Lunar COTS Concept: A Public-Private Partnerships Approach for Lunar Resource Prospecting, Extraction and Infrastructure Development

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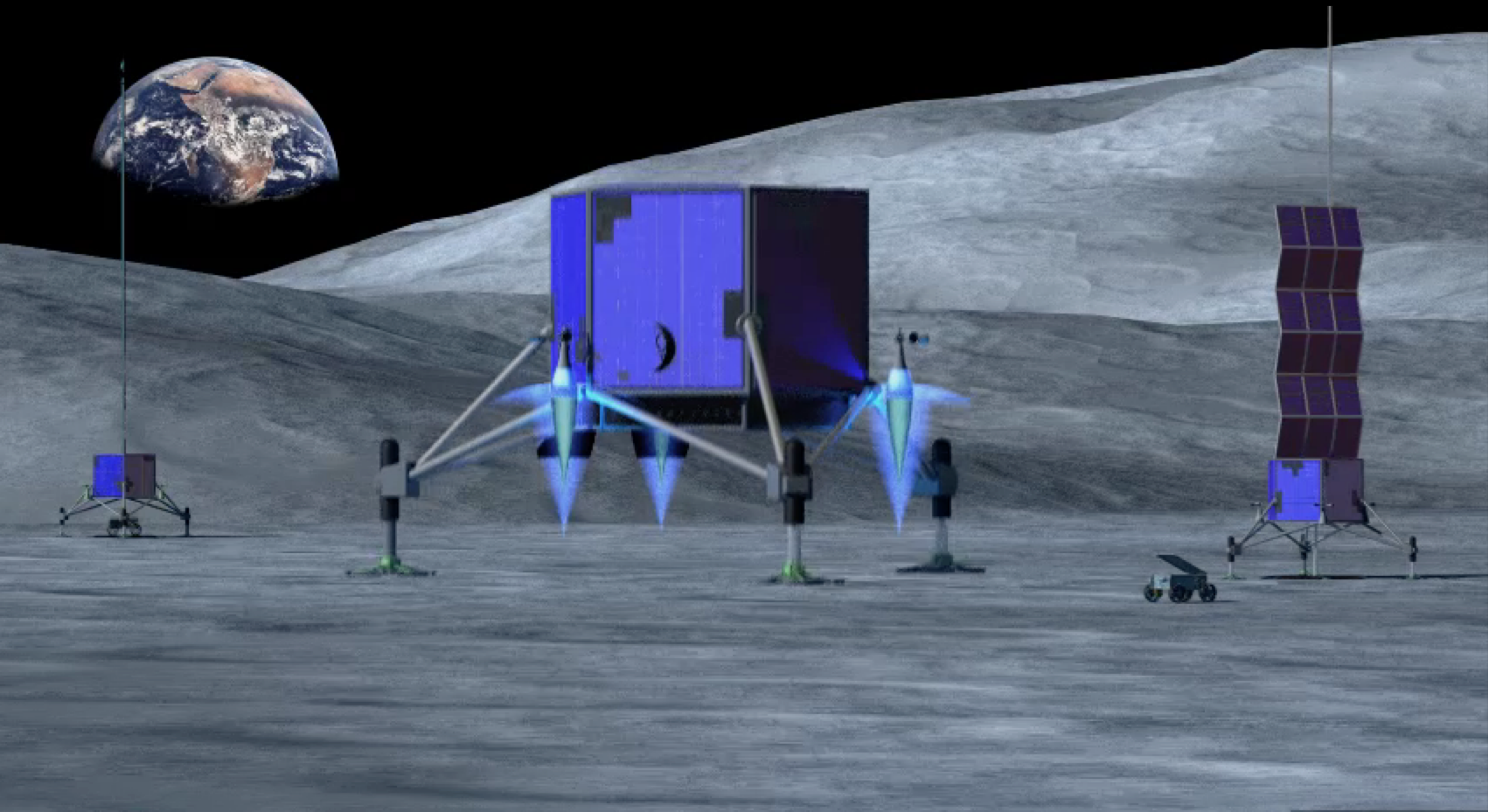


