



Why We Could Afford A Lunar Base

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- Governed by a statewide board of directors, the California Space Authority (CSA) is a nonprofit corporation representing the commercial, civil, and national defense/homeland security interests of California's diverse space enterprise community in all four domains: industry, government, academia, and workforce. Designated as California's Spaceport Authority, CSA is a member-based "enterprise" association working closely with stakeholders statewide to facilitate California's competitiveness and space enterprise vitality.
- **STRATEGIC PURPOSE:**
To Retain, Grow and Create California Space Enterprise
- **MISSION:**
To Provide Voice, Visibility, and a Competitive Edge for California Space Enterprise

“Human operations on the Moon can have as significant an impact for life on earth as has been obtained from operations at geosynchronous orbit.”
-Presentation to Aldridge Commission, April 2004



Moon Base Affordability

- Affordability has two dimensions
 - Cost over a given time period related to available resources
 - Return on investment for stakeholder compared to other opportunities
- It is also important to ask: Affordable to whom?
Who pays?
- Therefore, the value chain of lunar activities will strongly influence affordability: What will be done by whom, for whom, and what is it worth?



Moon Base Value Chain Considerations

- What will a lunar base do?
- Who will benefit?
- What will they pay?
- Who will participate in delivering the value chain?
- How will value chain participants benefit?
- How much are they willing to invest?



Lunar Activities Value Chain

- Elements
 - Services to end users
 - Lunar utilities for service providers
 - Infrastructure to support lunar operations
- Government or private interests can participate at each step in the chain
- Of course, there are other considerations not in the direct value chain
 - Economic stability, financial health of the state or country, scientific and workforce development, job creation, etc.



Typical Services to End Users

- Space science, e.g.
 - Astronomy
 - Space physics
- Global security
- Energy production and distribution
 - To earth-orbiting vehicles
 - To earth
- Earth observation
 - Military, civil and private markets
- Cis-lunar space observation

Services can be provided by government or private interests.



Observation from the Moon

- **Takes advantage of lunar characteristics**
 - Large, stable, earth-facing and anti-earth surfaces
 - No atmosphere
 - Potential availability of solar and nuclear power
- **Which enable**
 - Large distributed aperture collectors
 - Optical and RF
 - Active and passive
 - On site data processing and analysis
 - Broadband connectivity with earth
- **To facilitate applications such as**
 - Long dwell high resolution earth observation
 - Observation and tracking of earth orbiting and cislunar objects and activities
 - Ultra-long range identification and tracking of earth-orbit-crossing objects, especially those coming from beyond the Jovian orbit

