
**[A publication of the Milwaukee Lunar Reclamation Society,
a chapter of the National Space Society and of the Moon Society]**

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# Outbound #12, January, 2019

**Dave Dietzler of the St. Louis National Space Society, and with whom I have co-authored many an article for Moon Miners Manifesto through the years, sends this.**

**What we need to get set up on the Moon**

It would seem expedient to land robots or teleoperated rovers that can bulldoze rocks out of the way and prepare a landing field. The robots and rovers could use microwaves to sinter the top several centimeters of regolith to form a nice solid surface. They could also berm up some mounds of regolith around the landing field. This way, more landers won't blast dust all over the place. Robots and rovers rolling over the sintered surfaces won't kick up dust too. Dust control is very important. The fine abrasive dust of the Moon in the upper few cm of regolith could ruin all sorts of machinery by penetrating joints, sliding metal surfaces and bearings and wearing them out. Earthly mine sites struggle with the same problem and equipment has to be repaired frequently. Dust seals around moving parts will be essential. Not kicking up dust in the first place is also important.

I would imagine the landers would have solar panels that fold out. The robots and rovers would hook up to the landers and recharge when necessary. Naturally the robots and landers would have sensor systems to monitor battery power levels, temperatures, etc. The landers would have some RTGs to make power and waste heat thru the long lunar night on the equator at 33.1 deg. W where the mass driver will be erected. Power from the RTGs will feed electric heating systems in the landers and robots. Storage systems will consist of batteries and flywheels. Fuel cells are a possibility but these require cryogenic storage tanks, deep refrigeration systems and water electrolysis cells. Batteries and flywheels seem to be simpler, especially in the first stages of development. The robots and landers will be built to withstand

the heat of the lunar day. That will require reflective skins and internal insulation as well as the use of the right alloys.

Once the landing pads and rolling surfaces are done we can land more cargo including solar panels that deploy automatically, oxygen makers ( furnaces that roast regolith at about 2000+ C to drive out oxygen or magma electrolysis cells), oxygen liquefiers and LOX storage tanks, inflatable habitat, vehicles (open cockpit and pressurized cabin), tools, power storage systems (flywheels, batteries and fuel cells), some highly insulated tanks of hydrogen to combine with oxygen in fuel cells to make water, tanks to store the water and a large inflatable "bagel." We would also land some bags of cement so we can make a work surface or floor inside the "bagel." The "bagel" will be the work chamber. There should be at least two of them. Humans will have landed during this time to do set up that the robots cannot. It would seem wise to wait until water and oxygen have been stored up before landing humans.

The bagels will have Kevlar and metal (titanium?) airlocks for moving small and large items in and out. Machine tools, precision grinding machines and 3D printers will be set up inside...Some 3D printers work better in vacuum so they will be set up outside on a hard sintered regolith surface. Workers going inside and out will only walk on sintered surfaces to avoid dust exposure and "turtleback" spacesuits will have airlocks on the bagels. Water and imported oil will be used for lubricant and coolant for the machine tools and condensors will recover water from the air inside. Air fliters will absorb oil vapors.

Sodium silicate will be imported at first and later made on the Moon from in situ sodium, silicon dioxide and water made from imported hydrogen combined with lunar made oxygen in fuel cells. Mini-excavators will dig up regolith and pour it thru sieves and screens to get the right particle size and this will be used to make sand molds. This will be done at some distance from the base because it will kick up a lot of dust. If the sand isn't right because basaltic regolith melts at 1150 to 1350 C while highland regolith melts at 1500 C. we may have to extract pure silica with a m.p. of 1700 C. to make molds for steel because steel melts at 1200 C to 1500 C. depending on carbon content.. Aluminum melts at 660 C. and magnesium melts at 600 C. so it seems any old regolith will work for casting those metals. Casting titanium at 1900 C. requires yttrium and zirconium oxide sands and those are unavailable unless we import them. We would also need an electron beam furnace to melt titanium out in the vacuum. Fortunately we can make all sorts of titanium parts with electron beam 3D printing out in the vacuum and we can use CNC machining. To do 3D printing we will need devices to powder the metals or draw them into wires. Powdering metals can be done with an electric arc or by melting them and spraying them thru a nozzle and hitting the metallic sprays with water or inert gas jets in a sealed chamber so we can recycle the water or inert gas. The gas will probably be imported helium or argon. Grinding the metals wouldn't make a very fine powder and it would be contaminated with grit and we'd need to replace the grinding wheels as they wore down.

Rovers with magnetic separators will thresh thru vast areas of the smooth mare plains to harvest meteoric iron-nickel particles. The iron-nickel particles are fused with silicates. They will be purified with sieving and centrifugal grinders as described by Dr. Willam Agosto years ago. The iron-nickel fines will be melted in furnaces, either electric induction or solar furnaces, outside because the heat build-up inside the bagels would be too much to bear. Molds will be made inside the bagels with sodium silicate and sand that are hardened and

dried out with microwave guns. The molds in metal or ceramic boxes on metal pallets will be hauled thru the airlocks with pallet jacks and the molten iron-nickel will be poured into them. We will also take iron-nickel and combine it with some imported carbon to make steel by the ancient crucible steel process. I don't know if we can just mix iron-nickel powder with carbon powder and heat it up or if we must cast slabs or rods and pack it in carbon powder then heat that up to convert it to steel. Either way we have to get it to red heat for several days so we will need some kind of thermally insulated electric induction heated crucibles and that will use a lot of energy. Then we will use the steel to make rolling mills by casting up large heavy parts in sand molds. Motors, gears and bearings will be imported. Rolls will be finished in imported precision grinding machines inside the work bagels. We will need furnaces to hot roll steel and magnesium. Aluminum can be cold rolled. Mild steel could be cold rolled also. Building the rolling mills will not be all that simple but will be essential unless another process for making flat plates, curved plates, sheets and foils is invented like metal vapor deposition that is more efficient than rolling.

