"Towards an Earth-Moon Economy - Developing Off-Planet Resources"

Moon Miners' Manifesto

& The Moon Society Journal www.MoonMinersManifesto.com

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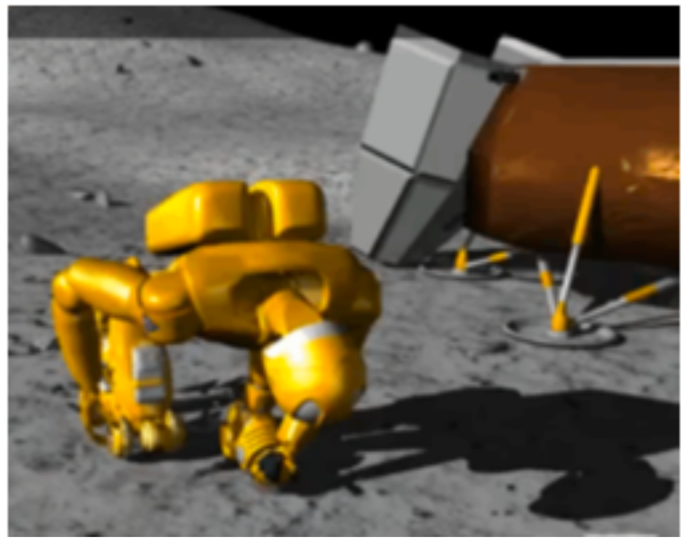
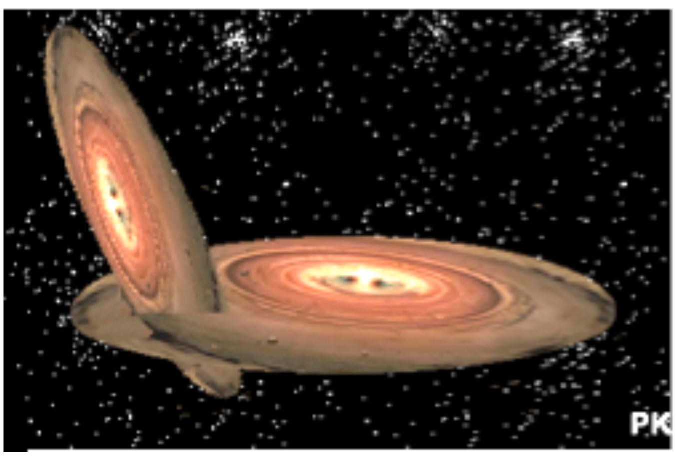
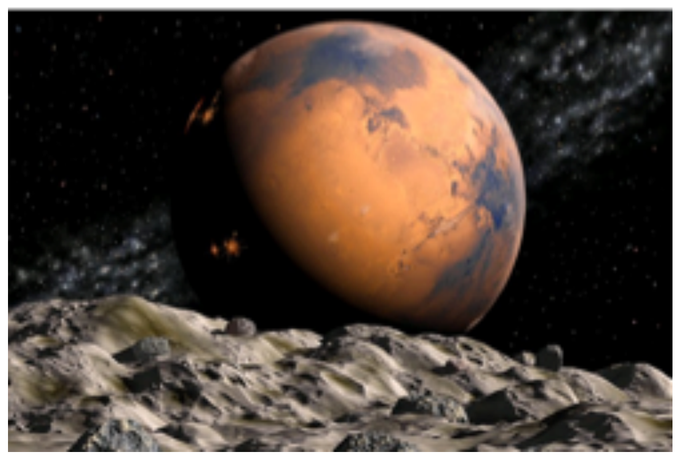
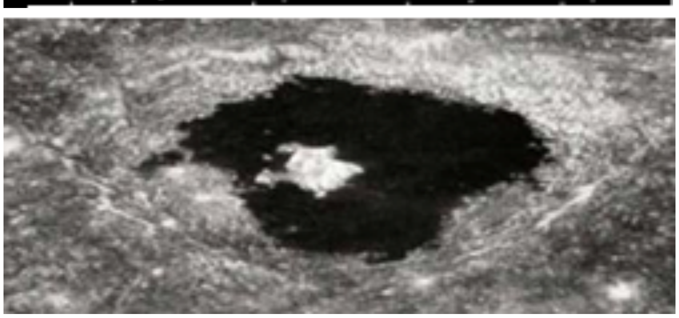
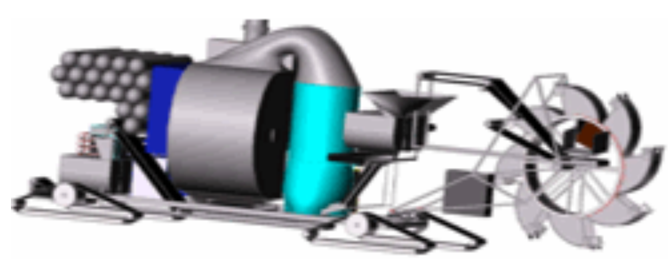










As usual this year, we covered a wide range of topics, attempting to shed new light on all of them.

Outer Space Resources or Bust!

"All the elements needed for Solar Power Satellite construction can be found on the Moon and in asteroids"

By Dave Dietzler

Forward

In a nation where women spend $100 billion a year on fashion, half the people are overweight or obese, and debate rages over global warming despite the fact that the majority of the world's scientists agree that man-made global warming is real, a few of us think about the future and the creation of a space faring civilization. Ominous clouds hang over this future, but there can be no doubt that the technologies exist to prevent the downfall of civilization.

Options and Alternatives

Nuclear fission, breeder reactors and thorium could power civilization for centuries if we are willing to tolerate a meltdown now and then and underground disposal sites for nuclear waste. Geothermal energy might "save the day" in a non-polluting way, but we must wonder if a geothermal well can compete with a 10 GWe SPS. At five cents per kilowatthour an SPS construct could sell $4.38 billion worth of electricity per year! 10,000,000 kilowatts * 8760 hours/ year * 0.05 dollars per kilowatt-hour. Only 30 of them could deliver $131.4 billion per year worth of electricity. A thousand of them could provide half the world's energy demand in 2050 if all consumption was electric rather than thermal. The profits from a small number of SPS could be reinvested in the construction of larger numbers of SPS and conceivably a thousand or more of them could be afforded.

What it would take to build an SPS system

It is estimated that a 10 GWe SPS would amass 100,000 metric tons at least. To build merely 30 of them would require 3,000,000 tons of aluminum, silicon, glass and other materials. Mass drivers on the Moon launching 600,000 tons of material per year have been envisioned, thus it would take only five years to launch three million tons of materials into space from the Moon.

97% is not good enough

Here's the catch--I have often read that 97% of the materials needed for the construction of a SPS would come from the Moon and the rest from Earth. That means 90,000 tons of material must be launched from Earth and at the rock bottom price of $10,000 per kilogram to GEO or L5 this would cost $900 billion! For bootstrapping lunar mining bases we were only considering a few thousand tons at most! There can be no disagreement:

> One hundred percent of the materials needed to build SPSs must come from outer space after bootstrapping up all the infrastructure needed to produce those materials from a seed of only a few thousand tons launched up from Earth.
>
> At least that's how I see it.

Easy things first

Aluminum, silicon, glass, iron and many other materials are abundant on the Moon. Processes like metallothermic reduction with calcium or the use of electrostatic isotope separators can extract those materials easily enough.

The harder part

What about copper, zinc, nickel, cobalt, platinum and other metals?

> Isn't the Moon so deficient in these that we might as well "throw in the towel" and forget about Moon mining and go to Mars? The answer is a loud and resounding "NO."

Meteroric fines

About half a percent of lunar regolith, both mare and highland, consists of meteoric iron fines that contain about 5% nickel and 0.2% cobalt. Robotic vehicles with magnetic separators can sift through vast areas and millions of tons of regolith to get those meteoric fines and they can then be processed with carbon monoxide gas or electrostatic isotope separators to get iron, nickel and cobalt separately. Nickel can be used to alloy iron and as a catalyst and cobalt can make high strength drill bits and machine tools.

Pyroclastic glass

Copper, zinc, gallium and chlorine are present in lunar pyroclastic glass. They form coatings on the surface of the glass particles and can be extracted simply by roasting or possibly with fluid solvents. From 19.5 million tons of volcanic glass, that's in the range of regolith mining schemes proposed for mining volatiles, iron fines, etc. we'd get by roasting the glass at over 1000 C. about 1.1 million tons of oxygen; 8,800 tons of sulfur; 5,800 tons of zinc; 1,900 tons of chlorine; 1,900 tons of iron; 1,500 tons of nickel, 510 tons of copper, and 310 tons of gallium [1]. That much glass could be mined from an area about ten kilometers square to a depth of about one or two meters in one of the glass fields near Aristarchus or in Mare Serenitatis. That's about 2500 acres and a rancher or farmer would not find that intimidating. Launching 510 tons of copper up from Earth at $10,000 a kilo would cost $5.1 billion and that is intimidating. As for roasting at over 1000 C., some would ask where all that energy would come from and i would simply say that large parabolic foil reflectors and solar furnaces would be called for. Certainly we could bootstrap up the industry required to produce all these materials on the Moon rather than spend $58 billion to get 5,800 tons of zinc into outer space!!!

PGMs

What about **p**latinum **g**roup **m**etals? The lunar regolith is actually somewhat enriched in these elements; a result of eons of meteoric bombardment. Clever chemical engineers should be able to figure out how to extract these.

Capturing a suitable half-megaton mini-asteroid

If PGM extraction on the Moon is too challenging, we could mine asteroids for them. In Wikipedia we read,

"A NASA design study evaluated a 10,000 ton mining vehicle (to be assembled in orbit) that would return a 500,000 ton asteroid fragment to geostationary orbit. Only about 3,000 tons of the mining ship would be traditional aerospace-grade payload. The rest would be reaction mass for the mass-driver engine, which could be arranged to be the spent rocket stages used to launch the payload.

"Assuming that 100% of the returned asteroid was useful, and that the asteroid miner itself couldn't be reused, that represents nearly a 95% reduction in launch costs. However, the true merits of such a method would depend on a thorough mineral survey of the candidate asteroids; thus far, we have only estimates of their composition."

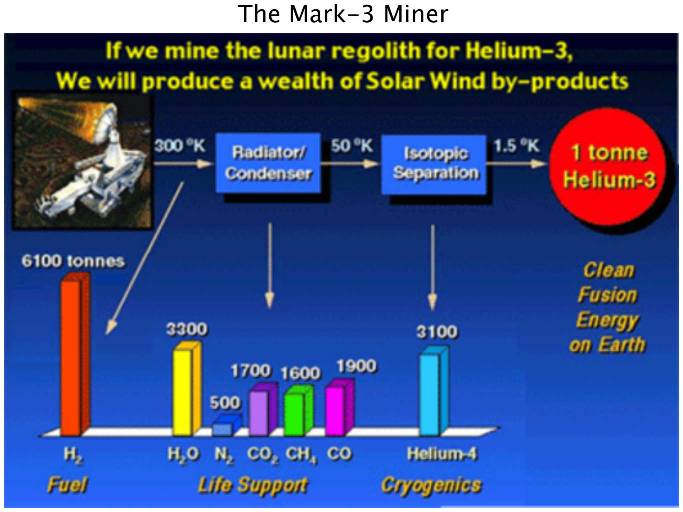
Finding just the right asteroids

There is no reason in the world why we cannot do thorough mineral surveys of NEAs with telescopes and space probes to determine their precise composition. With lunar industry, the construction of robotic ships with lunar materials becomes more inviting. Certainly, we can acquire PGMs from outer space for use in space and on Earth.

Solar Wind Volatiles

What about light elements like carbon, nitrogen and hydrogen? These do exist in the lunar regolith and their production along with helium 3 has been studied. One Mark 3 miner like that proposed by Dr. Kulcinski and others at the University of Wisconsin could produce 109 tons of H2O, 201 tons of H2, 16.5 tons of N2, 56 tons of CO2, 63 tons of CO, 53 tons of CH4, 102 tons of He4 and 33 kg. of He3 in a year's time. That's 82 tons of carbon contained in CO2, CO and CH4. If 201 tons of H2 is combined with 1600 tons of O2 that's another 1800 tons of H2O [3].

The Mark-3 Miner



Polar Cold Trap Ices

There are richer sources of water and carbon in the permanently shadowed craters of the lunar polar regions. Millions of tons of ice containing water, carbon dioxide, ammonia and other compounds and elements have been proven to exist on the Moon. The "**cryo-technologies**" needed to mine in these super-cold craters must first be developed, but where there is a will there is a way. Expect this new technology thrust to be a major direction for NASA and other space agencies in the coming decade, as "ground truth" landers follow orbiters.

Carbonaceous asteroids and old burned out comets might also be sources of light elements.

KREEP Rare earth elements also exist on the Moon, mostly in KREEP terranes. The term KREEP stands for K-potassium, REE-rare earth elements, and P-phosphorus. Do not be misled into thinking that these minerals are purely potassium, REEs and phosphorus. They are mostly SiO2, Al2O3, FeO and other constituents of most lunar rock, but the KREEP minerals are richer in these elements than typical lunar rocks. It would then be logical to mine these minerals and extract the K, P and REEs. Rare earth elements are used for optical glass, electronics, lasers, magnesium alloys, electric motors, magnets, computers and cell phones. Certainly they will find their way into the high power electronics of SPSs and it would be more cost effective to mine them on the Moon rather than ship them up from Earth.

This rock is rich in KREEP:
K Potassium
REE Rare Earth Elements
P and Phosphorous,
elements rare on the Moon but
abundant in the splashout from
the impact that created Mare Imbrium,
the nearside "Sea of Rains"
This resource may be vital to lunar
industries and is not found at the poles.

All we need is out there

In conclusion, all the elements needed for SPS construction can be found on the Moon and in asteroids. Sophisticated robotic machines that can dig through millions of tons of dry lunar regolith every year and roast out solar wind implanted volatiles or boil metals off the surfaces of volcanic glass particles will be needed. Artificially intelligent space ships will be needed to mine asteroids. Bioleaching might be used to extract elements present in low concentrations from lunar regolith. This will require water, nutrients, salts, temperature control etc. Environmentally controlled habitat will be needed to use bioleaching.

Decades of development ("bootstrapping") on the Moon will be required to build industry up to a point at which these machines and other equipment can be manufactured on the Moon with onsite materials and enormous quantities of materials can be extracted from lunar regolith and asteroids to supply a large SPS construction project.

1) www.moonminer.com/Lunar_Volcanic_Glass.html

2) http://en.wikipedia.org/wiki/Space-based_solar_power

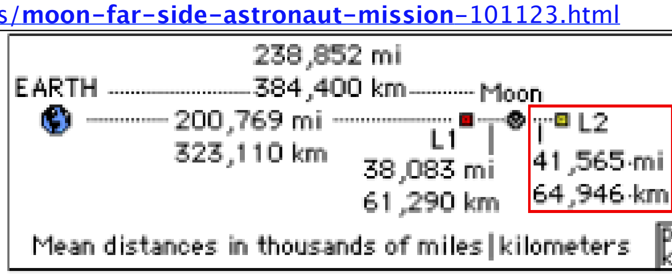
3) www.moonminer.com/Lunar-Water-and-Carbon.html

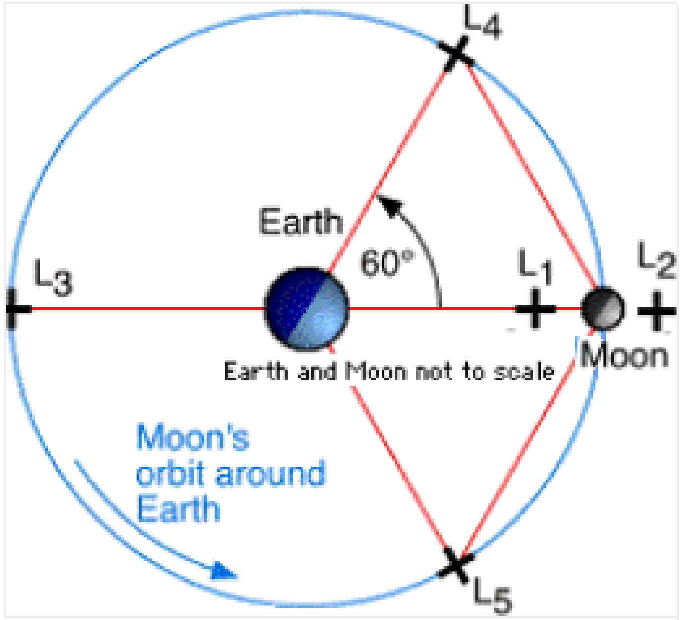
About the writer: For nearly a decade, Dave Dietzler, co-founder of Moon Society St. Louis, has contributed quality articles on the possibilities for Lunar industry. **MMM**

Lockheed-Martin Proposes Tele-Robotic Exploration of the Moon's Farside From the L2 "Perch" using its Orion Crew Capsule

By David A. Dunlop and Peter Kokh

Proposal to Send Astronauts to Moon's Far Side
By Leonard David: 23 November 2010
http://www.space.com/news/moon-far-side-astronaut-mission-101123.html





This proposal is a cleaver bit of "space strategy" in the context of the US political climate.- D. Dunlop

An L2 Mission and the new "Flexible Path"

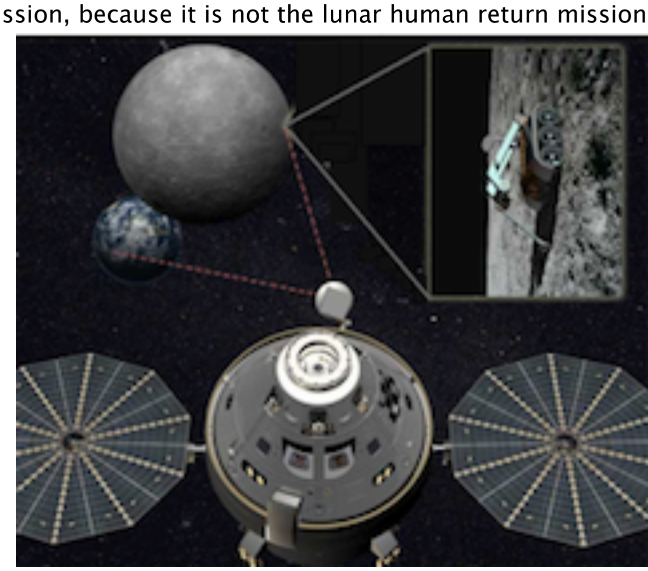
Instead of a Manned Space Program focused on the Moon, the new space paradigm is a "Flexible Path" that would use deep space missions of increasing difficulty to advance our capacity to operate beyond Earth orbit. Missions to near Earth asteroids, then to the moons of Mars have been identified as consistent with this goal.

But there just may be a neat way to sneak in a manned Moon Mission. LockMart would not send its craft and crew to the Moon's surface but rather to the stable L2 point some 40,000 miles above the Moon's Farside,. Here the crew would be able to stay in contact with Earth but also teleoperate rovers on the Moon's farside surface that would investigate some of the Farside's secrets and mysteries. These science goals are at the top of the wish list of many, if not most, lunar scientists, as Farside is notably different from Nearside in several ways.

Lockheed-Martin cites these mission plusses:

- It could sharpen skills and technologies needed for a trip to an asteroid
- It showcases techniques useful for exploring Mars by teleoperation as astronauts orbit the red planet.
- It would serve as a "shakedown cruise" to practice medium duration missions and the higher-speed reentry needed for exploration missions before the next step - missions to asteroids.
- It would demonstrate additional capabilities for longer and more distant exploration before the Mars orbit mission.
- It would prove out the Orion capsule's life support systems for a one-month duration
- It would measure astronauts' radiation doses from cosmic rays and solar flares to verify that Orion provides sufficient protection, as it is designed to do

All of these demonstrations need to be done at any rate, and doing them from a point beyond the Moon, increasing our knowledge of the Moon and our operating abilities on its surface seem to this writer as a bouquet of plusses. Not to support this mission, because it is not the lunar human return mission we want, would be foolish.



Above: The Orion craft left, with a view of farside while in line of sight with Earth, teleoperating surface rovers.

This proposal reinforces the Obama Administration's space goals of advancing NASA's mission to go beyond LEO to the asteroids and Mars while actually first going to the Moon to pursue lunar exploration goals that would otherwise be abandoned. This nicely positions it to be supported by the Republicans in control of the House and who favored the Constellation Moon program. It ensures continued funding for the Orion capsule, which is being built under Marshall Space Flight Center in Alabama, and it supports lunar lander projects.

The Advantages of an L2 Teleoperations Perch

From a "halo" orbit around the L2 Lagrange point where the Moon's and Earth's gravitational forces cancel each other out, at an average distance of 41,500 mi ~ 65,000 km above the center of the lunar farside, the Orion capsule could remain in-line-of-sight of Earth, essential for communications, while being able to tele-operate robotic equipment anywhere on the lunar farside surface below, something that otherwise cannot be done directly from Earth or Earth-orbits. The lunar "farside" is the side of the Moon never visible from Earth, as the Moon turns on its axis in the same period of time that it orbits Earth, always with the same "nearside" facing us. It is sometimes erroneously called the darkside of the Moon but Farside takes its turn in the sunlight just as does the familiar Nearside and on the same 29.5 day cycle.

The point is that there is much on the farside that has our scientific curiosity aroused. Lunar probes in low lunar orbit have mapped this whole area in visual light and other revealing wavelengths. But such craft, being out of line-of-sight of Earth at the time, cannot be used to relay teleoperation commands to robotic equipment on that side of the Moon. If we want "ground truth" landers and rovers to tell us more, we either have to fully automate them, letting them download their findings to orbiting craft when they pass overhead, for delayed relay to Earth, or we have to have such a perch as L2 from which human teleoperators can work directly.

Beyond operation of ground truth probes, at some time we might want to preconstruct landing areas, and places to store supplies for future manned surface missions. From L2, all this is possible. From L4 and L5 we can see 60° around the limb of each side of the Moon, but cannot see the central Farside 60° slice.

Having a lunar lander vehicle (which had been eliminated with the cancellation of the old Constellation program is also another way to "practice for Mars". The lunar exploration roadmap calls for a sortie mission capability to sample areas of the Moon other than those visited by Apollo. So these are "face-saving" ways to consider putting back the human lunar lander module in the NASA budget. In essence this is a way to have a Moon Program without calling it a Moon Program! But this is not part of the Lockheed-Martin Proposal.

Hardware: Getting Orion to L2: Heavy-lift vs. Delta-V

Another fight in Congress is about the development of a heavy lift launch vehicle versus man rating the Atlas V. This scenario show that it could be done either way. If an Atlas V was used to boost Orion into LEO then another vehicle (Centaur) would have to rendezvous and dock with it to boost it beyond the Moon. The Orion capsule is too heavy to be boosted by the Falcon 9. So using Orion in essence makes the Atlas V the key launcher system for manned operations beyond LEO. It also creates a requirement for secondary launches to fuel these missions. That also is something that justifies fuel depot requirements, which is yet another strategic piece that is needed to routinely go beyond LEO and the ISS.

Salvaging parts of the puzzle

Rendezvous and docking is another one of the strategic capabilities covered in the new Obama budget. Development of an unmanned heavy lift vehicle that uses shuttle-derived technologies and infrastructure is what Congress demanded and which keeps up employment levels at Marshall, Johnson, and Kennedy space centers. It would continue to use the space shuttle main engines, the external tank, and solid rocket boosters like the old shuttle system. It would however have a top mounted large (15 m diameter) faring. This is in essence the Direct Proposal that was an underground rebellion against the old Aries V design.

This is also a political fight within NASA and within Congress. Some at NASA want to see everything contracted out while others want to preserve a NASA government launch capability with its associated infra-structure and employment.

Political suspense

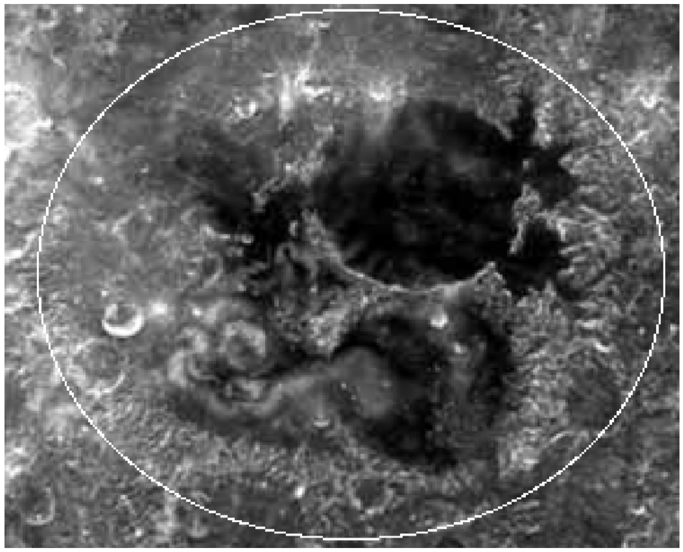
The real issue is whether NASA will be deeply slashed and cut back to 2008 expenditure levels of $17.4B from the recently agreed $19B level or continued on the current spending level on a continuing resolution basis in Congress if no political agreements are reached.

Our curiosity about the Moon's Farside

If you look at a globe of the Moon, the farside and nearside look like parts of two different planets. Some 2/5th of the nearside is covered by the dark lava plains, called maria (MAH-ri-a) or "seas." Lava basalt products will be a key early industry, and the pre-sheltered subsurface lavatube networks that are found in these "seas," may become the major areas for human settlement. The farside, in contrast, has a much smaller share of such dark, basaltic terrain.

And between the equator and the South Pole on farside, lies the deepest and largest lunar basin. As there are only scattered areas of subsequent lava flooding in this basin, it is expected that some of the basin floor may be covered with lunar mantle material, so far unsampled. However, some central peaks of larger craters may contain upthrust mantle material as well, and there are plenty of these on the nearside. But we won't know until we go there in person or with teleoperated mining equipment and samplers similar to Mars-bound Curiosity.

The growing interest in the Moon's farside is thus mainly a scientific one. But make no mistake; the farside will see its share of human frontier activity. Some of the relatively flat lava sheet areas may make ideal sites for extensive of radio telescope arrays, future successors to those at Socorro, NM and the larger array now being built in Chile's Atacama Desert: ALMA. [following article]

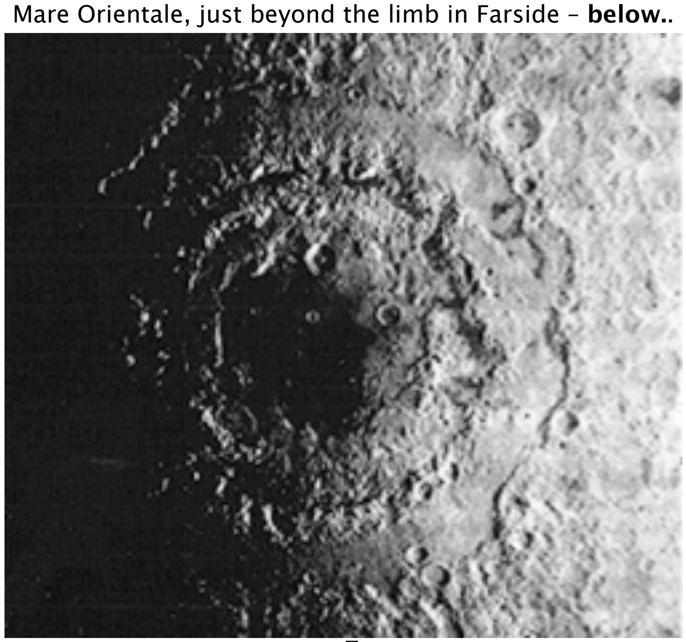


Bottom previous page: Mare Ingenii, which could host such an array, is of special interest because it has a small local magnetic field" antipodal to the point of impact that created the great nearside Mare Imbrium basin. The ionized plasma cloud from that impact surrounded the lunar globe in minutes, converging over Mare Ingenii.

Below: The Crater Tsiolkovsky has a dark sheet of lava covering it, with a magnificent bright central massif, Mt. Nikolas (if we follow our suggestion to name central Peaks with the first or given name of the person in whose honor the crater has been named) From a distance, such as from L2, this crater will stand out, proud.

Some very low altitude areas in the Apollo crater might have mantle material on the surface.

And then there is the most spectacular multi-ring "bullseye" impact basin on the Moon, Mare Orientale, just beyond the limb in Farside – **below.**.



Additional Science Goals on Farside:
The International Lunar Network Commitment

There are international agreements NASA has signed for the development of an International Lunar Network. This initiative is also located a Marshall. It involves placing four different landers on the lunar surface. There is also a push for a lunar lander sample return mission at the South Pole Aitken Basin in the Science Mission Directorate competition for a large new mission. This proposal ties that mission to the manned mission so a number of lunar related missions are involved.

http://en.wikipedia.org/wiki/International_Lunar_Network

"The **International Lunar Network** or **ILN** is a proposed network of a series of landed stations of the United States and the other space-faring countries on the lunar surface in the 2010s. Each of these stations will act as a node in a lunar geophysical network. Ultimately this network could comprise 8-10 or more nodes operating simultaneously. In the ILN concept, each node will have a minimum of two core capabilities. These capabilities include seismic sensing, heat flow sensing, and laser retro-reflectors, and will be specific to each station. Because some nodes are planned to be located on the far side of the Moon, NASA will study a lunar communications relay satellite capability as a part of its contribution to this project.[1]

"Individual nodes launched by different space agencies can and likely will carry additional, unique experiments to study local or global lunar science. Such experiments might include atmospheric and dust instruments, plasma physics investigations, astronomical instruments, electromagnetic profiling of lunar regolith and crust, local geochemistry, and in-situ resource utilization demonstrations.[1]"

Lunar Science Program, Science Mission Directorate, NASA.Solicitation Number: NNH09ZDA005L.
Release Date: November 17, 2008

While we are there: a Farside Phase Photo Set

This Mission as proposed would last two weeks, allowing the crew to teleoperate probes and rovers on the surface for the full 2-week long dayspan duration at any one place. But we might want to teleoperate more than one rover at more than one place, mutually displaced east-west from one another, the mission would need to be longer to fit in partially overlapping local dayspans.

But for however long the crew is hovering over the farside, they could take daily Moon Phase photos. These photos are useful for the enriched long-shadow terrain details they show along the day/night and night/ day terminators. We have no such photos of the farside, and this inexpensive frosting project would contribute to public familiarity with "the rest of the Moon."

Close-ups of areas ideal for a farside Radio Tele-scope array dedicated to the S.E.T.I. would also increase public interest; also photos of farside lava tube skylights.

The farside has much fewer lava flow mare areas; its crust seems to be notably thicker than that on the nearside; its southern South-Pole Aitken ("SPA") basin is the largest and deepest on the Moon and may expose deep mantle materials not sampled by the Apollo crews.

Where does advocacy come in?

While such a mission would not put humans on the Moon, it would increase our knowledge of the Moon and could fill in many blind spots in our grasp of the Moon's history and future potential. Further, it would keep the Moon in the public eye, increasing support for a future manned return.

The Moon Society has yet to consider taking a position on this option! We do not know if there is an NSS position. Speaking for myself, this sounds like a win-win proposal for both lunar and Flexible Path advocates. Time will tell if it goes anywhere. But we see no downsides.

MMM

A Farside S.E.T.I. Radio Telescope Array

By Peter Kokh

In the previous article, we suggested that the deployment of a major array of cutting edge state of the art Radio Telescopes could most easily be done through teleoperation of robotic construction equipment from a perch in the Earth-Moon Lagrange 2 position some 45 thousand miles ~ 65 thousand kilometers above the lunar Farside surface. Such a facility has been the dream of many for several decades. As a boy in my teens in the 1950s, I dreamt of being assigned to such a facility and making a career of it (I have a monastic side).

For most of us, the special appeal of such a location is not for radio astronomy itself, but as the most radio-quiet place within a few light years from which to listen to the "sussuri" - [Latin] "whispers" from the stars, from other intelligent species out there. Yet these days, there is a quite premature discouragement settling in among SETI advocates - those focused on Searching for Extraterrestrial Intelligence, or clear signs thereof.

Why haven't we found any "others" yet?

"We should have heard something by now!" This is a common complaint among the impatient. Yet as the same time, the odds of the existence of other "Earths" out there have never seemed greater. "Nature never does anything once," I quote. But people forget that Time is as Vast as Space. That a civilization would be found that was not only "nearby" but also "contemporary" with ours is asking to win the cosmic lottery twice in one dice roll.

The difficulty barrier

But there is more to consider. For the most part, we have only been listening, and briefly, with many inter-missions. If every species that wanted to broadcast their existence also did so intermittently and for short periods, it is easy to see how we could have missed their signals. If a race wants to be heard, to be found, it should occur to them that broadcasting must, once begun, continue indefinitely: not for a few days, not for a few years; not for a few centuries. Broadcasting must be a species "cathedral-building" class endeavor, absorbing consider-able resources of power and cost.

Simply put, it is orders of magnitude easier to listen than to broadcast. The upshot is that it is not unlikely, given the cathedral-building demands cited, that "everyone is listening, no one is sending."

Whom would a sender want to reach?

I'm not afraid to tell anyone that I am a romantic; it doesn't pay to be anything but. So it is not surprising that I find a universal logic in the Star Trek myth (if you will) about the "Prime Directive." A superior civilization should avoid contact with interior ones, as that contact could destroy them, snuffing out their own native inventiveness and originality. Human history is full of examples where contact between unequal civilizations has meant the death of the inferior one. This is ongoing!

It is not likely that there are any inhabited worlds were such unequal cultures have not come into contact. So as a culture matures, it must come to the conclusion that premature contact is not a friendly thing to foist on inferior civilizations, no matter how eager individuals of an inferior civilization may be to skip painful progress on their own, and beam ahead historically through access to advanced technologies.

What is a "primitive" technology?

Well certainly any civilization, which has not come to caring terms with its own environment, must be judged as primitive. Ours certainly qualifies, as those who care about preserving the health of the environment, which nourished us, are still in the minority, effectiveness wise. We still decide things by armed conflict or by financial battles. Face it, as far as we have come, we are very much an adolescent species.

Now it could be that one reason our ventures into space have been so discontinuous, halting, unsure, is that we simply do not have our act together yet. Let's suppose that a mature, environment-conserving species able to resolve all issues by a process that sidestepped conflict and aggression and resulted in widespread consent, wanted to reach out to other species, but only to species at its own state of maturity. How would they filter out signals from getting through to those who were not ready for them?

Well, picking a wavelength that could not pass through a breathable atmosphere (oxygen, water vapor) might be one way. If you sent signals that not only could not be picked up on the surface of a habitable planet, but could not even be picked up where radio-noise from an adolescent civilization was pervasive, then you might have reason for confidence that no one would detect or read your message who was not ready for it.

Not all habitable worlds are going to have moons of size that are rotationally locked, as is our Moon. But perhaps, one could hope, that a civilization mature enough technologically, culturally, environmentally, etc. to deploy a radio array on the farside of such a moon, just might be mature. By this argument, it is not at all surprising that we have heard nothing, but that on the other hand, once we are advanced enough to build a major radio array on our Moon's farside, we just might, with a lot of luck, pick up intelligent signals. Now the chances are greater that such signals reach us from far away in space-time, and are not those of a nearby and contemporary civilization.

