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

Moon Miners' Manifesto

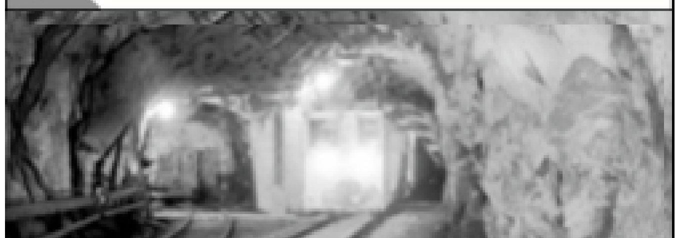
& The Moon Society Journal www.MoonMinersManifesto.com

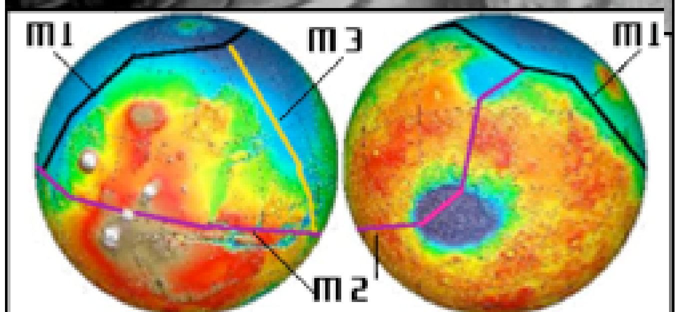
MMM Classics Year 24: MMMs 231-240 DEC 2009 - NOV 2010

Illustrations Key:

Six of the more interesting articles in this publication year (six illustrations at right) were:

- **Lunar Industrial Seed 3b-**
- **Alternative sites for Analog Research (abandoned dry mine galleries, quarries, hangars**
- **Eartly road network on Mars**
- **Apollo 13 Essays: "Human Exploration is worth the risk"**
- **The importance of hallways on outposts and settlements**
- **Getting past the Macims of Peenemunde**





Other Articles of note include:

- A Page from the Luna City Yellow Pages
- Basalt Fibers industry
- Lunar Base Preconstruction
- L1 Gateway to the Moon
- Platinum MOON (Book Review)
- Peter's Shielding Blog
- Pendeulum of views on ancient Mars
- Mars Analog Stations
- "Thermal Wadis" on the Moon
- Expanding on the Google Lunar X-prize technology opportunities
- Basalt as the linchpin of lunar industry
- More than one settlement - role of trade
- Research and Development for the International Lunar Research Park
- Is Bigelow tackling only half the challenge of TransHab?
- Kalam , NSS, and Space Solar Power challenge
- "in this Decade" win the race, lose the war
- Fresh look at the Spacesuit Concept
- Lunar Cold Traps key to outer solar system
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- Calcium Reduction for processing moonduat
- Mining Asteroids *on* the Moon
- An Asteroid Mission that makes sense
- An Avatar Moonbase?
- Lavatubes: from skylights to Settlements
- Sweet Spot in farside's Mare Ingenii
- Lunarcrete: a concept from two decades ago

Read and enjoy!

Zubrin: "Earth is to Moon and Mars *as* Europe is to Greenland and North America"

So says Mars Society founder Robert Zubrin in a recent release. Let's get real! *Earth is to Moon and Mars as Europe is to Iceland and Antarctica.* This comparison is truer both in distance and logistics costs, and in terms of economic viability. North America is every bit as fertile and livable as Europe. That certainly is not the case of Mars in comparison with Earth.

We agree 100% that Mars is destined to be the second most populous human world. But that will take some time. Meanwhile, there is an economic case for opening the Moon: first, lunar tourism, while expensive at first, is eminently doable. But who, no matter how rich, is going to spend three years of his/her life, a year of more just in transit to and from Mars, and then a year plus on Mars before being able to come back home?

More to the point, there is a real and significant market for lunar products: Anything that can be made on the Moon can be delivered to Low Earth Orbit and to Geosynchronous Earth Obit (LEO & GEO) at a significant transportation cost advantage over competitive products made on Earth and shipped up the steep gravity well; That means building products with which to make space stations, space industrial parks, orbital tourist complexes - all in LEO, as well as giant satellite-hosting platforms in GEO (only 180 available slots 2° apart), energy relay stations and solar power satellites. All of these things will be needed to further build out our terrestrial economy without further damage to the environment.

What is the economic case for Mars? Zubrin had reached into tenuous fantasy to come up with "pharmaceuticals made from soils on Mars that can't be made on Earth. We have been after him for two decades to work on *the Economic Case for Mars.* So far there has been only one realistic suggestion, and it is ours, and something RZ opposes or ignores: mining Phobos and Deimos for volatiles (should the postponed Phobos-Grunt probe confirm that one or both are of carbonaceous chondrite composition) and then shipping them in the form of liquid ammonia (NH_3) and liquid methane (CH_4) to volatile-thirsty markets on the Moon.

It does not matter that Mars has a much more complete set of resources on which to base a self-sufficient second human world. What matters is that no one, no set of companies, no set of governments, is going to pour that kind of investment into Mars, *with no hope of return, no hope of Martian exports to defray the cost of a world-making flood of capital goods imports!*

A point needs to be made. No how much wetter and warmer Mars once was in its past, it is now stuck in the same thermal range as Antarctica, a place with fresh breathable air, and surrounding sees full of seafood. Yet no one is beating down the gates of the Antarctic Treaty to earn the right to settle even the friendlier fringes of the western coast of the Antarctic Peninsula. The terrain may be similar, but the temperatures are not. Below: what Mars looks like (top), and what it feels like (bottom).
http://www.moonsociety.org/images/vallesmarineris.gif

Once this fact is driven home, the pool of willing Mars settlers will dry up, …. except for one source: hardy Lunans who will see Mars as a "walk in the park." **PK**

Industrialization of the Moon

Defining the Lunar Industrial Seed:

By Dave Dietzler pioneer137@yahoo.com

Part 3B: Manufacturing

The "cle" part of the Industrial Development MUS/cle Strategy*

http://www.lunar-reclamation.org/papers/muscle_paper.htm

Complex, **l**ightweight and **e**lectronic (or expensive) small to medium sized items will be upported in the early stages and mass produced when the base grows and the masses of parts demanded exceeds the mass of the machines and manpower needed to produce them. Manpower involves not just the mass of the worker, but also the mass of the habitat and life support needed to support the worker. These items will include computers and telephones for a long time because it costs billions of dollars to build a chip factory, but there might be a miracle like nanofabrication with low mass nanoassemblers that changes this picture. Parts that will be Moon made after the MUS manufacturing stage is in full swing include hinges, nuts and bolts, pumps, switches robot parts and much more.

3D Additive Manufacturing

This method of automated manufacturing includes stereolithography, selective laser sintering and direct metal laser sintering. These machines build up material layer by layer. Guided by CAD data in computers they can make almost any small to medium sized part and not just simple ones but very complex detailed parts too. Accuracy is within thousandths of a millimeter, so precision parts can be made. Parts can be made of plastic, metal, glass or ceramic.

Stereolithography makes plastic parts up to 20" by 20" by 24." These parts could then be pressed into plaster to make molds for aluminum and magnesium casting; or they could be used to make impressions in sand molds for casting metals with higher melting points like iron or titanium. They biggest drawback to stereolithography is the cost of the photo-curable resin that costs \$300 to \$800 per gallon [1]. On the Moon, some way of recycling the resin would be needed so that we could make plastic parts for molds, convert the plastic back to photo-curable resin and make more molds.

Direct metal laser sintering can make parts from powdered metals. Parts can be made within dimensions of 250 x 250 x 215mm (9.84" x 9.84" x 8.46") [2]. The machine can run on its own 24 hours a day and make many parts faster than by conventional casting and machining. It is also possible to sinter metals with a device that uses an electron beam instead of a laser. This must be done in a vacuum and the Moon offers free vacuum. Since radiation can be emitted by e-beam sintering, piles of regolith for shielding will surround such machines during operation.

What kinds of parts will we make with Direct Laser (or E-Beam) Metal Sintering? I see casings and rotors for centrifugal pumps and pistons, rods, cylinders and crankshafts for reciprocating pumps. We will need pumps to move liquid gases, water and sewage. Electric motor armatures, bearing races and roller bearings, refrigerator compressor parts and high pressure gas compressor parts, perhaps parts for power tools also could be made. In the early years these could be upported. In time we will need very large numbers of these things. Everyone will want a small refrigerator in their cabin and some people with multi-room apartments will want full sized refrigerators. We will need lots of power tools and the plumbing systems will use lots of pumps. Compressors will be needed to drive oxygen gas through space radiators and pumps will be needed to move LOX into and out of storage tanks. Compressors will also be needed to drive hydrogen into hydrides or carbon nanotubes and to fill oxygen gas tanks in spacesuit life support backpacks.

While 3D sintering looks like the key to almost magical "Santa Claus machines" it might also prove that casting steel, aluminum, titanium, iron and magnesium parts is cheaper and quicker than using 3D sintering exclusively. Laser machining devices guided by computers would make the final cuts on the cast parts and drill holes in them. Robot arms and human workers would then assemble the parts.

