Journal of Space Philosophy 6, no. 1 (Fall 2017)

Logic for the Description of a Viable Path to a Cis-Lunar Transport System and Lunar Mining Base

By John Strickland

Abstract
This article covers the need for an integrated, clean sheet set of space vehicles for the cis-lunar transport system and lunar mining base, and the problem that we will probably not get such a system. A system created from a mish-mash of existing designs and elements will take much longer to integrate and become economical. It also presents a list of some of the required critical components for cis-lunar bases and lunar mining bases.

Keywords: clean sheet, cis-lunar transport, reusable boosters, reusable in-space vehicles, reusable lunar ferry, propellant depots, cargo transfer capability, heavy excavator, cargo unloader, power sources, fuel production system.

Given the current lack of direction by the national space program in the United States, but at the same time noting that individual companies are starting to choose their own directions, which may or may not be compatible with common goals, how can any responsible group that has any influence in the space community best suggest a way forward to create the currently desired goal of a cis-lunar transport system and lunar mining base that is fiscally supportable and practical? The dilemma faced by any such effort is the choice between supporting the slower but more probable direction of a piecemeal approach led by the individual companies, or the possibly much faster and more efficient clean sheet system approach, which requires coordination between companies. Is any compromise or hybrid of these two paths possible? To solve this problem would be like successfully herding jaguars.

There have been many proposals for lunar transport systems, but these have mostly been descriptions of *individual components* of a transport system, (one composed of already existing designs), or a *clean sheet* and integrated system, which is less likely to be built, since a significant number of new components would all need to be designed in concert, built, and then operated as a unit. No one company currently has the industrial muscle to do this. NASA is not currently in a political or fiscal position where it can do this. If a system is designed component by component, each by a different company, it is likely to take decades to make the pieces work together. As an example, when semi-trailer trucks first appeared, they competed with railroads for long-distance shipping. Later, it was found advantageous for certain types of cargo to be carried both on rail cars and on semis, which led to the concept of simply placing the trailers on rail cars for the longest part of the trip and using trucks for local delivery. But such solutions do not always happen. Australia still has three different railroad gauges nearly 200 years after the first railroads.

If a group wants to create a realistic scenario that could lead to an efficient cis-lunar transport system, it needs to deal with the piecemeal vs. clean sheet system divide. Individual companies' decisions are made by their own executives, but they do not live in an information vacuum. News about advances in space transport come in almost every day, and they could affect the viability of any design. The diameter and lifting capacity of launchers also limit what can be built, so that it may be launched in the near term. The nearer the required launch date, the more restrictive the launcher choice is.

The logic to create such a transport system may thus be divided into two phases:

(1) One using existing or very near-term boosters and mostly existing designs to create a temporary lunar transport system, which may be able to bootstrap a more efficient later system.

(2) A full-size transport system, with components made by different companies, but designed to work with the components made by the other companies for mutual profit.

How can NASA or any other agency or group expedite the efficient creation of either type of system? Proof of profitability seems to be the largest issue. This means (a) the ability to produce a product such as lunar-derived water or rocket propellant in sufficient volume, and (b) the existence of one or more markets for that product (cis-lunar commercial travel and/or Mars expeditions mounted by government or private agencies). Of course, the cost of providing the service or product must be sufficiently less than what can be charged for it.

Some examples of near-term systems include the ACES depot concept and the XEUS lunar lander concepts being promoted by ULA and Masten. SpaceX is favoring an infrastructureless design for its Mars transport system, using tankers instead of depots for fuel transfer, but as of July 2017, it was in the process of updating its overall launch vehicle and Mars vehicle designs. Blue Origin has not yet defined any of its in-space transport and infrastructure concepts in concrete terms. Other companies such as Moon Express are working on lunar landers with significant cargo capacity, but no crew-sized lunar vehicles are under serious development yet. It is not clear whether any of these smaller vehicles will be reusable or not.

If any of these companies or NASA goes ahead with a near-term design that can be launched on a near-term booster, how long will it then take before any of the companies decide they need a blank sheet design for efficiency. Will the companies eventually work together? Will they work with NASA for long enough to get real results such as actual lunar rocket fuel production and its transfer to L1 or an equivalent location?

If companies and the government could decide on a cooperative, integrated approach, there would still be one more major decision to make. Would each company build a complete, separate vehicle, or would some companies agree to build common components such as rocket engines and habitation modules, and then have companies designated to assemble the vehicles and modules from the components? Which method would cost less in the long run if NASA were the primary customer?