Recently, we have grown more optimistic that the our galaxy has many millions of solar systems, and that there may be many worlds able to sire intelligent species sooner or later in their history. Top this by adding that the number of galaxies outnumbers the stars within our own. The universe must be full of life, the vast majority of such instances effectively isolated and out of contact with others by the barriers of time and space. For me it is enough to know that there must be others, virtually everywhere and everywhen, however mutually remote. Here and there will be pairs of civilizations that beat the odds and find themselves neighbors in both space and time. For me, it is enough to look up at the stars and say "Hi," fully confident that all over space and time there are others looking up in wonder and doing the same.

Building first a Radio Array on farside and then finding wavelengths that can go the distance but not be picked up by those not ready for them, and then building a facility to send out messages of our own: "Hi there, we made it! You can too! Life is worth it! May you find all the richness that we have found and continue to find. We go through life apart in space and time, but together in spirit. Peace, love, courage, persistence!"

After many decades of contemplating "SETI" this is where I'm at. **PK**

Telepresence-operated "Robonauts" will revise all "Scenarios"

By Peter Kokh

At first impression, those of us who want to see human frontiers develop "and prosper" on the Moon, Mars, the asteroids and elsewhere in the Solar System may think that the emergence of robonauts threaten that dream. But quite the opposite is likely. These "stand ins" will pave the way at far less expense,

We have already integrated "teleoperation" of equipment" into our expectations. Japan and Russia, as well as our own Carnegie-Mellon robotics team, have suggested that site preparation and many construction chores could save substantial amounts of time and money. It costs a lot to put a human on the Moon! Humans are most effectively assigned to chores that cannot be teleoperated. Teleoperated equipment will allow humans to go to the Moon to begin at once to do what only they can do.

Enter the "robonauts" and telepresence! Here the human controller on Earth "sees what the robonaut sees, feels what the robonaut feels." This is ideal for scientific tasks - for example, where it is not the size, shape or weight of a rock which is of interest, but its chemical-mineralogical makeup." Robonauts can collect samples of special interest, freeing humans of that tedious chore, so that when they arrive, they can examine a pre-selected collection, without wasting hours and days in field work.

Roboanuts do not need food, rest or relaxation.

They can work around the clock, through a team of tele-presence operators on Earth. They do not get bored. Thus the quality of their work is more likely to be high. As to teleoperated equipment, there will be many chores which cannot be done into their manipulation tools, one of a kind chores, that could not be foreseen, or which will be so uncommon that it would not be cost-effective to further specialize those tools and programs. A robonaut with hands human-like in their degrees of motion, can use hand tools for a limitless list of special tasks. Robonauts can do things too dangerous or risky for human crews. T companions can relieve humans of all sorts of risky and tedious chores.

In his article "O'Neills High Frontier Revisited and Modified" blow, Dave Dietzler shows how the emergence of robotic technologies also radically changes that scenario of how solar power satellites will be produced and deployed. No need for hyper expensive Space Settlements, that could delay the construction of SPS systems by many decades. Humans will still be involved, in lesser numbers, with far lower thresholds of support.

To sum up, lunar resources are still a best bet to lower SPS construction and deployment costs, but the cost of accessing those resources will fall by an order of magnitude or more by reducing the amount of human workers involved.

Consider that a lunar settlement can begin very small and grow as needed, module by module. In Contrast, a Space Settlement has to be built to a set size, whether it is occupied by a starter crew, or at full capacity. Space Settlements have a built-in high threshold, greatly exacerbated by the insistence on Earth-normal gravity levels.

PK

Role of Robonauts & Robots on the Moon Once Humans have settled in to stay

By Peter Kokh

We have realized for a long time, at least since the early Apollo mission days, that radiation exposure on the Moon from cosmic rays and solar flares was a big problem. The week or so of unprotected vulnerability could be tolerated. But it would be better to provide some sort of shielding for persons intending to stay a while. Two meters of moondust overburden should protect those within habitat modules for stays up to a few months. But long term, 4-5 meters would be better.

We've known this for some time and most moon-base plans have some sort of shielding incorporated as part and parcel of the plan. This need has also made the possibility of locating human installations within lava tubes very appealing. These voids, whole networks of them, are common in the lava flow sheets that filled most large nearside basins, creating the maria (MAH-ri-a, singular MAH ray, mare) or"Seas." But these handy hollows are not to be found at or near either lunar pole, both poles being located in highland areas.

The inspiration out of which the original Moon Miners' Manifesto was born, was that while we had to live "underground", we would not have to live like moles, as Robert A. Heinlein had suggested in his classic novel: "The Moon is a Harsh Mistress," as there were ways we could take the sunshine and views "down under with us." http://www.moonsociety.org/chapters/milwaukee/mmm/mmm_1.html

But surely we have business out on the naked, radiation-washed surface! We need to explore, to prospect for minerals, to build roads, to trade with other settlements! No people, and surely not the Moon's people, will freely be virtually imprisoned full time. How do we handle this? Read on.

Radiation Exposure Limits and Monitoring

Perhaps every Lunan settler or pioneer or visitor will be required to wear a wristband or other device that monitors one's accumulated radiation exposure. Those whose exposure is under set levels will be allowed to go "outside" – "out-vac" on the exposed, vacuum and radia-tion-washed surface for limited times, and on limited occasions.

Jobs and Careers

There are those in any population that feel most at home "outdoors" and/or "on the road." But living such a life-style – having such an occupation, could result in radiation sickness and even premature death. Unless!

There are three ways to sidestep this nasty fate.

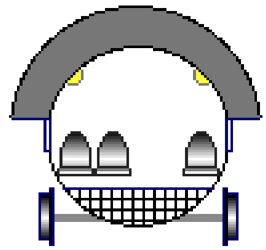
(1) Outside jobs could be managed from the safety of shielded habitat spaces, by telepresence operation of robonauts or avatars.

(2) The cabs of over-the-road trucks, motor coaches, trains and construction equipment could be jacketed by water (somehow kept from freezing or boiling). The jacket need cover only that portion exposed to the sky.

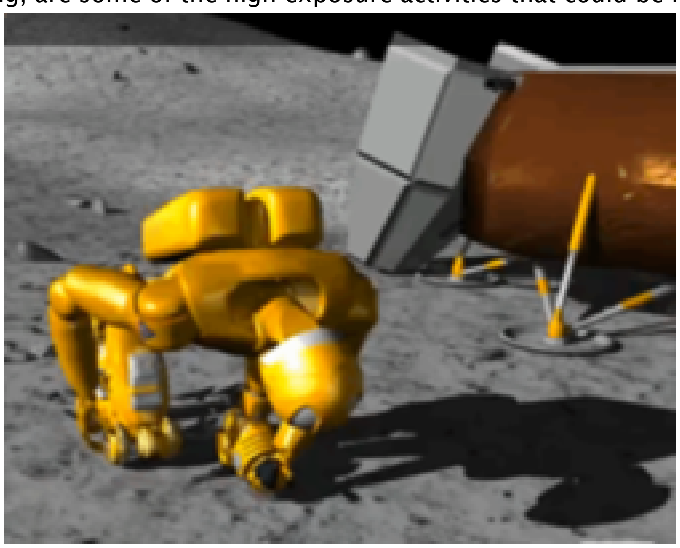
3) Outside jobs could be filled by rotation from among a large pool of persons, who would do safe "inside" work most of the time. This would not suit those who wish to be out on the surface regularly, but such types could work in jacketed conditions as described in (2) above.

At left, a concept for a protected railroad passenger wagon to be used by frequent travelers at a "first class" rate.

Infrequent travelers could safely make overland trips without such protection.



We might expect to see some out-vac duties preferentially entrusted to robots and telepresence-controlled robonauts that can be put to work "24/7" without fatigue, boredom, and errors, and some to be filled by humans on restricted shifts, but from within the safety of shielded mobile cabs. Routine prospecting, mining, extensive construction, and road-building, are some of the high exposure activities that could be managed this way.



NASA-JSC Project M robonaut: ideal for prospecting and field science controlled from a shielded mobile unit.

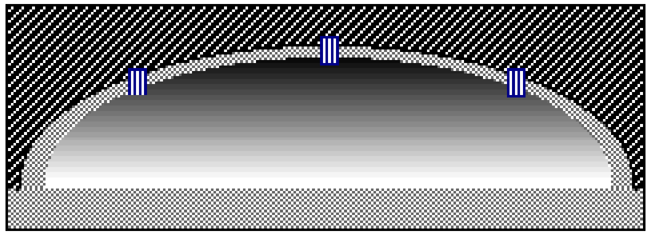
Thus a truck cab could be shielded even if there were no need to shield the cargo containers. How is this different from human workers guiding deep sea well-drllling from the safety and comfort of a pressurized submersible at depths at which human divers could not work? Clearly, those who say we can't work out of our element, have already been proven wrong again and again. Wherever there is something to be gained, we will find a way to conduct our business safely.

Those who rarely travel by train or coach could ride in unshielded units at a bargain price, while busnessmen who travel frequently could ride in shielded units at a first class rate. Common sense and a close watch of one's rem-exposure monitors, will allow most pioneers to enjoy an almost natural familiarity with the great lunar out-vac and with its magnificent desolation and spectacular sterile beauty.

Recreation and Sports

In this situation, out-vac leisure activities such as rock collecting, hiking, road rallies, camping out under the stars, and prospecting for the fun of it, would have to be exercised with caution and sparingly. We won't become "Lunans" until we are "at home" on the Moon, and that means "at home" out on the surface as well as in cozy urban burrows. Even so, the availability of a mobile shelter when not actually engaging in the out-vac surface activity in question would make for good policy.

As to sports, the out-vac provides not only one-sixth gravity, but also vacuum, and pioneers will invent interesting and fun sports for such conditions. But here too, there is a way out: pioneers could build a shielded but unpressurized stadium in which low-gravity vacuum sports could be played.



Cross-section of shielded but unpressurized sports arena

Are Demron-layer spacesuits be the answer?

Recently, there have been a flurry of reports that a new polymer fabric offers sufficient radiation protection. But Wikipedia introduces its article with the following warning:

"This article is written like an advertisement. Please help rewrite this article from a neutral point of view. For blatant advertising that would require a fundamental rewrite to become encyclopedic, use {{db-spam}} to mark for speedy deletion. (June 2009)"

"**Demron** is a radiation-blocking fabric made by Radiation Shield Technologies. The material is said to have radiation protection similar to lead shielding, while being lightweight and flexible. The composition of Demron is proprietary, but is described as a non-toxic polymer. According to its manufacturer, while Demron shields the wearer from radiation alone, it can be coupled with different protective materials to block chemical and biological threats as well. Demron is roughly three to four times more expensive than a conventional lead apron, but can be treated like a normal fabric for cleaning, storage and disposal. More recent uses for Demron include certified first responder Hazmat suits as well as tactical vests. Demron is proven by the United States Department of Energy to significantly reduce high energy alpha and beta radiation, and reduce low energy gamma radia-tion. When several sheets of Demron are laminated together the result is a much more powerful shield, though Demron cannot completely block all gamma radiation."

There is an enormous difference between the kind of radiation hazards found here on Earth such as exposure to radioactive wastes from nuclear power plants and exposure to high-energy cosmic rays coming from all directions of the space or the lunar sky.

In MMM #238 Sept 2010, pp. 4-5, "A Fresh Look at the Spacesuit Concept" ee suggested a two-garment approach: an inner "skinsuit" counterpressure suit, and a loose outer suit to handle thermal exposure and provide puncture proofing. Perhaps a Demron layer incorporated into such an outer suit would allow the wearer to stay out on the surface a longer time before accumulating "x" amount of radiation dosage. But Demron has not been tested in realistic space conditions in Earth-orbit much less beyond the Van Allen Belts. It may or may not help, but certainly won't be a cure-all.

A lesson some have not learned

At the 2010 International Space Development Conference held in Chicago last May, a speaker confident of what he was saying, crossed off Moon and Mars as future settlement territory on the grounds of surface radiation exposure "unless we wanted to live under-ground full-time." Nonsense. If there is one thing the history of the human Diaspora beyond Africa, and even within it, has amply demonstrated, it is that resourceful, ingenious, and determined people can learn to make themselves "at home" and comfortably so, in the most seemingly inhospitable environments. Settlers on Moon and Mars will defy the warnings of such persons, even as have the Eskimo and Inuit of our Arctic regions. "Where there is a will, there's a way. And we will find ways to survive in environments much more unforgiving and hostile than Moon and Mars.

On frontier after frontier, we have been faced with new climate conditions, new geological and mineral resources, new plant and animal species. Where old tools did not work, or work well, we forged new ones that did. True, some frontiers would not support large popula-tions. But everywhere, people have learned to live happy and productive and fulfilling lives.

Radiation will be a problem for those living and working on the Moon or Mars only until we have learned to deal with it "as if by second nature." Sure Arctic and Antarctic temperatures can kill! But who would go outdoors in those places without adequate clothing and protection!

Lunan pioneers will soon learn what they can and can't do in their challenging environments. More, they will continue to find new ways to push "this envelope" ever further and further, to the point few would see surface radiation as a game-stopper. Doing the right think, the safe thing, will have become second nature. The pioneers will have become Lunans. And the same transition will occur on Mars and other even more challenging locations.

Take anyone "as they are" off the streets of Mumbai or Cairo and set them down in Antarctica, and we have a problem. But someone from Edmonton or Irkutsk might fare better.

Unlike specialized animal species, humans cannot be defined by their habitat. We are adaptable, and neither the Moon nor Mars defines the limits of that adaptability. We will learn to handle the risks of the lunar surface "as if by second nature" under penalty of death, just as the Innuit have adapted to the Arctic. We will not be at home on the Moon until we do.

To coin a word, we are a **prokalotrophic** species: **we feed on challenges.** And those who warn us that we "can't" do this or can't do that, do us all a favor, by spurring us on to prove them quite wrong. And in that sense, science-fiction stories, which can get pretty wild, do us a service. They make us, even if only some of us, confident and determined to spread the human ecumene - the human ecosphere - beyond the four corners of Earth, beyond the seven continents and the seven seas, to wherever our ingenious heavenly chariots will take us.

The Moon, as a humanized world, will become more interesting and nourishing a life-environment because we have accepted radiation-protection as a challenge. The more formidable the challenge, the sweeter the victory! We would still be in the caves or swining from the trees if it were not so.

So thanks for the warning. "Bring it on!" **PK**

Cooking on the Moon

By Dave Dietzler

We don't have to rely entirely on space food sticks
and freeze dried meals from little foil pouches.

Most early industrial operations on the Moon will be primarily robotic, but it is likely that a small manned presence will be necessary to do jobs the robots can't, service and repair the robots and even rescue the robots that have gotten stuck. Physiochemical air and water production and purification systems will be used at first. Years, even decades, might elapse before a closed ecological life support system is established.

Food will be upported during the early years of bootstrapping development on the Moon and it is likely that most of this food will be freeze dried or dehydrated and mixed with recycled water to reduce upport costs. My opinion of freeze-dried backpacker food is that it isn't very good. Perhaps some men and women could be happy living off this kind of food for years, but not me. If we must feed the crews freeze dried meat I think it will be necessary to spice the stuff up real good and spices will not add a lot of costly upport mass to the project's budget. Freeze dried fruits and vegetables might use spicing also. My experience with the texture of these kinds of foods is that their quality is less than appetizing. Perhaps slow steaming will allow the freeze-dried foods to plump up. All I ever did was add water or immerse freeze dried foods, and that was long ago--an experience I never cared to repeat.

We don't have to rely entirely on space food sticks and freeze dried meals from little foil pouches. There are many dried foods in the supermarket that most of us consume regularly like pasta noodles such as spaghetti, elbow macaroni, lasagna, etc. The problem here is twofold: we will need sauce and freeze drying might not mean high quality. There are condensed sauces that aren't so bad, but we might also go straight for a small tomato garden.

Lighted cabinets for producing fresh salad greens have been demonstrated and I think those are a good idea from the start. Why not a tomato cabinet(s)? Moon dust can be sieved, steamed to form vermiculites and fertilized with upported plant food and later with hydrothermally treated and/or composted wastes to provide an excellent growth medium.

While we are talking about Italian food, why not a mushroom cabinet(s) as well? Mushrooms require preformed carbohydrate but no light. Since electrical power demands by night for crop illumination can mean some massive power storage systems, mushrooms become appealing. These high protein items in the hands of a really creative chef might become a staple on lunar dinner tables. Fresh salad greens, tomatoes and mush-rooms sound good, and we could even grow algae by day and stock up plenty for night as long as we save some for reinoculating the algae tanks when the Sun rises again.

Algae can double its mass every few hours, so producing large algae harvests won't take too much time--as long as we have the water, tankage and nutrients. However, I don't know if green slime is all that appealing although Miso soup isn't too bad. It might be possible to keep some breed of hen alive and healthy on a primarily algae and mushroom diet; in which case with a small chicken coop and a few hens we could have plenty of real fresh eggs for our small crew during the early stages of lunar industrialization and bootstrapping.

Other dried supermarket foods with which most of us are acquainted include instant coffee, drink mixes (Tang), Jello, powdered milk, dried beans, brown rice, whole wheat flour, corn meal, instant mashed potatoes, stuffing and dried gravy mixes. I like eating these. There are complete pancake and waffle mixes but without syrup and butter these are not very satisfying. There are also foods like oatmeal and cream of wheat, but once again without sweetener and cinnamon these aren't too great.

Quinoa is similar to cream of wheat and contains complete protein, but the flavor is not too rewardng, in my opinion. Perhaps we will just have to foot the bill for shipping syrup and butter to the Moon, unless we can produce genetically engineered algae strains that secrete syrup and honey!

But, for those who don't like margarine, what about butter? It will be a long time until goats or cows are kept on the Moon, or will it? There are **Nigerian dwarf goats** that give two quarts of milk a day. Adults weigh about 75 pounds. Within a couple of years of manned lunar base development we should be able to keep dwarf goats on the Moon. Since livestock can be 100% grass fed it seems livestock could also be 100% algae fed. Then we could have our butter as well as milk, cream and cheese. We will need kitchen countertop milk processors for butter and cream production and cheese molds. The first Moon miners won't just be technicians; they will have to be culinary hobbyists.

http://en.wikipedia.org/wiki/Nigerian_Dwarf_(goat)

There are also light weight calorie dense foods like peanut butter, soy jerky, hard salami, meat jerky, olive oil, cheeses like Cheddar at about 115 cal/oz. and Parmesan at 130 cal/oz., crackers, dense bread, dried fruit (that includes raisins), nuts (e.g. cashews, almonds) and chocolate; preferably dark chocolate. Cheese is very tempting. If we have salad greens, tomatoes and mushrooms some shredded cheddar would be fine for salads with olive oil dressing and we could even make small pizzas by baking these on dense breads. If we have pasta and tomatoes for sauce we'll need some Parmesan. Whole fat powdered milk will be desirable until goat milk production exists.

Whole grain cereals with dried fruit and nuts will be good for breakfast especially for those who don't care for cream of this and cream of that or other forms of warm glop.

At: http://www.adventurealan.com/sample_food_list.htm

we find an interesting no-cooking food list for back-packers consisting of: Cookies, Fig Newtons, Sunshine Raisin Biscuits, Peanut M&M's, Power Bars, Pemmican Bars, Fruity Gummy Candy, Gorp, Cashews, Mincemeat, Prunes, Dried Apricots, Dried Figs, Raisins, Dried Cranberries, Peanut Butter, Jelly, Hard Salami, Turkey Jerky, Gatorade, bulk (2.1/qt), Grape Nuts, Familia, Milkman Milk, Inst. Pudding. (needs 2c. milk), Chocolate Milk, Cheese, Crackers (triscuit, wheat thins, etc.) Dense Bread, Caffeine Pills, Vitamin C. This food list was designed for 5 days and 4 nights on the trail for one person and supplies over 3000 calories per day at an average of 123 cal/oz. and a total mass of 6.35 pounds. That would be about 460 lbs. of food per year for one Moon miner. For Moon miners getting less exercise than backpackers this could be reduced.

We must wonder if it will be cheaper to upport frozen foods along with refrigeration systems and power supplies, or canned and tinned foods? Some whole foods in addition to freeze-dried and dehydrated foods will be good for morale. I don't mind eating out of cans. Refrigerated foods can get freezer burned after awhile. I believe freezer burn can be prevented thru vacuum packing. Of course, canned food won't go bad if something happens to the refrigeration unit and I tend to favor reliability over risk, and since the loss of the food supply could halt the project at a cost of millions of dollars per day perhaps, the reliability of canned and tinned food over frozen food appeals to me.

Since whole canned food will be largely water some will say this is a "no-no," but somewhere along the line we have to stop being so damned efficient and allow a little fat in the budget for the sake of human pleasure! Based on this philosophy, a few bottles of real wine for the holidays at least should be rocketed to the Moon! Some beer making equipment and supplies might be included too. Executives receive enormous paychecks. Workers on the Moon could at least have some booze and some real steaks at company expense!

Eventually we will set up farm modules that produce a variety of foods for a tasty and nutritious diet that is primarily plant based. Except for hens, dwarf goats, fish tanks and as some have suggested- guinea pigs, I don't foresee large animals like cows or large herds of animals at least until we start sealing lava tubes that are hundreds of feet in diameter and miles long and eventually build domed cities[1] like those seen in science fiction art and movies. Even then, meat cultured in petri dishes might replace livestock. Edible chicken nuggets have already been produced this way and the future meat supply on Earth as well as in outer space might come from vats of cells in factories rather than from grazing herds and slaughter houses. DD

1 The Classic Sci-Fi Dome will be most unlikely on the Moon and Mars as it sets up a single point of failure that could doom everyone within. Risk must be distributed, not shared.

Articles on Food & Cooking from past MMMs

The following articles are preserved in the MMM Classics volumes which you can freely download from

www.moonsociety.org/publications/mmm_classics/

- Moon Garden, P. Kokh – MC#1 pp 3-4
- Animal Life, P. Kokh – MC#1 p 23
- Saving Money on Food in Space, P. Kokh – MC#4 pp 58-9
- Food Animals in Biological Life Support Systems, S. Love – MC#11 p 51
- The Independent Lunar Farmer, P. Kokh – MC#15 pp 25-26
- EARTHPATCH: Anchoring Lunar & Martian Homesteads, P. Kokh – MC#15 pp 40-44
- Homestead Gardens & Early Cottage Industry, P. Kokh – MC#15p 3-4
- Farming on the Moon, D. Dietzler – MC#16 pp 39-40
- (Lunar) Food is Mostly (Lunar) Water, P. Kokh & D. Dietzler – MC#17 p 56
- Beverages on the early Lunar & Martian Frontiers, P. Kokh – MC#18 p 63
- Cooking on the Moon, P. Kokh – MC#19 pp 44-45
- The first BBQ-Grill Restaurant on the Moon, P. Kokh – MC#20 pp 9-11

"What's for Dinner" may seem to be a trivial topic at first. But to most of us, when the day is done, and we are tired out and in need of serious regeneration, "what's for dinner?" trumps "what happened on the stock market today" anytime. And we also want to be assured that what's-for-dinner is flavorful, varied, and palate-pampering. Some pleasures are essential, after all!

This will be all the more true on the Lunar and Martian Frontiers for pioneers who have already given up many of the pleasures of life on Earth that can't easily be replicated on the Moon or Mars. Resourceful pioneers will produce a great variety of tasty dishes. **DD / PK**

O'Neill's High Frontier
Updated and Modified

By Dave Dietzler

Choosing the machines for the lunar industrial seed[1], designing them and building them will require years of careful consideration and a small army of engineers, but there is no fundamental scientific or philosophical reason that this cannot be done.

Introduction

It has been over thirty years since "**The High Frontier**[2]" was published and during that time most of the people I've discussed it with have agreed upon a modified version of things. In discussions and e-mails most of us have agreed that

The 100 million ton plus space colony is out of the picture and most SPS assembly work should be done in GEO with teleoperated robots.

O'Neill and others focused on the space colony and kind of slighted the Moon.

They figured the mining machines and mass driver would be launched from Earth with low cost Shuttle Derived Vehicles landed on the Moon in pieces and assembled by a crew of about 50 Moon miners3.

Raw regolith would be launched into space where it was processed into metals for construction, oxygen for rockets and excess raw regolith and slag that would be used for space colony radiation shielding as well as mass driver propelled space ship reaction mass. Regolith processing would be done at L5 construction shacks. These modular construction shacks would be launched from Earth, assembled in LEO and propelled with arc-jets to L5. The space colony would come next and 10,000 workers would be transported from Earth to do the work of SPS construction. Solar Power Satellites built at L5 would be moved down to GEO to sell power and start accruing profits.

The Moon plays a much more complex role in our vision. We will include tourism, astronomy and scientific research, SETI, asteroid mining, asteroid deflection and materials for ships to Mars and other destinations in the solar system. Moon mining will not be limited to simple open pit mining of regolith. Mining bases will be located on mare coasts where aluminum and calcium rich highland regolith as well as basaltic iron, magnesium and titanium rich mare regolith can be accessed.

There will be polar ice mining camps, KREEP mining in the Imbrium rim, mining of pyroclastic glass for native glass and elements that can be extracted from the surfaces of glass particles more easily than by extraction from complex minerals, and possibly even drilling for volcanic gases. Mining of vast areas of the mare for solar wind implanted volatiles including normal helium 4 and possibly helium 3 that are not likely to be found in polar ices of cometary origin - these all feature prominently in our vision.

Numerous mining bases will be linked by dirt roads and railways to mass driver sites and a circumlunar power grid will emerge for 24/7 power. All materials, or at least the 99.5%, needed for bootstrapping of lunar industry, creation of construction shacks and space tugs, and for SPSs will come from the Moon and possibly from the asteroids as well.

We are not certain about launching materials and finished products to L5. It might be possible to launch to L2 mass catchers and then haul cargos down to GEO or even launch directly to GEO. It might also be more plausible to launch to LLO (low lunar orbit) and collect the payloads, and then haul them down to GEO.

It is probable that L5 will not be very important and that construction shacks will all be located in GEO and that these will be mostly robotic.

While the nearly three second lag time that exists for teleoperation of robots on the Moon will hamper robotic operations on the Moon but not prohibit them entirely, the fraction of a second lag time for teleopera-tion of robots in GEO will not be a significant barrier to robotic construction in space.

Transportation System

Earlier it was thought that the space shuttle or a space shuttle-derived vehicle would launch cheap and that LH2/LOX fueled rockets would be used to propel cargoes from LEO to the Moon. Our view is quite a bit different. Launch costs are high, even with Falcon rockets that offer the lowest price to LEO at present.

- We propose the use of **electric drives** to move cargoes from LEO to an L1 space station economically. Propellant masses for electric drives will be only a fraction of the mass of the cargo. Chemically propelled rockets would require propellants that amass several times the cargo mass and subsequently the cost of launching this extra mass to LEO would be several times higher than with electric drives.
- At **the L1 station** space storable water from lunar polar ice would be converted to LH2 and LOX for landers. The first payloads would consist of solar panels, digging machines, regolith refining equipment and fueling systems for aluminum and liquid oxygen powered reusable landers.
- **Lunar fuels** must come on-line early to eliminate the cost of launching propellants for landers from Earth's surface to LEO.

Bootstrapping and ISRU [In Situ (Latin for "on site") Resource Utilization]

We will not ship a complete mining system to the Moon and then focus on space construction. To reduce upported[4] mass and costs, we will land an industrial seed that will include manned habitat to bootstrap up industry on the Moon.

We will start out with small mining machines and build bigger ones. We will even build the mass driver or drivers on the Moon. We will mine at **multiple sites** (poles, mare coast, pyroclastic glass fields, KREEP terrains, crater central peaks, lava tubes, perhaps even drilling near volcanic domes) to get all necessary materials and link the mining sites with railroads to the mass driver sites.

Several years, perhaps decades, of work will be needed to build up industry on the Moon to the point at which SPS construction can begin. Long-term bonds will have to be sold to finance this project along with support from international governments.

The bootstrapping and ISRU concept will be applied to the SPS construction shacks too. We will launch the "bare bones" for these stations from Earth and enlarge them with metals and finished products from the Moon until we have the space infrastructure needed to build SPS. The construction shacks will be located in GEO. Lunar mass drivers will launch materials into space and mass catchers will haul those materials to GEO instead of L5. The GEO construction shacks will house only enough humans to supervise the robots that are teleoperated by Earthside crews with only a fraction of a second lag time for radio waves to travel from Earth to GEO and back.

More Brains Equals Less Payload and Lower Costs

The construction of lunar industry and SPSs will require a lot of planning and intelligence to figure out just how to do; But physically, it will involve no more time, energy, robot labor and manpower than building a giant space colony for 10,000 people would!! Why build that space colony when we need more infrastructure on the Moon and 90% + work in space can be done with teleoperated robots and ground crews around the world connected by the internet???

We need more than just a single strip mine in the mare. While the **mare** can supply plenty of iron, titanium, magnesium, silicon and oxygen and lesser amounts of aluminum and calcium, the **highlands** can supply more vital aluminum and even cement produced by roasting highland soil in solar furnaces. There are highland areas where the regolith is 98% anorthite and this would be ideal feedstock for aluminum, calcium, silicon and oxygen production.

Calcium might become the conductor of choice since it is a better conductor than copper and highland soil is richer in this metal than mare soil. Calcium metallurgy and manufacturing for out-vac cables and perhaps even mass driver coils must be developed. So the coasts become attractive.

There might even be blasting into hard rock with magnesium/LOX-based explosives if we find rock out-crops rich with industrial metals. The Imbrium coast is attractive because it contains lots of KREEP that can supply rare earth elements, potassium, phosphorus, thorium and uranium.

The Aristarchus pyroclastic glass fields that could supply nickel, copper, zinc, gallium, chlorine and other elements and the Marius Hills beneath which there might be chambers of volcanic gas evoke curiosity. Crater central peaks have never been sampled. Could they contain heavier elements thrust up from the mantle?

I have speculated that since chromite is found in mare regolith, and this heavy mineral sinks in lava to form thin layers like those of the Bushveld igneous complex in South Africa, there might be layers of chromite deep beneath the mare that have been thrust up in some crater central peaks. If so, this would be quite a find, since chromite is a source of the vital industrial metal chromium.

The best mining sites and the best mass driver sites might not match so it will be necessary to build **a system of roads and railways** to link them. While it has been stated that mineral processing would be best done in space where solar energy is constantly available, a system of cables and solar power plants at the limbs of the Moon could supply energy to mining and mass driver bases constantly and when we are looking at things on this scale it should not be impractical to build a lunar power grid. It's also possible that a lunar power beaming system might prove to be superior to GEO powersats. The major obstacle here is not the construction of vast solar power farms at the limbs of the Moon for LPS but the construction of transmitting dishes miles in diameter. Perhaps large farms of small phased array dishes could do the job of transmitting microwaves 240,000 miles to reasonably sized rectennas on Earth but I am no expert when it comes to this so I might be way off target.

Choosing the machines for the lunar industrial seed, designing them and building them will require years of careful consideration and a small army of engineers, but there is no fundamental scientific or philosophical reason that this cannot be done. Three dimensional printers guided by computers that can crank out parts made of basalt, glass and metals could be at the heart of the bootstrapping lunar industrial seed. Robots will be key to assembly work.

Metal casting seems likely, but we will rely on cold working like forging and extruding as much as is possible. A manned presence will also be essential. Skilled human workers are the ultimate multipurpose robots. Humans might need biological sustenance, rest and recreation, but we are very versatile. Robots tend to be better and rapid repetitive jobs where high accuracy and reliability are required. **DD**

Footnotes & comments by editor:

1 **The (Lunar) Industrial Seed**:

"Defining the Lunar Industrial Seed", Part 1, D. Dietzler, MMM #229 October 2009
"The Lunar Industrial Seed", Parts 2, 3A, D.Dietzler, MMM #230, November 2010
Note: these issues of MMM are only available by member username and password from
http://www.moonsociety.org/members/mmm/

However much of this material is also available from
http://groups.google.com/group/international-lunar-resarch-park?pli=1

Also check out these Google Dox files
https://docs.google.com/document/edit?id=1n3OXV0zYqfMCNCjj4Znaqf3lVw8s_0u7ChuGwMXKDzQ&hl=en#

2 **The High Frontier** by Gerard O'Neill,
an Apogee Books Publication: "In the mid-1970's the late physics Professor Gerard K. O'Neill published his book High Frontier. In it he laid out a possible road map for human settlement."
http://www.apogeespacebooks.com/Books/Highfrontier.html

3 O'Neill branded people who preferred living on a natural world to living inside constructed space settlements as "planetary chauvinists." He firmly believed that as few people as possible should be stationed on the godawful Moon, and then in short tours of duty only. To this day he has a strong following. For our critique of his space settlement concepts see: "Reinventing Space Oases"
http://www.moonsociety.org/publications/mmm_papers/reinv_so.htm

4 "**upport**, upported, upports" - shipping "up" Earth's steep gravity well. (and thus, "downports" as well **DD**

The new Space Age Era of Human-Robonaut Synergy

By Peter Kokh

Robotics has come a long way in the past six years! And the promise is becoming real. Robotic assistants can relieve humans of tasks that are dangerous, boring, tiring, repetitious, etc. And they do not need life support, rest, entertainment, or socializing. They will not only pave the way for humans, but work side-by-side with humans after crews arrive, with future settlers also.

Whether the word "robonaut" sticks, or becomes replaced with the earlier "'droids" (short for androids) is immaterial. The evolution of humans and robots working together is now well underway. Robotic assistants can take care of chores that are boring, tedious, repetitious, and/or dangerous. They do not need food, rest, sports, relaxation, or entertainment. They do not require life-support in transit or on the job. They do not produce wastes that need to be treated and recycled.

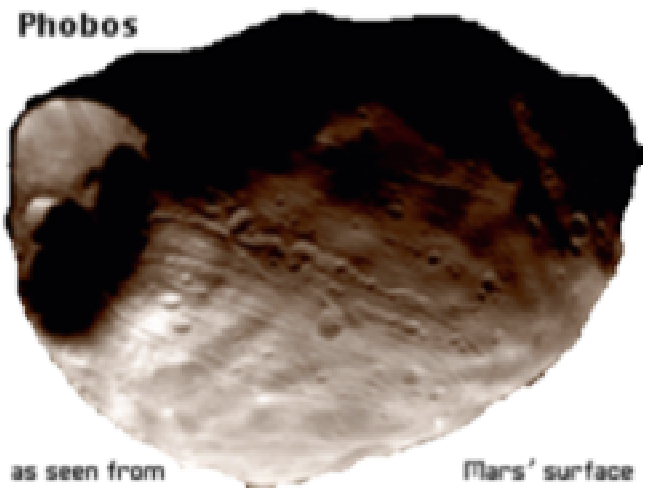
As for **R2, now aboard ISS**, the coming year will see it undergoing tests to make sure the trip to the space station caused it no trouble. Astronauts aboard the station will have a chance to get used to R2 and learn to work with it/him. In time, both will become comfortable working together. We need to get to the point where we can trust robonauts as reliable helpmates. No one can predict how long that will take, as adjustments in the robonaut's capacities and abilities may be needed. In the real world, needs emerge which might not have been foreseen.