Chemical Vapor Deposition

All sorts of items can be made by depositing carbonyl iron vapors on mandrels, heated to a few hundred degrees Celsius. The carbonyls would be formed by reacting iron fines with hot high pressure carbon monoxide gas made from Moon mined carbon and lunar oxygen. The work would be done in inert gas filled inflatable chambers so that when the carbonyls decompose and leave a steel coating on the hot mandrels the CO or CO2 that is released, can be captured by air scrubbers to recycle the precious carbon. Galactic Mining Industries Inc. has done lots of work on this technology. See: http://www.space-mining.com

The process of depositing carbonyl vapors on mandrels to make things is called chemical vapor deposition or CVD. Usually, this process is good for making objects that are only about 1/16 to 1/8 of an inch thick. A tank this thick could hold water, but not high pressure gases. High-pressure tanks, valves and piping will have to be made with more conventional processes. __Iron fines that are 5% nickel and 0.2% cobalt when subjected to hot high pressure CO gas form carbonyls that can be vaporized and distilled to separate them at moderate temperatures. Nickel can be used as a catalyst and to strengthen iron and steel. Cobalt can be used for tough cobalt steel drill bits and we might be doing some extreme drilling jobs on the Moon. It can also be used to stain glass. Just ten pounds of cobalt can stain a ton of glass deep blue. This would add color to the drab Moon where psychological survival is as important as physical survival.

Spinning Metals

Steel, iron, aluminum, almost any ductile metal, can be spun. A metal disk is placed on a rotating lathe and formed against a mandrel into a lamp vase, bell, pot, pan, wok, musical drum, even CO2 cartridges and high pressure gas tanks. HP gas tanks will be needed for spacesuits, life support systems, and welding gas tanks. CO2 cartridges might be used for dart guns used by security guards to subdue troublesome characters.. A metal spinning lathe and upported or Moon made mandrels will be useful on the Moon. See: http://en.wikipedia.org/wiki/Metal_spinning and http://www.terrytynan.com/metalspinning.html

Blacksmithing

This ancient art might find use on the Moon. Lunan blacksmiths with electric forges and power hammers could make all sorts of things including tools, hinges, pins, bolts and ornate metal work from iron and steel. We won't be able to do much without steel tools and ornate iron work will help with psychological survival. Iron could also be used for nuts and bolts and just about everything else today made of mild steel on Earth. Lunar iron will be rather pure like wrought iron and have similar properties (about 40,000 psi tensile) as opposed to cast iron that has more carbon in it than steel. Cast iron has about 3.5% carbon and steel is about 0.2% to 1.5% carbon. Iron from molten silicate electrolysis should be rather pure while iron from meteoric fines will contain some nickel and cobalt that makes it stronger.

Nuts and Bolts

Eventually we will need tons and tons of nuts and bolts for all the machines and vehicles that we assemble on the Moon. Bolts can be made by rolling extruded rods between steel dies. They can be made of aluminum, iron, titanium and rarely steel. While titanium bolts will be almost as strong as steel bolts, iron bolts will not be that strong but they can be made thicker and heavier. This shouldn't be a problem in lower lunar gravity.

Electrical Parts

These will be upported in the early years, but the time will come when we need large numbers of them therefore large masses that will be costly to upport. Electric furnaces will require cables, switches, possibly microwave generators, electrodes and other parts. Cables and wires can be made by extrusion. Switches and other electrical parts might use cast basalt or glass insulating parts produced by casting or 3D sintering. Aluminum will be desirable for conducting components of electrical parts like switches as well as wiring. Titanium might be used for conducting components in some electrical parts too. Although it is not nearly as good a conductor as aluminum it has a much higher melting point and short thick sections of Ti in switches for instance won't offer a lot of resistance.

Glass Working

Silica is glass in its simplest formulation. Sodium and potassium can be added to lower its melting point and make it easier to work with. It could be used to make glass fiber reinforced glass composites, also known as glass-glass composites or GLAX. This material has a low coefficient of thermal expansion and has high tensile strength. Fibers could be made by extrusion. These fibers could also be used for fiber optic telecommunication cables on the Moon. Translucent GLAX could be used to make hangars for mining and other machines during the intense heat of day. Glass will also have mundane uses like windows, tableware, bottles, and laboratory ware. Glass fibers could even be woven into fabrics. We also need jars and bottles. A bottle blowing machine will be called for eventually.

Glass has other more exotic uses. Tubes filled with CO2 and rods doped with neodyminum from KREEP could be used for lasers. Quartz is basically pure silica and it can be used for high temperature windows in solar furnaces. Glass extraction and mining equipment as well as glass working equipment should be part of the lunar industrial seed.

Sand Mold Casting

Plastic forms could be used to make sand molds for casting iron, if we can make a decent sand mold with regolith. Regolith is like a very fine sand, but it is not like clay used to make sand molds. We must experiment with sieved and sized wetted regolith to see if it can be used to make sand molds. We must also look at the use of sodium silicate, an inorganic adhesive that can be made on the Moon from SiO2 and Na2O that is also used as a sand mold binder. Also, we must consider sintered regolith molds.

Robots and Electric Motors

Beyond materials and various items discussed above, we will need to make more mining and manufacturing robots. This will be very complex. Small titanium parts for robots could be made by 3D sintering. Massive, unitary, and simple parts could be made by casting and laser machining. Complex, lightweight and electronic parts for robots could be upported from Earth.

Robots must be capable of welding as well as assembly. Most welding will be done by simple electric arc welding with steel rod electrodes that won't need shielding in the vacuum. High voltage DC power sources will be needed, so DC from solar panels might be inverted to AC, stepped up in transformers and rectified back to DC with upported solid state devices.

Electric motors will be needed in large numbers and in a variety of sizes to drive pumps and compressors, and to provide motion for robots and vehicles. Titanium, iron and steel parts and aluminum wires will be the primary components of electric motors. This will not be simple and the equipment sent to the Moon to make electric motors will be essential for industrial seed growth. Motor winding machines will be part of this. Power hammers to knock out motor housings from plates of iron or steel will probably be needed too. Small motor parts might be made of 3D sintered titanium. Some silicone or vacuum grease might be upported to lubricate the motors' bearings.

Works Cited Part 3B

1] http://en.wikipedia.org/wiki/Stereolithography
2]http://www.morristech.com/dmls.asw

Part 4: Conclusion

At this point, we can list these things to be produced on the Moon:

Heavy furnaces of bricks and slabs, rolling mills, LOX, iron, steel, storage tanks, piping, pumps, radiators, solar panels and their components of silicon, aluminum, phosphorus and glass, wires, cables, electrical parts like switches, bricks, slabs, roads of bricks and slabs, sulfuric acid, leaching vats, plaster, titanium, molds, cement, water, electric motors, robot parts and robots, vehicles.

The equipment needed to do this includes (some made at least partially on the Moon, some upported):

Molten silicate electrolysis devices, solar panels, wiring/cabling, electrical parts (switches, transformers, solid state invertors and rectifiers), an aluminum rolling mill, extruders (for metal bars, rods, cables and wires and glass fibers); glass working equipment, electric arc welding devices, carbonyl vapor deposition systems, inflatable work chambers, furnaces for making cement, sulfuric acid making systems, electrostatic separators, metal extraction equipment for silicon, Al, Fe, Ti, Mg, furnaces for carburizing iron to steel, brick and slab making systems, electric motor making systems, grinders, 3D sintering systems, laser machining and drilling devices, and robots for mining, assembly and welding.** Also some carbon and hydrogen for metals and water; chloride salts for metal extraction and argon to fill the casting chambers.

That's a start. I have no idea what the mass of this will be. That will depend on how small engineers think the seed can be and how fast and how large it can grow. There are sure to be many things I have not thought of or chosen not to discuss in this article for the sake of brevity.

As the number or mining and manufacturing robots grows, along with oxygen, metal and solar panel production, larger and larger machines will be built to make larger and larger parts for things like human habitat modules, pressurized vehicle cabins, and mass drivers. Also, larger and larger mining robots will be built to mine vast amounts of regolith to supply the solar power satellite builders. The process will probably be slow at first and mistakes will be made and corrected. Fortunately the Moon is only three days away, unlike distant Mars, and it won't take a long time to correct mistakes by rocketing up some extra equipment. There will probably be humans supervising the robots and doing fine tasks by hand that are beyond the abilities of the robots. Humans on the Moon could fix mistakes shortly after they occur. Progress will then accelerate after the learning phase as the lunar industrial seed grows exponentially.

Timeline – I believe that within months of setting up the initial manned and robotic base, production of cement, oxygen and some metals could begin. Aluminum might be produced early not just for solar panels but also for rocket fuel. Powdered aluminum mixed with LOX can make a monopropellant about as powerful as a solid rocket. Magnesium does not require upported chemicals to produce as does aluminum, but it is shock sensitive and will detonate if it's tried for a monopropellant. See: www.space-rockets.com Perhaps a mixture of Mg and LOX can be used as an explosive. Within a few years it should be possible to produce all the major metals in regolith and some minor ones: chromium, manganese.

Within just a few years time it should be possible to make all the low-tech items listed above and many of the more complex items. In ten to fifteen years of rapid growth, the base will have grown into a true lunar settlement with numerous outposts and railways in action. Mass drivers should be working at this time and materials for solar power satellites, space stations, ships to Mars, asteroid deflectors, robotic asteroid mining ships, and whatever else will be available in space at a tiny fraction of the cost that would be paid to launch them up from Earth. ** Mining robots will consist of robots with onboard furnaces for roasting out solar wind implanted volatiles-hydrogen, carbon, nitrogen and helium. There will also be robots with magnetic separators for extracting iron fines of meteoric origin that compose 0.15% to 0.5% of the regolith. Other robots will simply excavate regolith that has been gone over for volatiles and iron fines and load it in devices that extract oxygen, silicon and metals. **DD**

Luna City Yellow Pages

Help Wanted

The Lunar Infrastructure Development Corporation is seeking researchers for these and related positions described below for employment at the **International Lunar Research Park** Must be willing to relocate to the Moon for a period of at least one year barring serious illness or injury.