Then we will set up Lunar Dust Roasers and All Isotope Separators as described, written about and patented by Dr. Peter Schubert to produce silicon, aluminum, iron, titanium, sodium, potassium, chromium, manganese, phosphorus and more oxygen. The CaO-MgO slag will be reduced by the Magnaterm process to get magnesium. The CaSiO3 slag from the Magnatherm retorts will be processed in FFC cells to get calcium. We will make molds in the bagels and pour aluminum slabs outside and feed them thru the rolling mills to make aluminum plates. We will roll them into curved plates and weld them up to make large cylinders or tubes. Flat aluminum plates will be cut into circles on laser cutting tables and spun into domes on large engine lathes. The domes will be welded onto the ends of the cylinders or tubes probably by friction stir welding and we will cut holes with lasers and install windows. Thus we will have pressurized cabins for ground vehicles (road and rail), sub-orbital vehicles and spacecraft. We will raise a fleet of vehicles for travel on and above the surface of the Moon. Frames for the vehicles will either be printed from titanium or cast from aluminum and/or steel. Nickel and titanium will be alloyed to make a memory or shape alloy that is extruded and drawn into wires then woven somehow into tires. Many small parts will be made by 3D printing, casting and machining. Motors will be imported and so will batteries unless we make flywheel power storage systems on the Moon with in-situ materials.

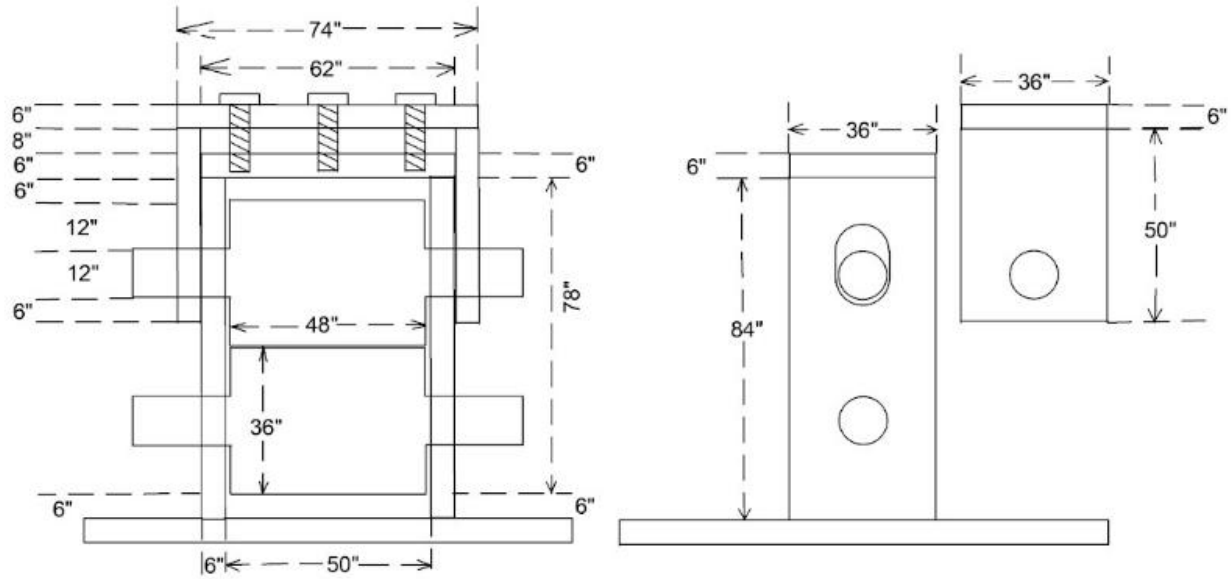
Meanwhile we will be assembling a mass driver that is imported in sections. Perhaps we will make the mountings from cast basalt on the Moon. We should be making solar panels on the Moon by then with silicon, aluminum, phosphorus and glass produced on the Moon with LDR-AIS devices. We should be extruding aluminum rods and drawing them into wires by then too. We will cast the extruder machine parts with steel on the Moon.

We will also have to get to work building solar wind implanted volatiles (SWIVs) mining machines. It is possible that the south polar base built by NASA will produce hydrogen, carbon and nitrogen from icy crater bottoms and they could send it to us at 33.1 W by sub-orbital rocket “hoppers.”

