ShipinSpace – A Proposal for a Heavy-Duty Cargo Transportation System for Space Travel

Daniel Ramos, Gabriel Zanko, *MobileyourLife – Bogotá, D.C., Colombia*

Abstract

The future of space exploration is looking brighter by the day, with manned flights returning to the spotlight and a focus from the main space agencies to return to the Moon with the intention of establishing lunar bases that could facilitate the exploration of further planets. However, this goal presents new hurdles in the form of efficient and safe transport of large quantities of building materials, which requires different approaches compared to the transport of human crews. ShipinSpace is developing a solution that could not only reduce the costs of space launches dedicated to cargo, but also take advantage of the eventual implementation of Low-Earth Orbit stations to further increase the efficiency of this process.

***Index Terms* – Space exploration, Moon, lunar base, space launcher, lunar module, cargo transportation.**

I. Introduction

In recent years, we have witnessed the resurgence of space exploration as a relevant field in terms of technologic innovation and economic relevance. On the first place, the numerous unmanned exploration missions sent to Mars in the last two decades have kept the space launch industry and the development of autonomous explorative vehicles alive, while providing us with insight on the atmospheric conditions of the planet closest to our home.

In addition, the development and implementation of reusable orbital launch systems by companies like SpaceX has been under the spotlight for the last few years, with the launch of their first manned flight in May 2020, to resounding success and opening the doors to achieving goals like returning to the Moon (NASA's Project Artemis) and the eventual sending of astronauts to Mars, which seem closer than ever before.

However, even if costs are cut greatly from the reusing of rockets, there are still concerns about our capacity to plan and execute manned missions to Mars from the economic and engineering points of view. Reviews of past missions show how the managing of budget, fuel and payload weight are the main concerns when planning these missions1, so these have been the focus of many projects in recent years.

In this research document, we will be focusing on the solution proposed by the team at ShipinSpace, a startup based in Witney, England led by Fabrizio Boer, which includes a design for what they call a Lunar Base Launcher (LBL), a new transportation system especially created to move large and heavy loads from Earth to the Moon having the highest capacity ever with its capability to deliver over 58 metric tons to the Moon surface, and that could eventually help in shipping the materials required to build a lunar base, which could act as a checkpoint for longer missions.

II. Concepts and Proposal

To fully understand ShipinSpace proposal, we must first look at their original idea for a new kind of space launcher. A 4-stage Launcher, the Lunar Base Launcher or LBL, based on the use of one single booster type for 3 stages, then with reduced development costs, with a total of 11 boosters (10 boosters surround the main cargo compartment and a last one is attached to the bottom, which would sit underground during launch, see Figure 1). Achieving a thrust of 5400 tons at launch, it is calculated to reach payload masses of 240 tons in Low Earth Orbit (LEO) and over 58 tons to the Moon surface.

These calculations were performed using the Tsiolkovsky rocket equation, which describes the motion of vehicles that apply acceleration to themselves via thrust by expelling part of its mass (in this case, the fuel):

$$\Delta v = v_e \ln \frac{m_0}{m_f}$$

Where Δv is the maximum change of velocity of the vehicle, v_e is the effective exhaust velocity (calculated by multiplying the specific impulse by gravity), m_0 is the initial total mass and m_f is the total final mass. This expression considers how the fuel is being expended through the flight, and how this reduction generates greater thrust through time (Figure 2).

However, this same equation can be applied to their project MTLM or Multi-Task Logistic Module, basically the LBL 4th stage scaled down to fit within current Launchers Fairings such as Ariane 5-6 or Falcon 9, so it can be adapted to the fairing of launchers that are currently in use. For example, when considering the Ariane 6 system currently employed by the European Space Agency by reducing the diameter of the container from 12 to 5.2 meters, the total payload that could be transported from LEO to the Moon is calculated as follows:

$$\Delta v = v_e \ln \frac{m_0}{m_f}$$

Solving for the final mass, we have:

$$\frac{\Delta v}{v_e} = \ln \frac{m_0}{m_f}$$
$$e^{\frac{\Delta v}{v_e}} = \frac{m_0}{m_f}$$
$$m_f = \frac{m_0}{e^{\frac{\Delta v}{v_e}}}$$