CONTACT INFORMATION:
Lunar Infrastructure Development Corp.
Human Resources Department Office
PO Box 6666, St. Louis, MO 63101, USA
attn: David Dietzler, Recruitment Officer
US code +314.562.6666 work.moon@lidc.com

BIOLOGISTS AND ECOLOGISTS

Responsibilities include R&D related to CELSS and food production on the Moon. Background in permaculture and organic farming desired.

CIVIL ENGINEERS

Surveying, site improvement. Design, construction and maintenance of the physical natural Lunar environment, including works such as roads, bridges, tunnels, retaining walls, and buildings

CONSTRUCTION WORKERS

Experience in extreme environments such as the Antarctica, offshore drilling, Athabasca Tar Sands, Deep Mining, etc., will be an asset.

ENGINEERING TECHNICIANS

Electrical, electronic, mechanical, manufacturing, chemical, bio-tech, computer and robotics technicians to test, operate, perform routine maintenance, repair, assist in research labs and shops, and do light assembly and manufacturing are needed for groundside and lunar positions.

EXTRACTIVE METALLURGISTS

Responsibilities include R&D related to development of cost effective methods of producing oxygen, metals and other materials on the Moon. Development of chemical processes in addition to production of equipment for such using lunar on-site materials is emphasized. Metallurgists will also develop alloys using only lunar materials including rare earth elements and thorium.

COUPONS for Luna City Pizzeria on Page 3

MACHINISTS & FABRICATORS

Experience in making and/or modifying metal parts. Steel, gas metal, and gas tank arc-welding. Stereolithography and electron beam free-form fabrication (sbf3) experience desirable.

MANUFACTURING HARDWARE AND SOFTWARE ENGINEERS

Numerous openings for the dedicated individual willing to work on teams to develop the multitude of products needed on the Moon for survival and industrial expansion using only on-site materials with the latest 3D printing and computerized manufacturing equipment and robots. Knowledge of traditional manufacturing processes required.

ORGANIC CHEMISTS & CHEMICAL ENGINEERS

Responsibilities include R&D related to production of cost effective methods for synthesizing silicones and other synthetic materials from on-site lunar materials and development of equipment for the same using lunar materials. Lubrication engineering also to be researched.

PRESSURE ENGINEERS

Experience with boilers and other pressure vessels is helpful. Experience helpful in areas of design, manufacture and/or construction and maintenance of pressure seals of airlocks, habitat and other modules designed to hold breathable air pressure against an exterior vacuum

ROBOT TELEOPERATORS

Groundside and lunar positions available for experienced robot teleoperators with at least two years experience operating submarine and underground mining robots.

SKILLED TRADESMEN

Machinists, tool and die makers, welders, plumbers, pipe fitters and electricians willing to work in spacesuits as well as "shirt sleeve" environments on the Moon. We will provide free spacesuit training and hazardous duty pay for work in vacuum.

On the Moon, as on the Earth,
You can rely on your friendly
YELLOW PAGES
For the assistance you need!

Lunar Analog Stations
Without "Moonlike" Terrain

By Peter Kokh

Not every organization that would like to start its own lunar analog research station program, is going to be able to find an ideal "vegetation-free picturesque desert" location, especially one located to minimize the logistics costs of frequent visits and support. In such a case, what are the options?

Situation I: You want to build a lunar analog station but do not have any "logistically convenient" "moonlike" terrain nearby.

Situation 2: You want to do analog research on activities at a Moonbase that would we confined to the outpost complex interiors.

The two situations, of course, are match-mates made in heaven. One suggests the other. In this article we would like to suggest some options.

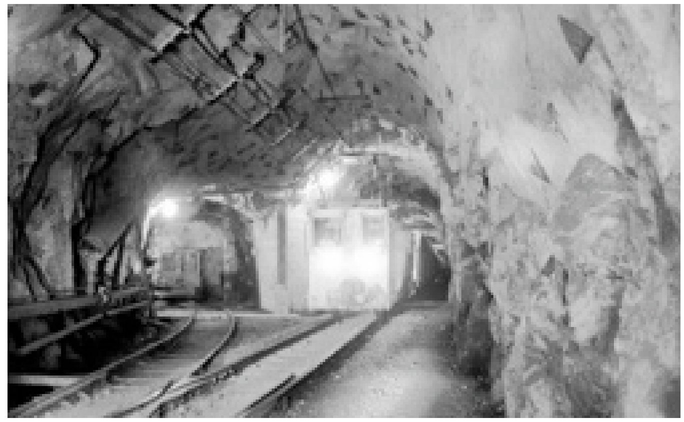
SITUATION 1: you definitely would like to do "outdoor" type activities such as experimenting with bulldozer and rover designs, teleoperations experiments, etc.

Look for an abandoned quarry: *there are many!* The vegetated surroundings may well be out-of-sight from the quarry floor, and the floor may be vegetation free.

This is the active Hollister mine (NV?): imagine replacing the mine buildings and equipment with an analog station!

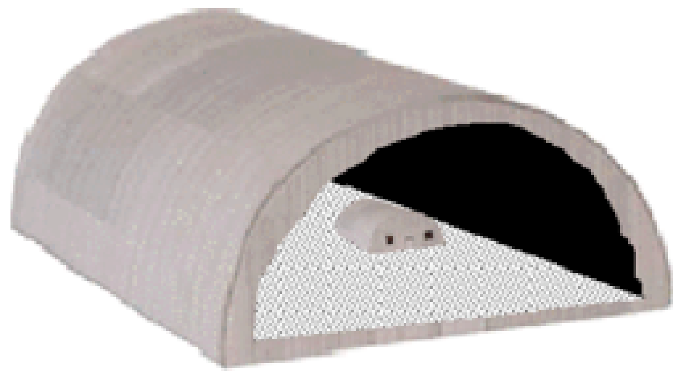
Option 2: an abandoned mine gallery, especially one that lies above the local water table and does not need constant pumping: better yet, one in a low rainfall area.

SITUATION 2: You have in mind experiments with life support systems; experimental agriculture under lunar dayspan/nightspan sunlight availability constrictions; you want to experiment with operations scheduling that tries to reserve energy-intensive chores for the two weeks of abundant lunar sunshine; with energy-light, manpower-intensive chores preferentially put off until the two-week long nightspan period when sunlight is not available.



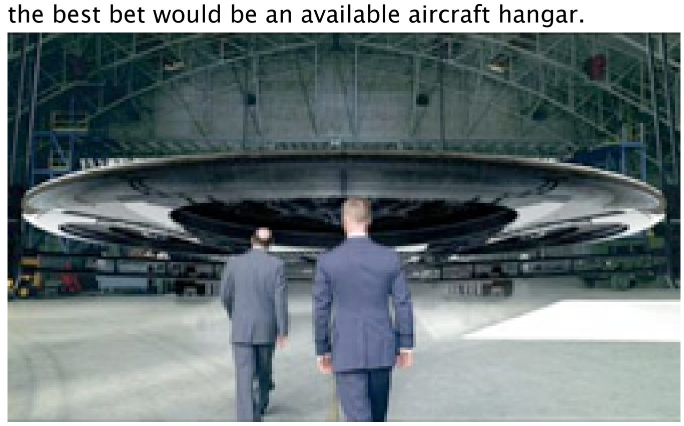
This happens to be a dry, roomy, and spacious copper mine at El Salvador, Chile, near which the proposed Moon/Mars Atacama Research Station may be built. Another essential quality is that the mine gallery must be secure from cave in, roof or sidewall collapses.

Option 3: Build your own ideal environment!



Above: a small habitat module inside a much larger high ceiling warehouse or hangar, in which all interior "sky" surfaces are painted matte black; the floor a simulated moonscape complete with mini-crater. During nightspan, fiber optic "stars" would brighten the sky. In dayspan, a spotlight "sun" with a fresnel lens to broaden its light cone, could brighten the surface. An Earth" globe (ideally of proper size, axial alignment, and face turned toward the "Moon" in proper lighting phase, would be idea.

While a domed or curved space would be ideal, if need be, a spacious pillar-free big box warehouse would do, or an abandoned sports dome of some kind. Perhaps the best bet would be an available aircraft hangar.



This one would be ideal, minus the UFO, of course! A hangar has the advantage of unobstructed clearspan. **PK**

AUGUSTINE RESULTS IN A NUTSHELL

John K. Strickland jkstrick@io.com November 2009

With the obvious proviso that the US government should **not** be building launch vehicles itself, for the next decade at least, the government, for good or ill, will have a large influence on any exploration or activity outside LEO.

The Augustine commission has given us some real direct benefits with its discussions and conclusions, such as stating in plain English the following points, of which I consider these to be the 20 most important ones: (Paraphrased points – all are from items appearing in the original Commission release on September 8, 2009). Here is a link to the summary report for reference:

http://www.nasa.gov/offices/hsf/related_documents/summary_report.html

(1) Human spaceflight program planning should **begin with choices about Goals** *before* picking Destinations. (Here at last is Official Acknowledgement of the importance of first stating fundamental goals.) !!!!

(2) There is a strong consensus in the US that the next manned spaceflight **goal** should be to go **beyond LEO**.

(3) The intent or ultimate **goal** of the human program should be **expansion into the solar system**.

(4) The best human **exploration goal** (with an extended human presence on the surface) is Mars, for a variety of reasons. (NOTE: *This does not address the Moon as a **space** development goal or location*)

(5) Mars is the **ultimate long range destination** for human activities in the solar system, but it is **not** the best initial one.

(6) A **transportation architecture** should be created which is "**flexible**" and can support **multiple objectives**.

(7) (Human) Exploration will benefit from the availability of a **heavy lift booster**. (70 tons to LEO or more).

