07 – The Lunar Ferry and Spaceports

SUMMARY

Let's not ignore the reusable vehicles that Blue Origin is specifically developing. Although its Blue Moon Mark 2 lander doesn't deliver the cargo mass anywhere close to SpaceX's lunar Starship, with on-orbit refilling and sourcing its propellant from the Moon, Blue Origin can establish a lunar ferry greatly reducing the number of refilling required in LEO.

LUNAR FERRY

The Blue Moon Landers

This book talks a lot about SpaceX's Starship fleet because it will likely become a growing reality by 2030, because of the implications of so much capacity, and because we know more about it because of their greater openness. But Starship is designed for Mars and not the Moon.

But there is a heavy lift vehicle being developed specifically for the Moon -- namely, the Blue Moon landers by Blue Origin, Jeff Bezos' company. Significantly, its propellants are hydrogen and oxygen which can both be resourced from lunar resources specifically, the water ice whose existence NASA proved in their 2009 LCROSS Mission. They found a spot where concentrations were at one part per 18 which is certainly high enough for use as propellant. The best estimate is that there is at least 600 million metric tons of water ice on the Moon. If one were to launch the equivalent of a Shuttle external tank from the Moon every day, propellant from lunar water would last for more than 2,200 years -- plenty of time to develop and import propellant from alternate sources (e.g. asteroids). So, in practice, the Moon will never run out of water.

A Lunar Ferry

Why is it so valuable to source propellant from the Moon? One can imagine a lunar ferry on the lunar surface being refueled with lunar-derived propellant. It ascends to about EML1 (an Earth-Moon gravitational balance point), retrieves a cargo or crew module from a vehicle coming from the Earth, and then brings it back down to the lunar surface.

To understand the significance of the lunar ferry, one only has to ask how much would it take to deliver that same propellant from the Earth. Rocket scientists measure the difficulty in moving to different orbits and locations with the term delta-V (DV). This indicates how much a rocket needs to accelerate a payload in order to change its orbit. To get lunar ascent and descent propellant from the Earth to the lunar surface, the DV is about 16 km/sec. Think about that, increasing the speed by 16 kilometers each second! Whereas the DV for ascent and descent propellant from the Moon is, in a way, 0 km/sec because you don't need rockets to transport water from a permanently shadowed region to the lunar ferry.

Now, that said, the Blue Moon Mark 2 lander has a dry mass (meaning mass without propellant) too high to be a good lunar ferry. We will have to wait to see if Blue Origin comes up with a Mark 3 lander specifically designed to be a ferry. If so, then the Blue Origin "tortoise" (not known for its speed) could ironically take the lead by having chosen a much closer finish line (the Moon) than SpaceX's "hare" which never stops running but has chosen a finish line (Mars) 70 times further away in terms of round-trip time. For the sake of lunar development, a lunar ferry would be tremendously helpful.

LANDING PADS

Sandblasting While Landing

Concern has been raised about vehicles landing on the Moon. The exhaust velocity of such landers is actually greater than lunar escape velocity. Some have commented that dust and rocks kicked up during the landing process could be traveling so fast that they would pose a danger to the orbiting Gateway. They also point out that the dust and rocks thrown up would be traveling in an orbital ellipse and as such they would tend to come back to the exact same landing point. But whether these scenarios happen or not, it is incontrovertible that the dust kicked up during landing would sandblast nearby objects whether solar drapes, habitats, outdoor equipment, rovers, or whatnot. It would certainly seem prudent to prevent this.

This latter point is not a theoretical concern. Apollo 12 intended to land close to Surveyor 3, which was an unmanned lander which arrived on the Moon just a few years before. The Apollo 12 crew did such a good job conducting a pinpoint landing that they actually saw Surveyor 3 even before landing and landed so close that they were able to walk over to it. Upon inspection (and they returned with a piece of it) they found evidence of it having been sandblasted by their own exhaust blast.

Landing Pads

One obvious solution to this challenge is to construct landing pads so that only gaseous exhaust and no pebbles are blasted outward. Circular berms constructed around the landing pad would redirect any exhaust away from local structures. A fair concern would be about whether an "off-nominal" landing where the lander misses the mark and conducts an emergency landing off the landing pad thereby kicking up unprotected regolith. This situation could be partially addressed by locating landing pads at the bottom of natural craters so that there is a large, natural berm protecting distant structures.

An additional solution would be to locate landing pads away from structures but within easy driving distance. It has been suggested that a two-kilometer distance from structures should be sufficient. These would be the regional spaceports that the Space Development Network advocates.

Work has been done looking into whether pavers could be produced via microwave sintering and then the telerobotic placement of the pavers to make a landing pad. As can be seen in the image to the right, this was demonstrated in an experiment conducted in Hawaii.

Another quick and low-energy approach would be to deliver tarps for the outer lander zone. These thin tarps would prevent the gaseous flow from the exhaust from interacting with the lunar dust. Telerobots could secure these tarps into the ground using spikes.

Yet another (and rather ingenious) proposed solution to the initial landing would be to inject aluminum powder into the exhaust of the lander. This aluminum would be immediately melted and so would spray onto the landing site providing a type of metallic mortar to hold the regolith together just prior to landing.

All things considered, we believe that some combination of the proposed sandblasting and landing pad solutions will adequately address the challenge.

SPACEPORTS

Location of Spaceports

Given the ability of spaceports to be connected to bases and structures via roads, it then follows that a single, well-placed spaceport on the Moon could serve a region. And once one spaceport is created, that

experience could be used to duplicate the construction of spaceports elsewhere on the Moon. So, where should the spaceports be located?

It seems that there are logical locations for spaceports namely, places that people will want to routinely visit. Probably the site most desired to visit would be the Apollo 11 landing site where humanity first set foot on another planetary body. So, one could look around there to find some feature that could act as a natural shield to protect the Apollo 11 site from blast from an off-nominal landing. This could be something like the cluster of craters 5 km to the northwest called the Cat's Claw.

Visiting Tourist Sites

One could imagine lunar spaceport and tourism companies establishing and operating regional spaceports and the roads connecting them to local sites of interest. Roads could snake along the terrain to logical overlook points where sintered platforms and tourist facilities with large windows could allow the tourists to have a relaxed environment overlooking the point of interest. In particular, on the rim of major craters, beautifully architected centers could give tourists views looking out at dozens or hundreds of kilometers of pristine view to view the central peak and distant crater walls.

A student group in the Space Concepts Studio class at the University of Southern California Viterbi School of Engineering proposed a very promising idea. He envisioned two towers being erected on either side of the Apollo 11 landing site. Between the tips of the towers there would be a cable from which a gondola would take visitors directly in front of the descent vehicle and over the footprints from Neal Armstrong and Buzz Aldrin. In this way, visitors could get a very close view of that history without risking that their own footprints would obscure those historic footprints.

Tourists viewing the Apollo 11 site.