There are not enough detailed current system component designs to fill out a complete lunar transport and mining base system. Perhaps the best thing to do is to create a description and possibly a video of a blank sheet coordinated system to show the disparate companies what the benefits of such a system could be. Such a video could show near-term refueling of lunar payloads in LEO to allow larger ones to be landed on the moon, prospecting for the lunar volatiles and initial validation of quantities and qualities. Then the entire transport and base system could be shown in full operating mode, supplying thousands of tons of propellant to Mars expeditions. Emphasis should be on the operating elements like propellant depots and cargo-handling equipment that are still missing from most official cis-lunar plans.

A List of Components for a Cis-Lunar Transport System and Lunar Polar Mining Base

This list is just an *example* of one approach with multiple components. Any transport system must consist of both mobile vehicles and stationary nodes such as bases or stations. The transport system is needed first to create the bases, first at L1 or equivalent, and then at a lunar pole, which can then help support the cis-lunar transport system and propellant production for Mars expeditions. Reusable in-space vehicles must carry enough propellant for a return to the departure point. These represent the building blocks needed to create the bases and supporting transport systems, which are integral to the design. This is an ideal, clean slate system based mostly on new, purpose-built elements. This path may not happen.

1 Rockets
   - a Reusable first-stage rockets: **Falcon 9, Falcon Heavy** (existing), **New Glenn** (proposed).
   - b Reusable second-stage rockets: possible Falcon 9 upper stage, ITS upper stage (both proposed).

2 LEO logistics base with *propellant depot* and cargo transfer capacity with crew habitat(s) (part of the required cargo transfer capability already exists on the International Space Station).

3 Cis-Lunar logistics base with *propellant depots* and cargo transfer capacity with shielded crew habitat(s). Initially, this will need several hundred tons of propellant storage. Roughly 2,000 tons of storage is needed to support realistic Mars expeditions with reusable vehicles.

4 Reusable LEO to L1 ferries (capable of single-pass aero-capture for return to LEO), versions to carry crew, cargo, and propellants (here, L1 represents a range of possible cis-lunar locations).

5 Lunar ferries
   - a Reusable L1 to Lunar surface ferry – propulsion module (when alone – acts as a flatbed cargo ferry).
   - b Reusable Lunar Ferry – crew version (with crew cabin) (used with a propulsion module).
   - c Reusable Lunar Ferry – tanker version (with propellant tanks) (used with a propulsion module).

6 Lunar polar mining base
   - a Infrastructure

Power sources (reactors/turbines, solar panels, cables, power management, battery or fuel-cell backup).

Heavy excavator and narrow trencher.

Cargo unloading and transport system including cranes, flatbed trucks, and tanker trucks.

Assembly robots.

b Crew and Science equipment

Two or more buried habitat modules with redundant life-support and power equipment.

Pressurized crew rover.

Local ATV crew transport.

Tools and science equipment.

Food and water reserve.

c Mining and extraction equipment

Specialized excavation and separator system for volatile deposits.

LOX-LH2 fuel production system from lunar water.

Lunar propellant depot (initially several hundred tons of storage needed; can be located in sunless area if near base).

****

About the Author: John Strickland has a BA degree in Anthropology and another in Computer Science. He retired as a senior Analyst for the State of Texas in Austin in June 2009 after 20 years. He is a member of the Board of Directors of the National Space Society and of the Protect Lake Travis Association in Austin, TX. He serves as the NSS Assistant Treasurer, is the chair of the NSS Awards Committee and Roadmap Committee, is an Advocate with the Space Frontier Foundation, and is an active member of other pro-space organizations. His specific interests include access to space, reusable spacecraft, space policy, space solar power, and planetary and space logistics base infrastructure. He contributed chapters to the 1998 edition of Dr. Peter Glaser's book: *Solar Power Satellites: An Energy System for Earth*, and to the 2005 book *Return to the Moon*, edited by Rick Tumlinson. Since 1976, he has produced articles and papers for *The Humanist*, *L5 News*, *Solar Power*, *Ad Astra*, *Space News*, *NASAWatch*, *The Space Review*, the *Journal for Space Communication*, and for other local and regional publications and sites. He is currently finishing work on his major book *Developing Space*. He lives near Austin, Texas.

Editors' Notes: John Strickland has been positively influencing the Space Community for over fifty years. He founded the Austin Space Frontier Society (Texas) and been its Chairman since 1981. He was a member of the National Space Institute and the L-5 Society, from which flowed the National Space Society (NSS), the distinguished leading global space organization. He has a career of research, publications in the Space Review and presentations for Space conferences and symposia while serving on the Board of Directors of the National Space Society. This article is his first in the *Journal of Space Philosophy.* Returning to the Moon for both capturing resources for Earth and facilitating exploration to Mars has revived over the past ten years as a feasible goal. John Strickland here describes what will be needed, and how companies and the government could cooperate for an integrated approach to a complete lunar transport and mining base system. *Bob Krone and Gordon Arthur*.