(8) Switching to a **single launcher** development program from a 2-launcher program is more economical and could speed development.

(9) Crew Transport to LEO should be turned over to the **Commercial Sector**.

(10) **A new competition** to create this crew transport service should be initiated.

(11) **Launch Service Guarantee Contracts** should be considered by the US Government to stimulate investment in and development of advanced launchers and to reduce ground to LEO costs.

(12) **Commercial Transport of propellants to LEO** is important (and the Committee members showed strong interest in **Propellant Depots** as key to future human space operations – you need them for commercial propellant delivery.)

(13) The Human spaceflight program should align with **national objectives**. (This could be an opening for **Space Solar Power** if clean energy is a national objective).

(14) NASA should **resume** its critical role in long-range and critical areas of **technology development**.

(15) **International Partners** should be engaged and integrated into the critical path components for future programs (This includes transport vehicles).

(16) NASA's Administration needs the **authority to manage its own budget** and funding once it has been authorized.

(17) The arbitrary **deadline** of late 2010 for ending the Shuttle program **should be relaxed** in the name of safety.

(18) The planned Human exploration program is **not feasible** with the current budget. (An "Emperor is Naked" notice)

(19) NASA will probably not have an Ares launcher ready **within 7 years.** (Another "Emperor is Naked" notice).

(20) The Space Station should **not be de-orbited** just after it is finished. Such a move would be **illogical and wasteful**; and keeping it until at least 2020 will allow continuing scientific work and further international cooperation in space. (Still Another "Emperor is Naked" notice).

The "Flexible Path" or Third Option

The "Flexible Path" or Third Option the Commission created can be both an obstacle and a benefit. *If the option results in the creation of specialized, expendable spacecraft to explore asteroids, we will get some good science results (and good practice for long duration missions) from a few human expeditions to asteroids, and that is all.*

If, on the other hand, it results in the creation of a set of flexible, re-usable spacecraft and a rational, integrated space transport system using private launchers to reach LEO, *we will be ready to go to either the Moon, Mars, or asteroids*. Let us hope it leads to the latter option.

FLEXIBLE PATH: GOOD OR BAD

A discussion about NEO missions under the Augustine Commission's "flexible path" option led to these conclusions.

http://www.telegraph.co.uk/science/space/6425811/Asteroids-should-be-next-small-step-for-man-in-space-panel-tells-President-Barack-Obama.html

In reference to flexible path missions to near earth asteroids, we should remember that: *The vast majority of asteroids are basically made of very primitive rocks (ordinary chondrites), neither pure nickel-iron metal mix nor water-rich carbonaceous chondrite. (There are, however, significant amounts of the nickel-iron in the ordinary chondrites, but it would have to be separated from all of the rocky material).*

Low Relative velocity Near Earth Objects tend to have very long intervals before they return to the vicinity of Earth again, since the orbits of NEO's are often similar in period to the Earth. *Thus any mineral extraction from a specific object is a process that would have to occur on the scale of decades.*

- Objects which have more elliptical or highly inclined orbits and which may be synchronized with the Earth by accident, will have much higher flyby velocities, making rendezvous and return harder.
- Before you create a mining industry to exploit asteroid resources, you need a reason for that industry to exist. (What are you going to use the asteroidal materials for?)
- No one has yet created a spacecraft that uses artificial gravity, so there would be no gravity on any asteroid mission until we develop such spacecraft.
- '**Asteroids only**' missions *could* become a near-term dead end, even though, long-term, they represent a vital source of bulk materials and minerals for a spacefaring civilization.
- We have to deal with the economics of space as it exists now, not in 30 years. *Thus we need generalized infrastructure (and transport) development first, missions second.* **JKS**

A Basalt Fibers Industry

New Basalt Fiber Industry Launched in India

MMM Special Report

http://www.fibre2fashion.com/industry-article/3/256/new-reinforced-material1.asp

Now there is a new reinforcing material for textile composites: basalt fiber

From the website above:

By: Hireni Mankodi - Sr.Lecturer, Principle Investigator of Career Award for Young Teacher (AICTE Research Grant): Textile Engineering Department, Faculty of Technology and Engineering, M .S. University, Kalabhavan, Baroda: 390001, Gujarat, INDIA. email: hir_mak@yahoo.com

Introduction

Basalt fiber or is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. It is similar to carbon fibre and fiberglass, having better physico-mechanical properties than fiberglass, but being significantly cheaper than carbon fiber, It is used as a fireproof textile in the aerospace and automotive industries and as a composite to produce products such as tripods.

Basalt fibers are used in a wide range of application areas such as the chemical, construction and marine sectors, not to mention the offshore, wind power, transport and aerospace industries. This is due to their superior properties: not only do they boast good mechanical and chemical resistance, but also excellent thermal, electric and acoustic insulation properties.

Characteristics of Basalt Fiber

The raw material for basalt fibers is a naturally occurring mineral that belongs to the family of volcanic rocks. As a mineral, basalt ranges from dark gray to black. Basalt fibers are mineral fibers, which are 100% inorganic. Fiber compatibility with matrix resins can be ensured by using organic sizing agents. Basalt is well known in rock form and is found in almost every country around the world. It is traditionally used as crushed rock in construction and road building.

The fiber is 100% mineral continuous filaments. The focus is on the range of 9-13 microns for filament diameters. These diameters give the best compromise between tenacity, suppleness and cost. They are also safely larger than the 5 micron limit for non-respirability. As the fiber presents no hazard to health and environment, it is very suitable for asbestos replacement. The natural golden-brown appearance of the fabrics, can be covered for decorative purposes.

Main features of basalt fiber reinforcements

- High strength • High modulus • Easy to handle
- Corrosion resistance • High temperature resistance
- Extended operating temperature range

Basalt fiber and Preformes for Composite

MMM #232 - FEB 2010

Lunar Base Preconstruction

A Basic Public Demonstration of Using Moondust to Make Building Materials

By Peter Kokh kokhmmm@aol.com

PK: I had been invited to sit in on a presentation of Jay Witner's *"Apollo Village Proposal"* during the 2009 International Space Development Conference in Orlando, FL over the Memorial Day Weekend.

To put it in a nutshell, Jay was proposing that we raise seed money approaching one million dollars to convince the government to fund a pre-construction mission on the Moon. *Teleoperated bulldozers and other equipment would be sent to a spot on the Moon that had been previously selected for a NASA Moonbase. At that location, the selected equipment would be delivered by a Delta launcher and begin to "make bricks."*

Jay would use solar concentrators to melt moon dust in molds. Actually, you can compact moon dust and use microwaves to sinter and stabilize the outer layers, and for many purposes that would be good enough.

> *"The public has never been shown that we can go to space and build structures out of local materials. Live video of buildings going up on the face of the Moon is an incredibly powerful means to ignite interest in and support of our space program."*

We do not have the expertise to weigh the merits of Witner's proposed methods. Nor should this article be construed as an acceptance of their feasibility. But his proposal did get us to thinking:

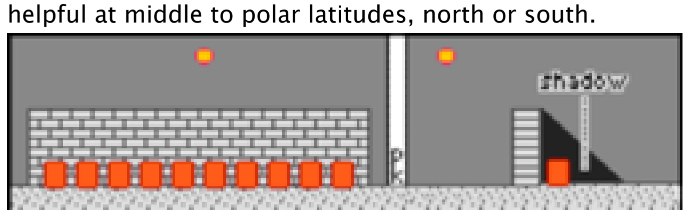
What can we do with bricks made by sintering?

The suggestion that we make buildings ready for astronauts to occupy seems to us to be rather impractical. It is *our own non-professional expectation* that *no structure made of bricks,* no matter how well made, *can hold pressure against the outside vacuum.*

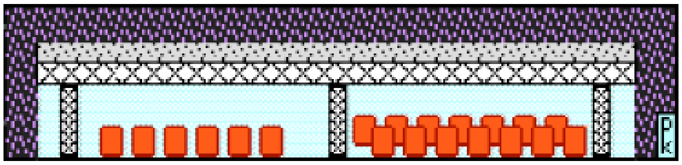
But fortunately that does not exhaust the possibilities. There are sevreral practical construction projects in which brick structures can play a supporting role in setting up a lunar outpost. Let's look at some of them.

Depending on the north/south latitude of your chosen location on the Moon, brick walls could provide shade for things stored out on the surface that must be kept cool, or at least, must not be allowed to get too hot; Tanks of fuel and/or various gasses, for example. Tanks storing blackwater (toilet) wastes are another example. Eventually, such wastes will prove most valuable as a source of agricultural nutrients, but we may not be ready for such operations right off the bat.

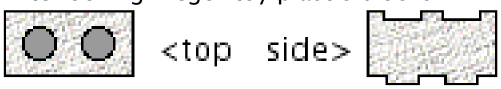
How high a shade wall would have to be will depend on the latitude. At the equator, it would throw no shadow and be useless. So such walls will be more helpful at middle to polar latitudes, north or south.



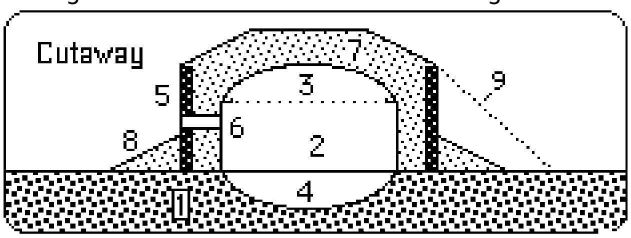
Bricks can also be assembled into columns sturdy enough to support space-frame canopies for unpressurized lee-vacuum storage areas protected from the cosmic elements of radiation, solar flares, micrometeorites and the extremes of dayspan heat.