Magnesium and aluminum sheets and maybe even foils will be made with the rolling mills. The gaps between the rollers can be varied with big adjustment screws as necessary so we can roll sheets and thicker plates and maybe even foils. Sheet metal has many uses including reflectors to increase solar panels output. We could make big sheet metal “troughs”

and mount the solar panels on basalt supports and this will increase solar panel output and efficiency if they don't overheat. ##

## Pictures follow: rolling mill to be cast on the Moon



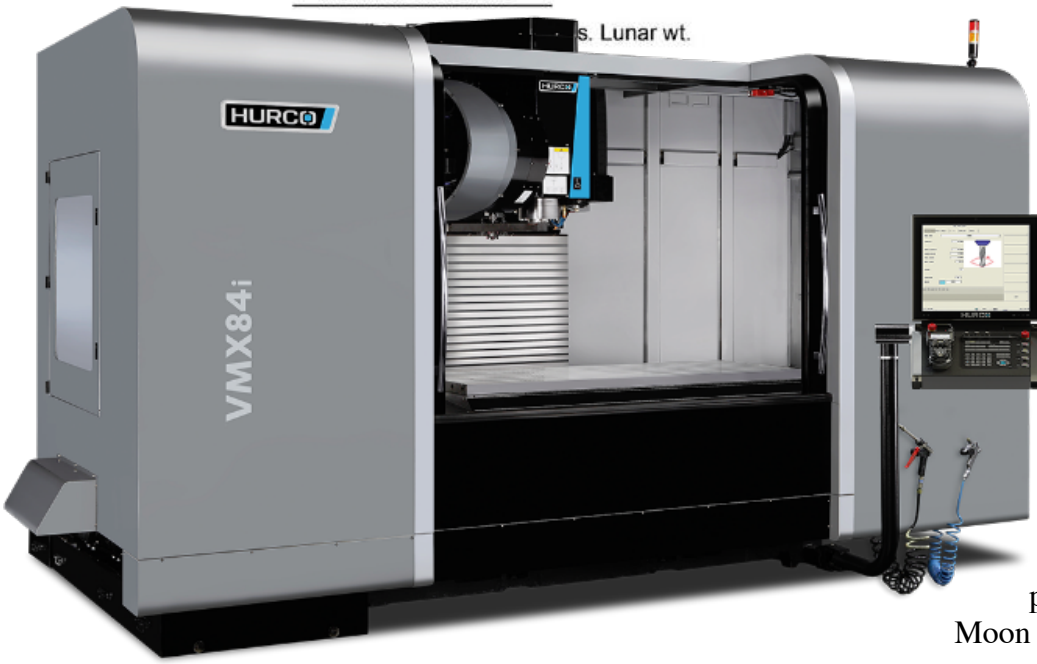

FRAME WEIGHTS

| | | |
|---|---|---|
| 2) 6" X 36" X 84" | 5100 lbs. x 2 = 10,200 lbs Earth wt. | 1700 lbs. Lunar wt. |
| 1) 6" X 36" X 62" | 3766 lbs. | 628 lbs. Lunar |
| 2) 6" X 36" X 50" | 3037 lbs. x 2 = 6074 lbs. Earth | 1012 lbs. Lunar |
| 1) 6" X 36" X 74" | 4495 lbs. | 749 lbs. Lunar |
| TOTALS | 24,535 lbs. Earth | 4089 lbs. Lunar |

Gears, Bearings, Motors, Electrical parts imported from Earth. Everything else made on the Moon.

ROLLER WEIGHTS

s. Lunar wt.




Precision grinding machine that can support 5000 lb work pieces on Earth therefore 30,000 lb pieces on the Moon for grinding

rollers to within 0.0002 inches...we may need a bigger one because those rollers can be massive

**a series of rolling mill stands for turning metal slabs into sheet metal**

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## **My Early Romantic Picture of Mars** by Peter Kokh

[Wikipedia: "*Viking 1* was launched on August 20, 1975, and the second craft, *Viking 2*, was launched on September 9, 1975, both riding atop Titan III E rockets with Centaur upper stages. *Viking 1* entered Mars orbit on June 19, 1976, with *Viking 2* following suit on August 7, 1976.]

After orbiting Mars for more than a month and returning images used for landing site selection, the orbiters and landers detached; the landers then entered the Martian atmosphere and soft-landed. The *Viking 1* lander touched down on the surface of Mars on July 20, 1976, and was joined by the *Viking 2* lander on September 3. The orbiters continued imaging and performing other scientific operations from orbit while the landers deployed instruments on the surface.]

The pictures steadily flowing in from the Viking orbiters revealed not so much a Moon-like surface, as one as hauntingly beautiful and awe filling as our own southern Utah and northern Arizona. For millions raised on celluloid sequences of cowboys chasing and being

chased up and down Monument Valley (located on the Arizona–Utah border (c. 36°59′N 110°6′W, 37°N 110° W) near the Four Corners area.)

