

03 – What About Mars?

SUMMARY

Like the Moon, Mars is a legitimate destination in its own right. Given that the Starship is specifically designed for Mars and SpaceX has the Starlink revenue to fund Mars development, Moon and Mars development will occur simultaneously. But, because of the much greater distance, Mars will be developed much more slowly.

Mars' greater resources itself is not a big argument in its favor because the Moon has more than enough resources. But the ease of accessibility of its volatiles is a definite plus. But, once ice harvesting operations have been set up on the Moon, the production of the next increment of volatiles will be fairly cheap.

To be clear, there is no need to be opposed to the exploration, development, and settlement of Mars. Indeed, we should be very enthusiastic and supportive of it. But the Moon will likely be developed and settled a few years prior to the same happening on Mars and also, the growth rate of a lunar base / settlement will be substantially greater than that on Mars primarily due to the much shorter round-trip time to the Moon. So, the case for the Moon is more of a question of where the bulk of development and settlement will occur in the early decades. It seems apparent that the Moon will be the location where this will happen.

There is a supportive relationship between the Moon and Mars. Martian development and settlement could still occur whether the Moon existed or not, certainly. And yes, much of the testing of Martian habitats and systems could be done more cheaply in environments on Earth than on the Moon. But the Moon is there and it will be developed a short while before Mars. So, systems implemented long-term on the Moon in its vacuum and in the logistically challenging setting will yield some lessons which can then immediately be applied to Mars where many of the systems will be nearly identical.

However, this is not to say (as so many do) that the purpose of the Moon is only as a steppingstone to Mars -- that Mars is the ultimate and only truly valuable goal and so lunar development should essentially be paused after initial development and then we'll move on to the "real"

destination which is Mars. No, the Moon is a legitimate end destination in its own right. As we will see later in this book, its resources are more than sufficient to support a very large population for a very long time. And its proximity to Earth means that it will grow substantially faster than any development on Mars.

Finally, it would seem prudent to have humanity's eggs in three baskets ASAP and not just two including a basket substantially further away than the Moon is from the Earth.

THE PROS

Mars has some substantial advantages which deserve to be acknowledged.

Resources

The first thing that should be mentioned is its atmosphere. Although only about 1/200th the density of Earth's atmosphere, it none-the-less is a very convenient source for propellant, air, plastics, and other organic compounds.

A second, and related pro, is the availability of fairly pure water in an easily accessible form. The form is that of very large glaciers at high latitudes. Sites being identified for initial bases make sure to be on those glaciers. A good source of hydrogen, combining this with the CO₂ and N₂ in the Martian atmosphere, any number of useful organic molecules are possible given the right chemistry equipment. Given enough power, plastics could be produced which would be of great value for structural material for use in things like furniture, counters, shower stalls, etc.

Radiation Protection

It is true that the Martian atmosphere provides some protection against space radiation. It is probably sufficient by itself to prevent plants from dying from a solar particle event (SPEs, i.e. solar storm). The thickness of the Martian atmosphere would be sufficient to prevent the immediate death of unprotected crew for most SPEs.

But it would be unhealthy in the long term for crew to work within unshielded greenhouses. We can also give SPE warnings to crew wherever they are so it's a convenience and not an essential.

“Oceans of Water”

Yes, we know that Mars has oceans’ worth of water in the form of glaciers and this fact is highlighted by many a Mars advocate as to why only Mars can support settlement. But it is not the amount of water that matters. The Moon has at least 600 metric tons of water sufficient to support a million-strong city that recycles for about 1,600 years. Rather, the advantage that Mars has in terms of water is its relative ease of access. Using what is called a “Rodwell” a pipe could be drilled into the glacier. By simply pumping heated water down the pipe, an increasingly large void is melted into the glacier freeing up more liquid water. By contrast, on the Moon, the water must be heated out of icy regolith in cryogenically cold craters. This process is doable but does require a more involved operational process.

Life

Another major pro that Mars has to offer is the potential for the discovery of fossil and/or extant life. This is of far greater scientific interest than questions mostly of geology which the Moon has to offer. Whereas this scientific potential is supportive of a program of scientific exploration, it is not a great rationale for private Martian development or settlement.

Gravity

The higher gravity of Mars ($3/8$ ths gee) is often put forward as a pro compared to the gravity of the Moon ($1/6$ th gee). The logic usually stated is that we don’t know how much gravity is needed for long-term health, but more is undoubtedly better than less.

Inspiration

It should also be acknowledged that Mars, for some reason, has a greater hold on the imagination than the Moon in terms of exploration and settlement. There are more movies, books, pieces of art, etc. about Mars than there is for the Moon. Mars also offers more interesting sights including the largest canyon and volcano in the solar system.