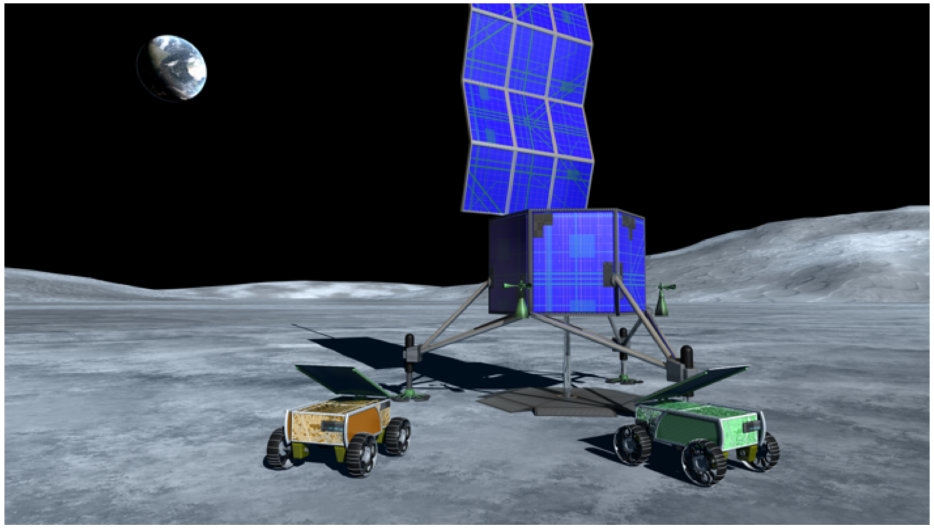
Background

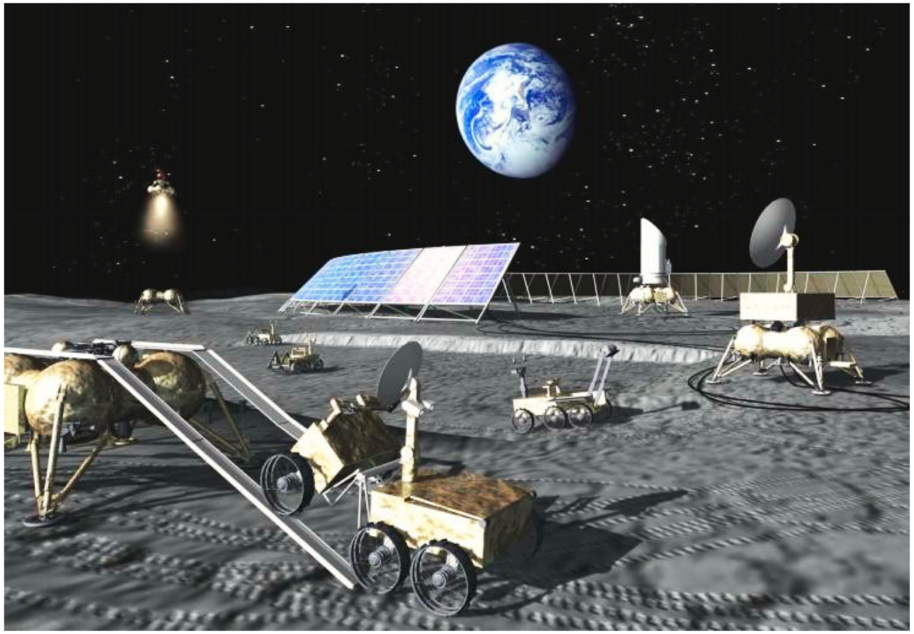
- NASA’s Commercial Orbital Transportation Services (COTS) program was very successful in demonstrating ISS cargo delivery capabilities.
  - Resulted in development of 2 launch vehicles and spacecraft (SpaceX’s Falcon 9 and Orbital’s Antares with Cygnus)
  - Public-private partnerships approach resulted in significantly lower development costs, as much as ***10-to-1 reduction in costs*** for Space-X’s Falcon 9 development.
- NASA’s Lunar CATALYST initiative sponsored by NASA’s HEOMD Advanced Exploration System division has competitively selected partners in 2014 to develop commercial lunar cargo transportation capabilities to the surface of the Moon.
  - Established no-funds-exchanged Space Act Agreements with 3 U.S. companies including Astrobotic, Masten Space Systems and Moon Express.
  - Commercial lunar transportation capabilities could support science and exploration objectives, such as sample returns, resource prospecting and technology demonstrations.
- NASA has recently released several RFI’s for lunar payloads and lunar cargo transportation services and a draft solicitation for Commercial Lunar Payload Services.
- Lunar COTS is a concept study focusing on the technical and economical feasibility of building lunar infrastructure as well as the benefits and challenges of using a COTS-like model.

