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

# Moon Miners' Manifesto

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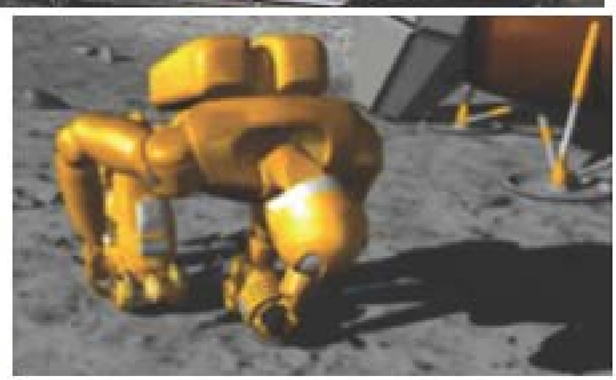
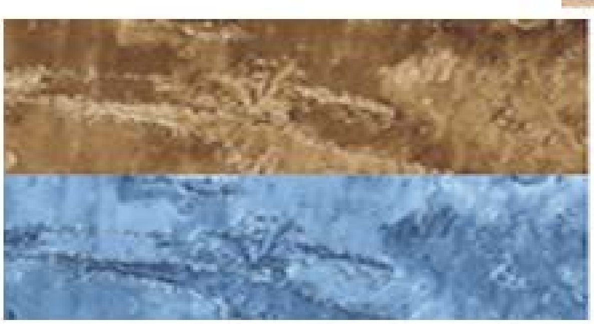


# Rock, Rubble, and Regolith Part II

By
**Ron Brooks**

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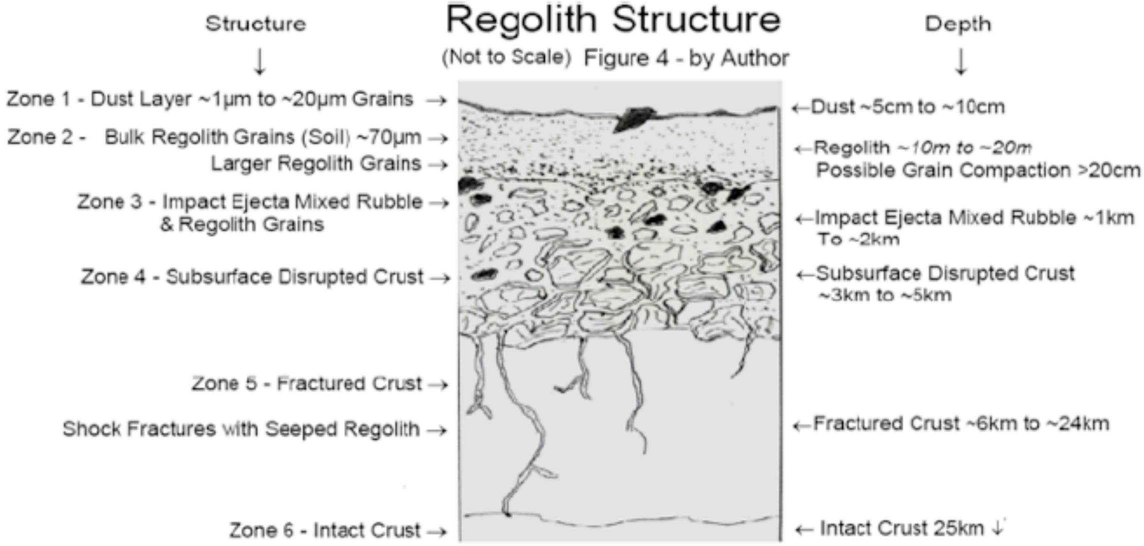



Regolith Structure
(Not to Scale) Figure 4 - by Author
(Crust Depths Range ~64km Nearside to ~ 86km Farside)

**Zone 1. (Dust layer)** The dust layer is the finest of all regolith and consists of grains sized from ~ 1_m to ~20_m (ultra-fine to 0.01 _m _m) of covering the top 5cmto 10cm of the surface.

**Zone 2. (Bulk layer)** consists of regolith grains averaging ~70 _m (lunar "soil"). This upper surface varies widely across the lunar surface, but averages somewhere between ~10m to ~20m thick. Maria regolith can range from ~1m to ~5m, and highland regolith averages ~10m to ~20m or more.

**Zone 3. (Mixed Rubble)** Consists of a mixed bag of larger rubble from impact ejecta and intermixed regolith grains. This zone lies~1km to ~2km below the surface. This zone is generally protected from weathering.

**Zone 4. (Disrupted Crust – Megaregolith)** A layer of disrupted (broken) blocks ~ > 1m in size with regolith grains dispersed throughout. The result of impacts that fractured and broke the crust into large size blocks that has not been exposed to weathering. This zone is referred to as the megaregolith and lies ~3km to ~5km below the surface.

**Zone 5. (Fractured Crust)** Lunar crust that has been fractured but is firm. Most likely grains of regolith will have seeped into the fractures or cracks. The fractured crust averages ~6km to ~24km below the surface.

**Zone 6. (Intact Crust)** Part of the lunar crust not affected by impacts and is generally intact. The intact crust slabs lie at ~25km and below from the surface.

The structure configuration such as in in Figure 4 may also not remain in a static condition in any one discrete location. A meteoritic impact of varying magnitude could bring about a fragmentation of any compaction, overturn or bury the existing regolith structure, and virtually destroy what was achieved over time. Nevertheless, as the aeons pass, cosmic weathering and soil mechanics would again most likely return the site to a similar structural pattern.

## 6. Regolith Compaction through Meteoritic Impact and Moon Quakes

Some additional points need to be made in regards to better understanding of the regolith structure. It is also interesting to note that, below the top 20cm, the grains are thought to be strongly compacted.. Taylor believes the compacting is brought about by shaking during impacts (1982). It does seem likely that large regional impacts could produce sufficient violent shock waves and shaking to jar the abrasive, jagged grains into an inter-particle linking, producing a strong compaction. However, it seems likely that in addition to impacts, Moon "quakes" would be a significant contributor to regolith compacting.

During the Apollo excursions, seismometers were placed on the lunar surface. The seismometers clearly detected Moon quakes of various magnitudes at varying durations. In his paper, "The Importance of Establishing a Global Lunar Seismic Network," C. R. Neal states that some "quakes" detected by the seismometers registered up to 5.5 on the Richter scale and lasted up to ten minutes. He also expresses that the quakes can make the moon "ring like a bell" (2005).

**Three types of Moon quakes have been identified:**

(1) thermal quakes, which are caused by the extremes of lunar cooling and heating,
(2) shallow moonquakes, which occur relatively near the moon's surface, and
(3) deep moonquakes, which take place more than 600 miles under the surface. This is about halfway to the center of the Moon much deeper than any quakes on Earth. The vibration and shaking produced by stronger moonquakes would definitely seem to be a strong factor in compaction of the regolith lying on the surface above.

## 7. Cosmic Weathering of the Lunar Surface through Meteoritic Impact

The most visual and impressive weathering of the lunar surface is that by meteoritic impacts. "Meteoritic" is an inclusive generalization of the surface impacts made by asteroids and comets or fragments thereof. (For more information on meteorites, asteroids, and comets, see Note 2.) Impacts on the Moon's surface have formed structures ranging in size from .01μm (assigned the name of a "zap pit") to the multi-ringed basins that can measure over 1000km across, e.g., the South Pole Aitken (SPA) Basin.

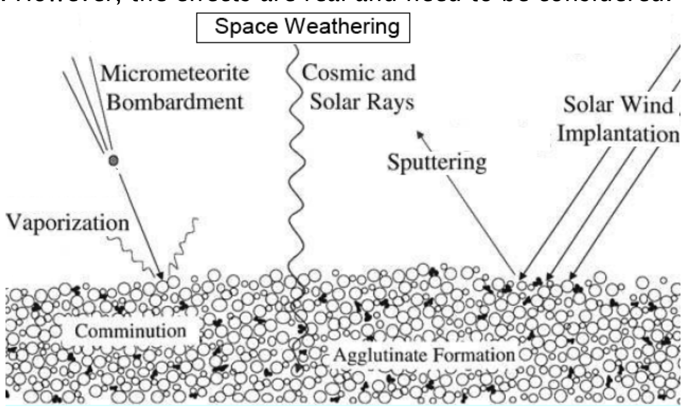
However, what we are not considering here are the events that took place in the young solar system of three billion years ago in which heavy blankets of impact ejecta were produced by great bombardments and the lava emplacements of the maria. What we are considering is the meteoroid flux comprising mainly of dust-like particles that constantly strike the Moon. In our maturing solar system, larger objects, say, the size of a compact car, strike the Moon every century or so.

This small but constant hammering away at the Moon's surface by meteoroid flux produces three primary physical weathering mechanisms that have altered surface features. The impacts have produced rock and mineral fragments derived from what is called "comminution," or the breaking of rocks and minerals into smaller particles, and "agglutination," which is a fusing of mineral and rock fragments forming impact-produced glass particles and vaporization of grains.

With vaporization of grains, the lighter materials escape while the heavy materials usually condense on nearby grains. So what we have is a process of constant **pulverization, dissipation, and reassembly.** The ultimate outcome, however, is the diminution of the lunar surface material. The three mechanisms above are impact-based. However, space weathering also consists of almost imperceptible actions caused by solar wind, solar flares, and cosmic rays.

## 8. Lunar Surface Weathering through Ionizing Radiation from Solar Winds, Solar Flares, and Cosmic Rays

As mentioned earlier, the Moon has a tenuous atmosphere and no magnetosphere; it has no protection from outside forces. The weathering through solar wind, solar flares and galactic cosmic rays (Taylor, 1982 b) is very subtle and beyond sensory detection. However, the effects are real and need to be considered.

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As the solar wind hits the unprotected lunar soil it causes an implantation of ions into the surface materials. (The solar wind is a steady stream of mostly protons and electrons that is constantly emitted from the Sun's upper atmosphere at about 400 km/s.) The solar wind also generates radiational surface damage that produces some fine-scale rounding (Taylor, 1982c). At the same time, the effect of solar wind produces an amorphous coating of ions at about 400Å (angstrom or nanometers) (Taylor, 1982d) on the adjoining grains of dielectric crystals (especially in grains of plagioclase) (McKay, et al., 1991c), producing granular changes.

Solar flares have even higher energy than the solar wind and produce three occurrences:

**(1) the implanting of ions** into the surface grains,

**(2) the production of cosmogenic nuclides** and

**(3) radiational tracking** (Taylor, 1982e; McKay, et al., 1991d). Solar flares, as with solar wind, implant ions into the surface grains. Solar flares also produce cosmogenic nuclides when high-energy cosmic rays from the solar flares interact or collide with the nucleus of an atom.

When the atom is struck, an erosional effect occurs through **spallation** [expulsion of nucleons (protons and neutrons)] from the nucleus of an atom] and **sputtering** (atoms are ejected from a surface particle) leaving behind **cosmogenic nuclides** (or cosmogenic isotopes), a rare form of isotopes.

The third effect of the flares is **radiational tracking,** which occurs within the mineral crystal structures in the lunar soil. The crystals are preferentially dissolved or tracked (i.e., an etched channel is generated) as the ion from a high-energy ray passes through the crystal (Krätsghmer & Gentner, 1977). The track lengths (or etching) of the crystal within the grains differ in differing minerals, usually in order of feldspars > pyroxenes > olivine (Taylor, 1982 f). The radiational tracking is considered "damage" in that it changes the structure of the crystal grain. The grains affected are usually found within the upper ~1mm of the lunar regolith.

Cosmic rays (Especially Galactic Cosmic Rays (GCRs) and Solar Energetic Particles SEPs) also produce radiational tracking and can generate rare isotopic species through spallation, as previously explained, with solar flares. They do not, however, implant ions into the surface grains due to their high energies.

The damage and changes made by the solar winds, solar flares and cosmic rays to the lunar soil grains may seem minor to the informal observer. However, it is a significant factor in lunar weathering and needs to be studied for a better understanding of the forces affecting our Moon's surface. It is a point of interest that the process of lunar weathering, such as sputtering, also contributes to the Moon's exosphere, but that is a story for another day.

A visible side-effect of continuing space weathering is the slow darkening and reddening of the regolith. As an impact strikes the lunar surface, the underlying lighter-colored regolith, which has not been darkened through weathering exposure, is ejected outward, forming the lighter ejecta rays overtop the weathered, darker regolith. Eventually, the impacts that produced the spectacular bright ejecta rays of the craters Kepler and Tycho will darken through weathering and blend into the surrounding regolith, as have the rays of older crater ejecta.

## 9. Regolith Mineral Composition

There have been about 100 minerals identified on the Moon, in comparison to Earth, where approximately 2,000 have been identified (Rickman & Street, 2008). In general, the major mineral composition of regolith is of plagioclase feldspar, clinopyroxene, orthopyroxene, and olivine (Schrader 2010). However, there are noteworthy additional minerals in most regolith samples. It appears that the major differences in mineral make-up lie within the two distinct lunar topographic forms, the highlands and the maria.

The major mineral composition of the lunar regolith generally holds throughout the surface. However, the regolith found in the highlands is additionally rich in aluminum and silica and poor in iron, as are the highland rocks. In contrast, the regolith covering the maria is rich in iron and magnesium and is silica-poor because of the basaltic rock (from lava flow) from which the regolith covering the maria was formed. The mineral differences between the highlands and maria seemed to have been maintained over billions of years with a relatively small amount of lateral mixing (mixing from one surface area to another). Spudis believes up to 95% of all material in the regolith is locally derived and that usually this percent is upheld within a few kilometers of any one sample (1996). McKay, et al., also concludes that the general mineral composition of any given distinct sample of regolith reflects the composition of the bedrock underneath (1991e; Taylor, 1982g).

There is some mutual mixing from the maria basalt layers and highland locations. This mixing is especially true within the sloping plains that lie between areas of the maria and highlands. Nevertheless, it is not enough to suppress the basic regolith differences between the two distinct topographies. The mixing that has taken place seems more contingent from highland impact ejecta being transported to the maria than the reverse (Li & Mustard, 2005).

Nonetheless, due to repeated meteoritic impacts and the possible contiguous traveling lateral spread of ejecta radii from one location to another, especially impacts such as Copernicus or Tycho, any given sample of regolith may reveal mixed-in material from anywhere on the Moon.

## 10. Regolith Depth

Regolith depth anywhere on the Moon has to do with the results of crater formation. The oldest surfaces in the solar system including that of our Moon are characterized by a topographical condition called maximal cratering density. This means that one cannot increase the density of craters because there are so many craters that, on average, any new crater is formed over the top of existing craters by obliterating all or part of older craters, leaving the total number visible for a realistic density count unchanged. Some regions of the Moon, especially the highland regions, exhibit nearly maximal cratering density.

In contrast, the original lunar crustal formations of the maria regions were struck with colossal impacts followed by extensive lava emplacement, which destroyed the original crustal formation and any accumulated regolith. The regolith blanket that covers the ancient highland regions, where maximal cratering density has been maintained, would logically be thicker than that covering the lava-emplaced maria.

However, the average depth or thickness of the regolith in both the highland and maria regions varies widely, as has been confirmed by research. The average measurements seem to range from approximately 1 to 5 meters thick over the maria to an average of 10 to 15, even up to 20 meters or more in some highland regions. This reflects the true inconsistencies in the regolith depths from one discrete location to another. It seems to have been difficult to determine exact measurements of regolith depth over a few or several kilometers in a given discrete area in both the highlands and maria.

However, regolith depths are continuously being confirmed by research. One such research technique is called equilibrium diameter depth measurements. A key to this type of regolith measurement is hypothesized from crater counts using the solar incidence angle of the crater image(s) with crater counts determined by sun angles, which helps reveal craters with diminutive features, as proposed by Young and most recently by Wilcox and Ostrach (Young, 1975; Wilcox, et al., 2005; Ostrach et al., 2011).

The equilibrium diameter is a measured dis-crete topographical area where the function of crater mechanics has created a steady state between the formation of new craters and the removal of old craters. The total number of craters visible for a realistic density count seems to remain unchanged, as with the function of maximal cratering density, keeping in mind that the presently visible craters are less than the total number of craters that existed in the given area at any one time.

Two major mechanics are in action to create this steady state. First, craters start as voids in the lunar surface, and as they age their protruding rims erode and their interiors slowly fill in with regolith, making them almost indistinguishable from the surrounding landscape. Secondly, a number of aging craters become even less visible when the lunar surface is impacted and a new crater is formed, obliterating all or most signs of the old crater(s) within the impact zone. Hence, the topographical area in which the total number of craters that can be identified on a discrete lunar surface area remains the same, but is less than the number that was actually there at any one time is the equilibrium diameter.

The result of such mechanics in turn has significant implications for inferred regolith depth. Measured regolith depths increase with the size of an equilibrium diameter. In other words, when new craters, which produce additional surface pulverization, are consistently formed over and near old craters in an increasing proportion, the regolith grows in depth. It would be obvious to the observer that the depth of the regolith, especially in the highlands, could not have been produced by the existing visible craters alone.

There are exceptions and extremes in regolith depths. In one lunar location, the Taurus -Littrow Valley on the southeastern edge of Mare Serenitatis, extreme depth variations have been detected ranging from 6.2 to 36.9 meters (Taylor, 1982h) In a few exceptional instances, regolith has not accumulated to any significant degree or not at all on some inclines along crater walls or on sheer rocky outcrops. **RB**

**Look for Part 3, in our next issue, MMM #252, February 2012**

## Lunar Development in the 21st Century

# The “Planet Moon Project”

**By David Schrunk**

The spectacular advances of science, engineering, and the humanities in the 20th century established the basis for creating permanent human settlements in space in the 21st century. Since the Moon is our closest celestial neighbor and is in orbit around the Earth, it will logically be the next principal focus of human exploration and settlement. The Moon is an unparalleled platform for astronomy and other scientific investigations, and for technological development. It also has access to the virtually unlimited energy and material resources of space, which can be applied to the global exploration and expansion of the Moon. Excess solar-electric power that is generated on the Moon can potentially supply the Earth with all of its future needs for clean, low-cost energy. These opportunities, combined with the universal desire of humanity to explore and settle new lands, assure that the global transformation of the Moon into an inhabited sister planet of the Earth will become a reality in this century.

A major impediment to the exploration of space is the high cost of delivering cargoes from the surface of the Earth into space. For example, the cost of launching a payload into low earth orbit by the Space Shuttle is approximately $10,000 per pound, and that figure will be an order of magnitude higher for missions to the Moon. Thus it appears that even limited lunar projects will be prohibitively expensive, even with the design of an improved lunar transportation system. However, there are three emerging technologies that may delimit the cost of lunar industrial and scientific activities.

**First**, new generations of more cost-efficient, less complex launch vehicles will become available for space missions in the decades ahead. **Second**, advances in micro-device technology and the miniaturization of complex opto-electromechanical systems toward the nanotechnology regime will mean that increasingly smaller, yet more capable payloads can be delivered to the Moon. **Third**, and most important, methods will be developed for using lunar resources to manufacture everything that is needed on the Moon itself, rather than shipping goods from the Earth. This process of “in-situ resource utilization,” or ISRU, will herald the most dramatic reduction in the cost of lunar projects. **Finally**, global economic reces-sion, climate change, overpopulation, and excessive exploitation of Earth’s resources, may motivate humanity to utilize more space resources and to benefit from off-world enterprise.

Industrial processes on our home planet use energy, raw materials, labor, and machines to manufacture sophisticated products such as computers, medical imaging devices, launch vehicles, and communication satellites. Within the next two decades, it will become possible to use lunar regolith (Moon dirt) as feedstock to manufacture equally sophisticated products (such as wires, pipes, machined lunar rocks, and bricks) in lunar factories. Few of the processes or tools for doing so yet exist in a mature form - they will have to be developed from existing technologies as we go, essentially “bootstrapping” from small caches of Earth-manufactured machine tools, communications devices, and other portions of payloads yet to be defined. Once these technologies and innovations beyond Earth have been developed for lunar purposes, they will have ubiquitous applications in outer space on asteroids, planets, and moons throughout the solar system.

The Moon has a reliable source of energy in the form of sunlight, and the lunar regolith contains abundant supplies of iron, silicon, aluminum, and oxygen. The regolith also contains helium-3, an isotope that holds promise as the ideal fuel for future fusion reactors, and traces of other light elements such as carbon. In addition, the past Clementine and Lunar Prospector satellite missions detected and mapped increased hydrogen concentrations in the north and south polar regions, suggesting the presence of water-ice in these areas. Scientific data will be gleaned from these lunar materials and resources, and they will then become the feedstock for manufacturing processes and other lunar base activities.

Thus a significant reduction in the cost of space projects can be achieved by simply transporting the basic components of Earth's industrial base, such as mining and processing equipment, lathes, drills, ovens, robots, and electro-mechanical control devices, to the Moon. The lunar industrial base will then use solar energy and indigenous materials to manufacture the tools and products that are needed to begin the global transformation of the Moon into an inhabited planet. Through many iterations using a "learn as you go" approach, increasingly sophisticated tools and products will be manufactured on the Moon. By this means, the costs associated with transporting materials from the Earth to the Moon will be reduced drastically, and large-scale, economically viable space projects will become a reality. The process will also begin the development of a twin-planet economy between Earth and its sister Moon.

Initially, the "labor" component of lunar Industrial processes will be performed by teleoperated and autonomous robotic devices that have been delivered to the Moon. Tele-operation is the process by which remotely located devices are controlled using visual and haptic feedback systems. It is widely used on the Earth for diverse applications such as mining, undersea projects, and even certain surgical procedures (telemedicine). It is fortuitous that the Moon always has the same face directed to the Earth and that the round-trip time for communications between the Earth and the Moon is less than three seconds. Telemedicine is another application of such communications technologies, so that medical treatment and procedure that originate on Earth can be applied to lunar dwellers. These conditions will allow Earth-bound operators of lunar tele-robotic devices to have a virtual presence on the Moon 24 hours per day, 365 days per year. Robots will become vital surgical helpers.

The site for the first unmanned base will likely be on the Earth-facing side of the south polar region of the Moon. There are several promising sites in the south polar region that always have the Earth in view for continuous telecommunications, and that receive over 300 days of sunlight per year for the generation of solar electric power. A south polar base will have access to increased concentrations of hydrogen (possibly water-ice) that will be useful for industrial operations and eventual human habitation. The tall peaks and deep depressions of this region also offer the opportunity for the placement of long line-of-sight telecommunication links and power beaming facilities.

Many countries currently have rocket launch systems that can be modified to place payloads on the Moon. In one scenario for the establishment of a lunar base, one or more of these rocket systems will be used to transport solar panels, communication systems, scientific equipment, and other payloads from the Earth to the south polar region of the Moon. When these components are in place, tele-operated rover vehicles will explore the lunar surface and transmit data back to Earth for analysis. Protocols for the preservation of unique features of the lunar environment will be observed, and scientific data will be obtained before local materials are utilized for experiments. When surveys and analyses have been completed, the rovers will then assist with experiments in the production of bricks, wires, transistors, and glass products from lunar regolith materials. These pioneering activities will be ongoing 24 hours per day, and there will be opportunities for direct participation by virtually anyone on Earth via the internet.

Since abundant, reliable electrical power is the key to any large-scale development, priority will be given to the fabrication of solar cells from lunar materials. The generation of electric power on the Moon from the first lunar-made solar photovoltaic cell will be a milestone in space exploration because it will prove unequivocally that human enterprises can be self-supporting in space. From that beginning, lunar-made solar cells will be added to the electric power system of the lunar base. As electric power levels then grow, additional scientific and manufacturing equipment will be delivered from the Earth, and the lunar base will expand in all of its capacities.

Within a decade after the first unmanned base has been established, humans will return to the Moon on short-duration missions (60-90 days) to service and maintain complex machinery and to supervise operations. Initially they will live and work in lunar lander spacecraft evolved from present-era technology. During the build-up of the first lunar base, controlled ecological life support systems (CELSS) will undergo continued research and development on Earth and on the International Space Station. Work will also commence with the development of reusable rocket systems that can ferry people between the Earth and the Moon. When a reliable lunar electric power system is in place and pressurized underground habitats (for protection from radiation, temperature extremes, micrometeorites, and lunar dust) have been constructed, regenerative life support systems and agricultural modules will be delivered to the lunar base. Humans will then return to the Moon for longer periods, and all aspects of lunar base activities will be expanded until the lunar industrialization and settlement is sufficiently mature, to enable further planning for human missions to Mars and its moons.

In this same time frame, the solar-electric power system will be expanded in east and west directions from the lunar base to create a circumferential electric grid. The advantage of a solar powered electric grid that is placed around the circumference of the Moon is that 50% of the solar panels will always be in sunlight, thus delivering continuous electric power to the grid. Energy in the grid can be transferred from the sunlit side of the Moon to the dark side (and eventually into the interior) so that consumers - new arrivals - can simply “plug and play” into an extant electric power system.

The construction of the lunar power system will give rise to the need for an efficient surface logistic system that can deliver tools and building materials between manufacturing facilities and construction sites without disturbing the cohesive abrasive dust of the lunar surface. To meet these needs, a rail road system is proposed. The "lunar railroad" would be an effective, efficient, and simple (mostly automated) logistic system on the Moon, and it would avoid most of the problems of lunar dust accumulation that plague "off-road" vehicles. Iron rails for the railroad could be made from lunar iron, for example, to construct a simple two-track rail line from the first base to other areas in the south polar region, including the geographic south pole.

A "southern rail line" would greatly expand the ability to carry out exploratory missions and would facilitate the growth of all lunar projects. The challenge of building the circumferential rail system would be similar to the challenge of building the solar-powered electric grid, and both construction projects could thus be undertaken simultaneously. Since communication systems and pipelines for thermal management and the transport of fluids will be needed on the Moon, these infrastructure elements would also be constructed in parallel with the railroad and electric power networks. As the railroad and other infrastructure elements grow and eventually become linked together, the first circumferential utility network, extensive geologic expeditions will be carried out in the south polar region. The lunar industrial base will produce products and scientific instruments, including optical and radio telescopes, that will initially be placed at the south pole and the far side of the Moon, respectively. The rail line and other utilities will be extended northward to the mare / equatorial regions of the Moon, and then to the North Pole.

Power levels in the circumferential grid will rise to the multi-megawatt range as construction of the utility infrastructure continues, and experiments will be conducted with the first microwave beaming of electric power from the Moon to the Earth. With continued growth, it will become possible to supply the Earth with terawatt levels (one terawatt = one trillion watts) of clean, low-cost solar electric power. Lunar development will thus contribute to increased living standards on Earth and to the "greening" of Earth's biosphere through less need and usage of fossil and fission fuels. Revenues from the sale of electric power to Earth, Moon, and cis-lunar markets will support the expansion of the lunar power system and other utilities.

Hundreds of people will then be able to live permanently in each of several large underground habitats and a tourism industry that operates between the Earth and the Moon someday will be established. Given the wide and growing range of lunar activities, a broad cross section of humanity will participate in creative and economic pursuits on the Moon. Sculp-tors, artisans, athletes, and musicians will join entrepreneurs, technicians, and scientists in the unique conditions of the "Planet Moon" to create a rich, diverse, and desirable cultural environment for people to work, live, and even retire there. The Moon can become a human laboratory for meeting the challenges and hazards of off-world existence. This knowledge, learning, and experience can then be transferred to development of other celestial bodies, beginning with Mars and near-by asteroids. Going off-world enables humanity to fulfill our evolutionary potential through the creation of a new type of being - spacekind!

With proper planning and execution, the "Planet Moon Project" will reflect upon our highest aspirations, and provide significant benefits for the people of the Earth. It will emphasize international cooperation and draw upon the expertise of all interested parties, including governments, entrepreneurs, investor-supported commercial enterprises, and non-profit institutions, such as universities and schools. As experience with lunar operations increases, the scientific and industrial capability of the Moon will approach parity with the Earth, perhaps within three to five decades after the founding of the first base. Widely separated, permanent human settlements will be established, and the only cargo that will need to be transported from the Earth will be humans - the scientists, technicians, tourists, and immigrants who will explore, develop, and eventually inhabit the Moon.

When humans permanently inhabit the Moon, they will explore the mountain ranges, mares, craters, and rilles of the Moon, and investigate lava tubes that have been sealed for billions of years. By then the Moon will be our principal platform for making astronomical observations. Thousands of lunar-made tele-scopes will be placed at regular intervals on the Moon so that objects of interest in the universe, including the Earth and the Sun, may be observed continuously under ideal viewing conditions. People will live and work in extensive underground spaces that have Earth-like living conditions, including luxuriant vegetation and large lakes of water (without poisonous snakes or mosquitoes!). A wide range of research projects will use the unique conditions of the Moon to advance knowledge in such areas as materials science, super-conductivity, power beaming, and bioscience.

Advances in existing technologies will accelerate the phased development of the Moon, and it may be expected that new, as-yet-unimagined innovations will greatly enhance our evolution into a space-faring species. A magnetic levitation rail system will provide high-speed access to all areas of the Moon, and abundant supplies of solar electric power will be beamed from the Moon to the Earth and other locations in space by the lunar power system.

Before the end of the 21st century, thousands of spacecraft will be manufactured on the Moon and launched by electromagnetic "mass drivers" to all points of interest in the solar system, and robotic missions from the Moon to nearby stars will be underway. Communication, power, transportation, and life support systems that have been manufactured on the Moon will be launched to Mars and other locations in space in support of the exploration and human settlement of the solar system. Asteroids and "burned out" comets in Earth's orbital vicinity, especially those that pose a threat of collision with the Earth or the Moon, will be moved out of harm's way and mined for their hydrocarbons, water, metals, and other constituents. These resources will then be delivered to the Earth, Moon, or cis-lunar locations as needed. The binary Earth-Moon planetary system will thus draw upon and benefit from the vast capital of space. More important, lunar settlement will challenge us to trans-form ourselves, extending knowledge, disciplines, and cultures into new dimensions.

