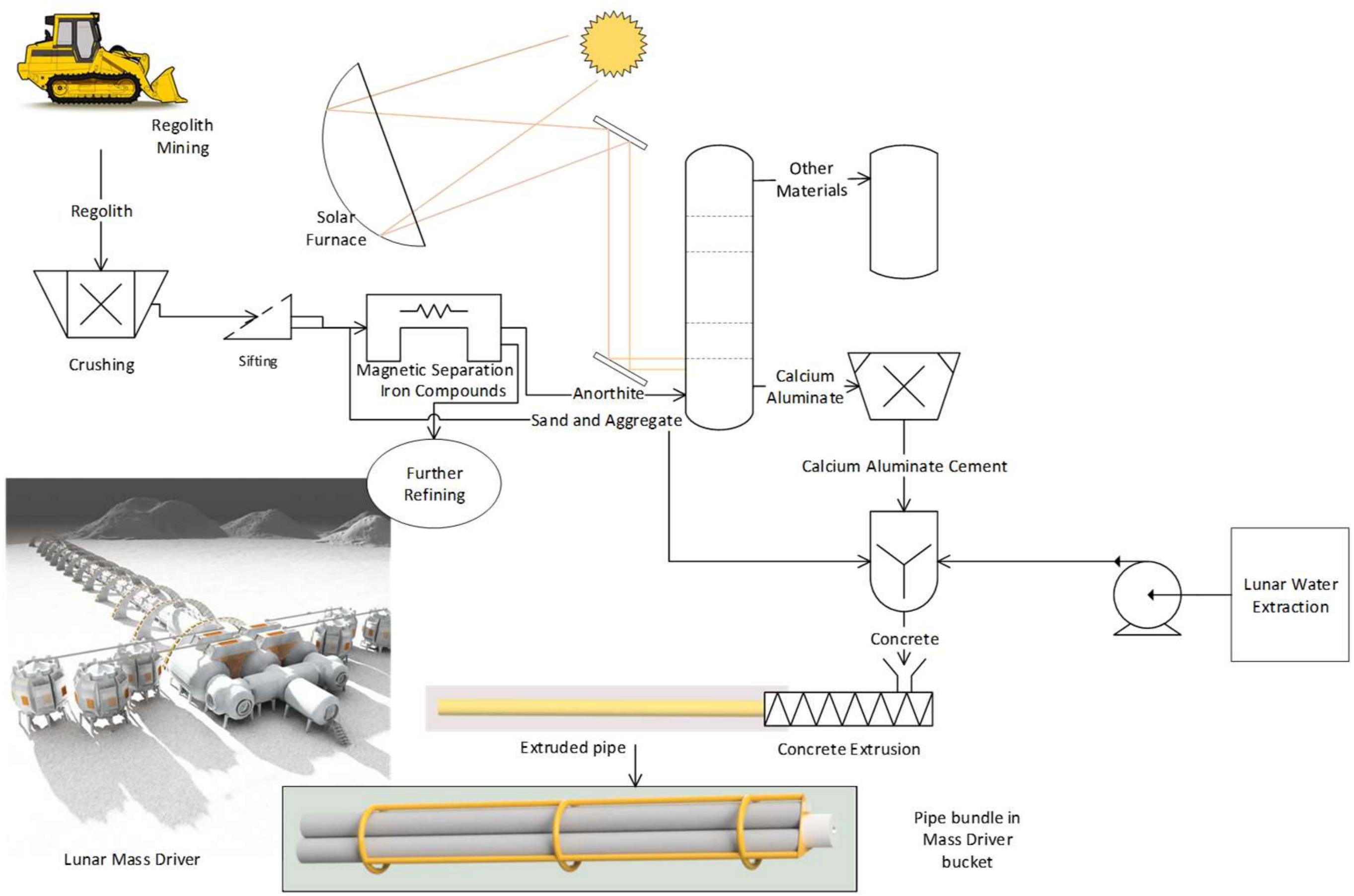
Making Concrete Extrusions on the Moon



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Curing Lunar Concrete

- The use of concrete requires water.
  - While calcium aluminate cement requires less than gypsum cement, it still requires a water-to-cement mix of 0.485:1.
  - Sufficient water should be available at high latitudes that lunar concrete should be a viable material.
- The concrete product must be stored in a pressurized, high-humidity environment for ~24 hours until the curing process has completed.
  - However, this atmosphere need not be high-pressure nor breathable. .
- The extrusion plant proposed here would use light-weight reusable containers for this purpose.
  - Initially these would be brought from Earth but later they could be made on the Moon.
- The new concrete would be extruded directly into the container which would then be capped with a small additional amount of water to allow proper curing. Once the concrete has cured, the container would be emptied and reused.

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Conclusions

Lunar Concrete Will Become an Important ISRU Resource.

- Lunar Concrete can be produced from Anorthite mined on the Moon.
- We can develop the ability to produce concrete from this cement
- We can also develop the ability to extrude and cure this concrete into tubes and slabs under lunar conditions of vacuum and temperature.
- This will give us the ability to form truss and other structures from these extruded elements.
- All of this can and should be tested on the Earth using using lunar regolith simulant and terrestrial Anorthite.

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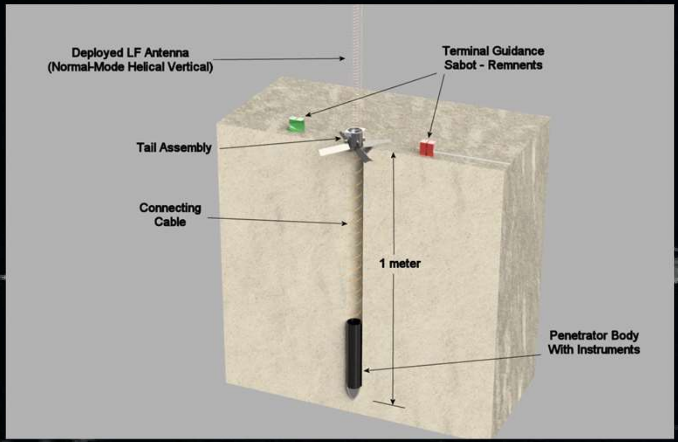
Space Initiatives Inc (SII)

- **We see real commercial market potential in Lunar Infrastructure.**
- **The first step is low mass, low cost sensor networks – the Motes.**
- **Next are PNT and communication solutions, including our "COMPASS" VLBI beacons for positioning.**
- **The long-range goal is enabling prospecting, networking and construction for mining operations.**

We are developing "Mote" lunar penetrators for rapid deployment anywhere on the Moon as part of the AFRL Lawn Dart effort.



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