As we are talking about mortarless applications, a better brick/block design would take a cue from the familiar interlocking "Lego" toy plastic blocks.

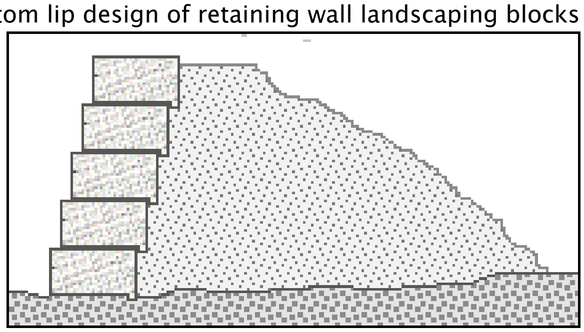


Another use for simple bricks would be to create retaining walls for moodust used as shielding.



In the illustration above, (9) represents the slope of the moondust shielding mound if a retaining wall were not used. Now in 1/6th gravity, the weight of the retained moondust might not exert enough pressure to topple a well-built brick wall. Experience will tell, however.

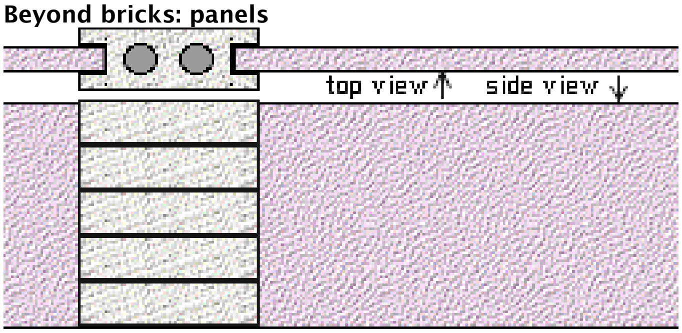
A better option would be to use the now-common bottom lip design of retaining wall landscaping blocks



Beyond bricks: pavers

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.

Beyond bricks: panels

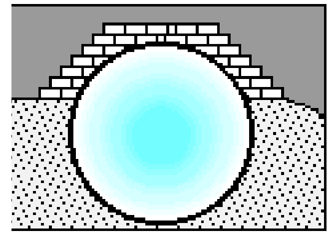


Panels, whether of concrete or made in the same moondust sintering fashion as bricks and blocks, could be held in place by Lego type blocks with forked ends.

Such panel walls could be used to shade stored items that need to be kept within specific temperature ranges, as mentioned above. They can also be used as visual barriers along roads and paths, blocking the view of warehousing and recycling sites, for example.

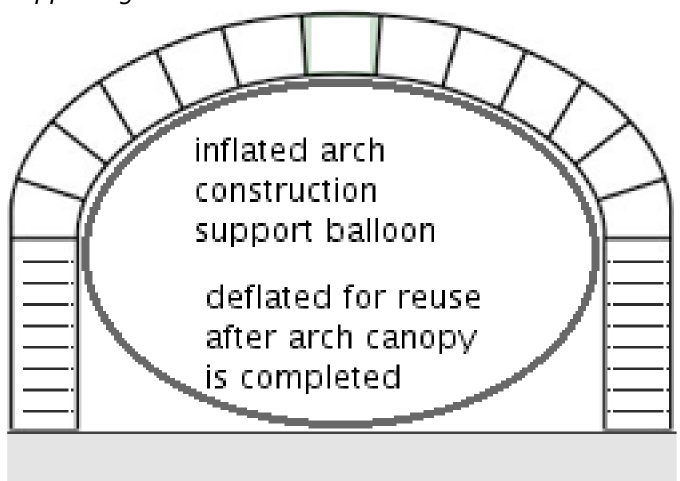
From Romance to the Prosaic

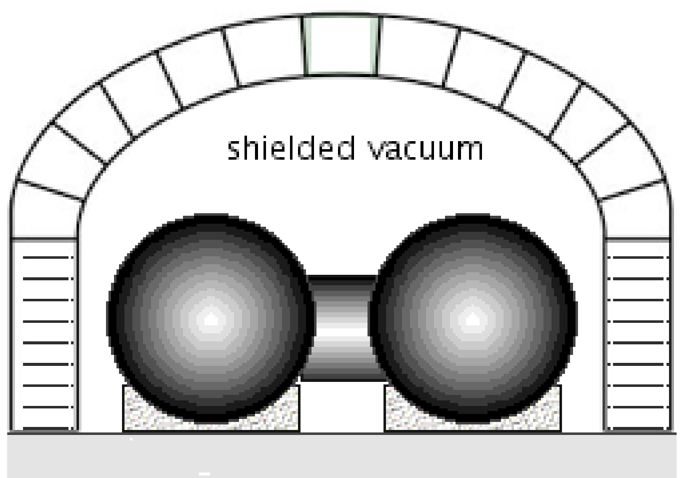
We must be brutally honest and say that we see no construction role for bricks in creating lunar shelter other than as retaining walls for moondust shielding or brick/block shielding which like sandbags could serve as removable and temporary shielding. Removability would allow repair, maintenance, and modification access to the module's exterior.



However, this form of shielding can only be constructed *after the habitat module is in place.*

However, there is one 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.*





Should the Apollo Village proposal of presenting NASA with ready-made shelters is unrealistic, *we can* *help to prepare a site for NASA* by creating a supply of bricks/blocks which could come in handy in many ways.

What about sandbags?

As implied, we could also create piles of ready-to-use sandbags. It would boost the viability of this option, however, if we could make the "bag" from local material: glass or basalt fiber mesh. But a lot of prior experimentation will be needed to demonstrate that this can be done early on, on the Moon.

What about pressurized buildings?

Except for the unpressurized arched canopy option, even if we can't put up brick buildings, ready for NASA or anyone other agency to use, it is clear that we can provide brick, block, paver, and panel structures that will go a long way to making the job of setting up shop on the Moon that much easier. And this would go a long way towards serving the same purposes as The *Apollo Village Proposal* has been designed to do.

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.

We'd have to train 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 would and then actually get to do some of the work *on the Moon* would be a lifetime feat hard to surpass, surely something to tell the grandchildren about.

While waiting for NASA, we can do more!

The *Apollo Village Proposal* suggests that space enthusiasts raise a million dollars or so for a publicity campaign that would get NASA to put in the budget the money needed to deliver the required equipment to the Moon. I think that misses major opportunities.

Why wait for NASA to do the brick and block design, to develop the equipment needed and which is to be teleoperated? Can't we help do that? NASA now has college and university groups help ferret our design options by such means as Rover competitions, regolith-moving competitions, and so on. It would seem that the next step, is not to raise money for a publicity campaign, but to get NASA to sponsor a new set of Engineering Challenges. This would involve many young people across the country in brainstorming how, indeed, we could do something like this: manufacture bricks, blocks, pavers, panels etc. on the Moon, ready for NASA or whomever to use. The moondust handling equipment as well as the manufacturing equipment needs to be pre-engineered and tested.

This would include tests using regolith moon dust simulant to see what process would work best and require the least weight of equipment and the least energy to produce the bricks and blocks. The proposal suggests using solar concentrators to melt moondust in molds. But sintering moondust compacted in molds by using microwaves could work if the product performance is sufficient.

While we could expect college and university teams to be eager to get involved, NSS chapters and chapters of other space organizations should be allowed to try their talents. What more captivating an activity could one imagine for chapter public outreach? Of course, most chapters would be hard pressed to put together a team with sufficient talents, and to purchase necessary supplies and equipment. But let's give them the chance!

A dedicated website for this project would showcase:

- √ Product design and service purpose options
- √ Equipment design and performance
- √ Progress along related lines such as design of sandbags, which could be made on site of lunar materials, and automated/teleoperated sandbagging equipment
- √ Illustrations and artwork
- √ Photo gallery
- √ List of college/university teams involved
- √ List of other teams (chapter-based, etc.)
- √ Information about related NASA Challenge events
- √ Updates on Moonbase plans of various agencies

The Moon Society could host such a site, but the National Space Society could do so also. Meanwhile, progress could be showcased at the annual International Space Development Conferences, and any demonstrations would be sure to attract a crowd. This activity could be a welcome added draw for the ISDC.

Can we push this idea further?

We do not now know where the first moon base will be located, or at least a few of us *not on the bandwagon* do not know. The South Pole location is very hilly and rugged and a builder's challenge. *A site on or near a mare/highland coast would allow us to similarly pre-manufacture cast and/or hewn basalt products (from tiles to blocks) as well.* A site which had flat areas for an initial base to morph into an industrial settlement, *as well as nearby high ground for overlooks* as well as scenic relief, would be visually more interesting.

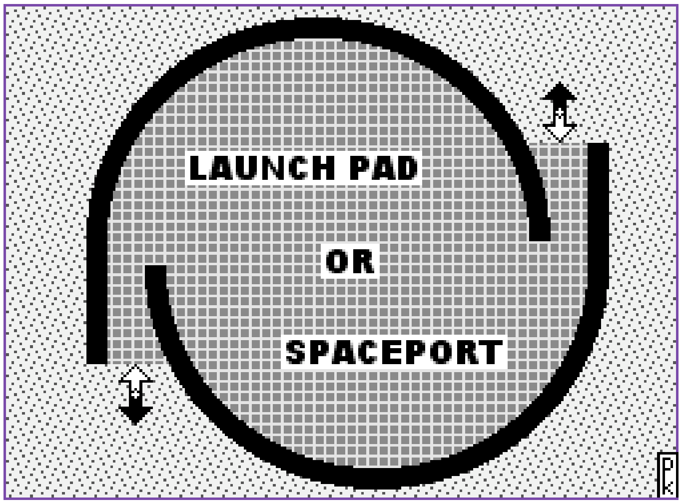
Imagine that we find such a place, and prior to first base module landing, prepare the site not just by grading it and building a launch pad, but by tele-manufacturing bricks, blocks, pavers, panels, etc. for multiple helpful uses. Then, while waiting for the base components themselves to arrive, we tele-construct a "nature trail" to and up on any *overlooking* high ground. Our bricks, blocks, pavers, and panels could be used to make steps, restraining walls too near any precipices, benches to rest on along the way, and a paved, walled overlook on top with the panorama of the ever growing base-into-settlement below.