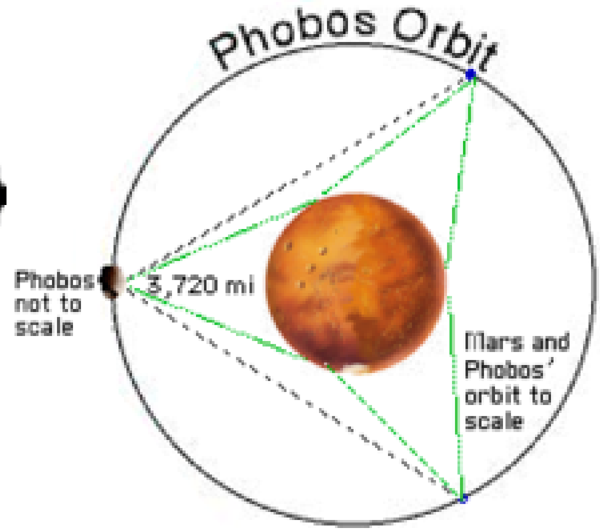
One big challenge for NASA engineers has been to retrofit all of the robot's electronics to withstand radiation in space. They also worked to make Robonaut 2 as "smart" as possible. R2 has some 38 Power PC procesors, including 36 embedded ones. The embedded chips are running in the machine's joints: its hands, shoulders, waist, elbows, neck and five large joints in each arm.

NASA also plans on periodically upgrading R2, it will be attached to a pedestal on the space station and it will work in place. By year's end, one or two legs may be installed to allow R2 to move around the station. A single leg could be easily attached to the robotic arm outside the space station so it can assist astronauts during spacewalks. In time, R2 could relieve astronauts of EVA assignments. Unlike humans, robonauts will not have to go through time-consuming pre-breathing steps. EVAs are risky and tiring.

We can expect to see robonauts fully integrated into ISS crews, becoming comfortable and reliable as partners, with a significant increase in overall mission productivity. Meanwhile, we will probably see robonauts become common in upper income households (as in the Jetsons cartoon series.) The "humans vs. robots" debate will become a curiosity of history. Both sides will have won, and the future of space activities will unfold more quickly and at less expense.

Some science fiction scenarios foresee humans in danger of replacement. Some see "Borg-like" transformations of humans. We see robonauts becoming faithful and enabling companions to humans, a path that dogs have been down long ago. Robonauts will hasten and deepen the pioneer settlement of space frontiers. Science-fiction stories that do not include this partnership will become dated. We have lived to see the day when this brighter, more promising future was introduced! **PK**





The Most Economic Way to Open Mars: Construction Equipment and Robonauts, Telepresence-operated in near real-time from Phobos directly, and via co-orbital relays

By Peter Kokh

In the previous issue of MMM, #242, we talked about how pre-human missions to the Moon, bringing teleoperable equipment and telepresence-operated "robonauts" could speed up realization of a first human outpost, and do so at greatly reduced expense. Human crews would arrive ready to do what they came to do. All the site preparation and construction chores would be done beforehand by robotic predecessors who do not tire, do not get bored, do not need rest or relaxation, do not need life-support, etc. And now, with the arrival of Robonaut 2 or "R2" at the International Space Station, to join the crew, the new Space Age 2.0 of human-robonaut synergy is upon us. This is an historic moment!

If robonauts can speed up the realization of a Mars outpost and get it ready for the first humans, at a similar savings, then we must rewrite our Manned Mars Mission scenarios accordingly. **But there is a significant difference between where we are at on the Moon and where we are at on Mars.** Our orbital mineralogical exploration of the Moon is much more advanced. But more to the point, rovers on the Moon can be teleoperated from Earth in near real-time. On Mars, which varies from 35 to 400 times as far from Earth as the Moon, time delays are measured not in single digit seconds but in minutes: from 6 minimum to 40 maximum, as Mars distance from Earth varies greatly. What has taken 7 years for **Opportunity** and **Spirit** to do on Mars, would have taken perhaps a month to accomplish on the Moon.

If we are going to really explore Mars – so that we know better where the resources are and where best to set up shop – a **Forward Teleoperations Base in orbit around Mars is absolutely necessary**. And not just anywhere in Mars orbit, on Phobos!

Why an Outpost on Phobos?

Wouldn't a small "Space Station" in some other orbit around Mars do just as well? Back around Earth, ISS gets significant shielding from cosmic radiation and solar flares from the Van Allen Belts. Mars lacks a magneto-sphere and hence lacks similar belts. Astronauts in a Mars orbit space station would be much more exposed.

An outpost "on" the surface of Phobos would be less exposed (to just one half of the celestial sky). But, given Phobos' mini-gravity, its "regolith" dust blanket has been much less compacted than that of the much more massive and significantly larger Moon. It should be relatively easy to pile up a blanket of protective Phobos dust powder over the modules of any complex.

From Phobos a bit less than half of Mars is visible at any time, but a pair of unmanned relay satellites in Phobos orbit 120° ahead and behind Phobos respectively, would allow teleoperation of probes, rovers, and robonauts anywhere on Mars surface except at either pole.

The time delays involved are minimal, and even if relayed, would be much less than the time delay between an Earth-Moon L1 station and the Moon's surface. In fact, the perceived delay would be much less than that of global telecasts on Earth via Geosynchronous orbit. The near "real-time" control of rovers, construction equipment and telepresence-roboanauts would allow extensive global operations on Mars. In contrast, a manned outpost on Mars would (without satellite relays) be confined in its reach of operations to a very local area.

http://en.wikipedia.org/wiki/Phobos_(moon))

Phobos is 7.24 times as massive as Deimos. It is named after the Greek god Phobos ("fear"), a son of Ares (Mars). Phobos orbits about 9,377 km = 5,827 mi from the center of Mars, 3,719.5 miles above Mars' surface, closer to its primary than any other known planetary moon. Its orbital period is 7h 39.2m. It orbits so close to the planet that it moves around Mars [more than three times] faster than Mars itself rotates. As a result, from the surface of Mars it appears to rise in the west, move rapidly across the sky (in 4 h 15 min or less) and set in the east.

[Because is orbits so close to the surface, at moonrise and moonset, from on the surface of Mars, one would peer a bit around one side of Phobos, then the other.]

Clearly, a manned outpost on Phobos would immensely speed up global exploration of Mars, as well as pre-human-arrival site-preparation and construction of a first and any additional outposts so that when the first pioneers do arrive, they can get down to the real business of establishing a viable and enduring frontier presence. MMM

Only 'Going to Mars To Stay' Makes Sense

By Peter Kokh

"Marstostay does not segue from Marsandback. Marstostay must be pursued instead of Marsandback."

It is only to be expected that that people, even seasoned space advocates, would imagine "the first" manned mission to Mars to be a "souped-up version" of the first manned Moon-landing mission. But there is one critical difference. No matter how we do it, a "first" manned Mars mission will be an order of magnitude more expensive, even in 1969 dollars. In fact, the cost may be larger than the entire set of 6 manned Moon landing missions; and throw in the 2 non-landing missions, Apollo 8 (flyby) and Apollo 10 Snoopy (descent to within ten miles of the surface.

Humans are notorious for not learning the lessons of history. The Apollo program came to a not so glorious "Flags & Footprints" conclusion after the 6th successful landing. The lesson is that any expectation that there would ever be a 2nd Manned Mars landing, let alone an endless succession of landings, is an exercise in fairytale daydreaming. The odds are that the "been there, done that" shallowism of Aldrin and Obama will set in immediately after the first mission, or before work on a 2nd mission gets too far. "Flags & Footprints II "- this time on Mars, will be all the history books have to relate.

Unless ...

- **Unless** we pre-land equipment to produce (and keep producing) a nest egg of fuels, plastics, and other supplies from Mars' atmosphere before the first crew arrives
- **Unless**, we pre-prepare the landing site, and pre-construct a modular outpost **not confined to the landing crew compartment** as the FMARS and MDRS Mars Society analog research stations presuppose. That complex should be livable long term, not something a crew can tolerate for a limited time.
- **Unless** we preland a greenhouse operation that has vegetables and salad stuffs ready to harvest when the first crew arrives
- **Unless** we design the first mission to leave crew members behind
- **Unless** the return crew capsule is large enough to return home with only a fraction of the crew
- **Unless** all crew members who volunteer for the mission are prepared to stay, free of personal and other ties to Earth, with the mindset of our forefather pioneers on the Mayflower

Past MMM Articles on "Mars to Stay"

Download from http://www.moonsociety.org/publications/mmm_themes/mmmt_Mars.pdf

A stay behind scenario

If no one stays behind on Mars from the "first" manned mission, there is a strong possibility that there won't be a follow-on mission, and if there is, the chances of no further follow-up increase each time. Witness Apollo. Those watching the public purse will cry "enough already" louder and louder each time. There is only one way to make a commitment, and that is for at least some of each crew, starting with the first, to stay behind.

Then, between departures and fresh arrivals, In order to accommodate fresh incoming crews, the outpost will have to grow and grow and keep growing. Again, per the previous article, equipment and robonauts operated from a forward base on Phobos would handle much of the expansion work, while remaining crew members handle things only humans can do.

Inflationary Expansion

The larger the percentage of crew members of each successive crew who stay behind, the faster the permanent population will grow. Here is the population growth chart for 5 incoming crews of 12 (over 11 years):

If half of each crew go home each trip

1st crew: 12 arrive (6 return) perm pop 6
2. 12 arrive (6 return) perm pop 12
3. 12 arrive (6 return) perm pop 18
4. 12 arrive (6 return) perm pop 24
5th crew: 12 arrive (6 return) perm pop **30**

If only a quarter go home, then

1st crew: 12 arrive (3 return) perm pop 9
2. 12 arrive (3 return) perm pop 18
3. 12 arrive (3 return) perm pop 27
4. 12 arrive (3 return) perm pop 36
5th crew: 12 arrive (3 return) perm pop **45**

If more ships arrived each window, growth would be exponential. So if only a quarter return each time:

1st mission: 12 arrive (3 return) perm pop 9
2. 24 arrive 8 return) perm pop 25
3. 36 arrive 12 return) perm pop 49
4. 48 arrive 16 return) perm pop 81
5th mission: 60 arrive (20 return) perm pop **121**

Not counting children born on Mars! – Plymouth, MA was settled in 1620 by 101 pilgrims on the Mayflower

Recommendations

- Pioneers with an increasing genetic
- New recruits have an increasing diversity of occupational talents, educational backgrounds, and aptitudes.
- The physical complex of the outpost-becoming-settlement grows to support development of indigenous arts & crafts, sports and recreational activities

The Right Mix - Men and women, single, unengaged, without dependents, and with diverse talents

Perks for those committing to staying

- Security benefits for anyone left behind on Earth
- Weight and volume import allowance on next flight for personal items (furnishings, hobby supplies, etc)
- Pick of better quarters, furnishings, hobby supplies

This plan prioritizes build-up of recreational, hobby, and other facilities, continued diversification of food, entertainment options, personal vehicles on Mars, getaway retreats and changes of scenery options, etc.

Outlying Outposts are needed

A settlement effort must be broad-based, access different resources, provide cultural, architectural and horticultural diversity, for insurance against catastrophes, and to begin appropriating the planet at large.

If you think this scheme is unworkable or outra-geous, don't volunteer! Consider the siren call Ernest Shackleton placed in the London Times in 1905:

> **MEN WANTED FOR HAZARDOUS JOURNEY**
> Small wages, bitter cold, long months of complete darkness, safe return doubtful.
> Honor and recognition in case of success."—Ernest Shackleton

Five thousand eager men answered that ad! Are those with such "right stuff" a vanishing breed? Has our society become so risk averse that no one will answer a no-punches-pulled call to pioneer the frontier? We think not. Forget the Earth-lullabied majority. Blessed are "the second best" – those of us who are restless despite everything life in these times can offer us, who sense we don't quite fit in, who yearn for a chance to start fresh, those of us willing to make space a place. That is the history of human expansion, first within Africa, then "out of Africa." As always, pioneering is the work of those who accept the considerable risks, the large chance of failure, and the hardships sure to come. – There will be plenty of volunteers, even after vigorous vetting.

“Mars to Stay” gains support

Robert Zubrins’s “Mars Direct” steers clear on this issue, but his rhetoric and passion make it clear, that establishing a new frontier, not mere exploration of an intriguing planet, is the passionate dream that drives him. His novel, First Landing, makes that clear. A woman astronaut discoveries that she is pregnant and refuses to return home; then the astronaut involved, owns up to his responsibility and insists on staying behind with her.

That said, Zubrin has not adjusted his “Mars Direct” scheme to provide for the possibility that some crew members may make such a decision. To get to Mars in the first place, requires support from those too timid to wrap their minds around such options.

Type “Mars to Stay” in your Google search box

72,500,000! MTS advocates are a minority, yes, but are becoming ever less shy about their conviction. And we need to return to the Moon in the same fashion, with the same preparation, and with the same determination.

Now government space agencies, which must proceed with the approval of the majority who will surely ridicule such ideas, will not plan for such scenarios. That is why any outpost plans which freeze out corporations and the private sector must necessarily fail. Constellation was such a sterile program, and “sterile” is the apt word. We need a program for both Moon and Mars, that in its design is “pregnant’ with open-ended possibilities and preparations. Space is for the bold, not the timid! **PK**


Schackleton's Crew

ACCESS TO MARS:
A Fully Re-usable Mars Ferry – Logistics and Transport for Crew and Cargo

John K. Strickland, Jr. (jkstrick@io.com) 2-28-2011

Engineering analysis and support by

Engineer Raghavan Gopalaswami, Hyderabad, India

This article is a **preview** of a fully detailed presentation and paper for the 2011 ISDC in Huntsville. It will focus on the Mars Ferries themselves. These ideas originated about 20 years ago during the NASA Outreach 1990 and after the advent of Mars Direct. Since 2005, the full extent of the Mars EDL (Entry, Descent and Landing) problem has become very apparent. Much of the credit for the work to identify and focus attention on it must go to Dr. Robert Braun and his colleagues at Georgia Tech. Dr. Braun is now Chief Technologist for NASA.

Human Mars Exploration Concepts

When Robert Zubrin’s Mars Direct concept burst on to the scene over 20 years ago, it was clear he had made a very major advance in thinking about Mars Missions, with the concepts of using local materials like CO_2 to produce propellant and pre-positioning of equipment for redundancy. Zubrin intended his concept to be used for permanent occupation of Mars. However, his original design maintained no active operational base in Mars orbit and is based on all-expendable launchers and vehicles, which virtually forces any human Mars program based on them to be an unsustainable flags and footprints type program as conducted by a government, no matter the sincere intent of the designer.

Rationale for a Low Mars Orbit (LMO) Base to support Mars surface base Logistics

A space-faring civilization needs to be able to operate both on planetary surfaces and in orbit for maximum effectiveness, such as increasing payloads to Mars per ton delivered from Earth. The Ferry concept assumes the creation of a LMO Base to support the crew and continuing orbit to surface base logistics operations. It would also maintain a redundant cryogenic propellant supply in the LMO Depot for the departure from Mars orbit to Earth. A special transit vehicle would carry each Depot from Earth Orbit to LMO while full of propellants, using aerocapture and an orbit trim maneuver. The Depot allows the continuing storage of cryogenic propellants in LMO without loss to boil-off using a combination of sun-shields, super-insulation, and active cryo-coolers.

Why We Cannot Land Humans on Mars Right Now

Right now, in 2011, we **cannot** land anything larger than the ~1 ton Mars Science Laboratory rover on the surface of Mars. This is called the Mars **EDL** problem (**E**ntry, **D**escent and **L**anding). **No** combination of avail-able parachutes, re-entry shields and terminal descent rockets can land even a 10 ton payload on Mars. This problem first got serious attention in 2005, so the field is only about 5 years old. Things decelerate differently in a thin atmosphere. (On the Moon, we just decelerated and landed with pure rocket power since there was **no** atmosphere). Earth's dense atmosphere slows re-entering spacecraft to about Mach 1 at about 25 miles high. The atmosphere density of Mars at the surface is like that of Earth at 36 miles up. It slows objects from orbital velocity to about **local** Mach 5 – assumed to be about 543 mph). Below that speed, it is too thin to continue to slow a spacecraft enough all by itself. You could use expendable parachutes, ballutes or hypercones to slow down, but the object here is to produce a fully re-usable vehicle.

It is really hard to slow down after entry, since we would be about to hit the surface at supersonic speed. We are glad that Mars has an atmosphere, but if Mars had no atmosphere, it would be easy to land on; it just would take a lot more fuel. With an atmosphere, the descent engines probably cannot fire during the peak period of re-entry. However, they may be able to fire during or at the end of re-entry (starting at about 3200 mph or about local Mach 6.)

Supersonic Retro Propulsion (SRP) requires rocket engine thrust firing directly through the heat shield and against the supersonic flow of air pressing against the base of the vehicle as it decelerates. The rocket engines must be fixed in position with the nozzle ends flush with and sealed to the heat shield and thus they cannot gimble for steering. Instead this is done by varying the thrust of individual engines or by using small side-mounted vernier engines. SRP appears to be crucial to future access to Mars. No rocket vehicle has ever flown backwards at high speed in the same direction as its thrust. SRP's viability could be proven with a few inexpensive sub-orbital tests.

Think Re-Usable: The Case for Re-usable Mars Ferries

The debate over re-usable launch vehicles has been going on for decades while the debate over re-usable spacecraft or IN-space vehicles is just starting. Current scenarios for Manned Lunar or Mars landings envision a large lander which has, inside it (Mars) or on top of it (Moon), another **entire** vehicle for the ascent with its own engines, tanks, controls, structure, etc. I call this a Matryoshka-style architecture, after the traditional sets of Russian Nested Dolls, (Matryoshka) which are a metaphor for an object with another similar object inside.

Thus every new trip to the surface requires an entire additional pair of vehicles with all of the descent propellant, all of which has to be brought from Earth. It wastes all of the perfectly good descent equipment, leaving the crew dependent on the ascent vehicle. This exposes them to a loss of crew risk caused by a single vehicle failure, since there is no practical escape system, especially during ascent. Apollo astronauts were exposed to this risk on liftoff from the lunar surface 6 times. This architecture leads to the extremely marginal "one-way" Mars trips currently being proposed by some of those desperate to see any kind of Manned Mars Mission occur during their lifetime.

With a **fully re-usable vehicle,** nothing is thrown away. The descent engines, fuel tanks, and vehicle structure can also be used for the ascent**.** Fewer ferries would need to be built and shipped from Earth to Low Mars Orbit. . It increases reliability & safety after the **first** use of each vehicle (which is the riskiest use). Having the vehicles after the first use provides additional backup vehicles for rescue. It allows replacement of failed internal equipment modules (which would all be designed for rapid swapping) from older (retired) vehicles. It does require an integral (to the vehicle) aero-shell for re-entry, since the entire exterior of the vehicle would be exposed to some entry heating during descent. Cargo items would be inside the ferry, fully protected from entry.

New information about Mars affects the ferry design

20 years ago, we had no knowledge of the wide-spread existence of water on Mars in the form of relatively pure sub-surface ice deposits and ice regolith, some fairly close to the equator. Mars Direct (1989) and related concepts assumed we would bring hydrogen to make methane fuel from all the way from Earth. Now we know that hydrogen can be obtained from Mars ice in large enough quantities to use as a fuel directly.

Producing liquid oxygen and hydrogen propellants at a Mars surface base would **not** be an exotic zero-gravity technology that still needs to be developed. Since we will have the ability to maintain the cryogenic (LOX-H2) propellant supplies both in orbit and on the surface, we should use them, due to the huge advantage they give in allowing a surplus of Mars-derived propellant to be delivered to and used in orbit.

The SSTOAB Fully Re-Useable Mars Ferry - Transport and Logistics System

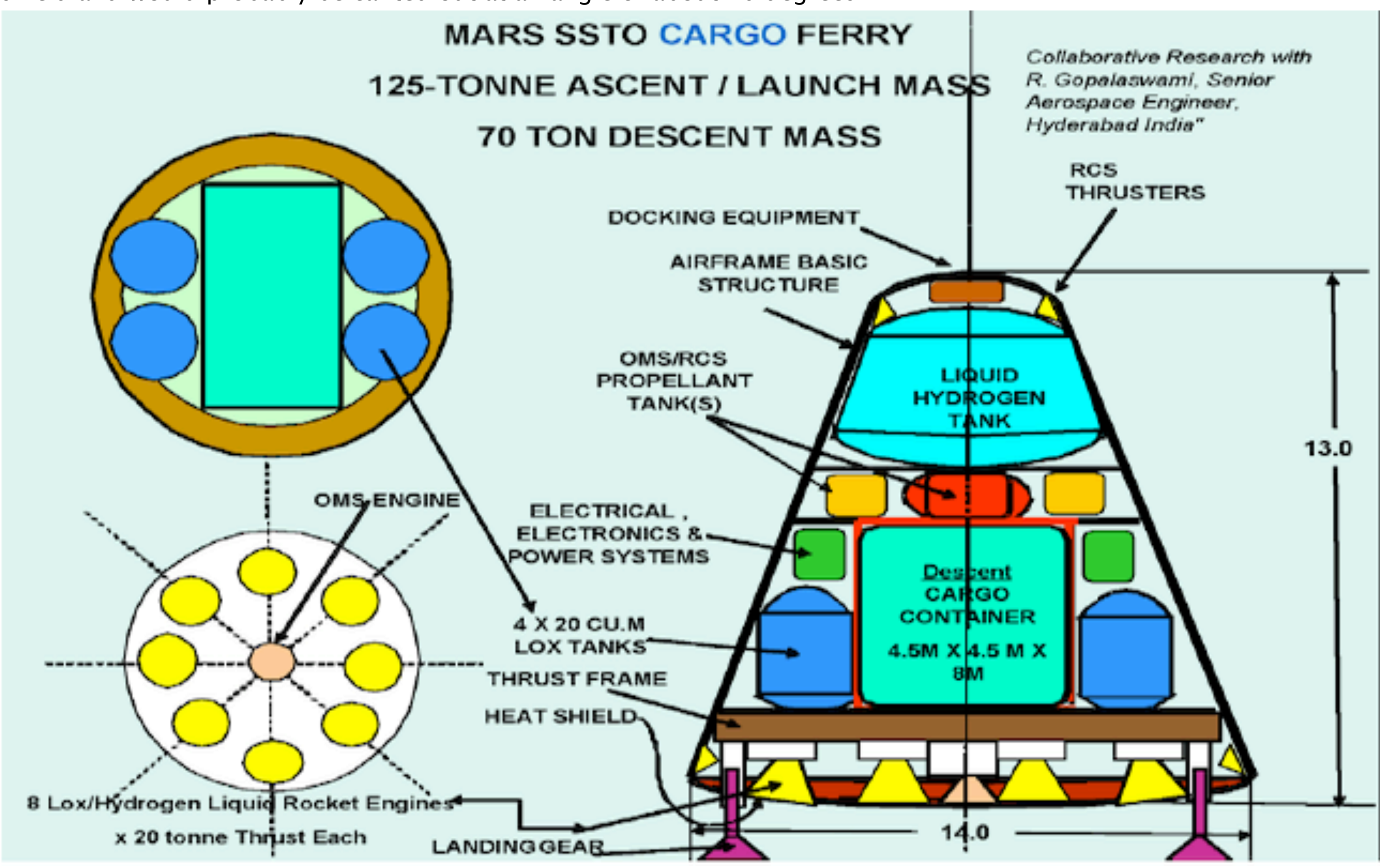
The Mars Ferry is essentially a Single Stage to Orbit And Back (SSTOAB) vehicle for Mars. Mars has about 1/10th of Earth's mass, and is about 8 times the lunar mass. Mars gravity is 38% of Earth's, so achieving low orbit is much easier than on Earth – about 2.1 miles per second (4.1 km/sec) instead of over 5 miles per second. This means reaching LMO it takes only about ¼ of the energy needed to reach LEO. (On Earth, an SSTO can barely reach orbit even with zero payload). If there is no staging, then there is no first stage to recover – the entire vehicle goes to the orbital "base" and back to the surface base – intact. Much less fuel is needed to land than to return to orbit since re-entry sheds up to about 2.4 km/sec of speed (out of the initial 3.36 km velocity).

What would the Ferry look like? Since the air on the surface is so thin, air resistance and "Max Q" (maximum dynamic pressure) on ascent are not significant issues. This means we do not need to make the vehicle narrow like the pencil-shaped boosters used on Earth. During descent, propellant tanks would be only 16% full, reducing vehicle density. Wide base vehicles with more cross section exposed to friction, and with lower density slow down more during re-entry, and thus need less propellant to land than a narrow base vehicle. During entry, a conical, capsule like shape is known to be stable, and would require less internal structure and less external shell surface than a long, narrow vehicle. The current design has the ferry shaped somewhat like a giant Apollo capsule, slightly taller (18 meters) than wide (14) meters if the crew capsule is included. It would have a cargo hold capable of carrying a 25 ton payload to the surface. The hold is a horizontal box-shaped area which would be located just above the engine compartment and extending through the middle of the vehicle to accommodate cargo or containers about 4.5 by 4.5 by 8 meters long.

Two types of fully reusable Ferry vehicles are proposed: a Cargo Ferry and a Crew Ferry. They would be identical, except that the Crew ferry would carry a 5 ton combination crew cabin and escape capsule for abort to surface or abort to orbit self-rescue during in-flight emergencies, so it can only carry 20 tons of cargo down. The crew would never be exposed to a single failure leading to a fatal crash. In case of a vehicle failure or loss of control in flight, the crew cabin would separate from the ferry and the crew would descend to the surface or return to orbit under power This capability could be used during both descents and ascents.

Payload to orbit for both vehicles is 20 tons, including the crew capsule for the crew version. The cargo hold for both versions would normally be empty during ascent. A ferry can carry either 15 or 20 tons of LOX-Hydrogen back into to orbit for use on the next trip down, because there is little or no cargo other than propellant to go up. Rock samples for return to Earth would amount to a few hundred pounds at most. About 5 tons of extra propellant would be loaded into the orbiting Depot for use by other vehicles by the cargo ferry only. Each vehicle would be retired after about 10 flights depending on engineering calculations of overall system reliability compared to safety on the very first flight.

The Ferry's main rocket engines would be mounted in a unique way: fixed in position, not gimbled. The nozzles would be flush with the base heat shield and integrally attached to it, to prevent entry of hot air flow and rocket exhaust gases into ferry's interior. Steering would be done by varying the thrust of individual engines. With 8 main engines, there would still be three pairs left to power and steer the vehicle, in the case of a single engine failure providing an engine-out capability. The engines would be mounted in a ring close to the outer rim of the base heat shield and would probably be canted out at an angle of about 20 degrees.



Approximate Mass Mars Cargo Ferry Configuration

(The **Crew** Ferry carries a 5 ton crew capsule and thus carries only 20 tons of payload Down and 15 tons of propellant Up)

Rounded Values in Metric Tons

CONFIGURATION	DESCENT		ASCENT	
Component	Mass	%	Mass	%
Payload -	**25 tons**	**36**	**20**	**16**
Structure	**30 tons**	**43**	**30**	**24**
Fuel	**15 tons**	**21**	**75**	**60**
TOTAL:	**70 tons**	**100%**	**125 t**	**100%**

A trip to the surface would start with a loaded ferry with 15 tons of propellants in the 400 mile LMO. It would perform a small de-orbit burn about 180 degrees around Mars from the surface base site. The resulting elliptical Hohmann transfer orbit would intersect the atmosphere and have an “aim point” (deliberately inside the atmosphere) of about 60 km or less, depending on the exact trajectory design. The following table shows the descent sequence. NOTE the difference between absolute and relative (to the surface) velocities! [see table p. 8]

After landing and unloading its cargo at a fully operational base, a Ferry would be re-fueled with 75 tons of LOX and LH2, along with 15 or 20 more tons of fuel as payload and begin its ascent back into Low Mars Orbit at 400 km high. This requires a delta-V of 4.2 km/second with a circular orbital speed reached of 3.36 km/second using an ascent mass ratio of 2.52.

Entry Descent & Landing Sequence
(DETAILED DECELERATION BUDGET FOR EDL)

Descent Delta-V Requirements met with mass ratio 1.39

NOTE the difference between absolute and relative (to the surface) velocities!

Velocities at each stage of EDL	Delta-V Remain.	Velocity
Starting V. 400 mi circular orbit (**absolute**)		360 m/s
ΔV de-orbit burn fr Low Mars Orbit –	**82** m/sec	3282 m/s
Approx entry V. at **118** km (absolute)+	260 (gravity)	3542 m/s
Subtract Mars rotational velocity (**not** ΔV) –		240 m/s
Relative Vel. to shed to Mars surface at Entry - Total		3302 m/s
ApproxImate Total Velocity shed from passive entry drag	2406 m/sec	896 m/s
Delta-V to perform **S.R.P.** from ~Mach 4 to < Mach 1	606 m/sec	290 m/s
Entry Drag **simultaneous with** SRP Phase (**1/4** of total)	202 m/sec	88 m/s
Remaining V. removed during final Landing Phase	**88** m/sec	0 m/s
Total passive drag deceleration:		2608 m/s
Total Propulsive Descent ΔV (H2-LOX):		776 m/s
Reserve ΔV (for hover and translate margin):		328 m/s
Total ΔV Capacity of descent configuration:		1104 m/s

Surface Base Integration and “Bootstrapping”

It is important to realize that the LMO base, the surface base, propellant production equipment and transport vehicles are an integrated system, which is **not** complete until fuel production begins and ferry vehicles can return to LMO. To support continued construction of the surface base, you need the source and store of LOX and liquid hydrogen on the surface (ISRU) and a large propellant supply in orbit (stored in the Propellant Depot) to operate the Ferries repeatedly, once fuel production begins. This means the base site must be where ice exists underground. Once a base site was picked, fuel producing equipment would be the first payloads sent down to the surface by cargo ferries. The equipment could be offloaded and set up via tele-operations by crew in LMO.

Mars Ferries compared to expendable landers

Without re-usable vehicles, you have to bring to LMO from Earth an expendable cargo lander and all of its propellant for every 20-25 ton cargo you want to use on the surface.

With re-usable vehicles, you can make repeated trips, saving 1.8 tons brought from Earth for every 1 ton delivered to the surface. Duplicate crew Ferries would also be available for emergency flights back to orbit. They would also allow a larger crew (a minimum size of 12), with a greater range of skills such as medical, for improved safety.

This also means more exploration and science will get done. The ability to bring fuel back to Mars orbit means the Earth return vehicle can use cryogenic fuel for its departure from Mars. Most importantly, re-usability tips the balance of mass brought from Earth away from vehicles and fuel and towards usable payloads landed at the surface base.

Permanent orbital and surface bases can thus be established with the very first human mission, bypassing the “Flags and Footprinta” architecture phase. The bases can then be counted on as existing refuges for the next mission, with equipment health monitored from Earth or Mars surface (or Phobos).

What do we need to support such a plan?

- Define and accept clear, supportable goals for the Mars expeditions, such as deep drilling for life.
- Agree on a clear, politically and financially sustainable budget commitment for the program.
- Agree that the **initial** architecture fielded to access a new destination (Mars or the Moon), **needs to be reusable from the very beginning**.
- Agree on an internationally supported Mars program effort, with each participating country getting to build major segments of the equipment depending on their commitment level.
- Create an HLV manifest to clarify the demand for large payload launchers.
- Develop fully re-usable private HLV boosters capable of launching payloads with a wide diameter to get the large mass of equipment and propellants into LEO and keep the launch costs down.

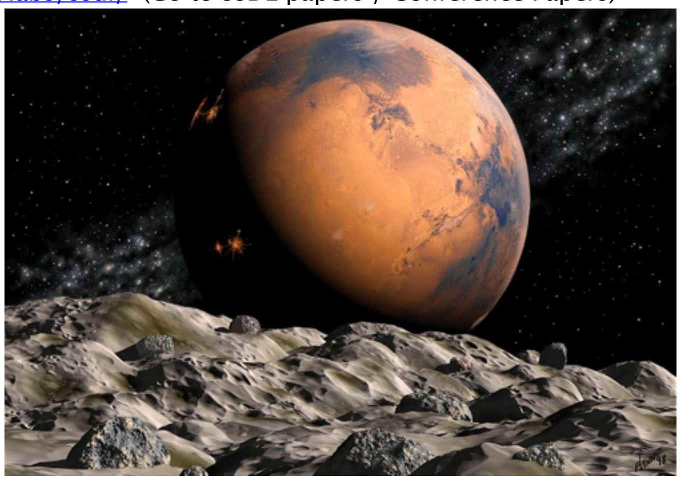
• Create an integrated IN-space transport and logistics system consisting of standardized vehicles, equipment, modules and stationary nodes, such as propellant depots to support the LEO zone effort.
• Continue a multi-arena basic Technology Development program including flight tests of Supersonic Retro-propulsion using sub-orbital vehicles in Earths atmosphere.
• Design and Integrate the Mars mission vehicles and bases.

Lets Keep Going to Mars

Our objective is to create a capability for continuing Manned Mars exploration. Let us use the time until the First Mars Expedition to make sure that once we go there, we can afford to keep going there. Assuming the first expedition would take place after 2030, we have over 20 years to create Re-usable space vehicles. Surely that is time enough to do it.

Major SRP Papers:

http://soliton.ae.gatech.edu/labs/ssdl/ (Go to SSDL papers / Conference Papers)



Artist rendering of Mars seen from Phobos - Note the city lights of settlements.

Mars will look very large from Phobos, many times the apparent size of the Moon from Earth. [We've had this painting in our files for years, but have never been able to determine the identity of the artist. If you know, contact kokhmmm@aol.com

MMM #244 - APR 2011

Humans need Shielding on Moon & Mars

But some food plants may not, and robotically operated factories may not. If so, the cost of settlement will drop significantly, as both agriculture and industry are acre-intensive

By Peter Kokh

Can we do agriculture in pressurized but unshielded places on the lunar surface? Perhaps! - Source:

http://www.colonyworlds.com/2011/03/raising-radiation-resistant-planets-off-world.html

Flax plants thriving in highly radioactive soil near the Chernobyl Nuclear Plant in the Ukraine

Lava tubes are useful, but

We have been putting high value on the discovery and use of intact lava tubes precisely because these voids totally reduce the need to erect shielding overburdens to protect human pioneers from the cosmic elements, of which cosmic rays and solar flares are most dangerous. But does that mean that outposts and settlements in areas of the Moon where lava tubes are not to be found must specialize in activities that are less area-intensive than industrial parks and agriculture? Not necessarily!

Agriculture, even in hydroponics setups, aimed at feeding a growing pioneer population, can take up a lot of space. If we use lunar regolith transformed* into good agricultural soil, to make it unnecessary to import those nutrients already in moondust, we will need even more space. Providing the needed moondust shielding could be a major construction burden, and cost. Of course, pioneers will not shrink form "doing what we have to do."