In our racial human loneliness, most of us hoped that life would be found on Mars after all, in however humble a form. I remember well my own high excitement at the first teasing results of the pyrolitic release experiment. But when these suggestive indications were not borne out out by other subsequent tests, **I was filled with a crushing and abysmal disappointment** ***that lasted all of 20 seconds before giving way to a new euphoria:***

***IF there is no native life on Mars,***
***THEN MARS IS "OURS!" BY DEFAULT***
***-- ready and waiting for our own Terran life forms to colonize it,***
***Just as they will on the Moon, if only within pressurized environments.***

Mars took on for me the raiment of ***"a virgin world, with mankind serving as the male reproductive agency of Earth by which "Gaian Earth-life" would fertilize Mars and bring this long-waiting sterile world to the glory of planetary motherhood, to which it could never aspire on its own -- no matter how long we left Mars alone." ##***

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## How Railroads might help open up Mars

*Most of us are familiar with the critical role that railroads played in opening up the American West. The story was repeated, with some differences, in Canada and Australia and Siberia. And with the railroads came the benefits of the Industrial Revolution. Railroads extended telegraph communications and redeveloped the territory they passed through.*

On the Moon and Mars, we won't find building materials, other than basalt, that we can "throw together" to provide shelter from the cosmic elements. Pressurized modules made in a first quickly industrializing settlement can be shipped by the railroads to points along the route to provide the nucleus of new settlements in previously uninhabited areas of Mars.

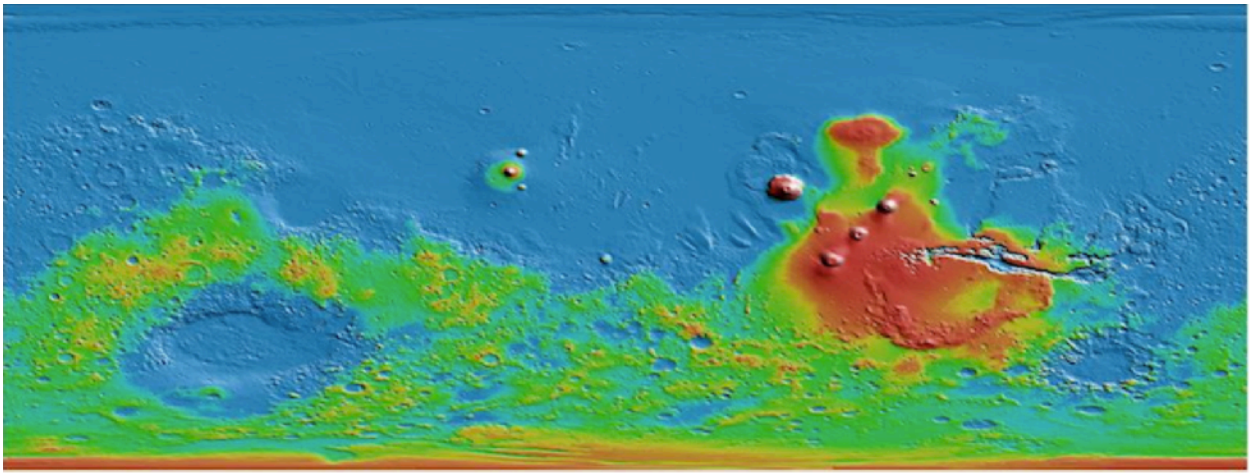
**Pressurized modules have to be handled with care.**

Try to haul them overland on unimproved roads and the stresses of bouncing around are going to compromise seals and maybe open cracks. On the other hand, ***railroads will provide a relatively smooth low-friction ride to a prepared siding complex*** where they can be dropped off and connected with one another to provide the core of a startup outpost.

New "town starters" might be called "**sidingtowns**" instead of "settlements." Every new train could bring additional residential units, along with ready to plug in "**container factories.**"

Now it is going to take some time before we are building pressurized modules on Mars. Until then, inflatable modules will cost significantly less to produce and ship from Earth, and the railroads could carry these to desired locations as well. ***Railroads could establish chains of interconnected settlements on the Martian frontier much faster than by any other option.***

***If the human frontier on Mars expands this way from one point of origin, we won't have the problem of distant settlements isolated from one another, for they will be inter-connected by the railway system.*** But one look at a map of Mars showing elevations will show that ***this form of expansion of human presence on Mars will remain confined to fairly level plains, up to the foot of hilly and mountainous terrain, or to the edge of vast canyons.***



Hellas ^ basin Valles ^ Marineris canyon

**Where railroads may be built**

√ Along the southern shores of the northern basin (blue area at top)
√ Along the floor of the Valles Marineris canyon (equatorial, left) and down the winding outflow channels into the northern basin, and
√ Along the shores of the deep Hellas basin (blue area lower left).

But if we are going to open Mars by railroading, we need to do some homework first.

***Top priority is production of a high vertical resolution map of Mars so that we can plot logical rail corridors along which grade changes are modest. We need to look for places where elevation change pinch points are located.*** On Earth, these are ***straights and passes through which traffic funnels.*** Those will be critical anchors along proposed routes.

***Between such narrow points, lie very scenic areas that would draw tourist traffic****, for example*. ***Scenic and Geological treasures along the selected route would go to the top of the list for route determination, and for location of adjacent visitor concession areas to set the stage for tourist and excursion companies, serving Mars pioneers.***

Next we need to really work to define ***a useful "economic geography" of Mars - a map that shows where "all" the critical resources are to be found, [basalt and water being the most critical] and in what degree of concentration, and where any other elements from which building and manufacturing materials can be made are found to cluster, are potential new industrial centers.*** Tracks through feasible routes that do not connect such basalt & water resource clusters would be options for development at a later date.