If such a trail were tele-constructed before the first crews arrived, it would be a welcome after-work and free time diversion to check on the progress from an overlook like this. What could we do to make the first crews feel more welcome than to have such a "Jay Witner" trail ready for them?

In summary, even if the *Apollo Village Proposal* should prove to go too far, we think that that the general idea of providing pre-construction building materials out of moon dust by teleoperation has great potential, both to speed up construction of an operational Moonbase and to excite the public beforehand.

And we thank Jay Witner for that! **PK**

Supporting illustrations and photos



A Launchpad with paver floor and moondust berms between retaining walls

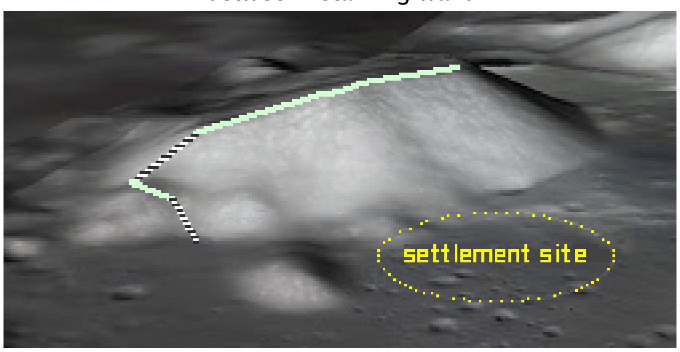
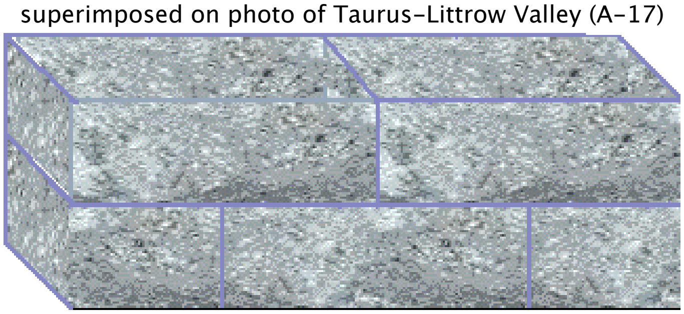
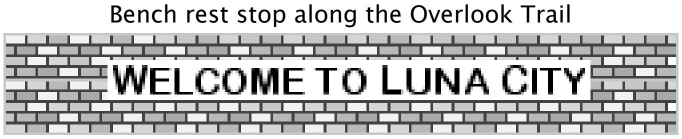


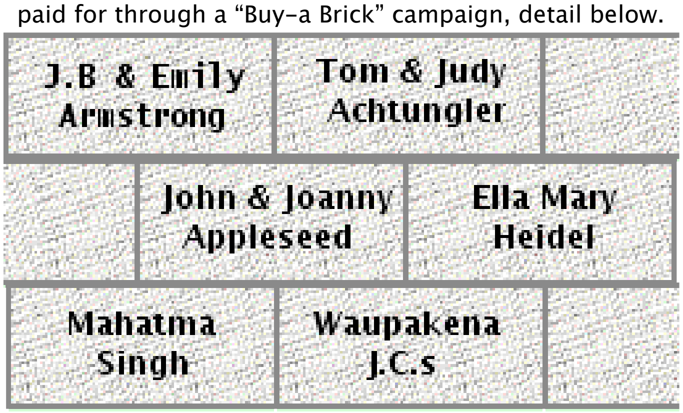
Illustration of an overlook trail and settlement site below, superimposed on photo of Taurus-Littrow Valley (A-17)



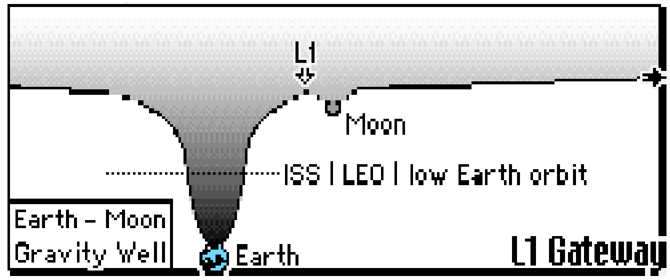
Bench rest stop along the Overlook Trail



On the road from the launch pad to the Settlement Site, paid for through a "Buy-a Brick" campaign, detail below.



An L1 Space Station: Gateway to the Moon



by David Dietzler pioneer137@yahoo.com

Introduction

A space station at the Earth-Moon L1 point could greatly facilitate the build up of a manned lunar base. Humans could travel to the L1 station with chemically propelled rockets that dash through the Van Allen Belts to minimize radiation exposure time and descend to the lunar surface in chemically fueled Moon Shuttles. They could land anywhere on the nearside within hours to a day. Propellant for the Moon Shuttles would be delivered to L1 economically with electrically propelled robotic tankers that spiral slowly from LEO to L1. Cargos for the lunar base could be sent to L1 with electrically driven robotic freighters and then landed on the Moon with chemically propelled rocket landers. The best form of electric propulsion might be solar powered VASIMR with argon propellant.

The L1 station would allow humans to inspect, refurbish and even repair spacecraft for descent to the Moon or return to Earth. Back-up Moon Shuttles could be docked at the L1 station just in case Moon Shuttles on the lunar surface malfunction so that teams on the Moon don't find themselves stranded. This would improve safety and mission success rates. A small crew could remain on the station to monitor and if necessary repair tracking and communication equipment vital to the safety of explorers on the Moon. They could also maintain space telescopes on the station.

In the early days of lunar base buildup, crews on the L1 station could teleoperate robots on the lunar surface with only a fraction of a second delay time. Since there is a three second delay when teleoperating robots from Earth, robots must move slowly and can only do crude tasks. From L1, finer telerobotic tasks could be done necessary for readying a base for human inhabitation without incurring the cost of landing humans.

Although L1 is outside of the Earth's magnetic field, workers there would only endure radiation exposures similar to those expected for travelers to Mars and this will be tolerable if a solar flare shelter is included on the station.

Manned Transportation

Since it takes less delta V to reach L1 than to retro rocket into LLO with a fully fueled lunar descent/ascent vehicle and then rocket back to Earth, Apollo style, a much smaller Earth launch rocket is needed. Instead of the Ares V monster rocket being developed at taxpayer expense, I suggest using a SpaceX Falcon 9 Heavy with a new cryogenic upper stage. This rocket could put 65,280 lbs. in LEO. Rocket engines burning LH2 and LOX could have a specific impulse of 460 seconds and an exhaust velocity of 4.5 km/sec. This is found by multiplying the specific impulse by 0.0098. Then we use the rocket equation, e^(dV/c), to find the mass ratio. The mass ratio is the mass of the rocket and payload loaded with propellant divided by the mass of the payload and rocket empty after burning all propellant. The term e is the natural log, 2.718. This number is raised to the power of the quotient of the delta velocity, dV, that is the change in the rocket's velocity, divided by c, the exhaust velocity. Since the dV to L1 is about 3.15 km/s, we can use the rocket equation to determine:

- e^(3.15/4.5)=2.01375 65,280/2.01375 = 32,417
- 65,280-32417= 32,863 propellant mass
- tankage and motors 15% of 32,863 = 4929 lbs.
- 32,417 - 4929 = 27,488 lbs or 13.7 English tons for the crewed module. This would include about a ton of propellant for maneuvering into and out of L1

A 13.7 ton spacecraft is very respectable. The Apollo Command module amassed 12,800 lbs, the Soyuz 14,350 lbs. and the Orion CM 19,000 lbs. The crewed module to L1 does not need a large service module with rockets capable of braking into LLO and accelerating to lunar escape velocity.

Landers, or Moon Shuttles, would be sent to L1 with electric drives and fueled at L1. I envision reusable single staged vehicles powered by LH2 and LOX. To prevent problems with cryo-propellant boil off during lunar surface missions, reliquefaction devices tended by robots would be landed ahead of time.

Robotic Transportation

Electric propulsion will definitely lower the cost of cargo transport to the Moon because it uses far less propellant and allows much more cargo from LEO to reach the Moon, so the price per pound is less. However, electric propulsion is slow so we must use space storable propellants like MMH (mono-methyl-hydrazine) and NTO (nitrogen tetroxide) for lunar landers. Non-toxic and inexpensive kerosene and nitrous oxide are also possibilities. These propellants are not as powerful as LH2 and LOX so they will land less cargo.

What if we shipped space storable water to low lunar orbit and cracked it to hydrogen and oxygen at a LLO station, liquefied them and pumped them into empty landers with cargos on board arriving from LEO via electrically propelled vehicles? We could land larger cargos. The only problem is that a station in LLO is not going to stay in orbit because of the Moon's "lumpy" gravitational field caused by masscons. What if we shipped water to a L1 station and converted it to LH2 and LOX there?

MMH and NTO 316 sec. Isp or 3.097 km/s exhaust V. Since the delta velocity from LLO to the lunar surface is about 1.6 km/sec. we find:

- e^(1.6/3.097) = 1.67
- LH2 and LOX 460 sec. Isp or 4.5 km/s.