THE CONS

Cost

Will this interest be sufficient to overcome the substantial barrier of travel time and cost? Probably not. The 60 times greater travel time to Mars is a real bear that will give many second thoughts. But probably the greater factor is the increased cost of traveling to Mars. The greater cost of travel to Mars is affected by:

- Lunar craft being reused 70 times more frequently than Martian craft
- Longer travel times require more provisions thereby eliminating more passenger space
- Passengers will require more "elbow room" for the long trips thereby also eliminating more passenger space
- Fewer passengers per flight means a higher ticket price.

There are more passengers on the low end of savings than the high end. A certain percentage of passengers will only be able to afford to move to the Moon than to Mars. And for those who could afford to go to Mars, doing so will consume more of their savings than if they go to the Moon instead.

Gravity

It is certainly true that more gravity is better than less for health. But we have some indication that even Martian gravity is going to lead to long-term consequences. So Martian gravity will likely only slow the deterioration rather than stop it altogether.

A study was done in which the tail of laboratory rats was partially suspended so that the forces on their hind legs were the same as they would experience on Mars. The result was that they lost bone mineral density. One should presume that the same level of force on the limbs in the Martian environment would yield the same results as these lab tests have shown. Artificial gravity (e.g. indoor centrifuges) might sufficiently mitigate these results. But the inconvenience of such an approach would largely negate the gravity advantage of Mars.

And there is the flip side, the lower level of gravity on the Moon would allow for significantly increased freedom of action (e.g. dancing up the walls to the ceiling). Most settlers would probably prefer more freedom of action than less.

Separation From Loved Ones

Mars advocates rarely acknowledge the relative separation from loved ones that moving to Mars would require. About 85% of the attendees of Mars Society Conventions are males. Even for those who are married, their wives often do not join them as they don't have as much interest in Mars as their husbands do. It seems to me unlikely that men who would like to move to Mars will essentially divorce their wives to do so. Perhaps the reluctant wives would be willing to move with their husbands if their husbands were dead set on going. But limiting connection to family and friends to only video emails pose a substantial barrier which deserves to be acknowledged by Mars advocates.

In contrast, two-way, real-time telepresence is possible from the Moon with only an annoying but bearable 2.6 second time delay. Lunar settlers could be virtually present at their family's holidays gatherings and their grandkids' graduations and marriages. If still participating in business, the Moon would allow for teleconferencing while Mars wouldn't.

Life

The potential discovery of life on Mars is very exciting. But it is a two-edged sword. Even if solid, scientific arguments against planetary protection concerns can be made in a compelling manner, it simply remains to be seen whether logical, emotional, and political arguments based upon these concerns will manifest themselves as a substantial barrier to the exploration, development, and settlement of Mars. There's a real risk as to how this will play out the closer that we get to being able to go to Mars.

Telerobotic Workforce

The Moon allows for the presence of a very large, robotic workforce, teleoperated 24/7 by operators on Earth. This is not possible for Mars. The obvious solution is for robots on Mars to be autonomous. This seems not only possible but inevitable in the years ahead. So, teleoperations would only be an advantage for the Moon in the early years.

CONCLUSION

The primary advantage of Mars is the accessibility of its resources, particularly its air. The other advantages seem unconvincing and have associated disadvantages. When comparing the resource advantage to the increased cost of going to Mars, the inconvenience of traveling to Mars, and the loss of interactive communication with loved ones, it is likely that the Moon will be the favored destination for settlers for the next several decades such that it will have the largest and leading off-Earth settlements.

WHAT ABOUT FREE SPACE SETTLEMENTS?

Within the space advocacy community, people typically divide themselves into one of three categories when it comes to destinations for space settlement: The Moon, Mars, and free space (or O'Neillians). The term "free space" doesn't mean that it costs nothing or is necessarily democratic. Rather the term is used to mean empty space free of large gravitational bodies such as the Moon or Mars. So, free space can include Earth orbit, a gravitational balance point (i.e., the Lagrange points), orbits around other planets, or in the asteroid belt.

These settlements are typically envisioned to be very large spinning structures which produce their own artificial gravity. Settlers can walk around in one gee while apparent centrifugal force pushes them down on the floor.

Free space settlement must, by necessity, be very large. When one resides in a spinning structure it creates a situation where one experiences Coriolis forces whenever one turns their head. The Coriolis forces become less the larger the radius and hence the slower the rate of rotation necessary to achieve one gee. Just how many RPMs residents can adapt to over time is debated but it is probably between 3 and 6 RPMs. Given these numbers, it appears that the smallest spinning habitat would be at least 110 meters in diameter.