## Co$t Questions

The big question is ***what percentage of the various transportation options involves the least mass to be shipped from Earth - Earth sourcing is by far the most expensive option of all.***

We need to design a railroad system that has a lot of features with no guarantee that they will all be ready early on:

√ ***Lowest total component mass to be "upported"*** out of Earth's deep gravity well
√ ***Highest percentage of component mass that can be manufactured on location*** in time to start building the system

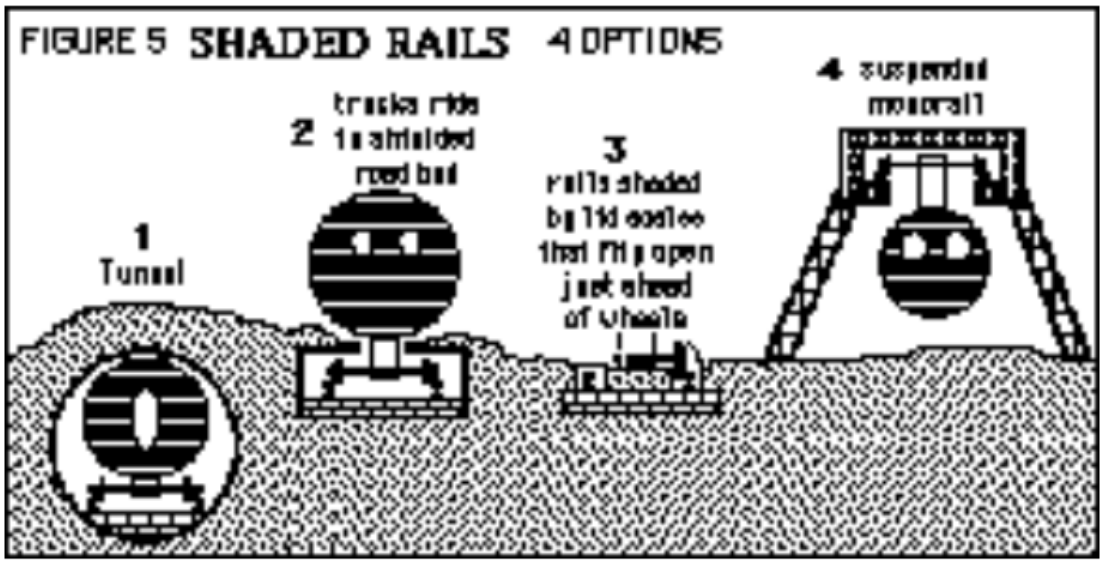
√ ***Most rugged in terms of wear and tear***, but also with respect to constant exposure to the Mars almost naked cosmic environment.
√ ***Overall architecture that best supports spread of settlements and route-side development***
√ ***The most rugged system and least prone to degradation and early repair*** or replacement.
√ ***The system design that best supports quick deployment of new siding town settlements.***

## Mars-Specific Design Challenges

Seasonal thermal extremes on Mars (from just over the freezing point of water to temperature lows far below the lowest ever reached in Antarctica, means that ***railroad tracks must be designed for thermal contraction and expansion.*** Now on the Moon, the challenge is greater. It gets just as cold on the Moon as in the Martian winter, and in-between far hotter than the highest temperatures ever experienced on Earth on a monthly schedule.

On the Moon we may have to shade the rails somehow. unless we can find an alloy with a very low coefficient of thermal expansion. The same will hold true of whatever we come up with to keep the lateral rail-rail separation within close tolerances: a functional equivalent of our railroad "ties."

Below are 4 different railroad design options: **I favor #2 as the tracks are always shaded from the sun, as well as least likely to be covered up by shifting sand or Mars dust.**




But **#4 might be best in rugged terrain.**

On Mars we must use elevation contour maps to identify locked, no outlet basins, which could, in a terraformed future Mars become lakes or small seas. It makes no sense pushing tracks through such depressions, no matter how conveniently level the grade.

On both worlds, ***we have to "design out" the possibility of derailment that would involve upturned cars losing pressurization with a total loss of life.*** The #2 rail design does that.
√ We will be dealing with lower gravities while momentum and mass remain the same.
√ ***Very wide gauges*** (rail to rail separation) and ***very low centers of gravity***, even some amount of banking of curved track sections may reduce any problems.

But perhaps the best approach would be to take a page from modern all steel roller coasters with ***wheels above and below the rails so that the cars cannot come off the track***. If we have to complicate rail design to meet these constraints, then track switching becomes more complicated as well. But there should be ways to do it other than the "roundtable."

For passenger trains, there is another issue. On Earth our passenger cars are connected by **flexible accordion like passageways above the couplings that allow protected access between cars.** On Moon and Mars producing such flexible corridors that are air-tight and maintained without any air leaks and pressure loss may be a design challenge. But as the old saying goes, "show me something that can't be done, and I'll show you how we can do it anyway!" Our civilization is built on that foundation!

