THE DEIMOS WATER COMPANY

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ABSTRACT

Deimos, the outer moon of Mars, is presently the only probable early known accessible source of water to LEO (Low Earth Orbit) or HEEO (Highly Eccentric Earth Orbit). It is the most accessible small body that is "geophysically" anomalous for outgassing in the inner solar system, and thus is a probable source for water ice. Water is needed in LEO and Martian exploration for propellant, life support, and as a chemical and physical process media. None of the above will be accomplished unless it is for a profit.

INTRODUCTION

At the present time everything in LEO has the value of gold at $379.00/oz or $10,000.00/kg. If present published estimates are correct, this will decline in the future to about $37.90/oz or $1,000.00/kg by about the year 2010. The sooner water can be supplied to LEO from sources in space, the larger the selling price that can be obtained. One hundred tonnes of water ice at LEO in the year 2000 will have a value of roughly $1,000,000,000.00, and roughly $100,000,000.00 in the year 2010. The markets will be Mir, the Space Station and possibly a proposed orbiting hotel proposed by Japan for a tourist industry in this time frame.

Space is the driest of deserts! In a desert, no resource is of any value unless there is water, first for life support, and then to process the resource. With water everything is possible. Without water nothing is possible.[K] Water is used for life support, propellants, chemical and mineralogical processing. We are mostly water.

Water, the source and sustainer of life on Earth, is a very rare commodity in our solar system, while ice is plentiful. Sixty percent of the fresh water is tied up as ice at the poles and in alpine glaciers. Our understanding of the role and behavior of ices (water, carbon dioxide, carbon monoxide, nitrogen, methane ices, etc.) will be of fundamental importance as humans move out from Earth.[D]

The large bulk of mass placed in orbit is low-technology materials, mainly propellant. These might be obtained from the Moon, nearby asteroids or Phobos and Deimos. The real killer for the Moon is the fuel needed for the 3 km/sec take off delta-V. From LEO the outbound delta-V to some asteroids is as little as 4.5 km/sec (compared with 6 km/sec for the Moon), and for some asteroids the return to LEO would only require 0.06 km/sec. Availability of propellants on nearby bodies in space is of crucial importance.[L1]

HISTORY

In 1964 Dandridge M. Cole and Donald W. Cox published Islands in Space, about the importance of resources from nearby asteroids. Cox and Cole also point out importance of Phobos and Deimos as sources of propellant and mineral resources.[L1]

Another function of automated (unmanned) materials-processing experiments, such as the process proposed by Kuck in 1995, is to test them on recovering water as well as recovering about 100 kg of Deimos rock as drill cuttings.

DEIMOS SURFACE

May 30, 1971 Mariner 9 blasted off and rendezvoused with Mars on November 13. It arrived during planetary dust storms but photographed Phobos and Deimos and eventually the Martian surface.[L1]

DEIMOS CHARACTERISTICS[C]

Semi-major orbit axis: 23,459 km (14,577 mi).
Orbit eccentricity: 0.00052
Orbit inclination: 1.82°
Orbit period: 30 hrs, 17 min, 55 sec.
Diameters: 7.5 km x 6.0 km x 5.5 km
Rotation: synchronous.
Density: approx. 2 gm/cm^3
Mass: 2.0×10^{12} tonnes.
Mean surface gravity: approx. $10^{-3}g$
Escape velocity: approx. 10 m/sec

Deimos (the outer moon of Mars) should have water ice at depth. Deimos is accessible every 26 months.[L1]

Velocity Changes for Missions in the Mars System[L1]

Mission	delta-V (km/s)
Mars to Low Mars Orbit (LMO)	4.4
LMO to Phobos	0.54
LMO to Deimos	0.87
LMO to Mars	0.05
LMO to escape	1.43
LMO to Earth return	3.42
Deimos to Phobos	0.74
Deimos to LMO or Mars	0.67
Deimos to escape	0.56
Deimos to Earth return	2.55

A comparison of ΔVs in km/sec follows.

	ΔV LEO to	Trip Time days	ΔV to LEO	Trip Time days
Lunar Base	6.2	3	3.2	3
Deimos	5.6	270	1.8	270
Mars	4.8	270	5.7	270

ΔV for Transfers from LEO.[L1] The minimum velocity change (ΔV, in kilometers per second) and trip time in days required to reach each of these destinations to and from LEO is displayed for comparison. Deimos, is still more accessible than the Moon.[L1] Anthony Zuppero proposes using extraterrestrial water based propellant for boosting vehicles from non- orbital trajectories to LEO by rendezvous with a space tug which will propel it to LEO.[Z] The space tug operating on exofuel would descend from orbit to just above Earth's atmosphere and grab onto whatever had arranged to be there at the right moment. An airplane, for example, could lob either itself or a payload pod into the sky to have it snatched away. The tug would then boost itself into space, pulling the cargo along with it. To snatch a payload traveling at Mach 10 would require to or three kilograms of exofuel per kilogram of payload.[Z]

Other possible markets for water based propellants in LEO are refuelling the shuttle for trips to GEO to retrieve and replace out of service communication satellites, or for excursions around the moon like Apollo 8. Propellants for trips to the Near-Earth asteroids, both manned and unmanned could be supplied from Deimos.

