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MARS, SOONER AND CHEAPER: using the new small launch systems to get to Mars earlier and at a lower cost

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There is a risk with this. Once we start shipping the cryogenic fuels the sun and Earth screens must be very good. Also we cannot put the cryogenics fluids into the craft until we are otherwise ready to go. There are too many heat paths, and the electronics and some other things will break if they are brought that cold so boil off will become an issue. I would not want to do this without fully understanding the reusability of the launcher. If it is done with the Falcon 9 line then there should be at least four falcon9's, and there can not be a halt on further launches for two years while a study of the accident is conducted to determine what to do. The launches must continue. I can not see NASA doing this the way it must done. This calls for fifteen launches of the F9 and there is a big risk there. The Falcon 9-S9 and -S5 calls for most of three Falcon 9's so that the four should not be a real issue. If NASA put out a contract for the ship ready fueled and ready to leave Earth orbit it could work.

I think a test must be done to prove the just the sun shade will be cold enough to keep a tank near the freezing point of oxygen, and a with the Earth shade must also keeps the tank near the 5K of interstellar space or cold enough to keep hydrogen near it's freezing point. A test of the orbital fuel transfer should be conducted.

I intend to discuss problems and solutions to take advantage of the much lower launch costs now becoming available by using many launches of the reusable launch systems to do a Mars Direct Plan. Some of the new launch companies are offering deliveries to LEO (Low Earth Orbit) for far below the cost now being charged by the larger traditional launch companies. The one company I want to talk about is Space X. The size and the fact that Space X publishes their costs make it easier to create a plan and yes, they, like all launch organizations have had problems, which they feel can be overcome. Their published price for a package of about ten tons is twenty seven million dollars, but they said once they can prove that their equipment can do the job many times, and if there is a market then they will bring their rates down accordingly.

When Space X announced their Falcon 5 and 9 they also declared:

“Falcon 5 and Falcon 9 will be the world's first launch vehicles where all stages are designed for reuse. The Falcon 1 has a reusable first stage, but an expendable upper stage. Reuse is not factored into launch prices. When the economics of stage recovery and checkout are fully understood, Space X will make further reductions in launch prices.”

I talked Elon Musk of SpaceX at the Washington DC Mars Society right after his talk. He said that he will lower the cost to LEO to less than ten percent the current published price once they have verified the ship worked and wear as planned. This works out to about two point seven million a dollars for a ten ton Falcon 9 ship to LEO or \$135 a pound. This averages \$40,000,000 a year for launch cost.

That works out to abut eighty million dollars. Lets look at about between thirty launches every two years. The last time I checked the Falcon 9 was expected to be flying about in 2008 or so. We cannot design the Mars vehicles within 2 years but there is no reason to wait until NASA's projected date of 2020 or later.

To do them and how much will it cost. Extensive assembly (like needing to attach and seal separate pieces of walls, floors, and sides) in orbit can greatly increase cost, time, and risk. The largest unique assembly in the Mars Direct Plan is five tons. If this can be launched as one piece then there is little negative impact. Moving and strapping down food, rovers, and such has little negative impact. Fuel storage, transfer issues and solutions will be discussed later.

We should ask the question "What is the best way and place to do final tests of MTV's habitats and ERV's?" I feel that the best place and way to test would be in orbit months or years before being sent to Mars. They should be lived in during the latter part of testing in order to find and repair any problems and to better mature the design. Of course, especially during early testing there must be suits and another place to go if there is a problem. Something like a crew exploration vehicle is not good for very long stay but can be used as a place to go if the habitat become unsafe and evacuation is needed in an emergency.

What is the support needs of people during orbital work? Do they need a space station? I say that the habitats are a perfect place to house the assembly astronauts during the assembly of the full vehicle and maturing of the habitats. This can solve both problems. They can be added to the space station to further mature the design, or a few of some at other orbits.

What are the required launch ground support? That can be handled almost entirely by the launching organization, possibly Space X.

Even the Mars Homesteading Project does not need anything too massive to fit on the Space X. Falcon 9. Should we wait for the SSTO, or Heavy Lifter (Shuttle C, D or whatever)? I don't think we need to unless NASA is managing it all.

The habitat is the only object that is too large to fit into the larger Falcon fairing but Space X will work with other sizes for a very modest charge. we may be able to modified the habitat and fairing to fit. We may also be able to use an inflatable like the one the Bigelo Hotel is planning to use in space, and recently launched a working model of its inflatable system. Space X has said that they will do other fairing sizes and shapes if needed, for a modest charge.

Dr. Zubrin has done a lot of work and research but we still need to look at other answers concerning fuel storage and transfer issues. An object well shaded from heat, especially the sun will approach the interstellar temperatures of five degrees absolute. Even hydrogen can be stored for long periods of time if kept this cold. If all the oxygen is orbited first then the hydrogen only needs to be stored for a very short time. If something like the near egg shaped shuttle tank has one end painted white that is always facing the sun, and the rest is black it is cold enough to store oxygen and methane for many years with no appreciable boil off. A separate shield protecting from the sun and another facing

the Earth will keep hydrogen cold enough for long time storage. Hydrogen tends to flow through anythings. Keeping it very colds helps slow this down.