*First sifting out the micro-powder portion to avoid the clogging of drainage systems, then heating the moon dust remaining to a point where a fraction is transformed into Zeolites good at storing nutrients, then adding in composted human and agricultural wastes

But whatever food-growth systems we use, a need to provide radiation protection could be a burden. Now there has always been some indication that the protection of seed stock is much more important than that of plants intended for human consumption. But now this new evidence from Chernobyl gives us some hope that many, if not most agricultural operations may not need a heavy moon dust overburden, and certainly not as thick an overburden as needed for humans.

However, we have to consider more than plants. What about the human workers tending to those crops? We learned from Biosphere II that agriculture takes an unsupportable amount of manpower if not highly auto-mated. We need to reserve humans for other duties.

In addition to automated systems, robonauts, telepresence-operated from the safety of fully shielded operations centers, can take care of those cultivation chores not easily automated. So would this get us "home free" and "off the hook" for providing shielding for agricultural areas? Consider this aging piece of artwork.

In this scene, fruit pickers have zero protection from cosmic radiation. This has always been an absurd depiction. Replace the humans in this scene with robonauts. What now? There is still a problem. Shielding does more than provide radiation protection. It provides some thermal equilibrium inside the structure between high dayspan temperatures of 200°F and above and equally low nightspan dips to -200°F and below. So it seems there is a very essential need to provide some shielding over-burden even if radiation is not an issue. It's a matter of thermal "insulation."

Now for humans on short stays, a couple of yards ~meters of moondust is enough shielding for radiation protection, but we need to double that plus for those intending to stay years, if not lifetimes. But what about robotic-roboanaut-assisted agricultural and industrial operations? How much shielding do we need to maintain thermal equilibrium? I do not pretend to have any idea, but it may be significantly less than needed for radiation protection. By significantly less we mean an amount that makes a difference in financial feasibility. It would be helpful to know, and a series of relatively simple experiments may give us an idea.

We'd need a simulant to use in our experiments. This need not be a chemical or mineralogical simulant but a medium with very similar thermal absorption and retention properties as does moondust, figures that we suppose NASA researchers have known for sometime. The ideal insulation level would be one in which in probable living conditions, negligible cooling would be required throughout the dayspan, and negligible heating required through the nightspan – both spans 14.75 24-hour days long. Or more practically put, at what amount of insulation does the cost of proving further shielding balance the cost of providing further heating and cooling.

Of course, the cost of power generation on the Moon would have to be factored in, and we can only guess at those figures as we have yet to determine the least massive and most efficient power generation and power storage methods of the many options proposed.

While we have not settled anything in this article, we have brought to attention a number of unknowns that we need to pin down before we return to the Moon. **PK**

Could the "Space Experience" Sector Open the Moon Faster, for Less?

Paying Working Tourists vs. Paid Astronauts?

By Peter Kokh

How we've done things up to now: who builds what

The cost of doing things in space is undeniably increased by the way hardware (rockets, for example) are contracted out with provisions that highly favor chosen contractors, by decisions motivated by political considerations of which state or Congressional District will be most benefited, and selection of winners prior to construction and competitive testing.

The switch to real competition between commercial companies should help to reduce costs and improve equipment by a substantial margin. The NASA-Contractor monopoly has had its chance and given us space transportation systems impossible to continue financing.

In the next few years we will see real competition between a variety of crew reentry vehicles and space planes. Some will be best for this use, others for that. And all will be significantly less expensive thanks to real competition.

Crews: the cost of training and support

The NASA Astronaut Corps is rightly held in very high esteem. There will always be some individuals with problems. That's neither here nor there. But there has been significant criticism of the cost of the program.

> An "excess of astronauts — and what they do with their non-flying time — costs the space program far more than money. Their influence throughout the agency contributes to a NASA culture that is artificially enthusiastic, overconfident, contemptuous of outside advice and excessively obedient to short-term goals (as defined by the pilots) — often at the price of sound engineering."
>
> www.usatoday.com/news/opinion/editorials/2003-07-30-oberg_x.htm

How much does such a system add to the cost of missions to the International Space Station? How much would it have added to now-cancelled Moon Missions? We don't pretend to know.

But if we are going to switch to commercial providers of hardware, how about also switching to commercial suppliers of trained astronaut crews? We need both, commercial equipment and commercial crews to break out of the amazingly non-American paradigm of "socialized space," which, as much as we are all proud of NASA, is what it is has been, from day one.

Beyond Commercial Crews

Providers of commercial crews must factor the cost of personnel training, and attrition into the price for their service. While this cost could prove to be a fraction of what it costs N ASA to train astronauts and to maintain an oversized astronaut corps, it would seem that there is a way to do even better, in fact,

a way to zero out the cost of crew training and support, so that the cost of a mission reflects only the cost of purchasing competitive space transport systems, and tools and equipment that crews will need.

Zeroing out Crew Training and Service Costs

We are all now familiar with the "Space Tourism Industry." It began with Space Adventures arranging to bring Dennis Tito to the International Space Station. "Tito joined Soyuz TM-32 on April 28, 2001, spending 7 days, 22 hours, 4 minutes in space and orbiting Earth 128 times.[8] Tito performed several scientific experiments in orbit that he said would be useful for his company and business. Tito paid a reported $20 million for his trip."

http://en.wikipedia.org/wiki/Dennis_Tito

Tito paid for his training as part of the price for his ticket, and also was required to make himself useful while onboard ISS, and all space "tourists" to ISS since have done likewise.

The "Space Experience Industry"

Right now, we are approaching the dawn of commercial flights to the edge of space. Perhaps it is time to junk the term "Space Tourism" in favor of "Space Experience." The future of the Space Experience Industry seems to us unlimited. Thanks to John Spencer, the president of The Space Tourism Society, for this term!

Now in the near future where the focus will first be on prolonged zero-g flights to the edge of space, then orbital flights, finally commercial space hotels and resorts, we will be talking primarily about people on "the vacation of a lifetime." They will do this to enjoy, not to work! Yet crews and staff catering to their needs will also benefit. While flight crews will most certainly be paid as these will be steady occupations, some "staff" - for space hotels, for example - could be paying volunteers, paying a bit less than tourists, for the privilege of staying in space longer, in trade for working assignments.

The pay-to-work Paradigm already exists

For some time now, individuals have volunteered, and some even paid, for the privilege of participating in archeological and paleontological "digs." Something quite similar is common on "Windjammer Cruises" where tourist crews man the sails and do other jobs - everyone works, and they do so with enthusiasm for the privilege of a vacation experience otherwise out of reach.

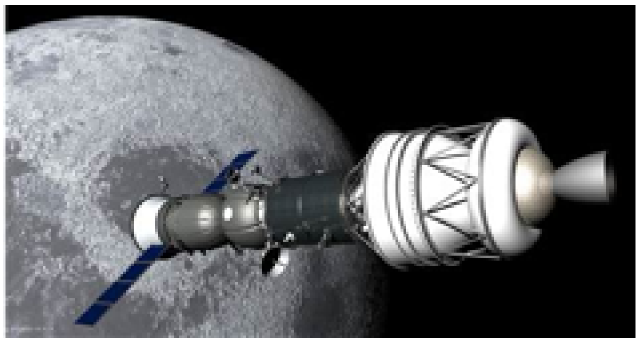
Paying to work in Space

Now most of us need to "get paid" for work, and are hardly in a position to "pay for the privilege of working." But make no mistake. Those who pay to work do get paid! Their pay is an unforgettable experience! Yes, of course, this is an option available only to those with enough income or resources to pay for the privilege. That this is not an option open to most of us is quite irrelevant. The point is that there is a population class growing in size that has begun fueling a "pay-to-work" sector of the economy that is growing year by year.

Fast forward a bit: we foresee the emergence of commercial companies that supply personnel who have paid for their own training, and who are ready to pay for the privilege of using that training on actual assignments – in space. Some will staff budget space hotels and resorts. And beyond that?

Space Adventures'1st Private Moon Expedition

"Make history as the world's first private lunar explorer.
"Witness Earth rise as you emerge from the far side of the moon.
"Become a catalyst for humankind's expansion into space."
"Space Adventures invites you to join us for the most significant private expedition of our time – launching the first private mission to circumnavigate the moon."



Space Adventures, working with Russian providers of the vehicle and service module needed, have already signed up one of the two tourists, who, with a Russian astronaut pilot, will make the first commercial Apollo 13 type loop-the-Moon trip. (Apollo 8 made several orbits about the Moon before returning.) A second customer is said to be ready to sign. **Watch this Space Adventures Video:**

http://www.spaceadventures.com/videos/LunarMission_no_ZG_msg_300kbps_480x270.mov

This flight could occur within the next to years, and will be the first presence of humans near the Moon in forty years, many years before any national space agency.

What next for the Space Experience Industry?

Once this flight is history, or perhaps even before out of anticipation, there will be a growing interest and demand among "experience-seekers" willing to pay the price for lunar landing excursions. Now there will be no on site facilities to cater to them. So what would be the cheapest way to provide such facilities? You got it! The ideal site for an ever-growing tourist complex having been identified in advance, the first paying experience seekers will plot out the site, photograph the site in detail and do additional investigation to supply architects on Earth with the information they need to draw up plans for the first structures, and a game plan for additional expansion. Perhaps this first crew could also leave a robonaut behind to be telepresence-operated by persons back on Earth to continue making site improvements in advance of the arrival of a second private crew again paying not only for their own training, but for the privi-ledge of working on arrival at the selected site.

For an ideal site location idea, read **"An 'All-in-One' Moon Resort"** pp. 82-85, **MMM Classic Themes – Lunar Tourism**, a free download at:
http://www.moonsociety.org/publications/mmm_themes/mmmt_tourism.pdf

Because "pay for the experience" tourists will be taking on serious work assignments, and have even paid for the training to allow them to do so, their tickets to the Moon (resort) will be cheaper than those of purely passive tourists. Those willing and able will pay-to-prepare, pay-to-build, pay-to-explore, pay-to-prospect, and pay-to-deliver services.

Yes, these people will come from the wealthy, as few of the rest of us will be able to compete for these positions. But the point is that in this manner, lunar surface facilities including not just tourist resorts but science outposts, even initial factories, will get built sooner and at far less taxpayer expense (translate that to freedom from political veto power).

As we have suggested, pay-for-experience tourists will be accompanied by and work with robonauts who will do the boring, repetitive, and dangerous tasks. They need no life support, no rest or recreation, and no need to return to Earth. They also require less room aboard the craft that bring pay-to-work tourists to the Moon. Thus robonauts promise to greatly multiply the cost-effectiveness of this approach, and bring down all costs even more. So we can add to the "pay-to" list, pay to teleoperate, and pay to maintain equipment.

This scheme can serve to expand science on the Moon as well as tourism. "Pay-to" personnel can also go to the Moon for the privilege of collecting specimens, of prospecting, and doing all sorts of scientific research. The can also pay for the privilege of testing equipment to turn moondust into usable materials – "ISRU" – "in situ" [on location for those of you not familiar with Latin] resource utilization. Thus people may "pay-to" develop building materials with which to expand habitat and outpost complexes with far less "upports" from Earth.

We do not pretend that this scenario is certain to develop. The World Economy is too near implosion, and that could put off all plans, commercial as well as tax-supported inefficient government programs.

Wikipedia "**Extreme tourism** or **shock tourism** is a type of niche tourism involving travel to dangerous places (mountains, jungles, deserts, caves, etc.) or participation in dangerous events. Extreme tourism overlaps with extreme sport. The two share the main attraction, "adrenaline rush" caused by an element of risk,"
http://en.wikipedia.org/wiki/Extreme_tourism

Yes, there will be space tourists in the traditional sense who want to just enjoy and sightsee and they will pay even more to go into space. But here we talk about those who will pave the way and create places for others to visit. Here we talk about space tourists willing to pay for own training, pay their own insurance etc.; who pay (rather than get paid) for work and assignments.

How do we cover cost of equipment, vehicles, etc.? A first answer would be the commercial companies and consortia who want to operate lunar resorts, and deploy factories on the Moon, mining operations etc. Keep in mind that this is an introductory article aimed at getting further brainstorming in high gear. We offer this article as a contribution to a **Commercial Model for settling the Moon**.

Addenda: Opening the Moon to the less-well-to-do

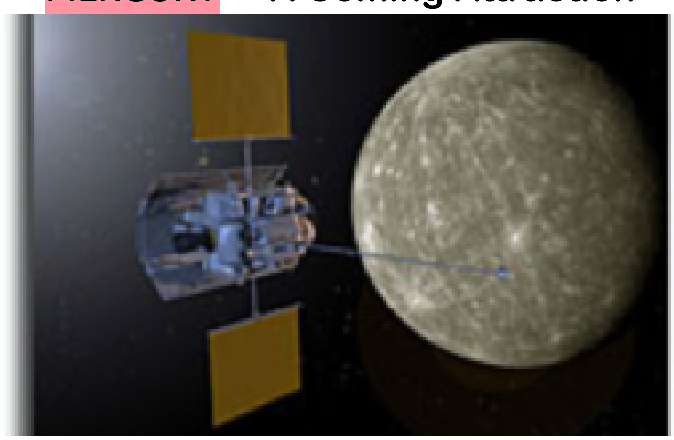
The overwhelming majority of us would never have the resources to participate in such a scenario. But there could be **lotteries**, with drawings to be held when the combined entry fees exceed the costs to be covered. Winners who did not pass medical and other tests, could sell their rights to the highest bidder. But there could also be limits on those who could enter, to minimize such situations.

When Weight is an Issue

One thing we have not discussed is the simple hard fact that transporting anywhere in space those who are bigger and heavier goes up in proportion. Should otherwise capable midgets, dwarfs, and just smaller individuals pay less? For passage perhaps, but maybe not for training.

We hope you enjoyed this article ant that it sets of a chain of constructive brainstorming. **See you on the Moon!** (I wish!) **PK**

MERCURY - A Coming Attraction



MESSENBGER (**ME**rcury **S**urface, **S**pace **EN**vironment, **GE**ochemistry, and **R**anging) enters orbit about Mercury on March 17th. Science Mission begins April 4th

By Bryce Johnson

We are about to add another planet to the short list of potential New Worlds for human habitation. Much of the planning being done today for lunar bases is founded on data gathered by the Lunar Reconnaissance Orbiter. That mission gave us a global picture of the Moon's composition. With it we are able to strategically plan lunar exploration and settlement using real-world facts, not just wishful thinking. The Messenger mission ot Mercury has a similar role. Over the net year, data gathered by Messenger will educate us about Mercury's surface chemistry to a level far surpassing what w knew about the moon prior to the Apollo landings. Aside the Moon and Mars, Mercury will be the only other planet for which we have so much knowledge.

Messenger is already an unqualified success. The spacecrart has photographed the Earth and the Moon, flown by Venus twice and Mercury three times. The three Mercury flybys have revealed details about Mercury's atmosphere; the presence of relatively recent volcanic vents; higher than expected abundances of Titanium and Iron in Mercury's regolith; the presence of a molten outer core and a much better understanding of Mercury's weak, but persistent, magnetic field; all that in less than a week's worth of combined encounter observations.

The orbital mission is expected to last a year and the spacecraft is healthier than expected. In particular its existing fuel reserves are about 40% of what they where when the spacecraft left Earth. This is better than expected and is owed to the incredible accuracy with which Messenger has hit its planned targets during its long flight. The targeting has been so accurate that 21 of 38 originally planned Trajectory Correction Maneuvers (TCMs) were as unnecessary.

A possible result of this efficiency is that Messenger may have enough propellant on board after its planned mission to support an extended mission of at least 90 days - an entire Mercury year. This has yet to be suggested by the science team, however. The science data likely ot come from the orbital mission is planned to dwarf the data already in hand from the flybys. It will take year to shake out firm conclusions about Mercury's history and present phenomena. However, as a foundation for human development, what is in hand to date portrays Mercury as a potent venue for industrial scale resource development.

"Understanding Mercury is fundamental to understanding terrestrial planet evolution."

For starters, Mercury is evidently the most Titanium-rich planet in the Solar System. According to one report from the University of Arizona, there are at last three locations on Mercury's surface where Titanium concentrations exceed 25% of the regolith bulk material. Most of this is contained in oxides of Titanium, such as rutile or mineral garnet. In one particular region west of the Caloris Basin, rutile concentrations of up to 37% were derived from both mid-infrared telescopic observations and data from the second Messenger flyby. Pure rutile is 60% Titanum by weight. This would imply that a metric tonne of regolith in this region would contain as much a 222 kg of actual Titanium metal. For other regions of Mercury, rutile seems to have roughly the same compositional role as ilmenite does on the Moon. Ilmentie has also been suggested in noticeable quantities elsewhere on Mercury. This was initially evidenced by spectrographic observations made shortly before the probe's launch

Iron in Mercury's regolith was previously thought to be in concentrations limited to no more than 3% iron-oxide. Messenger data now indicates concentrations may be more like those in "high titanium/high-iron" lunar mare basalts, such as those collected by luna 16 (15.1% iron) and Apollo 11 (15.45). Actual iron oxide (FeO) abundances on Mercury may be between 7 and 10 percent.

Mercury's iron is apparently distributed differently. Rather than ave tiny amounts mixed more or less evenly through the regolith, Mercury's surface iron appears to be in the form of 'blebs' or tiny bits of iron situated inside basaltic rocks much like tiny bubbles of air might be seen frozen into an ice cube. This could explain the seeming conflict between the historical observations indicating low iron content in the regolith and Messenger's data. As with so many similar mysteries, the orbital phase of the mission should provide some conclusive answers.

Generally, Mercury's surface mineralogy includes magnesium-rich othopyroxenes and olivines (the latter curiously low in concentration inside the Caloris basin); clino-pyroxenes rich in calcium, magnesium and sodium; potassium feldspars and sodium-bearing feldspars. Both calcium-and sodium-rich garnets, such as pyrope and grossular, are also apparently present in insignificant quantities. Actual percentage abundances have yet to be confirmed and will require consistent data from a number of orbits by Messenger to be characterized with certainty.

Messenger's second flyby also revealed the astonishing presence of water in Mercury's atmosphere. The word "water" is something of a misnomer here as what Messenger actually discovered were hydroxyls - various molecules that include the (OH) hydroxyl radical, minerals which may have formed in the presence of water. The particular instrument that revealed the presence of hydroxyls was the Fast-Imaging Plasma Spectrometer (FIOS) that measures energetic ions. Water or hydroxyls are detected by first collecting energetic ions in Mercury's atmosphere, then determining a ratio of their mass to their charge.

What the FIPS instrument discovered were 'free radical' ions corresponding to molecular weights of 16 and 18. Oxygen has an atomic weight of 16 while water molecules have molecular weights of 18. No plausible elemental combination has been envisioned for these particular readings, leading the Messenger science team to conclude that there must be a source of water molecules on Mercury itself. The abundance of the hydroxyls is roughly one for every three or four sodium ions in Mercury's atmosphere. This is likely to be more than can be reasonably expected from solar wind deposition alone. Getting more definitive data for the presence of water is a high priority for the orbital phase of the mission.

Messenger's orbit over Mercury will start out with a highly elliptical near-polar orbit with a periherm [near Mercury] distance of 200 kilometers and apoherm {away from Mercury] of about 15,000 kilometers. It will be oriented more or less over the terminator with about six degree inclination referenced to it. In other words, the orbit will be inclined to Mercury's equator by about 82 degrees. This will bring it over both of Mercury's poles and it should allow confirmation of any polar ice deposits, if they exist. The low point of Mercury's orbit corresponds to a point on Mercury's surface centered at about 60° north longitude. Messenger will be in constant sunlight while not having to be too severely heated by sunlight reflected from mercury's surface. The same orbit strategy might be followed by early manned missions to Mercury as well, particularly if a polar site is chosen for the initial base.

Physical features on Mercury include an astonishing system of over 200 "graben", or trench faults, radiating from the crater Apollodorus located inside the Caloris Basin. There are similar features of this type else-where in the solar system. Scarp formations have been identified all over the planet and the overall picture is that Mercury at one time went through a period when the plant's crust uniformly shrank.

To date no lavatubes have been identified, but that is not surprising as they are subsurface features sometimes betrayed by local "skylight" collapses on very high resolution photographs. Mercury's gravity is similar to that of larger but less dense Mars – 3/8th G. So lavatubes on this planet like those on Mars are expected to be of intermediate size between smaller ones found on Earth and much vaster ones found on the Moon. Mercury has extensive areas covered with lava sheets so it would be surprising if we did not find equally extensive tube networks in time.

Taken as a whole, Mercury is a planet with all the energy and resources needed to economically construct advanced facilities; sustain agriculture and comfortable, large-scale habitats; support large-scale space transportation systems; conduct valuable solar, planetary and stellar science programs and, eventually support numerous industries.

Mercury's solar flux is perhaps its single greatest asset, averaging 8.2 times the solar flux at Earth's distance, This flux generates temperatures on Mercury's equator over 700° Kelvin, 427° C, 800°F. It would be easy focus this energy to process metals out of the regolith (surface rock powder blanket.) Surplus energy combined with the presence of workable resources generally results in export-scale productivity. In Mercury's case, even relatively low-grade oxides can be worked economically due to the super-abundance of energy available. What is then needed is an economical transportation system that can transfer substantial masses of product to consumers.

The high velocity requirements for trips between Earth and Mercury do not favor 'high-impluse' transportation systems such as LOX.LH2 rockets, at least for very large payloads. However, solar sails are capable of delivering hundred-tonne payloads to Mercury form Earth. Sails starting from Mercury can deliver payloads ot any planet in the solar system with flights departing every 116 days to Earth 145 days to Venus, 101 days to Mars and just over 8 days to just about everywhere else. The time of flight for solar sail missions is a function of the area and mass of the sail and the mass of the payload Typical solar sail missions usually involve spiraling orbits around the Su requiring trip times that can be several times longer than classic Hohmann transfers. This why solar sails are often relegated tby some writers to unmanned cargo service.

In truth, solar sails can be considered for manned flights from Mercury if it is assumed the manned pay;oad has its own propulsive system and the sail itself is left on a high velocity, flyby trajectory past the target planet. Since solar sails require no in-space servicing, repair or refueling and since they can, in all likelihood, be use for several flights, they do not have the recurring cost issues that plague all other reusable, high performance technologies. As a result, in net terms, Mercury can produce anything made with the metals and alloys commonly used in industry today. Silicates and silicate composite materials are also possible. Cast basalt items are bound to be common products.

Glass is a Much better bet on Mercury than on the Moon, owing to the greater abundances of the additives used for special properties. For example, high quality optical glass requires 318 parts of pure silicon, 125 of potassium, 56 of zinc, 37 f sodium, and 9 of boron per 1000 parts of product, the remaining 545 parts being oxygen. With the probable exception of boron an maybe znc – together just 6% of the total – all the rest is available in Mercury's surface material. Since boron and zinc are likely available on Mars, there is potential for coordinated trade. The high grade optical glass produced would be available for construction of trly large mirrors used in telescopes that would easily have several times the size and power of the Hubble ST. And Mercury's 88-day-long nightspan makes it an ideal platform for astronomy of all.

Volatiles are still a major unknown. Hydrogen has been detected by Messenger in Mercury's atmosphere. Surface resources of hydrogen are another matter. The quantity u free hydrogen has been estimated at around 200 atoms per cubic centimeter but this predates Messenger and it is not clear that this is an estimate for the surface or at orbital altitudes. This does not sound like much, but it is way more than can readily be explained by solar wind implantation alone given the high temperatures of Mercury's surface. Evidence has accumulated for water ice deposits in shadowed craters near both poles. Whether this ice contains any other volatiles remains to be determined. However, Mercury does have a resource eo carbon, hydrogen, nitrogen and chlorine available; Venus' atmosphere.

In an industrial development scenario, there Is incentive for cislunar facilities to tap Venus' atmospheric resources preferentially to Mars'. Venus does have a light mission energy advantage, over seven times the solar flux, a slightly more frequent launch window frequency to Earth when compared to Mars. The problem is that with the notable exception of high solar flux, the advantages enjoyed by Venus over Mars are usually less than a factor of 1. This means that, form the point of view of real costs o access and develop either planet, there is not enough difference between the two to ignore the inaccessibility of Venus' surface.

Mercury, on the other hand, has every incentive to access Venus' atmosphere and would probably not need any materials from Venus' surface. Flight opportunities between Mercury and Venus are six times more frequent than from either Earth or Mars to Venus. Solar sails are still quite efficient as mass transporters from Venus and some sail materials can actually be produced from Venus' atmospheric carbon.

Venus' atmosphere can also slow down an inbound spacecraft even at the velocities characteristic of Mercury-Venus transfers. The net effect is that a routine transfer of materials between Mercury and Venus can be an economically competitive option. An ongoing combination of Mercury's resources and energy abundance combined with Venus' atmospheric resources and energy abundance would have massive implications for progressive exploration and settlement in the Solar System.

Colonization of Mercury rests on the need for a variety of bulk materials, manufactured products and operational characteristics represented by Mercury's unique environmental attributes or its location in the Solar

System. Other planets have ‘hard’ vacuum available on a scale equal to Mercury’s. Other planets have high heat of day available; ditto intense cold at night. But no other planet outside of Earth-Moon space contains them all simultaneously As solar sails become a proven transportation technology, accessing Mercury will become a much easier proposition than is now the case with chemical propulsion.

Mercury is not without dangers. Writers go out of their way to point out how hot it gets on Mercury’s surface at noon. What is never mentioned is just why anyone would want to be out on the surface at that time. Science fiction scenarios aside, Mercury’s surface does not become deadly hot the second the Sun pops up over the horizon. Since Mercury rotates so slowly compared to the Moon, It actually takes about six weeks before the Sun is high enough above the horizon to raise temperatures to the boiling point of water.

Structures on Mercury do need to be protected from extremes of temperature, ionizing radiation, and micro-meteorites. These are al issues for bases on the Moon as well. Superficially, the only real difference between the two might be the greater thickness of regolith shielding needed by the Mercury facility. Suitably protected, the same technology used to build bases on the Moon can be directly applied to Mercury.

Looking downrange, Mercury can leverage much more rapid development of Mars and serve as a hub for development of the asteroids and outer planets. It can be successfully developed even if more potent transportation technologies, namely nuclear based are not developed right away. It can provide unique and advantageous assets to science and industry.

The research goes on. For now, the nail-biting phase of the Messenger mission no longer preoccupies the work of our ad hoc committee. We are now monitoring the Messenger data return and wil be able to answer, more authoritatively, all of the issues raised here, plus a host of others, before many more months. **BJ**

MESSENGER LINKS:

http://messenger.jhuapl.edu/mer_orbit.html

http://messenger.jhuapl.edu/news_room/Mercury_PK_Web.pdf

Previous MMM Articles on Mercury

MMM #78 Sept 1994
MERCURY: the other terrestrial planet, M. Thomas
DYSON CAPS: ultimate solar power station, M. Thomas
GATEWAY GRAND CENTRAL: Mercury, P. Kokh
Preserved in MMM Classic #**8 pp. 37-39**

MMM #204 Apr 2007
Three Myths about Mercury, Bryce Johnson
Preserved in MMM Classic #**21 pp 23-26**

MMM #205 May 2007
Mercury Frontier Speculations, P. Kokh
Preserved in MMM Classic #**21 page 27**

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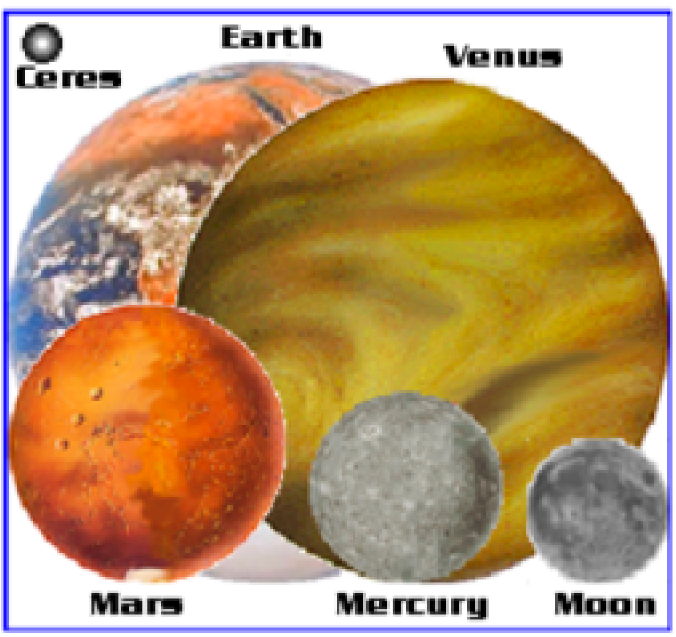


How does Mercury Stack Up?

M	Merc	Venus	Earth	Moon	Mars
Mass 1024kg	0.33	4.87	5.97	0.07	0.642
Diameter km	4879	12104	12756	3475	6794
Density kg/m3	5427	5243	5515	330	3933
Gravity m/s2	3.7	8.9	9.8	1.6	3.7
Escape Vel km/s	4.3	10.4	11.2	2.4	5
Day hours long	4222	2802	24	708.7	24.7
Sun Dist10(6)km	57.9	108.2	149.6	0.384*	227.9
Insolation avg	6.68	1.91	1	1	0.43
Orb. Period days	88	224.7	365.	7.3	68.7
Orbit Speed km/s 4	7.9	35	29.	8 1	24.1
Orbit Inclined	7°	3.4°	0°	5.1°	1.9
Orbit Eccentric	0.205	0.007	0.017	0.055	0.094
Axis Tilt	0.01°	177.4°	23.5°	6.7°	25.2°
Mean Temp °C	167	464	15	20	-65
ATM Pressure bars	0	92	1	0	0.01
Number of Moons	0	0	1	0	2
Magnetic Field?	Yes	No	Yes	No	No

Mercury trivia: Mercury’s day, noon to noon, is 176 Earth days long. One need travel only 3.75 kph or 2.33 mph to keep up with the advancing sunrise or sunset, at the equator. **MMM**

Lunar Mascons: Masterpieces of Complexity

By Ron Brooks, Ed.D.

1. Introduction

Since the 1950's knowledge of our Moon's gravitational field has grown, leading to some significant discoveries. Of the most intriguing is that of gravitational anomalies referred to as high-density mass concentra-tions or mascons. Research conducted on both the near and farside has produced a great deal of data on how these enigmatic and complex anomalies formed and their effects on the Moon's gravitational field. In recent years, our ability to understand the anomalies has greatly improved with the use of technological advancements such as multiple synchronous satellites, imaging tech-niques and Doppler. It is true that our knowledge has steadily grown about mascons, but all this gain has been from a distance. A thorough understanding will most likely not happen until the long awaited time arrives that we are able to move about the Moon again and conduct rigorous research first hand.

The information presented is for those with varied levels of interest in the Moon and is not intended to be exhaustive or definitive in coverage. The references can provide a basis for anyone wishing to pursue in-depth readings.

2. Gravitational Anomalies

Investigations and predictions by H.C. Urey, starting as early as the 1950's, were revealing the possibility that some sort of gravitational anomalies may exist within the dark maria on the Moon (Urey, 1956). A decade later, in 1966, the Russian Luna 10 Orbiter while circling the Moon confirmed these predictions by detecting anomalies generating from some of the maria (Christy, 2010). The growing accumulation of data was showing that something definitely was going on over the maria.

Then by the mid 1960's, enough data was being accumulated about the Moon's gravitational anomalies that an acceptable theory about what the anomalies were and how they were formed was near. In the spring of 1968, after extensive research and continued data coming from the Orbiter 5 satellite, P.M. Muller and W.L. Sjogren felt certain enough to describe the geological formations that produced the gravitational anomalies and assign the name mascon(s); short for mass concentra-tions (Muller & Sjogren, 1968). This benchmark of insight set the stage for more intensive on-going research. Muller and Sjogren received credit in the spring of 1968 for the discovery of these (high-density) mass concentra-tions. Both received the Magellanic Medals by the American Philosophical Society in 1971 for their discovery.

Mascon Formation

All impact basins and mascons exhibit unique geology and structures, especially those found on the farside. However, all mascons still share a common geo-logical history. During early research, it was suggested that mascons might have been caused by collisions with heavy bodies of nickel and iron. However, this was dismissed as not credible and is now fundamentally believed to be the results of huge impacts on the Moon's surface.

In a short sequence, an impact would have instantly created an excavation basin. Simultaneously, the force would have broken through the Moon's crust and fractured the Moon's mantle. This colossal force not only produced the traumatic fracturing but also an impact rebound that triggered the uplifting of the mantle bringing it to or close to the surface. The uplifted mantle, after some degree of compensation, would become frozen in a static state. In most cases, after a passage of time lava flows would fill the impact basin. Together, the iron rich mantle uplift and lava flows would create the mascon. The above sequence is rather simplistic, but it serves as a basic framework in which a more comprehensive understanding can be developed.

More Ideas Regarding Mascon Formation

In the early 1970's, Muller and Sjogren theorized that mantle uplifting after an impact produced near surface mass shaped disks (not to be thought of as necessarily circular). They found that the midpoint of the disks emanated the strongest positive gravitational anomalies while the outer edges produced a negative gravitational anomaly (Muller & Sjorgren, 1972). In contrast to the nearside gravitational configuration found by Muller and Sjogren, Namiki et al., after studying Doppler measurements from the SELENE satellite mission in 2009, found that farside mascons seemingly emanate positive and negative gravitational anomalies in alternating concentric rings (Namiki, et al., 2009a).

Regardless of the gravitational configurations, the uplifted mantle structures from the impacts seemed to defy the principle of isotactic compensation and once lifted remained in a static state. However, this static state may not have been achieved immediately following the uplifting. S.C. Solomon and R.P. Comer believed from their research that the topographic relief of a newly formed basin was at least 50 to 60% compensated (a seeking for equilibrium with the regional topography) by crustal thickness and temperature variations prior to any lava flows beginning. Mare Tranquillitatis on the nearside was used as an example of demonstrating significant compensation prior to any lava emplacement while the South Pole-Aitken basin on the farside was used as an example of not exhibiting any significant viscous relaxation (Solomon & Comer, 1982). The Moon's lithosphere apparently solidified at various stages of compensation for each discrete impact basin. In a summary rendering, it seems probable that any discrete mascon was not "frozen" immediately but at some point in its stage of isostatic compensation.

Temperature variations or the thermal conditions below the impact basins were a major factor in solidification. After researching data about the viscosity of the Moon's interior, J. Arkani-Hamad concluded that there have been no thermal convection currents inside the upper 800km of the Moon since the formation of the mascons or about 3 billion years (Arkani-Hamad, (1973). This conclusion and other data about the Moon's internal thermal state seems to confirm that the Moon's crust was already ridged and the interior temperatures were cooling soon after the Moon's molten state (most agree it had one) which leads to a relative rapid (in geological time) solidification. Even with isostatic compensation occur-ring, the crustal rigidity and lower interior temperatures seemed enough to stop the compensation and hold the mantle up sufficiently to help generate a mascon.