Since the calculated Δv for travel between LEO and the surface of the Moon (regardless of the vehicle) is 6.12 km/s, the specific impulse for engines using the LH2/LOX configuration is 465 seconds, and the maximum load (fuel included) is limited to 21.65 tons, solving for the final mass, we have:

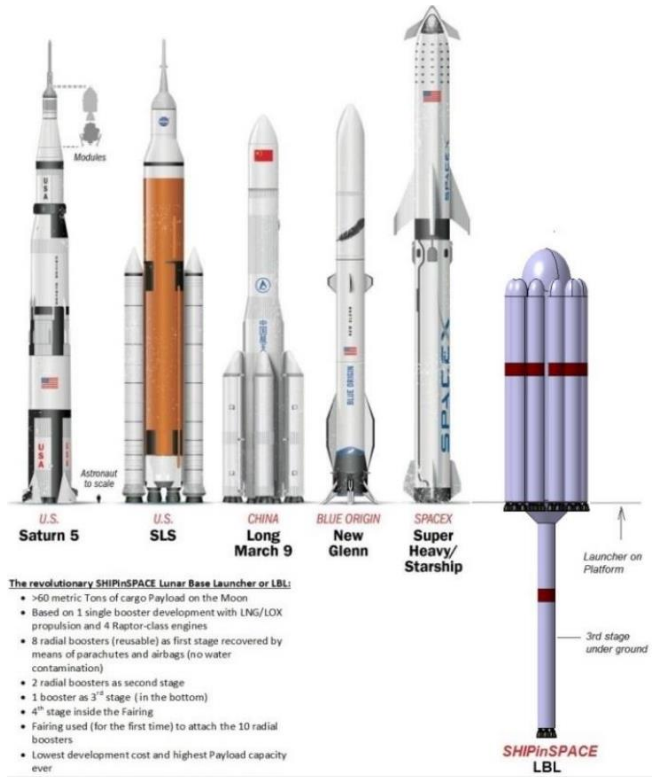

Figure 1. Comparison between multiple space launchers currently in use and ShipinSpace’s Lunar Base Launcher (LBL). Notice how the third stage of the LBL is designed to rest underground before launch.

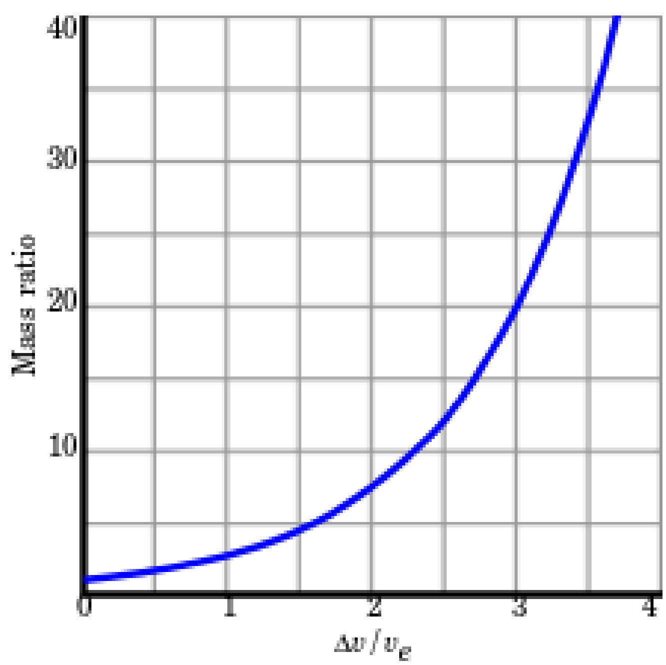

Figure 2. Plotting of the principle behind the Tsiolkovsky Rocket Equation, where the thrust generated is directly proportional to the mass ratio. Note how the burning of fuel, which increases the ratio, alters the growth rate of the thrust generated.

$$m_f = \frac{21650\ kg}{e^{\frac{6120\frac{m}{s}}{465\ s*9.81\frac{m}{s^2}}}}$$

$$\boldsymbol{m_f = 5660\ kg}$$

By assuming a structural mass ratio equal to 6.8% by using airbag technology that helps stabilize the structure against buckling (just 1 mm CFRP wall thickness is necessary) which equals to nearly 1472 Kg, a payload mass of 4188 Kg is achieved.