Lunar Commercial Operations & Transfer Services (LCOTS) Concept

GOALS

- Develop and ***demonstrate affordable and commercial cis-lunar and surface capabilities*** in partnership with industry.
  - Lunar cargo delivery; mobile power stations; communication towers; lunar surface rovers; etc
- ***Establish commercial and economical lunar infrastructure services*** to support pre-cursor lunar robotic missions in preparation for return of humans to the Moon.
- Encourage creation of new space markets for economic growth and benefit; ***and to promote a new era of Lunar Industrialization.***

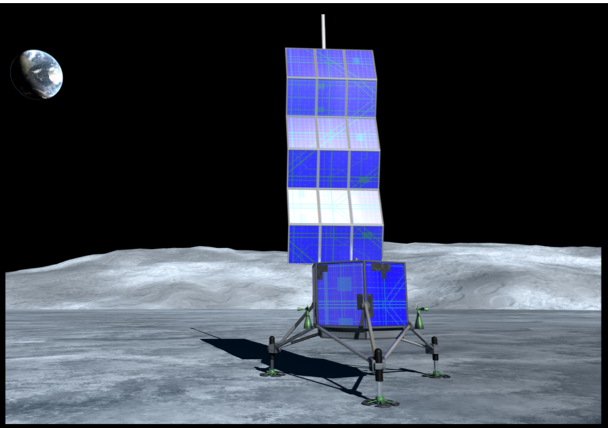


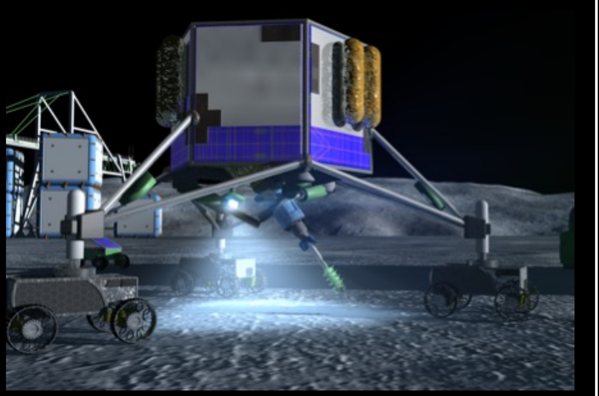


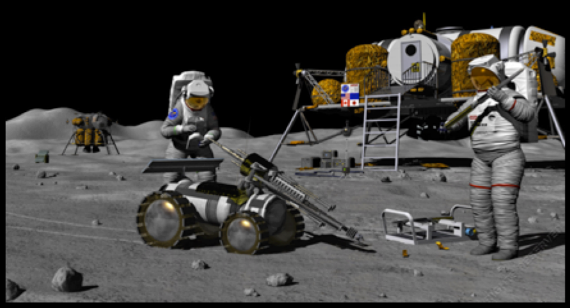
Approach

- Use NASA COTS Program's acquisition approach to demonstrate capabilities and partner with industry to ***share cost, development and operational risk***.
- Use 3-phase approach in partnership with industry to ***incrementally develop commercial capabilities and services*** for mutual benefit.
- Initial phase consists of ***fast, low-cost, commercial-enabled missions to assess resources and hazards at several landing sites*** while developing infrastructure capabilities.

