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The Interplanetary Superhighway and  
Human Habitation on the Moon  

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Abstract

NASA’s new vision to return humans to the Moon is the next practical step in expanding human habitation beyond Earth. As the Habitation 2006 Conference website states: “new knowledge and new technologies are required.” Along with the development of new habitation systems, an important consideration is how to transport these heavy structures cheaply to the Moon? We propose the use of ultra-low-energy orbits in the Interplanetary Superhighway as an economical and effective means to deliver cargo to the Moon. This approach not only reduces the propulsion cost, but also provides enormous flexibility and robustness to the mission architecture.

Extended Abstract

1. Introduction

NASA’s new vision to return humans to the Moon is the next practical step to expand human habitation beyond the Earth. This time, we plan to stay. As the Habitation 2006 Conference website states: “new knowledge and new technologies are required.” Along

Figure 1. Artist’s (Cici Koenig) conception of the Interplanetary Superhighway in the Solar System.

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with the development of new habitation systems for humans living beyond our home planet, an important consideration is how will we get these heavy structures and supplies cheaply to the Moon? Perhaps in the distant future, propulsion technologies like Star Trek’s warp drives traveling through black holes will be available, but, for the here and now, what can we do with what we have? In this paper, we propose the use of ultra-low-energy orbits in the Interplanetary Superhighway as an economical and effective means to transport the habitat modules, cargo and supplies between the Earth and the Moon. This approach will not only reduce the propulsion cost and increase the final mass delivered to the Moon per kilogram of fuel, but it also provides enormous flexibility and robustness to the mission architecture that is not available by considering the traditional conic orbit approach for interplanetary travel.

2. What Is the Interplanetary Superhighway?

The Interplanetary Superhighway (see Smith, Lo) is made up of ultra-low energy orbits generated by the gravitational dynamics of three or more bodies in the Solar System. These orbits are organized in tubes traversing the entire Solar System. Figure 1 is an artist’s conception of the Interplanetary Superhighway. For the rest of this abstract, we will focus our attention on the Interplanetary Superhighway in the Sun-Earth-Moon system for application to the exploration and development of the Moon.

These tubes of low energy orbits are generated by special periodic orbits. For example, halo orbits around the L1 and L2 Lagrange points are examples of such periodic orbits, as are unstable resonant orbits around the Earth and around the Moon. Figure 2 illustrates a previous concept of the NASA Exploration Team for human servicing of deep space missions enabled by these tubes of low energy orbits (see Lo and Ross). Figure 3
Figure 1. The Lunar Sample Return Mission plotted in Lunar Rotating Frame, centered on LL\textsubscript{2}. The Figure on the left shows the entire mission. The Transfer Trajectory is the segment from the Earth just above the X-axis to the lunar region in the small square. The return trajectory is the rest of the trajectory departing from the small square around the lunar region. Note the return trajectory passes by the EL\textsubscript{1} region and actually uses the dynamics of the Sun-Earth halo orbit for the return. The figure on the right is the exploded view of the lunar region within the small square region on the left. It shows the use of the LL\textsubscript{1} to LL\textsubscript{2} ‘heteroclinic connection’ where the mother ship is conveyed from the Earth to an LL\textsubscript{2} halo orbit. The Lander trajectory departs from the LL\textsubscript{2} halo orbit to the backside of the Moon.

illustrates how the tubes provide a cheaper approach for the Lunar Sample Return mission (see Lo and Chung, Chung and Weinstein).

The caveat for low energy orbits is the fact that they generally require longer travel time in exchange for the reduction of propulsion energy. Instead of taking 3 days to go from the Earth to the Moon, low energy orbits may require 30 days to well over a year to go from the Earth to the Moon. But, the mass savings is highly significant. For example, the Lunar Sample Return mission design team started out with the Apollo style quick trip to the Moon and back, only to find midway that their mass growth and cost constraint did not permit a speedy direct roundtrip to the Moon. Ultimately, they settled for the slower but cheaper low energy orbits to and from the Moon. Where humans are concerned, a long travel time like 30 days to the Moon is not suitable. But, for the transport of cargo like lunar habitats, fuel, supplies, low energy orbits are the way to go. Consequently, low energy trajectory technology is critical for this phase of the development of space.

3. How Can We Use Them For Cargo Transport?

On Earth we typically use the slower but cheaper transport like ships and trains to deliver cargo and raw materials, but save the faster and more expensive jet planes for human transport. In the same going to the Moon, the Crew Exploration Vehicle can take the fast route to reach the Moon in 3 to 5 days, but the cargo like the habitation module, equipment, supplies and fuel can take the slower but much cheaper low energy orbits in the Interplanetary Superhighway to reach the Moon.
These low energy routes not only provide fuel savings, they also provide flexibility in ways which are not possible with conventional conic orbits. In this paper we will explore the tradeoffs between the fuel savings and the longer time of flight, and analyze the many potential applications low energy orbits offer NASA’s new plans to return humans to the Moon, this time to stay. We will also discuss the current state of the art for low energy orbits and the technology development that is necessary to raise the Technology Readiness Level to prove the concept in space and develop the infrastructure so we can take full advantage of this new technology.

References

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