**There would seem to be at least two ways around this problem.**
(1) ***restrict car to car*** (in Europe, wagon to wagon) ***passage to periods when the train is at the depot, or otherwise parked on straight level track sections.*** While so parked, the cars could snuggle up to one another, effectively docking as we do in space. For breathing purposes, Mars might as well offer a high vacuum, as does the Moon.
(2) There is another option. As the railroads will be pushed through new unoccupied lands with no transportation infrastructures in place, there will be as yet no overhead clearances to observe. Nor will the rights of way be expensive to acquire. ***Mars, and the Moon, are virgin territories and the railroads will have the chance to set both rail gauge and clearances.***

***There is no reason why a Mars/Moon passenger car/wagon could not be double the width, double the length, and double the height (two floors) able to carry as many passengers as a Jumbo jet.*** Not that traffic will mandate such jumbo one-car trains at first, but the point is ***we should design the system so that in the future, when and if traffic warrants, we could build such capacious cars that could "Be" the whole "train."*** But as the word "train" means "a coupled chain of cars," one following the other, pulled/pushed by an engine car, we might have to find a new word, such as "**railcoach**." Railcoaches could run more frequently as traveler demand rises. Another solution, however, would be to ***allow passengers in interconnected coaches to walk between them only when the "train" is at rest in a Depot Station.***

On the new frontiers of Moon and Mars, we have the option of starting with a clean slate, and ***we should take the opportunity to design for a more densely populated frontier with many major settlements.*** Now most people are not thinking that far ahead, but if we don't, then we risk making a slew of unnecessary, stupid, and contraceptive dead-end decisions.

## The Railroad as Land Developer

Another thing worth paying attention to well in advance of the time when we starting to expand out of an initial outpost, is the role "the railroad land grant system" played when railroads opened the American West, Canada, and Australia or China or Russia or India?

***Martian (and Lunar) railroads could be a major force in developing the strips of land that they pass through.*** This is too significant an opportunity to ignore. But we'll need to get it right from the outset.

## Many more issues

How will railroads be powered? Nuclear power is an option that was taken quite seriously back a few decades ago by the Norfolk and Southern running between Cincinnati, Ohio, and Norfolk, Virginia. That brainstorming effort was abandoned. If we can make a nuke sized to run a submarine, then why not a railroad? But they are heavy units requiring water for cooling.

As it seems very likely and helpful to run power lines parallel to the tracks, electric power trains (the hidden rails in design option 2 above carrying the power) seems a good all around solution.

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## A Lighter than (Mars) Air Craft Might Solve Mars' Biggest Mystery

√ *In this design, the "hull" is two shells, held apart and in shape by a lattice between them. The lattice could be made of steel, or aluminum,* ***or basalt fiber rebar.***

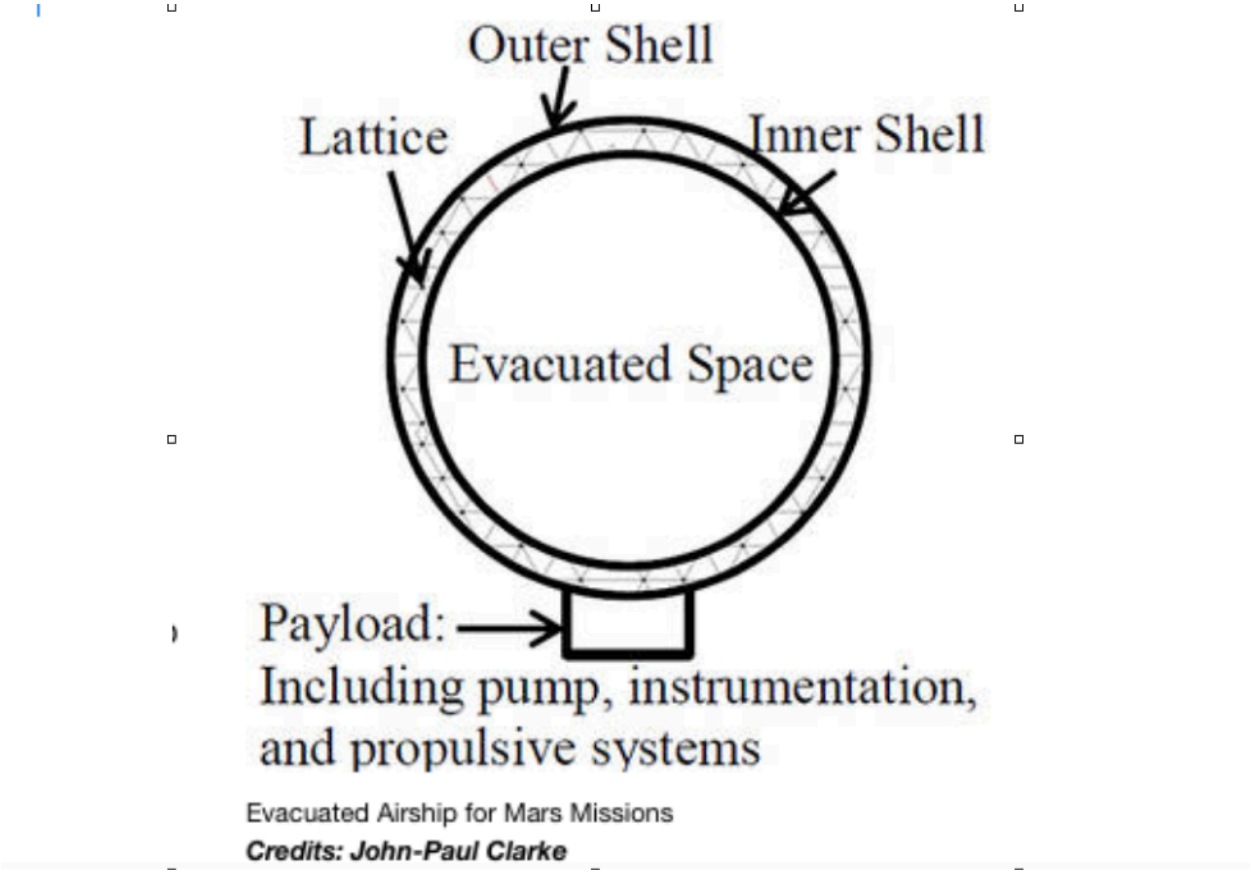
√ *In this design,* ***the craft has more lift than a dirigible filled with hydrogen****, for example.*