Lunar COTS Phased Implementation



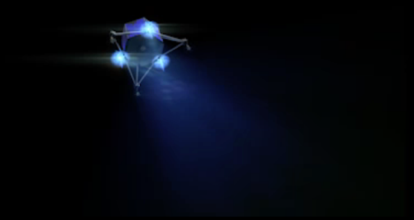


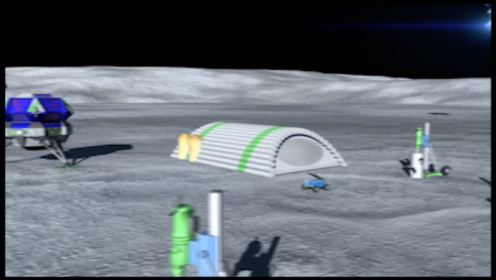


Phase 1: Fast, Low-Cost, Commercial-Enabled Missions	Phase 2: Pilot Scale Demonstration	Phase 3: Long-Term Contracts

• Partner with industry to develop and demonstrate capabilities to enable an evolvable lunar infrastructure, including:
  • Lunar cargo delivery, mobile power stations, communication towers and satellites, lunar surface rovers, etc
• Obtain ground truth data at several lunar sites:
  • Identify resources and hazards
  • Assess economic viability for resource extraction.
	• Demonstrate multipurpose infrastructure services on a pilot-scale to support future NASA crew missions and commercial activities, such as, lunar mining.
	• Develop a pilot-scale ISRU plant to extract water and produce up to 1 metric ton of propellant.
	• Evaluate feasibility and economics of scaling up production to full scale.
		• NASA awards long-term contracts for infrastructure services, such as, lunar cargo delivery and power/comm services to support human missions.
		• NASA may also award long-term contracts for full-scale resource extraction and/or delivery of resources to cis-lunar destinations.

LCOTS Concept of Operations





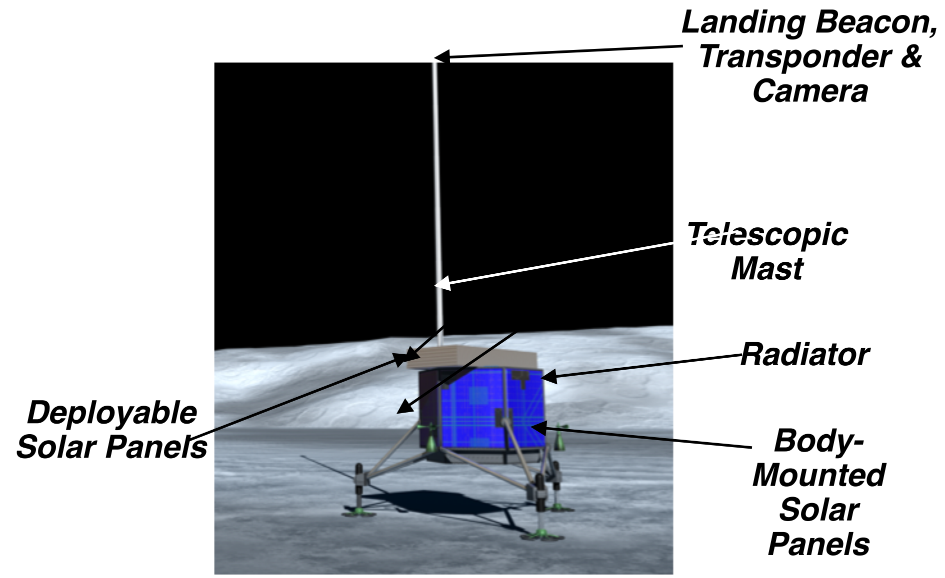
NASA Lunar COTS Concept (LCOTS)