The terraforming of the Moon into an inhabited sister planet of the Earth is an achievable and highly beneficial objective that can be realized in the coming century. The first robotic missions will establish a permanent unmanned lunar base, short-duration human missions will follow, and, with continued experience and growth, permanent human settlements will be established. The "Planet Moon Project" will result in a substantial expansion of scientific know-ledge, advance all engineering disciplines, and it will create a higher awareness and appreciation for the Planet Earth, her environment, and ecology. It will provide high quality job and business opportunities, improve living conditions on Earth, and lead to a greatly expanded program of solar system exploration. When the first lunar base is commissioned, the accumulated technological and cultural expertise of humanity will become linked to the virtually limitless energy and material resources of space. The space-faring epoch of human existence will thus be firmly established and the entire solar system will be open to in-depth exploration and human settlement. **DS**

**NOTE:** "**The Planet Moon Project**" article is part of the introduction to **Phil Harris' book, "Lunar Pioneers**." The article is republished in this issue of MMM with Dr. Schrunk's permission at Phil Harris' suggestion.

Schrunk, a Moon Society member and Advisor, is the author of **The Moon: Resources, Future Development and Settlement,** (co-authors Burton Sharpe, Bonnie Cooper, Madhu Thangavelu) to which we were invited to contribute our own look forward (Appendix T: "Beyond Our First Moonbase" http://www.moonsociety.org/publications/mmm_papers/beyond_moonbase_1.pdf ) We highly recommend this book for your reading, and library.

Raised in Iowa, the author now lives in the San Diego area. **MMM**

MMM #252 - FEB 2012

# Rock, Rubble and Regolith - Part 3

**By Ron Brooks**

## 11. Regolith - When is it Soil? When is it Dust?

There is a difference between lunar "soil" and lunar "dust." This difference is promulgated on the size of the pulverized and weathered grains and impact melt fragments in a given sample. As reviewed above, the overall average lunar regolith grain (including melt fragments) size is ~70μm. There seems to be a general agreement that the uppermost regolith surface is also covered with nearly pure dust with a grain size >~20 μm (McKay, et al., 1991f). This extremely fine, dusty grain makes up about 10-20 wt% of the regolith (McKay, et al., 1991g).

The dust layer has varying reported depths or thickness, but probably averages somewhere between 5cm to 10cm thick. Heiken believes there is a relationship between the increased overall total regolith depth and the accumulation of finer (dust) grains on the surface (McKay et al., 1991h). The top layer of lunar dust could consist of grains as small as >1 μm and as small as grains considered as ultra-fine at <0.01μm (Park, J., et al., 2006b).

One should take into consideration that the larger regolith grains tend to sink into the lower stratum, a result of what is called soil mechanics, whereas the heavy-density soil grains sink downward to leave the very finest grains on the surface (Ostrach & Robinson, 2010a). Ostrach and Robinson worked with soil particle density in their well-known "Brazil Nut" experiments, which supported the idea of density sorting, which leads to having the finest particles on the surface (2010b).

## 12. Properties of Lunar Dust

The properties of lunar dust are best described as loose and fluffy and thus liken to talcum powder. However, that is where the comparison stops. Unlike the talcum we all know, this dust is hard and abrasive instead of soft (Spudis, 2009). While it may look soft and fluffy, you would not want to get this dust on your skin and definitely not into your lungs for any length of time.

If you have ever worked with Portland Mortar Mix and let it smoothly slip between your fingers, you know how the grains are silky and super fine. However, the mortar mix grains are much larger in size with an average of ~ 90μm, in comparison to lunar dust grains, which can be from ~20μm down to ~1μm or even 0.01μm in size.

This dusty lunar powder has been generated by billions of years of bombardment by micrometeorites of less than ~ 1mm and impacting at speeds estimated to be 10-30 km/s. Even with the very small size of the micrometeorites, enough energy is generated to melt the impacted regolith and produce glassy melt fragments of extremely small, hard, abrasive particles of 1 μm or less.

Dust, then, is defined as the finest component of the regolith. McKay and Halekas describe the dust as grains of <20 μm or less (McKay et al., 1991i; Halekas et al., 2006b). Spudis believes the uppermost few centimeters of regolith is a little greater than ~10μm and the uppermost surface layer of regolith could consist of dust of > 1 μm (2006b). Katzan and Edwards also found that the lunar regolith consists of significant amount of grains of 1μm or less (1991). Lunar dust grains seem to range from less than 1μm up to 20μm.

A curious finding about lunar dust was made during the Apollo flights. Lunar dust has a distinct smell. It is well known that the space suits of Apollo crews were covered with lunar dust, which was then transported into the lunar module. The dust was released into the module and breathed in by the astronauts. The crews reported the dust had a smell like gun powder (Halekas et al., 2006a). Fortunately, due to the small amount of dust and the short duration of exposure, the astronauts were not harmed.

## 13. Conclusion

As one studies the lunar regolith, one quickly finds it to be extraordinary in what it is and in the way it is produced. The lunar regolith comes in all shapes and sizes, including boulders, rocks, sandy grains, and dust, all with graduated layer depths and distributions. The concoction that covers the Moon's surface has resulted from billions of years of persistent meteoritic impacts and is part of a unique type of space weathering that also includes ionizing radiation from solar winds, solar flares, and cosmic rays.

From the fear that a lunar module might sink into a parched quagmire of dust and rubble, to problems for astronauts and possible malfunctioning of their equipment and instruments, the lunar regolith has been a stimulating topic to those interested in the Moon for many years. Our knowledge of this subject has grown steadily from research leading to and following the Apollo landings and up to the present day.

Those interested in investigating the regolith in more detail should avail themselves of such books as Heiken's **Lunar Sourcebook: A Users Guide to the Moon**, Taylor's **Planetary Science: a Lunar Perspective**, and Paul Spudis' **The Once and Future Moon.** These volumes are excellently written and a treasure trove of information on the Moon's regolith and a myriad of other lunar topics. There are also numerous journal articles and presentations available for more in depth study.

Our Moon is indeed a captivating world that does not follow or need to follow our Earth-generated conceptions. It presents a true challenge and investigative adventure to those who have chosen to study it. Slowly, the mysteries are being revealed about our puzzling and fascinating companion world.


## Acknowledgement

The author would like to thank Dr. Timothy Stubbs for his content review and supportive suggestions. His willingness to sure his knowledge was invaluable.


## Note 1

Boulders are > 200mm (8 inches) in diameter - in turn, rocks are considered < 200mm in size.
≈ means approximate or the same.
~ means a poorer approximation but in the same order or size.
µm is a micron or 1 millionth of a meter
Å (angstrom) is a unit of length equal to 0.1 nanometer or $1\times10^{-10}$

## Note 2

A meteoroid (classification) can range from a few microns in diameter to meters, perhaps up to 10m to 100m in size. All are of asteroid origin.

An asteroid (classification) can range from a few microns in diameter up to 1000 m or more in size.

Asteroids are most likely to be in an orbital path, mainly between Mars and Jupiter.

Meteoroids and asteroids are basically made from similar compositions with up to 75% being carbonaceous in nature.

Comets are an icy, small solar system body that, when close enough to the sun, display a visible coma and (sometimes) a tail. Comet nuclei are them-selves a loose collection of ice, dust, and small rocky particles. (According to NASA guidelines, a comet must be at least 85% ice.) Comet size ranges from a few hundred meters to tens of kilometers across. Comets travel in orbits that generally take them close the sun and then into the far reaches of the solar system. Comets that have had all their volatiles vaporized by the sun's radiation pressure and solar wind can appear as asteroids.

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**Editor's comments:** Many thanks to **Ron Brooks** for this in depth article. We cannot deal with moondust if we don't know what it is and how it behaves. For Lunar Pioneers, that will be job #1. **RB**

## Whoa! Wait Just A Minute on those Water Engines!

By Bryce Walden, Researcher Oregon L5 Society - http://www.OregonL5.org/ - January 03,2012

I recently viewed a very nice science special about the Moon ("Do We Really Need the Moon?", BBC2 2011). Toward the end they revealed that we now think there are significant deposits of water on the Moon, most notably in permanently-shadowed polar zones, deposited by comets. As usual, one of the first things they thought of was cracking the water into hydrogen (rare, on the Moon) and oxygen (common, in lunar rocks), in order to create fuel and oxidizer for the "clean" and high-ISP rocket engines whose exhaust is nothing more than intensely hot, energetic water vapor.

On Earth, with increasing concerns about exotic and mundane pollution of our atmosphere, such "water engines" are considered righteous and desirable. Given further thought though, on the Moon, maybe not so much.

Despite the discovery of 'certain icy deposits in ultra-cold traps, the fact remains that most of the Moon's rocks and regolith are extremely dry, or anhydrous. This gives them very special properties, some good and some bad from our perspective. Ultraviolet and cosmic ray bombardment may have led to unique compounds and properties in the lunar regolith. Many planners are intending to make use of regolith properties for winning various resources, including, but not limited to, elemental iron, strong anhydrous glass, solar wind volatiles captured atom by atom over the millennia, etc.

Start spraying water over all this and elements that have remained pristine and undisturbed chemically for billions of years will start reacting and changing immediately. Add a molecule-thick layer of water on each particle of regolith and watch its handling characteristics change, not to mention the processes it might have to be put through just to get back what you once could have had for free.

It is true that if the amount of free water being added to the Moon by rocket exhausts will be very small in relation to the Moon as-a-whole. However, it will be concentrated near our bases which is also where we will be wanting to start regolith processing for reasons of efficiency and convenience. So we will be polluting exactly the places we will be working.

Further, the presence of water vapor, some of which may remain in vapor form or sublimate from frost into vapor every sunrise, will introduce a small but "sensible" atmosphere in the vicinity of the base, changing the high vacuum condition and adding extra trouble to optical astronomers, laser-beam communications, radio propagation, etc.

In other words, the same rocket exhaust we regard as "clean" and "desirable" on Earth might well be considered pollution and undesirable on the Moon. A rocket that burns oxygen and aluminum, on the other hand, would have an exhaust of powdered aluminum oxide, already a regular constituent of the Moon. ﬂOn Earth: dirty; on the Moon: natural. And the powdered aluminum will quickly, ballistically fall back to the Moon, adding just another thin layer of dust and staying out of the near-vacuum atmosphere around the base.

Finally, until we get a much wider solar system economy working, such that we can cheaply import hydrogen to the Moon, using what little hydrogen we have natively on the Moon for throwaway rocket fuel is practically criminal and at the least short-sighted and not very bright. Hydrogen on the Moon should be priced at its replacement cost, and until there's a lot of solar system traffic that includes hydrogen compounds, that replacement cost is the cost of shipping hydrogen to the Moon from Earth. Compare that price to the price of lunar-derived abundant aluminum (or magnesium or other suitable elements) and oxygen, add in the cost of water polluting the local lunar environment, and the water engine no longer seems the easy shoo-in it has been considered so far. **BW**

# Desolate, Lifeless, Unforgiving: Is the Moon too Forbidding a Challenge?

By Peter Kokh

## Why many space enthusiasts are more interested in Mars

Many space enthusiasts see Mars as a more attractive goal than the Moon, despite Mars' much greater distance, and the much harder to reach at very limited travel opportunities.

- **Mars has color:** its pallet is not one of unrelieved light to dark gray tones.
- **Mars sky is bright, not black**, and even though it is not blue that brightness surely helps one's mood.
- **Mars' day is the same length as ours**, almost - just 37 minutes longer and that may be easy to get used to (especially for late sleepers)
- **Mars may be cold, but it is never life-squelching hot.** Mars has an atmosphere, not the kind one can breath, but thick enough to provide shielding from the meteorite rain that is a constant "weather" condition on the Moon
- **Mars air can be mined** for nitrogen, oxygen, methane and other basic organic feed stocks. While the air pressure is very low, less than 1% Earth normal, there is much more CO2, the major ingredient of Mars air, locked up in the polar caps, and it appears to be a feasible goal to use various methods to thaw those ices to raise the pressure significantly.
- **Mars also has a large ocean-like basin**, suggesting possibilities for terraforming Mars into a more Earthlike place. No matter that these possibilities are far-off options.

The Moon, in contrast, has no atmosphere to speak of, and if we were to create one, we'd have a "dustbowl from hell" for millennia. The Moon may be nearby, but it seems to unforgiving, too unattractive.

### Getting past appearances: Any "disadvantage" should be approached as "an opportunity in disguise"

This maxim was a lesson learned from my mother in my early teens. I was helping her redo a room in our home and commented, "If that radiator were not where it is!" To which she replied, "Well, keep looking at it until you figure out how we can turn its position into an opportunity!" And soon we did so. This experience transformed my life, and still gives soul to everything I write as well as to how I am able to turn every crisis in my life into something unexpectedly good.

**Optimism** (Latin "best") is useless.

**Pessimism** (Latin "worst") is useless.

**Meliorism** (Latin "better") is the only attitude that works. Whatever the situation, whatever the facts, we can take the situation and make things better!

Once you try this tack a few times, it takes over your life. Why? Because it works every time. Because it is the only "attitude" that has the power to produces better results. This applies not only to how we see the physical world, but how we fare in the human world that we all have to share.

**Is the Moon a wasteland?**

**"There is no such thing as waste, there are only resources we are too stupid know how to use."**

Arthur C. Clarke - to Walter Cronkite during launch of Apollo 13

## The Moon: Just the "facts" - one by one

• **Challenge: The airless surface is exposed to constant pulverization**

√ micro-meteorite bombardment,

√ cosmic rays, and periodic solar flares.

√ Temperatures vary from very very hot to very very cold because the Moon is airless, and the day night cycle is so long (29.53 Earth days long).

√ The surface has been pulverized into a moon dust blanket 2-10 meters thick.

(See Ron Brooks very informative 3-part article in MMM #250, #251, with part 3 in this issue above.)

> **Opportunity: We can tuck our habitat structures under that blanket** (2 meters is enough for short tours of duty, 5 meters best for lifetime stays) and be fully protected not only from micrometeorites, radiation and solar flares, but also from the extreme dayspan heat and nightspan cold. Being underground, we can use heat pumps to store excess dayspan surface heat to use for nightspan heating, and conversely, to store surface nightspan cold for dayspan cooling. See link below:

http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=89

• **Challenge: The Moon's day-night ("dayspan/nightspan") cycle is too long** 29 1/2 Earth days, the Sun being over the horizon for 14 3/4 Earth days, and below the horizon for an equal amount of time. One result is that solar power if available for just half a lunar month (since it is defined by the period of sunrise to sunset, not the Lunar month, perhaps we should call it the "sunth")

> **Opportunity: as the pole is not significantly inclined** to the orbit around the sun, there are no "seasons" so to speak, to provide variety of weather and break monotony. For the welcome biweekly change of pace see below.

# **Helpful Reading: "Dayspan" - "Nightspan" - "Sunth" pages 10-13 in**

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

• **Challenge: The Moon's long nightspans make industrial operations impractical**

> **Opportunity: as the Moon's dayspans are equally long,** there is ample opportunity to store up power. It is absurd to think that having to store up power in one form or another is a handicap. Power storage has been the backbone of industrialization for thousands of years.

# **Helpful Reading: "Multiple Energy Sources" pp. 7-10** http://www.moonsociety.org/publications/mmm_classics/mmmc4_Jan2005.pdf

**"OVERNIGHTING: Consummating the Marriage of Moon & Base" pp. 52-55**
http://www.moonsociety.org/publications/mmm_classics/mmmc9_Jan2006.pdf
**"Potentiation" pp 31-35**
http://www.moonsociety.org/publications/mmm_classics/mmmc13_July2006.pdf

• **Challenge: The Moon has been geological dead for billions of years** and did not go through active geology and tectonic processes in the presence of water that created ore-rich lodes on Earth, helpful to mining.

> **Opportunity: the same bombardment which produced the meters-thick regolith moon dust blanket means that the Moon is essentially pre-mined:** no deep shaft mining, no landscape-scarring strip mining, Everything we want is in this handy pre-pulverized surface blanket

# **Helpful Reading:** "**Moon Mining & Common Eco-Sense**" p. 60 and "**Moon Mining and Engineering Realities**" pp. 61-61 in www.moonsociety.org/publications/mmm_classics/mmmc4_Jan2005.pdf

**Challenge: The moon's vacuum means that we have to wear space suits or travel in pressurized vehicles outside our cozy underground complexes.**

> **Opportunity:** our habitat areas can all be actually or virtually interlinked so that one can go almost anywhere without donning a spacesuit

# **Helpful Reading "Middoors" and "Matchport" pp. 14-15 in**

http://www.moonsociety.org/publications/mmm_classics/mmmc1_Jul2004.pdf

**Making do without the "outdoors" page 39 in**

http://www.moonsociety.org/publications/mmm_classics/mmmc10_Jan2006.pdf

• **Challenge: the lunar "sky" is black all the time. That will be hard on the eye, leading to black sky blues**

> **Opportunity:** Both inside and "out-vac" there are ways to create a pleasant and comforting atmosphere

# **Helpful Reading: "M is for mole"** http://www.moonsociety.org/chapters/milwaukee/mmm/mmm_1.html

**"Black Sky Blues" (1) pp 57-59** http://www.moonsociety.org/publications/mmm_classics/mmmc14_July2006.pdf

"Black Sky Blues" (2) p 37, (3) p 56 http://www.moonsociety.org/publications/mmm_classics/mmmc18_Jan2008.pdf

also www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=12

- **Challenge: the Moon's gravity is too light**

√ The human body will deteriorate physiologically during stays on the order of a year or more, and may not stabilize at an acceptable level; Infants born on the Moon may not develop or mature properly.

> **Opportunity: First,** one cannot legitimately argue from the physiological degradation that is experienced by many months in a space station at"zero G" that the same degradation will occur at 1/6th lunar gravity or at 3/8ths Mars gravity. No one has been on the Moon for more than a few days. We can do long term experiments with small animals in a rotating environment at or near the Space Station to learn more.

**Second, it is precisely the Moon's lower gravity that makes the Moon economically vital as a supply of building materials for structures elsewhere in space** (Low Earth Orbit, Geosynchronous Earth Orbit, Earth-Moon Lagrange points, even Mars – because it takes only 1/22nd as much fuel to reach such destinations from the Moon as it does from Earth's surface. The Moon's reduced gravity level is the foundation of its economic and industrial potential. M**ars in contras**t, (1) is at greatly variable distance from the Earth-Moon "system", (2) is handicapped by the infrequent travel windows to and from Earth, and (3) its greater gravity and deeper gravity well, also handicaps Mars in any economic rivalry with the Moon.

**Third** pioneers will develop sports – and even dance and skating forms that are unique and which may be very entertaining to watch by Earthbound fans.

# **Helpful Reading:**

**"Native Born" pp 34-36** www.moonsociety.org/publications/mmm_classics/mmmc5_Jul2005.pdf

**"Hexapotency Toning Centers" pp 13-15**

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

http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=45

- **Challenge: The Moon is too poor in the volatiles needed both for life support (food, agriculture, biosphere) and serious industrialization**

> **Opportunity: While is true that the Moon is impoverished in volatiles in comparison to Earth and even in comparison to Mars, it is not true that the Moon lacks an endowment large enough to both support human settlements and to industrialize.**

√ **The solar wind buffeting the powdery regolith blanket of the Moon for billions of years has enriched the surface layer** with hydrogen nuclei (protons), carbon, nitrogen, and with the noble gasses such as helium, argon, etc. These can easily be harvested while constructing roads, settlement sites, etc.

√ Previous **probes such as Clementine and Lunar Prospector** gave strong indications of water-ice and other cometary volatiles in "harvestable" abundance within permanently shaded north and south polar craters – confirmed by **Chandrayaan-1, Lunar Reconnaissance Orbiter and** its **LCROSS impactor**

# **Helpful Reading: Byproducts of Helium-3 and Hydrogen Solar Wind endowment harvesting**

http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=45

http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=59

**'Gas scavenger" – pp 15-17 –** http://www.moonsociety.org/publications/mmm_classics/mmmc3_Jan2005.pdf

**"Primage" – pp 49-51 –** http://www.moonsociety.org/publications/mmm_classics/mmmc4_Jan2005.pdf

**PK**

MMM #253 – MAR 2012

## Turning the Detours along the Road to Space into Opportunities

Editorial By Peter Kokh

Many "**Return to the Moon**" **Enthusiasts** lament the policy change taken by the Obama Administration. But stop and consider! The overly expensive "socialized and bureaucratic" NASA program was going nowhere, and any partial steps along that now (temporarily?) abandoned path would most likely to have led to "Flags & Footprints 2" – something that may have been temporarily exciting but have at best left the ruins of an outpost, a lunar "ghost town" to the relics of Apollo now dotting the Moon's nearside. NASA is set upon outdated, ill-conceived brute force rocket technologies.

Meanwhile, the new "Flexible Path" can advance technologies to serve a "Triway" of destinations:

(1) To the Asteroids (for planetary defense, science, and resources),

**(2)** To Mars to answer the questions about life long ago, and perhaps even today, to learn more about that fascinating world, and to prepare for establishment of a second "basket" for humanity, good in itself, but especially as humanity's insurance policy if something were to go terribly wrong on Earth: some environmental disaster, or a significant asteroid impact, and

**(3)** Back to the Moon, for scientific exploration of course, but also because anything pioneers could make for themselves out of lunar materials, could be shipped for 1/23rd the fuel cost to "markets" in Geosynchronous Earth Orbit, **GEO** for constructions of giant platforms hosting hundreds of satellites in the too few allocated spots (180 - 2° apart) and possibly solar power satellite arrays - and to Low Earth Orbit **LEO** - for the construction of large space stations, tourist hotels and more.

But what is really exciting about the "Flexible Path" is that it would prioritize development of technologies needed to pursue each of those paths "successfully" - so time and resources sent to develop life support and transportation technologies (but 2 of a long long list of technologies needed in common) and in that sense, any "delay" encountered on this "**Triway Detour**" path will be a very productive and fertile one. When we do "do" the Moon, it will be "done right, done for keeps," ditto the Asteroids, ditto Mars.

Pouting by dedicated but "horse-blindered" Moon and Mars advocates is a waste of their time. **Get with it!** Yes, we may not get to your favorite destination as soon as you would like, and maybe **not in you lifetime**. Letting such highly personal goals get in the way of humanity doing in right, doing it for keeps, would be bogus. The priority of each and every one of us, and of the various destination-focused groups to which we may belong, is best served by doing it right, doing it for keeps. And as the key technologies needed to pursue each of these destinations are developments needed in common.

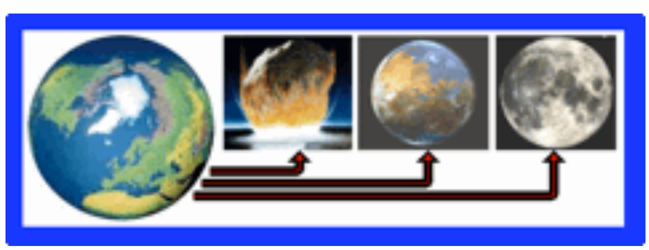
Nor should any of these Triway goals be pursued by any "national" space agency, as opposed to by an international effort. The experience of ISS is clear. As long as America (Congress and NASA) were proposing this goal separately, Congressional support was weak, unfocused, and ephemeral. Once President Clinton proposed that we build a station together with the Russians (to keep their scientists "out of mischief") Congress was motivated to give the go-ahead. And as we took on more and more "international partners" ISS took on a certain immunity to cancellation. We are all "human from Earth." And our individual histories are but local "episodes" of one shared epic: the Epic movement "out of Africa" to become an "Intercontinental" species. It has taken many thousands of years for this "intercontinentalization" to mature and ripen as it has in the past century. Yes, "ripen" is the right world as we now "bloom and seed" to "birth" a second "epic chapter" - we are about to become "Interplanetary."

Many, if not most people. are slow to see this, but crossing thresholds are always like this. We do not realize that we crossed one until we are well on the other side. The Moon is the nexus between our "intercontinental habitat" and our much larger "interplanetary" one. Nor, I am sure, will that be the end of our "Out of Africa" epic. It is just a dream right now, but someday, if we play it right and do not selfishly destroy ourselves first for short-term economic advantages, some day, possibly less far in the future than we could reasonably expect, there is another "inter" level of "the beyond" out there. Someday we could, we might, we should become "interstellar."

Not to long ago, we Americans could delude ourselves into thinking that the future belonged to us, or would be led by us. But given the "globalization/intercontinentalization" of the "world economy" in the past decade or so (beginnings commonly go unnoticed) it is no longer possible to pretend that we are not all in this together.

The "flexible path" more aptly called the "Triway to Space" is pregnant with success. We each owe it to our own dreams, to push this path forward. Moreover, it is a path tailor made for significant commercial contribution.

If you listened to the sorry debates by this year's crop of Republican presidential candidates, none of them is aboard the train to the future we all want. Gingrich alone seems pro-space. Romney dismisses space, The others ignore it. But the international approach will project a pro-space force that cannot be ignored, and a "Triway" approach will allow us all to reach our goals at a steadily accelerating pace, not the steadily decelerating pace that has prevailed since Apollo 17 boosted off the Moon 50 years ago next December. Take heart! **PK**



http://www.moonsociety.org/presentations/pdf/Triway1.pdf

**NB. One page "Whereas --- Therefore" document in preparation along with expanded Background Paper**

By Peter Kokh and Al Anzaldua

# The Challenges Of Mars

By Peter Kokh, onetime Martian "wannabe"

Many people are understandably more enthusiastic about the prospects of human exploration and eventual settlement of Mars than they are about further human missions to the Moon. The Moon is enormously more visible in out skies, even at times in the daytime, than Mars, and we are bored with its unchanging gray tone appearance. "Familiarity breeds contempt," as the proverb goes.

Mars, while less frequently, and much less revealingly present in our skies, has become legendary through science fiction as well as by early misunderstandings of the planet's current climate, similarities to Earth, and of the challenges of thus who would transform Mars into a more Earth-like human frontier by "terraforming."

Make no mistake, Mars will play an enormous role in humanity's future. But we will be in a better position to move in that direction, if we better understand the challenges the Red Planet poses for us.

## Mars temperature range is much lower than Earth's or that of the Moon

**http://en.wikipedia.org/wiki/Climate_of_Mars**

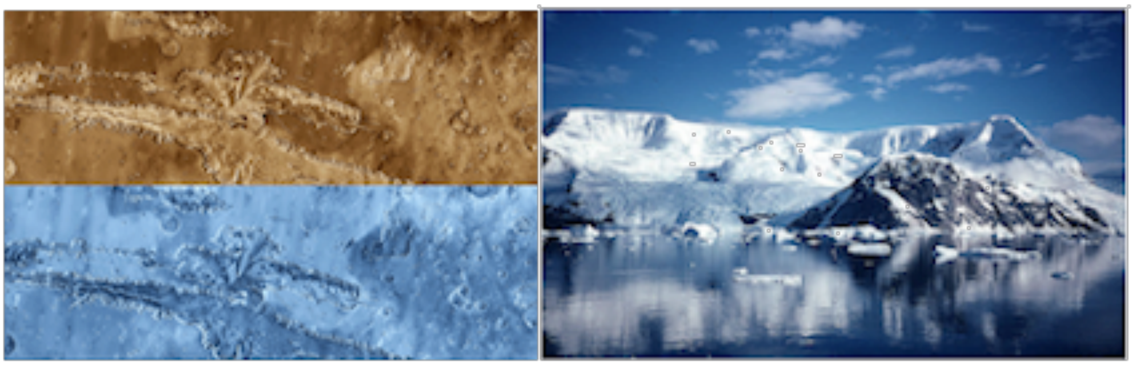
"Surface temperatures have been estimated from the Viking Orbiter Infrared Thermal Mapper data; this gives extremes from a warmest of 27 °C (81 °F) to −143 °C (−225 °F) at the winter polar caps.[17] Actual temperature measurements from the Viking landers range from −17.2 °C (1.0 °F) to −107 °C (−161 °F)."

**http://en.wikipedia.org/wiki/Climate_of_Mars#Temperature**

In fact, these figures are very similar to the temperature range on Antarctica, which few people seem anxious to settle despite the continents fresh breathable air and surrounding fish-teaming waters, and its improving accessibility from other, populated, regions of Earth.

**http://en.wikipedia.org/wiki/Climate_of_Antarctica**

**http://en.wikipedia.org/wiki/Climate_of_Antarctica#Temperature**



Mars may look amazingly like Arizona, but we must not fool ourselves. It will feel much more like Antarctica!

**http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=112**

It is puzzling that so many would-be Mars pioneers have made "life-style" decision to relocate from the US "snow-belt" to the US "sun-belt."

Given that Mars thins atmosphere and lack of a protective magnetic field provides little protection from cosmic rays and solar flares, we will have to shield ourselves under a blanket of "Mars dust" or loose soil (within lava tubes is another option) at any rate, and this will greatly moderate temperature swings. But make no mistake. The average temperature on Mars at a depth of 2-5 meters is 50° C lower than on the Moon. That means, that whereas Lunan pioneers can store excess dayspan heat for nightspan heating and nightspan cold for dayspan cooling, on Mars, no such easy way to moderate interior temperatures exits. Martian pioneers will need to be tapping various sorts of energy to warm themselves year-around.