The Mars Direct Plan uses 100 tons of fuel to send about 40 tons of payload towards Mars. It was thought that would need an eight to one ratio to get full burning, but it appears that a higher hydrogen content would be better. Two launches of hydrogen would hold twenty tons, which makes it four tons of oxygen to one ton of hydrogen, a four to one ratio as opposed to an eight to one ratio. If we only need to move oxygen this gives another potential method to move from one tank to another. About eight tanks of oxygen, and two of hydrogen can be used, but it's better if a just one large tank of oxygen is used instead of eight or nine. The cryogenics could be attached with external tanks after all else is ready to leave. Eight or nine tanks filled with ten tons of oxygen would be more awkward and more massive than one larger one, but not a showstopper. The difference between one and two external strap on tanks of hydrogen is not an issue.

Once in orbit and without the help of gravity, there are problems with transferring fluids from one tank to another. On earth gravity separates liquids to the bottom and gasses to the top in a container. In orbit a half empty tank has globs of fluid floating surrounded by the gasses. Wherever in the tank the empty tub is, it moves both the gas and liquid together unless there is some differentiation of them. In orbit we want to be able to just move liquid in one direction and gas in the other. We know of three ways to differentiate oxygen gas from liquids: gravity, centrifugal force, and magnetically. Oxygen like iron is affected by magnetic fields and none of these methods require a very strong separation force.

A net gravity force can be generated by having a tether a few miles long. A slowly spinning tether of about a hundred feet would create an adequate centrifugal force. A ship wanting to transfer fluids could go to the center of gravity of either of these, hook onto a winch and be lowered to the end that has the other tank. There would need to be a counter weight at the other end of the tether. With both tanks at the end far from the counter weight, after some settling time, the fluids can be moved as we do here on Earth. Also if a significant magnetic field is generated, oxygen can be differentiated and moved. It would be better to be able to move any fluids, but oxygen is the most important for a Mars Direct plan. The gravity or centrifugal separation and moving shadowing would be the major tool to start a fuel depot.

The Mars Direct plan calls for one hundred and forty tons in Low Earth Orbit. Lets call this one hundred and fifty. Breaking these into smaller parts that require very simple assembly in orbit will take a small amount of extra mass but will be much cheaper because they are being moved by well used reusable rockets. Doing the Mars Direct plan calls for two ships or three hundred tons or thirty Falcon nines. Doing the Math, that's times twenty seven million times the ten percent working out to about eighty million dollars per Mars Direct mission. The habitat and supplies will likely cost over ten million each. Ground support will likely cost over one million a year to run, but that's only a guess and those are minor costs in comparison. Fifty million a year f one hundred million every alignment is not a problem for NASA, most federal agents, or even

someone like Bill Gates. NASA could even handle the none discounted average of five hundred million yearly.

There are estimates that range from four and a half billion to trillions of dollars for a NASA Mars mission. Estimates of the trillions of dollars are only made by the uninformed and would not be feasible for a Mars attempt. There is no real reason to even talk about that much money when using the Mars Direct plan would only be a modest hit to the NASA budget at 200 million. At this point very little needs to be developed by NASA. The habitat, power supply, and rovers just need their designs finished probably at a modest cost to complete and build.

If Mars Direct or even NASA could offer a contract for the thirty ten ton packages to low Earth orbit every other year, the cost of missions to Mars would be viable. Even better NASA offers a contract for manned ships in orbit outfitted and ready to leave for Mars, the Moon, Asteroids, or beyond. It would be feasible to have a Mars Habitat, Luna, or wherever in orbit as a good counter weight to the depot, which will be used as part of the fluid differentiator. The Habitat could be inhabited when needed, and at other times the depot could be automated. The depot will be discussed in more depth at another presentation.

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Again, there is a risk with this. Once we start shipping the cryogenic fuels the sun and Earth screens must be very good. Even then we must quickly finish and leave Earth. Also we cannot put the cryogenics fluids into the craft until we are otherwise ready to go. There are too many heat paths, and the electronics and some other things will break if they are brought that cold so boil off will become an issue. I would not want to do this without fully understanding the reusability of the launcher. If it is done with the Falcon 9 line then there should be at least three falcon9's, even if there is a crash or two launching must continue w/little more delay than a few days to evaluate and make improvements. There can not be a halt on further launches for two years while a study of the accident is conducted to determine what to do as is NASA's typical mode. The launches must continue. I can not see NASA doing this the way it must done. This calls for fourteen launches of the F9 and there is a big risk there that one will fail. The Falcon 9-S9 and -S5 calls for most of three Falcon 9's so that the three or four 9's should not be a real issue.