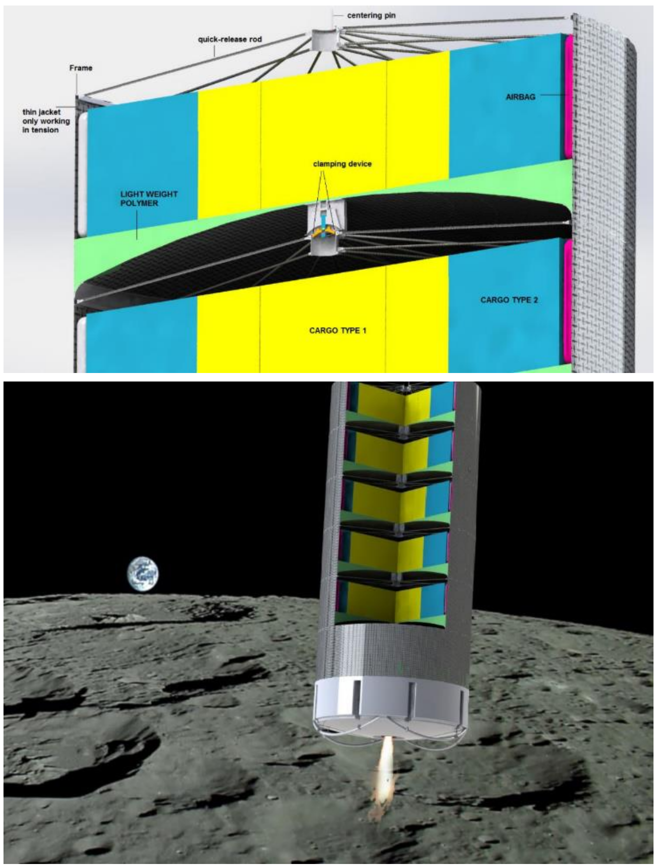

Figure 3. Diagram showing the placement of the cargo containers, protective airbags, and other structural devices in the adapted ShipinSpace solution for smaller launchers (above), along with a visual representation of how the MTML can reach and land on the surface of the Moon (below).

What is new in the ShipinSpace concept is the methodology to hold the cargo using pre-compressed airbags to avoid movement and damage (Figure 3), which makes the shipping an extremely secure process and avoids designing specific mechanical interfaces which are extremely expensive.

However, since ShipinSpace's proposal also aims to take advantage of LEO modules that could act as "mid-points" for larger shipments, in which the cargo is accumulated in the module to be picked up by the docked Powered Module during an orbital rendezvous, the maximum capacity that could be transported from LEO to the Moon is 6,128 kg, which is 36% better than other proposals, like Amazon's Blue Moon, which has a maximum capacity of 4,500 kg and requires to be set into lunar orbit instead of reaching LEO, and over 4 times higher than the European Lander EL3 which has a capacity of only 1,500 Kg.

III. Market and Competition

Both NASA and ESA have already declared their interest in establishing lunar colonies3, 4, which is why projects like ShipinSpace could prove their worth as they would allow for transportation of hundreds of tons of building materials for the necessary facilities. In this regard, launch costs when coupled with a Falcon 9 can see reductions from their current cost of $50,000/Kg using the NASA new Launcher SLS to

$7,180/kg of payload price, and the eventual implementation of LEO loading and refueling stations could reduce that cost even further, to a projected $2,046/kg.