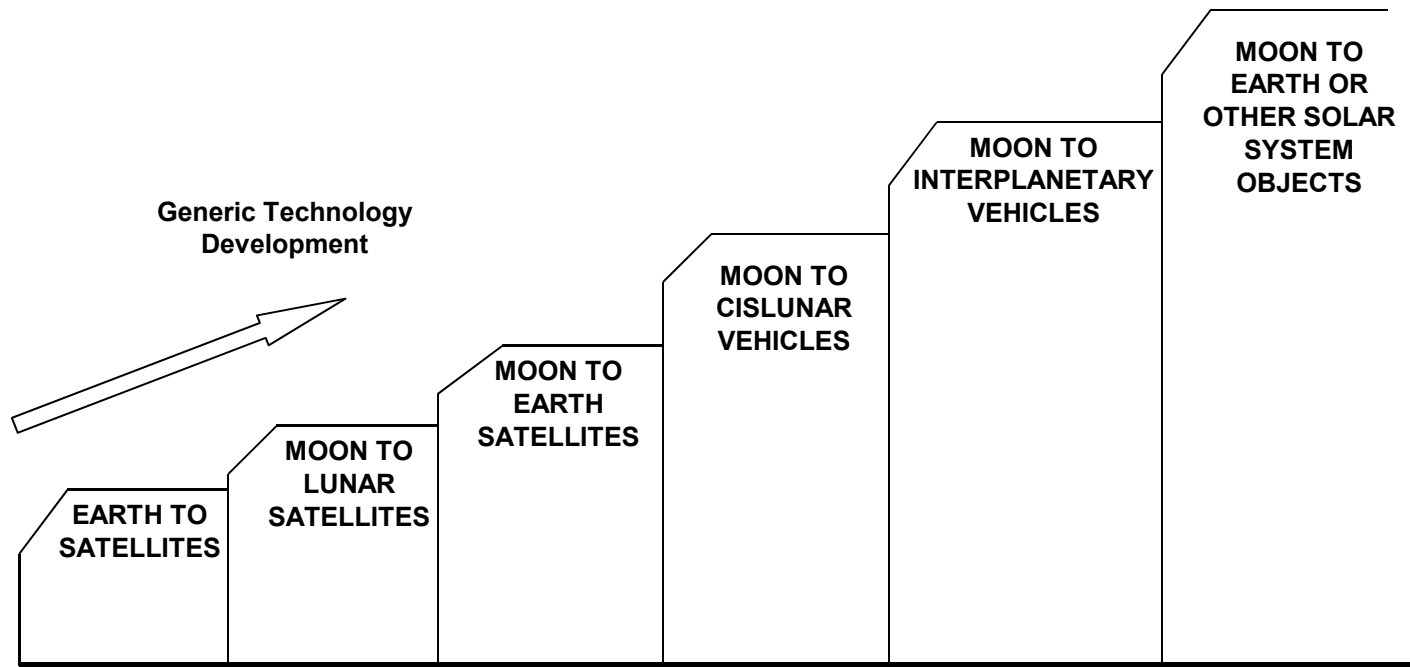


Lunar Surface as an Energy Transmission Platform

- Nuclear and/or solar power generation
- Laser and microwave energy transmission to
 - Earth orbiting satellites (power and propulsion)
 - Cis-lunar vehicles (power generation , propulsion, light sailing)
 - Planetary probes (power and propulsion)
 - Other bodies in the solar system
 - Asteroid trajectory shaping?
 - Earth surface (power and communication)



Possible Lunar Power Beaming Growth Path





Example Case

- Emplace ten 100 KW reactors on the lunar surface, providing 1 MWe.
- Assume 80% loss (conversion, dispersion, pointing, etc) to deliver power to an earth-orbiting satellite
→ Would provide 200 KW for spacecraft power
- Could be time-shared among several spacecraft, using secondary batteries for storage
- Possible applications for ~50 KW earth satellites
 - High performance space radar
 - Orbital materials processing
 - Very high capacity, high data rate communications
 - High performance, medium thrust propulsion



These Applications Have Direct Significance for Multiple Sectors

- Civil Government
 - Environmental monitoring
 - Remote sensing
 - Communications relay
 - Orbital operations
 - Global protection
- Security
 - Observation
 - Communications
 - Surveillance
 - Environmental monitoring
 - Assured nav reference
 - Space situation awareness
 - Orbital operations
- Commercial
 - Data relay
 - Broadcast services
 - Mobile communications
 - Remote sensing
 - Environmental monitoring
 - GIS
 - Manufacturing
 - Satellite operations
 - Energy

And Also Indirect Implications



Potential Lunar Utilities

- Utilities support both establishment and operation of lunar services, e.g.
 - Power
 - Communications
 - Surface transportation
 - Life support
- The primary need for life support may be to sustain robots and crews for construction of automated or remotely tended facilities.

Utilities can be provided by private suppliers.



Examples of Infrastructure

- Earth-to-Moon-and-return transportation
- Earth-based operations sites
- Payload processing
- Other logistics support activities

Infrastructure can be operated by government or private organizations.



Assessing the Value of Lunar Activities

- Affordability from a government perspective
 - Is needed budget available, considering
 - historical agency budgets
 - other national needs
 - commercial participation
- Affordability from a commercial perspective
 - Is sufficient capital available?
 - Is ROI sufficient?
 - Global collaboration and international ownership supported by global funding (World Bank, IMF, European, Pacific Bank of Reconstruction, etc)



Possible Answers to Value Chain Considerations

- What will a lunar base do?
 - Lunar-based science, space exploration support, terrestrial and cislunar “applications”
- Who will benefit?
 - Governments, private sector
- What will they pay?
 - Depends on the value of the products and services delivered
- Who will participate in delivering the value chain?
 - Governments and private sector, probably in a diverse market
- How will value chain participants benefit?
 - By delivery of products and services all along the value chain
- How much are they willing to invest?
 - Depends on anticipated return on investment, affordability and risk



Implications

- Affordability should be assessed in the context of a large range of potentially valuable lunar-based capabilities.
- Affordability should be assessed in the context of shared government and private sector involvement across the value chain.
- Private sector participation can begin early, assuming that lunar operations will produce value beyond science and exploration.



A Final Question

- What steps can be taken in the near term to incentivize private investment?
 - Guaranteed market for services?
 - Rights to lunar resources/site lease?



The California Space Authority encourages continued investigation of these opportunities. The real answers are ahead of us!