2. Basin Lava Flows

As stated earlier, the impact of fracturing set the forces in motion causing not only the basin uplifting of the mantle but also allowing an iron enriched lava to spew into the impact basin. However, it seems generally accepted that lava flows did not happen immediately after impact, and the basin uplifts where frozen in a super-isostatic state long before the lava flows started (Neumann et al., 1996). It is possible that impact basins and their uplifted mantel formations may have lain dry for about 100-500 million years before flows began (Shoemaker, 1964; Baldwin, 1970). After the flows began, they repeatedly moved through the basin fractures, one over the other in varying degrees for over a billion years (Ronca, 1972).

It is interesting to note that L.B. Ronca asserted the idea that some of the later flows were "tongue-shaped" indicating that later lava flows did not come from fractures below the impact basin but from fractures in the circumferential region around the basin (Ronca, 1973). This would indicate that some of the final flows were emanating from hot places likely beneath the surrounding highlands.

This idea of the transfer of mass (lava) from the highlands to the impact basin is further supported by Arkani-Hamad (1973b). He presented the idea that a laterally heterogeneous thermal regime developed in the Moon's interior after the impact. This development seemed to result in the following possible events. The thermo regime created a lithosphere that supported both the formed basin mascon and the highlands surrounding it. It also induced the fast cooling of the region beneath the lava emplaced basins and in reverse caused the remelting (on a slower scale) of the base below the surrounding highlands. The mass of the highlands and the additional weight and pressure brought on by the thick insulating ejecta blanket on the highlands surrounding the basin augmented the base remelting. The result of the remelting was an amassed collection of viscous material. These dynamic events produced high stress fractures in the highland lithosphere lying between the forming viscous material and the upper levels of the highland surface. The stress fractures became the conduits for the transfer of the viscous mass (lava) from beneath the highlands into the basin. These events are complex but do eliminate any exclusivity to the concept that the basin lava flows emanated strictly from fractures beneath the impact basin.

The Japanese SELENE mission revealed yet another interesting dimension to the lava flows. Mare Serenitatis was found to have a regolith coating layered between subsequent lava flows. This helps to validate that enough time elapsed between flows to build up (sandwich like) stratification (Ono , 2009). It would seem very likely that most maria would have this regolith stratification.

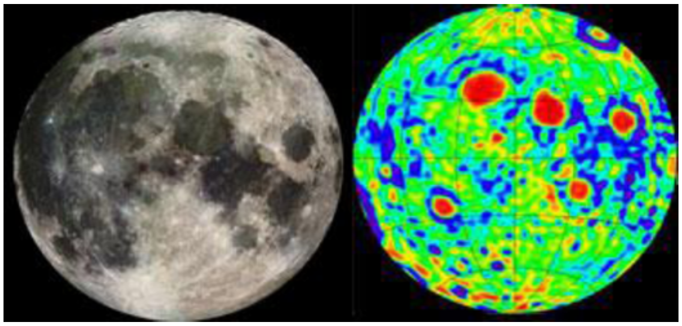
3. Volcanism

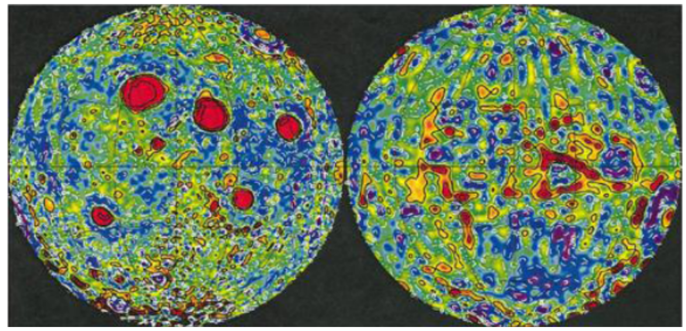
Moon volcanism, such as the large basaltic lava flows in Oceanus Procellarum, has not produced the discovery of any significant gravitational anomalies. This finding has eliminated volcanism alone as a serious contender as a cause of mascons. There are also mascons on the Moon's farside that have limited if any emplaced lava flows. This seems to confirm that uplifting of the mantle alone may be sufficient enough to produce a mascon. As it appears, mantle uplifting and lava emplacements contribute to mascon formation collectively or that uplifting alone can create a mascon discretely.

4. Where are the Mascons?

Of the five major nearside maria containing detected mascons, Mare Imbrium is the highest density site followed by Maria Serenitatis, Crisium, Nectaris and Humorium. (See the Gravitational Map Figure 1). A moderate density mass concentration lies between Sinus Aestuum and Sinus Medii that is probably an ancient ringed mare. Mascons are found in Mare Orientale, which wraps itself around the far western limb to the farside and the crater Grimaldi (a large walled plane) that lies close to the western limb. More mascons are being identified as research continues. In 2000, A.S. Konopliv presented evidence that about 12 additional mascons existing in impact basins have been discovered on the nearside or close to the limb (Konopliv, et al., 2001).

LEFT: **Gravitational Map Nearside** **RIGHT: Gravitational Map – Near and Farside**





Left – Near Side -- Right – Far Side

LEFT ABOVE: Fig. 1 The 5 large red globule shapes (right gravimetric map) are mascons. You can see how the red globules match the maria to the full Moon image on the left.

Right Map – right to left: Mare Crisium, Mare Nectaris, Mare Serenitatis, Mare Imbrium and Mare Humorum.

Image Credit: NASA (Left Image from Galileo mission – Right Image from Lunar Prospector)|

RIGHT ABOVE: Figure 2 Above is a gravity map of the near and farsides of the Moon made by the Lunar Prospector spacecraft (Konopliv et al., 1998). The map shows the mascons of the nearside (left) as shown in Figure 1 and the mascon formations on the farside (right). The red globules show the intensity of the gravitational anomalies. The reader can see the intensity variance of the mascons on the two sides of the Moon. Image Credit: NASA

The gravimetric maps above clearly show mascon locations. The intensities are also shown and contrasted between the near and farsides.

5. Differences – Near and Farside

It is obvious in Figure 2 that the nearside mascon basins are much more predominant and appear geologically different from those on the farside. It has not been clearly established why this has happened. However, it is probably linked to several unique geological differences that have existed between the near and farside. The nearside has a thinner crust placing the mantle closer to the surface. Sjogren believes the crust difference on the farside is close to an additional 33 km. (Sjogren, 1977). This difference would make the lithosphere much more rigid on the farside. However, this is not to say that the crust depth is the main or only contributor to the maria differences on the two sides of the Moon. Nor, can we logically say that the nearside just took larger impacts, which resulted in the surface differences. Unraveling the complexities seems problematic.

However, a plausible additional theory of differ-ences is the comparatively very high lithosphere temper-atures that existed below the nearside basins as compared to the farside. The enduring high temperatures under the nearside basins would have melted the lower crust and upper mantle boundaries into a viscous material. This viscous layer allowed a prolonged basin/ maria deformation that continued even after the final lava emplacements. (Most likely, the ridges and rills found in the nearside maria are validation of this deformation.) The viscous material amassed at the crustal/mantle boundaries would have also relaxed the upper litho-sphere and would have contributed to the sea like appearances of the nearside lava emplaced basins.

The actual crustal and mantle boundaries' temperatures for the nearside were in excess of 1000K, whereas the crustal/mantle boundary for the farside was less than 800K, which would be sufficient to produce the lower crust and upper mantle melting (Namiki, 2009b). The differences in the thermal evolution of the litho-sphere and the crustal variances would contribute greatly to the near and farside impact basin differences.

Namiki, et al. developed the map (Fig.3) below that demonstrates some of these geological basin differences (Namiki, 2009c).

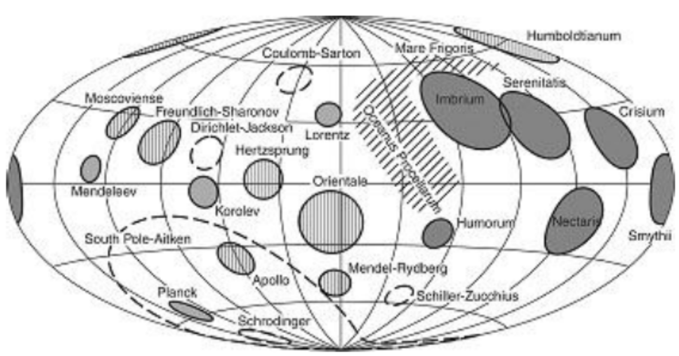


Figure. 3 from: Farside Gravity Field of the Moon from Four-Way Doppler Measurements of SELENE (Kaguya) Reprinted with Permission from AAAS.

Note: Figure 3 displays the names and locations of major lunar basins/mascons on both the near and farsides. The lunar nearside is on the right side of the figure, and the farside is on the left. The western limb of the Moon viewed from Earth (270^0E) is at the center front. Within Figure 3 of the Moon, Namiki, et al. displayed three basin/mascon designations:

(1) Darkly shaded are Type I basins or basins with a sharp gravity peak with excess mass at the center.

(2) Hatched shaded basins are Type 2 basins that have broad gravity peaks, generating 20^0 to 60^0 less magnitude than Type 1 basins and account for the principal farside mascons.

(3) The dashed lined basins are unclassified. The reader can see the clear difference in the types of mascons that formed on the near vs. the farside.

Some of the significant mascons on the farside, as shown in Figure 3, are Orientale, Smythii and Mendel-Rydberg which wrap themselves around the far to the nearside. Other significant farside mascons are Apollo, Planch, Mendeleev, Moscoviense, Freundlich-Sharanov, Hertzsprung, and Korolev.

6. Do Mascons Exist on Other Rocky Planets?

To this date mascons have been detected on the planet Mars and possibly Mercury (Atkinson, 2008). It seems research is indicating that mascons do not exist on Venus. Peter James of MIT believes that plate tectonics may be unique to Earth and not a rule for rocky planets. James further believes the absence of mascons is consis-tent with the idea that the Venus surface experienced some type of catastrophic overturning about 500 million years ago, and it is possible that Venus periodically goes through a "resurfacing" process. This of course would eliminate any possibility of mascon formation (Bettex, MIT news, 2010). Venus looks as if it has had no plate tectonics and has taken a very different course.

On our home planet, mascons have not been discovered. We know that Earth has had continuous plate tectonics. This convulsive crustal movement on Earth has provided for a more homogenous distribution of dense mass materials destroying the possibility of mascon formation.

7. Mascons and Exploration

The mascons have had dramatic effects during past exploration and will need to be considered in future planning for satellites and manned missions. One example of the effect that mascons can have was clearly demonstrated during the Apollo 11 mission.

In 1969, the Apollo 11 landing module was pulled downrange from its planned landing site by up to 6 kilometers by the mascon Lamont located in the western Mare Tranquillitatis (Dvorak & Phillips, 1979). The module was being pulled off course and over a crater and a field of large car sized boulders. If it were not for the skill of Neil Armstrong who took over the controls of the Lunar Module in the last few minutes of the landing approach, the Apollo 11mission may have ended very differently. This was one of the first dramatic effects of a gravitational anomaly produced by a mascon.

During the Apollo 16 mission in 1972, a small subsatellite (PSF-2) was released for a scientific experi-ment. The satellite was to maintain a low orbit around the Moon. The orbit fluxed widely and the satellite came as close as 6 miles to the Moon's surface and then would return to a safe 30 miles away. After two weeks in orbit, the satellite crashed onto the Moon. The increased gravitational pull of the mascons seemed to have been sufficient to alter the orbit and eventually bring down the satellite.

Trudy Bell reviews the gravitational effects of mascons in her NASA article, Bizarre Lunar Orbits (Bell, 2006). Bell states that Konopliv believes the Moon to be a gravitationally lump place and sites Konopliv saying:

> "The anomaly is so great - half a percent - that it actually would be measurable to the astronauts on the lunar surface. If you were standing at the edge of one of the mare, the plumb bob would hang about a third of a degree off vertical, pointing toward the mascon. Moreover, he further states: If an astronaut in full spacesuit and life support gear, whose lunar weight was exactly 50 pounds at the edge of the mascon would weigh 50 pounds and 4 ounces when standing in the mascon's center."

With the examples cited above, one can clearly see that mascons can create interesting but somewhat benign effects or forces that can be dramatically perilous and must be accounted for as exploration continues.

8. Conclusion

Even with growing knowledge, mascons are still somewhat obscured in mystery. Most scientists agree that the mascons resulted from large impacts on the Moon's surface. The impacts broke through the crust and fractured the iron rich mantle allowing it to uplift. Most likely, the uplifted mantle in the impact basin laid dry for millions of years. Once the lava flows started, they repeated over long periods allowing emplacement of one flow over another with later flows probably emanating from the highlands as demonstrated with Serenitatis.

The uplifted mantle and the lava flooding within the basin are probably collective in producing the mascon strength. However, mascons exist with little if any lava flow emplacement. This fact indicates that mantle uplifting may be sufficient to produce gravitational anomalies.

The similarities and differences among mascons can be striking. Many of these differences are most dramatic as compared to those found on the near and farsides. Still, further research needs to be done to comprehend mascons in all their dimensions regardless of location or geological formation. Some questions about mascons may not be answered until we are able to move about the Moon and conduct the research first hand. Even when that is accomplished, these master-pieces of complexity will still add another dimension in making our Moon a unique and intriguing world.

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Note: this article is online at:

www.moonsociety.org/science/Mascon_Article_Ron_Brooks.pdf

Ron Brook lives near Akron, Ohio and is a candidate for the Moon Society Board of Directors. With his considerable scientific knowledge about the Moon, he has a lot to offer.

Apollo 15, Hadley Rille, and Beyond
Ideas for Encore Missions and Projects

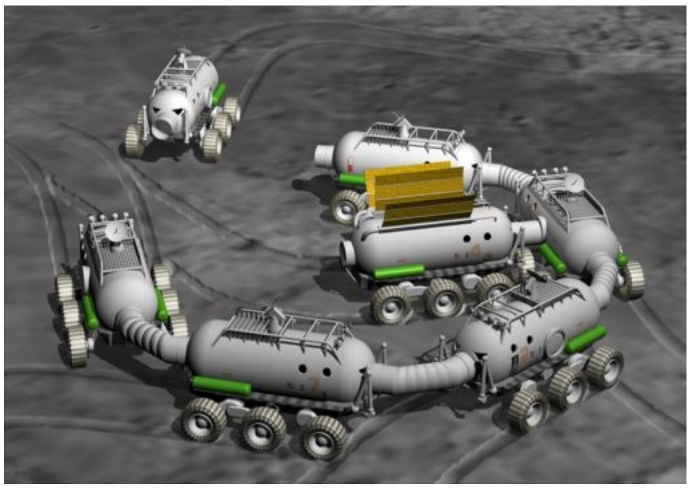
By Peter Kokh

Future Lunar Transports

Apollo 15 was the first Moon mission to include an open, electric "moon buggy" to allow the astronauts to explore farther afield. Given that the chosen landing spot was the first truly scenic and geologically complex area visited to date, this was a very timely inclusion.

In the years since, NASA has tested a variety of successors, concentrating on suspensions, at first. More recently, NASA has been testing a pressurized rover from which astronauts could exit out on to the surface via what I cal "suit-locks" instead of air-locks with their time-consuming pre-breathing process. (Below) More on that in a special article in next month's MMM, #246.

All sorts of utility vehicles will be needed if we are to establish a permanent outpost, not just explore. But there have been studies of mobile outposts where the whole purpose is to explore on the move. (Below)

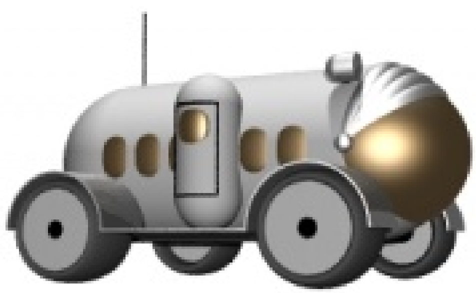


Gathering the wagons into a circle for nighttime camp: straight out of the US Western expansion days in the second half of the 19th Century! There could be a large inflatable for special functions. Unfortunately, to visit a neighbor 3 "wagons" away, you would have to make your way thru the intervening ones!

On the Moon, night does not come on a convenient 24-hour schedule, so perhaps some shading provision should be made when one's 24-hr scheduled "night" is at local "high noon!" It would help with heat management.

For another concept of a "mobile base" on the move, as illustrated by Pat Rawlings, go to:

http://www.moonsociety.org/images/changing/asi200100007.jpg

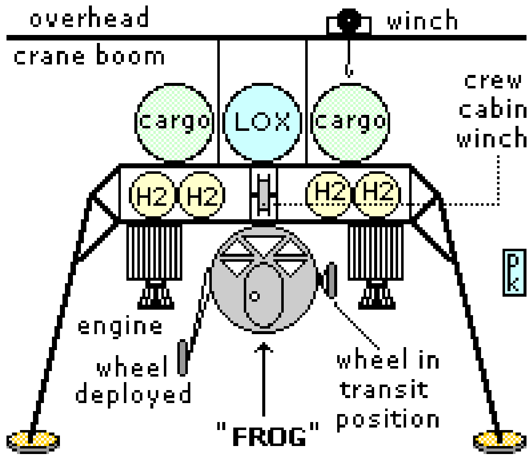


A 15-person Moon bus designed by Gregory Bennett and Shane Pekney for the Artemis Project 1999

For a full set of drawings for this 15-person bus, see: http://www.moonsociety.org/images/changing/asi199900030-33.gif

“Amphibious” Lunar coaches

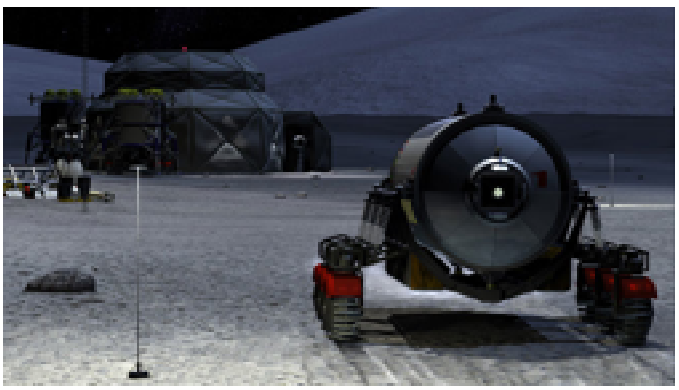
In our 1991 paper on the Lunar Hostel, we introduced the concept of amphibious vehicles, capable of traveling in space and on the lunar surface. The “Frog”



This lander crew cabin, with its own ground chassis, would winch down to the surface, and after its mission was done, winch back up for the ride home. Thus one crew cabin serves as transport on the Moon as well as to and from the Moon. The “Toad” would be similar, but stay on the Moon for the rest of its service life.

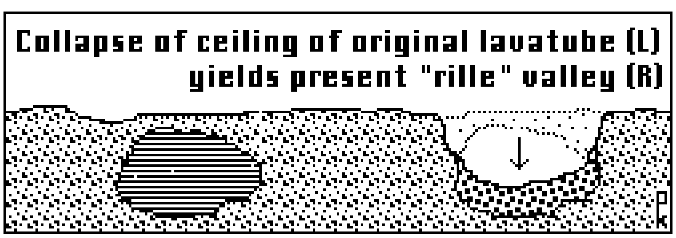
http://www.moonsociety.org/publications/mmm_papers/hostels_paper1.htm

Later, Pat Rawlings developed a similar amphi-bious concept with the chassis waiting on the Moon for the arrival of a lander crew cabin. Lowered on the waiting chassis, it drives to the waiting outpost. An improvement, this universal chassis can fit various width cabins.

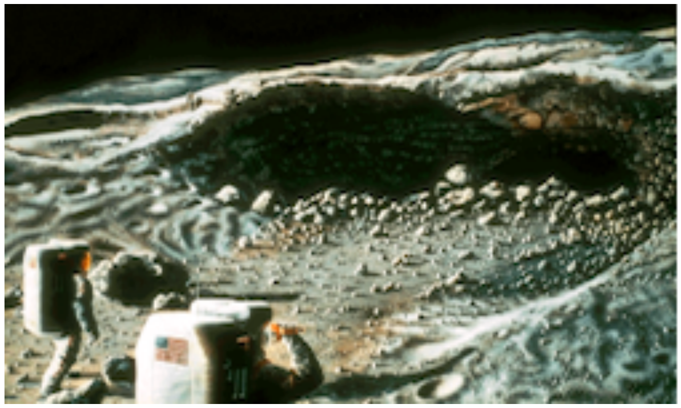


Exploring Rilles

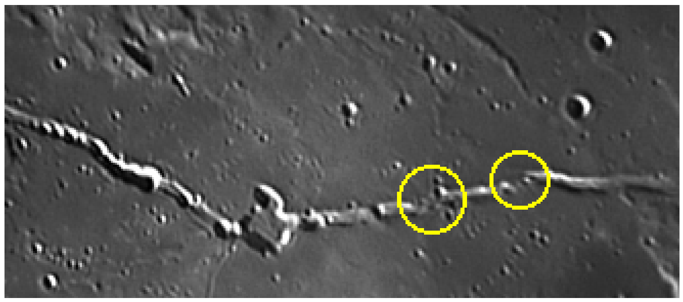
Rilles are universally believed to be the collapsed remains of very large lava tubes whose ceilings were not thick enough to prevent collapse. But there are borderline cases where part of the original tube has collapsed, part remaining intact, and that presents the opportunity to access a lavatube from within the rille. The vertical cross section of a rille depression gives a good indication of the cross-section area of the lavatube whose collapse left the rille as a relic.



BELOW: The classic Pat Rawlings painting that follows shows astronauts gazing at such an entrance, which as collapsed rubble or talus, will be challenging to traverse in order to get inside.



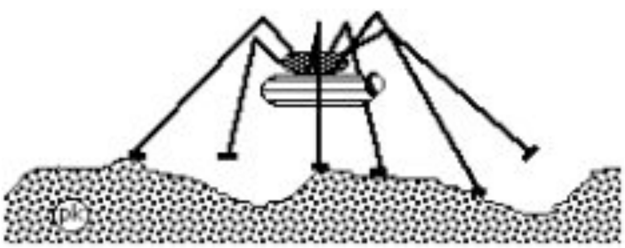
The discovery of spacious waiting shelter! One of the Moon's legendary "Hidden Valleys," a Lava tube!

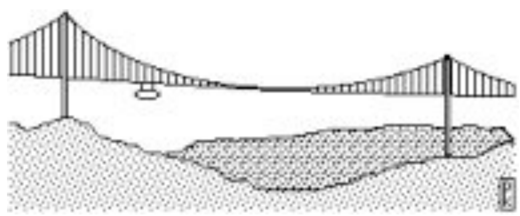


Above: suspected intact tube sections in Hyginus Rille

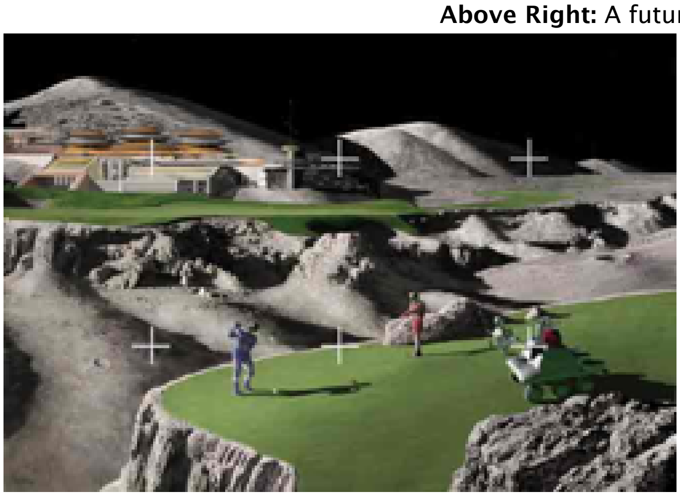
Rilles as Obstacles

We find rilles in the otherwise relatively smooth- and easy traverse lava plains or maria. Some rilles are short, a few miles or tens of miles, but others meander considerably longer. Crossing them could be a challenge. But a detour could mean trips tens to hundreds of miles out of the way**. If we foresee a need to cross such an obstacle repeatedly, we'll have to engineer some way to do that.** A bridge would be warranted only for expected high traffic, however. So what could we rig in the meantime? In the early years? Some rilles are narrow, others quite wide. **This is the subject of one of the design contests announced on page 16 this issue.**





Above Left: a "Daddy Longlegs" spider craft such as we have suggested as the vehicle of choice in many rugged highland areas, would be one way to climb down into a rille and up the other side. Could we program it to return to the first side on its own? Or if we found it parked on the other side, could we signal it to come back to our side and fetch us? **Above Right:** A future solution, once traffic warrants.



Fantasy Golf Course

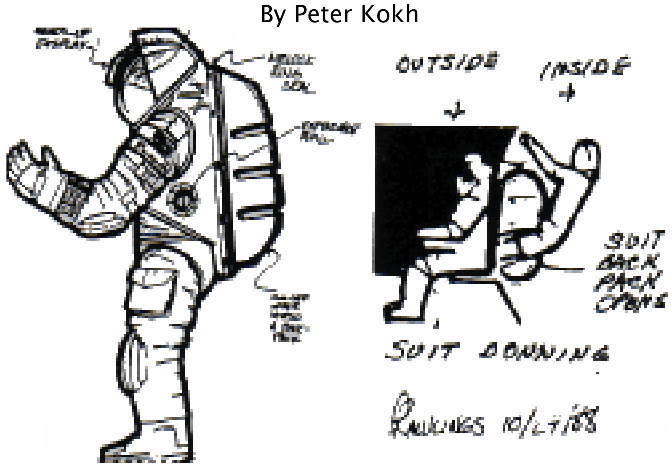
Is it far fetched to think that future scenic drives or parkways or scenic train routes might hug the crests of meandering rilles? Not sure about the green faux turf, but someday, we might go even further, vaulting and pressurizing larger rilles and creating luxuriant green "national parks" within them. Lunar pioneers will need to dream and dream big, and to keep pursuing those dreams. Frontier life is rough, and chasing dreams is essential to eventual prosperity and fulfillment.

At least there is nothing wrong with letting our imagination help us introduce the future bit by bit! Send us/ MMM your own suggestions and designs! **PK**

MMM #246 - JUN 2011

Turtle-back Spacesuits & Suitlocks - Recent NASA Experiments

By Peter Kokh



VIDEO: http://www.wimp.com/lunarrover/

The suit demonstration is 6-7 minutes into 10.3 minute video

Foreword:

NASA is now working to engineer a concept that seems to have originated with Pat Rawlings way back in 1988, and about which we have written several times since then: a minimal air-lock of which the spacesuit itself is an integral part.

We got the idea from a 1988 sketch Pat Rawlings did for the then upcoming made-for-TV science fiction movie "Plymouth" aired May 29, 1991. The concept did not make it into this movie itself, however.

From Past Issues of MMM

MMM #89, October 1995 "**Dust Control: Engineering Counter-measures - Suit-Locks**" - reprinted in MMM Classics #9 pp, 43-44

MMM #151 December 2001, p 3. "**Engaging the Surface with MOON SUITS instead of Spacesuits-** reprinted in MMM Classics #16 pp. 2-4

www.moonsociety.org/images/changing/turtleback.gif

"The idea behind this 'turtleback' or 'clamshell' suit is to avoid tracking moondust into interior spaces without the expense of sizable and complex 'carwash' airlocks. Ideally, the back of such a suit would include the back of the helmet as well. The wearer would back in to a conformally shaped dock, with the suit locking to it. The dock and the suit back would open together into the habitat space, and the wearer would reach up inside to a grab bar and pull him/herself out of the suit. The dock would close and the suit taken away for storage outside as in a dry cleaner rack. Very little inside air would escape in a very tight cycle process."

The whole idea is to conserve interior air by prevent wholesale exhausting into the exterior vacuum by the repeated cycling of airlocks. Not only do we need to conserve oxygen, though it is abundant on the Moon locked into the various minerals in moondust, but even more importantly, the nitrogen component: Nitrogen, of all the major elements needed to support life, is the least abundant on the Moon, present only as a solar wind component. In contrast to "turtle-back" suit-locks, inefficient airlocks would be more expensive to

, and take up a lot more space. This last point is critical for vehicles from which egress to the surface is provided.

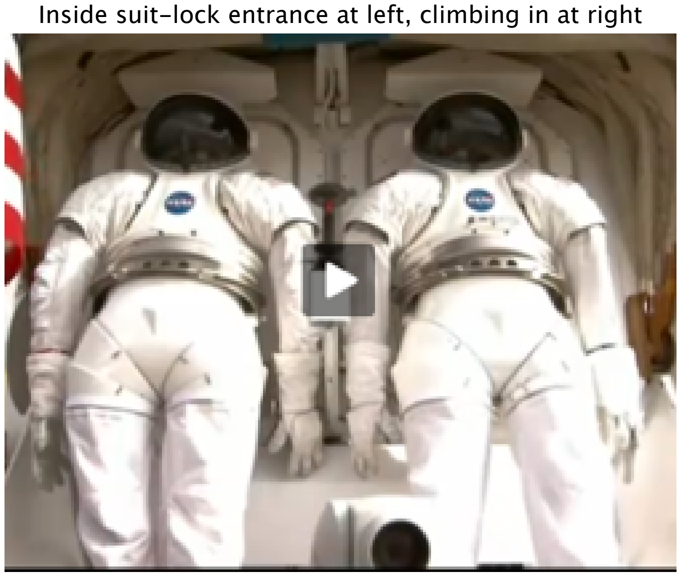
Differences in Rawlings/MASA version from our earlier suggestion

You will notice that in the Rawlings' version, the suitback does not include the back of the helmet; nor does NASA'x new experimental version. We personally think that this makes ingress and egress from the suit more of an acrobatic chore. The advantage is that the wearer can turn his/her helmet side to side, up and down. But with a wrap-around panoramic visor, the wearer's head could turn and tilt freely inside if the helmet was rigid, its back a part of the rigid suit-back. But to see this concept finally taken seriously by NASA is very encouraging. It is a sea-change in suit design that is long overdue.

Stills from the video, showing step by step process:

two empty suits ride on back of rover

Inside suit-lock entrance at left, climbing in at right



From outside, astronaut getting into suit at right

astronaut extending arms into suit sleeves and gloves

suit back has closed, suitlock begins to close, closes

leftt: astronaut ready to leave porch - on foot right

The future of Space-suit design

Previous NASA manned rover research has been concentrated on unpressurized vehicles. But the clear need for more capable pressurized vehicles has forced major rethinking of air-lock concepts. To include the much larger "car-wash" type airlocks that included "de-dusting" operations and suit-storage, would greatly increase the size and cost of surface vehicles.

We predict that as these new suit-lock concepts are perfected, suitlocks will become the obvious choice for fixed moon bases and outposts as well. The plusses overwhelm the minuses:

- **vastly more compact**
- **conserves oxygen**
- **conserves nitrogen**
- **greatly reduces import of moondust in habitat and vehicle interiors**
- **greatly reduces size and mass and cost of vehicles**
- **requires standard backpack, while allowing personally tailored suits**

NASA's switch to this concept will instantly date all past depictions in art and film of what operations on the Moon and Mars will be like. **PK**

Could Some Lunar Lavatubes be Hiding Valuable Resources? Let's Speculate!

By Peter Kokh with input from David Dunlop

Forward [Reprint of an article in MMM #44, April 1991]

For centuries we've realized that the Moon's surface was desert-dry. The first good telescopes had shown the great dark areas hopefully called "Seas" to be really dry low-lying plains (filled with a dry quicksand of dust, many wrongfully supposed). We took it for granted that the Moon had formed wet, as had Earth, and that it its low gravity was insufficient to hold on to its aboriginal atmosphere so that its waters had been lost to evaporation and ultraviolet disassociation.

The findings of the Apollo missions and follow-up studies of their precious hoard of Lunar Samples told another story. The maria seas were really great sheets of frozen lava with the upper few meters pulverized and gardened into a dust blanket (the regolith, a feature shared with highland areas). Moreover, nowhere was there to be found any relics or clues of a past wetter epoch. There is no rusted iron. In fact, even with a gross composition of 42-45% oxygen, the Moon seems under-oxidized. For what iron there is, is either FeO, ferrous oxide (a less oxidized state than our commonplace Fe2O3), or pure iron fines. Nor are there any hydrated minerals or clays, so common on Earth. The Moon had apparently formed hot and dry, quite unlike the Earth, perhaps from vaporized material cast off (but retained in orbit) following a major collision between the forming proto-Earth and a smaller but rival body forming at roughly the same distance from the Sun. One day we may know the 'rest of the story' but this is our current best solution to the puzzle.

What we have found instead, quite by surprise, is a non-negligible endowment of hydrogen atoms (1 ton in a football field sized area 1 yard deep - far less than in Earth's driest desert sands) adsorbed to the fine particles of the regolith 'top soil', apparently a gift of the Solar Wind which has been softly buffeting the Moon's surface for billions of years.

[skipped paragraphs irrelevant to argument]

Yet it has occurred to the writers that there is some possibility, indeed an appreciable chance that vaporized cometary materials have been cold-trapped in places not exposed to the loss mechanisms of cosmic radiation and solar wind gusts. The greatest wave of comet bombardment of the Moon may have been in the formative era. But even in the past 3 plus billion years since the great impact basins were filled with runny lava, an appreciable number of comets (in episodic waves or not) may have impacted the Moon.

The maria are not totally flat, but have a slow gradient, stepped by lava flow fronts, with highest elevations near the source(s) of the magma upwellings. It is in these relatively higher regions of the mare seas that we expect to find lava tubes. Very near-surface [and especially large] lava tubes would have collapsed, and it is probably their relics we see in the many sinuous rilles (like Hadley, visited by Apollo 15). And we see winding 'rows' of rimless sinkholes, which would seem to indicate partially intact tubes a bit deeper below the surface. Here and there, a stray comet might have hit the jackpot, crashing through the roof of a lava tube and vaporizing. While perhaps most of the vaporized material would have escaped out of the impact crater, it is possible some fraction fleetingly pressurized the adjacent segments of the lava tube (too much pressure would only blow out the roof) long enough to freeze out as frost on its floor, ceiling, and walls, at a distance where they wouldn't have been heated by the thermal shock of the impact. Down here, there is no exposure to cosmic rays or errant wisps of solar wind. We may have won the Solar 'Lottery'!

[skipped paragraphs irrelevant to argument]

The technical feasibility of deep-looking radar is quite real. Improvements on the radar that have revealed ancient river bottoms beneath dry Sahara sands, may someday reveal the existence and whereabouts of many near surface lava tubes in the lunar basalt seas. In our earlier article "Lava Tubes" in MMM # 25 APR 1988, we stated our belief that deeper lava tubes may lie in subsequently buried early lava sheets. Many of these may have been later filled and plugged, but some few could remain void. But whatever the case, only near surface tubes could have been entrusted with this gift of the comets. Will such improved deep-looking radar find a few unmistakably ice-walled lava tubes as well as the more common bone-dry ones?