For many would-be pioneers, this constant "war" with Mars climate will be too demoralizing. Pioneers from Earth's cold desert regions will fare much better than those who enjoy sun-bathing on Earth! We do not want to discourage anyone. Humans will meet the challenge. But many Mars enthusiasts need to remove their sunglasses. Even if they realize that Mars is not for them, we encourage them to keep supporting human missions to Mars!

## Mars' Long Irregular Seasons

**http://en.wikipedia.org/wiki/Climate_of_Mars#Seasons**

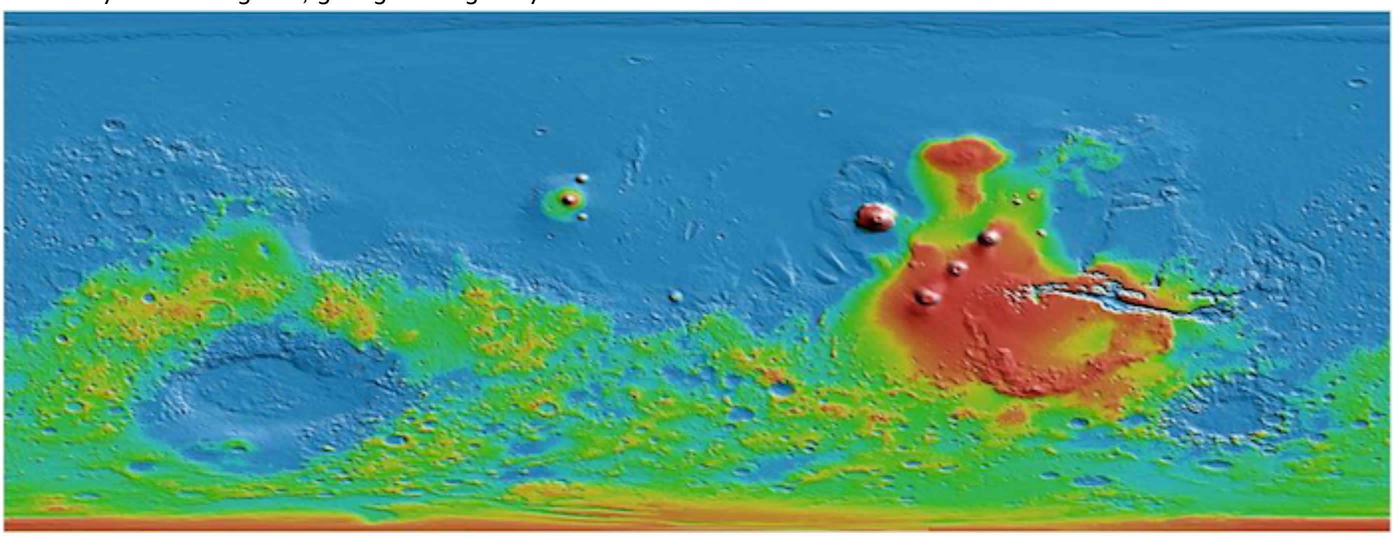
One of the characteristics of Mars that has long endeared this "future homeland" to would-be pioneers is that Mars has a climate pattern very much like Earth's Winter, Spring, Summer, Fall, with the seasons in the Southern Hemisphere in inverse sequence from those in the Northern Hemisphere, again as on Earth. But there are two significant differences,

- The sequence is not "cold" – "moderate" – "warm" – "moderate" but rather "very very cold" – "cold" – "moderate" – "cold"

- As Mars orbit is significantly more eccentric, bringing the planet much closer to the Sun during Southern Hemisphere Summer and much further from the sun during Northern Hemisphere Summer as attractive as some northern sites may seem for settlements, the Northern Climate will be the more challenging. To make it worse, since Mars slows down in its orbit when as it gets further from the Sun, colder Northern Spring (=Southern Autumn) and Northern Summer (= Southern Winter) will be longer than there warmer Southern counterparts. "Daddy why can't we move to the South? Please!"

Again, since the pioneer habitats will be under the surface at a level where the year-around temperature will be a constant "cold", future Martians will only notice these climactic differences when they are out on the surface. Now many look forward to the eventual terraforming of Mars: "Red Mars -> Green Mars -> Blue Mars "(but Kim Stanley Robinson forgot a color/stage between Red Mars and Green Mars - Muddy Mars! "Terraforming" (making Mars more Earth-like) vs. "Rejuvenescence" (meeting Mars halfway) is a whole separate topic in which there is a dire need for realism and respect for Mars. We will bring this up in another issue, perhaps # 263, next year.
**http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=115**

Meanwhile, in choosing sites for a first outpost (hopefully located where it can grow into a viable permanent settlement rather than be doomed to become a historic preserve or the first "ghost town on Mars") the implications of Mars' irregular seasons will be taken into account along with other, economic advantages. We have previously written about the unique and superior advantages of a location on the western slopes of Mars Pavonis astride the equator (riddled with lava tubes; ideal site for a launch track up the western very gradual slope, from which spacecraft and payloads could be launched directly into an Earth-Moon rendezvous orbit.) Another site which has unequalled characteristics is Hellas Planitia in the southern hemisphere, the lowest basin on Mars, in which atmospheric pressure will always be the highest, giving it marginally the best climate on Mars.



The Mercator Projection map above has been vertically compressed by the editor to 75%. The blue areas are below "sea level" and do not indicate ocean beds, but they are where oceans could have been located, "if." The large blue basin at left is Hellas. On the right we see three volcanoes in a slanting row. Pavonis Mons is the middle one, smack on the equator. This whole "red" area is one lava sheet on top of the other and probably riddled with lava tubes with a "world" of pre-sheltered volume, and could hold the bulk of setter population in the future. Pavonis was the site of a space elevator in Arthur C. Clarke's "Fountains of Paradise."

Can future pioneers adjust to Mars' long and irregular seasons? Of that, I have no doubt! There have been many attempts to create a Mars Calendar. All of them respect the length of Mars' year, but only one reflects Mars actual seasonal patterns while minimizing cultural implications of the length of Mars year. You are invited to check out my "Mars Pulse" calendar.
**http://www.moonsociety.org/publications/mmm_papers/marspulse_cal.html**

## The Challenges of Shielding Habitats on Mars

On the Moon, thanks to Apollo on location measurements, we have a good feel for how deep the moondust "regolith" blanket is, and how that depth varies. In the more recently formed lava flows that feel many of the Moon's impact basins and other lowlands, as these areas have not been subject to as much bombardment as have the much older "highlands" the blanket is generally 2-5 meters, whereas in the highlands it can be as thick as 10 meters. In both cases, this is more than adequate for the purpose of "tucking our habitats under a blanket" to shield not only from cosmic rays and solar flares, but also for moderating interior temperatures through the dayspan-nightspan-dayspan cycle.

On Mars, we have much less feel for the depth of the Marsdust "regolith" blanket. But clearly, as Mars does have a thin atmosphere, the winds have concentrated dust to great depths in "dunes" areas, and scraped the surface nearly clean in other areas where patches of bedrock were quite visible to the passing through cameras on the Mars Exploration Rovers **Spirit** and **Opportunity**, witness the image on the cover page.

In the "dunes" areas, which are quite extensive, we could place a habitat complex in between dunes and pull down the marsdust on top. These dunes do move, as do their counterparts on Earth, but given the greatly reduced power of Martian winds, these changes will be tolerably slow. Another suggestion is to burrow into a mountain side. Sounds easy, but that could be quite a project!

Yet another idea, and a good one, is to use what soil is available to make mars bricks or blocks and build a sheltering structure with them. At the least, a perimeter of Mars blocks or bricks could be used to tightly contain marsdust so that we need less of it.

But where the surface dust is not very deep, shielding may require import of marsdust from elsewhere, hopefully nearby. It is quite clear that the availability of shielding material must be a consideration in choosing a site to locate any outpost that we intend to be the seed of a permanent settlement. It is not at all clear that anyone had considered this.

The way pioneers shield themselves in various areas on Mars, will create a characteristic "architectural style" that will encourage visiting tourists from Earth, as well as from any settlement on Mars, to travel to other areas for one of the reasons tourists on Earth to visit "different" and "distinctive" regions on our home planet. And that will be a plus for the infant Mars' economy.

The challenge of keeping habitat spaces at "room temperature" will be greater at distances north and south of the equator, as it is here on Earth. Our prediction is that Mars pioneers, if carefully selected or self-selected, will be up to the challenge. The results will add to the tourism-worthy differences between different settlement clusters on Mars.

### Mars has as much land area as all Earth's continents combined

That's a challenge? Well, that's a lot of land to settle. Settlements could be antipodes apart. There could be clusters of settlements here and there with great stretched in between providing transportation challenges. It may be quite a while before there is any sort of circum-global road network. The implications are that unless the original settlements are "clustered" in a way that makes mutual access (trade, collaboration, sports, rescue, etc.) easy, it will be that much more difficult to build a "Mars economy." Yet there are in fact areas that will not be soon mutually accessible but yet are each attractive for settlement. My choice would be the lava-flow-built Tharsis Ridge which gives access to the Valles Marineris area, the most scenic tourist-tempting area on Mars. Other areas can come later. If NASA or an international collaborative effort are tasked with setting up just one location, not looking at the options for growth, they will pick a site fated to be that "first ruin" on Mars.

## The Import/Export Challenge of Mars

Mars is a long way from Earth, or rather from the Earth-Moon "econosphere" - in terms of the speed of light, a 6-40 minutes conversation gap vs. less than 3 seconds. In terms of one-way travel with present rocket technology, 6-9 months vs. 3 days. But that is the least of it. The Moon is in an orbit around Earth at a distance that does not vary greatly. Travel between the two is possible at virtually any time. Earth and Mars are in two different orbits around the Sun. Mars has a longer trip to make at lower speeds. They "line-up" every 25 plus months. So travel "windows" are brief (a month or so) and infrequent. And we must not overlook that some of these launch windows, as many as 2 or 3 in a row, may be in "Active Sun" periods in which the possibility of Coronal Mass Ejection solar flares could erupt with not enough notice, endangering those caught in space en route.

Someday, Vasimir-type rockets ("technologically infeasible" say some, "not" say others) and nuclear-thermal rockets could shorten the travel time and widen the departure-arrival windows, easing things greatly for travelers.
**http://en.wikipedia.org/wiki/Variable_Specific_Impulse_Magnetoplasma_Rocket (Vasimir)**
**http://en.wikipedia.org/wiki/Nuclear_thermal_rocket**

It is clear that import and export supply runs will have to be planned well in advance. It will be vital to stockpile needed supplies - enough to last perhaps two cycles c. 51 months, over 4 years! Whereas lunar settlements can live and thrive at the end of an "**umbilical cord**," for **Mars**, a "yolk-sac" situation is the only one viable under travel conditions currently feasible.

For both Moon and Mars, the principle export markets will be installations in Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO) where, when timing is not the number one issue, shipments from Mars will require less fuel cost, and from the Moon much lower fuel costs yet, than sourcing equivalent products up from Earth's surface, simply because of the differing depth and intensity of the three gravity wells. Installations in any of the Earth-Moon Lagrange Points will also be markets for goods from Mars and the Moon.

Yet imports from the Moon will be more attractive than those from Mars, all else (type etc.) being equal, as the Moon's gravity well "dimple" is much shallower than that of Mars. If cargos can be launched directly into an Earth-Moon orbit using only electric power and no fuel (the Mons Pavonis launch track) and needing no engine except to ease into orbit at the chosen Earth-Moon system location, that could go a long way towards diminishing the Lunar launch advantage - EXCEPT that one can launch from the Moon, in an emergency, at virtually any time.

That Mars is volatile-rich in comparison with the Moon, gives it an edge in products composed largely of such elements: natural organic material products and plastics.

Finally, Mars and the Moon will make natural trading partners.

**http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=45 PK**

# The Red Planet "Blues"

By Peter Kokh, onetime Martian "wannabe"

Mars would seem to offer both viewers from afar and future visitors and pioneers, a monotonous pallet of orange-salmon-beige coloration. Now the Moon's pallet is perhaps just as monotonous, but at least Mars' hues do have noticeable color from afar.

Up close, the situation is a little different. The Moon, is transformed into a mini-Mars during eclipses when the Sun's light reaches the surface only after being refracted by the orange-hued dust in Earth's atmosphere. That may seem a curiosity for those of us on Earth, but for future lunar settlements, that will mean big bucks from tourists timing their visits to the Moon to experience this awesome temporary and infrequent transformation, as well as for lunan pioneers themselves. We stray off topic.

**http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=91**

Mars pioneers will "compensate" in several ways. Inside their living and working spaces, there will be abundant greenery. Plants will be an integral part of the Life-Support System as well as an integral part of the "morale system" if you will. Of all systems, the human one is the most fragile, and thus maintenance of high morale has top priority, after just "keeping alive." Foliage itself comes in many shades of green as well as other colors. Flowers will be highly appreciated. You can expect that the "green thumb" culture on Mars will be much more cultivated than here on Earth, where nature provides so much "outdoors."

**http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=63**

Clothing on Mars will be as colorful or more so than on Earth, for the same reason. Ceramics and stained glass will add. How about glass windows which "translate" Mars' "salmon-colored skies" into blue ones? The ruddy skies could give one the blues after a while.

Out on the surface, brightly colored vehicles and signage will be easier to pick out against the landscape, a matter of safety. Although, a test at the Mars Desert Research Station showed that regular shapes with set colors can be picked out from the background fairly easily. Roadway signs will have to stand out, both in daylight and headlight conditions

**http://www.moonsociety.org/home-page/center-column/changing-images/showimage.php?image=60**

But what about those distinctly "blue" rocks that show up on **Spirit** and **Opportunity** photos of Mars surface, such as the photo on the cover page of this issue? If you get MMM as black and white paper hardcopy, you can see another such image at:**http://www.astrobio.net/images/galleryimages_images/Gallery_Image_7054.jpg**

While NASA says it does not doctor the colors on this or similar photos, one wonders if we can be certain that a human eye will see the same shades and tones? We might have to wait until we have "people on the ground." But who can argue with some welcome coloration outside the range of the usual Mars hues pallet?

Would chemical treatment of rock surfaces to alter the color be something the Martian "Green" Movement would embrace or want to ban? It would be better if we found areas where the coloration of rocks and/or soil was different, as such places would become tourist destinations, boosting at least the local economy. But surely sculpture gardens at "take a break and rest" road waysides would be universally welcome, and here the coloration could come from metal tones, ceramics, stained glass - a treat for the eye that gives the tired body a break as well.

For the Moon Society's "Artemis Moonbase Sim 1" exercise at the Mars Desert Research Station in Utah in early 2006, of which I was the commander, on a hunch when I happened to see them at a hardware store in iron Mountain, Michigan (my summer cottage is nearby), I picked up six pair of sunglasses with very large wraparound green lenses. Sure enough, they transformed the decidedly Martian coloration of the MDRS landscapes from orange family hues to whitish tones with a very faint orange tint. The transformation was remarkable.

Most of us have seen photos of Martian sunsets, and these leave a lot to be desired, as the gradation of hues is very coarse. Again, we'll have to wait until humans are there. Perhaps **Curiosity**'s camera(s) will be much improved and can stun us with more believable photos. Curiosity, aka The **Mars Science Laboratory**, is due to arrive on Mars August 6, 2012.

**http://mars.jpl.nasa.gov/MPF/ops/best_sunset.gif**
**http://www.jpl.nasa.gov/images/mer/2004-02-26/mars_sunset-640.jpg**
**http://en.wikipedia.org/wiki/Mars_Science_Laboratory**

How would fireworks look against the Martian sky? (do they need oxygen to ignite?)

Mars narrow color pallet is a challenge. One could get bored with it all too quickly. But I have a hunch that the pioneers will be inventive enough and challenged enough to be able to insert all sorts of treats for the eye. **PK**

**For More on Mars in MMM's past, and on Mars vs. Moon see the following:**

**http://www.moonsociety.org/mars/**
**http://www.moonsociety.org/publications/mmm_themes/mmmc_Mars1.pdf**
**http://www.moonsociety.org/publications/mmm_themes/mmmc_Mars2.pdf**

# Artificial Gravity enroute to Mars and back strongly advised

By Peter Kokh, onetime Martian "wannabe"

## Why there is a need

While some brainstorm designs for Mars-bound craft have included provisions for simulating gravity, most writers and designers dismiss the need. Admittedly, such a design requirement would make the craft heavier, more expensive, and because of the added weight, such a craft would require a more robust and more expensive propulsion system – all conditions to be avoided. But hold on a minute! Compare that extra expense to the cost of minutes wasted on Mars by crew members taking time to get their legs back so that they can use their priceless hours on Mars to accomplish the goals they came to do! Most of us are aware how helpless persons find themselves on returning to Earth after a year in "zero-g."

There is no comparison of the cost of wasted time on Mars to the cost of avoiding the problem by providing shipboard artificial gravity – at the 3/8ths G level they will experience on Mars, and which would allow them to "hit the ground running." The tipping of the scale is so very self-apparent that it makes one wonder what universe its proponents are living in. Zubrin's "Mars Direct", NASA adaptions thereof, and Elon Musk's Falcon Heavy Mars trip scenarios do not address this problem, despite its obviousness (when you think about it in the terms stated above.

Now if the pennies need to be pinched, the crew could return to Earth in "free fall" as there would be no such urgency to get back on their feet on arrival. Like the MIR and ISS astronauts returning to Earth after very long stays in space, they would eventually recover for the most part. Permanent vision problems reported are hardly disabling. Most people lose some visual acuity as they age anyway. (This writer gets to see 2 or 3 stars where everyone else sees but one. But I can still type and do all I need to do. It's not fatal!)

If we do provide artificial gravity on the return trip, it could start at Mars-normal 3/8ths G and gradually ramp up to full Earth-normal gravity by arrival, so that the returnees could hit the lecture circuit right away!

## How we can provide artificial gravity en route

We do not intend to go into design options in this article. To help you visualize the options, consider the artificial G rotating circular running track in the classic film 2001: a Space Odyssey. There are a number of other films where set designers have gone where no NASA designer dared to go.

Rotating cylinders are the common answer. They do create a problem as their rotation would induce a counter rotation in the rest of the vehicle and that is to be avoided. A pair of mutually counter-rotating sections is one answer. A simple flywheel turning in the opposite direction would be much simpler.

Most of the illustrations show a very short radius which might induce corriolis problems. The simple trick of colored directional cues, with experience, would keep crew members from turning too fast in certain directions.

Another solution that has been advanced, is to divide the ship into two sections, crew quarters and everything else, pay them out and apart on a tether (a twist-resistant beam or truss would work much better if it were collapsable} then induce rotation about a common center of gravity.

Now there is an ideally perfect option: thrust at 1 G halfway to Mars, flip directions and decelerate at 3/8th G until you arrive. Unfortunately, we know of no engineerable way to do this, or of no propellants with this much oomph for the same mass. With such a system, one could get to Pluto in a week, if I remember correctly (I did the math for all Earth to planet destinations 3 decades ago, on paper, and have no idea if that sheet of paper still exists. Oh yes, to Alpha Centauri in 3 years and we know that isn't going to work! Jerry Pournelle did the math as well I believe and it may be in one of his paperbacks. Back to the real early 21st Century!

Our purpose here is not to pick the ideal engineering solution, but to help ostrich-minded designers to take a peek at the real world and abandon and start from scratch. Look at all the options and their variables and weigh the plusses and minuses of each, compare the nickels and dimes, determine what needed technology and engineering items are not yet on the shelf, and in general, get to work and give us some real designs.

And Oh by the way, if you can give us some shielding while you are at it, enough shielding so that we can make the Earth-Mars run and Mars-Earth run in Active Sun periods as well as in Quiet Sn years, that would be marvelous. It would be a pity to send out a crew on a very expensive mission only to have them fried on the way by some unexpected Coronal Mass Ejection solar flare event. Now to be honest, these events are directional, and by luck none will expand in the vector our Mars-bound or Earthbound ships are traveling. The gambler needs to know when to fold the cards, however.

If we are only going to send a ship or two to Mars just to say "Kilroy was here" on an expensive remake of "Flags and Footprints I" perhaps we can take the gamble. But if we are going to stay, the only option that makes any sense at all, including economic sense, we need to gamble intelligently.

## Calling all readers

If you find any designs of Mars-run ships that provide artificial G – online – please email MMM the URL (web address) to **kokhMMM@aol.com** (caps not necessary) and when we get a few, we will publish them. **PK**

## Is Competition Bad for Space Development?

Guest Editorial by Al Anzaldua, Tucson Space Society

Western society tends to look fondly on competition. Perhaps this idea first sprang from the world of sport, where competitions like the Greek Olympics provided us with athletic ideals. Much later, Adam Smith's 1776 book, The Wealth of Nations, showed us how business competition can provide an "invisible hand," making products cheaper and companies more productive, thereby increasing the wealth and prosperity of all.

In Charles Darwin's 1859 book, On the Origin of Species, we see credit given to competition among organisms and "survival of the fittest" as explaining the evolution of species. Certainly today in the United States, competition is lauded in sport, business, politics, academics, and elsewhere.

But is competition always good? Does competition always bring benefit, or is something missing from our understanding of the role competition plays within the natural sciences and human society? Whether one is speaking of economics, evolution, politics, or space development, close examination shows that cooperation can also play a crucial role in the advancement of a given sector.* And there are times when competition alone can be downright counterproductive or even destructive.

Our reasons for landing and walking on the Moon in 1969 are now an old story. Also old are the reasons given for our failure to advance into space significantly after Apollo. The United States was in high competition with the Soviet Union at the time. The moment we landed on the Moon, we won that competition, and therefore nothing more needed to be done on or with the Moon. In hindsight, it is even surprising that the United States even went on with Apollos 12 - 17.

With a more thoughtful Apollo program, we could have laid down the first stage of Solar System infrastructure and human prosperity. By now we could be living and working in Space and reaping its rewards. But it didn't happen because we went to the Moon for the wrong reason. We went to the Moon with an expensive crash program based on competition instead of reason.

Are we making similar mistakes even today? China, which has already vowed to build a space station and put astronauts on the Moon, has just announced an ambitious five-year plan for space exploration. Some in the space advocacy camp are cheering this development thinking that more space competition with China will spur our leaders to give better funding to NASA. But if competition with China does indeed produce more funding for NASA, to what end would this funding be used? Will we again plant our flag somewhere and then feel we have "won" the competition and need do no more?

Perhaps competition to lay down permanent space infrastructure would make sense? But would cooperation with China on space make even more sense? Granted China at this stage would not likely accept any offer of cooperation on space. Also, there are deep fears in Washington that technological cooperation with China would allow that country to steal secrets with military applications. On the other hand, unbridled competition and increased rivalry with China could lead to a more dangerous world for all of us. For this reason alone, we should keep our collective eyes open for opportunities to cooperate -- even small ones. We should not forget that it was ping-pong games that thawed relations with China, in the first place!

Finally, space advocacy is another area where competition is sometimes counterproductive at least and downright destructive at worst. Within the space advocacy community separate groups chauvinistically push for apparently separate goals. Against a backdrop of scarce resources, one group sees lunar settlement as the most feasible goal and is convinced that lunar resources will help prevent further degradation of Earth's environment.

Another group sees Mars as the only logical place to establish another human civilization and insure the survival of humanity. A third group, believing that near-Earth asteroids (NEAs) represent both an existential threat and huge repository of natural resources, wants to make the deflection of NEAs into safe yet accessible orbits the highest priority.

Unfortunately, chauvinistic competition among these three groups for government and public support does little to garner that support and instead tends to discredit the whole space advocacy movement. What are the public and our leaders to think if we cannot agree among ourselves as to space priorities? If instead there was more cooperation and collaboration among these three groups, what Peter Kokh has called the "Triway" (2) approach, these advocates might then be able to agree on an integrated vision of space development -- one which could garner support for all three goals simultaneously.

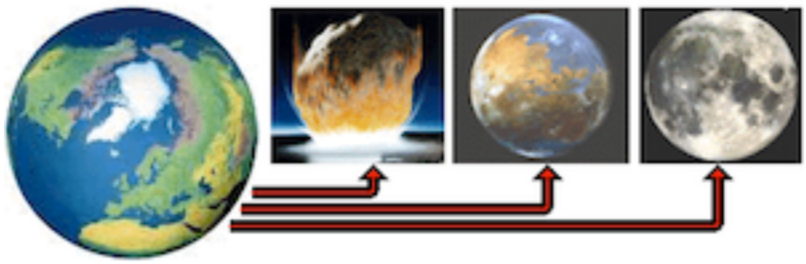
Now that private space companies like Orbital Sciences, Space X, Virgin Galactic, Bigelow Aerospace, and Stratolaunch are making serious efforts to bring down space launch costs and develop credible plans for various space activities and destinations, the time is ripe for the space advocacy community to get its act together and present a unified front for the benefit of all major space-development players. After all, in the long run, reaching all three goals will create infrastructure and synergies, which will make each goal more viable and sustainable.

Triway collaboration could be carried out through joint position papers and by urging NASA to invest in R&D that will advance all three goals simultaneously, while it continues to facilitate private space development. Certainly the infighting and denigration of the other camp's priorities has to stop. Let us look for opportunities to collaborate instead. This would show the general public and our government leaders that we indeed have our act together and have ideas worthy of serious consideration – and even funding.

(1) A good example of the crucial role cooperation plays in evolution is laid out in the 1986 book, Micro-Cosmos, by Lynn Margulis and Dorian Sagan. Dr. Margulis, building on earlier work by the Russian Konstantine Mereschkowsky, is responsible for the modern theory of symbiogenesis, which describes how symbiotic cooperation among life forms is crucial to evolution and even human existence.

(2) http://www.moonsociety.org/presentations/pdf/Triway1.pdf

**Al Alzandua** – Tucson Space Society.



## Space Precedents for an International Lunar Research Park

By Peter Kokh

Despite the Cold War rivalries between United States and the Former Soviet Union, and now the one-sided rivalry between the friendly International Space Station Partners and a suspicious China, International cooperation in space has a strong history. We will not try to provide a complete list. Examples will do.

### The Apollo Era

Several nations around the world helped by monitoring the paths of US spacecraft and relaying messages so that NASA had a global link. Jodrell Bank in the UK, Muchea in Western Australia. But perhaps the classic example was **Apollo-Soyuz in 1975** when a NASA Apollo and a Soviet Soyuz docked together, with the Americans speaking Russian and the Russians speaking English, a failsafe way (the only way) to avoid misunderstandings as each side would only use words native to the other. Another example was the setting of a world-wide standard for docking apparatus design so that crews of one nation could come to the assistance of those of any other nation in space. Unfortunately, China has not followed suite, perhaps paranoid about being boarded, an adolescent attitude.

**http://en.wikipedia.org/wiki/Apollo-Soyuz_Test_Project**

### MIR and NASA's Shuttle-MIR program

**http://www.nasa.gov/mission_pages/shuttle-mir/** **http://spaceflight.nasa.gov/history/shuttle-mir/**

Mir was not the world's first space station, but it was the first to be long-lived. Here the shining example was the highly successful **"Mission to MIR" program**. We had the Space Shuttle, but nowhere for it to go. For several years, American and Russian astronauts worked together. Mission to Mir was very popular with US Space enthusiasts and the public. By all means get the IMAX video. Delightful! **http://www.imax.com/mission2mir/**

### The "I" In "ISS"

At first a NASA Program, the proposed US Space Station was on the verge of being shot down by Congress until Bill Clinton proposed that a joint station might be the only way to keep Russian scientists and Engineers productively busy in the wake of the collapse of the Soviet Union, rather than selling their services to the militaries of other nations. Adding the I to SS, convinced enough congress people to save the program. The Russian contributions to ISS, both in modules and in supply missions and periodic reboosting (to higher orbits) has been essential.

But the European Space Agency (ESA) joined the effort as did Canada (CSA) and Japan (JAXA). Canada and Japan added modules and/or other hardware. ESA and Japan contributed Freight modules. International crews man the station and work together.

**Note that not all nations participating in the International Space Station program are "spacefaring" in their own right,** at least not in the sense of having the capacity to send humans into space on their own vehicles. ESA, Canada, and Japan have relied on US or Russian crew transports. The lesson here is quite clear. Nations that are not spacefaring by themselves can certainly play a big role in any future International Lunar Research Park.

Brazil and India, both invited, have yet to accept a role in ISS, though three astronauts of Indian origin have been in space as well as one from Brazil. Astronauts from other nations can train either with NASA or Roscosmos.

## One ILRP core component is missing: Commercial contributions

Once Bigelow Aerospace's BA 330 inflatable modules are ready, we could see the first commercial contribution to ISS. That is an event that many of us in the space movement have pushed for over the years. Such a unit could be unstructured within and used as a free fall gym for the station crew. A structured one could be a sort of space hotel annex for VIP and other visitors. Adding berth space to allow expansion of the crew beyond 6 is also an option. The proposal for such an addition predates the launch of ISS. NASA itself thought of adding an inflatable TransHab unit to the proposed station. Congress nixed TransHab and NASA licensed the technology to Bigelow.

**http://www.ilcdover.com/Transhab/**

**http://farm1.static.flickr.com/195/512805504_5d3504e3db_o.jpg**

## ILRP Phase I on Hawaii Island

Already several nations are involved, US (NASA, State of Hawaii), Japan, Germany, Canada. Others are invited and most welcome. Corporations are involved as well (Boeing: a key member of the world's largest interna-tional research Park in Stratford, England, UK.) A commercial company could provide supplies and key services (waste management, warehousing, transportation, etc. as well as house VIPs and other guests.) Contractors could provide all the habitats and other structures. Corporations are very much involved in the Antarctic, demonstrating their value. This writer will not be convinced that ILRP Phase I on Hawaii is on the right track until contractors and other commercial concerns are involved.