GERARD O'NEILL'S VISION

The person who really did the most to promote this vision is Princeton professor Gerald (Jerry) O'Neill. Immediately after the end of the Apollo Program, he famously posed the following question to his students, "Where would be the best location for a growing, industrial, settlement in space". As the story goes, the students and he ultimately decided that spinning settlements in free space was the correct answer to that question. Dr. O'Neill proceeded to write a very influential book titled, "The High Frontier" which described in fair detail what a spinning settlement would be like and how it could be constructed. There were some obvious, big challenges to O'Neill's vision. For starters, free space habitats would be exceedingly large and massive.

Gerard's vision was written out many times in the popular press and even on TV. He had the opportunity to present his vision before Congress and even NASA considered the vision. But the magnitude of what it would take to accomplish the vision left many with the view that it was implausible. Indeed, the NASA Senate subcommittee chairman, William Proxmire, once quipped about O'Neill's proposals by saying "...not a penny for this nutty fantasy." There were studies, annual Space Manufacturing conferences, and even some hardware built but until the present, that funding never did come through and the O'Neillian vision remains just that, a vision. Unfortunately, Gerard O'Neil died in 1992 at only 69 years of age after a seven-year battle with leukemia.

But O'Neill's vision never died. Indeed, many of the early members of his space advocacy organization, the L5 Society, went on to become long-term leaders in the succeeding National Space Society (NSS). And when the NSS conducts space settlement design for students, it's rarely Moon or Mars settlements but free-space settlements.

What's more, the free space settlement vision has received some very needed updates. In particular, Al Globus has significantly simplified the vision by identifying a low radiation orbit (Equatorial LEO or ELEO). This prevents the need for millions of tons of material to be launched from the Moon or imported from asteroids to provide radiation shielding for very large, spinning settlements.

A second major improvement that Al Globus has identified is that the Coriolis effect can, to some extent, be adjusted to in a relatively short period of time. He believes that the evidence points to people being able to adapt to as much as 6 RPMs.

Put together, Al has proposed relatively small spinning settlements which he has termed Kalpana One and Kalpana Two with the latter having a diameter of 110 meters and with a population of about 500 people. That's a large habitat but much, much smaller than O'Neill's original vision.

THE ADVANTAGES OF FREE SPACE SETTLEMENTS

Before we get to the problems with free space settlement, we do need to acknowledge some of the main reasons that some advocates argue for them over settlements on the Moon and Mars.

Proximity to Earth

Earth is where the bulk of humanity's markets are and will be for a long time. O'Neill's original case for free space settlements envisioned that the settlers would earn a living construction massive power satellites. That was probably yet another unrealistic aspect of his vision. Most likely things in space will be assembled at much lower labor costs on Earth and then simply launched and deployed to space. Telerobotics can do any remaining assembly.

A better argument is that settlers in LEO will be able to continue their business provided that it is telecommuting in nature. Clearly, this is an advantage over Mars with its average of 14 minutes' time-delayed communication. For the Moon, the time delay is only 2.6 seconds, so LEO doesn't have that much of an advantage on this point. But who will be putting the money down to move off Earth? Only those who have lived long enough to save up enough money. Many of those people will be retirees who...want to retire.

Rather, the stronger argument that favors LEO and lunar settlements over Mars is that, in both cases, settlers can be telepresent at important family gatherings on Earth. This may especially be true for spouses. Advocates who are excited about becoming an off-Earth settler tend to be males as any attendee at a space conference can tell you. Convincing their wives to significantly cut ties with friends and family (including those grandkids) could be a pretty hard sell.

So, what's the problem with free space settlement?

THE DISADVANTAGES OF FREE SPACE SETTLEMENTS

Lack of Local Resources

The leading problem with free space settlements is exactly that -- they're in free space where resources are lacking. Both the Moon and Mars have immediate resources. Free space advocates think that proximity to Earth is an advantage. But in free space you must transport all your material up from Earth's very deep gravity well or you have to develop the systems from scratch to import material from either the Moon or from asteroids. On the contrary, for the Moon and Mars, you don't need to transport materials using rockets. The materials are there on the surface and can be transported to the base via electric vehicles.

To help better understand this issue, free space advocates often point out that it takes less energy to deliver material from the Earth to LEO as compared to delivering material from the Earth to the Moon or Mars. That's true, but entirely irrelevant. Let's say that you were to launch four kilograms of material to LEO. That's four usable kilograms. But if one wants to transport that to the lunar surface, about three of those kilograms would need to be propellant to push and land that last kilogram on the surface of the Moon. But, if that one-kilogram part was a motor that kept a 10 kg telerobot working and that telerobot produced 100 kg of material (e.g. water or metal) before needing to be replaced then that one kilogram resulted in 100 kg of usable material. That 25 times greater usable material than was possible for the same launch to LEO. The same holds true for Mars. And the lack of immediately available resources prevents the potential for the exponential growth of a telerobotic workforce like is conceivable on Mars and especially on the Moon.