Since the dV from L1 to the lunar surface is about 2.4 km/s. we find:

- e^(2.4/4.5) = 1.7

So even though the delta V from L1 to the lunar surface is higher, LH2 and LOX have so much higher performance than MMH and NTO that the mass ratio therefore payload is about the same. In addition, less electric drive propel-lant would be needed to reach L1 because the dV to L1 is less than to LLO and just as important, less time would be required, and time is money. So there is an advantage to sending cargo to the Moon via an L1 way station.

Moreover, landers designed to run on LH2 and LOX could eventually be fueled on the Moon with propellants derived from lunar ices, if we can get them.

R&D Projects to LEO

- Falcon 9 Heavy, 65,280 pounds payload

R&D Projects to o L1

- Solar electric drive systems for propelling a medium sized space station with inflatable habitat modules and fuel storage tanks assembled in LEO, or even a renovated ISS?
- Propellant tankers using SEP (Solar Electric Propulsion) to deliver water to L1
- In space water storage, electrolysis, cryogenic liquefaction and propellant storage and transfer systems
- A cryogenic upper stage using LH2 and LOX for propulsion of a crewed module capable of re-entry at near Vesc that amasses about 27,000 lbs. to L1
- Reusable SEP cargo vehicle for moving landers and other payloads from LEO to L1

To the Lunar Surface

- Reusable single staged manned landers that use LH2 and LOX.
- Initial propellant for first descent sent to L1 with SEP in the form of H2O that is processed to LH2 and LOX at the L1 station.

These vehicles will load up with enough LH2 and LOX to descend to the lunar surface and return to L1. Cooling equipment to keep the cryogenic propellants cold during a prolonged stay on the Moon will be landed ahead of time. Using hydrogen mined on the Moon to fuel these vehicles is undesirable because lunar hydrogen resources are so scarce. Since oxygen is abundant in regolith it would be possible to land these vehicles with only enough LH2 for return ascent to L1 and tank up on LOX on the lunar surface. Eventually, other fuels like aluminum will be produced on the Moon.

- One-way LH2 and LOX fueled cargo landers that will be "cannibalized" on the Moon

Conclusion

An L1 space station and Falcon 9 Heavy. rockets in addition to more new hardware like VASIMR drives would make for a cheaper, more reliable system for the Industrialization and settlement of the Moon. The Apollo system might have been the quickest way to defeat the Russians during the Space Race, but it is not the most efficient way to reach the Moon and the present Return to the Moon project is misguided. Instead of a taxpayer funded Ares V monster rocket that is too large for any commerical or defense payloads, a system based on privately financed Falcon rockets and an L1 way station should be developed. Electric drive systems and a reusable tug for transporting unmanned cargos from LEO to L1 where the tug docks with the L1 station and leaves its cargo module then returns to LEO to pick up another cargo module containing machines or water are also essential parts of this system. **DD**

On “L1” from Past Issues of MMM

MMM #159 “Expanding the Manned Space Envelope: The Earth-Moon L1 Gateway”
and #160 Constructing an L1 Gateway on a “Just-in-Time” Schedule (as Business & Industry would do it)

Both preserved in MMM Classic #16 pages 45-47 and 51-53 respectively. Download from www.moonsociety.org/publications/mmm_classics/

NOTE: “L1” and “L5” are esoteric terms for many!

Dave Dietzler and Peter Kokh have been tossing about some more *people-friendly* names:

“**The Pass**” and “**The Lagrange Gap**”

i.e. *through the “mountain ridge”* between the Earth’s deep gravity well and the Moon’s shallower well.

See the illustration just below the title of this article.

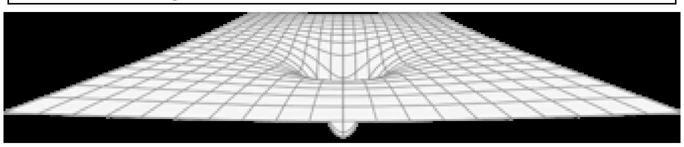
Too many people have grown up with the proverbial dictum about there being no “up” and no “down” in space. For all practical reasons, in travel between gravity well destinations, this is a misleading sophism.

It is commonplace to show Earth-Moon and Earth-Mars trajectories in a flat plane, when it would be more helpful to show them against a gravity well map. Yes that is harder to do, like most things worth doing!

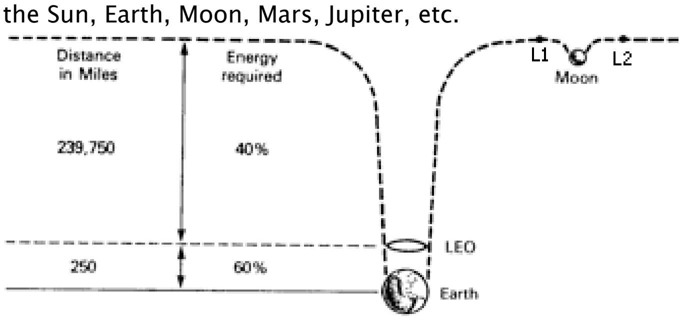
Gravity Wells Comment:

Perhaps this is *something we need to promote!*

This should be part of our strategy of getting across to people the need to place infrastructure waystations to enable less expensive, more heavily trafficked personnel and cargo travel between Earth and Moon: LEO, GEO, and L1 were all bypassed by NASA because, for a low traffic operation like Apollo, it made no sense to invest in such infrastructure, and we all now understand that this “low traffic” assumption was/is a “self-fulfilling prophecy.”



Above, how space is warped by a heavy mass “at the bottom of a gravity well.” Applies to all bodies of size: the Sun, Earth, Moon, Mars, Jupiter, etc.



Robert A. Heinlein first noted,
“once you are in Earth orbit, you are *halfway to anywhere!*

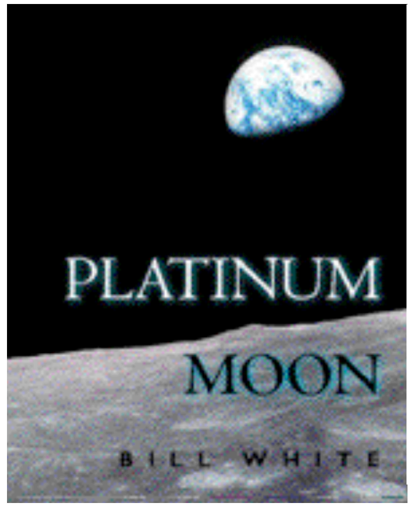
Gravity Wells: an animated illustration
http://www.opencourse.info/astronomy/introduction/06.motion_gravity_laws/gravity_well.gif

An illustration by our own Ken Murphy
http://www.outofthecradle.net/WordPress/wp-content/uploads/spacefarerseml1.jpg

A great YouTube Explanation
http://www.youtube.com/watch?v=VBQHtF3WhMw&feature=player_embedded

“If Earth’s gravity well is 22 steps deep, the Moon’s gravity ‘dimple’ is only 1 step deep in comparison.”

The general “terrain” of the Solar System is like a great *plateau, seemingly flat,* but like the Great Plains States, gradually *sloped uphill* from the Sun outwards as this area is on *the shoulders* of the Sun’s giant gravity well.



Moon Society member **Bill White** comes through with first science-fiction novel that takes the recent “sea-change” in NASA’s mission plans as the given situation for his story

International intrigue, adventure and suspense wrapped around a moon landing

[from www.platinum-moon.com]

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“A well orchestrated media and marketing campaign culminates in unprecedented worldwide television ratings as Lt. Commander David Anders, an expatriate naval aviator, leads an international crew to the lunar surface on-board PGM-1, the world's first fully reusable lunar lander. Hewitt’s ambitious plans, however, threaten powerful interests and when unexpected trouble strikes PGM-1, the entire world watches and wonders whether they will soon witness another first - the first humans to die stranded on the barren lunar surface.

“Platinum Moon is filled with scientific and engineering detail as well as insights into the nuances of international relations, the power of the global media and America’s uncertain role in the 21st century. Implications arising from the ownership of extraterrestrial resources and extensions of national sovereignty beyond Earth are also addressed, as are the internal struggles of vivid characters wrestling with conflicts between personal goals, obligations to family and duty to country. The novel also breaks new ground by portraying a privately owned EML-1 Gateway Station and a thriving sub-orbital rocket racing league centered at Spaceport America near Las Cruces, New Mexico.”

Platinum Moon is available through this website as well as on Amazon.com in both paperback and Kindle editions. **Peter Kokh’s review** of this novel can also be found on the Amazon.com page. You can download the first third of the novel in a variety of e-book formats without cost or obligation via Smashwords.com

Bill White lives in Downers Grove, IL, Chicago suburb. MMM congratulates him for this achievement, and for his positive vision for the future of the Lunar frontier.

PETE'S SHIELDING BLOG

By Peter Kokh kokhmmmm@aol.com

Well, first, I don't like being called "Pete" unless you are about to give me money or treat me to dinner. And second, a blog is an online page airing personal opinions on a regular, if not daily basis. That said, "shielding" has been a favorite topic of mine since MMM #1 in December 1986, commenting on a May '85 visit to a unique "Earth-sheltered" (read "shielded") home some 25 miles north of my home in Milwaukee, Wisconsin.