In terms of future plans, the MTML project is divided in 7 work packages focused on communications, development, partnerships and manufacture, with the project currently going through the fundraising for their Phase I, which includes work packages 2 (Technology readiness level 4 prototype, including airbag technology, analysis of structural impact and mechanical design of a 1:2 scale simplified prototype) and 3 (phase B development plan, covering validation plans, propulsion subsystems, thermal protection, design of the electric power subsystem, and other aspects), along with all the tasks regarding management and communications with NASA, ESA and other space companies included in work package 1 (which continues during the entire duration of the project).

Further, Phase II of the project included the final development of all the systems, structures, and manufacturing drawings (WP4) and the initial bids with space agencies and private companies (WP5), and Phase III will then focus on the manufacturing of the final design for the MTLM (WP6) and product assurance and validation testing (WP7).

In terms of sales, the success of the project relies on the correct setup on a refueling system, one of the first priorities to build the basic infrastructures that will eventually support the first Moon colony, which will most likely be located near the lunar poles, where ice has been detected and electrolysis could be used to extract H2 and O2.

Taking an estimate of 300 metric tons of materials and machinery required for construction and the price of $50,000/kg at the NASA SLS Launcher, the bill rises to $15 billion. By implementing the MTLM and setting an operational cost of $10,000/kg, not only does the total operation cost fall to a fifth of the current expected price, but it could also achieve profit margins of 4.88.

The MTLM could also be an attractive solution for private companies looking to venture into the world of lunar exploration. We have seen how SpaceX thrived as a private company before reaching agreements with NASA, which acts as a precedent for this type of interactions and, given how ShipinSpace focuses on the sending of cargo instead of human crews, there could be more potential clients for their solution.

IV. Other Potential Applications

As we mentioned before, the success of ShipinSpace is tightly related to the implementation of fully functional LEO stations that could act as checkpoints for refueling and reloading of cargo. NASA has already shown their interest in developing what they call a "Low-Earth Orbit economy"5, with the International Space Station opening for business, which could push forward the creation and coupling of modules that could fulfill the roles needed for the MTLM. In addition, ShipinSpace system could even be used to send large amounts of materials, tools and devices for further experiments or equipping extensions of the ISS in a single launch.

On the other hand, the MTLM can eventually become a safe and efficient way to transport resources extracted on the Moon back to Earth. Metals like silicon, iron and aluminum are found in lunar rocks in useable concentrations, and other rare-earth elements and resources (like solar energy) could also be extracted, which would require the use of safe transport to bring back certain amounts of these products to Earth, a field which ShipinSpace is trying to enter and eventually dominate with their ambitious yet viable proposal.

V. Conclusion

Projects like ShipinSpace not only work to broaden the scope of space agencies towards the future of space exploration, since they focus on the development of new technologies while agencies can focus on planning ways to implement them in the future, turning the situation into a joint effort worked simultaneously on both ends.

If ShipinSpace solution reaches the end of their development cycle, we could be looking at a turning point in space launches that diversifies between cargo flights and crew flights, much like the aviation industry, that could increase the efficiency of the entire field and open the way for new agencies or divisions focused on cargo, which could translate into the creation of new jobs or the opening of doors for new countries or regions to join the cause of establishing a lunar base in the near future.

VI. References

1. Herath, Anuradha K. (2011) "Why is it so hard to travel to Mars?" Space.com. Retrieved from: https://www.space.com/11417-mars-missions-space-travel-challenges.html
2. European Space Agency "Ariane 6". Retrieved from: https://www.esa.int/Enabling_Support/Space_Transportation/Launch_vehicles/Ariane_6#:~:text=Ariane%206%20will%20be%20available,11%20000%E2%80%9316%20000%20kg.
3. NASA (2018) "NASA's Lunar Outpost will Extend Human Presence in Deep Space". Retrieved from https://www.nasa.gov/feature/nasa-s-lunar-outpost-will-extend-human-presence-in-deep-space
4. ESA (2019) "Concept for a Moon base". Retrieved from: https://www.esa.int/ESA_Multimedia/Videos/2019/01/Concept_for_a_Moon_base

5. NASA (2020) “NASA Moving Forward to Enable a Low-Earth Orbit Economy” Retrieved from: https://www.nasa.gov/press-release/nasa-moving-forward-to-enable-a-low-earth-orbit-economy