COMPARATIVE STUDY OF ISRU-BASED TRANSPORTATION ARCHITECTURES FOR THE MOON AND MARS: LOX/LH2 vs. LOX/Methane. J. Diaz[1] and B. Ruiz[2], [1] [2]Center for Space Resoureces. Colorado School of Mines, 1310 Maple Street, Golden, CO 80401, jadiaz@mines.edu

Introduction: Space exploration missions are dependent on large vehicles launched from Earth even when the payloads are small. Even though staging would increae the efficiency of missions to other planets and celectial bodies, the massive launch vehicles needed for the completion of such missions make them practically infeasible. If propellants can be produced and stored on the Moon, Mars, etc., the need for these massive systems disappears, making space exploration more feasible (technically and economically) and safe because redundant and emergency systems can then be created at lower costs and shorter times.

Background: Obviously, the availability of resources plays a mayor role as it does the performance of the current rocket engines. When studying the Moon and Mars there are two clear choices: oxygen/hydrogen, and oxygen/methane propulsion systems. We have chosen to use data from the Apollo missions to asses the availability of resources o the Moon and other data from NASA missions for the resources on the Moon and Mars, as well as other bodies. Table 1. provides an overview of the abundancy of resources on the Moon, Mars, and Phobos.

	Resource	Origin	Location	Abundance	Comments	Models
MOON	H_2O	Ice Deposits	Poles	~ 1.5% wt.	Hydrogen as water was assumed	1.0 % wt.
	H_2	Solar Wind	Everywhere	~ 50 ppm		50 ppm
	C	Solar Wind	Everywhere	~ 150 to 210 ppm		150 ppm
	O_2	Pyroclastic glass	Everywhere	~ 4% wt.		4 % wt.
MARS	CO_2	Atmosphere	Everywhere	~ 95% wt.		95 % wt.
	H_2O	Bound Water	Everywhere	~ 10% wt.		5 % wt.
	H_2O	Ice Deposits	Poles	Up to 90% wt.	Cover of dry ice during winter	0
PHOBOS	O_2	Carbonaceous chondrite	Everywhere	~ 12.6% wt.		12.6 % wt.
	C	Carbonaceous chondrite	Everywhere	~ 4.43% wt.		4.43 % wt.
	H_2O	Bound Water	Everywhere	~ 10% wt.	No ice considered	0

Table 1. Resource availability

The performance of oxygen/hydrogen rocket engines is superior to that of the oxygen/methane ones, but the technical difficulties for hydrogen storage and its impact on the mass of the architecture makes oxygen/methane propulsion systems attractive . Both options have been proven feasible for mission durations of a few months. Hopkins [1].

For a mission to the Moon with a small payload, the amount of material that needs to be moved and process on the Moon favores the oxygen/methane option as shown by Ruiz et al. [2]. In the case of a transportation architecture where reusable vehicles between the Moon and L1 are used, refueling at L1, the amount of methane to be produced is twice that of hydrogen, when a fixed payload is assumed. Should we choose to transport the oxygen from Earth and produce only the fuel in situ, the oxygen/hydrogen option proves to be better. However, if the oxygen and the fuel are to be produced in situ, the amount of material to be excavated is twice as much in the case of hydrogen (LOX/LH2) than in the case of methane (LOX/Methane). This advantages disappears if the ratio of the concentration of hydrogen to carbon is 2:3 or higher. Note that we have considered an equatorial location for this comparison (See Duke et al.[3]).

If we now consider a large scale lunar base or the propellant production capacity needed for a Mars reusable architecture, the only viable option is to use the hydrogen from the lunar poles, and therefore the LOX/LH2 choice is best.

Extensive research on these particular topics has been conducted at the Center for Space Resources in recent years, but we had not included the possibility of a reusable methane architecture. We have now compared the hydrogen and methane options under the reusability assumption.

References: [1] J. B. Hopkins (2005) *American Institute of Aeronautics and Astronautics AIAA 2005-6740* [2] B. Ruiz (2003) *Space Resources Roundtable V.* [3] Duke et al. (2004) *STAIF.*