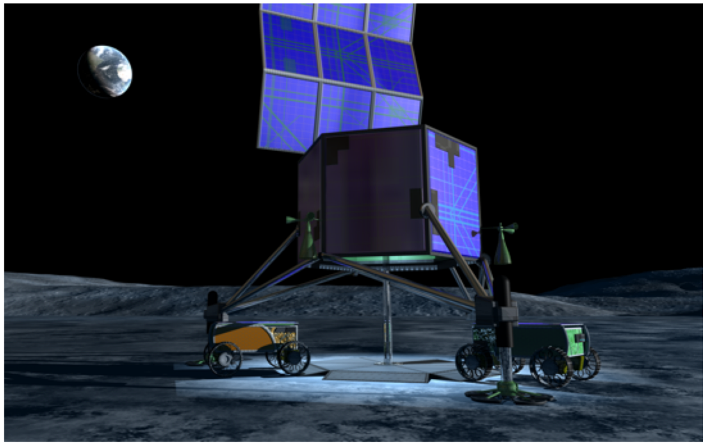
Concept Objective:

Partnering with Industry to Build an Economical Infrastructure Leading the way to the First Lunar Industrial City

LCOTS Reference Design

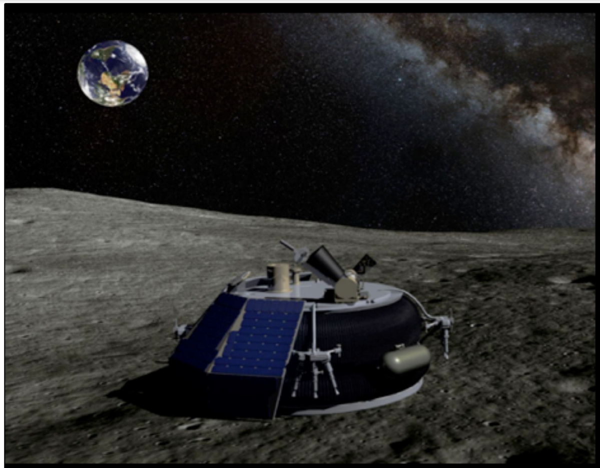
- Targeted landed mass from 800-900 kg
- Payload mass ranges from 250-350 kg incl. batteries, beacons, comm tower
- 2 meter Diameter modular hex Bus
- Lander legs are < 4 meter dia fixed
- 10 meter tall comm/beacon mast
  - Allows for over 1 km line of sight
  - Mast is telescopic and deploys after landing
  - Tripod legs can self level after landing
- Solar panels
  - Polar lander: body mount as shown
  - Equatorial Lander – deployable solar panels
- Lunar Rover Dock
  - Provides keep alive power for rovers
  - Can recharge rover during daylight

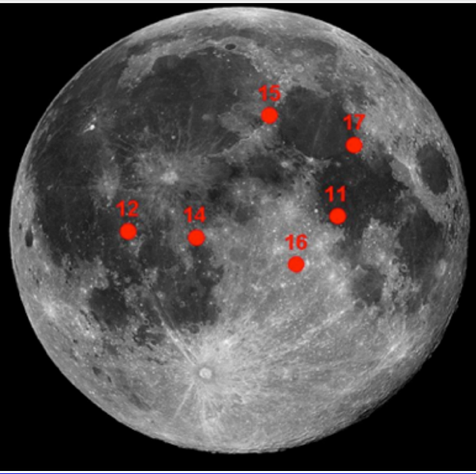




- ***Power station provides re-charge and thermal control to rovers to survive multiple 14-day Lunar Nights.***
- ***Extends mission life to several years (6 to 8 years depending on battery life)***
- *Adding mobility system to power station can* ***extend traverse distances to hundreds of kilometers***