Deimos, the outer moon of Mars, is possibly the most accessible source of water to LEO. Lewis has shown the delta-V to go from LEO to Deimos is less than that needed to land on Earth's Moon. Partial loss of velocity at Mars might be obtained by a shallow dip into the Martian atmosphere. The delta-V to return from Deimos to HEEO (Highly eccentric Earth orbit) is very small. The travel time is roughly two years. The Moon may be used as an aid to accelerate and decelerate a vehicle as it leaves LEO and arrives at HEEO. Shallow penetration of the Earth's atmosphere may be used to loose velocity and aid in capture into HEEO.

ΔV's and trip times between LEO and the surface of the Moon, Deimos and Phobos[L1]

	OUTBOUND		INBOUND	
Body	ΔV, LEO to Surface (m/sec)	time of flight (d)	ΔV, Surface to LEO (m/sec)	time of flight (d)
Phobos/ Deimos	5600	270	1800	270
Moon	6000	3	3100	3
Mars	4800	270	5700	270

Phobos and Deimos are more accessible more often than any known asteroids.[O] A disadvantage of Deimos is the 26 month delay between launch opportunities.

The surfaces of Phobos and Deimos are very dark like carbonaceous asteroids, but they lack a detectable absorption feature due to chemically bound water.[L2] This does not preclude interstitial water, only chemically combined water, such as in phylosilicates. This fits with the classification of Deimos as a type D body, which may never have been heated to a temperature adequate to hydro- thermally form phylosilicates. Carbonaceous type C chondrites are divided into sub-classes P, D, RD, T, F, G and B. Only in the middle asteroid belt were bodies heated enough after accretion to melt the ice and create hydrated silicates through the action "groundwater" protected from the vacuum of space by a permafrost layer. In the P-class and D-class asteroids, ice is still present and was never mobilized. Deimos contains water as permafrost even though the surface is anhydrous.[B]

Hartman has reported that Phobos, Deimos and some NEAs are class "D" bodies which originated near the orbit of Jupiter at 5.2 AU. Ice is stable at this distance as a solid without transpiration into the vacuum of space.

Thee surface temperature varies from 40°C (313°K) at the equator to -210°C (63°K) at the poles. The axial tilt causes large annual temperature swings as a function of latitude.(N) This would cause any surface volatiles to be driven off long ago. With Deimos being a class-D asteroid having no combined water and the baking of the surface, the anhydrous spectra should be expected.

Fanale calculates that ice should exist at a depth of 100 meters at the equator and at a depth of 20 meters at the poles of Deimos. Thus, the drilling equipment proposed in 1995 by Kuck should be able to reach ice at or near the poles, but not near the equator.

Two isolated solar wind disturbances about 5 minutes in duration were detected by the Russian spacecraft Phobos-2 upon its crossing the wake of the Martian moon Deimos about 15,000 kilometers downstream from the moon on 1 February 1989. These plasma events are interpreted as the inboard and outboard crossing of a Mach cone that is formed as a result of an effective interaction of the solar wind with Deimos.(S) Possible mechanisms such as remanent magnetism, cometary type interaction caused by heavy ion or charged dust production or neutral gas emission through water and other volatile loss by Deimos at a rate of about 10^{23} molecules/sec.(S) Due to the age of Deimos, the later interpretation is favored. This is the equivalent of a geophysical anomaly indicating the presence of water on Deimos.

To move 100 tonnes of water ice from Deimos to LEO will require 250 tonnes of water ice for propellant.(Z) Thus, in order to leave Deimos 350 tonnes must be