The lack of immediately available material is a major reason why free space advocates generally agree that it will be a very long time before settlements will be established in free space. And therein lies the rub. Moon and Mars advocates can agree that O'Neillian settlements will sprinkle the solar system one day. But that day won't come anytime soon. And so, for now, our attention would best be focused on where settlement will begin.

When Gerard O'Neill testified before Congress about his vision for free space settlement, that vision was so far out there that the chairman of the Senate Subcommittee responsible for NASA's budget responded "It's the best argument yet for chopping NASA's funding to the bone I say not a penny for this nutty fantasy". He then went on to succeed in eliminating spending for research on space colonization from the budget. It has been approximately 45 years since that time and O'Neill's original vision still seems pretty far out there.

Seeing the Sea

Equatorial LEO is the orbit with the lowest radiation levels. But if one is living in orbit, it would be nice to have a better view. An equatorial orbit is over ocean 85% of the time. And there's not a lot of highlights along the equator either. People who settle in ELEO likely won't ever orbit over their home country, see the boot of Italy, see the Hawaiian islands, use a telescope to see the pyramids or the Great Wall of China, etc. The view would still be beautiful but repetitive. By contrast, people who settle on the Moon and Mars will likely first launch to a hotel in an inclined LEO orbit which, in time, will pass over much of the inhabited Earth. After staying there for a few weeks taking in the views, they will then transfer to an interplanetary craft and head to their final destination.

Orbital Debris

Another big problem with having a large settlement in LEO is all the orbital debris that will eventually puncture the settlement. One could bulk up with shielding but that would add a great deal of mass to the structure and wouldn't be effective against the largest of orbital debris. O'Neillian advocates recognize this problem. And they agree that LEO would have to be cleared of orbital debris before long-term settlements could be established there. Again, we're talking about something that pushes space settlement far down into the future.

By contrast, on the Moon and Mars, there is little orbital debris to be concerned about, and micrometeorites are naturally addressed by placing lunar dirt on top of habitats which one would be doing anyhow for radiation protection.

THE ARTIFICIAL GRAVITY ARGUMENT

The one major, and legitimate argument that the advocates of O'Neill's vision is that, for natural growth (i.e., settlers reproducing themselves), it would require that children be born from the settlers. The fair question is, can people successfully reproduce in lunar and Martian gravity levels? O'Neillian advocates reason that, because we know that a full gee 24/7 is natural and hence healthy then we should just pursue O'Neill's vision regardless of the cost because, maybe, we won't be able to have children on the Moon and Mars.

There are several problems with this reasoning. First is the definition of settlement. Many space advocates argue that settlement isn't settlement unless there are children. Similarly, they argue that a settlement cannot be sustained unless a settlement can grow by having children.

SETTLEMENT DEFINED

But technically, settlement doesn't necessarily require having children. This would be like saying that communities on Earth can't be communities without having children. Well, what about active retirement communities? They can have thousands of people, involved with all sorts of community activities, and even have their own local governance. Are we to say that they are not a community because they are not able to have children? Of course not.

But can retirement communities grow? Yes, active retirement communities typically grow continuously and can grow to be very large. But obviously, it is not from natural growth but from retirees entering the community in greater numbers than they "leave" the community. And this analogy is fair. The initial settlements will most likely be composed primarily of those who have lived long enough to have saved up enough money to go. And most will be freed from childrearing and occupational responsibilities. So, retirees are the prime candidates for off-Earth settlement.

The key to understanding this matter is to simply recognize that there isn't just one type of space settlement but several different types. There can actually be government settlements, retirement settlements, company towns, and general settlements (with children).

However, just because all settlements don't require having children, this doesn't mean that having off-Earth children isn't something worth pursuing. It's very important to the full scope of space settlement. Chapter 24 describes the steps to determining the artificial gravity prescription for healthy gestation and childhood.

WHAT IF THE AG Rx DOESN'T WORK OUT?

There is the very real possibility that, after the animal studies are completed, that we will find out that the reduced gravity of the Moon and Mars will have unacceptable health consequences for gestation and childhood even given full artificial gravity in a centrifuge for a few hours a day. Proposals exist to create large settlement railroad cars continuously moving around large, circular tracks. Whereas this is technically possible, it is not a near-term solution, nor would it be particularly enjoyable to grow up in a train of railroad cars. At that point, we should accept that the O'Neillian vision is the only practical option for a naturally growing settlement even if it would take many decades to realize. But even if this turns out to be the case, very large settlements of adults will be established on the Moon and Mars first.

CONCLUSION

So, given the significant challenges that free space settlements face, the question that Gerard O'Neill asked his students seems to me to be the wrong question. We should now be more concerned with what the next steps should be rather than what the situation might be a century down the line if the near-term path doesn't work out perfectly. And for the near-term it is clear to me that, given the immediate resources and the proximity of the Moon, then the Moon is where large settlements will develop first.