Potential Landing Sites

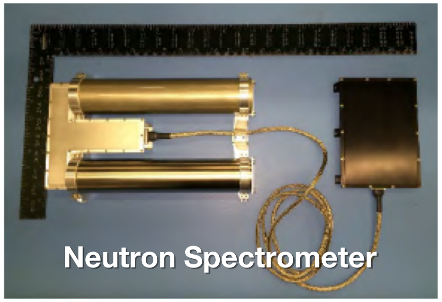


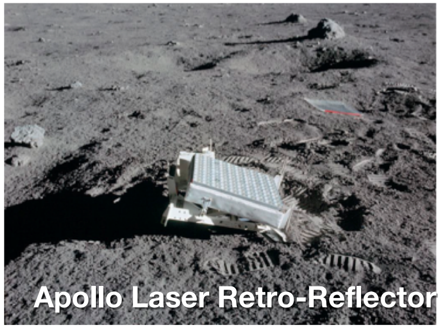


Lunar Polar Landing Sites	Lava Tubes and Lunar Caves	Apollo Historical Landing Sites
▪ **North and South Poles** may contain an abundance of water ice below the surface in permanently shadowed regions (PSRs) and surrounding areas. ▪ **PSRs are very challenging** to operate in due to extreme low temperatures, low visibility, steep and rocky terrain, etc. ▪ **Several robotic missions are necessary** to determine quantities, depth, composition and accessibility of the water-ice concentrations.	**Several lava tubes and lunar caves exist** in various locations on the Moon. ▪ These caves can serve as human habitations since they are very large and can provide a good amount of radiation shielding. ▪ Several robotic missions to these areas are necessary to provide structural integrity and radiation data as well as accessibility information of these caves.	▪ **There are 6 Apollo landing sites** with existing US hardware almost 50 years old. ▪ These sites can provide valuable information on **micrometeorite damage** and hazards assessment on the 50-year old hardware. ▪ Some of the Apollo sites also offer very **intriguing geological areas** that may be rich in valuable resources. Missions to these areas would build on the Apollo legacy.

Draft Instrumentation Options

Sample Instrumentation Options	Key Measurements
Neutron Spectrometer System (NSS)	Senses hydrogen-bearing materials (eg. Ice) in the top meter of regolith.
Near-Infrared Volatile Spectrometer System (NIRVSS)	Identify volatiles, including water form (e.g. ice bound) in top 20-30 cm of regolith. Also provides surface temperatures at scales of <10 m
Camera, LEDs plus NIR spectrometer	Provides high fidelity spectral composition at range.
Radiation sensors	Measure radiation shielding by lunar regolith in lava tubes.
Drills	Captures samples from up to 1 m; provides more accurate strength measurement of subsurface.
Magnetometer	Measures variations in the strength of the Moon's magnetic field.
Seismometer	Measures propagation of seismic waves through the Moon to help understand the Moon's internal structure.
Laser Retro-Reflectors	Improved knowledge of Moon's orbit, variations in the rotation of the Moon and rate at which Moon is receding from Earth.





Benefits to Lunar Industrialization

Industry

- Opportunity to be first to corner a space-based market which may be very lucrative (e.g. lunar cargo delivery, lunar mining, lunar tourism, etc)
- Estimated projections state potential for multi-trillion dollar economy.

Public

- Exciting new adventures for explorers of all races, genders and background!
- Benefits humanity in offering expanded opportunities and resources.