NASA already relies on contractors for many things. While some designs originate within NASA, often enough they are just suggestions to guide contractors in putting together concrete proposals. **PK**

# Antarctica as a Model for International Moon and Mars Outposts

By Peter Kokh

In many ways, a hundred years of human experience in Antarctica can be seen as a prelude to human exploration of the Moon and worlds beyond. And the cooperative spirit that pervades human activities at the bottom of our world is a good recommendation for following suite on the Moon. We will more throughly explore the Moon together, than as rivals. And that collaboration will be most essential in learning how to make practical use of lunar resources: the number one goal of the proposed International Lunar Research Park.

In Antarctica, many national stations are isolated from one another, but not all, and it is those exceptions we are interested in. See this map: **http:/www.scar.org/information/Antarctica_stations_map.png**

The hub of activity in the continent is the 56 year old US **McMurdo Station** (100+ buildings, summer pop. 1,200+). Built on the bare volcanic rock of Hut Point Peninsula on Ross Island, it is the farthest south solid ground that is accessible by ship. **McMurdo** has a close neighbor just next door: New Zealand's **Scott Station**. They share an airport (Pegasus) and the power grid. **Scott** Station recently added three high power wind mills to create the southernmost wind farm in the world. The two stations undoubtedly share other resources and services, and they have been close partners in Antarctica from the start. The US supports McMurdo out of Christchurch, New Zealand.

**http://www.antarcticanz.govt.nz/image-galleries/category/12-windfarm**

**Concordia** Research Station, which opened in 2005, is **a research facility shared by France and Italy**, 3,233 m above sea level at a location called Dome C on the Antarctic Plateau. On the coast south of South Africa, in an ice-free rocky area known as the Schirmacher Oasis, the **Russian station Novalazrevskaya** and **India's Maitri station** are neighbors, sharing the Russian built airport. Elsewhere on the continent, there are several locations where different national stations are located close enough together to share resources and services, at least in emergency situations. This is especially true in the Antarctic Peninsula where many outposts are clustered.

Where possible and practical it makes sense to share infrastructure and services needed in common.
**ShareSense:** Logistics (airfield/spaceport); warehousing (fuel, supplies) Power grid and sources and power storage;, construction equipment; hospital and other medical facilities; shared recreation and assembly space; final stage waste treatment facilities; tools and equipment used infrequently; unusual talent pool; "SuperPerk" facilities and retreats; manning joint expeditions. Such a plan and philosophy of sharing anything not needed by each full time makes economic sense.

If we can do this in Antarctica, why do so many space enthusiasts see our future in space of one of rivalries? In the light of our experience with the International Space Station and in Antarctica, that makes no sense. No country can afford to throw away money out of spite or rivalry. We are in Antarctica together. We can be on the Moon together! Ditto for Mars. Moreover, international facilities will more quickly lead to local autonomy and eventual home rule as international settlements grow. Nationalists, and there are still many in the US, are living in the past as a hundred years of collaboration in Antarctica demonstrates. Finally, international efforts are notably more resistant to government budget shrinkage or cancellation than purely national programs.

There are many things done in Antarctica which could be done much better: another story.

**Above: the extensive dormitory residential buildings at McMurdo:** Insulated but without visible protected pedestrian passageways between them. Built underground or at skywalk level, they would not interfere with surface vehicle access. This is the prefect place to demonstrate the merits of an interconnecting "**Middoors**" environment. McMurdo could be a much nicer place, but most people are there on temporary tours of duty and have enough perks to endure. And this "oversight" is understandable as the station has grown well beyond the vision of its first planners in the mid 1950s. Growth has been haphazard and often without effective planning. McMurdo's history is lesson to be learned by planners of an International Lunar Research Park. Warehousing and storage of discarded items got very bad, but has been mitigated after a GreenPeace expedition called the "shameful mess" to the world's attention. Now the station is much more sensitive to its environment. **PK**

**Virtual Tour - McMurdo Station, Antarctica** http://astro.uchicago.edu/cara/vtour/mcmurdo/

## The Big Role of Sports in Antarctica (and on the Moon and Mars)

By Peter Kokh

One might think that "sports" on remote bases here on Earth as well as in space, might consist of chess, checkers, and computer gaming. Wrong! In Antarctica, at least at McMurdo Station, indoor and outdoor sports that task one's body, not merely one's brains, are a very big thing: essential in maintaining both morale and health.

http://sports.espn.go.com/espn/thelife/news/story?id=5761185

We all need time to unwind from our assigned work, whether that be purely mental, or mostly physical or a mix of both. And that unwinding is more complete if it involves the body as well as one's mind. Now we can workout in a gym, or engage in other solitary exercises. But "sports" and "sporting activities" that involve others serves a double purpose. We keep our bodies in shape, unwind from work-related stresses, and we build extra-professional relationships with other shipmates or station-mates. Thus planning for sports activities, while something that outpost designers may tend to overlook, is vitally important to the overall continued success of the outpost mission.

Some recreational sports are easier to support than others because they require less space and volume. Table Tennis or Ping Pong is an example. Wrestling is another. In Antarctica, with breathable air outside, one can engage in Nordic skiing, and other outdoor activities in the world's freshest air, on snow in ice-free areas. Sports let us unwind from the stresses of the workday and help us bond with our crew mates. Of course, we can compete against our own previous performance records, but competitive sports have a strong value too - and we don't mean watching others compete while we drink beer. They feed our need for competition, and they let us keep fit while we blow off some steam and frustrations.

McMurdo is not as isolated as the Moon or Mars, but is the only community of size on a continent as big as the U.S. and Mexico put together. The Shackleton-Scott station at the south pole is next in size and a thousand miles away. Here there are no "lawns to mow, children, pets or parents to care for." So crew personnel have more time and energy on their hands and need other ways to channel all this unspent energy. Of course, one can pursue one's hobbies or personal self-education in off hours. But that does not take care of the social needs and outlets. To avoid both boredom and a sense of being incomplete, inter-personal recreational outlets are essential.

McMurdo's gem, the "Big Gym," has a climbing wall, as well as courts for basketball, volleyball, soccer and dodgeball. The "Gerbil Gym," offers cardio equipment such as treadmills, bikes, and weightlifting equipment.

Can we plan for something of the sort at a multi-national Lunar Research Park? Surely, larger "shared, common facilities" will be more economically feasible at such a facility than at individual isolated one-nation outposts. And that adds to the attractiveness of the ILRP concept. Not only do several nations get to share seldom used equipment, the spaceport, warehousing, etc. but besides their own individual limited recreation spaces, they will have access to a larger shared "Commons" with recreational space being one of its assets.

At an ILRP, not only will scientists and technicians be able to work with others in their field on larger joint projects, they will have access to larger joint labs, and talent pools. Such a "metro" base will be a much more attractive one, and not just for the many things that will make it more livable. It will also be much more attractive for individuals as well as national crews, because there will be much more going on, with new cross-enabled projects and experiments and explorations made possible by the "critical talent and facility mass" an International Lunar (or Martian) Research Park will allow. TV spectators on Earth could encourage by time-delayed cheering and applause.

Besides a McMurdo style big gym complex, an ILRP should be able to support a variety of experimental out-vac and lee-vac sport activities. A corner of a shielded but unpressurized warehouse would allow individuals and "teams" in less cumbersome pressure suits try their hand at a great variety of new types of sports tailored to the lower gravity as well as airless conditions. Most of these experiments will lead nowhere. But some team sports might be developed and matured in such conditions that are worth televising to Earth on the Sunday Afternoon "Wide Worlds of Sports." In indoor gyms, new 1/6th g sport forms could be perfected as well. And why not dance forms as well? If they look good on TV, this kind of exo-sport and exo-dance experimentation could grow support and interest among Earthlubbers.

The mission of an ILRP is to develop and advance manufacturing and production techniques for building and manufacturing materials made out of moondust to use not only in space construction projects but also for expansion of habitat and settlement space on the Moon itself. Anything made on the Moon for use there, is a potential money-making export for similar or analogous uses in space. This mission is a big challenge, and a multi-national shared site approach seems to be the most promising way to realize such an outcome, with economic self-sufficiency as the goal. At that point, lunar settlement will grow quickly, free of massive economic support from Earth. In the process, significantly more exploration of the Moon will occur, and in greater depth and detail, than it would if we had no such economic "ISRU" local resource utilization plan as a driver.

We can see now how recreation and sports will help both develop and explore the Moon. Better yet, such ILRP experiments in sport and recreation activities will boost the "itinerary options" for lunar tourists from Earth.
It all works together! **PK**

## In Processing Lunar Materials, the Devil is in the Details. Or The Case for an International Lunar Research Park

By Dave Dietzler

**Free Lunar Vacuum: Asset or Challenge?**

Molten titanium can be poured and cast in a vacuum. Titanium can be electron beam welded in a vacuum and 3D electron beam sintering of titanium powders is done in a vacuum. Metals can be melted, atomized and sprayed in a vacuum to form powders for pressing and sintering without oxidizing. Nothing rusts in a vacuum and there is no moisture to contaminate materials like titanium or iron aluminides which can react with moisture and absorb hydrogen when casting. Processes like forging, rolling and extruding, cold or hot, can be done in a vacuum.

Experiments with regolith simulants have shown that at 1200°C. FeO will volatilize and at 1500 C. + SiO2 and MgO will volatilize, in a vacuum of course. Samples of anorthite have been roasted at 2000 C. to drive off SiO2 and the result is calcium aluminate which can make a refractory cement [1]. It seems likely then that if we can obtain rather pure anorthite on the Moon, we should be able to roast it at 1500 to 2000 C. to drive off SiO2 and enrich CaO and Al2O3 contents to make cement.

Now we encounter some devilish details—Can we find pure anorthite on the Moon or purify anorthostic highland regolith to make cement by simple roasting? How long and at what temperature do we roast it? Can we recover the silica for other uses by condensing it on a cold plate? What's the best and strongest cement formulation? How much energy will we need? If we work out a process on Earth with simulants in vacuum chambers, what will happen with real regolith in low gravity? The concept is simple enough and has some bench top laboratory support, but to really figure out how to make cement on the Moon we will need an International Lunar Research Park where intensive experiments are done.

Free vacuum offers same advantages, but it also creates problems. Vacuum welding of metal parts in contact is one problem. Aluminum is welded with a shield gas to prevent oxidation in air, a problem that won't exist in a vacuum, but molten aluminum in the weld will probably evaporate! Most molten metals will boil away so casting will not be so simple. Casting is not so simple to begin with. In principle it is but in practice it is not.

### Casting a simple Basalt part might be a devilish project

The first thing we have to get right is the chemical composition of the basalt. It's easy to say just shovel up some mare regolith, melt it in a solar furnace and pour it in a mold; maybe just a sand mold dug in the ground! There are low and high titanium mare "soils." What's best? We could adjust the sodium and potassium concentrations to effect the melting point of the basalt but then we have to have Na and K production. Backing up a little further, we have to shovel the stuff up and that means a rather complex machine just to do that job and the machine must work in extremes of temperature as well as survive temperature extremes when it isn't working, as during the super cold of lunar night. It has to endure the abrasive moon dust also. We have to have a power source for the machine; probably solar panels. This machine alone will set us back millions of dollars.

Bootstrapping is believed to be essential to the industrialization and colonization of the Moon and Mars, so we have to be able to replicate this machine on the Moon after metals production is demonstrated and becomes routine. The design must be robust and simple, and it's a lot easier to say that than design it.

So let's say we have a lunar digging machine that works and we have good mare regolith and control of its chemical composition. We have to melt it. The specific heat is 840 j/kg K. So if we want to make 100 kg. of cast basalt bricks and we are starting with a temperature of about 100 C. during the lunar day we have to raise this by about 1100 C. to melt it so we need 92.4 megajoules or about 25.7 kWhrs. of energy. If we use a solar furnace made from a sort of aluminized Mylar reflector shipped up to the Moon it would need an area of at least 25 square meters (270 sq ft) to melt all 100 kg, in an hour, but that assumes nearly 100% absorption of energy by the basalt.

Some energy will be reflected and some will radiate away. To make matters even more difficult, the reflector has to be aimed at the Sun and some kind of optical arrangement with a secondary mirror made of solid polished chromium perhaps is needed. Then we have to have a crucible to hold the basalt and this has to be sealed so the molten basalt doesn't just evaporate into the vacuum. It will need a pure silica window. The window could foul as windows often do in solar furnaces! My hunch is that an electric induction or microwave furnace and solar panels for power will work better. Next we have to pour the molten basalt, so the furnace has to be a ladle furnace along with the mechanical devices needed to move it over to the molds and pour the stuff. So the furnace, be it solar or electrical, is going to be a complex device too that sets us back millions of dollars when we consider R&D and rocket transport to the Moon.

Some engineers have suggested that the cooling basalt will stratify. This can be prevented by running the molten basalt through a homogenizing drum before pouring. So we need another piece of equipment. What about boil off in the vacuum? A fellow Moon Society member has informed me that basalt, at or near its melting point, has a very low vapor pressure and another pointed out that lava sheets have flowed on the Moon without boiling away.

Even so, there is likely to be some boil off. That won't matter much in pouring simple bricks, tiles or slabs wheew the loss of a little basalt won't matter—there's plenty of it. If we want to cast complex parts or draw fibers we might have a problem.

Now the molds: simple trenches dug in the regolith might not work. Regolith is an excellent insulator and the only way the molten basalt is going to cool is from the exposed surface. Given the insulating properties of regolith we must ask, how long is this stuff going to take to solidify? And won't the product be rather crude? We will need imported iron molds that might sit on an iron slab heat sink with iron lids placed immediately after pouring to prevent evaporation. Heat will be radiated into the vacuum from the iron molds and the iron slab they sit on. We might even print up iron molds with magnetically harvested iron fines via the processes of electron beam sintering or selective laser sintering. But I am only guessing.

You can see how just this one simple job will involve numerous details. I am confident that those details can be worked out. We have seen far more complex things done. The best place to work those details out would be an actual Moon base where materials and manufacturing research was paramount. Vacuum and real regolith, not just simulants, will be abundant and full scale experiments could be done. This might be a second or third generation base. Learning how to isolate basic types of lunar soils is one of things that must come first.

I honestly do not see this ILRP being funded by private enterprise. Governments doing basic research on the Moon in partnership with private business seem like the financiers to me. But if governments are financing major in-orbit projects such as solar power arrays and giant platforms to hold many satellites, that will create incentives to develop the needed lunar processing and manufacturing technologies. Once the cost of lunar production facilities are amortized, lunar components will be much cheaper to ship to LEO and GEO than equivalent items made on Earth's surface. It takes vastly less fuel to ship "downhill" than "uphill" – gravitational hills, of course.

### More Challenges: the promise of basalt fiber

Basalt fiber is a very promising lunar material. Molten basalt is drawn through platinum bushings to produce fibers 9 to 13 microns thick. What about evaporation of the fibers? Could we draw thicker fibers and let some volatilize? This will be another project that the devilish details of will have to be worked out on the Moon. We might find that it is necessary to construct pressurized spaces to do this work in. How do we cool the fibers? On Earth a spray of water is used. That would require pressurized chambers where water and humidity are recaptured and reused. What if there is a way to do it in the vacuum? What if we draw thick enough fibers so that some outer materials of the fiber can volatilize and the final fiber cool by radiation before we wind it on a spool?

Basalt fibers could be used to make "sand bags" which when filled with moondust would provide "removable shielding" in cases where down the line we may want to add to a habitat complex, or need to make repairs or replace external systems and connections. Basalt fiber fabric could make the decking over a space frame structure that could then be loaded with moondust to create shielded but unpressurized warehouses.

### Casting Aluminum

What about casting aluminum in plaster molds? Simple in principle. We rocket up some plaster, mix it with water produced on the Moon by volatiles mining and/or polar ice mining, make some molds and pour some molten aluminum. Then we just remove the solidified part, smash up the plaster, wet it and make a new one. Once again, the liquid metal will evaporate unless we have some kind of pressurized foundry on the Moon. And what kind of robots will we need to do the work or will humans do a better job? And how do we construct a foundry on the Moon? Solving one problem seems to raise additional ones. But it has been that way throughout the history of the industrial revolution.

### The Point

The point of this exercise is to make you think. The seemingly simplest jobs on Earth (which are in reality never that simple when everything is considered) will be more complex on the Moon. The bottom line to me is that the only way to work out the details of manufacturing on the Moon will be at a Moon base itself. We cannot foresee all the challenges.

But if we jump in over our heads we are doomed to fail. Meanwhile, we can continue to think about these things and pre-troubleshoot basic approaches. The actual doing is going to cost large sums of money and require lots of man hours of work. Much, but not all, of that labor can be done by teleoperation, reducing crew support costs. It all depends upon how important creating a space faring civilization is in the future. If the market for lunar materials (when shipping costs dwarf production costs) is great enough, it will happen. **DDz**

1] Rudolf Keller and David B. Stofesky of EMEC Consultants

" Selective Evaporation of Lunar Oxide Components" reported in SPACE MANUFACTURING 10 PATHWAYS TO THE HIGH FRONTIER Proceedings of the Twelfth SSI-Princeton Conference May 4-7, 1995; pg. 130.

## MMM #255 - MAY 2012

## Why Advocates of Moon and Mars Settlements should work to amend the Antarctic Treaty

"Failure to "responsibly modify" the current Antarctic Regime could very well result in a Treaty ban on "settlement" of the Moon and Mars, allowing scientist-explorers only."

**Antarctic Treaty Precedent - In 1959,** Twelve nations, involved in Antarctic exploration, and with land claims frozen, established a treaty that would allow peaceful collaboration and coordination, signed the original Antarctic treaty. Since then 31 others nations who wish to conduct exploration and scientific research there have now "asceeded" to the Treaty which was extended in 1989. It will next be open to review in another thirty years, that is in 2019. That gives us seven years to marshall support for some key changes.

The most significant of recent protocols was signed in Madrid in 1991 therefore being known as the Madrid Protocol, though it's official title is, "**The Protocol on Environmental Protection to the Antarctic Treaty**" which came into force in 1998. Most of the provisions are reasonable. But some of the provisions create a precedent that must be rejected if we are going to open the Lunar and Martian frontiers to resource-using settlement. Article 3 Environmental Principles is fine as it stands and is not the area of concern.

Article 7 states "Any activity relating to mineral resources, other than scientific research, shall be prohibited." In our view, it would be better to rate specific areas of the continent according to environmental risk, and to set standards for mining practices such as to protect the environment. If all mining were bad, we would still be in the stone age.

Article 8 does make distinctions between activities with (a) less than a minor or transitory impact; (b) a minor or transitory impact; or (c) more than a minor or transitory impact. But the overall effect has been chilling.

We certainly do not object to a rigorous review of all mining and commercial activity proposals. But the outright "ban" is counterproductive. In effect, Antarctica is off-limits to settlement, if settlers are to produce any percentage of their needs, specifically, building materials.

Not helpful, the treaty applies to areas poleward of 60° south. If the Antarctic Circle had been the "fence," about a third of the Antarctic coastlands (that portion south of Australia and the Indian Ocean) and much of the Antarctic Peninsula (below South America) would be excluded from this ban.

The principal base of McMurdo Sound and the very unique Dry Valleys lie south of New Zealand. These valleys are environmentally unique in all the world, but even there some scientific research - (these valleys offer the best Mars analog site conditions anywhere) - and even some commercial operations such as "photos and footprints only" tightly-guided tourism - should be allowed.

In our view, the Treaty notwithstanding, humanity has a right to settle and use the resources of both treaty-excluded and treaty-protected areas, under strict safeguards and protocols. The pro-space community sat on its hands when the Treaty was extended last time. We must rise to the challenge in 2019 and that will require a lot of careful and detailed preparation. We offer some suggestions in the article that follows.

1. **First, we consider what we might be able to do within the limits of the present language.**
2. **Then we show how some simple modifications would allow much more without undue harm** to this magnificent natural frontier.

Failure to "responsibly modify" the current Antarctic Regime could very well result in a Treaty ban on "settlement" of the Moon and Mars, allowing scientist-explorers only. **PK**

# Antarctica Activities can Blaze the trail for Pioneers on Moon and Mars

By Peter Kokh

**It is essential that we demonstrate here on Earth, in Antarctica, that development and settlement can be pursued in a way that respects and preserves nature.**

To do this, we need to set standards, something we have failed to do previously except retroactively, after damage done has become too significant to ignore. In that light, not to set standards in advance would be to disrespect the gift that is Antarctica, and that is the Moon, and that is Mars. Put it this way: to win a broader base of public support, we need to earn the respect and support of the "Environmentalist" community (to which, by the way, we personally are personally proud to belong.)

In his recent article "Are We Ready to Settle the Solar System?" [Moon Miners' Manifesto India Quarterly 14 pp 27-33] Dave Dunlop writes:

> **"Pushing the Boundaries**
>
> Today there are many long term outposts on the continent of Antarctica, clearly the most challenging and "alien environments" on our home planet with the possible exception of the deep ocean. For the moment we have forbad ourselves the "luxury" of creating true settlements in this harsh terrain but have enduring outposts for scientific study and now increasingly tourism. The Antarctic enterprise shared by many nations is the best model of how we our aspire to poke our nose into new space environments. Our global Antarctic Program is The Grand Daddy of Space Settlement Initiatives but it is far from a sustainable settlement largely dependent on in situ resources."

## Potential Settlement Sites

There are a few science outposts "out on the ice" in Antarctica: Amundsen-Scott Station at the South Pole, Concordia Station (France-Italy), and Vostok (Russia) for example. The only local resources are ice and wind. Most other stations are on or near ice-free ground at various locations along the coast, or on coastal islands. But these stations have only one purpose: science. They are totally dependent on support from the sponsoring nation(s),

Even McMurdo which has over a thousand residents during the summer and is physically bigger than many a small country town elsewhere, cannot be considered a "settlement." None of its residents is "permanent" - all are there on limited tours of duty - no families, no children. Official visitors only.

## Raw Material Sources for Settlement and Settlement Basics

Most Antarctic outposts, McMurdo-Scott among them, are on exposed ice-free ground, where conceivably, some limited use of **local rock and rock debris (including basalt** from neighboring Mt. Erebus volcano) is a potential "resource" given enough experimentation and imagination. Adjacent seas are teaming with "food." The ever-present steady winds blowing seaward off the Antarctic ice cap provide a significant energy-source. Coastal outposts may see occasional driftwood, beached animal carcasses, wood and steel shipwrecks, all sources of materials to creative and resourceful people.

That "mining" necessarily disfigures the landscape and poisons the environment is a blanket assertion and proposals to access materials for local use should be allowed to have a hearing before the Treaty nations in advance of the next scheduled review in 2041. Environmentalists stand to gain from such a process as

**Ways to mine more responsibly and with less negative environmental impact, here in Antarctica, have the potential to transform for the better, how mining is done elsewhere on Earth. as well as to pretest means and methods of responsibly accessing resources on Moon and Mars**

## The idea of self-supporting settlements in Antarctica

Any true settlement has to provide for a wide variety of needs of its members. In short that means that

1. **What a settlement cannot produce locally, it must import from elsewhere,** and to do that,
2. **The settlement must produce products that it can trade for what it needs to import.** Some of that trade can be with other Antarctic Settlements, of course, but collectively, Antarctic settlements must export commodities to the outside world to pay for whatever they must collectively import from the outside.

## Specific products

Together, this covers a lot: food, clothing, building materials (primary and secondary including furniture and furnishings); power, manufacturing equipment, vehicles; tools: the list is long, but can start small.

Currently, the only places in Antarctica that produce anything exportable are those that engage in fishing in the Antarctic ocean, which is, however, perhaps the most food-rich ocean of all. But most of this fishing is done out of ports in southernmost Chile and Argentina. Some amount of whaling has been supported out of small towns in South Georgia, which is hundreds of miles north of the Antarctic coast.

## Beyond fishing: some options: wind power; rock products; minerals; fossil fuels

**Wind:** The Antarctic Coast enjoys the strongest steady winds on Earth, continually blowing coastward of of the polar interior. Wind power is being used in Maitri (India's station) and at McMurdo-Scott (US, New Zealand). All that power is used locally. To be exported, wind power would have to be converted into some other power source or actually beamed elsewhere by orbital relay. So, at least near term, wind is a local resource, not an export option.

Nontheless, this domestic source of power is definitely of significant value. **Most communities around the world are not as energy-independent as Antarctic Settlements could be.** Of course, this is electrical power, and fuels for non-electric vehicles and equipment must still be imported. But a greater reliance on batteries and fuel cells could increase wind-power applications to cover a growing percentage of non-electrical power needs.

**Rock (and gravel):** these are crude building materials, but in light of the fact that there are no trees in Antarctica, that assumes some real importance. The makings for cement would make this rock and gravel resource cover more construction needs: blocks, bricks, slabs, beams etc. are a great start. Basalt on the slopes of Mt. Erebus at McMurdo can be used as cast tiles, bricks, slabs, hewn and carved items, and as industrial fiber.

**Other mineral resources:** Metals, gems, etc.: We have no idea what lies under the ice, but the fact that at one time Antarctica was connected to South America, Africa and other "continents" that formed Gondwanaland, it should be expected that mineral resources in once contiguous areas should be similar. For example, what we find available in the southern Andes of Chile and Argentina, we should expect to find in the mountains of the] Antarctic Peninsula. But for clearly practical reasons, we are looking at only exposed, ice-free locations. Except for the exposed nunataks of the TransAntarctic Mountain chain, that means **we are looking at ice-free coastal areas only**.

There are interior ice-free areas, the so called "Dry Valleys" across the Ross Sea from McMurdo Station, but these are so geologically and biologically so special that they deserve to be permanently protected as World Geological Nature Preserves, as they already are, with limited escorted tourist excursions only, except for restricted science camps. There is no better place on Earth than here for a Mars Analog Station, but the logistics would be even more expensive. Off shore oil drilling should remain forbidden as there is no fool-proof way to prevent spills.

**Fossil fuels:** there is coal and oil in Antarctica, from the forests and vegetation this land once sprouted before it wandered south to the pole. Clearly, however, the most stringent environmental procedures would need to be in place to allow these resources to be tapped so that surrounding areas inhabited by wildlife of any kine are not polluted or spoiled in any way. If tapping these resources was limited to serving local needs, that might minimize potential damage, but at the same time, prevent settlements from trading these reserves for other needs.

### A formula for responsible mining that we should strive for everywhere

Writing about how we should mine on the Moon, in MMM #22, February 1989, "Lessons from Mt. St. Helens" we pointed out that there is nothing that sparks the inventiveness and resourcefulness of artists and craftsmen and entrepreneurs in general as "free material" - in this case the inches of Mt. St Helens ash that covered large areas of the Pacific Northwest after the 1980 explosive eruption of this volcano.

Then, in the next issue, MMM #23, March 1989, our article "Tailings" addressed the issue that the bulk of what is mined is cast aside as "of no economic value" - tailings.

**From the MMM Glossary http://www.moonsociety.org/publications/m3glossary.html**

**Tailings** - what is left after the elements sought in a mining operation are removed. Actually, all other elements remaining are somewhat "enriched" in abundance by that removal. In a mining cascade, the tailings would continue to be further enriched in the elements not yet extracted. When if becomes impractical to mine tailings further, casting them into building materials would productively embody all the energy already spent, and minimize the amount returned to nature, the "throughput." The less the "**throughput**" of a operation or of an industrial settlement as a whole, the more efficient that operation or settlement can be said to be, and the more minimal its environmental impact or footprint.

**Tailingbrick, tailingcrete** - suggested building products to be produced from tailings.

You can read both articles, on page 11, and pages 17-19 respectively in Moon Miners Manifesto Classics, volume 3: a free download from: **http://www.moonsociety.org/publications/mmm_classics/**

Tailings-based Antarctic industries could help reduce the gross tonnage of imports from off-continent that will be required to support permanent settlements in Antarctica. And any tailings-based products used on the continent that are attractive enough to find a market elsewhere, will help pay for what must be imported.

It may take some time before Antarctic Settlements can reach and then exceed an economic "breakeven" point. But without the prospect of doing so, true settlement is unlikely. For supporters of Lunar and Martian settlement, the stakes in Antarctica are very high. We choose to ignore what is happening and can happen in Antarctica at our peril. Let's look at some other potential income sources

### Other sources of income for Antarctic Settlements

1. **Tourism:** In 2010-1 34,000 tourists visited Antarctica and the numbers keep growing! While agency tourist guides take care of most of the tourist agenda, they should be required to enlist local civilian guides from any "settlements" they visit. There are currently only two such spots, and we'll get to them below. The idea, however, is to set a precedent. If in time at the some of the various national science outposts, true permanent residents are allowed in support roles, this practice could be extended. Through such "subcontracting," a source of local income can be provided. Of course, we favor healthy competition, so at each location a choice of tour guide agencies would be ideal. We can see such an operation at an entry "gateway" to the Dry Valleys area for example. Tourists love souvenirs, of course, so such gateway civilian centers gift shops featuring crude unfinished souvenir rocks, as well as locally produced art objects made from local materials would help. Tourism could thus employ tour guides, transport vehicle operators, translators, artists and craftsmen, and even entertainers. We have to start somewhere! Many a town in America (and elsewhere) thrives largely on tourism.
2. **Fishing: Grytviken** (photo below), on the North coast of the island of South Georgia is the outstanding example. However, this site is well north of the Antarctic coast itself, and for a reason: it is accessible and ice-free for a

greater number of days than any site on the Continent, or on mmediate off-shore islands. Yet some anchorage for fishing ships and fleets is available there, and with some front money could be developed.