If so, will the frost layers be so diffused and thinned out on the inner surfaces of these voluminous hollow sanctuaries that, scientific treasure trove or not, they won't be economically recoverable? That's a possibility. The history of space development scenarios and speculations has been heavy on overly romantic expectations. Despite the dashing of many naive hopes, from hydrated minerals on the Moon, to lichen covered fields on Mars, the promise of a human-settled inner solar system rooted in the use of extraterrestrial materials, spring-boarding from Earth's ever growing energy thirst, is still concrete enough to keep us planning ways to work with the grain of nature off planet.

Ice encrusted cavernous tubes on the Moon may or may not be found. But if we don't find any, it will be a matter of bad breaks only. Until we've checked our ticket stub, we can't dismiss the not-so-unfavorable odds that we've won this Solar Lottery! < MMM >

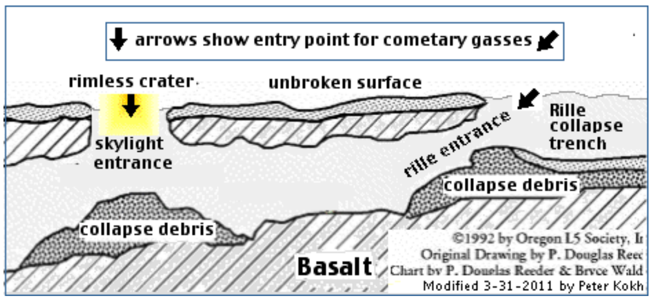
Twenty Years Later – Revisiting the Question
Lavatube Ice Reserves?

Most of us, I suspect, imagine these underground lairs to be nothing but barren, and somewhat boring caverns whose main value is their capacity to shelter extensive human settlements and all the activities that go with it.

Two decades ago, I wondered aloud (in MMM #44 bulk of text reprinted above) if it might just be possible, however low the odds, that a comet small enough not to obliterate a tube, but large enough to penetrate its ceiling with a precise hit, against very high odds, and vaporize with the cometary ices freezing out on the tube's inner surfaces, waiting hundreds of millions of years for some intelligent explorer-settler to discover this treasure. I dubbed such a comet strike "winning the cosmic jackpot."

But now we know that objects, probably small astrochunks rather than comets (but who can be sure?) have penetrated lavatube ceilings in several places on the Moon. And it occurred to me, that even if none of these penetrators was cometary in nature, the very presence of an opening might invite cometary vapors from a nearby strike to wander in, and take up abode. After all, this is how much if not most of the ice deposits in permanently polar craters slowly built up. Comets can strike anywhere at anytime, The sun and the solar wind will work to blow those gases away from the Moon. But if a comet strikes on a part of the Moon experiencing nightspan, and some of the vapors spread to the polar regions before the Sun rises, they are sequestered in these polar cold traps.

Now Chandrayaan-1 and Lunar Reconnaissance Orbiter data both show intact lava tube sections that open onto rilles, the collapsed remnants of once extensive tube sections. These entrances could also be penetrated by cometary vapors.



NOTE: The age of skylight collapse pits could be considerably younger than most rille collapses, thus skylight cometary volatile sequestration should be much less rich on the average than rilleside tube entrances. The former are easier to find at low-res, the latter requiring high-res for confirmation and even for original notice.

But there is a catch to this idea. When it first occurred to me, 20-some years ago the "word" was that we expected the temperatures inside intact lunar lavatubes to be on the order of 80° K, -193° C, -315° F. **But that may not be the case.** There is good reason to believe that lavatubes should be of a temperature that we would expect at that depth below the lunar surface.

Now during the Apollo missions. We probed the surface to a depth of 2 meters, not far, but far enough to suggest that at that depth, the temperature was fairly stable no matter whether the surface above was experiencing full dayspan heat or bone-cracking nightspan cold. While we did not really probe deeper, other evidence suggests that as we go down deeper, we should reach a point at which residual heat from the lunar interior balances any neat heat loss to space over the dayspan-nightspan cycle.

Polar craters are different. They are permanently exposed to the heat sink of cosmic space at a few degrees above absolute zero. Lavatubes are not so exposed, so they will not have cooled down below the temperature prevailing in the surrounding rock

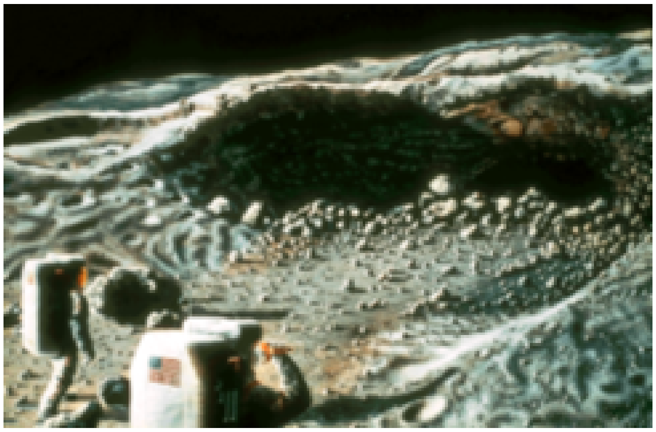
I put the question to **Dr. Alan Binder**, Principal Investigator for the **Lunar Prospector** mission 1998-9, and received the following prompt reply:

"As I state in [my novel] MOONQUAKE (p 170), the temp at 1 meter depth in the regolith is (in the equatorial regions - it will be somewhat colder at high latitudes) -20° C, is essentially constant, and the gradient in the regolith is 1 to 1.5° C/meter via Apollo measurements. Thus at the bottom of a typical 3-5 m deep mare regolith layer the temp is about -15° C.

"Now, the Apollo conductivity measurements were made in the outer couple of meters of the regolith, i.e., not even to the bottom of the regolith, but, we know from the passive seismic measurements that show that the P-wave velocity of successively deeper layer increases dramatically as a result of the decrease in brecciation of the mare basalts with depth. Thus, the thermal conductivity must increase and the thermal gradient will decrease with increasing depth.

"But right now, we do not know how much. Clearly, the deeper a lava tube is, the hotter it will be --- but right now we have no good data to tell us the gradient. Lets say a tube were 100 meters deep and the gradient is 0.1° C/meter, the tube temp would be say +5° C. But as you can see, until we know the latitudes' depths and the temperature gradients as a function of depth, this is just a game of rough estimates."

This argument explodes the previously heard expectation that Lavatubes would be cryoenvironments, cold enough to preserve refrozen cometary ices indefinitely.



The classic Pat Rawlings painting above shows astro-side. Now we know that they won't need ice-picks or ice skates!

Oh how reality has a way of dashing one's favorite expectations. If cometary ice were available at lavatubes far from the Moon's poles, the prospects for early settlement in those areas would have been much brighter.

As usual, simpler understandings give rise to expectations that are dashed by more complete knowledge.

What about volcanic gasses?

We now know, or suspect, that lunar volcanism may have been far wetter than previously expected, that the Moon did not form "bone dry." So in lavatubes that remained plugged at both ends, could there be trapped volcanic gasses of economic value? Sulfur, carbon, nitrogen, and hydrogen oxides? In a world where the key elements of organic chemistry are extremely scarce, such underground reservoirs or gas traps could be game changers.

Now to be fair, we can't yet pinpoint the location of lavatubes that are wholly intact, only those that have been compromised by skylight collapse pits or rille collapses. But even in these tubes open to the outside vacuum, if there had been some volcanic gasses, there might be residual traces left that could be detected and analyzed by sophisticated equipment.

This is certainly more than just an interesting question, it is one of potential great economic significance. On the downside, the surrounding basalt is likely fractured, allowing some slow seepage of such volcanic gasses to the surface to be blown away by the solar wind. But in cases were seepage has been at a minimum, what kind of pressure (and density) might we expect? Could some such deposits be of economic significance? We will never know if we never probe further.

Volcanic gases on Earth:

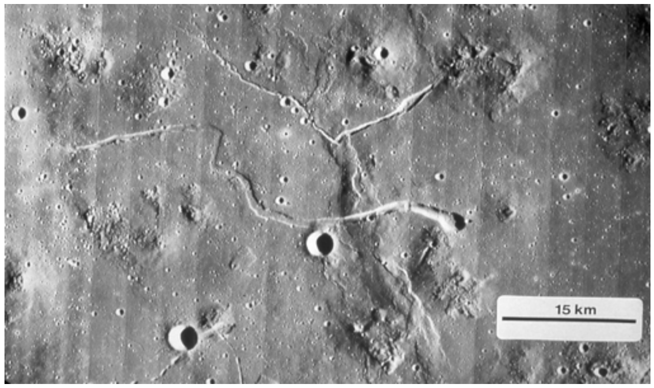
The principal components of volcanic gases are water vapor (H_2O), carbon dioxide (CO_2), sulfur either as sulfur dioxide (SO_2) (high-temperature volcanic gases) or hydrogen sulfide (H_2S) (low-temperature volcanic gases), nitrogen, argon, helium, neon, methane, carbon monoxide and hydrogen. Other compounds detected in volcanic gases are oxygen (meteoric), hydrogen chloride, hydrogen fluoride, hydrogen bromide, nitrogen oxide (NO_x), sulfur hexafluoride, carbonyl sulfide, and organic compounds. Exotic trace compounds include methy-lmercury, halocarbons (including CFCs), and halogen oxide radicals.

The abundance of gases varies considerably from volcano to volcano. However, water vapor is consistently the most common volcanic gas, normally comprising more than 60% of total emissions. Carbon dioxide typically accounts for 10 to 40% of emissions.

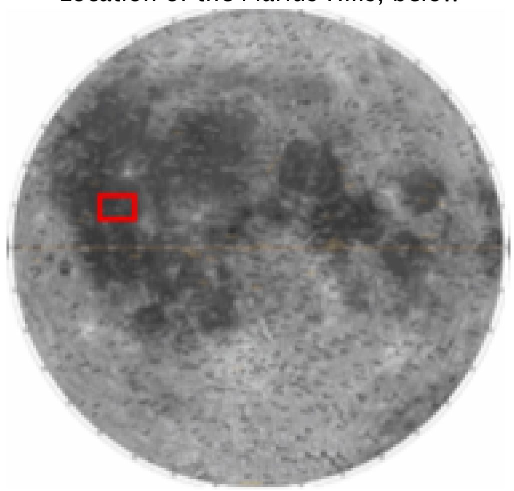
http://en.wikipedia.org/wiki/Volcanic_gas

Now until recently, the prevailing dry-Moon hypothesis strongly suggested that there would be no water, water vapor, or hydrogen in lunar volcanic gas. But given the findings of Chandrayaan-1 and other recent probes, this expectation has turned on its head. But without any experimental evidence we have no idea how "humid" lunar volcanic gases may be.

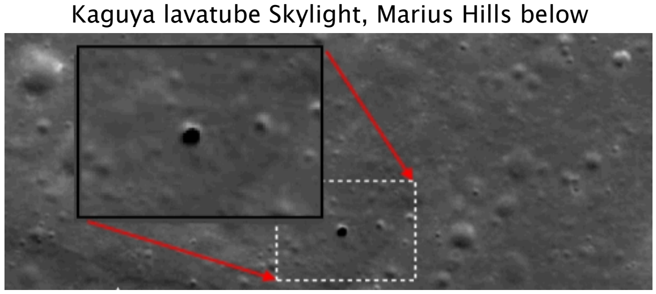
Instead of turning its back on the Moon, one would think that the agency would be working diligently on a mission to probe the Marius Hills area of Oceanus Proccellarum, the "Ocean of Storms" where there is much evidence of past volcanic activity, a number of suspiciously volcanic "domes," and a confirmed lavatube skylight!



A section of the Marius Hills: rilles, domes, etc.
Location of the Marius Hills, below



Kaguya lavatube Skylight, Marius Hills below



What are people in Washington thinking? But we already know that the political process is rarely moved by reason. Rather by "how many jobs will it bring to my district?" or "How will this help my re-election chances?"

What's at Stake

At present, these are just interesting questions, and it is frustrating, that even if the Obama Administration had not altered NASA's course, that the agency had no specific plans, at least none announced or even proposed in the public domain, to begin any kind of lavatube exploration. Why? NASA is driven by scientists rather than by potential settlers, and a determination of resources of economic value to settlers is of little interest to many if not most of them. This is a case of impatient shortsightedness, as there will be far more science done on the Moon if it is settled, by the settler population, than will ever be done by scientists from Earth, returning to Earth, laying no foundations., only interested in publishing arcane papers.

The Good News

There is a trade-off and something in our favor. If Lavatubes were truly cryogenic environments, heating settlements and factories and agricultural areas within would be a major challenge. That they are nonetheless below room temperature is also good. All human and industrial activities create heat, and if these tubes were any closer to room temperature, we would have a major problem in shedding excess heat.

So while we may not find much ice, if any within these voluminous "Hidden Valleys" and maybe precious little in the way of volcanic gases (we expect this to vary widely from tube to tube so it's definitely worth exploring them all) we are still blessed with a world well-endowed with these spacious pre-shielded environments that will make "settling in" on the Moon in a major way much more feasible. Again, it is the nearside maria, not the poles, where the bulk of Lunans will live and work. **PK**

Most Popular Souvenir from the Moon?

By Simon Cook

Now wait a minute! Bringing home a try of moon dust with one's boot print sintered in to keep the shape forever is going to be expensive. While it would cost much less fuel to bring such a thing back home than to bring something of equivalent mass to the Moon, it will still cost extra fuel and something this large might not be part of your "allowance." (Unless you earn points by being "underweight" in the first place! Hmmm?)

As proud a specimen and souvenir as a real boot print would be over someone's mantle, few will be able to fork up the cash. And a photograph won't quite do it.

Here is a compromise idea. A bootprint, yours, is scanned in 3-Dimensions on the spot, along with its surroundings, say a 1 foot by 2 foot area. You take the scan home with you on a CD (or its successor medium) or have it sent home to you by email. On Earth, a company takes the scan and faithfully reproduces your bootprint in your choice of media, some more expensive and realistic than others, and you have this as a faithful copy, fixed dimensionally so that it can't be disturbed or lose the fidelity of shape and detail in any way. Now you can hang it over your fireplace or plasma screen without any dust coming off, as the trophy it is.

Here is one way companies on Earth can cash in on early lunar tourism, perhaps offering a variety of moon dust simulant for the cast. And that day is coming sooner than you think. If Space Adventures doesn't sign up a $150 million dollar tourist for the second seat on the Russian Soyuz first loop-the-Moon tour, Space-X might beat them to it with lower prices.

Of course, you will come home with photos and videos as well! But your recreated 3-dimensional boot print would be special. **SC**

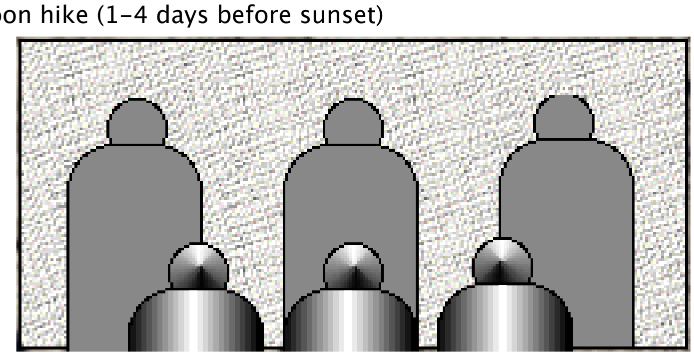
How to go for a nice Walk on the Moon - and not get lost!

By Peter Kokh, Wisconsin Northwoodsman

May 17, 2011 outside Florence, WI – This morning my 9-year old "alley" shepherd (va)Nessa and I went for a long walk along a dead end country road, facing east towards the sun, but then returning through the woods west-bound. While we were walking back through the woods (Spring is best, before the trees are too leafed out, so that the sun gets through), it occurred to me that my Northwoods instincts might work on the Moon.

Always keep the sun to your back
and follow your shadow.
You won't get lost or go far astray!

Now on the Moon, the "Dayspan" is 14 and 3/4 of our 24-hour Earth days long. So my advice is to pick a destination towards the west (WSW-W-WNW) for an early morning walk (1-4 days after sunrise) and towards the east (ESE-E-ENE) for a late afternoon hike (1-4 days before sunset)



Now to return, if you don't want to wait a week or more until the Sun-angle is just right for following your shadow, you can follow your bootprint trail – if – and this is a very big "if", you walked through "virgin" territory, and there are no other boot-prints but yours. But that's risky, as someone may have crossed your path since you made it, and then you could get confused. It is better to wait to follow your own shadow!

Dress for comfort

Don't wear a NASA-Apollo suit designed for maximum fatigue in the minimum amount of time. The traditional "spacesuit" combines two separable functions in one garment: (1) maintaining breathable air pressure, (2) protecting from thermal extremes and punctures from sharp rocks and from the constant dust-particle size micrometeorite rain. Instead, a **mechanical counter-pressure "skinsuit"** will allow you to breathe and yet move your arms and legs much more freely. Then don **a loose outer suit** with the same layers as an Apollo suit, to provide the needed puncture resistance without encumbering motion and tiring you out prematurely. Then with water and air supply, you should be able to walk at ease for many hours, thoroughy enjoying your sense of freedom during your walk on the Moon, "as if you were at home on Earth." What an achievement!

[See **MMM # 238** Sept 2010, pp. 4-5 "**A Fresh Look at the Spacesuit Concept**"]

Now as to bringing your dog along, in an equally comfortable 2-part suit, he or she might get frustrated, as bending down to sniff rocks but unable to sense any odor will disappoint and confuse them. And for a male, trying to lift a leg and mark his territory will only make one leg of his suit very, warm and wet. Maybe in time he would stop trying. Maybe a custom-made fitted urinal bag? Hmmm! I smell a lunar patent!

Yes, there are many areas of the Moon that are very boring, especially out on the maria (Tranquility Base) but areas in the highlands or along highland-mare coasts, or along rilles and scarps could be pleasantly scenic. And just knowing that you are the very first human to pass that way could be especially rewarding (look, ma, no bootprints but mine!) Not all humans enjoy a quiet walk in a nature setting all alone, communing with nature, with themselves, while deep in thought. But perhaps you are one of those like me, for whom there is a special bond with the raw outdoors and nature, best enjoyed alone, even though we may want to share this experience with another on a return trip!

PK

MMM #247 – AUG 2011

Moon Mining Machines: a Materials Challenge

By David Dietzler

Editor: Dave sends submits this article with a note:

> "I hope it gets the point across to the reader that we need to start looking at things built for the Moon and on the Moon of lunar mats rather than continuing to design ultra-light aerospace grade payloads that are rocketed to the Moon."

I have the utmost respect for Matthew E. Gajda, his associates at the University of Wisconsin, and their Mark 3 lunar volatiles miner designs. See:

http://fti.neep.wisc.edu/pdf/fdm1304.pdf

I have no doubt that this will evolve into even better machines in the future. We really have no other design for a Moon mining machine to base any projections on. However, the design relies on materials li-6Al-4V, Ti-6Al-6V-2Sn, Molybdenum alloy, stain-less steel and carbon-carbon that are not to be had on the Moon. In the future, we need to see designs for vehicles, mining machines, even trains based on lunar available materials. Tin, vanadium, zirconium, and molybdenum are not available on the Moon unless we rocket them in at great cost. Chromium and manganese are present in regolith but not in large concentrations. Carbon in the form of solar wind implanted volatiles and possibly from polar ices will be needed mostly for life support systems and what little there is for Indus-trial uses will be needed for tool steels, electric motor winding insulation and silicone lubricants.

The lunan engineers will have to figure out how to build things from straight titanium, titanium-aluminum alloys and titanium aluminides. There will be plain aluminum, aluminum-silicon alloys, and aluminum alloys with various amounts of magnesium, manganese and chromium. Magnesium can be alloyed with lunar aluminum, silicon, manganese and possibly thorium. These aren't the best alloys but they will have to do. Nickel might turn out to be the lunan engineers' savior. Carbon free **maraging steels** can be made by alloying iron with 18 to 25% nickel.

http://en.wikipedia.org/wiki/Maraging_steel

There is very little nickel in regolith, but it is easy to extract. Meteoric particles containing 5% to 10% nickel are present in regolith at concentrations of a few tenths of a percent. These can be extracted magnetically extracted by harvestors that process millions of tons of regolith every year. The nickel can be separated from the meteoric iron with carbon monoxide gas or by electrodynamic devices similar to mass spectrometers. There won't be much cobalt, niobium or molybdenum for maraging steels but there should be plenty of titanium and some chromium with which to alloy them.

At www.makeitfrom.com/data/?material=Maraging_Steel we read,"C-type grades contain cobalt, which is the main strengthening agent in the alloy. T-type grades contain no cobalt, and use titanium in the same role. Despite significant differences in composition, mechanical properties do not vary significantly between the two types:

(1) used in rocket parts, recoil springs, landing gear components, high-performance machine parts (including shafts, gears, and fasteners), and

(2) in extrusion and casting tooling."

Vacuum welding will be a problem that Lunan engineers will have to deal with. This can be prevented by making metal parts that come in contact out of dissimilar metals with different microcrystalline structures. So we might see titanium gears bolted in with maraging steel bolts and combinations of intermeshing maraging steel and titanium gears. Solid lubricants can also prevent vacuum welding, but molybdenum and tungsten for sulfide solid lubricants are lacking on the Moon. We might make do with cheap iron sulfide.

Pure iron might be used for low stress applications but otherwise won't have much use in machinery. Iron-aluminides are very strong and corrosion resistant but lack ductility. Magnesium might be used for reflectors and low stress applications that demand low weight. Glass fibers, glass cloth, and glass-glass composites might find uses (e.g. farings, coverings). Basalt might be used for its high abrasion resistance. Tubes that convey regolith and basalt coatings on mining buckets come to mind. Basalt is very hard but brittle. A basalt-coated bucket handling powdery moon dust should be okay unless it hits a rock and cracks.

Many terrestrial exotic alloys are made for high strength and lightweight for aircraft applications. This won't be so important on the Moon when it comes to ground vehicles and mining machines. Earthly alloys are also made for high temperature operation in jet engines and internal combustion engines. There won't be many combustion engines on the Moon, with the exception of Moon made rockets. Mining machines will use electric motors cooled with sulfur dioxide gas perhaps and the highest temperatures they will encounter will be about 250 F. during the lunar day.

Corrosion resistance won't be that important on the airless, dry, salt water free Moon. Exceptions to the above statements will be volatiles miners that have to heat regolith up to 700 C. to unleash solar wind implanted light elements in the form of $H2O$, CO, $CO2$, $CH4$, $N2$ and He. If sulfur is to be extracted thermally, higher temperatures will be needed and the possibility of sulfuric acid formation arises. Iron and nickel aluminides might be used instead of stainless steel in volatiles miners.

Engineers determine the stress on parts in machinery and figure out how stout a part made of a given alloy must be. They will have to "beef up" parts made of any "second-best" alloys producible on the Moon. This would not be good for a machine that is to be rocketed up to the Moon because mass must be kept low; but for machines made on the Moon, weight won't be an issue. It might even help to make lunar machines more massive so they can get more traction in low lunar gravity.

Machinability, weldability, ductility and ease of forming are also factors that engineers consider when they select materials. We can only hope that Lunan manufacturing engineers are able to figure out how to work with lunar available materials. Commercially pure titanium is said to be easily formed. I am not a metallurgist or engineer, but I've heard repeated complaints from an engineer friend about the problems with welding Ti-6Al-4V in a vacuum. It seems the aluminum boils out of the alloy.

The bottom line is this: We can land 1,000 tons of cargo in the form of 100 Mark 3 or more advanced Mark 4 or Mark 5 miners at ten tons each - or we can land 1,000 tons of production machinery and bootstrap up factories for making as many volatiles miners, excavators, bulldozers, slushers, drag lines and other equipment that we want. If these Moon-made machines have to be twice as heavy using thicker parts made from weaker lunar materials instead of exotic alloys available on Earth - it just won't matter. The cost of rocket transport from Earth will always be higher than making things on the Moon once industrial infrastructure is built there, or so we reckon.
The umbilical cord to Mother Earth has to be cut. DD

Star Trek Replicators for Spaceships, Outposts

http://www.youtube.com/watch?v=ZboxMsSz5Aw

Enthusiasm about this process needs to be tempered with reality checks.

Plusses - you get what you need right away.' The data needed can be sent from Earth at the speed of light.

Minuses - You have to have the powder supply - and if you can't produce that from materials where you are, you must import it, and that takes time and money. if it is not included in setting up your post.

On Mars, you may be able to make such powder on site if the secret ingredients are each easy to extract from the atmosphere or marsdust where you are.

On the Moon most likely this powder must be supplied before hand, so this would be more expensive than just shipping replacement items, but can be done in anticipation of needs.

This works for items whose need is unanticipated. But is not a way to cut overall imports. While the powder can be more expensive than the parts them-selves, the advantage is instant manufacture when needed, avoid having to wait until the next rocket from Earth can be scheduled etc.

Now if we can print out of a "powder" easily produced from easily extracted elements common in moondust anywhere, then we will be in business.

Relevant Links: http://boingboing.net/2009/04/09/homemade-3d-printer.htm

Lunar Iron and Alloys of Iron

By Dave Dietzler

(Continuing the thread from the article above)

Also of interest are iron-aluminides. These contain 10-30% Al by wt. and have excellent corrosion and oxidation resistance similar to stainless steel. They have also been under investigation for high temperature mechanical properties. At lunar day span temperature of 123 C. the Fe-Al alloy designated FAS (15.9% Al, 2.2% Cr, 0.01% B,) has a UTS of 109,000 psi with an elongation of 15% and a yield strength of 42,000 psi. [3]. Aluminum and chromium are present on the Moon. Boron is rare. Note than only 2.2% of this alloy consists of chromium, while stainless steels contain 10 to 25% Cr. This alloy is stronger than cast iron or cast titanium but lacks ductility and toughness.

In conclusion, it is evident that although the Moon is lacking in carbon for the production of steel making it practical to produce steel by the crucible or cementation process on the Moon only in small amounts when no other material can substitute (e.g. tooling), there are numerous iron alloys that can be produced with lunar available elements. Lunar industry will not rest on steel as does Earthly industry. It will rest on metals like aluminum, magnesium, titanium, iron and alloys of iron.

ALLOYS OF IRON

Name	Composition	Properties	Uses
Ingot iron	Pure industrial grade	Ultimate tensile strength (UTS) 42-48,000 psi elongation (el) 22-28%	Structures, beams, plates
Iron whiskers	Single crystal	0.00004 in. diameter UTS up to 500,000 psi	Structures, electronic parts small powder metallurgy parts
Iron powder	C and S free	10 to 40 micron powder	Propellants,
Iron-silicon	4.5% Si	50-60,000 psi UTS el 8-22%	Structures, beams motors, transformers
Iron-nickel	47-55% Ni	UTS 70-90,000 psi el 30-50% nickel increases strength w/o loss of ductility	Structures, containers
Iron-titanium	Eutectic solutions	Increased hardness and strength	Structures, containers
Iron-manganese	1% Mn	UTS 60,000 psi, el 40% Mn increases strength and hardness	Structures, beams

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In conclusion, it is evident that although the Moon is lacking in carbon for the production of steel making it practical to produce steel by the crucible or cementation process on the Moon only in small amounts when no other material can substitute (e.g. tooling), there are numerous iron alloys that can be produced with lunar available elements. Lunar industry will not rest on steel as does Earthly industry. It will rest on metals like aluminum, magnesium, titanium, iron and alloys of iron. **DD**

Our Planets may be the offspring of a tryst between ProtoSun and another protostar

By Peter Kokh

The consensus from time immemorial has always been that the Sun and our family of planets from Mercury out to Neptune formed from the same rotating disk of gas and dusk, the Sun forming at the center and the planets at intervals further out in the condensing disk. Suddenly, there is an unexpected mismatch in the solar and planetary "DNA" so to speak. The percentages of the isotopes of Oxygen and Nitrogen in the planets do not match those in the Sun. At this stage, everyone is perplexed, if not taken aback.

We propose a simple scenario whereby this might have happened. The disk of matter around our protostar, the condensing Sun, intersected the disk of gas and dust in the process of forming another solar system. The two embryonic stars did not touch or exchange matter, but their two surrounding disks did, and in the process exchanged gas and dust, each disk peppering or seasoning the other with their unique signatures of elemental and isotope ratios.   Here is what that tryst might have looked like.

Would such a sexual stellar encounter been unique? Consider that many stars are formed in clusters as the host gas cloud forms little eddies that begin to condense. In such stellar nurseries, near passes and actual collisions with an exchange of dust and gas may be relatively common. While all the stars forming in a cloud may have similar characteristics, if the cloud is not homogenous in its composition throughout, systems with "mixed genes" may occur.

Above: The famous Pleiades cluster of young stars – **Below:** This stellar "nursery" is the famed Lagoon Nebula

In MMM #MMM #61 December 1992, page 7,

[MMM Classics #7, page 5 – a free download from www.moonsociety.org/publications/mmm_classics/]

We ran an article with the title "Heliades Cluster" which posed the possibility that the Sun was not an only child but may have been born in a cluster. Helios being the Greek word for "Sun" we dubbed our hypo-thetical birth cluster the Heliades.

Since the Sun and our Solar System were born 4.5 billion years ago, we have circled the galactic core perhaps 18-20 times, and any differential velocity and vector between the Sun and its hypothetical cluster-mates may well have dispersed them so widely that we would be fortunate to identify any solar siblings.

The Evidence

So what is this difference in isotopes? The article we saw was this, dated June 26, 2011.

http://www.enewspf.com/latest-news/science-a-environmental/25123-**nasa-mission-suggests-sun-and-planets-constructed-differently.html**

"Researchers analyzing samples returned by NASA's 2004 **Genesis mission** have discovered that our sun and its inner planets may have formed differently than previously thought. Data revealed differences between the sun and planets in oxygen and nitrogen, which are two of the most abundant elements in our solar system. Although the difference is slight, the implications could help determine how our solar system evolved. We found that Earth, the moon, as well as Martian and other meteorites which are samples of asteroids, have a lower concentration of the O-16 than does the sun," said Kevin McKeegan, a Genesis co-investigator from UCLA, and the lead author of one of two Science papers published this week. "The implication is that we did not form out of the same solar nebula materials that created the sun -- just how and why remains to be discovered."

And so we propose the scenario above. As a rule the most probable hypothesis is that for which the odds are the highest, and the explanation the simplet. We think we nailed it, but it will be interesting to see what other hypotheses surface and if there is any way to settle the question with a high degree of confidence. We are all interested in our ancestry, and that goes for out solar system too. **PK**

MMM #248 – SEPT 2011

IN FOCUS The Moon: What's in it for Earth?

By Peter Kokh

, To most people, the Moon is a pretty sight, even romantic, but otherwise quite irrelevant. We need to show them how and why it isn't so, that opening the Moon is very relevant to us all. To do this, we need to we need to firm up our own understanding of "**What's in it for Earth?**" Below are some key talking points. We may add to this list, and we will expand on each in upcoming articles, starting in this issue.

• **Continuing our Frontier-opening saga:** Humanity's "home world" is Africa. Over more than a hundred thousand years, we have expanded to one continent after another. This expansion has increased our cultural diversity, and, more importantly, our capacity to adapt to frontiers with differing sets of resources, and different plant and animal species. This Epic has demonstrated the all but unlimited capacities of the human endowment to adapt. In many ways, the Moon is just another continent across another kind of sea, and it is part of Greater Earth. Not to open the Moon would become humanity's first significant failure.

All past generations of youth have enjoyed the options offered by new frontiers. Do we have the right to close the frontier door for generations of youth to come?

• **Booster shot for World Economics:** The Moon is the ideal and most environmentally friendly source of raw materials with which to realize the maximum economic potential of GEO, already a significant contributor, nearing $300 Billion a year, to the world economy, through various kinds of satellite operations.

It would take 1/23rd the rocket fuel to bring needed materials down the gravity well to Geosynchronous orbit as it would to bring them up the well a much shorter distance from Earth – and without the air pollution so many rockets might create.

• **Technologies for Healing our Environment:** Sadly, to many people, the ever-increasing degradation of our environment is not a pressing concern. Yes, we worry about passing on to our children a shattered economy, but not about passing on a shattered environment.

There are several ways in which opening the Moon can help on both fronts. On the Moon, pioneers will live "downwind and downstream of themselves." There will be nobody else's back yard to dump in. The pioneers will have to learn to live in harmony with nature within their mini-biospheres under pain of death. We can learn from them what we would never bother to learn for ourselves because we do not feel the ill effects of our bad stewardship in the near term.

• **Zero-G Exports from Lunar bases and settlements:** Some, many in fact, doubt the economic feasibility of developing usable construction materials from moon dust. Not only has most needed research into lunar on location materials languished in the early theoretical stage, but little homework has been done on a step-by-step process to "bootstrap" lunar industries, except by the Moon Society's St. Louis Think Tank.

Be that as it may, there are some "Lunar Exports" that are immaterial but still of significant economic value. And we take this up in this issue.

The bottom line is that the answer to "the Moon, what's in it for Earth?" is "one heck of a lot!" **PK**

Marketing the Moon

By Ken Murphy

The Moon occupies a strange place in space activities. Astronomers aren't particularly fond of it, as its light and size makes some observing difficult. Solar system scientists got some Moon science as part of their foundation in planetary geology, and so think they know all there is to know about the Moon.

Politicians crafting space policy are generally more concerned with their legacy than crafting a national policy that enables commerce and development, and so are focused on firsts – the biggest rockets, new locales (asteroids, Mars), things that haven't been done before, and the Moon offers few such opportunities. The deck is stacked against our Moon throughout society, and so The Moon Society has a quite a task for itself – advocating for people living and working on the Moon – when the populace, globally, is largely ignorant of the potential.

When a company faces the problem of having a phenomenal product to sell to an audience largely ignorant of the opportunity available, it calls in the marketers. Since The Moon Society (TMS) doesn't have a corporate budget, it has to rely on the efforts of its members to spread the word.

The problem we face is a populace largely ignorant of space activities in general. In the K-12 educational system, the middle school years (6-8 grade, varies by region) are typically the last time space is taught as a topic.

Very few are the high schools that might have a space class. The last opportunity for most folks is an Astronomy elective in college, and there are other 'science' electives that require less math.

So, in general, the bulk of the population has something approaching an 8th grade level of know-ledge about space, 'supplemented' by what appears in the popular media.

Ignorance can be cured by knowledge

The situation is not entirely grim, however. Ignorance can be cured by knowledge, and is a fertile breeding ground for curiosity. It is this curiosity that The Moon Society will seek to tap into, by providing the knowledge that sates that curiosity.

1. Revamping our website

There are a couple of ways of doing this. The TMS website contains a wealth of knowledge and information, and is currently undergoing a revamp to organize the information in ways that make it easier to find. To that end, please forward all suggestions to

president@moonsociety.org

2. What Chapters and individual members can do

Another way is for TMS members and chapters to get organized in arranging talks and lectures about the Moon in their communities. One way the Society can help chapters in this regard is to provide a set of prefabricated PowerPoint presentations on several Moon topics.