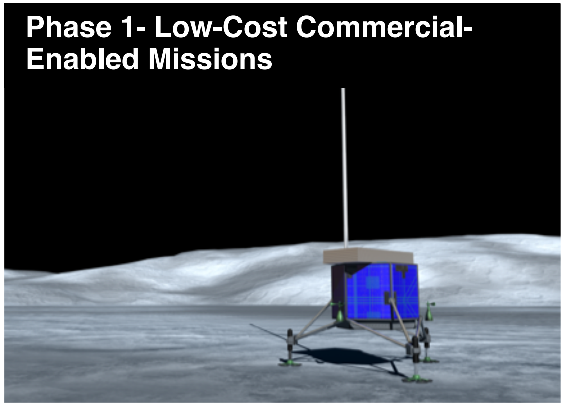
Govt's Role

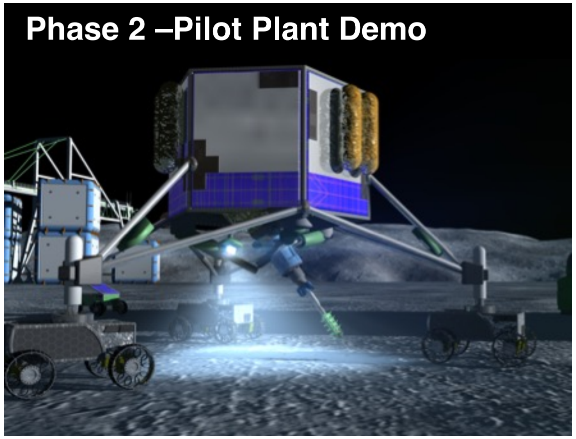
- No one company can industrialize the Moon alone. Investments to enter market are too huge and risky to enter alone.
- Govt can play key role by establishing Public-private partnerships to help accelerate infrastructure development.
- Other govt incentives should be explored to lower barriers of entry and enable new lunar industries and markets.

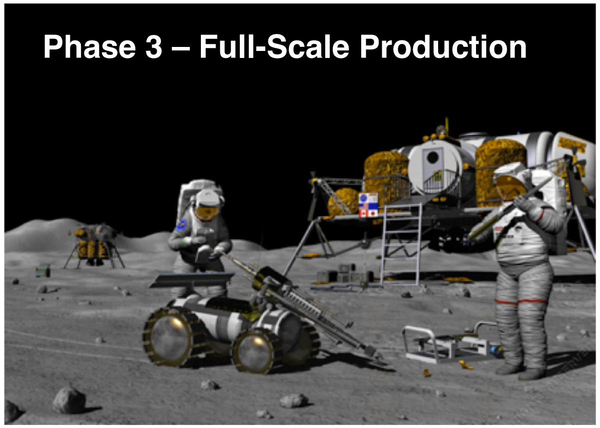
The Moon can serve as a Gateway to the rest of the Solar System and beyond.

Next Steps

1. Further develop mission concept options for 3-Phase approach to Lunar COTS.
   - Continue maturing design options for power generation and thermal control to ***extend mission life to several years***.
   - Add mobility and suspension system to power station to ***extend traverse distances to hundreds of kilometers***.
   - Use of ***impactors and/or penetrators*** that can be deployed on descent trajectory.
   - Develop design options for ***Lunar Drones*** to gather data over rough and steep terrain.
   - Investigate low-cost ***science instrument options***
   - Develop design options for ***Sample Return Missions*** (include options for ascent stage).
   - Use ***Deep Learning and AI technologies*** to rapidly optimize solutions for landing site selection, resource identification, traverse and mission planning, etc.
2. ***Develop plan for robotic, resource prospecting missions*** and prioritize landing sites that have greatest potential for valuable resources that can spawn a lunar economy.
3. ***Conduct series of lunar commercial development workshops*** to provide forum between commercial space companies and NASA technical experts to exchange ideas and develop plans.
4. **UPCOMING WORKSHOP: Surviving & Operating through the Lunar Night**
   Tentative Date: Nov 13, 2018 (precedes Annual LEAG Meeting)
   Tentative Location: USRA Facility, Columbia, MD







THANK YOU!

For more info:
https://www.nasa.gov/ames/partnerships/spaceportal/LCOTS