So the resources necessary for a core of self-sufficiency to be complimented by imports is a difficult goal to reach. Beyond fishing and logistics support for tourist excursions and possibly for nearby science stations, there does not seem much upon which to establish genuine settlements.

### The Obstacles and Challenges are Real but Must be Overcome

**Antarctica poses a number of serious logistical problems to any would-be mining or prospecting activities;**

- **Antarctica experiences the most extreme cold on the planet. Mars' climactic range is very similar:**.
- **Mutual isolation of outposts in Antarctica is a preview** of what it might be like on Moon and Mars. Such isolation is an impediment to internal trade. However, a clustering of inter-trading settlements on the Antarctic Peninsula and its off-shore islands provides an optimal place to start. On Moon and Mars both, some settlements will be very isolated, but for success, a critical collocation of neighboring settlements at some optimal locations will be critical to the development of lunar and/or Martian economies
- **The annual "icing-in" of Antarctica** imposes "no shipping" intervals, at least by sea, if not also by air. This "on your own" test will apply even more strictly on Mars as well, with launch/landing windows more than two years apart. If we can't succeed in Antarctica, it would be foolish to think we could succeed on Mars.
- **These "Antarctic Challenges" make the continent an analog of Moon and Mars as to the difficulty of setting up Lunar and Martian economies.** If we don't accept the challenge of trying out our proposed ways of "working around the obstacles" posed in Antarctica, both natural and artificial (Treaty), how can we be honest in our dreams and convictions of being able to do so in space? Space enthusiasts of all stripes, who ignore Antarctica and choose not to get involved in that continent's future, do so at their own peril.

### Note that there already are two "civilian" settlements in Antarctica

Despite the provisions of the Antarctic Treaty, there are two "settlements" there, **families welcome**, both off-shore, both "grandfathered" - having been established before the present Treaty amendments took effect.

(1) **Villa La Estrellas** (Chilean) (below) is one of the main ports of call of Antarctica cruises.

This town was founded in 1984 at 62°12′ S, 58°53′ W on King George Islands, one of the South Shetland Islands, above the Antarctic Peninsula. It is integrated with the Chilean Eduardo Frei Base, a scientific (meteorological center) and military (air base) station.

The hamlet has 20 prefabricated modules, 14 are **family residences.** It also has a **b**ank, post, hospital (one doctor, one nurse), school (15 students) kindergarten, hostel, gym, store/market, local shop, and a church. The post office is also an attraction for tourists and philately enthusiasts that travel to the town to send postcards and letters with an Antarctic postmark. Built for visitors, the "**Polestar**" dormitory has room for 90 people.

There is an aerodrome providing the settlement and other Antarctica bases with several connections, with some 200 flights each season. This also serves the neighboring Russian Bellingshausen Station founded in 1968 just 200 meters away. Further, the station is also connected by unimproved roads to the nearby stations: Chilean Base Presidente Edyardo Frei Montalva, Chinese Great Wall Station, and Uruguayan Artigas Base.

The Antarctic Peninsula and its off shore islands are by far the most condensed cluster of outposts in Antarctica, mostly above the Antarctic Circle. The Antarctic Peninsula and its nearby islands are considered to have the mildest living conditions in Antarctica. The average temperature around the station in the coldest month (August) is −6.8°C (19.76°F), and +1.1°C (34°F) in February, the warmest month. Russian polar residents have nicknamed the Bellingshausen Station "kurort" or "resort."

(2) **Esperanza** (Spanish: "Hope Base") is an Argentine base located i**n** Hope Bay, Trinity Peninsula, Antarctic Peninsula. Built 32 years before Las Estrellas, in 1952, the base houses 55 inhabitants in winter, including 10 **families** and 2 school teachers for a school built in 1977. The site enjoys an arctic tundra climate with one "summer" month when it sometimes gets just above freezing. Esperanza can boast that it is the birthplace of the first person to be born in Antarctica.

Esperanza's 43 buildings offer a combined covered space of 3,744 sq m (40,300 sq ft.) Imported fuel oil is used to produce electricity, but a wind generator was installed in 2008. Research is Esperanza's main product and projects include: Glaciology, Seismology, Oceanography, Coastal Ecology, Biology, Geology and Limnology. However the town's tourist facilities are visited by approximately 1,100 tourists each year!

### Expanding this list of just two Settlements – a "match made in heaven" proposal

Picking up and moving your family to Antarctica will appeal to very few people. Yet there will be some, so discouraged by current conditions at home, that might be willing to try something "this new, this far out.

But would there not also be **Eskimo, Inuit,** and **Samoyed families** in the high Arctic that are willing to resettle along the Antarctic Coast at a few favorable locations, with some level of promised support? There are no Caribou in the Antarctic, but there are seals and plenty of fish. Might resettled arctic families flourish and prosper? Perhaps not at first. The Arctic and Antarctic are quite different. But I believe that in time, transplanted Arctic peoples could thrive in the Antarctic Peninsula and offshore islands, and maybe elsewhere on the last continent.

An ad hoc conference of the US, Canada, Norway, and Russia, with representatives from the native arctic populations of all of them involved, could pursue this idea. There might be no interest, but that would surprise us. The flame of adventure and pioneering is alive within all peoples. Who else would be as hardy? Corporate partners might be involved, so long as this does not lead to "Company Towns" – a worst possible result. But that is a separate other article for a future issue.

Of course, room must be made for people from other non-arctic populations as well. **PK**.

## Working within the Strictures of the Current Antarctic Treaty

Modifying the Antarctic Treaty Strictures to include a more relaxed zone between 60° South to the Antarctic Circle at 68° 32' would be, to us, the first step towards a "pregnant" solution.] **See Map of below**.


Note that there are also several ice-free areas above the Antarctic Circle on the Antarctic Coast below Africa and Australia. That said, t**his might be a longer term goal. Our first goal** should be to see what we can do to expand the scope of civilian activities, including families, **under the present language** adopted in Madrid in 1998.

### Families, children and other dependents not allowed!

The place to start would be the US stations, which together involve the largest population in Antarctica, if not the majority. Besides the scientists and other researchers themselves, we have many more support personnel who maintain the various stations, vessels, aircraft and other equipment and systems, freeing scientists and researchers to do what they come to do. The Antarctic Treaty may not specifically forbid "dependents." But there would seem to be no room for them in the US Station support personnel programs.

### The USAP – "UNITED STATES ARCTIC PROGRAM"

**Guide to Programs/Funding Opportunities:** www.usap.gov.usapagov/JobsAndOpporunities/index.cfm?=1

Three corporations are the principal players: **Lockhead-Martin**, **Gana-A 'You Service Corporation**, and **GHG Corporation**, all equal opportunity employers: women and minority groups are encouraged to apply. But this does not include children or other dependents. What we have as a result are "artificial communities of transients." While at US Armed Forces bases, it is common to have off-base housing for spouses and children, this is not the case at US science stations in Antarctica.

Support personnel are hired for limited tours of duty, and many of the seasonal ones (Antarctic summer) return for repeat tours. For these seasonal people, the perk of having family nearby is not an issue. But what about the smaller core of support positions that must be manned year around? Yes, personnel can be rotated here as well. But might it not be a negotiated perk for long duration, all-season support personnel to have their families on location or nearby? Could not this be a decision for the major contractors involved, rather than for the UPAS? Indeed, should it not be the decision of the personnel involved themselves, so long as this can be managed at the employee's expense?

### Tourism discouraged or not allowed

The treaty even discourages "tourism" on the continent. It would be preferable to establish strict guidelines for tourist ventures, rather than forbid them outright. Only the peripheral shipboard tourism in and around the Antarctic Peninsula is now allowed. The places where tourists may set foot on the continent itself are quite limited. Yes, we understand that tourists must not be allowed to interfere with research and researchers. Yet we allow tourists with the White House, in Congress, even in the Pentagon, and do so, with a manageable minimum of interference and inconvenience. There is a time and a place for everything. One should not have to become an inner core member of Greenpeace to have access to Antarctica.

Greenpeace is an activist environmentalist organization that can take pride in some of its achievements - in fighting whaling, and in embarrassing the US to the point of forcing a badly needed cleanup of the McMurdo station premises among its credits. But it should not have Hight Priest privileges anymore than should NASA. Greenpeace deserves much credit for the recent revisions in the Antarctic Treaty. That said, some of those provisions go unnecessarily far, and need to be trimmed back. If we fail to integrate a protected Antarctica into our human world here on Earth, we shall surely fail to extend permanent human civilian presence beyond Earth to other worlds.

### Summary

1. We need to make a place for families (one's dependents) in Antarctica so that children can grow up there to become a first native-born generation
2. We need to expand the list of approved activities beyond research and tightly-constrained tourism, to include regulated economic activities that can become a basis for supporting permanent populations while respecting the scenic integrity of this pristine continent.

As on the Moon and Mars, the more people who settle these worlds, the more science and research will get done - by these people and their descendants on location. Humankind is not a cancer on Earth-life. We are the means, the only means, by which Earth-Life can be sown off-world, take root, and flower elsewhere on worlds where life cannot arise on its own. We cannot leave the future of Antarctica, the Moon, Mars and other frontiers to those who understand neither the possibilities of opening these frontiers nor the consequences of not doing so.

### We'd like to hear from you

- **Suggest economic activities in Antarctica that could support permanent populations** and at the same time, respect and preserve the environment at large.
- **Suggest ways to open up more of Antarctica while at the same time protecting its treasures**|
- **Suggest ways permanent residents might adjust** to very long daylight summers, and dark winters: Note in Alaska, the extreme seasonal lighting variation from very long days and very short nights to very long nights and very short days may be a source of the states very high suicide rate. Some of the ideas we have suggested for future lunans to adjust to long dayspans and nightspans by controlling lighting in indoor and middoor spaces should be applicable.
- **Show how your suggestions for Antarctica might help open up the Moon and Mars.**
  Send to kokhmmm@aol.com or to 1630 N 32nd Street, Milwaukee, WI 53208 c/o Moon Society

**Three Frontiers whose futures are closely linked together - it is up to us!**

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## Antarctic Cottage Industries based on "Found" Objects and Materials

By Peter Kokh

"**What is not expressly forbidden, is allowed.**" - age old legal maxim

"**Mining**" implies "excavation" of some kind to provide access to minerals or materials below the surface. This includes "strip mining" or removing of a shallow surface layer to reveal mineral or substance (e.g. coal) just below.

What it does not imply is "**collecting**" or "**gathering**" material lying loose on the surface. Collecting meteorites from the surface of Antarctic glaciers is not mining. Neither would be collecting driftwood form other continents tossed up on Antarctic shores by waves and storms. Nor would be salvaging shipwrecks and plane wrecks, or "dumpster diving" the trash piles outside Antarctic stations.

Neither would be collecting crystal rocks lying on the slopes of Mt. Erebus, the continent's only active volcano, on Ross Island overlooking McMurdo Station. It is 3,794 m, 12,447 ft. high.

http://skywalker.cochise.edu/wellerr/students/erebus/project.htm

"**Mt. Erebus crystals** are also known as anorthoclase feldspar, a type of feldspar that consists of aluminum silicate. ... Rich in sodium, potassium and silicate, there is only one other place on the planet where these crystals can be found, Mt. Kenya, Africa. Crystals grow in the magma beneath Erebus and get spit out of the mountain inside glassy volcanic bombs. The glass quickly weathers away leaving the mountainside covered in crystals. "While not an extraordinary mineral, these are extraordinarily large." "These crystals are embedded in these bombs and vary in size and shape, but all are of astonishing size for feldspar."

These crystals are coveted by almost everyone at McMurdo Station." Gathering these crystals has obviously been tolerated for some time, beginning with Shackleton's 2009 expedition which found "lumps of lava, large feldspar crystals, from one to three inches in length, and fragments of pumice; both feldspar' and pumice were in many cases coated with sulfur."

### What can be made from these crystal bearing rocks?

Nothing sparks the artist's or craftsman's imagination so much as free material. These crystal bearing volcanic "bombs" come in many sizes and shapes. The writer himself is a long time scavenger of found and tossed out objects out of which to make something useful. Among my creations are a number of lamps whose bases are found items with minimum modification.

A cottage industry of lamps made from suitable sized Mt Erebus crystals, along with other items made from these found objects could soon give a uniquely Antarctic "feel" to private and public areas of McMurdo Station - and other stations around the continent. Paperweights, ashtrays, bookends. Even countertops.

Anyone who has ever visited Arizona, New Mexico, and other areas of the US southwest is familiar with the special feel created by SouthWest art from Navaho rugs, to adobe construction, and on and on.

**Driftwood**

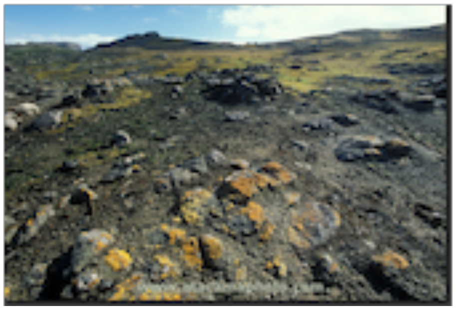
Most Antarctic stations are along the coast and on off-shore islands. Wood harvested by storms from shores of South America, Africa, Australia, etc. may occasionally be washed up on Antarctic shores. Many an artist-craftsman has transformed this free material into something useful, or at least decorative.

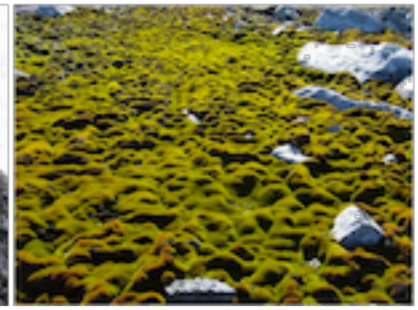
**Shipwrecks and Plane wrecks.**

Shipwrecks, when accessible can be sources of useful objects and materials. Add the artist/craftsman magic touch and imagination, and the possibilities are too numerous to list. Wrecked aircraft can yield a lot of scrap metal, as well as some intact items (seats? windows? etc.). The re-use possibilities are endless!

### Other possibilities: landscaping, gardening, agriculture

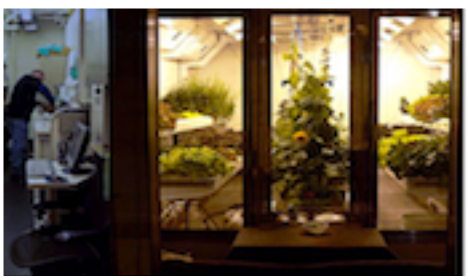
Except along the western shores of the Antarctic Peninsula, there is no plant life in Antarctica. The climate will not support it. What there is, however, moss and lichens, are not to be discounted.





Now imagine a large glassed-in vestibule to an Antarctic Station in which a moderated climate is sustatined, warm enough and wet enough to allow a transplanted bed of coastal moss and lichens to thrive, but no warmer, no wetter. It would provide shelter from more severe conditions "outside" and provide a uniquely Antarctic welcome and reassurance. If small planters of moss and/or lichens could survive indoors in private or public areas, such "house plants" might be preferred by some to "exotic" plants from "back home.

At the Amundsen-Scott station at the south pole, there is a much-cherished Food Growth Chamber designed, built, and maintained by the University of Arizona (Tucson) CEAC (Controlled Environment Agriculture Center) - http://ag.arizona.edu/ceac/ - which we have reported on before. The facility has an antechamber in which station personnel can come and relax, surrounded by living plants. Not only does this facility provide fresh salad stuffs daily, but it provides a significant morale boost. Could not similar aptly sized facilities be provided and maintained by entrepreneurs rather than by hired personnel? Outdoors, there is only sterility.




### Cottage Industries: from Pastime to Profession

Personnel "allowed" in Antarctica, discounting tourists and visitors, are those hired to assist scientists and researchers and to maintain Antarctic facilities. There would seem to be no place for "entrepreneurs" of any kind. Certainly, there is no place for people who do not earn their right to stay. And clearly, there is no social welfare system on the continent. "Out of work?" - return home, to where you came from!

But it is conceivable that some artist craftsmen could earn the Antarctic equivalent of "full time" income making income and at the same time making it unnecessary to import stock items that their products can supplant. But where would they live? Some stations may have spare space, or unused buildings. If not, maybe if what the artist-craftsman produces is of sufficient value, they could order prefab homes or quarters on mortgage terms. It does not seem likely that even a station as large as McMurdo might someday have an artist-craftsman "suburb" anytime soon. But it would be a start towards a small but growing Antarctic "citizenry."

### Fast forward to Moon and Mars: "earning the right to stay"

Might personnel hired for temporary service at an outpost on Moon and Mars, earn his/her right to stay by providing enterpreneurial service of this or any other kind that helps the outpost grow and thrive?  This could be how permanent settlement starts. Beyond arts and crafts produced furniture and furnishings that made it unnecessary to import equivalent items from Earth, entrepreneurs could undoubtedly find many other ways to make themeselves useful. It may pay to import the tools and supplies they need to keep improving and adding to the services they offer. And if they stay behind, that saves cost of a return home.

The various national space agencies or collaborations of them, may never recruit "settlers." It is then up to those hired to work at Lunar and Martian outposts to earn that right in their spare time.

**Could this be how settlement starts?** Those with side-talents hired to work at Antarctic stations could pave the way and establish a paradigm for the introduction of a "resident population." All great things can be traced to humble beginnings! **PK**

## The Critical Path to "Pioneering the Moon" - 1. The Situation

By Peter Kokh

Currently, some of us in the Moon Society and in the National Space Society are working hard to get more people aboard a path that will break the current log jam - the logs being different visions of our future in space, each with its own set of horse-blinders.

To this end, Board member Al Anzaldua and I have spent many hours working on a plan to promote priority development of the technologies needed in common to return to the Moon, to mount a manned mission to Mars, and to prospect the asteroids. This is the "**Triway to Space**" plan and Declaration, published in MMM #256 and online, in **Space Review**; **http://www.thespacereview.com/article/2078/1**

Also to this end, a number of us are working with John Strickland of NSS-Austin to mature **a Cis-Lunar Transport Plan** that will better, and more economically work to open the Moon, Mars, and Asteroids.

We all recognize the shortcomings in NASA's vision and goals, encumbered as they are by the inanities of the political process. But these efforts, as timely and revolutionary as they are, are not enough to those of us who share the core vision of the Moon Society,

> "accelerating the day when there will be civilian settlements on the Moon, making use of local resources through private enterprise both to support the pioneers themselves and to help alleviate Earth's stubborn energy and environmental problems."
>
> From: http://www.moonsociety.org/about/vision_mission.html - a document worth reading in full!

It is not enough to return to the Moon "to stay." "Stay" to do what? Build an outpost that overtime will be as busy with exploration activities as McMurdo Sound station in Antarctica? Many would settle for that several decades out. Yes we want to fully explore the Moon, deploy telescopes that can better explore the universe, including radio telescopes on the farside - the only place in our solar system where we can be shielded from the growing radio noise cacophony that comes from Earth. Yes to build a fuel production station at one of the Moon's poles to fuel our ships to go anywhere and do anything, especially to build the "Cis-Lunar Economy."

But to some of us, that is not enough. Our goal is to extend the human frontier to the "8th continent", not in the manner in which we have been doing on the 7th continent, Antarctica, but as we have done on the five other "new continents" since humanity's "Out of Africa" Epic began before our current memories and legends. Our goal is to transform the Moon into a "human world." Sorry, but fuel stations in the polar icefields, does not quite do that.

The Moon Society is pushing this first opening of course, as it must, as it should. But we should not kid ourselves that or mission stops here.

### What is needed to "Settle" the Moon

Because of the high cost of imports - even with transports burning liquid oxygen and hydrogen produced from lunar polar ice and brought up to fuel stations at L1 and in Low Earth Orbit - to expand operations on the Moon, we must be able to produce the great mass of items we need to expand our habitats and operations from materials produced on the Moon. In Situ Resource Utilization or ISRU ("on location" for those who do not need to show how erudite we are by using Latin phrases) has to concern itself with more than producing liquid oxygen and liquid hydrogen and drinking water.

We have to learn how to build and manufacture the heaviest in gross mass (number of items times mass each) that we will need - i..e building and manufacturing materials - from the elements in moondust or regolith. More on that below.

Now anything lunan pioneers make for themselves, can be exported elsewhere "in space" at less cost than similar items made on Earth. Products manufactured on the Moon will furnish space hotels and other stations in Low Earth Orbit, Geosynchronous Earth Orbit and elsewhere in cis-lunar space, earning income for the lunar settlements. Read more: http://www.moonsociety.org/publications/mmm_papers/muscle_paper.htm

In the next article, we will discuss what building and manufacturing materials are most realistic and most promising. "ISRU" research has to prioritize those materials if we are serious about making settlements in which pioneers can feel "at home" on the Moon. These materials will also build more outposts used just for science and exploration. So if you are one who feels anything more is unrealistic, you still owe it to yourself to see that these ISRU goals are prioritized.

### Where to live on the Moon:

Most serious (not science-fantasy) habitat/outpost designs circulated through recent decades confine personnel to cramped interiors very much as submarines and sea-floor outposts do. That is tolerable for short tours of duty. Submariners commonly spend six months under water, totally withdrawn from the "world" as they have always known and experienced it.

But if we are talking not just about persons on temporary tours of duty, but about "pioneer settlers" who intend to stick it out long term, and if things go well, live out the rest of their lives on this new world, even raising families, complexes of habitat modules do no do it. Rather, we must learn in various ways, approaching the daunting task from both ends, how to marry our frontier settlements with the barren, airless, radiation-washed Moon itself. And those who can't see how we could ever do that are part of the problem.

Now many readers may be familiar with Robert A. Heinlein's classic science fiction novel, "The Moon is a Harsh Mistress." Heinlein envisioned cities on the Moon, housed in complexes of tunnels carved out of the bedrock. That was the most realistic vision for some time.

Now that we know that the lava sheets of the lunar maria (the dark blotches on the side of the Moon that always faces Earth) must be laced with networks of lava tubes of considerable size, we know that at least in those areas, our "tunnels" are waiting for us. We have now discovered a number of lavatube skylights, and may in time learn how to read surface clues well enough to map some of these networks.

But there are no lavatubes in the highlands, and it is important to keep in mind that both lune poles are in highland areas. In fact, the closest mare areas to the south pole are 1,400 miles or so to the north (Humorum, Nectaris, Australe, etc.) The north pole is more blessed, with the northern "shore' of Mare Frigoris some 600 miles distant. Now some imagine pressurizing and "terraforming" these vast subsurface tubes, but that again, is a flight of science-fancy. The Moon is rich in oxygen but very, very stingy in Nitrogen, which is the very important buffer gas that makes up 4/5th of Earth's atmosphere. In short, pressurizing a sub surface lavatube is for now "science fiction" of they "way-off" kind. We will settle lavatubes but in the same general type of pressurized modular structures that we would elsewhere cover with a blanket of moondust out on the surface.

Some envision large cities on the surface, very much like cities on Earth, but protected from the life-squelching lunar environment by immense transparent domes made of "unobtainium." We say that, because while small domes of a few yards or meters in diameter might work (but fail to protect dwellers from radiation), much larger domes would be blown off the surface by the pressures they were trying to contain. The dome city would work only on a world with an atmosphere not too different than in pressure, from the Earth-like atmosphere inside, but of unbeathable composition. For example on Mars - if Mars atmosphere could be thickned substantially.

But how do we make our settlements any more livable than submarines! That is the challenge, and happily, there are lots of ways to meet that challenge and then some.

### Explorers and scientist are paid. How will Settlers earn their keep?

We've already given the major part of the answer: anything settlers make for themselves, big or small, simple or complex, be it building materials, modules, machine parts, - or even food! - they will be able to market in LEO, GEO, stations at L1, and other cis-lunar locations - at a cost advantage over items made or produced on the Earth's surface. Why? Because i takes only 1/23rd the amount of fuel to ship something "down the gravity well" than "up the gravity well" from Earth's surface. The Moon's 1/6th gravity is perhaps its greatest asset. And it will be some time, if ever, before fuel costs are too low to make a difference.

All articles in past issues of Moon Miners' Manifesto (the first 25 years) which have a direct or indirect bearing on the Lunar Economy have now been released in an MMM Theme Issue: the Lunar Economy, available as a free download PDF file: **http://www.moonsociety.org/publications/mmm_themes/mmmt_LunarEconomy.pdf**

### So How will Pioneers come to "feel at home" on the Moon?

We have pointed out that they must live underground to be shielded from cosmic radiation and solar flares. But this can be in tunnels, lavatubes or out on the surface but covered with a blanket of moondust on the order of 5-6 yards~meters thick. If you stop and think, that is how we on Earth are protected from radiation. Yes, we live under the shield of the Van Allen Belts created by Earth's strong magnetosphere. But our tick atmosphere protects us as well. If it were to get cold enough here on Earth to freeze the oxygen and nitrogen in the atmosphere, everything would be covered by an "analogous blanket" of nitrogen-oxygen snow!

Now this does not answer question of getting to feel at home, becoming comfortable with the forbidding lunar environment as a friend, not an enemy. That we will take up in the third article.

Note that we have already talked about making building materials and other products out of the elements present in moondust. That in itself is part of the answer! That the Moon furnishes us with these materials already makes this barren world "friendly!"

## 2. Building and Manufacturing Materials from Moondust

## Glass-Glass Composites

When I launched Moon Miners' Manifesto, seminal initial experiments with "glass-glass composites" was underway under the aegis of the Space Studies Institute, then headquartered in Princeton, New Jersey. The holy grail was to see if we could produce glass fibers with a high melting point to imbed in a matrix of a glass with a much lower melting point. Experiments funded in part by SSI using lead as a dopant to lower the matrix glass melting point produced promising results. That was in 1937, and not much progress has been made since, for lack of funding. We proposed a business plan that might finance continued experiments that would produce a product marketable here on Earth, with the idea that by the time we got to the Moon, we would have plenty of experience with a close analog of the technology needed on the Moon. We suggested replacing lead (which would have to be imported) with lunar sodium and/or potassium, abundant enough.

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

Of course, no one took up on this, and nothing happened. But the feeling was common that glass-glass composites could be used to make many useful things from parts for Solar Power Satellites to lunar homestead furniture and perhaps even pressurizable habitat modules.

**Cast Basalt Products**

Meanwhile, some time back I had learned about cast basalt products, such as abrasion-resistant tiles and abrasion-resistant pipes: just what we needed to handle moondust which is very abrasive. Indeed. It seem so very vital that we launch the first industrial complex on the Moon in a basalt-rich mare area for this very reason, that it seemed to be suicide to start setting up shop at the poles, as important as water and its components may be.

Cast basalt pipes and sluices and other objects needed to handle moondust in an industrial operation would not be the only prize. Cast basalt could be used for floor and wall tiles, for table tops, for watertight planters needed to begin lunar agriculture, and for much much more. A basalt industry seems essential.

**Lunar Alloys of Iron, Titanium, Aluminum, and Magnesium**

These are the four "engineering metals" all present in sufficient abundance in moondust, iron fines being everywhere, but more abundant in the maria, along with titanium, and with aluminum and magnesium being more abundant in the highlands. The catch is none of these "engineering metals" in pure form is of much use. We have found ways to alloy all of them to improve their performance. The trick is that the preferred alloy ingredients are not handily abundant on the Moon. We have to test "second best" formulations. Some of these have been tried on Earth but never put in production because we had better alternatives.

My #1 Brainstorming side-kick for some twelve years now, has been Dave Dietzler, of Moon Society St. Louis. Not afraid to go down a blind alley, Dave has found some promising options, such as "maraging steel" and these have been the subject of several recent articles.

**Basalt fiber products**

Meanwhile, I had stumbled on an article about about a basalt fiber industry in Northwestern India (Gujarat if I remember correctly) and between Dave and I we are learning what a motherlode jackpot of technology this is. Rebar used to strengthen concrete can no longer compete with "rockbar" made out of basalt fibers. The latter are water resistant (won't rust), stess resistant, less subject to thermal expansion and contraction.

We are now wondering what else this new wonder material could be used for: rails for lunar trains? Shells of habitat modules? This is a simple material abundant in the lunar maria, which can be put to a host of uses: parts for Solar Power arrays included. In contrast, no lunar-glass or lunar-metal alloy seems as "ready to hit the market" as cast basalt and basalt fiber products. Just don't look for basalt anywhere near the lunar poles! **So here is where ISRU should concentrate: in the Moon's maria.** Note: If we dig trenches to inset our modules, the basalt at the bottom of the trench will be more concentrated.

Basalt fibers could be used to make "sandbags" for deploying moondust over a habitat in a "removable manner. It could make tarps and matts and so much more.

At any rate, beyond oxygen production, development of **easily produced and widely useful lunar building and manufacturing materials must have priority** – priority now, not a decade after we return. Cast basalt, glass composite, lunar producible alloys all need attention that they have not been getting. This is what we must mean by "ISRU." What we now mean by it makes the users of this "secret code" term look shortsighted.

As we suggested in the Glass-Glass Composites paper referenced above, the place to start, with further development of the potential of basalt fiber, for example, is to find as yet unexplored but potentially profitable terrestrial uses, and then develop new products accordingly. The result is a process we have called **"spin-up" (as opposed to "spin-off") – putting a close analog of a technology we will need on the Moon, "on the shelf" ready to use when we get there.** Some could get rich doing this!