√ *The Payload box could include room for passengers and minimum cargo.*

√ *In front of that would be the "cockpit' - housing the crew flying the craft.*

√ *This is one way to explore Mars from above, but much closer than from orbit above the atmosphere. How does it maintain a set desired elevation above the surface? How does it land? This writer does not know.*

√ ***Such a craft could roam close above Mars' northern ocean-sized basin, looking for signs of former shorelines indicating that there was indeed (or was not) an ocean on Mars in eons past.***




Evacuated Airship for Mars Missions

***Credits: John-Paul Clarke***

In this writer's view, ***such a ship should be manned, as the human eye might notice things that the craft's automatic surface scanner might not be programmed to search for.***

And vice versa. Some writers in years past assumed that this ocean-sized basin was proof that Mars once had an ocean. But ***while water seeks basins, basins do not create water.***

Regardless, it is likely that some sizable mini-planet or very large asteroid, "bounced" off proto-Mars, at a time when Mars was cool enough for this impact basin to retain its shape.

It may take humans on location to determine what indeed happened in Mars' Northern Hemisphere and when, as well as what role this great basin will play in the settlement of Mars. #

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## Settling the Moon first will speed up the Settlement of Mars - Why?

(1) Items & parts needed on Mars can be shipped from the Moon using **far less fuel** than needed to ship the same load from Earth's surface, much deeper in the Earth-Moon gravity well.

***(2) Lunar settlers will have gotten the bugs out of making very many things needed by settlers out of cast basalt, carved basalt, and basalt fiber***

(3) Lunar settlers will have built up their industrial areas with a ***complex of "Container Factories" and Martian settlers can do likewise, but without the trial and error delays that early settlers on the Moon will have gone through***

(4) Mars, it seems likely, will not be able to produce anything made there that will be of use on Earth. On the other hand, ***Martians may invent and produce things useful on the Moon.***

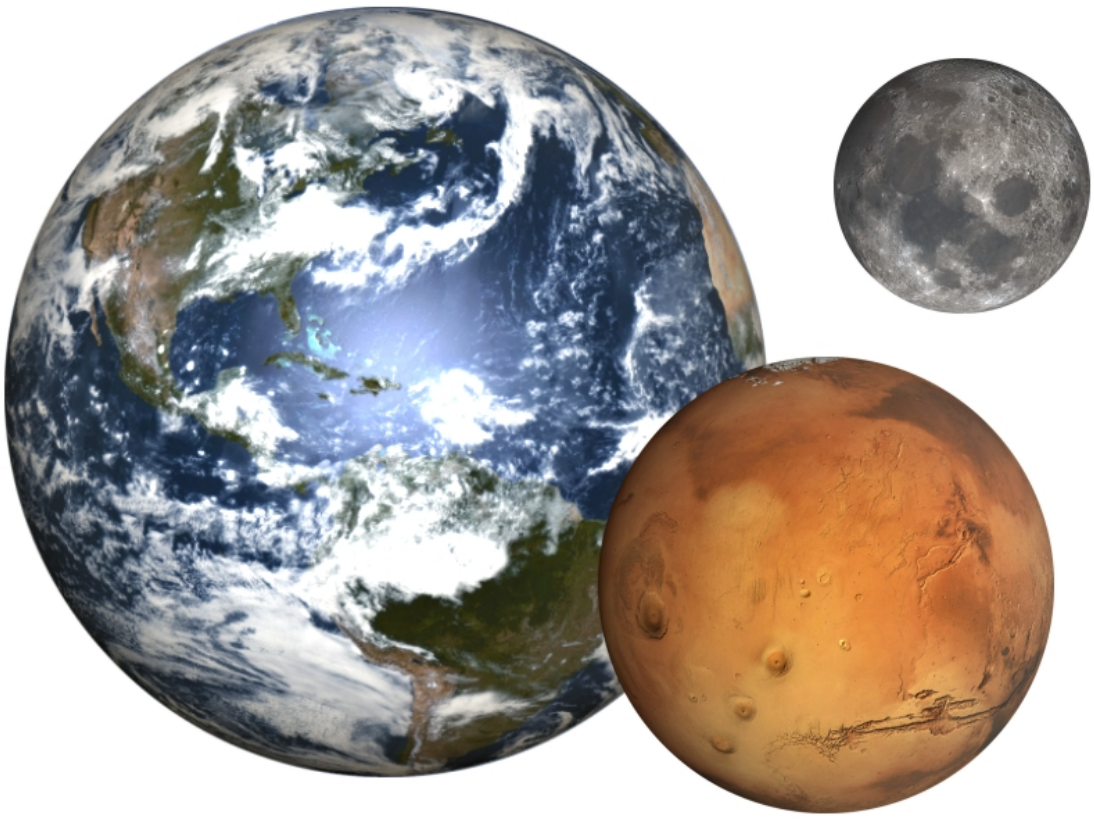
(5) ***If Moon settlers omade some mistakes, Mars settlers will benefit from lessons learned.***

(6) ***Lunar Thorium deposits can provide nuclear fuel*** for faster ships from Earth/Moon to Mars.

