Sustainable Lunar Exploration Requires a Competition-Based Open Architecture

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Open architecture strategies

Earth to orbit activities are separated from in-space transit

In-Space vehicles and lunar habitats are small and modular
Earth to orbit activities are separated from in-space transit

- The barrier to entry is lower if companies aren’t required to develop complete Earth-surface-to-lunar-surface services; this enhances competition

- Existing cargo ELVs and new Earth-to-LEO passenger vehicles easily fit into the lunar initiative, enhancing competition and economies of scale

In-Space vehicles and lunar habitats are small and modular

- *Battlestar Galactica* model causes many constraints (available volume for installing new gear, limits on access the vehicle surface for antennas, etc.)

- Mix-and-match method allows new entrants to develop specialized add-on exterior modules, for faster technology uptake and enhanced competition
  
  - For example, a closed-loop life support module that could be added to an in-space vehicle that started off with expendable air/water systems
Achieving an open architecture

- **Open architecture implemented with three staging points**
  - Low Earth Orbit (SpaceDock™)
  - L1 (Gateway Station) or on-the-way refueling
  - Lunar South Pole

- **Additional staging areas may be developed by industrial participants to serve their business models**
  - Additional LEO stations or depots
    - At different inclinations or altitudes
    - Using alternate rendezvous methods: berthing instead of docking, or tethers
  - Non-polar lunar stations or depots
  - Cycling orbits or other Earth centric high orbits
Minimal initial structure is put in place by t/Space

- Launch CEV (Crew Transfer Only)
- Propellant & Cargo
- Transit CEV
- L1
  - Ship-to-ship Propellant, Cargo & Crew Transfer
- Base Camp
  - Lunar Polar Site
- Cislunar Comm & Nav
Many elements contribute to a vibrant cislunar economy
Technology must *not* be the goal

- **Sufficient technology for the Moon existed in 1969**

  ...tools that now resemble the stone ax

Value, not new technology, is the right metric
Three ingredients of lunar value

Reduced Development Cost

- NASA always will be in a mixed mode of development and operations; every development dollar cuts into what the initiative actually can do.

Reduced Operations Costs

- Labor drives the cost of operations. We cannot afford the past practice of shifting big development workforces into big operations workforces.

Valuable outputs

- The results must impress the public
  - Visible economic paybacks
  - Opportunities for greater public participation, esp. telepresence
- Lunar science wasn’t sufficiently interesting to save Apollo
- Program must seek benefits to Earth from lunar resources, and from how the NASA initiative can jump-start vastly greater LEO-GEO enterprises
How to reduce development costs

- Use the rapid prototyping mode of Scaled Composites & AirLaunch LLC as the ultimate in “spiral development”
  - Many specifications flow from discovering what current hardware can do, rather than inventing hardware to match specifications

- NASA should not set minimum unit-size requirements
  - Good: “six astronaut-explorers delivered to the Moon”
  - Bad: “six astronaut-explorers per flight delivered to the Moon”
  - Big vehicles are more expensive to develop, limiting the number of companies that could compete to offer such services
Use CEV program to spur passenger travel to LEO

- If NASA “invents” a competitive LEO passenger market through its contracting strategy, it will reap huge economies of scale
- Economies make human-assisted in-orbit assembly cost effective
- Commercial market will rapidly overtake dollar volume of NASA ETO spending, shifting development costs to the private sector

Use EELVs as long as possible for heavy lift

- Compensate for modest lift capability via assembly in space
  - With a robust passenger market, the cost of human labor will be much cheaper, avoiding expensive tech-dev for robotic assembly methods
- Not spending $18 billion in 2010-20 on invisible-to-the-public heavy lift development means $18 billion more will be available for actual operations in space that the public can see and understand
Most lunar facilities needed by NASA should be privately owned to facilitate add-on commercial uses

- For example, specialized surface gear (rovers of various types, hoppers, diggers, etc.) would be rentable by private users

Even “science labs” ought to be owned commercially so that essential services can be sold to non-NASA users

- A rock sample lab, for example, should be available after hours to prospectors needing analysis of their finds

This will bring economies of scale and provide NASA with diverse and competitive supply sources

This approach also gives the public the maximum emotional return on their investment

- Private ventures will expand the range of “frontier” activities well beyond often-esoteric government science projects
**Example penny-pinching technique:**

**Cargo canisters as habitat add-ons**

T/CEV drops or winches the canister directly down, takes off with it still in place below.

*Many canisters can be pre-positioned by unmanned T/CEVs prior to human expedition, w/o robotic cranes or other complex gear.*

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Canisters later connect to habitats for unloading like MPLMs connect to ISS; but they remain attached to provide volume.

*Requires canisters able to link to each other, or habs w/many nodes.*
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Safety results from design choices, not oversight

- Attempting to produce safety by inspection, quality control, documentation, meetings etc., is ineffective and costly.
- The right choices include a robust and resilient concept, vehicles with ample margins and reserves, and high flight rates using smaller vehicles.

Flight history determines if a vehicle is “human rated”

- Requires hundreds of flights for statistical validity.
- “Determination-by-analysis” is just an estimate.

Cost is an object

- Expensive systems have too few units built to give resiliency to the architecture, and/or high operating costs lead to unsafe low flight rates.
Sustainability results from encouraging diversity of vehicles and systems, using our “Standard Gauge” view of interoperability of privately owned elements:

- Sustainability will be produced when the NASA spending for exploration is overtaken by the total economy of Cislunar space.

Diversity of future suppliers will give NASA real control over its destiny:

Poor performers can be fired, instead of being given bigger contracts to fix their failures.
- NASA needs improved value-to-the-public via lower costs and more meaningful results

- An open, competitive architecture drives down costs and delivers a broader range of results

- t/Space will develop an architecture, and proposed NASA policies, that sharply reduce costs as they produce faster achievements