## 3. Incorporating an Earth-like "Outdoors" in Middoor Spaces

### A Eureka Moment

Moon Miners' Manifesto saw the light of day in December 1986 only because of a "Eureka Moment" I had experienced a year and a half earlier in May 1985. You can/should (if you want to understand) read about this in http://www.moonsociety.org/chapters/milwaukee/mmm/mmm_1.html In short, a visit to a most unique and original underground home 20-some miles NW of Milwaukee convinced me, that though, as Heinlein predicted, we might have to borrow into the Moon to live safely, we could "bring the views and the sunshine down with us." While we had to be tucked under a moondust blanket one way or the other, that did not mean a disconnect with the best that the lunar surface has to offer: views of the landscape, and sunshine. Sunshine suggested house plants and vegetation-refreshened air, as well as food. Someone will reengineer my "Z-view" periscopic windows and other features, but they are too superior to a TV screen to ingore.

### Beyond a network of "indoors only" habitat and activity modules

The first starter outposts will be but a complex of modules some inline, other off T and X junctions. But eventually hallway and even pressurized street networks will arise. And with that comes opportunity. Even individual modules can have "house plants" even "living walls" (Wikipedia "Green Walls") to refreshen the air and assist in treating toilet wastes. If a modular biospherics plan is adopted to mate with modular architectures, then the capacity to refresh water and air will grow apace with the complex proper, minimizing what part of these processes has to be taken care of by central facilities. Halls can be lined with plants in the form of living walls, for example.

When the complex grow to the point that travel from one part to the other makes electric vehicles most welcome, then "streets" will emerge. These too can contribute to the biomass needed to sustain a self-frefreshing atmosphere. While "room temperature" will be maintained in habitat and activity modules, there is no reason not to let temperatures vary – within reason – as the 14.75 day long dayspan with continual sunshine passes and then rotates with the equally long nightspan.

The result is that we have a buffer, temperature- and climate-wise between the "indoors" and the "middoors" – an environment more reminiscent of the outdoors back on Earth. Forget about Heinlein's tunnels! Then if vehicles dock with outpost and settlement docks, so that passage between without spacesuits is possible, we have the start of a "virtual" global lunar pressurized Earthlike environment.

## 4. The Role of Indigenous Arts & Crafts

### The need for people everywhere to express themselves with local materials

Every time pioneers on Earth have left their familiar home country and ventured into places with different sets of easily available materials and plants and animals, they began to feel at more and more at home as they learned to build and adorn their homes out of things locally available. It will be no different on the Moon. Objects of cast and hewn (carved) basalt will be an early choice in much of the Moon's nearside. But artists also have a keen eye for the hidden possibilities within every bit of "free" material including scavengable scrap and "junk."

We have personally attempted to pioneer an analog of a lunar painting medium.

**http://www.moonsociety.org/chapters/milwaukee/painting_exp.html**

The pioneers will find them. Hand made or crafted objects in front of a window or on the surface outside will temper the lifeless and life-squelching lunar surface with things made by human hands. Slowly, both from inside and outside, human spaces and settlements will begin to belong to the moonscapes, and vice versa.

## 5. The Role of "Lee-Vac" and "Out-Vac" Activities

### Outside Sports and Hobbies

We've all seen paintings of lunar pioneers playing golf on the lunar surface. Some pioneers will love to go foraging for moon rocks that look special, or are of a carvable kind. Other will just like to stroll form time to time in the vast black-skyed outdoors – the "out-vac" (yes, after Australia's "outback.") There will be road rallies. As space suits become lighter and permit more movement, more types of outdoor activities will emerge.

But there is an intermediate environment, the "lee-vac" – moondust shielded but unpressurized hangers and domes and stadiums where lighter suits can b worn because neither radiation nor extreme heat nor extreme cold are a problem. In such lee-vac spaces, pioneers can attempt a lot of things in lunar gravity, in lunar vacuum, without the drawbacks of full-exposure.

Bit by bit, pioneers will adapt to this seemingly hostile world. No place is hostile if you know how to deal with it. Consider for example, how the inuit and Samoyeds have adapted to the extreme exposed coastlands of the Russian, Alaskan, Canadian, Greenland coasts. If we did not know about them, we would have thought such adaptation would be impossible. But it wasn't, was it. Neither will it be on the Moon. Come back in a century or so and you will find a frontier population as happy and settled in as most of us are here on Earth.

## The Critical Path to "Pioneering the Moon" – Conclusion

### A Contrast of Visions: "horse-blindered" verses "eyes wide open"

Perhaps most persons interested in opening the Moon only see small isolated outposts where persons clearly out of their element will do their best to put up with unearthly conditions for a tour of duty or two. The vision we have sketched of a quite more developed and satisfying frontier may seem science-fiction/fantasy to many, but this vision is grounded not only in the realities of the Moon and its features and makeup, but also in the capacities and drives that are characteristic of human pioneers. Were it not so, we'd still be found only in in Africa.

The human epic has been an "intercontinental" one. The Moon is another kind of continent (as big as Africa and Australia together) across another kind of sea. This final "intercontinental" colonization will also be the inaugural "interplanetary" one. Do not judge the possibilities from the challenges new lands confront us with. Judge the possibilities from the unlimited capabilities to adapt which are part of the human makeup. We should never doubt that we have it in us. Those who would have us "stay home on Earth" are of the same ilk as those who would not dare leave Africa.

And this is just the beginning. To correct Genesis if I dare, **"Of stardust thou art, and to the Stars thou shalt return."** We owe it to the Creative Agency behind our existence to realize all the capacities built into us. Not to do so would be the ultimate sin. **PK**

**Further Recommended Reading**
http://www.moonsociety.org/publications/mmm_papers/muscle_paper.htm
http://www.moonsociety.org/publications/mmm_papers/outpost_trap.html
http://www.moonsociety.org/publications/mmm_papers/beyond_moonbase_1.pdf
http://www.moonsociety.org/publications/mmm_papers/pioneer-mental-health.html
http://www.moonsociety.org/publications/mmm_themes/mmmEden_on_Luna1.pdf
http://www.moonsociety.org/publications/mmm_themes/mmmEden_on_Luna2.pdf
http://www.moonsociety.org/publications/mmm_themes/mmmArts_Crafts.pdf

MMM #258 – SEP 2012

## Neal Armstrong: ultimately, his legacy of is up to us!

By Peter Kokh

In the news recently, someone noted that no human being born since 1935 has set foot on another world. We have frozen out generations of young people from following the Apollo Overture. There are many reasons, but the first and most foremost reason is rooted in the very announcement of the Apollo Program way back in 1961. First, as we noted in our In Focus editorial in MMM #238, September 2010: "**In This Decade**" – three little words that won us the Moon Race but that have hamstrung us ever since" – in order to win, we built an unsustainable space architecture, good for a few short sorties, nothing else. We overawed even ourselves. The result is that we have six sites on the Moon at which Apollo mission equipment was left behind, including the LEM landing platforms, flags, footprints and rover tracks, and assorted equipment that was left behind to reduce weight for take-off back to Earth.

We agree with the ideas expressed in the following recent web post:

http://www.space.com/17330-neil-armstrong-death-moon-landing-site-preservation.html

> "The passing of famed astronaut Neil Armstrong, the first man to walk on the moon and commander of Apollo 11, may strengthen the **movement to designate the Tranquility Base lunar landing site as a National Historic Landmark.** The field of space heritage preservation is gaining momentum, and a recently authored bill aims protect the Apollo 11's Eagle lunar lander touchdown site and all the artifacts that astronauts Neil Armstrong and Buzz Aldrin left behind on the lunar surface." (Excerpt)

Why would we need to do this? Obviously, because many of us believe that humans will someday go back to the Moon, this time to dig in and stay, as the first "Lunans." And, there will be tourists, not only from the ranks of the first pioneers and those to follow, but also from Earth on short "bucket list trips of a lifetime."

The present movement seems to focus on the Apollo 11 site, the very first, but some order of protection should be given to the other five sites. Apollo 15 at scenic Hadley Rille with the very first moon buggy rover still on location, and Apollo 17 in the Taurus-Littrow Valley and the site of the very last mission getting equal billing.

This might involve installation of elevated walkways lest the historic bootprints get ground into the dust, and railing off the various artifacts left behind in a "see but can't touch" state of preservation. A small museum – tourist center could be within sight, but safely separate. I have seen a small number of proposals for such "National Monument" preservation, but we do not need to go into details here.

**Why we should enact such a "treaty" now.**

Once it becomes apparent that humans are going back to the Moon, not just for further exploration, but to learn how to use lunar materials to help build structures in Geosynchronous Earth Orbit (solar power satellites and large platforms that each host hundreds or more telecommunications and other satellites) at far less cost than shipping the needed materials up from Earth's surface, then we are going to hear from well-intentioned environmentalists (among whom I count myself) that we should leave the Moon to itself, "hands off!," in its pristine state.

If we enact such a historic site preservation and monument measure, that will help those of us who want to see the Moon developed in a way that preserves its beauty, not only from Earth, but from lunar orbit, and indeed on the surface itself. To this end, we have published a proposal for a Lunar National Parks & Monuments Treaty. Our

proposal appeared as an article "National Parks on the Moon" n MMM # **176 June, 2004** p 5. reprinted on **pp 34-35, MMM Classics #18. You can freely download this issue and article at**
http://www.moonsociety.org/publications/mmm_classics/mmmc18_Jan2008.pdf

Eulogies of Neal Armstrong are nice, but I can think of nothing better to honor his memory than a campaign for an Apollo Sites preservation Treaty, as an overture to a broader, more comprehensive treaty on lunar preservation respecting the lunar environment while allowing settlement and thoughtful industrialization. As I have noted before, the precedents set by the current Antarctic Treaty are extreme, and not a model to follow. **PK**

## Moon and Mars Outposts: Building Sheltering Structures First

By Peter Kokh

*Apollo left no occupyable structure on the Moon. There is no 'friendly' place to return to, no place where we can go and pick up where we left off. We must start over, from scratch, this time with a plan!*

### We can't "do the Moon" so long as we fear the Night(span)

All six Apollo Moon landing missions were confined to the early/mid-morning "hours" of lunar dayspans. NASA has never attempted to keep astronauts on the Moon for a full dayspan-nightspan cycle, much less for several of them. Given that deliberate "toe-in-the-water self-limitation, the new rounds of astronauts only being on the Moon for less than two weeks before coming home, there is no urgent need to provide shielding.

However, for longer missions, as essential as shielding is for radiation protection, it will also be essential for thermal management in the month ("sunth") long temperature cycle from 200° plus above zero to 200° plus below zero. Now, choosing polar sites or sites at high latitudes, north or south, would mitigate the problem. But consider an alien species visiting Earth and choosing a Pacific Island where the temperature varied very little over the year, radioing home, "we have mastered living on Earth." Yes the polar sites offer access to water ice, yes they are more thermally benign, yes there is less difference between nightspan and dayspan, but the poles are anything but characteristic of the Moon at large, and do not offer critical access to mineral resources found only in the Maria, or along Highland/ Mare "coasts" which means limiting ourselves to parts of the Moon we can explore, but more importantly, limiting ourselves to what lunar resources we can develop to fuel the Earth-Moon Cis-Lunar Economy.

### The Two Faces of Shelter

The key is providing shelter, not only from cosmic and solar radiation over extended stays, but also to provide thermal moderation at comfortable temperatures. We would want to "shelter" our living spaces to provide moderate temperatures without energy-intensive heating and cooling even if there were no such thing as solar flares, coronal mass ejections, and cosmic radiation!

### How to Shield

Considering the source of the author's original "eureka" moment in May of 1985 (read: http://www.moonsociety.org/chapters/milwaukee/mmm/mmm_1.html ) it is natural that I have long visualized an ever growing complex of interconnected habitat and activity modules and pressurized hallways, and as whole "neighborhoods" emerged, pressurized streets - all individually covered with shielding as they were added.

### Exercising due foresight

But, whether we are talking about a one-nation effort or about an International Lunar Research Park for the first "permanent" outpost, **it is likely that we will want to rearrange modules and hallways etc. as the complex slowly grows** and as experience suggests more favorable layouts. **Watch this time lapse animation video of the construction of the International Space Station, during which several modules were disconnected and repositioned elsewhere. - http://www.youtube.com/watch?v=h8kOAroNNAo**

This is the flexibility that we will need in building a full-function lunar outpost as well. The original plan for expansion may end up being scrapped, and probably more than once. The way McMurdo Station in Antarctica grew to its present size is a case in point. Early expansion plans proved quite inadequate to provide needed expansion not only in the physical complex but in the variety of activities supported.

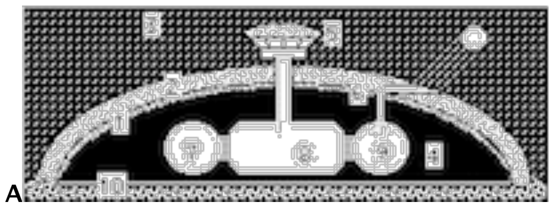
In this light, **it would be best not to start with a few modules**, shielding them as added. For when we wanted to rearrange the complex layout, we would have to remove some of that shielding. Even if we had used sandbags, this would be a chore. There is another way: **Build an expandable shielded canopy first, before delivering modules** to park and interconnect in a temporary arrangement underneath.

### Canopies, Hangers, "Ramadas"

A word frequently found in MMM is "ramada." I first learned the word driving through the American southwest in 1980, long before the first MMM. At roadsides where tired drivers can pull in and rest, eat a lunch they brought along, and perhaps use the restrooms, there is often a roof supported by four poles at each corner, its main function being to provide shade from the hot unrelenting sun, rather than shelter from infrequent rains. This shelter is called a "ramada" - Spanish for sun shelter.


**Above left:** a traditional “ramada” sun-shelter in the SW United States - **Right:** a quonset type shelter

On the Moon, we will probably want unpressurized shelters of various types that are shielded from all directions. That does not mean “closed.” Openings through which to bring in modules and other things to be deployed or stored inside can be baffled so that there is no direct path for solar or cosmic radiation to enter.



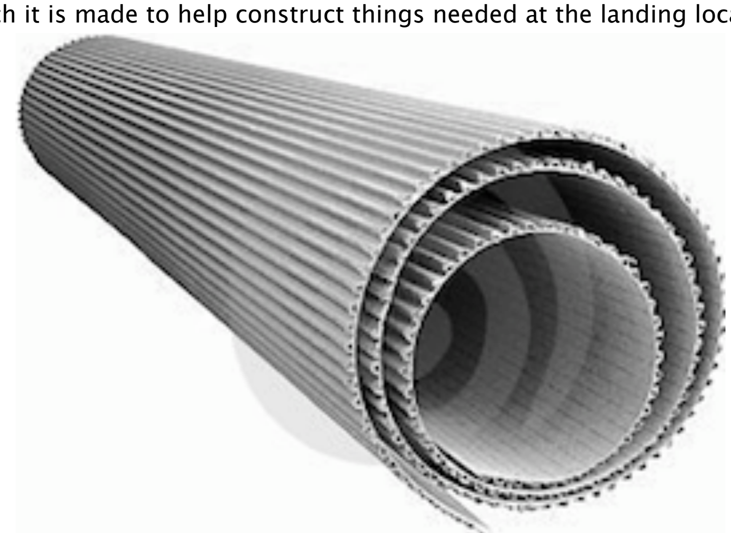

**Above left:** an illustration from MMM; **Above right:** a similar NASA concept

**Above left:** KEY: (1) Space Frame Arch, Fabric Cover; (2) 20 cm or more regolith dust shielding; (3) exposed vacuum, radiation, micro-meteorites, UV, solar flares; (4) protected lee vacuum service area; (5) observation cupola with ladder shaft to habitat space below (7, 8, 9)

### Two ways to deploy such a shelter “first”

1. We can send small crews to the Moon, living inside their lander, and working outside to assemble a suitable shelter. That would take several very expensive missions.
2. Or we can deliver the following package:
   - **teleoperable equipment** to fabricate useful building elements from moondust, and do some pre-assembly chores including producing sintered **building blocks in the “Lego” design** for self stacking without mortar, producing sand bags (basalt fiber fabrics if the site is in a mare area) and filling them


   - **“intelligent” “avatar” robots** operated by “telepresence” from Earth, to handle some of the harder routine tasks, including leveling the area, assembling support walls from sintered blocks, piling up and bags
   - **cargo container structures designed to be reusable**, for example with an unrollable wall for “roofing.” **Keep in mind that there are at least two ways to reuse a rocket stage:** a) **refuel it** for another trip or b) **reuse the materials** of which it is made to help construct things needed at the landing location.



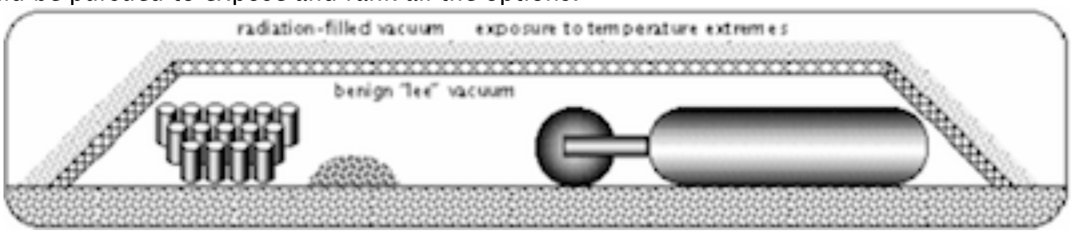
**Above: a roll of corrugated cardboard** suggests how the **corrugated aluminum skin of a landing cargo stage** (or empty fuel tank) could be reused as a roof to hold blown or bagged moondust, with sintered lego block columns spaced to support the load in1/6 G. If it proved too difficult to manufacture basalt fiber fabrics for bagging moondust to cover a space frame to create roofing, such fabric could be part of the cargo in this shipment.

The corrugation will strengthen this structure in at least one direction. A 2-layer cross-corrugated sheet could not be rolled. But it could be designed to unroll in an arc, short of flat, to provide strong support, the low ends resting on block walls and/or pillars, providing extra internal height.

An option would be two layers of material, placed so that the corrugation of one is at 90° to the other, making a very strong flat roof. (It is cross-grain plies that give plywood its strength and dimensional stability.)

**Question:** Could Cargo Hold wall unroll into a stable quonset structure? The arched hold wall roof supported in the middle would be stronger than a flat one.supported at the sides. If the corrugated cargo hold wall was designed so that it could not unroll completely but retained a shallow curve, it might be strong enough to hold considerable shielding mass in light lunar gravity.

This type of pre-made reusable roofing, would seem superior, if practical, to constructing a space frame that would then have to be covered with some sort of sheeting (aluminum? basalt-fiber fabric made on the Moon). Both avenues should be pursued to expose and rank all the options.




An earlier MMM Illustration: A hangar with "space frame" wall/roof construction requires sheeting to support moondust, Note warehousing area to the right.

The Advantages of pre-constructing a shielded hangar or ramada before first human crews arrive are clear: Each crew could simply park the modules brought along on its mission and connect them. The assembly area would be shielded, and the construction crew could wear lighter "pressure suits." If a following crew brought more modules that required rearrangement of what was already in place, this would be easy, with no contact shielding materials to be removed and then repositioned.

Of course, sintered moondust lego blocks, basalt-fiber sandbags, sandbag filling equipment, and the ramada/ hangar itself are not the only job that can be done beforehand. Teleoperable equipment can grade a landing site "spaceport" and compact and sinter the soil, and build berms around the site to contain rocket exhaust-blown moondust, which can be quite abrasive. And of course, the could level the area in which the hangar/ramada is to be built, and build some peripheral roads.

Open warehousing areas can also be pre-constructed, the ground leveled and sintered, the perimeter baffled by berms, sand bag walls, or lego-block walls, for items that can be stored unsheltered. The hangar/ramada should offer a limited amount of sheltered space for storing items best not exposed to extremes of heat and cold, as well as those that needed to be accessed frequently.

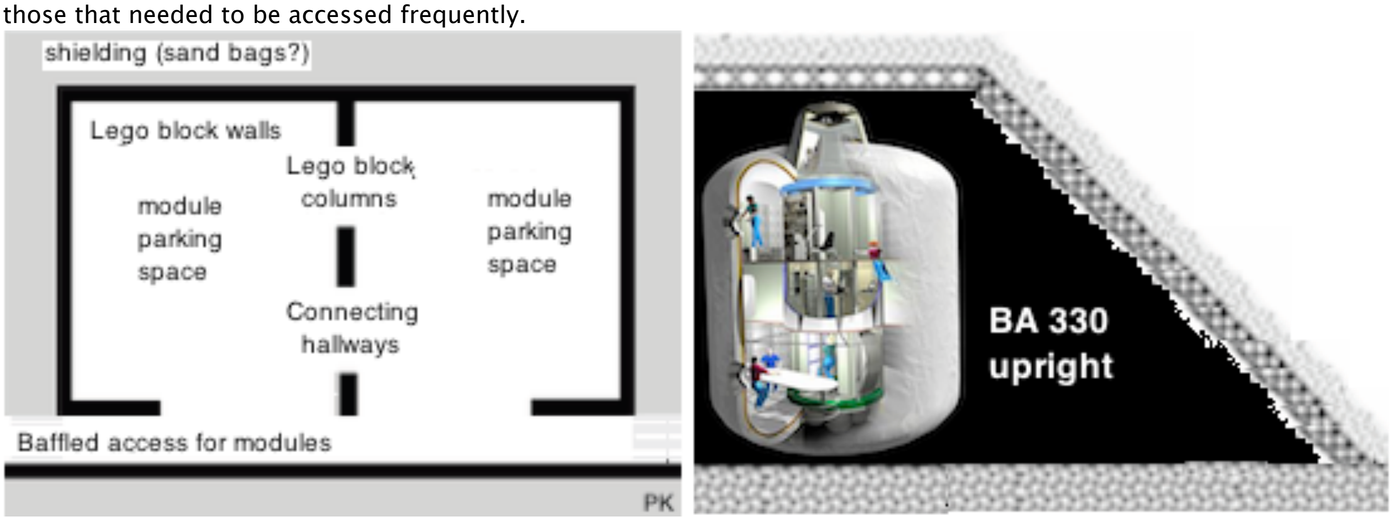



**Illustration of the shielded ramada/hangar concept:** Note that a shielded hanger could shelter upright BA 330 modules, difficult to shield otherwise. The vertical orientation offers maximum floor space. e!

**ISRU (on location resource use) items that need research now:**

- basalt-fiber technology is advancing quickly: can we make sand bags from such a material? What about sheeting strong enough to hold several feet (minimum 2 meters) of blown moondust?
- automated sandbag manufacturing

- automated production of sintered regolith lego blocks of standard size
- automated or teleoperated lego block wall stacking/construction
- compacting roller wheels (think steam roller size) shipped hollow, filled with compacted regolith

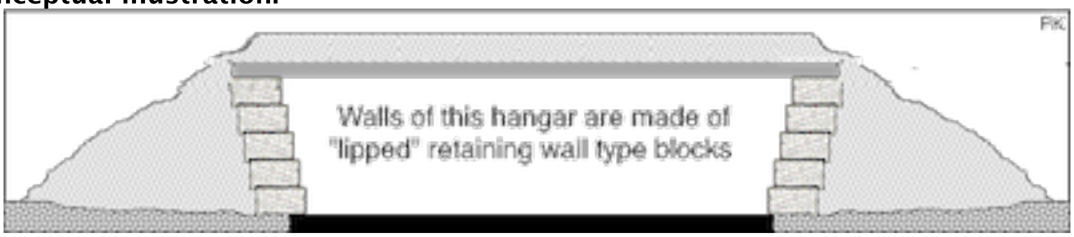
**You can help!**

Perhaps you can help fill in what we have missed or not thought of! Why not conduct local, regional, national, international engineering design contests to develop the ideas above.

### The Good and the Bad of the above scenario for outpost establishment

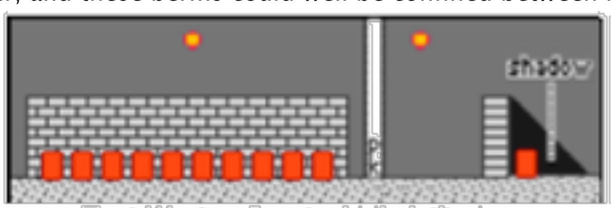
On the one hand, **very expensive on-location manpower** is reserved only for those things that cannot be done by teleoperated equipment or by telepresence-operated avatar robots. This also decreases the chances of serious injuries. Further, when the first crew arrives, and parks the modules they brought along or which have been pre-landed within the hangar/ramada structures, they will be ready to stay several lunar cycles, i.e. in ISS type length crew stints, for which 2 meters of pre-provided shielding will be ample.

### Another conceptual illustration:

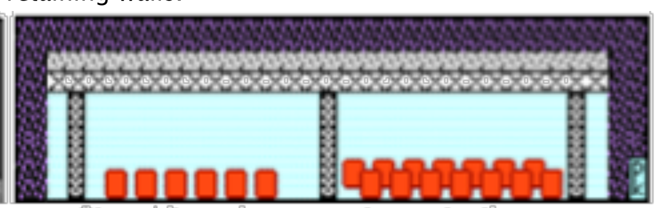



### Beyond bricks: pavers and panels

Closely related to bricks are "pavers" which can be brick like in size and thickness up to much bigger slabs. These would have a use as well, for example serving as pavement for rocket landing/launch pads to cut down on the spray of sandblasting moondust driven by rocket exhaust. Such pads would be bermed as well to present a horizontal barrier; and these berms could well be confined between retaining walls.




East-West walls, at middle latitudes provide shade for stored drums etc.



Stored items have greater protection under a shielded ramada-hangar canopy

Panels, whether of concrete or made in the same moondust sintering fashion as bricks and blocks, could be held in place by Lego type blocks with forked ends. Panels, whether of concrete or made in the same moondust sintering fashion as bricks and blocks, could be held in place by Lego type blocks with forked ends.

The hangar interior can be **naturally lit**, during dayspan, by providing intermittent broken-path sun-wells or direct path "sundows" made of bundled optic fibers that double as shielding. Electric lighting for nightspan can be separately suspended from the ceiling or placed above the exterior surface, to use the in-place sun-well or sun-dow light delivery system. A light pipe network suspended from the ceiling could be fed by sulfur lamps.

**Visual access** can be accommodated by broken-path (radiation-proofed) mirrored shafts from the habitat modules underneath through the hangar roof. With proper planning, such ready-access observation ports can be provided ahead of time as the hangar is expanded section by section. Alternately, a pressurized vertical ladder-shaft can lead from habitat below to pressurized observation dome on the hangar roof.

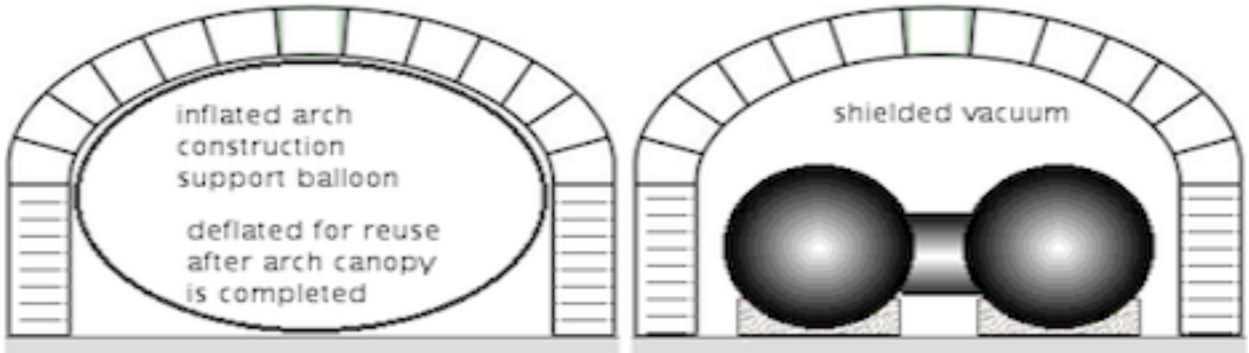
### Who gets to teleoperate the brick making and deployment controls?

Such a project, coordinated with NASA or any other contracting tenant, would be an early indication that a base was about to become real. Indeed, we think that we can make this proposal even more interesting by expanding on the teleoperation angle. Finding ways to select individuals from the public at large by lottery of other means and give them a turn behind the brick/block manufacture and deployment teleoperation controls, would give this project significant public attention. The use of supervised students selected by lottery would be even better.

We'd have to train the lottery winners, and they would only get a chance to do actual work on the Moon remotely, if they demonstrated a required level of expertise. But to win and then be approved for this privilege and then actually get to do some of the work on the Moon would be a lifetime feat, something to tell the grandchildren.

### Afterthoughts: Blocks designed for arches:

There is another way to create a brick/block shelter before any pressurized modules arrive from Earth. That would be to use blocks designed for arches. You could build interlocking rows of arches over a temporary supporting inflatable structure.




This slip-form sintered arch-block approach is well-developed in the paper "Lunar Base Design" by Peter Land of the Illinois Institute of Technology, pages 363-73, in "Lunar Bases and Space Activities of the 21st Century", Ed. W.W. Mendel, Lunar and Planetary Institute, Houston, 1984.

The '**ground**' under the arch (the floor of the hangar) can be graded smooth, compacted and sintered to provide a relatively dust-free apron for the sheltered outpost. As we will see in a later article, "site management", dust control, and good housekeeping habits must be in place from the gitgo if our attempt to establish an interface beachhead is not to fall flat on its face. (Inner and Outer "Yard" Managers or yardmasters will be critical job slots.) The hangar approach favors the early adoption and rigorous pursuit of good homesteading habits.