Then, at the TMS website, a member would be able to go to the chapters section and find some presentations and helper scripts on:

- Moon 101
- The Moon & Science
- Moonbases
- Cislunar Space
- Moon Exploration

[See this month's In Focus editorial above for additional ideas]

3. Finding Audiences

With these presentations in hand, members would be able to go to local libraries, community centers, and other locales and give educational presentations about the Moon. This approach faces the ignorance problem head on overcomes it with compelling facts and info.

Each presentation would be 20-30 slides: very simple; mostly imagery with a few bullet points. The details would be provided in the helper script.

- Moon 101 would provide a simple overview of the basics of our Moon, but in sufficient depth that people leave with excitement about what they've learned.
- The Moon & Science would be largely driven by the NRC's 'Scientific Context for the Exploration of the Moon' from a few years ago.
- Moonbases is of course where TMS would shine, and could start making business cases for the Moon.
- Cislunar Space would provide filler, so to speak, on the space that lies between the Earth and Moon, all of the space assets that lie therein, and transporta-tion strategies.
- Moon Exploration is where we would cover the history of exploration efforts, and more importantly, their future.

Moon Society members are encouraged to participate! This can be done in several ways:

- Contributing slides and suitable artwork
- Contributing helper script (with sources noted)
- Knitting together the presentations
- Reviewing the presentations for accuracy

Providing these tools helps to facilitate efforts to inform the public about the Moon and why it is important. It also helps set the stage for The Moon Society to become increasingly recognized as THE place to go for Moon information.

Do your part to make it happen. **KM**

NOTE: Existing Moon Society presentations (whch do not cover the above basics) can be fond at: http://www.moonsociety.org/presetations/

The following article touches on options that may push some buttons among the thoughtful.

The Moon: What's in it for Earth? Part I
Zero-G Export$ from Lunar Outposts & Settlements to Earth

By Peter Kokh

Many space enthusiasts are skeptical about the economic feasibility of producing anything on the Moon to send back to Earth. That's another article, but read pages 6-8 for clues. Here we want to cite those products that "ship free". Know-how processes and technologies that could be developed on Earth, but will not be, as the perceived need is less urgent.

• Environmental technologies developed first on the Moon where the urgency is immediate

Lunar Pioneers will learn to live in harmony with Nature within their mini-biospheres, and learn fast, because they have no choice. They will be "living downwind and downstream of themselves" and there is nobody's back yard to dump pollutants, especially organic compounds made of elements scarce on the Moon. The processes and technologies they develop, because they have no choice, can then be exported to Earth and as they are adopted on Earth, make a very critical and significant contribution to the preservation of Earth's fragile environment for future generations.

These technologies will include stale air and used water treatment, products and new production processes that make "total recycling" feasible and easy. They will also produce a mindset, beginning at a very young age, of ingrained personal responsibility to preserve their fragile mini-biospheres.

• Moon-appropriate building materials and variants that could find a niche on Earth as well:

As so many of the materials that we use on Earth include chemical elements rare on the Moon, we must make do with substitutions. Glass-glass compo-sites ("glax") is a promising area of research in which only minimal demonstrations have been done to date. We might make habitat modules, furniture, vehicle bodies, and other useful products form this material, which could be pre-developed here on Earth as it has advantages such as a substitute for wood. Read:

http://www.moonsociety.org/publications/mmm_papers/glass_composites_paper.htm

New types of concrete types; new metal alloys that do not use alloy ingredients rare on the Moon such as copper, zinc, even carbon, are some options. Once developed on the Moon where the need is urgent, such materials may well find a market on Earth in nations less well endowed with mineral wealth.

• **Technology options using elements not rare on the Moon** (i.e. excluding elements rare on the Moon)

Even given confirmation of surprisingly large quantities of water-ice in permanently shaded craters at both lunar poles, and recent evidence of unsus-pected quantities of water bound up in lunar materials in micro-drops, water will be harvested with much greater effort on the Moon than on our water-rich planet. New ways of conserving water and recycling it with ever-greater efficiency will be an effort that is pursued religiously as need grows with population.

As to mining, pioneers will treat the tailings with respect, as they are necessarily enriched in all elements not yet extracted. When no more elements can be affordably extracted, pioneers will find ways to turn these last-generation tailings into products that are useful. And some of the technologies and processes so developed will help reduce our "trash problems" here on Earth. The "**throughput**"* footprint of the settle-ment is thus reduced, with the result that population for population, the lunar landscape will be far better preserved than has Earth's been. And perhaps some of these technologies applied on Earth could in time "recover and restore" significant portions of industry- and wastes-wrecked lands here on Earth.

* The percentage of raw materials mined that ends up in landfills as a negative indicator

To conserve energy, lunar industrial parks may be arranged so that waste heat from those operations that require higher operating temperatures supplies those that need somewhat less, in a "**Thermal Energy Cascade**". It would make sense to design industrial parks on Earth to do likewise: reusing and reusing waste heat, which is potential energy.

• **Education of youth in environmental responsibility.**

The lunar settlement experiment will surely fail if living right, given the strictures of the lunar environ-ment does not quickly become "second nature," and anything but a resented burden. This means raising children and youth accordingly. **A "4th R" ~ recycling**, must be added to the curricula. Assigning recycling chores, a year of "universal service" in the water/air treatment systems or in bio-waste recycling operations would make sense. Survival is at stake.

• **Art Form Options that work on the Moon/Mars, will also work on Earth**

Art forms that are totally inorganic will have their own unique beauty and could catch on here. Check out: http://www.moonsociety.org/chapters/milwaukee/painting_exp.html

• **Social Experiments to maximize productivity of all inhabitants**

Making a frontier economy work will depend on everyone doing their part: no room for slackers and/or those who add to the burden. This means taking cradle-to-grave steps to minimize anti-social behavior. "Out-the airlock" solutions may seem severe, but chain-gang labor should not be dismissed for the stubbornly uncooperative. Handling the handicapped so that any burdens are offset with plusses will be a challenge. The lessons for Earth will be significant.

• **Retirement must mean switching to more relaxed forms of productivity.**

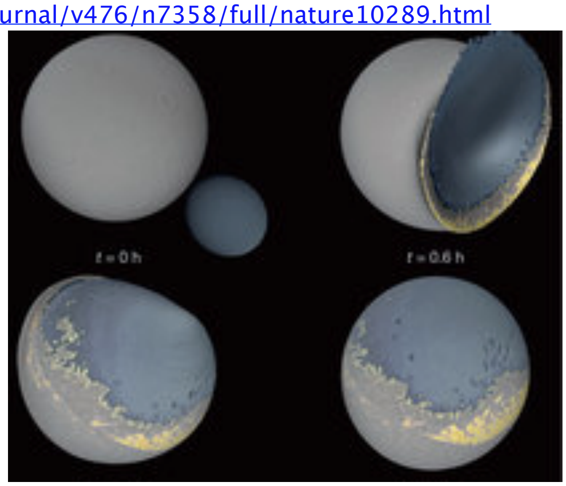
Better child-care options (such as pre-retire-ment part time grandparenting?) are needed to free adults in their prime for economically productive activities. Retirement should be a transition to other forms of productivity freely chosen

The above is not meant to be an exhaustive list of "Zero-G Exports from the Moon to Earth. **PK**

The Moon: Once there were 2!
Did Luna Swallow Lunetta?

By Peter Kokh

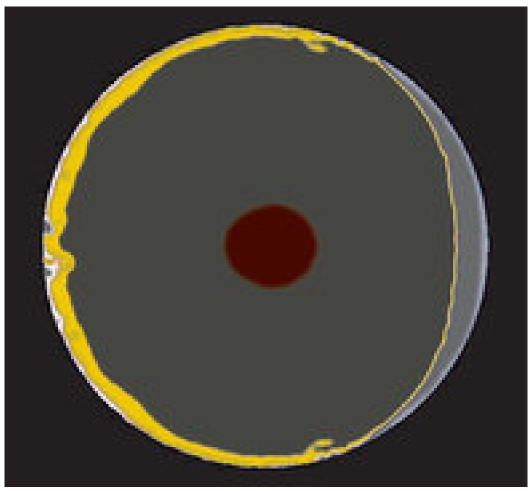
Forming the lunar farside highlands by accretion of a companion moon - M. Jutzi & E. Asphaug
http://www.nature.com/nature/journal/v476/n7358/full/nature10289.html



The most striking geological feature of the Moon is the terrain and elevation dichotomy [1] between the hemispheres: the nearside is low and flat, dominated by volcanic maria, whereas the far side is mountainous and deeply cratered. Associ-ated with this geological dichotomy is a composi-tional and thermal variation[2, 3], with the nearside Procellarum KREEP (potassium/rare-earth element/ phosphorus) Terrane and environs interpreted as having thin, compositionally evolved crust in comparison with the massive feldspathic highlands.

The lunar dichotomy may have been caused by internal effects (for example spatial variations in tidal heating[4], asymmetric convective processes[5] or asymmetric crystallization of the magma ocean [6]) or external effects (as the event that formed the South Pole/Aitken basin [1] or asymmetric cratering [7]). Here we consider its origin as a late carapace added by the accretion of a companion moon.

Companion moons are a common outcome of simulations [8] of moon formation from a protolunar disk resulting from a giant impact, and although most coplanar configurations are unstable [9], a ~1,200-km-diameter moon located at one of the Trojan points could be dynamically stable for tens of millions of years after the giant impact [10]. Most of the Moon's magma ocean would solidify on this timescale [11, 12], whereas the companion moon would evolve more quickly into a crust and a solid mantle derived from similar disk material, and would presumably have little or no core. Its likely fate would be to collide with the Moon at ~2?3 km/s, well below the speed of sound in silicates. According to our simulations, a large moon/ Moon size ratio (~0.3) and a subsonic impact velocity lead to an accretionary pile rather than a crater, contributing a hemispheric layer of extent and thickness consistent with the dimensions of the farside highlands1, [13] and in agreement with the degree-to crustal thickness profile [4]. The collision also displaces the KREEP-rich layer to the opposite hemisphere, explaining the observed concentration [2, 3].



2-dimensional view of the post-impact distribution of layers of target and impactor materials for the case of the head-on impact simulation. The companion moon collided from the right, accreting as a pile and producing the farside lunar highlands

The complete article can be purchased from **Nature** magazine for US$32.00

Comments by Peter Kokh

This shows that whatever our current picture of anything is, it is at best partial and presumptive. This new hypothesis that better fits the data is a thrilling conclusion and makes a lot of sense to me.

In fact, much of the debris that has created the pockmarked face of the Moon could have come from this accretion disk, rather than from errant asteroids.

That may be so of the cratered surfaces of all other rocky planets and moons.

Although many observers put this era of bombardment between 4 and 3.5 billion years ago, which would be long after most of the Earth-impact accretion disk material had found a home in the Moon.

The Moon is largely responsible for the rise of life on Earth. While the sun produces tides also, they are much lower and the gestation of life in tidal pools may have taken longer and been more at risk.

The Mars people have to realize the funda-mental difference between a Moon that belongs to its primary planet, and planets that belong to the Sun. Earth and Moon have evolved together and the exis-tence of "a Mars" would seem to have been quite irrelevant to that evolution. That Gaia (Earth-life) eould expand to the Moon is much more natural and signify-cant than that it also expand to include Mars and other bodes in the Solar System, which it will do in time.

I talk about the shifting of gears of human expansion from intercontinental to interplanetary. In this context the Moon belongs more to the intercontinental paradigm, than to the interplanetary one.

The Moon is an offspring of Earth, Mars but a brother. **PK**

Ten Billion Dollar$ to Industrialize $pace?

By Dave Dietzler

Where are we? What do we need?

Preceding a solar power satellite building enterprise we really need;

1) **Lower cost launchers** than those available today or in the near future
2) **Inflatable LEO hotels**
3) **Electrodynamic tether systems** to collect all that steel and aluminum junk in orbit that is estimated to be 1000 tons or more. Let's say that successful space tourism enterprises are doing things that prove they can do the job, what's next?

What if in the future, the dream of a reusable HLV that can orbit say 100 tons for $10 million is realized? For $8.7 billion, the amount of money to be made from the sale of electricity at ten cents per kilowatt hour in one year from a 10 GWe solar power satellite we could afford to launch massive amounts of cargo. Let's be more realistic and consider transmission losses and a slightly lower price for the electricity. Let's expect $5 billion. We could orbit 50,000 tons with RHLVs at the price stated above. It would be possible using NEP [Nuclear Electric Propulsion] or tethers and reusable Moon landers fueled with LUNOX and metal powders to put at least 30,000 tons on the Moon and in GEO where the construction shacks were located. In all likelihood, mostly robotic construction shacks will be located in GEO where the powersats will be finally located. Lunar mass drivers could launch to mass catchers at L2 that then haul payloads to construction shacks in GEO. If we could orbit 100 tons for $100 million we could still get 5000 tons in LEO and 3000 tons on the Moon and in outer space and bootstrap industry.

Three thousand tons is still a lot of cargo Self replicating seeds of lower mass have been imagined. NASA's Advanced Automation for Space Missions study in 1980 estimated 100 tons for a self-replicating robotic seed on the Moon and there were no 3d printers even back then! Let's say we did have 3000 tons of robotic and manned equipment on the Moon and in space at L1 and GEO and then we crank out one hundred 100 MWe SPS and/or power relays and get it done within 20 years to pay off the bond holders. After that we make clear profit for continued reinvestment and expansion until growth becomes exponential and the Moon and Earth orbital space is highly industrialized. The next step is Mars, the solar system at large and then on to the stars!

One of the keys to success is to maximize the use of lunar materials. Lightweight electronics will be upported [shipped up the gravity well]. Massive unitary simple things will be made on the Moon. Regolith refining processes often require chemicals such as chlorine and fluorine. These would be recycled but there will be leakage and to expand the industrial SEED to build FACTORIES we will need more and more chemicals upported at high cost.

New Technology to the rescue

I favor Dr. Peter Schubert's Lunar Dust Roaster and All Isotope Separator, a device similar to a mass spectrometer but much larger because it doesn't need chemicalsójust energy. However, part of the device is made of thorium oxide and thorium is present in KREEPy terranes at just 10ppm to 50ppm. Perhaps part of the device could be made of pure silica, alumina or titania with drilled passages and sulfur dioxide coolant since sulfur is available on the Moon.

At 53 tons for $100 million with Falcon Heavy rockets we could get 2650 tons in LEO for $5 billion and say 1500 tons on the Moon and in space. Of that 500 tons could be materials extraction equipment, 30 Genesis 1 modules for living and working would amass 45 tons, the rest would be mining and manufacturing machines, rocket landers and supplies like dehydrated food. Then we rocket Moon made parts to L2 mass catchers then to GEO and build up construc-tion shacks and build mass drivers on the Moon.

Preplanning of a million details and a few million people with a zeal for outer space willing to invest several thousand dollars apiece in 20-year bonds would be required. We will need at least $5 billion for the Falcon Heavy launches though we might get a modest discount for these 50 launches from Space-X, and we will need another $5 billion for R&D, hardware (actual payload costs) operations and to foot the cost of transporting humans to the Moon; more about that later. If we can get a discount and launch Falcon Heavies for $80 million a shot then we would spend $4 billion to orbit payloads and have an extra billion dollars to invest in R&D, operations, hardware, etc. That discount could make a big difference. A billion dollars is nothing to sneeze at.

Zero coupon bonds pay nothing until the bond reaches maturity. If we offer these bonds to raise about $10 billion with an interest rate of about 4.7% then after 20 years we'd need to pay back about $25 billion. This means we need to have 10 GWe of capacity at work by year 15 earning $5 billion a year so that we can gross $25 billion in years 16-20. After that we make clear profits to reinvest and expand. Hopefully there will be massive tax breaks to encourage this business. We could start offering stocks and pay dividends and this might attract much more investment. We will continue to build space power systems in years 16 thru 20 so that we will earn a large amount of money. We won't stop at 10GWe in year 15.

Of the 2650 tons in LEO for $4 billion or $5 billion we will devote 1500 tons to the previously stated purposes and locations and 1150 tons will be NEP tugs plus propellant or tether systems for travel from LEO to L1 or LLO in addition to propellant for the first automated landers that set up robotic fuel and LUNOX production for the reusable landers to haul cargo arriving at L1 or in LLO down to the lunar surface. Getting humans to the Moon would take a large bite out of things. To get those workers from LEO to L1 we'd need a lunar-fueled reusable ferry system. If tethers could toss a manned capsule to L1 or LLO with a retro system that would save a lot on upported LH2 and LOX or lunar metal powder fuels and LUNOX.

This 1150 tons could consist of 400 tons argon for NEP guessing propellant at about 15% of cargo mass and 250 tons for lander propellant prece-ding lunar propellant production.* The remaining 500 tons will be for the NEP tugs themselves, mass catchers, and an L1 refueling depot and powersat for lunar night power.* * Instead of NEP a 400 tons tether system would be pretty stout. Everything including upper stages would be cannibalized so we will have some scrap metal to get going. Even so, we'd really need to have 10GWe up by year 15 so we could sell $25 billion worth of power to make good on those bonds, and that might be a real challenge.

Moon tickets for us humans

Human transport could run a billion dollars for 20 Falcon 9/Dragon flights with 7 men each over 20 years with 35 men doing 5 year stints, so we'd only have $4 billion for R&D, actual hardware and operations, unless we get a discount. I guess the L1 depot and ultra-light powersat would be no more than 100 tons and the NEP tugs and mass catchers another 100 tons so let's estimate 300 tons for the initial construction shack in GEO. The construction shack would then be built up with steel and aluminum scavenged from Earth orbit with electrodynamic tether spacecraft and parts rocketed up from the Moon. Once the shack was built up mass drivers will launch loads of regolith to L2 mass catchers that haul the material for building powersats. About 90% of the work will be done by teleoperated robots controlled by crews on Earth, in space and on the Moon.

How low can we go?

It might be possible to do the job with much less than 1500 tons on the Moon. For those who would like to read about the mere 443 ton seed that would grow into an over 300,000 ton factory for a self replicating starship, see:

http://www.rfreitas.com/Astro/ReproJBISJuly1980.htm

A Self-Reproducing Interstellar Probe www.rfreitas.com

HTML Editor: Robert J. Bradbury

*250 tons to land the fuel and LUNOX production equipment.... with 250 second Isp Al and LOX motors that's 2.45 kps exhaust V to land from L1 about 2.3 kps.....so e^(2.3/2.45) = 2.557

I said 250 tons of propellant so (x+250)/x =2.557 (x+250) = 2.557x

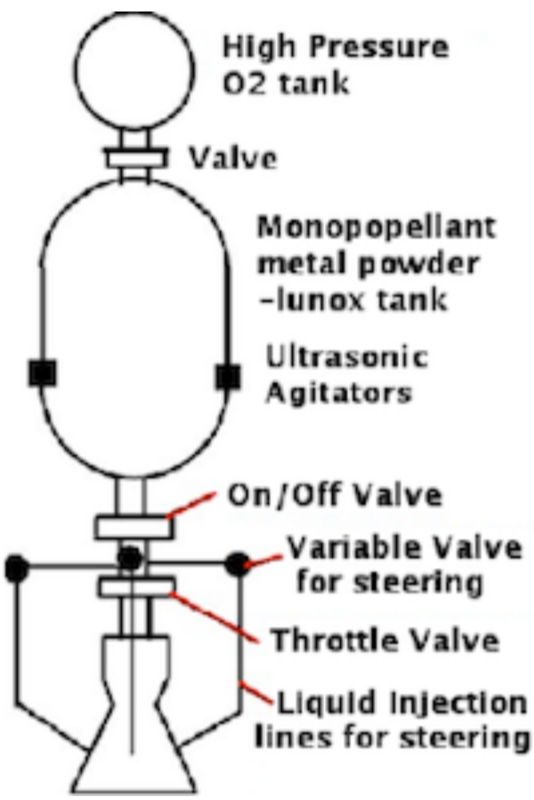
250 = 2.557x - x 250 = 1.557x x = 160

Thus we can land 160 tons of Al and LUNOX equipment plus landers.... with 250 tons of Al and LUNOX sent to L1.... if the landers amass 60 tons that's 100 tons of monopropellant production gear.. enough to refuel the landers and send them back up to L1 with payload of extra monopropellant in their tanks and transfer that to interlunar ferry rocket or land more cargo....the hard part will be keeping the propellant cold if we go by ion drive from LEO to L1....

*The SPS at L1 will have low mass thin film GaInP/GaAs solar panels.

The L1 station will consist of inflatables... Genesis 1 modules only amass 1.5 tons.

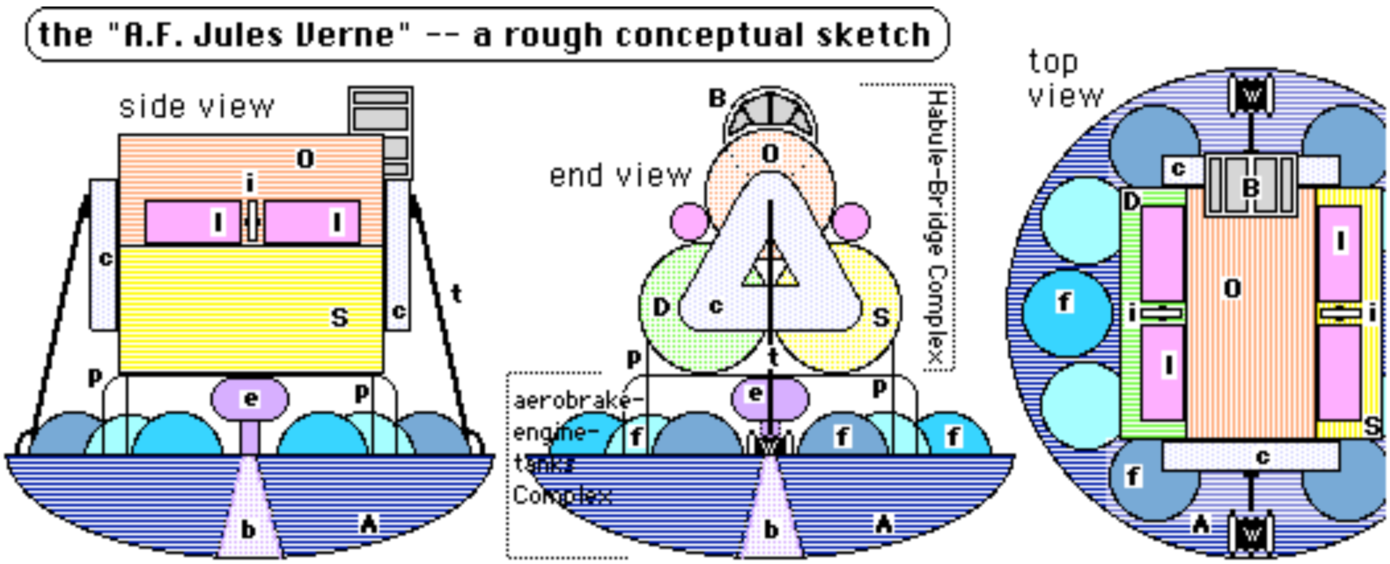
D Dietzler



Appropriate Back Reading

The Industrial Seed
MMM #229 OCTOBER 2009
p 5 Defining the Lunar Industrial Seed, 1, Dietzler
MMM #230 NOVEMBER 2009
p 3. The Lunar Industrial Seed, 2, 3A, D. Dietzler
MMM #231 DECEMBER 2009
p 3. The Lunar Industrial Seed (concl.) D. Dietzler

Lunar Overflight Tours
MMM # 21 DECEMBER 1988
republished in MMM Classics #3, pp. 4-8
http://www.moonsociety.org/publications/mmm_classics/mmmc3_Jan2005.pdf



Author's Postscript to the preceding article
Differences between this and former Visions

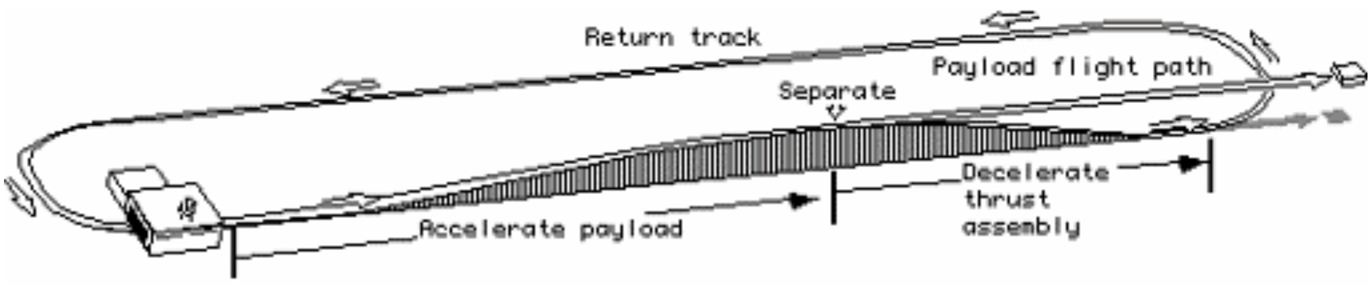
In the above article, I mention mass driver launch to L5 or GEO, this is not right.† I think the best thing to do would be to aim at' neither L5 or GEO, but at L2, behind the Moon.

From the northwest Imbrium coast we can mine anor-thositic highland regolith rich in Al, Ca and Si, mare regolith rich in Fe, Mg and Ti, and KREEPy regolith rich in potassium, phosphorus essential for solar panels and rare earth elements that have many uses, perhaps even high power vacuum tube filaments in pure form or when alloyed with other more common elements, as tungsten is not to be had on the Moon.

Mass drivers built on the Moon from aluminum rings, titanium or concrete supports, aluminum wire wrapped in silica fiber cloth insulation with high power vacuum tube electronics will amass about 625 tons [reference 1]. There will be at least two mass drivers in case one gets severly damaged so launches can continue on schedule. They will launch over the north pole to L2 where Dr. Peter Schubert's electro-magnetic mass catchers are located. The magnetic fields of these devices will draw in iron canisters even if aim due to mass driver exit velocity inaccuracy is slightly off.

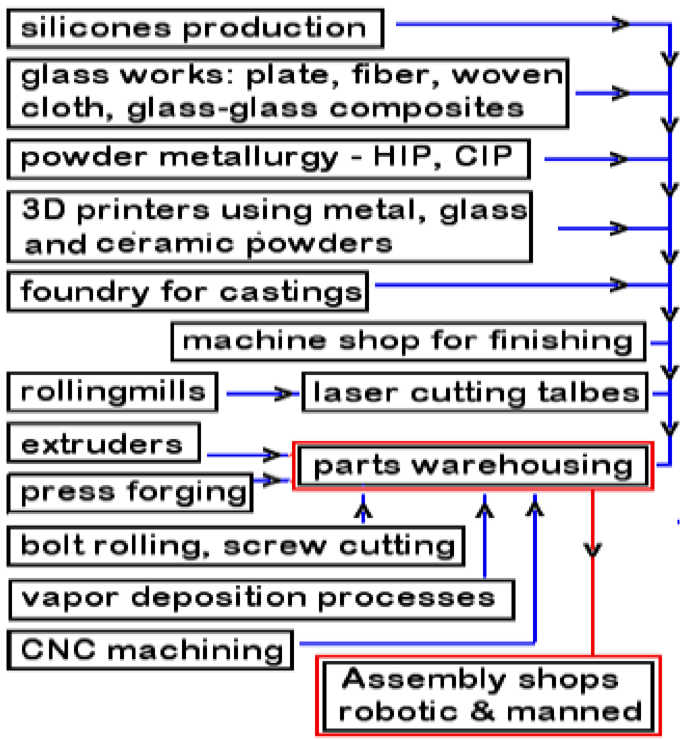
Dr. Schubert's mass catcher is superior to the old Kevlar bag catchers envisioned decades ago. Nonetheless, after mass driver launch there will be downrange stations that induce course corrections with various electromagnetic systems to achieve high target accuracy. Iron canisters of plain regolith will be launched as well as canisters of finished bulk products like metal rods, beams, rails, tubes, rolls of sheet metal and foil, spools of wire and cables, rolls of silica fiber cloth, etc. Moon Shuttles will rocket more delicate cargos to the L2 mass catchers, off load them, and the mass catchers when full will haul all this to GEO construction shacks that are built up with lunar materials until they can build SPS and/or power relay satellites.

The construction shacks will have small human crews and over 90% of the SPS construction will be done by teleoperated robots controlled by crews on Earth. Radio wave lag time between Earth and GEO is but a fraction of a second so good control of robots will be possible. Moon Shuttles could reach L2 and return but these low performance rockets could not reach GEO and return unless refueled in GEO which is a possibility especially after regolith smelting is begun at the construction shacks. There is no giant 100 million ton space colony with 10,000 workers in this vision but greater emphasis is placed on space robot systems with only minimal human presence on the Moon and in space. **Dietzler**



A mass-driver is a means to use solar power to accelerate cargo pods to lunar escape velocity without the use of rockets or rocket fuel, best-located on or near the Moon's equator.

Read: http://www.nss.org/settlement/L5news/1980-massdriver.htm



PRODUCTS: vehicles, mining machines, habitat modules, mass-drivers, more machine shops, mills, extruders, forgers, 3D printers, etc. The chart above is focused mainly on processes that use metals.

Materials from regolith: cast and sintered basalt from mare regolith, melted cast and sintered anorthositic regolith that will form a glassy material, ceramics like silica, alumina, calcia & titania; alumino-silicate glass, iron, nickel, titanium, aluminum, silicon, magnesium, phosphorus, potassium, sodium, sulfur, cement, calcium sulfate, and hopefully chromium, manganese and calcium. Limited amounts of hydrogen, carbon, nitrogen, helium. Alloys will include maraging steel (Fe, Ni and Ti), AlSi, AlMg, TiAl and iron aluminides.

Most of these processes can work in vacuum. Vacuum welding or vacuum cementation will affect metals with similar microcrystalline structures when smooth surfaces contact under pressure or for extended lengths of time. Since maraging steel, Al and Ti have different crystalline structures vacuum cementation will not be such a great problem if for instance aluminum plates are rolled between steel rollers or Al rod is extruded in steel extruders or Al parts are forged in steel dies.

3D Laser sintering of aluminum parts will be done in pressurized modules as Al will evaporate readily in the vacuum.

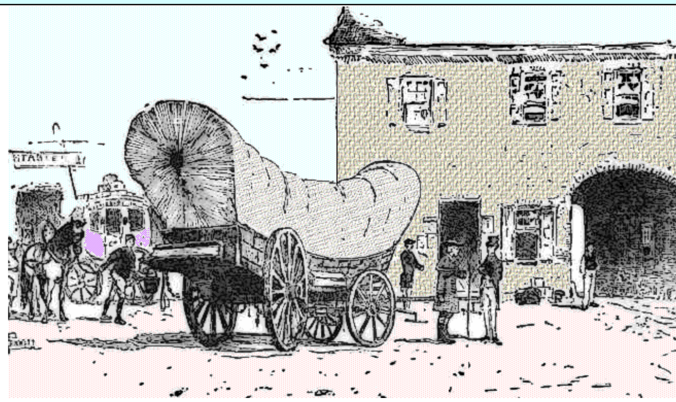
3D electron beam melting of titanium will work better in the vacuum and so will many physical vapor deposition processes to make thin metal parts.

Casting and alloying must be done in a pressurized foundry and machining is best done in some kind of atmosphere with water or oil lubricating coolant. **Silicone chemistry** will be performed in pressurized modules. **Glass** would be poured under pressure. Looms would probably work indoors too.

Powder metallurgy works better in the vacuum. Powder particles vacuum-weld with fewer voids, less porosity in the final product if it is pressed in the vacuum.

Manned assembly shops/garages will have pressure and this will make it possible for humans and robonauts to use pneumatic tools. Electron beam welding and brazing will be done outdoors in the free vacuum by robonauts. Cutting metal plates with lasers could be done in the vacuum also. **D Dietzler**

The Moon: What's in it for Earth? Part III:
The Benefits of a Challenging Frontier; Availability of Frontiers to Settle as a Cultural Stimulant and Safety Valve



"Wild wild west" as a forecast of the "wild wild Moon"?

By Peter Kokh

I can't think of anyone who has better illustrated and explained with due passion the importance of human frontiers beyond Earth than **Robert Zubrin**, since then the founder of the Mars Society. I encourage all to read "The Significance of the Martian Frontier", an article published in the September/October 1994 issue of **Ad Astra** – a publication of the National Space Society. This essay is online at:

http://www.nss.org/settlement/mars/zubrin-frontier.html

Zubrin begins by quoting Walter Prescott Webb from his **The Great Frontier**, 1951:

"It would be very interesting to speculate on what the human imagination is going to do with a frontierless world where it must seek its inspiration in uniformity rather than variety, in sameness rather than contrast, in safety rather than peril, in probing the harmless nuances of the known rather than the thundering uncertainties of unknown seas or continents. The dreamers, the poets, and the philosophers are after all but instruments, which make vocal and articulate the hopes and aspirations and the fears of a people.

The people are going to miss the frontier more than words can express. For four centuries they heard its call, listened to its promises, and bet their lives and fortunes on its outcome.

It calls no more..."

Zubrin quotes Frederick Jackson Turner, a young professor of history at the then little known University of Wisconsin over a hundred years ago:

"To the frontier the American intellect owes its striking characteristics, that coarseness of strength combined with acuteness and inquisitiveness; that practical, inventive turn of mind, quick to find expedients; that masterful grasp of material things, lacking in the artistic but powerful to effect great ends; that restless, nervous energy; that dominant individualism, working for good and evil, and withal that buoyancy and exuberance that comes from freedom — these are the traits of the frontier, or traits called out elsewhere because of the existence of the frontier."

He frontier has been slipping into the past. If we do not open new frontiers, we risk our civilization and culture becoming stagnant, ossified, fossilized, an intellectual and spiritual prison.

Yet it is clear that the personal characteristics that lead some to pioneer are not at all universal in our species. It is only certain types of personalities, with certain types of talents, who are so driven. And I believe I have stumbled on the key some years ago.

Here is the gist of my "eureka moment."

Those raised in, or familiar with the Christian faith will have heard of "the Beatitudes – eight or ten depending on the source.

http://www.searchthebible.com/beatitudes.html

To this list I propose to add another:

Blessed are the Second Best for they are
the ones who pioneer new frontiers!

Let me explain. Those who were doing well in Boston and Baltimore in the mid-19th Century stayed in Boston and Baltimore. Those talented and motivated individuals who found all suitable positions taken, no way to climb the ladder, were the more motivated to resettle in the wide-open West where they had a better chance of getting in on the ground floor. Their lives might be hard and difficult, but they would be rewarding, something that cannot be bought.

It was the same with talented and motivated Europeans who found little room to climb where they were, but with enough ability to reestablish themselves in the Americas or Australia and elsewhere. Indeed the paradigm can be found much further back, beyond the beginnings of humankind. Among lions, for example, and in other species, those capable males who were unable to successfully challenge the pack leader but still had leadership traits to offer were the ones who with their mates pioneered new territory and established new tribes.

It is not the best individuals, the cream of the crop, who pioneer. **It is the second best.**

The availability of frontiers, however rough and wild and challenging, has served both animal species (plants as well) and humans as expansion space and as a safety valve from time immemorial. Population pressure is a factor as well, of course.