(7) Lunar settlers who want to move to Mars can get used to a higher gravity level via various designs of banked circular tracks on which rail cars will experience Mars-like gravity.

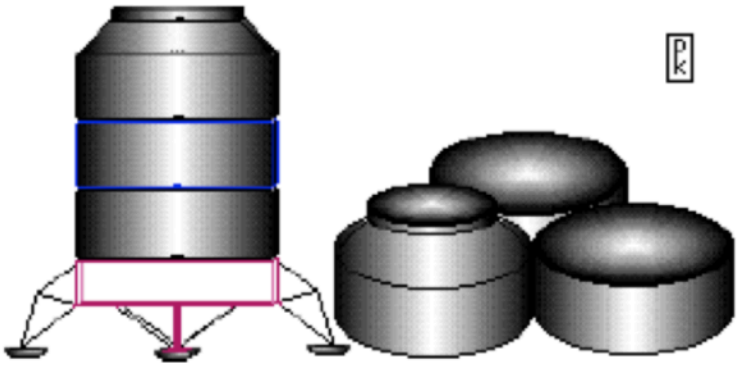
***(8) Lunar and Martian Settlements are more likely to be helpful partners than rivals.***

(9) Should Earth's nations commit mass suicide in a nuclear war, the Moon and Mars together will carry on human culture, traditions, and dreams as close partners, spreading outwards into the Solar System, and someday to the stars. ##. Below: Earth, Moon, and Mars to scale. ##



**The problem with the MARS SOCIETY'S 2 "practice" stations, FMARS** on Devon Island in far North Canada and **MDRS** analog station in Southern Utah - both 2-floor stacks - ***is that while stacked floor structures might be ideal for transit from Earth to Mars, they are not an ideal design for use on Mars, because it will be too hard to shield them from the elements.***

**Vertical stacking is okay for interplanetary flight only**
**With side by side deployment will be ßbest on site.**



**Above, left:** a 3 floor unit, stacked for transit, but placed side by side, right, with connecting doorways between units. This will make it much easier both shield the complex from the elements and to maintain a desirable room temperature with removable insulating bags of local soil covering the complex: in all, a much better design.

***The Mars Society's two stations, in Utah and on Canada's far north Devon Island, are designed to demonstrate Mars exploration tactics only, and are not designed to meet the elements on Mars.*** *A 3rd analog station (in Antarctica's Dry Valleys?) should be "unstacked."*

***Putting the floor units side by side, once the craft arrives on Mars (or the Moon, or any other body) makes it easy to cover the complex with bagged surface dust to provide temperate conditions inside, day or night, through all seasons, a design that makes much more sense.***

## Seeds of a First Mars Settlement Community

***A second (and third, etc.) triple deck unit(s) could land nearby allowing its three separable floor units to connect with the first set, the start of a community.***

Any vertically stacked Hab standing above the Mars surface, will be fully exposed to temperatures that can range at the equator from just above freezing to lower than anything we have experienced in Antarctica. Such an architecture invites catastrophic collapse.

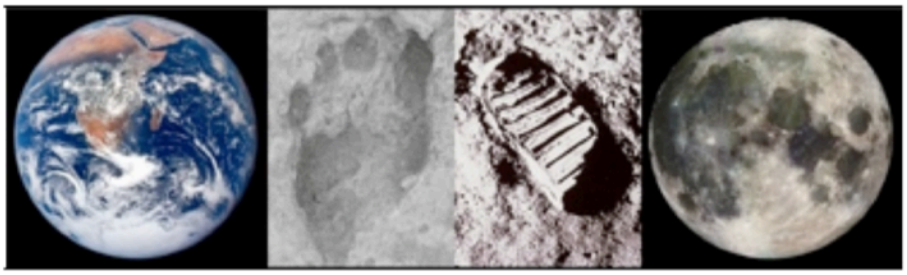
***What is easiest to ship and land is not necessarily the easiest to maintain on Mars.***

***Nor is the solitary Hab structure designed for expansion.***

***The demonstration goal should be technologies that allows expansion towards a more comprehensive permanently manned outpost leading to the first real settlement community.***

***NOTE:*** *I personally prefer a horizontal 2 floor cylinder: more design options, more room. (a mockup could be made from two quonset structures, the lower one upside down.) ##*

From Africa to the Moon, the Human Epic, told in footprints, Continues to the Stars!



Our Goal is Communities on the Moon involving large scale industrialization and private enterprise.

*And next, not to just set foot on Mars, but to make Mars ßyet another Human World!*

*"**Of stardust** thou art, **and to the stars** thou shalt return!"#*