**Conclusion:** There would seem to be many options to providing ready to use shelter for the first crews before they arrive. We need to further brainstorm and pre-engineer each line to see which is the most problem free not only architecturally but with a view to teleoperated pre-construction, and to utility and versatility of use.

Which options could be further shielded to provide adequate protection for crews staying up to a year or more? If several sites are to be developed, and that is likely, then the most promising technologies should all be tested and tried, first on Earth if possible, then on the Moon. In time, a truly indigenous lunar-appropriate architecture will be developed and continue to be elaborated and refined.

The bottom line is the need to reserve expensively-supported crew hours on the Moon to those things that only crew on location can do. In time, the total pioneer population will grow more quickly, not less so, **because we have taken the time to do it right.**

We admit that the above ideas may not be appropriate for polar areas because basalt which we expect to play a crucial role in lunar industrialization is nowhere to be found. But it is time to get off "the Poles Only bandwagon." We do need polar ice for water and fuel. But one of the most fundamental enabling technologies, cast basalt and basalt-fiber products require mare or highland/mare coastal siting that provides access to both major suites of moondust materials. Those who are only interested in accessing the Moon for ice-derived fuels should keep developing their plans and scenarios. That said, the rest of us need to realize that water alone cannot help us transform the Moon into a new human pioneer world. The author's recommendation? A site on the "northern shore" of Mare Frigoris, the Sea of Cold. Why?

- This places the outpost only about 200 mi (320 km) from the nearest ice-bearing craters to the North. The pole itself is some 600 mi (960 km) north. The nearest "shore" to the south pole is double that distance.
- This site has easy connections to the rest of the near side "mare-plex."
- The Sinus Roris - Mare Frigoris plain stretches 150 degrees E-W. A power grid with solar stations along the route, would provide power for some 83% of the local nightspan, equalling the power coverage at the poles.
- Thorium-rich (nuclear power) and KREEP-rich (potassium, rare Earth elements, phosphorus) are to be found just to the South in Mare Imbrium.
- The Mare Frigoris area, at 60°+/- North, experiences substantially moderated dayspan temperatures.

**Indirect Shielding Methods: Summing up**

Building a dust-shielded "hangar" that provides large unstructured "lee vacuum" space in which pressurized modules can be "parked" in various forms of interconnection, offers a much faster, and easier way to set up an open-ended expanding modular outpost. There is no shielding to remove when adding additional modules, nor any directly applied shielding to interfere with servicing and repair of system components on modules a.

As a bonus, there is extra radiation-free, UV-free, micrometeorite-free, and flare-proof unpressurized "lee" service space for storing tankage and other routinely needed, frequently tended equipment that does not need to be exposed to the sky. This allows wearing light-weight pressure suits for some exterior housekeeping chores.

The hangar shed makes sense if there is firm, review-proof **commitment to phased expansion** of the base beyond the original bare minimum habitat structure. For while its construction adds an original base-deployment "delaying" mission or two, the time-saving and effort-saving dividends down the road are considerable. If our commitment is scaled back to putting a toe in the water, rather than to "getting thoroughly wet" with a wholesale plunge, then, of course, the hangar will be seen as unnecessary. But then we have an Apollo "Flags & Footprints" "Kilroy was here" repeat, and for what? Anything that is worth doing is worth doing well, and doing right, so that it becomes the foundation of something greater and not a just a stunt that leads nowhere.

### Providing ready to use shelter will be even more essential for Mars explorers

Staying a year in orbit "within the van Allen Belts" is not the same risk-wise as staying a year on the Moon, where radiation shielding is strongly recommended. It will be even more so for Mars outposts which include travel time to and fro at risk. Crews arriving on Mars will already have been exposed to maximum acceptable limits of radiation. They need to have usable shelter immediately upon landing., not months later! This will minimize the chances of serious construction accidents in a place where getting to a hospital can be months, even years away.

Teleoperation and telepresence operation of equipment and robot avatars on distant Mars will be exceedingly tedious because of the 6-40 minute time delays strictly enforced by the speed of light. It would be helpful first to create shelter under the surface of Phobos or Deimos for teleoperators and telepresence operators who could then direct construction of surface shelters almost anywhere on Mars other than at the poles, in near real time. Those whose impatience demands that they bypass the "PhD" accelerator, will hopefully give way to those of us, who like the tortoise, realize that the fastest way in the end, is the most deliberate and carefully thought out, and patient way to do anything. Below is a well-intended but dangerously unshielded concept from **MarsOne.org** – **http://www.space.com/16300-mars-one-reality-show-colony.html** (video) **PK**

MMM #259 – OCT 2012

## "New Space" and the Moon

Editorial by Peter Kokh

"New Space" as the movement is now called, is a relatively new term, but the "movement" started in earnest 25 years ago. At the 1987 International Space Development Conference in Pittsburgh (where the former L5 Society and former National Space Institute formally merged to become the National Space Society) there was a special effort spearheaded by Rick Tumlinson, to begin raising money to mount a private mission to the Moon that would seek to determine whether or not there was ice in the Moon's permanently shaded craters. $700 was collected. At the following ISDC in Denver, the Space Frontier Foundation was formed and there was an effort to advance this "Lunar Prospector" mission, leading to a **Lunar Polar Orbiter Conference** the following March in Houston. You can read the whole story here. http://www.moonsociety.org/publications/mmm_papers/lp_prehistory_paper.htm

In the 1990s a number of non-NASA mission "projects" arose. They included the Artemis Project, the Lunar Retriever project, and a number of others – New ideas, new tricks, cheaper ways, commercial financing. In due time each of these would fail, their financing schemes proving unrealistic. But there would remain a strong widespread feeling that there must be other, faster, simpler, less expensive ways of advancing humanity's future in space than via NASA. To its credit, over the years, NASA has adopted and made its own, many of these suggestions. The agency regularly holds college level engineering competitions to flush out new ideas for accomplish various feats that are simpler, cheaper, but do the trick.

For several years now, the Space Frontier Foundation has held "New Space" conferences near NASA Ames in "Silicon Valley." At these conferences, individuals and startup firms pursuing new simpler, easier, less expensive ways to accomplish this or that present what they are attempting to develop, and awards of up to a hundred thousand dollars are given to the most promising enterprise efforts. New lighter, cheaper, simpler equipment or processes are thereby advanced. And to its credit, NASA is more than an interested observer. As there is more and more pressure to reduce NASA budgets, NASA needs to find ways to do more with less. The COTS program whereby the agency helps nurse along efforts to build commercial space transportation systems to bring crews and cargo to the International Space Station is the outstanding example.

At this year's New Space Awards GALA dinner, six different awards were given for entrepreneurial innovation in various fields related to space. http://newspace.spacefrontier.org/Gala/ – This year the award for the "best New Space Business Plan" went to **Space Ground Amalgam** [http://spacegroundamalgam.com/] http://spacefrontier.org/2012/07/space-ground-amalgam-wins-competition/ The company has locations in Montana and Colorado and provides **inflatable satellite reflector components** to meet and increase higher industry bandwidth demands, while reducing launch costs andincreasing design flexibility. Their technology can also be used for **booms and solar arrays.** The founders are Rick Sanford, Michael Potter, Chris Stott, Dr. Raz Itzhaki Tamir and Daniel Rockberger. Their market consists of satellite companies for HDTV, Mobile TV, high-speed Internet, bi-directional cellular, NASA, GPS, military, industry and academia. They seek further funding of $3.5M.

Last year's winner was Altius Space Machines [http://blog.altius-space.com/] Louisville, Colorado, near Boulder and the University of Colorado. Altius' CEO Jonathan Goff had first caught our attention ten years ago as a student at Brigham Young University in Provo, Utah when he organized the Utah chapter of the Moon Society, then the Brigham Young University Moon Society Student Chapter. After graduation he joined Masten Space Systems {http://masten-space.com/} in Mohave, CA (home to a hotbed concentration of "New Space" startup corporations) but eventually left to form his own company. At New Space 2011, Goff and Altius were awarded $25,000 for their "**Direct 2 Station**" (**D2S**) Deliveries system.

Video of Jonathan's winning presentation at: http://blog.altius-space.com/2011/08/biz-plan-pitch-video/

D2S explained: http://blog.altius-space.com/2011/08/direct-to-station-d2s-deliveries-system/

**How do we fit in?**

What can The Moon Society and/or the National Space Society do to encourage these "New Space" efforts? We can publicize them, give them good press, encourage our more entrepreneurial-minded members to get involved, as Goff did. But we can also organize engineering competitions which serve to flush out new ideas, for others to develop further. Face it. We need to return to the Moon, sooner, at less expense, yet at the same time more effectively planting a permanent ever growing presence on the Moon, as opposed to yet another "Flags & Footprints" episode to be recounted as a legend in future history books.

Two years ago, two such engineering competition ideas were developed individually by myself and Dave Dunlop. Read about the Lavatube Skylight Explorer at: http://www.moonsociety.org/competitions/engineering/ Dunlop has suggested competitions to develop cube-sat scale solar sail probes that can explore the advantages of various orbital locations near the Moon for future lunar communications systems. But without engineering design competitions to flush out novel and inexpensive ways to "build" and "fly" novel simple cheaper systems and components, nothing is achieved.

Perhaps the most effective means is for one or both organizations to raise money for (a)n additional new award(s) to be given out at future New Space conferences. This can be in the area of equipment, telerobotics and telepresence systems, simpler easier faster ways to make workable building materials from moondust, etc. etc.

Perhaps the single most ingenious and hopefully most effective effort to date to provide incentives to develop simpler, less expensive but equally capable technologies is the **Google Lunar X-Prize program**. The promise of substantial rewards for being first back on the Moon to accomplish one or more of a list of goals, has highly motivated 20-some teams around the world. There is a deadline to "put up or shut up," and that motivates teams even more. In the next two to three years, we hope to see some great results and new technologies.

Now Google has money to use as an incentive, money the likes of which none of the advocacy organizations could come up with on their own, or even together as a united front. But we can still play a role that may sufficiently motivate some bright minds out there and unleash their ingenuity.

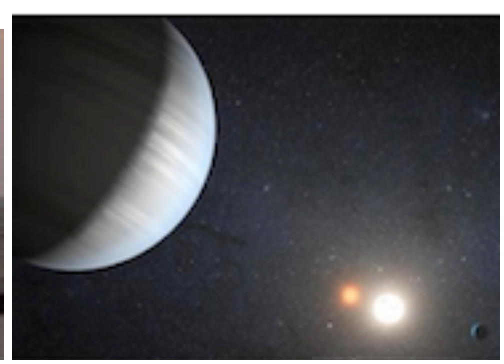
We urge the "New Space" organizations and supporters out there, to stop listing membership organizations such as NSS and TMS as "old space." Yes we have members who feel only NASA can deliver, but considering that NASA no longer believes this about itself, and that NASA strongly backs "New Space" efforts, such "put-downs" do not help the effort.

New Space must advance and overwhelm and transform Old Space or all our dreams will be for naught. The old ways become the victims of their own bureaucratic inefficiencies and cannot deliver on the dreams that led to their creation. We enthusiasts may seem like unrealistic pests. Time will show just the opposite. **PK**

## "Tatooine" Twin Sun Solar Systems may not be Uncommon

By Peter Kokh

"**Tatooine**" - a fictional planet and setting for many key scenes in the Star Wars saga. It orbited a "close binary" star system with G-type and K-type twin stars - http://en.wikipedia.org/wiki/Tatooine - By the way, the name Tatooine comes from the Tunisian community of homes dug into the surface named Tatooine, where the opening scenes of the film were shot. http://en.wikipedia.org/wiki/Tataouine



**Left:** A scene on Tatooine from in first Star Wars film

**R** Artist's depiction of a planet orbiting the close binary Kepler-47

It was an interesting concept, but could close binary stars really share a planetary system? Some astronomers doubted that any kind of binary or multiple star system could have planets. After all, the only planetary system we have known until recently, was our own, around a single star. But in recent years, since we have become able for the first time to detect planets around other stars, we have indeed found planets in binary systems.

There seems to be two distinct situations which alone favor the development of stable planetary orbits:

The stars form a close pair at the center with planets orbiting their common center of gravity. This is the "Tatooine class." And where the eco-zone, the orbital range within which it is warm enough but also not to cold for liquid water to exist on planets, we have an interesting situation. If we find just one such planet, there must be more.

**Other planetary systems and Life**

The era in which faith-motivated thinkers could believe that our solar system might be unique in all the universe is long gone. Not only will many, perhaps even most, single stars be suns with planetary systems, but now we know that at least two classes of binary stars are likely to have planetary systems as well.

There was also a time in which faith-motivated thinkers could believe that life was unique and in all the universe, found only on Earth. That space, not only within our system, but interstellar space in general, is pervaded with gas clouds composed of sulfur, phosphorous, oxygen, nitrogen, carbon, and hydrogen, the building block of life, suggests otherwise. And now we know this thin interstellar gas, immixed with inorganic ions, atoms, and molecules, is also peppered with amino acids from which the DNA of all living organism is composed. The only possible conclusion is that life is natural and will arise anywhere and everywhere in this vast universe where conditions are right. Life is still precious! That it will be found throughout the universe does not make it any less so.

**Life as we do not know it**

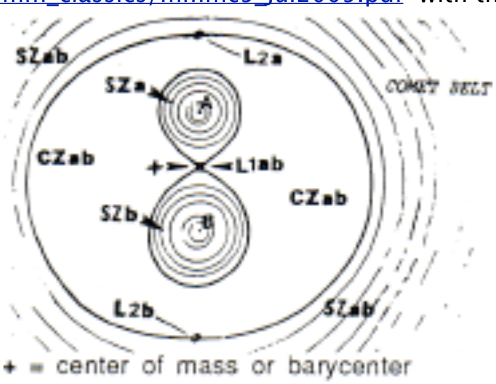
Until a few decades ago, we could only conceive of life on "land/sea" "continents/ocean" type worlds such as our own. Then we began to suspect that Europa, whose ice covered surface is very flat, might contain a sub ice-crust ocean below that could contain more water than our own oceans. At the same time, we began to suspect that life did not begin in tidal pools but deep in the ocean where hot water vents perculated the nutrients on which life could originate and evolve. We are a long way from being able to drill through Europa's crust and see for ourselves.

Meanwhile, we now suspect that Europa might not be alone. Ganymede and Callisto around Jupiter and Titan and Enceladus around Saturn may have oceans beneath their ice crusts as well. The key enabling factor is that these icy moons orbit a planet with enough mass to cause tidal heating within these moons. Ice moons with subsurface oceans might be many times more abundant in the universe than our type of surface land-water planet. That such tidal heating does not depend on how close or far the moon's primary planet is to the system's sun or suns, means "Europids" - if they can give rise to life - must be much more common than Earth-like worlds. Even rogue gas giants or brown dwarfs could have europids. Read :"Europids" pp. 47-49 (originally published in MMM #39) in MMM Classics #3 - http://www.moonsociety.org/publications/mmm_classics/mmmc4_Jan2005.pdf

**Widely separated binary systems**

Surely, where two stars rotate around a common center of gravity whether in circular or very elliptical orbits at a distance range where an eco-zone could exist, planets woud not form in that zone, though they could orbit individual stars close in, or both stars, much further out.

We discussed the case for Alpha Centauri A and B separated by a distance similar to Neptune's from the Sun, in our article "Alpha Centauri" (originally published in MMM #43) pp. 13-15, MMM Classics #5 - http://www.moonsociety.org/publications/mmm_classics/mmmc5_Jul2005.pdf with this graphic (source?)



+ = center of mass or barycenter

This graphic shows that in systems like Alpha Centauri A-B, there could be three systems of planets, one close in around each star, and a shared one at a greater distance with orbits in between being unstable.

Now there are trinary systems with 3 suns (actually Alpha Centauri AB has a distant companion star C known as Proximal Centauri) and even more complex systems.

The point is that life-hosting planets and moons are not rare and special but indeed, they are common. The universe as we know it is a planet-friendly one, even a life-friendly one. That said, the chances of finding a system that is close enough to ours that also happens to have a contemporary civilization, in a universe 13 or more billion years old, would be extremely unlikely in general. But the universe is so vast that here and there, there may be neighboring and also contemporary civilizations. We should not presume that we will be lucky enough to have won such a lottery.

But is it not enough to look up at the stars and know that "somewhere and somewhen" – indeed throughout space and time, there must be others looking up into their heavens with similar awe and wonder, whispering, "Hi whoever, wherever, and whenever you are. Isn't it wonderful!"

We whisper back, "yes!"

**Relevant reading:**

- http://www.space.com/17336-tatooine-alien-planets-two-suns-solar-system.html
- http://www.space.com/17343-tatooine-solar-system-planets-2-suns-gallery.html
- http://www.space.com/17348-tatooine-alien-planets-two-suns-kepler-74-infographic.html
- http://www.space.com/17347-tatooine-like-system-found-two-planets-two-stars-video.html
- http://www.space.com/17376-sharing-the-light-of-two-suns.html
- http://www.space.com/17582-life-survive-strange-alien-planets.html **PK**

**Note** that from time to time, we have had articles in MMM about what lies beyond our solar system, and why not? As we have noted, Genesis may have it only part right. A more accurate statement might be

*Of stardust thou art, and*
*To the Stars thou shalt Return!*

## Blending Commercial Space with NASA Space

Report and opinion piece by Peter Kokh

To most but not all space enthusiasts, the introduction of **NASA's COTS program** (**C**ommercial **O**rbital **T**ransportation **S**ervices) opened the door to an age where Space travel will be available to many, not just to what we have long dubbed, a "high priest class." But there have been many NASA supporters, both in the public at large and in Congress and in the astronaut corp, who look on this "democratization" of space as almost "unAmerican" as absurd as that would be. To them, NASA is "as American as Apple Pie." But as we have often wondered, how can what is essentially a socialized space program be put in the Apple Pie category? These lost souls keep hoping NASA can set the threhhold high enough that no commercial upstart company can gain entry to the sacred sanctuary of space. These objectors worry that commercial companies will cut corners to save money and that there transport vehicles will have higher risks of failure.

http://www.nasa.gov/offices/c3po/home/cots_project.html – http://en.wikipedia.org/wiki/Commercial_Orbital_Transportation_Services

Now NASA, which sees commercial space efforts as an aid to getting more done, in less time, for less money, had come out with a "**Space Taxi Certification**" program. The motivation is clear: the only viable option for the time being is to rely on the Russians for taxi service to the International Space Station. And when you have only one choice, that party can set the prices as high as it wants too. And we all know how much Russia needs income.

http://www.space.com/17599-**nasa-private-space-taxi-certification**.html http://spacenews.com/civil/091312-**nasa-launches-program-certify-space-taxis**.html

The Certification process will have two phases: a **Certification Products Contract** (CPC) to will run for 15 months and be worth up to $10 million will be offered to multiple firms. NASA is already working with Boeing, Space Exploration Technologies Corp. (SpaceX) and Sierra Nevada Corp. But NASA is broadcasting that the agency is willing to look at detailed proposals by other firms. Time is of the essence, however. NASA wants to shorten the period during which access to ISS is provided exclusively by the Soyuz.

"NASA is shifting to fixed-priced, Federal Acquisition Regulation (FAR)-based awards for the CPC effort. The first buy will be for data products related to "an end-to-end Crew Transportation System (CTS) for an ISS design reference mission."

Phase 2 includes "**final development, test and verification activities**, including at least one and possibly more demonstration missions to the space station." The expectation is that only Phase 1 contractors might successfully compete for Phase 2, narrowing the field.

**Only the Beginning**

This plan should go a long way to reassuring the doubters. But to us, it is only a beginning. The real "busting the door to space wide open" will happen when commercial space transportation has commercially built and owned destinations in orbit that need services. Commercial Stations built by Biegelow-Boeing or Bigelow-Space-X, and Excalibur Almaz will be the start. NASA and other national space agencies will lose their monopoly. ISS will either remain in orbit as a "National Lab" or be replaced by commercial-contractor-built-and-owned facilities.

http://en.wikipedia.org/wiki/Bigelow_Commercial_Space_Station
http://arstechnica.com/science/2012/05/spacex-announces-deal-to-shuttle-tourists-to-private-space-stations/
http://en.wikipedia.org/wiki/Excalibur_Almaz

Then, only then, will the door to space be open to whomever can buy (or earn or win) a ticket.

Now there is a danger. It could happen that super-nationalist-patriots succeed in militarizing space to the point where the door is slammed tight, perhaps for good. International rivalry will have pervailed over international collaboration. That's a future I would not want to live to see, and I hope our children will never see. But exageerated nationalism is a phenomenon that has stricken some elements in all populations, including ours. We can't let them win. We would have let Earth fall into the trap we have seen depicted on imaginary alien worlds in Star Trek and other science viction media.

"**Space is not worth opening unless we open it to everyone!"** - and that is not just my dream. It is the dream of the National Space Society, the Moon Society, Space Frontier Founcation, and most other space advocacy organizations. When we read contrary opinions, we need to respond, so that people know that we represent the mainstream, and that militarization of space is not the American way, any more than a NAZI takeover would be.

The first step is to realize that not everyone shares our dream. In general, space organizations tend to be neutral about most political issues and debates lest they offend some of their members This is good policiy. But further "socialization" of space should be resisted. Our organizations must have the guts to call a spade a spade.

This is not a Republican vs Democrat issue, nor a Conservative vs. Liberal issue. It is both an American issue and a human one. That a rejuvenated NASA itself is leading the way, is the most encouraging sign of all. **PK**

## Lunar Toll Roads - Taming the Magnificent Desolation of the "Out-Vac"

By Peter Kokh

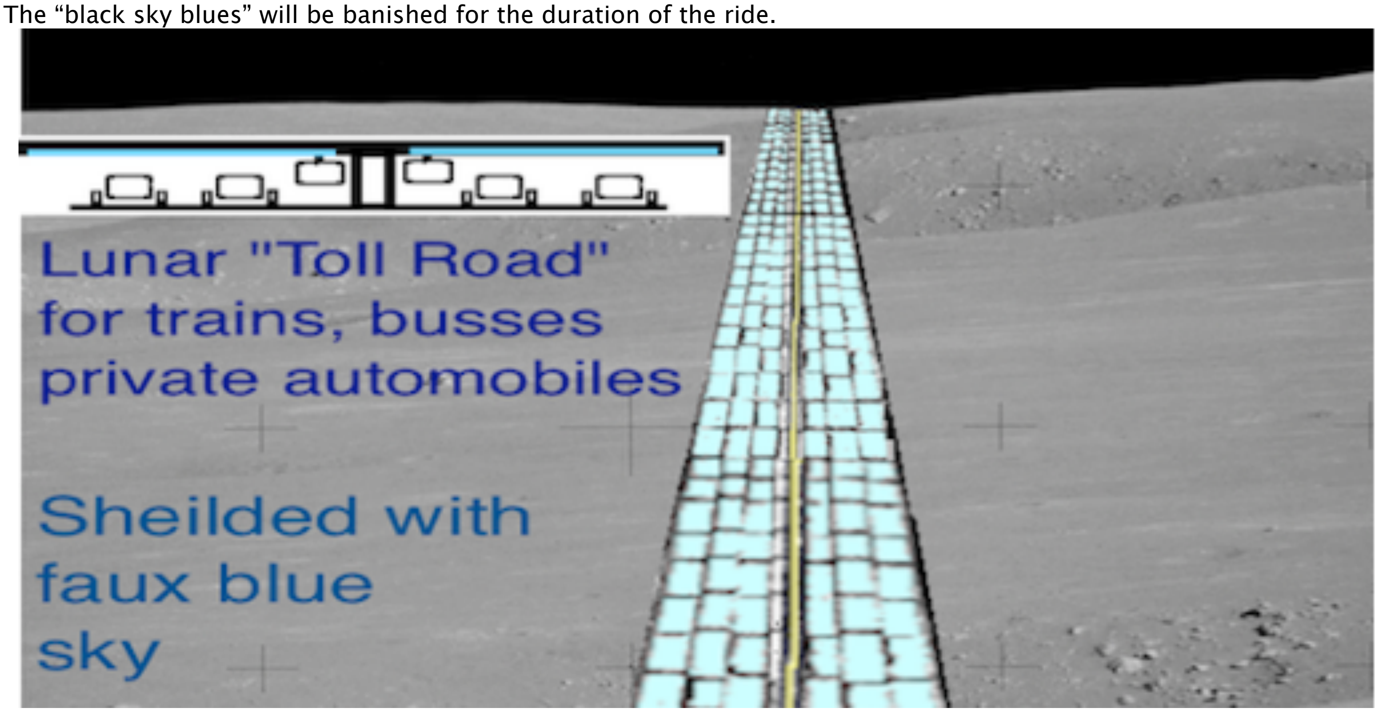
In the pages of MMM, we try to illustrate what is possible and feasible on the Moon, in time. It is important to envision ways in which the Lunar Pioneers will gradually make themselves at home on a dead, dusty, radiation-washed world. Yes, it is also important to illustrate the type of baby steps by which we will establish a "beachhead." But to really motivate ourselves and the actual pioneers who will be inspired to take on the awesome challenges of living on the Moon, we try to show "how we are going to make the Moon a great place to live bit by bit."

Our first roads will be graded and compacted moondust, a row of the removed boulders probably between the two opposite-direction lanes. Early vehicles, without shielding, will be used sparingly by individuals, who may be limited in their allotted time per month out on the exposed surface.

Now fast forward a few decades. We have a thriving frontier world with multiple growing settements large enough to be called cities. If there are two such, in close enough proximity to generate real "traffic", and whose complementary economies support frequent passenger travel and cargo shipments back and forth, why could we not design and build a "toll road" that makes travel, even frequent travel, rather safe.

First envision a canopy, a bit wider than the roadway underneath, supported on pillars down the middle and here and there along the edges. The canopy is covered with 6 foot or 2 meters of moondust. Travelers will still be exposed to some radiation coming in parallel to the surface along the sides, but this will be a small fraction of the amount of radiation they would receive without the canopy.

Now envision the underside of the canopy a bright sky blue, uplit by sulfur lamps in the base of the pillars. The "black sky blues" will be banished for the duration of the ride.




**Toll Road image by Dan Moynahan**, extended at both ends by Peter Kokh - **Toll Road cross-section by Peter Kokh**

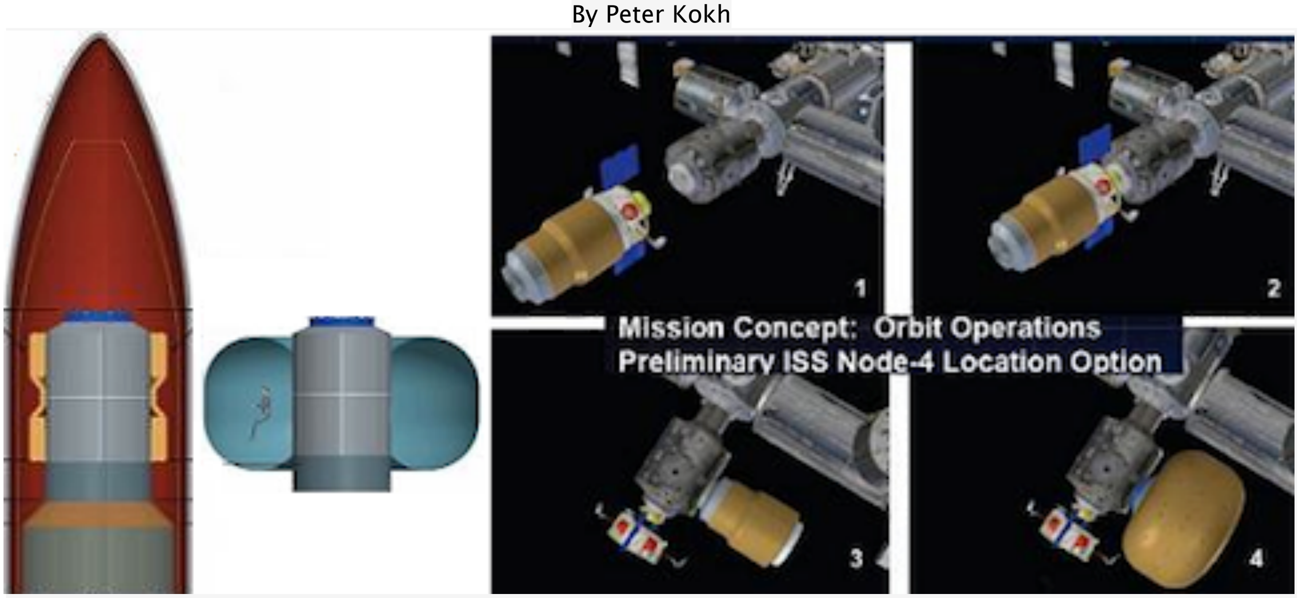
From the canopy towards the center on either side, will be a suspended monorail. Below, two lanes on either side for trucks, motor coaches, and private vehicles. Add even more hospitable "waysides" at junctions.

For high traffic corridors between settlements, here is one way that brings together experiences on old Earth and life on the desolate but magnificent landscapes of The Moon. The advantage over a tunnel is that travellers get to see the moonscapes to each side. Granted, pioneers are not going to see something like this until there are a number of substantial settlements with economies that generate traffic between them. But it will come. The chances of a meteorite causing significant damage are slim, but not zero.

