Lunar Industrialization: The First Step to the Solar System

(Skycorp Inc. Lunar Studies, 3D Manufacturing and ISRU)

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Skycorp and Lunar Activities

• Skycorp Incorporated has been actively involved in lunar research since its founding in 1998, and our founder for a decade before that.

• A fundamental principle of commercial lunar development is to pick a place with known parameters of resources and terrain, with a large day/night fraction in order to minimize startup costs and allow for rapid growth.
The Time is Now

- With the advent of recent scientific missions from Chandrayaan and the Lunar Reconnaissance Orbiter, coupled with legacy data from Lunar Prospector, Clementine, and Lunar Orbiter we now have sufficient remote sensing data to plan a commercial lunar development. The next step is ground truth with a high capability commercially focused lander and rover.
The Goal, Industrial Development

• The goal of lunar industrial development, once the realm of science fiction, is now attainable.
• Recent remote sensing missions have dramatically improved our terrain knowledge and Apollo samples continue to inform.
• The key is a systems engineering approach, selecting a site, importing enough infrastructure, then implementing additive manufacturing for growth.
Peary/Whipple Site
First Big Landing
This rendering is based on LOLA data for Whipple Crater (to the right) and Peary Crater (partial view of Peary floor and Rim). Small craters have water ice signatures.
Peary/Whipple Ground Truth (LOLA Data)

Figure 1a: LOLA 10 Meter Gridded Data Record Terrain from 87.5° North to the North Pole (3x vertical exaggeration)

Figure 4: Slopes in the area of Peary/Whipple craters with overlaid elevation contours at 200 meter vertical spacing. Slopes are derived from LOLA GDR.

Figure 5: Circular Polarization Ratio map from the Mini-SAR instrument on Chandrayaan-1 cropped to show the area from approximately 85°N to the pole. Anomalous craters suspected of containing volatiles, including several craters on the floor of Peary, are circled in green [see reference 1].

For the purpose of economic development the north lunar pole is far superior to other locations
Whipple Site Details

Using images from the LRO NAC high resolution imager, coupled with LOLA terrain data we now have the ability to plan not only the general outline of a site but to do a first order determination of locomotion and energy needs for mobility and day/night Cycles.
Mobility at Lunar Polar Sites (North)
Mobility at Lunar Polar Sites (South)
Local Robotics Positioning for Swarm Applications

Ultrawideband Radios can enable swarm robotics on the Moon as well as provide a local frame of reference for positioning.
Steps to a Lunar Development

• There is a fundamental difference between a science outpost on the Moon (think Antarctica) and any other use case.

• As on the Earth, a sustainable industrial infrastructure on the Moon must begin with, and is limited by, available power and local resources.

• The Moon is RICH with resources, we must start (after the recon period) with power.
The First Requirement, Power

• **Skycorp Power Lander™**
  • 100 Kilowatts power output
  • 3500-4000 kg
  • One Delta IVH or Falcon Heavy launch
  • Based on Modular Lunar Lander Heavy
  • Extended lander legs to get solar array into more sunlight
  • Provides standard 110//220/440 V AC Power
  • Closed loop 80 kW PEM Fuel Cell scavenging residual H2 and O2 propellants
  • Average power supplied over 708 hours is ~67 kW/hr/hr
  • Unit one supports outpost buildup
  • 5-7 units required for industrial self sufficiency.
First Task Outpost Landing Pads

- Powerlander power used to sinter landing pads
  - A set of high power S band transmitters couple to the regolith to sinter a landing pad ~1 meter deep
  - Can be used to sinter roads and building foundations
Initial Outpost
Adding Capability

- Leveraging telepresence and advances in terrestrial robotics
- Terrestrial robotics have exploded in capability in recent years. This, along with metals In-Situ Resource Utilization (ISRU) rewrites the book on lunar (and mars) development.
Versatile Robotics

Advanced robotics coupled with traditional cranes will provide high productivity for site development. This gantry crane could be used for large scale 3D printing.

Landers designed with modular parts could be disassembled and the parts used to build cranes, propellant storage, or even raw materials for ISRU systems. This leverages delivered mass fraction by 30-50%.
A rover based on the 1970’s Eagle Engineering LOTRAN modular design would give high mobility (20 km/hr), all wheel drive, and allow for heavy loads.

Slope angles on identified routes to floor of Peary have moderate slope and short distance.
3D Printing/Additive Manufacturing

• A truly transformative technology, allowing the rapid utilization of lunar resources.
• Lunar materials, from raw regolith to metal meteoric fragments can be immediately processed with little preprocessing.
• Laser Sintering is a key technology, ready for almost immediate deployment on the Moon.
Additive Manufacturing Fundamentals

- Fundamental experimentation (TRL-4 level) has begun by NASA for off planet 3D printing using ISRU derived materials.
Metal Fines in Lunar Regolith

Metallic Fe phases in Apollo 16 fines: Their origin and characteristics as revealed by electron spin resonance studies

• In the above titled paper, quantities of metal with sizes as small as 30 angstroms was found

• Some studies of lunar regolith show 0.5% by weight metal fines in the regolith (Apollo 16 highlands regolith)

• This type of material, when separated with a magnetic sorter can then immediately be used for 3D printing metal objects
Direct Metal Laser Sintering (DMLS)

DMLS is revolutionizing terrestrial industry and could directly use lunar metal Powders for manufacturing small and large parts. The Lunar vacuum enhances the properties of most parts.
3D printing/additive manufacturing is a revolution on the Earth that has profound ramifications for lunar/mars development. Using ISRU derived resources as a feedstock for building heavy equipment, buildings, and parts for large systems can reduce the delivered payload requirements from the Earth by 80% for an equivalent functional unit. Also, the payloads that do fly are parts such as computers, power systems, and other components not easily fabricated in-situ. This dramatically shifts the composition of payloads and supports a dramatically lower cost RLV-to-ISS-to-Luna supply chain.
This is not your grandfather’s lunar base. It is time to throw off the old conceptions and to use the benefits of 21st century technology development to build a lunar base that will then enable a solar system wide industrial and transportation infrastructure.