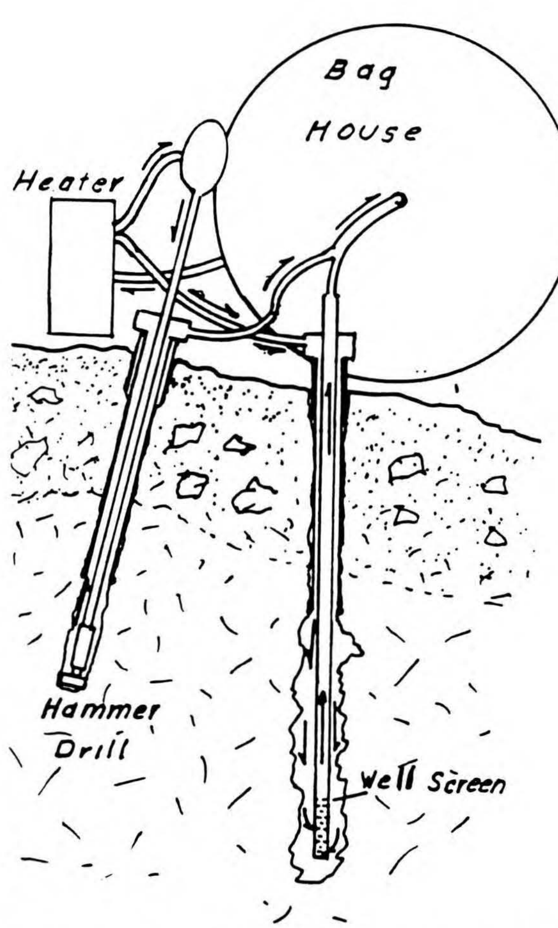

Figure 2. Drill rig proposed in "Exploitation of Space Oases" in 1995.

propelled from the surface. A 1,000 cubic meter collection bag should be large enough to contain the 350 tonnes of ice, cuttings & other precipitates.

Surprisingly, every two years, less propellant is required to travel to Phobos and Deimos from Earth than to reach our Moon. In addition, the low gravity on Phobos and Deimos avoids the need for high-impulse rocket propulsion systems otherwise required for soft landings and high energy take offs. A disadvantage relative to the Moon is that round-trip travel times are much longer, involving 26 months rather than days.(C)

Launch opportunities occur in 1999, 2001 and 2003 for a possible return to HEEO in 2001, 2003 or 2005. Three separate vehicles should be launched at the earliest possible date with a profitable return if only one of the three manages to return 100 tonnes of ice to HEEO. The longer the wait, the less money that can be realized for the sale of the water ice. This, like all other basic commodities looses value with time. Those who develop this market early, both become established in business, and benefit from the highest prices.

Two years ago when I wrote "Exploitation of Space Oases", the information that Deimos might be outgassing was not available to me. I found it in the 25 August 1995 issue of Science.[K,S] The system proposed in that paper should be adequate to drill for ices with some modification. The these would be a second string of casing, a larger collar pipe and more propellant/drilling fluid. Table 2. shows the components of the drill and their mass in grams.

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		Down The Hole Hammer Drill				Titanium drill pipe & accessories		
		L	OD	ID	Weight	Number	Weight	Ti
		mm	mm	mm	grams		grams	
Hammer	DTH	210	16		233	3	699	
Under-reamer Guide		78	20		49.40892	3	148.2268	*
Under-reamer		15	27		20	10	200	
Casing Shoe		21	24		16	20	320	
Tubing		2000	16	14	425.1465	325	138172.6	*
Casing		2000	22	20	595.2051	30	17856.15	*
Collar pipes		1500	32	30	660.7006	20	13214.01	*
Total							170610	

Table 1. Mass of Drill and equipment for the Deimos version of the drill presented in "Exploitation of Space Oases" presented at Princeton May 1995. The total mass is in grams. The drill pipe is titanium for lightness and chemical resistance to corrosion.

			1998	1999	2000	2001	2002	2003	2004	2005	2006
Proposed oash flow		12 Initial Vehioles									
30 spectra @ $2,500			75,000	75,000	75,000	75,000	100,000	100,000	150,000	150,000	200,000
IR spectra @ $50,000			100,000	150,000	100,000	100,000					
Development & Construction											
	Drill Rigs		50,000	50,000							
	Vehicles		50,000,000	100,000,000							
Launches	"@ $70,000,000										
	Phobos/Deimos	SeaLaunch				210,000,000		70,000,000			
Launches @ $60,000,000		Proton			60,000,000		60,000,000				
	1/5 Proton (no propellant)								24,000,000	24,000,000	24,000,000
General Expense	Estimate		20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000
External tank to Mir						10,000,000	10,000,000				
Totals			70,225,000	120,275,000	80,175,000	240,175,000	90,100,000	90,100,000	44,150,000	44,150,000	44,200,000
Interest @ 20%				14,045,000	40,099,000	96,964,000	120,392,000	14490000			
Grand Total			70,225,000	204,545,000	324,819,000	661,958,000	872,450,000	977,040,000	1,021,190,000	1,065,340,000	1,109,540,000
"Product Sales	100 tonnes						800,000,000	700,000,000			
	200 tonnes								1,200,000,000	1,000,000,000	800,000,000
	300 tonnes										
Annual Gross Income Estimate							800,000,000	1,500,000,000	2,700,000,000	3,700,000,000	4,500,000,000
Net Income Or Loss			-70,225,000	-204,545,000	-324,819,000	-661,958,000	-72,450,000	522,960,000	1,678,810,000	2,634,660,000	3,390,460,000

Table 2. Hypothetical cash flow for the Deimos Water Company through 2005. This uses five of the original twelve drill rig vehicles.