Meanwhile, new human frontiers soon develop fresh cultures and spirits, that through return visits to the homeland, revitalize stagnant cultures there. The opening of the Americas revitalized all sectors and aspects of European culture and civilization. Feedback from other national "diasporas" has done likewise, though sometimes this feedback is delayed.

Humans are a frontier-blazing species

And this began with the spread of human populations first throughout Africa, then "Out of Africa" to Europe and Asia, Australia and the Americas. The now more than 100 millennia long "**Epic of Man**" has taken us "Out of Africa" to one continent after another.

The Antarctic Exception

So far, Antarctica has been a frontier for explorers and scientists only, fisherman tolerated on the periphery. By international treaty, "settlement" and access to resources are excluded, out of fear that this pristine environment would be spoiled (as we have "spoiled" the other continents – fortunately not in their entirety!

While we have committed our share of environmental atrocities on other continents, that we cannot establish protocols and regimes that would preserve the most environmentally sensitive areas of Antarctic while opening less sensitive regions to controlled settlement and resource use is an assertion that desperately needs to be challenged.

If we allow the Antarctic Treaty to go unmodified, it could become a model for off-Earth non-expansion. Yes, we have sinned! No, **humans can learn and adapt to environment-respecting and cherishing lifestyles and resource-access**. And unless we are allowed to try new paradigms off-Earth, we will be doomed cultural and intellectual stagnation. Then we can write the final judgment on the human experiment right now: "a brilliant start, an abominable failure to continue."

Antarctica would be a great proving ground for prospective Martian settlers, as the climate has nearly identical thermal range. Mars, with less fresh water, no breathable air, and no fish in a surrounding sea, will be the harder frontier. Those who can't make it in Antarctica need not apply.

"Of Dust," or "of Star Dust"

Those of us raised in the Judeo-Christian tradition, are very familiar with the line from Genesis"
"Of dust thou art, and to dust thou shalt return." Yes, but that dust is star dust. Every atom in our bodies with the exception of hydrogen, has been forged in the interior of stars that have since exploded, seeding the interstellar gas clouds with the dust from which everything else has come, including our Sun and its family of planets. In that light, a correction is in order.

"Of stardust thou art,
and to the stars thou shalt return."

To close the door to frontiers beyond Earth would be the ultimate perversion, the ultimate slap in the face to our Creator or creative agencies.

Intercontinental > Interplanetary > Interstellar

Further, the Moon is not a sibling planet with its own orbit around the sun. It shares Earth's orbit and is bound to Earth. It is part of Greater Earth, and in a very real sense:

"another continent beyond another kind of sea."

We arose as an African species, and have since become an Intercontinental one. Settling the Moon will be the consummate chapter of our intercontinental epic, establishing the Keystone piece that prepares us for phase II: Interplanetary expansion starting with Mars. Then, on to the Stars! It is at once a human legacy, our birthright, and our destiny. And those remaining on Earth will benefit enormously just as those who stayed in Europe benefited form the settling of the Americas.

Lessons learned on the Moon of use on Earth

` Yes, planetary scientists and geologists learn a lot about the Moon that sheds light on the early Earth. But while intellectually interesting and illuminating, this new knowledge is unlikely to be of practical economic significance unless it indicated unsuspected resources in the upper mantle that could somehow be tapped – an unlikely scenario.

But pioneers, forced to adapt to an unfamiliar and a seemingly hostile and life-threatening environment on the Moon, would be facing the biggest test since early Siberians pushed into the arctic and conquered the ice and cold and snow as Eskimos and Inuit. Think of the phenomenal difference between the jungle-skirted plains of East Africa and the Arctic coasts of Alaska and Canada and you have some idea of the challenge that will face lunar pioneers. History says that with the right attitudes, determination, inventiveness and resourcefulness, pioneers can meet the challenge and turn life on the Moon into something rewarding and worth the sacrifices of favorite things about life on Earth that they leave behind.

They will have to develop new alloys of familiar metals, and new materials to substitute for wood and plastics and fossil fuels. In the process, they will come up with things we have never tried on Earth but would make welcome additions to our current stuff-inventories. New art forms, new sports that play to the 1/6th G but standard momentum that people on Earth might enjoy watching on TV, and yes, no dance forms too.

It is imperative that pioneers learn environment-preserving processes and techniques without delay under sentence of system collapse whereas we will not spend money and time learning such things as the punishing consequences of our environmental sins are long delayed. "Pioneers will live immediately downwind and downstream of themselves." There will be no lunar global water and atmosphere sinks to disperse pollutants, only local mini-biospheres.

The pioneers will have to learn to live with mischievous moondust and black skies and 2-week long dayspans and equally long nightspans, unbelievable nightspan cold and dayspan heat, cosmic rays and solar flares.. After some years on the Moon they may have to face the fact that they might not be able to readapt to life on Earth.

But they will not be alone. Pioneers will have brought along plants and animals, establish little "gaiacules." We must reencradle ourselves in pocket offspring of "Mother Earth."" Thus the pioneers will be spreading Earth Life ("Gaia"), not just humanity. To the extent that there is no other way for Earth-Life ecosystems to reproduce themselves beyond the atmosphere, humans are essential to any such reproduction. This gives settlements on the Moon a double mission, a mission with a significance that transcends human history. If we are children of Earth, we return the honor in midwiving mini-Earths wherever we go.

The effects and benefits on the life and culture of those who stay behind will be enormous. **PK**

Challenges Facing Would-be Lunar Pioneers

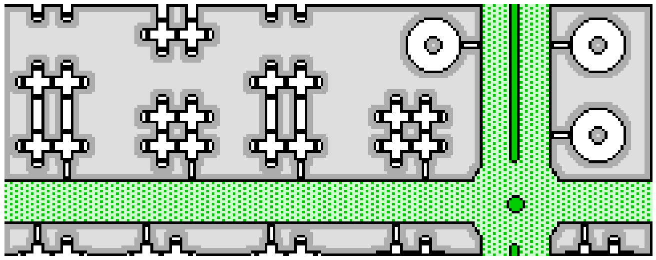
By Peter Kokh

• **Life-quenching surface vs. tightly shielded habitats**. As the Moon is airless and thus exposed to temperature extremes, cosmic radiation, and solar flares, pioneers must live in small, tightly sealed modules either underground or tucked under a blanket of moon dust. The "gap" between the life-squelching exposed surface (what we have dubbed **the "out-vac"** (<u>out</u>side on the surface and exposed to <u>vac</u>uum) (rhymes with Australia's "outback") and the pressurized, temperature controlled, shielded living and work spaces is daunting and enormous. But we propose two intermediate environments:

1. **The Middoors:** pressurized common spaces such as hallways, 'streets', parks, and squares with abundant vegetation, where the temperatures are allowed to swing between warm in dayspan and cool during nightspan) – Middoor spaces, along with agricultural areas. would hold the bulk of the outpost or settlement mini-biosphere and, as a hosting complex, would expand as the outpost or settlements expand. In effect, what we enjoy as enjoyable "outdoors" would be realized on the Moon. Thus the pioneers would not be confined to tight residential and work modules. The Middoors could even make use of water in the process of treatment for ponds, streams, and waterfalls. Each settlement could pick the climate, etc.

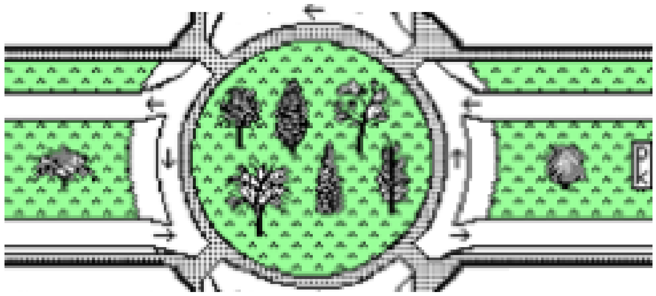
Read the entry "**Middoors**" in the **MMM Glossary**

http://www.moonsociety.org/publications/m3glossary.html



A settlement residential “block” showing pressurized roads with considerable vegetation.

Both “street” tubes and housing units are modular. Residences also contribute to the biosphere by containing garden spaces, living walls, and primary blackwater recycling systems. Thus as the modular settlement grows, the “modular biosphere: grows apace.

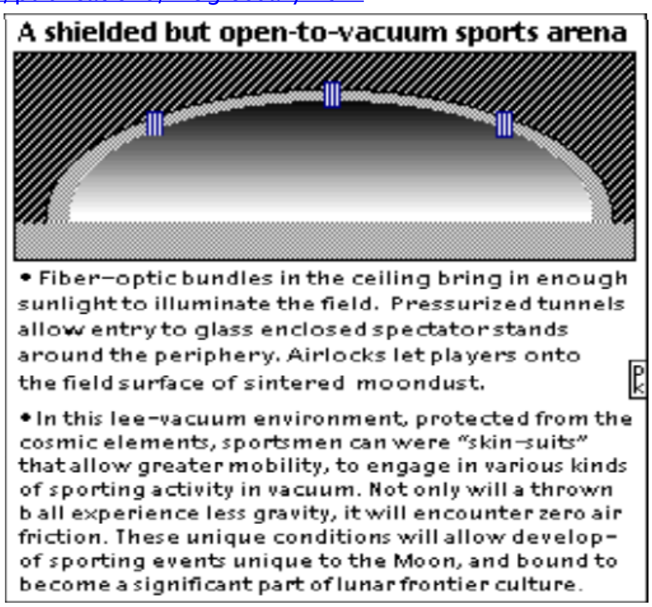


A vegetation-lush “round-about” intersection of the pressurized settlement road network

Read: Modular Biospherics II: “Middoor” Public Spaces - MMM Classics #21 pp 13-15
http://www.moonsociety.org/publications/mmm_classics/mmmc21_Jan2011.pdf

2. Lee-Vac or contained and shielded airless spaces protected from radiation and the micrometeorite rain that can be used for sports in vacuum with the need for mere pressure suits. Such spaces are also ideal for warehousing and storing items that will be needed often.

Read the entries “**Lee-Vac**” and “**Lee-Vac Sports Arena**” in the **MMM Glossary**
http://www.moonsociety.org/publications/m3glossary.html



Nb. Robots and teleoperated devices will do a lot of the “routine” work out on the exposed surface, minimizing the amount of time humans need to be outside, at risk of excess radiation exposure, except in those situations where robots and robonauts are not able to perform adequately.

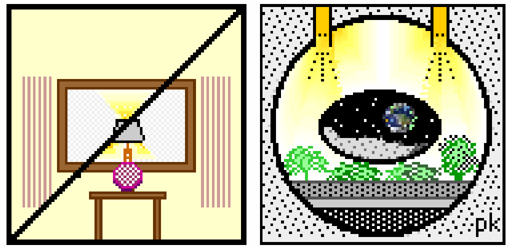
As to the hostile “Out-Vac”, pioneers could humanize it with sculptures made of lunar materials near airlock entrances and along graded and sintered paths and roadways. These materials will include hewn and cast basalt, metal alloys, concrete, glass-glass composites and ceramics. Road signs will also add.

And the pioneers can import inside “Zen Gardens” of raked moondust with carefully placed moon rocks.

More, they could place living plants and flowers in front of windows to filter their view of the desolation outside. **Read:**

"Picture Window Clichés" in the **MMM Glossary**

http://www.moonsociety.org/publications/m3glossary.html



[On Earth we often see a Lamp in the middle of a Picture Window.
Lunar pioneers may switch to a different cliché.
They will be less concerned with how their homestead looks from the outside
than with how barren and desolate and lifeless the moonscape looks from the inside.
Instead of a lamp, house plants may serve to psychologically buffer the view.]

- **1/6th G:** No one has been on the Moon long enough to determine whether deterioration of muscle tone and physiological processes will level off at some sustainable point, or sink to the level they do on the Space Station. We have no intellectual respect for those who argue that what happens in zero-G will happen in 1/6th G (or the 3/8ths G of Mars. There is an infinite difference between 1/6th and zero. But pioneers who wish to visit or return to Earth must surely exercise to maintain muscle tone etc.

Read: "**Native Born**" MMM Classics #5, pp. 34-36

www.moonsociety.org/publications/mmm_classics/mmmc5_Jul2005.pdf

Hexapotency Toning Centers,

MMM Classics #13 pp. 14-16

www.moonsociety.org/publications/mmm_classics/mmmc13_July2006.pdf

- **Tight mini-biospheres** without "sinks" to dissipate by wind or water: Pioneers will live immediately downwind and downstream of themselves, and that will be a challenge that will drastically change our familiar careless lifestyles.
- **The need to create space module by module:** Large pressurized volumes, such as domed cities, would be at extreme risk of decompression - we need to disperse risk, not share it. The inclusion of biosphere-maintaining systems in all habitat and activity modules (each toilet with its own blackwater systems, living walls, etc.) pioneer biospheres will grow naturally as more units are added.
- **Long dayspan/nightspan periods** each 14.75 Earth days long: With well-chosen and designed interior lighting systems-this should not be a problem except for energy-consuming activities. We can schedule energy-intensive tasks during dayspan, saving energy-light tasks for night-span - welcome and maintainable rhythm. Even with good power storage systems, we will always have more power during dayspan with direct solar, than during nightspan.

For the Lifestyle changes involved, Read

"Dayspan", "Nightspan", "Sunth"

pp. 10-13 MMM Classics #5

www.moonsociety.org/publications/mmm_classics/mmmc5_Jul2005.pdf

For the Energy supply challenges involved, Read

"**Potentiation:** A Strategy for Getting through the Nightspan on the Moon's Own Terms"

pp. 31-35, MMM Classics #13

www.moonsociety.org/publications/mmm_classics/mmmc13_July2006.pdf

- **Extreme thermal swings.** As we must heavily shield our living/work spaces, indoor temperatures will vary little. (2 meters ~ yards below the surface, temperatures vary no more than 3° C year around.)

Under a blanket of moondust, temperatures run -9°F (-23°C).
So taking a clue from passive solar heating systems on Earth,
we could store excess dayspan heat for nightspan heating and excess nightspan cold for dayspan cooling,
minimizing overall power needs.

- **Water will be scarce** and must be recycled with care, keeping it all within our mini-biosphere.
- **The Moon is poorly blessed with carbon and nitrogen:** Organic materials such as plastics, wood, paper that have become the mainstay of our "throwaway" civilization will need to be used sparingly and only in easily recyclable forms. Civilization reached a high state before plastics were available. We can do it again.

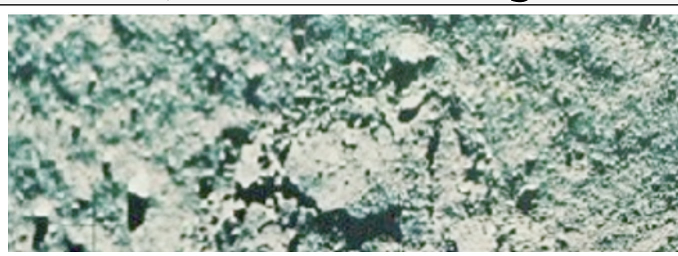
The Big Lesson

No matter what apparent obstacles, show-stoppers, and hardships that the Lunar Frontier might throw at us, our historic epic expansion into an amazing diversity of differently challenging frontier environments, we have been able not just to adapt and survive, but to adapt, learn how to turn any perceived drawbacks into advantages, and eventually thrive.

Lunar pioneers, self-selected for willingness to adapt and prosper, will overcome all these challenges and to "make themselves at home" as have all previous pioneers, having learned to deal with all "risks and drawbacks" as unsuspected springboards to a thriving, health culture. We have done it before, frontier after frontier. We will do it again!

But if we do not accept this challenge, our civilization will grow stagnant, no longer inspiring future generations to explore, master, and come to thrive beyond achieved limits. **PK**

Rock, Rubble and Regolith



By Ron Brooks

1. Introduction: "soil" vs. "regolith"

When we look at our Moon, what we are seeing is a type of "soil" covering resulting from billions of years of a complex "space weathering." Meteoritic impacts have played a major role in this unique space weathering process that has molded a soil-like covering consisting of a fragmented, unconsolidated mass of rocky rubble, sandy grains, and dust. By no means should this "Moon soil" be compared to or thought of as the soil covering found on Earth, which was produced by processes uniquely terrestrial with the presence of oxygen and the additional influences of wind, water and the activities of life. In contrast, on the lifeless and airless Moon, the "soil" is a result of a very different unique process (McKay, et al., 1991a). To describe the concoction of material that covers almost all the Moon's surface more adequately, researchers generally use the term "regolith" - [Greek for blanket [rego) - rock [lith] or rock-derived surface layer.

To those interested in the Moon, the Moon's regolith has been an investigative and problematic topic for many years. As research into the lunar regolith proceeded, many ideas were proposed over the years; especially prior to the Apollo flights in anticipation of the upcoming lunar landings. One such idea was the questionable rigidity of the surface regolith and its capacity to support not only a landing module but the astronauts themselves. (Some thought that the surface was covered with a loose dust blanket that would swallow anything attempting to land on it or traverse it - cf. Arthur C. Clarke's novel "A Fall of Moondust") (Another idea was a concern that the astronauts may encounter debilitating physical problems or that their equipment and instruments might malfunction due to the extreme dusty consistency of the regolith. Some of these ideas were confirmed, some were altered, and some discarded with the information gained from research leading to and following the Apollo landings and up to the present day.

The reader needs to keep in mind that almost all we know about the Moon has been derived from its regolith (McKay et. al., 1991b). Great research efforts have been made and a great deal of data has been complied about the Moon through its regolith. Some research findings have been inconsistent from one individual to another. However, the reader needs to appreciate that the Moon is a very complex world, and obtaining sound, consistent, and verifiable information is a slow and demanding endeavor. This is not troubling to those with a real interest in our Moon, but it presents a challenge and adds an element of adventure in revealing the mysteries of our curious companion world.

We need to reset our thinking and accept that our companion is truly another world and does not follow, or need to follow, our earthly conceptions. Hopefully, this article will provide the reader with a better understanding of another piece of the puzzle of our magnificent Moon’s unique structure and environment.

This is the second in a sequence of readings about our Moon’s structure, geology and environment authored for the Moon Society. As with the first article, "Lunar Mascons, Masterpieces of Complexity," which appeared in the May 2011 issue of MMM, this article is written for those with varied levels of knowledge in lunar science. The information offered is not intended to be exhaustive or definitive. The references can provide a basis for anyone wishing to pursue more in-depth reading

2. The Difference between Soil and Regolith

As the reader will discover, the word "soil" is not the best to describe the unconsolidated material that covers the Moon’s surface. Even here on Earth we would not call such debris "soil." Because of that, as mentioned earlier, most researchers use the word "regolith" when describing this comprehensive covering. Regolith was first used to define the loose, unconsolidated material covering the bedrock on Earth and over time has been used for the Moon.

Regardless of its definition and descriptive inaccuracies, lunar "soil" has become synonymous with lunar "regolith" (Taylor, 2008a). With this synonymous use, most researchers work interchangeably with both soil and regolith with a general understanding that "regolith" more effectively conveys the idea for the entire mixed bag that covers the lunar surface. The word "soil" has been generally abridged to identifying the subcentimeter particles that actually make up the greater part of all regolith.

"Regolith" thus identifies the entire comprehensive composition from the largest boulders to the smallest microscopic grains, but "soil" refers to the grains that average 70μm which are the most abundant grains and form the bulk of the regolith. The finest grains or what is considered “dust”, in contrast to “soil”, lies as the upper most layer of the regolith and has been identified with a grain size < 20μm and possibly contains grains as ultra-fine as <0.01μm (Park, J., et al., 2006a). Dust, soil and regolith will be used interchangeably as the context requires. (For μm see Note 1.)

Before we begin to work with the terms soil, dust and regolith, the reader needs understand that the weathering environment of the Moon’s surface is very different from that on Earth. During the Moon’s earlier history, great bombardments took place resulting in the dramatically cratered surface. Some of the catastrophic impacts resulted in volcanic activity that produced the dramatic surface changes of the basalt maria. The early heavy bombardments pulverized the greater percentage of the early Moon’s surface, leaving behind a varying degree of near site melt and pulverization and an enormous amount of layered impact ejecta that was thrown in all directions and distances and in all shapes and sizes. This jumble of rubble covered the Moon’s surface. However, while this rubbly concoction was the covering for the early Moon’s surface, it is not the regolith that presently covers today’s lunar landscape.

3. What Produced Today’s Regolith?

Today’s weathered surface, as reflected in the regolith, has been shaped from outside cosmic forces or what is referred to as "space weathering." It is not the result of the Moon’s atmospheric forces, but of a very different scenario from what happened on Earth.

The soil on Earth is composed of material that has been altered by chemical and environmental weathering produced by a thick, dynamic atmosphere. The Earth’s atmosphere has left the soil rich in two major components, moisture and air. Moon soil is devoid in both moisture and air since the Moon does not have a gas and moisture laden atmosphere that could produce Earth-like soil.

The lunar weathering force is of cosmic origin. The dramatic lunar features left over from the great bombardment era, including the maria, have all succumbed in varying degrees to this relentless force.

The cosmic forces that produce the lunar surface are the same forces that significantly affect the surface of Mercury and that strike asteroids without any resistance. Mercury has a weak magnetosphere as a factor <1000th of Earth's and a tenuous non-collisional atmosphere. The Moon does not have a magnetosphere, but does have what is considered a non-collisional atmosphere (even thinner than Mercury’s), where the molecules are so sparse that they do not collide or have the ability to interact with outside forces. In perspective, the Moon virtually has no atmosphere. This opens the Moon to all cosmic forces. Knowing this, we need to set aside preconceived ideas about weathering from our Earth-bound perspective.

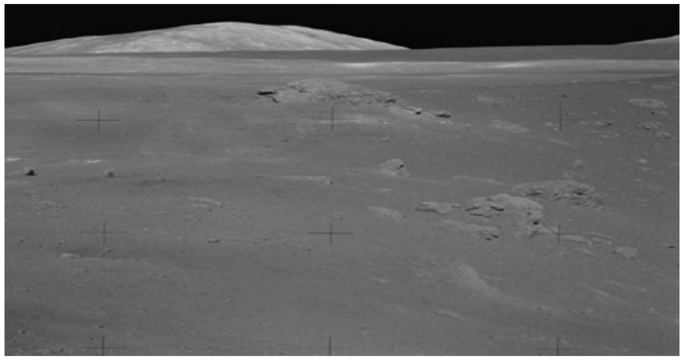


Figure 1. The Moon's Regolith Landscape. Credit: NASA

4. Regolith Grain: Size and Appearance

On average, a bulk lunar regolith sampling taken downward to approximately a 20m depth would reflect ≈95% of the soil that is finer than 1.37μm by weight and ≈5% finer than ≈0.0033μm. The median particle size of such a sampling is approximately ~72μm (Carrie, 2005). Spudis also supports the idea that the regolith soil grains, on average, are composed of grains of ~70 μm (Spudis, 2006a). With the soil grain sizes stated above, the reader needs to realize that the average grain size is almost impossible to be seen by the unaided eye. If one viewed the grains under microscopic enlargement, the shapes would be highly variable. In general, the particles would be somewhat elongated and ranging from spherical to extremely angular (Carrier, et al., 1991). Because of the limited effects of space weathering, most of the granules remain abrasive with jagged sharp edges and tend to pack together.

Below: examples of a very common lunar grain called agglutinates,good overall representations of lunar soil grains. But some grains will vary greatly from the examples given, e.g. the non-impact grains consisting of volcanic pyroclastic glassy spherical beads dispersed over the lunar surface. (See Fig. 2.) But compared to agglutinates, they are sporadic and do not contribute significantly to the bulk of the regolith.

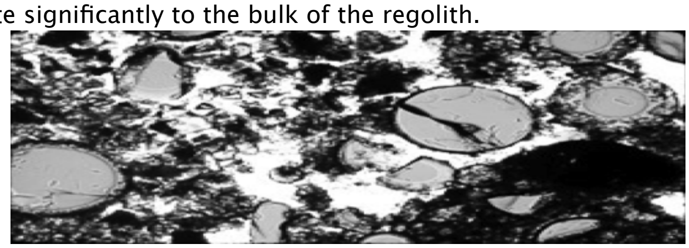
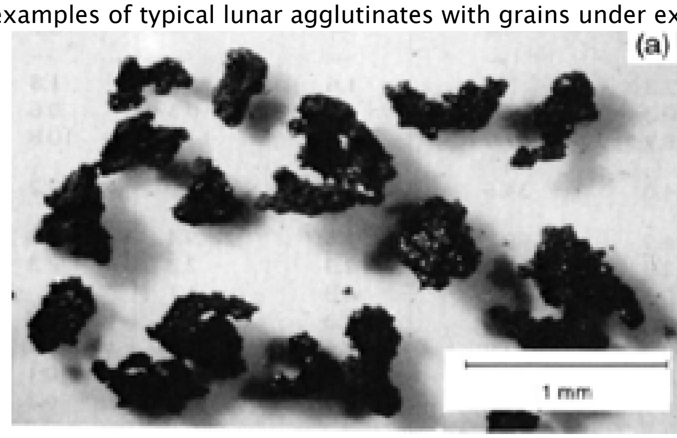
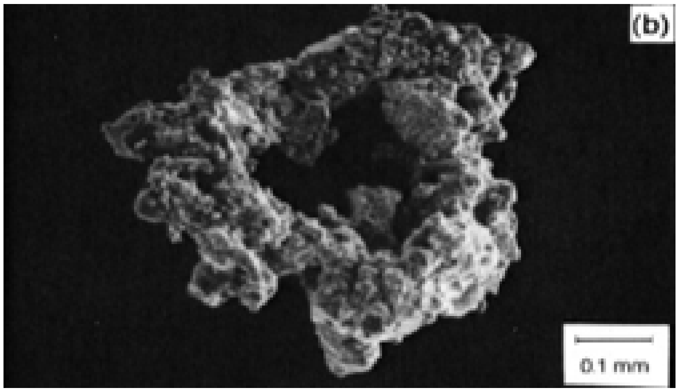


Figure 2. Cross-Section: Lunar Pyroclastic Beads: NASA

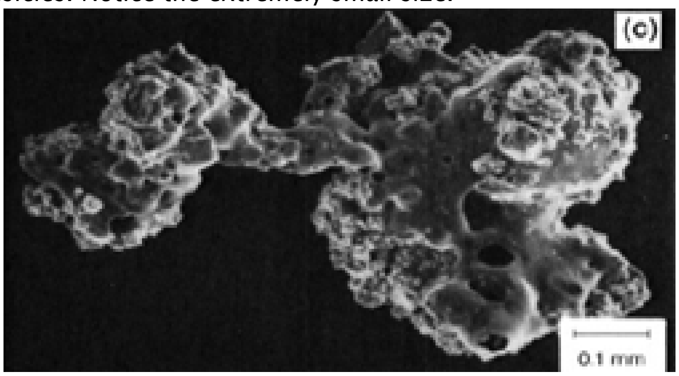
Agglutinates grains are aggregates of smaller soil grains or particles. The average agglutinate grain is usually <1 mm. Agglutinates are formed by heat generated by meteoritic impacts striking the lunar regolith, producing the melting, mixing, and bonding of mineral grains, glasses, and even older agglutinates. The soil grains take an endless array of shapes. An individual grain can have multi-faceted coatings and appendages, barbed and extremely abrasive. Figure 3 (a to f) **below** show examples of typical lunar agglutinates with grains under extreme magnification



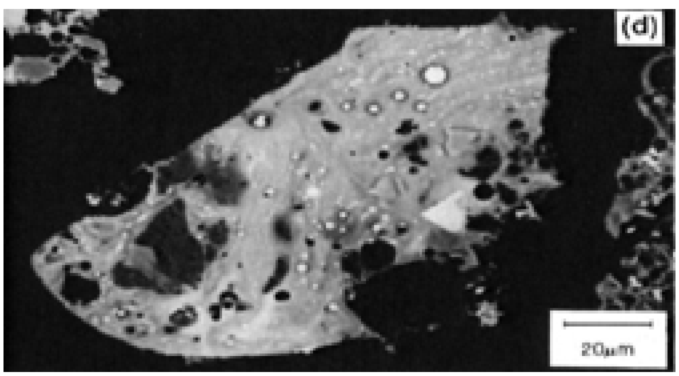
(a) An optical microscope photograph of a number of agglutinates from an Apollo 11 soil sample showing a variety of irregular agglutinate shapes.



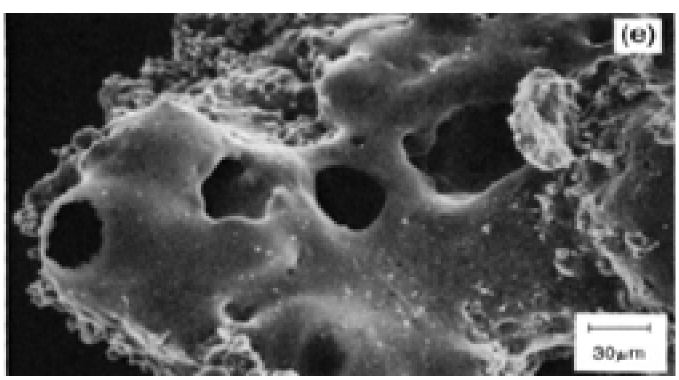
(b) A doughnut-shaped agglutinate. This agglutinate shows a glassy surface extensively coated with small soil fragments and a few larger vesicles. Notice the extremely small size.



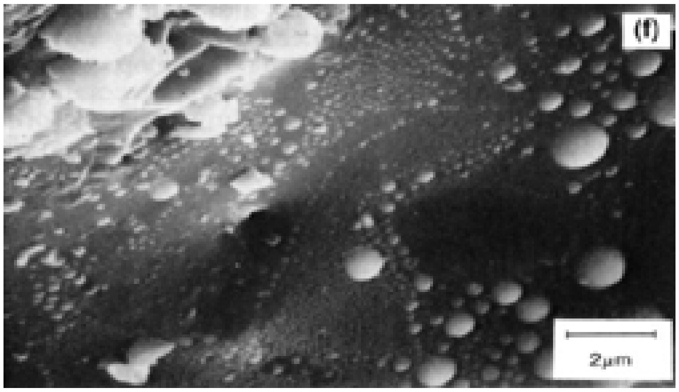
(c) Scanning electron photomicrograph of an irregular agglutinate soil showing some vesicular, glassy, fragment-free surfaces adjacent to fragment-laden surfaces. Some agglutinates are very delicate and display narrow bridges, necks, and dendrite-like arms



(d) Shown is a polished thin section of an agglutinate. The agglutinate particle contains a variety of vesicles with circular, elongate, and irregular shapes. Irregular mineral fragments in the glass include plagioclase (darker), pyroxene, and ilmenite (brighter). The bright circular features are metallic Fe (iron), which occurs as isolated droplets and trains and swirls of small droplets (<5 μm). Fe is not confined to surfaces, but is present throughout the volume of most agglutinates.



(e) Closer view of a glassy agglutinate surface, showing vesicular structure. Small mounds and trains of metallic Fe are visible as bright spots that occur over the entire glassy surface.



(f) Close-up view of a glassy agglutinate surface, with clusters of Fe mounds, with groups and trains of smaller Fe mounds (20-Å to 1-μm diameters).

5. Regolith Structure

As mentioned earlier, regolith in any one discrete area is a layered concoction of contiguous material and rock fragments and other impact debris possibly thrown in from adjacent and remote regions. After the large bombardment era and over time, in relative calm, this material tended to organized itself into a somewhat common structural pattern. Then again, even with these common structural dynamics in motion, any given pattern within varying radial distances will have its own unique variations.

Keeping in mind the structural idea of variation and replication above, Figure 4 (left) shows a possible representational structure of a vertical section of the stratified regolith layers, which might commonly be found on the Moon. Figure 4 starts at the uppermost surface down-ward to the lunar crust. The structure, for ease of interpretation, is divided into six zones representing structural layers and their depths. Measurements are averages of available information.

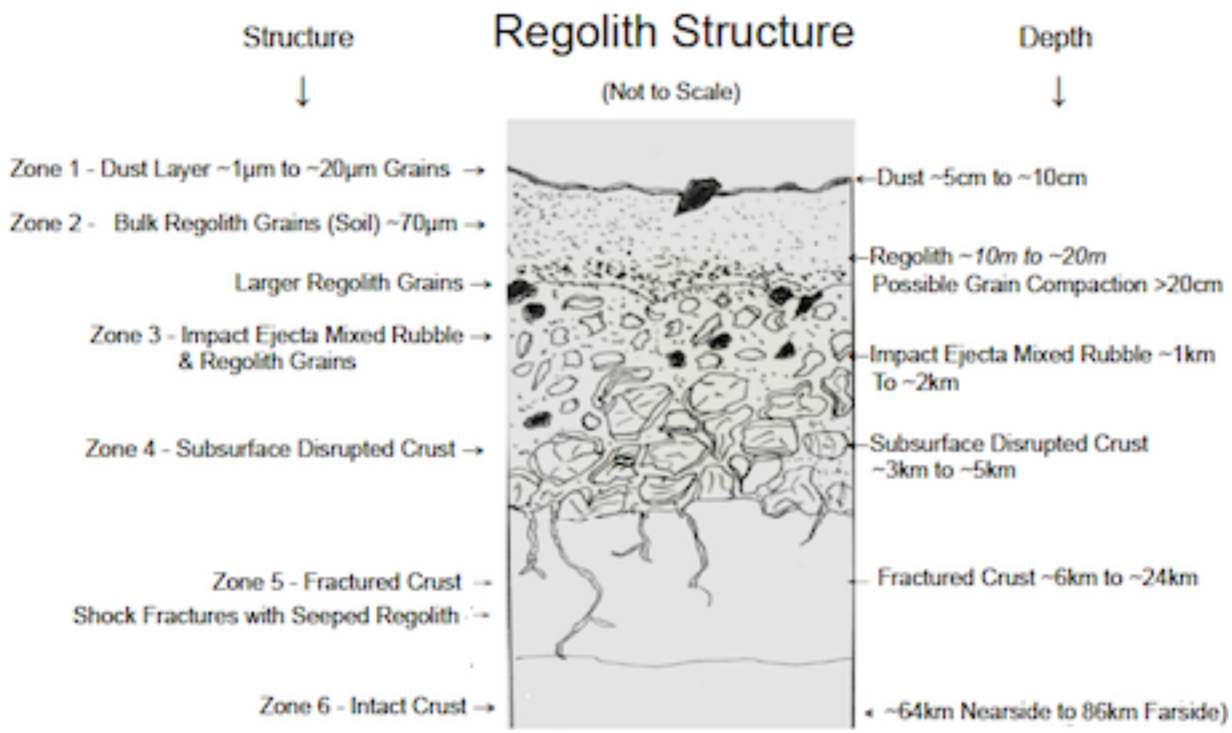


Figure 4 - by Author

TO BE CONTINUERD NEXT ISSUE,

* **Ron Brooks** is a new Director of the Moon Society, and brings with him 39 years of experience as an educator. This is his 2nd major article in MMM. In the May MMM #245, he contributed a very informative article about lunar "**Mascons.**"