Comments and suggestions always welcome. ###

## Why not attach a Bigelow 330 Inflatable to the International Space Station?

By Peter Kokh




**Left:** the BA 330 uninflated in the delivery stage, and inflated. **Right:** docking and inflation of the module

http://www.nasaspaceflight.com/2011/01/nasa-managers-discuss-prospect-bigelow-inflatable-iss/

The scenario for introducing the BA 330 inflatable unit to space operations, has been as a station all by itself, eventually mated with other BA 330 modules and serviced by Boeing CST-100 or Space-X Dragon crew capsules. But it might make more sense for the first BA 330 to make its debut in space attached to the existing International Space Station. Here are the advantages we see:

- **Easier** - ISS is there and nothing in addition to the BA 330 unit itself is needed
- **Less costly** - Crew already on ISS could perform any tests needed, no immediate need for a separate crew launch
- **Less risky** - in case of failure of any kind, test crew could retreat to the station proper
- **Testing at ISS** could expose further directions for inflatable evolution (wider and/or longer, outfitting options)
- **A pair on a tether** could be used for initial testing of artificial gravity

Once tests were concluded, the unit could make a great addition to the station

- **As a gym** and exercise place
- As a **zero-g** "space dancing" place
- **To test** various types of outfitting
- **As a refuge** for ISS crew in case the station proper was compromised by impact of a large space debris item
- **As a place to "practice"** being on a 6-month long trip to Mars, suggesting new design needs.
- **As a space motel** for visitors to ISS
- **As a conference room**
- **As a media room**

Meanwhile, having passed all tests, additional BA 330 inflatable units could be placed elsewhere in various Earth orbits for commercial use as Space Hotels, research facilities, and other uses.

By signing up as first customer, such a NASA-ISS-Bigelow Aerospace could greatly accelerate the first and subsequent BA 330 deployments.

**Space Development 2.0**

Once again, we see that far from there being a war or rivalry between NASA and Commercial Space firms, they are becomiong natural partners in space development, as new commercial firms are highly motivated to start with a "tabula rasa" - a clean blackboard - in coming up with real innovations rather than just evolved improvements in every aspect of space needs. The more so, because the Commercial firms do not have to wait for the rise of "Commercial

Users." In fact the debut of their products in NASA installation could greatly accelerate the rise of Commerrcial companies who find new non-NASA uses for the new technologies and hardware.

Adding a BA 330 to ISS looks like a proverbial "match made in heaven." In contrast, starting with a separate 3 BA 330 unit station is clearly a more diffiucult goal. See this Boeing-Bigelow video.

http://www.youtube.com/watch?v=Mn_gXEK5XmQ **PK**

MMM #250 - NOV 2012

## To the Stars - or "Back to the Stars?"

By Peter Kokh

Last month, we published issue #16 of the free PDF file newsletter, **Moon Miners' Manifesto India Quarterly** (**M3IQ**) - 4 full years under our belt! At the same time, we published the first issue of **To The Stars International Quarterly** (**TTSIQ**) essentially the same material, rearranged in a different way, and with a tittle that suggests a connection to the National Space Society, on whose behalf we are doing this to reach international space enthusiasts. NSS' long-running hard copy magazine is titled "Ad Astra" which is Latin for "To the Stars." TTSIQ is also cosponsored by the Moon Society, Space Renaissance Initiative, and hopefully by other organizations as well. But we don't want to talk about that right now, rather about those first three words "To The Stars."

**http://www.moonsociety.org/international/ttsiq/** - **http://www.nss.org/ToTheStars/**

Recently, there is new enthusiasm that advanced physics may find ways to cheat the "Speed of Light Barrier" and NASA is supporting an effort to get people thinking about how a "100-year starship" could be built and flown. To reach the closest star system 4.3 light years away, **Alpha Centauri,** a binary with a distant third star, **Proxima Centauri**, in 100 years, we would have to maintain an average speed of 23% of the speed of light averaging acceleration and deceleration, meaning a peak velocity of near half the speed of light.

The honor of being the first (or among the first human{s) to visit another star system will be enormous, but few would go without prior telescopic or robot probe confirmed findings that a human-friendly paradise planet was awaiting our arrival, not some inhospitable planet, too hot or too cold, atmosphere too thin or too thick or unbreathable, no surface water, etc. etc.

Now it is conceivable that we might have learned all this from not yet deployed advanced and highly sophisticated exo-planet hunting space telescopes. Sending probes to a all exo-planet systems in "near" stellar space would be both expensive and generation-consuming, however desirable confirmation and elaboration of telescope findings might be. We will simply have to build more powerful, more capable space telescopes equipped to detect signatures of key atmospheric ingredients such as oxygen, nitrogen, methane, and water vapor.

The ability to determine if a world was of the terrestrial "land-sea" type should be the gold standard of telescopic ability. Why would anyone want to sacrifice decades of one's life traveling through empty space just to find another Venus, or even another Mars? The goal of such a venture should be nothing less than exploring what has been pre-determined to be "another Earth!"

Say that our super-scope found such a candidate. We should be able from its Sun's spectrum to tell the age of the system. Is the host star old enough that its "other Earth" had time to nurture life to the metazoan stage - multi-cellular plants and animals? Our world developed multi-cellular life only in the past 600 million years, that is, in the last 15% of its lifespan to date! Is that host star considerably younger or older than ours?

If the host sun was old enough, but not too old ... But how can we tell that with only one sample to test, that of our own home planet?

Without a prior visit by a fleet of very capable probes, with all the time delays (very long flight, long report back time, analysis time) sending humans would be a very big gamble. It would seem that despite all the hooplah over the 100-year Starship Project, that a fist human venture to a "nearby" star system is quite a bit into the future. Now to be honest, this writer is extremely skeptical that physicists will find a human-survivable way to make an end-run around the speed of light barrier.

There seems to be considerable new optimism that we will find new secret pathways not apparent to us now because our knowledge of physics and cosmology is considerably less complete than we had thought. At the same time, there is recognition that it will be one thing to get a ship to go that fast, quite another to be able to support human life over a number of generations for the duration of the ship.

An alternative, which we put forth many year ago, was to send fertilized human eggs and sperm in suspension, and only "when and if" we were approaching a planet that instruments aboard determined was capable of supporting human life, and not already inhabited by sentient beings, robots would combine sperm and eggs and put them in artificial wombs, and when ready for "birth." Nanny robots would nourish, and raise, and educate. Sort of like the sowing the seed everywhere, and somewhere it takes root and grows, other places not. No humans beings would make the trip, or be brought to term unless circumstances at a distant target star warranted. This avoids all the problems of “Generation Ships” and bypasses most of the problems facing human crews heading out into space without adequate knowledge of where they are heading. It also makes the speed of light irrelevant.

But the point is that we now know that amino acids, the building blocks of life as we know it, pervade the star clouds, and probably the universe. Exploding super suns are the incubators of these building blocks. Life is natural to the universe. Life on Earth may have been sown by the death-struggle output of many suns now gone.

In that light, it would be fitting to replace “To the Stars” with “Back to the Stars!” It would be a pilgrimage! The culmination of the epic of our species and of any intelligent species. But will we really embark on such a quest? Some species will, many will not. Of those that do, not all will succeed. But the universe is so large in both space and time, that we do not doubt that some, maybe many species will succeed.

Nonetheless, the age old dream of exploring, even settling far-flung star systems will not die. It will be there to urge us on, not to the stars, but back to the stars. Our sun is probably just one of a hundred or more that formed in a cluster, like the well-known Pleiades. But after 4.6 billion years, the Sun’s crib-mate stars have long wandered off to considerable distances, very slowly drifting. The Greek name for our sun is Helios, after which Helium is named (this element was first detected in the Sun), so we have suggested the name Heliades for our birth cluster. One strong motive for an effort to seek out and identify and study the Sun’s cribmates is that they are of the same age, and thus their planetary systems have had the same amount of time to evolve and mature. But just as in the Pleiades, our Sun’s siblings will come in many sizes with differing spectra. We’ll want to look at G type stars especially, though some low-F type stars with diminished lifetimes may be worth studying. Read the article “Circling some Yellow-White “F” Spectrum Stars may be a Scattering of “Welcome Matt” Worlds” from MMM # 45, reprinted in the newly published MMM Starbound Theme issue:

http://www.moonsociety.org/publications/mmm_themes/**mmmt_starbound.pdf**

You will find many other interesting and relevant articles in this issue.

in our “Out of Africa” epic, we humans have become thoroughly “Intercontinental.” Becoming “Interplanetary” is the next chapter, but we have yet to establish a permanent presence on the “threshold“ between the two, that is, on the Moon which is on the border between Earth-space and Interplanetary-space. But we will get there.

By the time our foothold on the Moon has gotten to the “no turning back now” stage, the next generations of Exoplanet hunters will have found some very, very interesting nearby solar systems. Such findings will feed the imagination of young people and interest in interstellar exploration will grow.

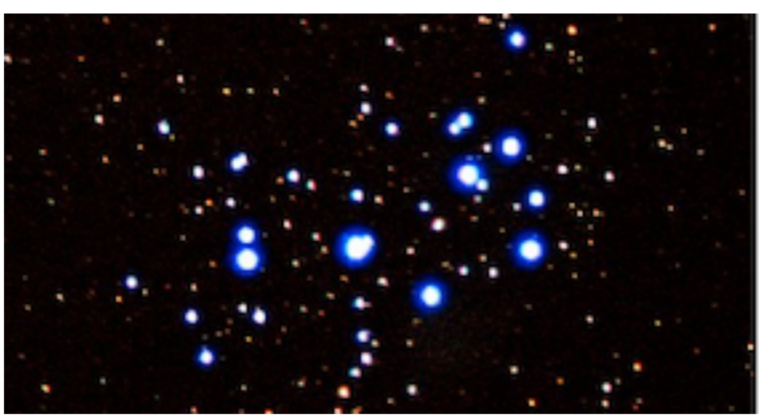
In the meantime, we should know if there are any human-survivable end-runs around the speed of light barrier. If not, maybe that is good, as it may have thwarted visits from any more advanced, colonizing (in the bad sense of the term) nearby intelligent species. (Personally, we believe the universe is swarming with other civilizations but that the average distance in both space and time is so great that encounters are most unlikely, and that is good, as culture-shock could destroy one or both.

Among humans, it is quite clear that the majority in any society is quite content with a slowly advancing status quo. Few ever consider the long term epic path of our species. Thus to rely on political support will get us no where, unless the plan is misguidedly linked with short term military strife within our own population. Our civilization may stall in a static inwards downspiral. But somehow, somewhere, some of us will settle for nothing else but seeking out our cosmic destiny, even if it takes many generations, many centuries, many millennia.

Perhaps just the confirmation that we are almost certainly not alone, even if no contact has been made, will be enough for us to understand our own existence in perspective, and to encourage healthy cultural and spiritual growth. Read the article “Skyfields” in that same Starbound theme issue (address above)

We have humbly suggested that the biblical statement “of dust thou art and to dust thou shalt return” be paraphrased “of stardust thou art, and to the Stars thous shalt return.” Well, we may never get there, but more likely we will indeed venture beyond our local vicinity. It is not “getting there” that will transform us, but just the effort to do so will make its mark on human culture and civilization in coming centuries.

“Isn’t life wonderful?!” - Back to the Stars! It is who we are. It is a hidden human instinct. Keep the dream alive! **Below:** The Pleiades star cluster only 150 million years old. **PK**



**Links:**

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

http://www.astro.wisc.edu/~dolan/constellations/extra/nearest.html (26 closest stars)
http://www.atlasoftheuniverse.com/12lys.html (3 dimensional map of our stellar neighborhood)
http://100yss.org/ – http://en.wikipedia.org/wiki/100_Year_Starship
http://www.space.com/13135-100-year-starship-symposium-darpa-nasa.html
http://cosmiclog.nbcnews.com/_news/2011/11/02/8603075-reality-check-for-starships?lite
http://online.wsj.com/article/SB10000872396390444868204578066863905510662.html
http://www.tgdaily.com/space-features/66998-esa-steps-up-search-for-earth-like-planets

## Why finding an Earth-size planet around Alpha Centauri B is sobering news

By Peter Kokh

**The good news:** Alpha Centauri B, the smaller of pair has a planet slightly bigger than Earth.

**The bad news:** This planet orbits its sun **at about a tenth Mercury's distance from our a sun,** so close that **sun-facing surface must be permanently molten**.

We ask why so close? The likeliest reason lies in a "detail" that I had previously ignored. First let's look at the basic "plan" of this system.

Alpha Centauri is really two stars, "A" and "B," not just one. The two circle one another around a common center of mass or barycenter making this a "binary system."

In an article I wrote about Alpha Centauri 21 years ago, I gave the two stars proper names. Why shouldn't the two major stars closest to Earth be given names?

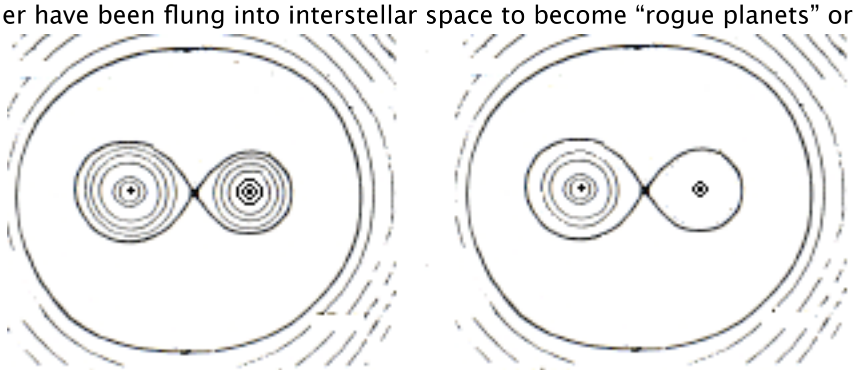
1. Alpha A is **slightly** more massive and brighter than the Sun, and Alpha B, a bit less massive and less bright. If there is even 'some' possibility that either or both have planets, shouldn't these two solar neighbors have names of their own? For the purposes of the discussion that follows, let us call them **Ixion** and **Nephthele** respectively, "**King and Queen of the Centaurs**."
2. In the case of this double star, "during the pair's 79.91-year orbit about a common center, the distance between them varies from about that between Pluto (40 times Earth's distance) and the Sun to that between Saturn (9 x Earth's distance) and the Sun." [http://en.wikipedia.org/wiki/Alpha_Centauri]

For some time, the common expectation was that orbital dynamics did not allow stable planetary orbits within a binary system. But there are a range of possible binary orbits, and such a generalization is not worth its repeating. First, binary stars cab orbit one another very close or at great distances, and anywhere in between. Second, their orbits about a common center of gravity an be anywhere from fairly circular to very eccentric.

Now there are two parts to this situation. On the one hand, it would seem that "inner rocky planets" – such as our Mercury, Venus, Earth, and Mars – would have stable orbits around both Alpha Centauri A and Alpha Centauri B. Likewise, it would seem that there could be some "outer" planets – gas giants and "plutoids" – in stable orbits around A-B's common barycenter, as in the diagram above. But there is a sleeper in the data the repercussions of which I had not previously realized. And that is point 2 listed above, the very eccentric (off-center) orbits of both A and B around their common barycenter.

When the more massive A (Ixion) (1.1 times the Sun's mass) vs. B (Nephthele) (0.9 times the Sun's mass) when their mutual distance is at minimum (9.5 A.U. vs. 40 A.U.) must exert tidal pull on any of B's planets that will increase the eccentricity of those planets orbits, until their maximum distance from B intersects or transcends the current distance of the barycenter between the two stars, and one by one are either flung out into interstellar space, or captured by A (see the bold figure 8 orbit in the graphic above.)

These same tidal forces my force planets fairly close to B to circle ever closer. All the rest of B's original retinue will either have been flung into interstellar space to become "rogue planets" or captured by A.



**Left: Original Planets** **Right: most of B's planets ejected, outer planet of A also ejected**

Could an Earthlike planet in orbit around A stay put? While B's tidal power is less than A's, it is likely to have distorted the positioning of A's original retinue of planets as well, or at least left them in orbits of ever shifting eccentricity and distance from A. This is what I suspect, but I claim no expertise in orbital mechanics.

The upshot would seem to suggest that we would do well to cross binary systems off our list of potential future homes for mankind except for those who circle each other at a much greater distance. Note that Alpha Centauri A and B are also 6.1 billion years old, vs. 4.6 for the Sun. An interesting system, but the "good news that Alpha Centauri B has an Earth size planet" turns out to be "discouraging news" instead.

Hey, we are adults. We can take it. Let's move on! **PK**

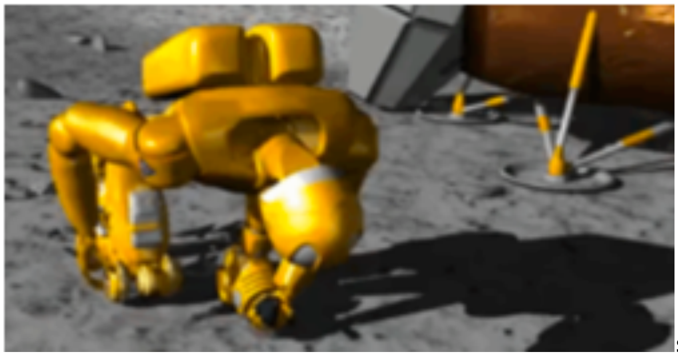
**http://aether.lbl.gov/www/classes/p139/speed/Alpha-Centauri.html**

## Telepresence Tours of the Moon? How Soon?

By Peter Kokh

**Scenario:** It is July 20, 2019, the 50th Anniversary of the Apollo 11 Moon Landing by Armstrong and Aldrin, and NASA is celebrating big style. At all eight NASA centers around the country, new Moon Telepresence Centers will open up. At each center, you can make reservations for use of a Moon Telepresence Booth, by the quarter hour.

Inside the booth, you are helped to get into a telepresence outfit which includes moon-visors, special moon gloves, and and moon-shoes. On the Moon, at the Apollo 11 site or a number of other interesting sites, "avatars" will walk, bend over and pick up rocks, and look at them, or just scan the horizon, as you wish. You will have all the sensations of being there yourself, except that you will still have your Earth-weight (Oh shucks!)



**How soon?**

Telepresence equipment is advancing by leaps and bounds, and the six and a half year window may just be enough. Now NASA and a number of commercial firms specializing in robotics are not pushing this technology for you the visitor, but for the sake of science and exploration. For most of the involved parties, the incentive is not public use. But for some, it may be. Indeed some of the breakthroughs needed may be motivated by potential profits from such tele-tourism markets. That's the process of "spin-up" that we had described way back in 1989. Read:

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

This development path is just the opposite of "spin-off." Instead of NASA embarking on a crash research program at exorbitant cost and then turning over the resultant technology at no cost to commercial enterprises with the taxpayer footing the bill, in "spin-up," a private enterprise, seeking profits, develops the technology, with the consumer paying the bill. As a result, when the technology is needed on the space frontier, it is already "on-the-shelf" and in need of relatively inexpensive adaptation only.

In a recent article in Space Review(online), there just such a possibility is discussed:

"Is there a way for humans to be on a surface of another planet without actually physically being there? Dan Lester argues that, thanks to the increasing capabilities of robotics and related technologies, telepresence can be the next best thing to actually being there, at considerably less cost and risk."

**http://www.thespacereview.com/article/2150/1**

**So what?** For billions of people who cannot afford a multimillion dollar "loop the Moon" tour, this will be a much less expensive opportunity, not to skim over the Moon's surface at an altitude of 5-100 miles, but to have all the experience and sensation (less the lighter gravity) of walking on the Moon, picking up and feeling a moon rock, and doing a little exploring. Each option will offer different "unforgettable" experiences. This is important because as more and more people take such a telepresence Moon tour, and tell their friends about it, the more public interest in supporting permanent outposts, then tourist centers, on the Moon itself will grow.

The catch is less in developing the "avatars" through which you will see and feel yourself on the Moon, than in sending enough avatars to the Moon to meet telepresence demand, and in their maintenance. The first such experiences will be expensive. But the cost will come down as demand increases.

**What about Mars?** The reaction time delay for command and response in telepresence on the Moon is of the order of three seconds, the time it takes for command signals to get to the Moon, and perceived command execution at the speed of light. For Mars, the delay will be from a 6 to as much as 40 minutes - it is just not practical.

When will lunar telepresence tours come to a NASA Visitors Center near me? The timeline suggested above seems realistic, especially if commercial firms take the lead in the "spin-up" process described. If it is left up to NASA, it becomes a budget item, which we all know will always be at high-risk for cancellation at any stage of the process. In the meantime, do watch this video: **http://www.youtube.com/watch?v=kFPNcWN7QnM** **MMM**

# A low-cost Europa Life Relics Explorer Mission may be Feasible

http://www.space.com/18217-planetfall-solar-system-photography-interview.html

**Comment by "Planetfall' Author Michael Benson**

**Which future planetary science mission would you most like to see become reality?**

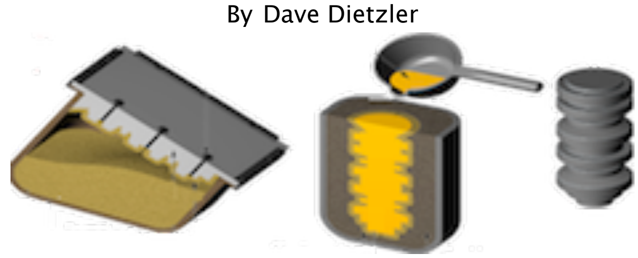
"A: Now there's a nice segue, because I've been advocating that NASA focus its robotic efforts on Europa for years now. But although a mission to Europa would be roughly comparable in cost and complexity to the new Curiosity rover on Mars, or the Cassini mission to Saturn, unfortunately the assumption has taken hold that discovering whether there is life in the Europan ocean requires not only landing on its surface, but also developing the technologies that could permit the spacecraft to lower an automated submarine capable of melting through what by all accounts is an ice crust that's many miles thick. Needless to say, that's a very fraught proposition, very complex technologically, and far more expensive than Curiosity or Cassini.

"But you know what? That's also totally erroneous. Europa's surface has plenty of faults that, as Galileo Orbiter images from the 1990s reveal, provide plenty of evidence that **water from the ocean below has welled up, and been deposited neatly on either side of the fault before freezing**. Rick Greenberg of the Lunar and Planetary Lab at the University of Arizona has pointed out that all we really need is a lander that can set down at the edge of one of those cracks, directly on top of an area that seems to be comprised of extruded and frozen sub-surface ocean water, and then c**ollect samples from only a few meters below the surface.**"

**More on Europa:** Over the years, MMM has featured a number of articles about this fascinating moon of Jupiter.]
You can read them in our recently published Solar System Theme Issue at:
http://www.moonsociety.org/publications/mmm_themes/**mmmt_solarystem.pdf** **MMM**

# Casting the "Engineering Metals" on the Moon: Steel, Aluminum, Magnesium, Titanium

By Dave Dietzler



**Steel** can be cast in sand molds because it melts at 1200 to 1500 C and silica (sand) melts at 1700 C. Since solid molds would tend to crack we use sand molds. We do have steel alloying ingredients like chromium, manganese, nickel and cobalt from meteoric  fines even abundant silicon...so we can make lots of grades of steel...

Steel is so important that without the carbon from lunar polar ices, we would need to import it and that would be costly. Carbonaceous chondrite asteroids would be the obvious source. It was long believed that Mars' two moonlets Phobos and Deimos were captured asteroids of that composition, but that expectation is now challenged. The cheapest way to ship carbon might be as liquid methane, CH4, as we could always use the extra Hydrogen also.

(We would need to co-import liquid ammonia, NH3, as well, for of all the key volatiles hydrogen, carbon, and nitrogen, the latter is by far the most scarce on the Moon in proportion to the amount we will need, simply as an atmosphere buffer gas. In other words how many people we can support on the Moon depends on how easily and inexpensively, we can import enough Nitrogen for the "air" we will need.)

**Aluminum** and **Magnesium** can be cast  in basaltic molds as they melt at 1250 which is high enough. As the Moon lacks an oxygen-rich atmosphere, magnesium products used outside (in the out-vac) will work well.

**Titanium** will be more difficult to cast. It melts at 1900 C, depending on the alloy...so silica and basalt will melt. We will need yttrium and zirconium oxide sand molds and some kinda binder. .....also Ti is melted with electron beams and cast in a vacuum...at least the vacuum is free....Yt and Zr exist on the Moon but only in like 100 and 300 ppm so they'd have to be imported to cast Ti....also, we lack Ti alloying ingredients like vanadium, tin, etc.

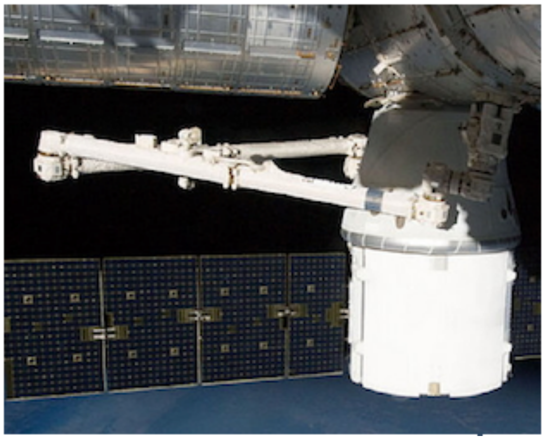
Titanium powder could be used in 3D electron beam printers in the free vacuum to make elaborate intricate parts...Dave Heck (Boeing St. Louis) has done that for a living....instead of casting....but for real big parts we need to cast... **DDz**

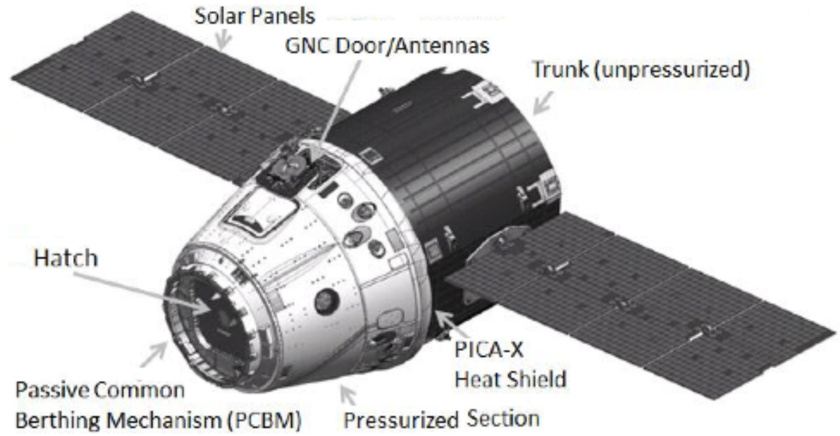
# NASA/Contractor Throwaway Culture vs. Space-X' Reusability

By Peter Kokh

Launch Date Oct 7; arrival date; departure date, safe landing Oct 28th

Space-X first returnable cargo vessel to serve ISS (other than the exorbitantly expensive Shuttle)






Having demonstrated in May that it could deliver the Dragon Cargo vessel to ISS safely, with token cargo, and then return back to Earth with an ocean landing, intact and ready for another assignment, this was the first of 12 such missions that Space-X will do according to its contract with NASA.

Now both JAXA's HTV (http://en.wikipedia.org/wiki/H-II_Transfer_Vehicle) and ESA's ATV (http://en.wikipedia.org/wiki/Automated_Transfer_Vehicle) can deliver cargo to the Station, but are not designed to return to Earth in one piece to be reused for another mission. All that money thrown down the toilet!

Meanwhile, with the shuttles retired, the only way NASA could return experiments and other items to Earth has been to sneak them in on a Soyuz capsule, with severe limits on size and mass.

Sierra Nevada's Dream Chaser, a mini-shuttle in design, will also be able to return cargo and experiment materials back to Earth.

The "Throwaway Culture" otherwise known as the "path of least ~~resistance~~ effort" has been with rocket science from the gitgo. The original space shuttle plans called for a fly-back booster, but these were scrapped for expediency, and to keep start-up costs low, even if it meant greatly increasing overall program costs. So we got the reusable SRBs, and an External Tank that could have been parked in a high safe orbit for potential reuse, but which was always dumped back into the atmosphere to burn up.

In previous articles, we have called for a radicle culture change in which only fuel is used but once: "If it isn't fuel, it's payload." Well **the Peenemunde Culture which respects only the nose cone payload**, still rules NASA and most of its contractors (Boeing's Dallas Bienhoff is pushing orbital refueling stations.)

In this climate, only the upstart commercial companies, who need to make it better, faster, cheaper in order to compete, can finally purge us of this culture which, rather than opening space, is guaranteeing that we remain planet-bound forever.

### Where does the space-enthusiast community come in?

The NSS Policy Committee would let NASA continue to do its thing. Well, they are right in believing that it is hopeless to try to change NASA Culture. But there is another pathway. We bypass NASA, and try to convince Congress that there is a better, cheaper way to do more in space with less money. **We ask Congress to mandate that NASA open all mission design and build contracts to commercial companies.**

Face it. Money for Space is not ever again going to be as free-flowing as it once was. We have a global economy in crisis (and trying to fix the national economy while ignoring the global situation is stupid) so Congress will be very open to the idea of doing more with less money. And only upstart companies like Space-X are up to the challenge. To be sure, once that becomes clear, you are going to see Boeing and Lockheed-Martin and other traditional space contractors take a hard second look at their internal "culture."

So it has to start with Congress. We space organization representatives need to sing this song in unison. Our opposition is members of Congress who represent entrenched contractors. But these congress critters are significantly outnumbered by those who have no such allegiance.

**We need to get the press on our side firs**t. As future commercial missions prove out, this message will get out. We can grease the skids for those who won't change. **PK**