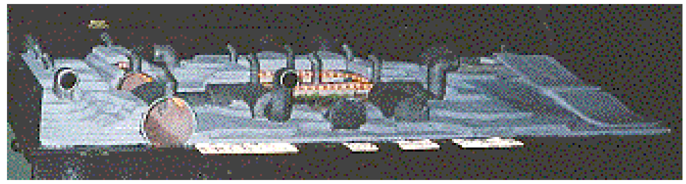
I have a friend who refuses to talk to me about space because his teacher told him that it was not possible for humans to live on the Moon, and as he respected her, I had to be "talking nonsense." Of course, his teacher was right, literally speaking. No one can live "on" the Moon, not for long, given the thermal extremes, the total exposure to cosmic rays, solar flares, full industrial strength solar ultraviolet, and the micro-meteorite rain. Indeed, we can live "on" Earth's surface only because our thick atmosphere sufficiently insulates us from these aspects of the Cosmic Weather.

Our atmosphere serves as a blanket. There would seem to be no such *air* blanket protecting the Moon's surface. But take another look! The bombardment of the Moon's surface by big objects (most of that stopped over 3 billion years ago) and smaller micrometeorites (still ongoing) has pulverized the upper layer of the Moon's surface, gardening it to a depth of 2-10 meters (~yards), thinner in the maria which are only 3 plus billion years old and formed after most of the early bombardment ran low on material, and thicker in the older highlands. We've all seen film and photos from the Apollo missions and are familiar with what the surface moondust looks like. We call this layer the "regolith" - Greek for "rock powder."

The point is that tucking ourselves under this *blanket* would provide *the same degree of protection* that our atmosphere blanket gives us. Consider that if it got cold enough (very, very) to freeze out our atmosphere, it would settle out on the Earth's surface (and ice-covered ocean) as a layer of Oxygen and Nitrogen "snow" 15 ft or 5 meters deep - *in the same ballpark, thickness wise!*

Over the years we have written many articles about shielding and methods of providing it. Getting ready for ISDC 1998 here in Milwaukee, I made a model of a modular lunar homestead on a 36"x80" hollow core door base to exhibit at ISDC. It teaches many things:

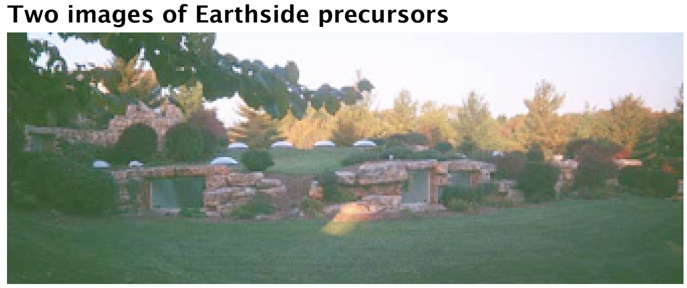
- How to build shelters on the Moon by using building materials made from moon dust (metal alloy, glass composites, concrete, etc.) to make modules (on the illustrated pattern of PVC plumbing components - I used 4" sewer schedule and smaller PVC/CPVC parts) - to make homes of any size, with many design options.
- Covering our constructed shelters with 2-4 meters (~yards) of moondust (I used sculpted layers of 3/4" Styrofoam)
- Each home has access to sunlight, and visual access to the moonscapes outside
- Each module has a wastewater system that treats toilet wastes while providing clean water, lots of vegetation and color, and sweet fresh air - "modular biospherics!"
- All homes are connected to a pressurized street system so that one can go anywhere in town without a spacesuit
- Bringing tools and factories, seeds and resourceful people from Earth; making most everything else locally



We are now in the process of making minor changes to this exhibit that we hope to bring to ISDC 2010 in Chicago next Memorial Day Weekend, so that it is more self-explanatory. I love explaining it to people whose eyes light up as they begin to understand how living "on" the Moon might be possible *and quite comfortable* - just by tucking ourselves under a moon dust blanket. Perhaps many space enthusiasts, who try to explain how we can set up shop on the Moon, neglect to put full emphasis due on "shielding." That is perhaps the major root of the skepticism they encounter.

Meanwhile, back here on Earth, those of us who have seen or visited "Earth-sheltered" homes have had a preview. Now most such homes have an exposed south-facing window wall to tap passive solar heat, and that is something we can't do *that way* on the Moon. The home I had visited back in 1985 did not have that feature and did break new ground on the methods of solar and visual access. See the article "MMM" is for "Mole" in MMM #1, now online at: www.lunar-reclamation.org/mmm_1.htm

Two images of Earthside precursors



Terra Lux, the home I had visited. Note exposed windows - upper portions of a unique periscopic system.

Necessarily exposed entrance to an "Earthbag" home
http://earthbagplans.wordpress.com/introduction/

Also do Google Image searches for "Earthbag homes" - "Earth-sheltered homes" or "underground homes"

It is a mistake to neglect the shielding option and to tell people we will build in lavatubes. Yes, we will, and the possibilities are enormous, *but not near-term,* as lava tube construction will have its own challenges to address. Talk "shielding!" *and you will convince more!* **PK**

The Pen*dul* um of "Mars"

From **"Once Earthlike but *Dying* World"**
to **"Dead World from the Start"** *to*
"Once Earthlike, and *still living* World"

A Remarkable Journey!

By Peter Kokh

Saturn's rings notwithstanding, and no matter that Venus is Earth's twin in size; reddish Mars has always been the planet with which we have been most fascinated - *by far.* Those readers who became aware of Mars after Mariner 4's flyby visit in 1965, which by misfortune, happened to be over the heavily cratered southern hemisphere, have always seen Mars as a dead, almost moonlike world.

But those of us born in the 1930's and 40's grew up with a vision imprinted on us by Percival Lowell, of a dying planet laced with canals, evidence of intelligent civilization that sent spring melt water from the polar caps to the temperate and tropical regions of the planet. That the canals were still working, whether their builders still survived or not, was clear from the season changes in shading, some areas getting darker every Martian Spring, a sign, no doubt of vegetation springing back to life. We knew of course, that Mars air was thin, maybe 10% of the atmospheric pressure we enjoyed on Earth.

Speculative writers differed on whether we would find the Martians still alive, just barely hanging on, in a brave old world, or whether we would find only ruins of a now long dead heroic civilization. If we found writings, we hoped to find a "Rosetta stone" of sorts so that we could glean from them their accumulated science, and wisdom. Maybe there would be some surviving wildlife.

Mariner 4's view of a surface as crater-pocked as the Moon's southern highlands, erased that dream picture in one quick second. But the romantic view above had already been under attack. Modern telescopes could not detect the canals of Schiaparelli and Lowell, and in 1961, Carl Sagan had come up with the correct and non biological explanation of the seasonal shading changes: the seasonal trade winds on Mars blew darker soil over lighter areas, which were later blown clean again.

Worse, we soon found out that Mars atmosphere was far thinner than anyone had expected, only 10% of the 10% we had expected, that is, only 1% of Earth-normal. The surface was exposed to radiation and raw, untempered solar ultraviolet. Mars was a harsh, life-squelching world. It might never have been "alive."

But then observers found what looked like beaches in the great northern depression called Vasitas Borealis - the Northern lowlands. For the past thirty years the debate has raged. Did Mars once have an ocean?

The brave and romantic among us were shakingly confidant that it did. Others could see no evidence. As you may know, none of us are perfectly objective. Our temperaments influence us one way or the other. There are those with a "need" to "know" that we are alone in the universe and prejudge all evidence accordingly. The there are those of us who wax eternally optimistic, buoyed by the dictum "nature never does anything once." Our temperaments determine what we thing of as evidence.

Suddenly, the impasse has been broken. We now have overwhelming evidence that the valley networks to the south of the northern depression are twice as extensive as thought and that their dendritic features could only have been produced by regular seasonal rains over millions of years. We are now suddenly confidant that, yes, Mars did have an Ocean! There is still room for debate on how deep that ocean was, that is, how far up the slopes of the great northern depression the waters reached. In time, we will find the maximum shoreline elevation. Regardless, we now know that Mars once had a considerable ocean-scale amount of water.

Where all that water went is the question. Some of it must have sublimated, as the air got steadily thinner. But it is impossible to believe that there were not suterranean aquifers that must still exist, however frozen. And it is likely that at that point drilling down where Mars internal heat begins to be felt, there may be some appreciable volume (in toto) of liquid water.

Water must have subsisted on the surface long enough during a period when Mars enjoyed warmer temperatures, to have favored the rise of living organisms from the amino acids that it now seems clear have been spread by interstellar gas and dust clouds everywhere in the universe. Life is not unique. It is natural, and must arise everywhere that it is given a chance.

The discovery of persistent methane in Mars' thin atmosphere suggests that microbes or bacteria native to Mars still survive. The "conservative" (temperament, remember!) view that this methane must be of geological origin flies in the face of the evidence that Mars has been geologically dead for some eons now. Pursuing the arguments further, it is the suggested abiological/geological mechanisms that are not holding up.

Finally, the evidence from Mars meteorites (it is their trapped gas species and ratios that tell us their origin) that what looks like fossilized life must be just that, is clearly routing all the abiological explanations offered. NASA has indicated that it will soon announce convincing evidence that Mars once had primitive pre-cellular life, and very well still may have.

In the past 45 years, we have come full circle, almost. Mars was wet and alive in its youth, and maybe through human intervention, can be restored to something of its former self. I personally do not like the word "terraforming." First, our whole experience is in DE-terraforming our own world. Second, to be true to Mars, we should be talking about "rejuvenating Mars," bringing it back to what it once was, and then meeting it halfway, adapting *to that Mars*, not to a recreated Earth. **Rejuvenaissance**, or ***rejuvenation*** if you will. I fear we will try quick schemes to raise air pressure and temperatures that will box us into dead ends. Best results come slowly.

Still not back with us are the mythical ancient Martians. There will be Martians someday. But they will be our descendants, not beings restored from trace DNA of former inhabitants that never existed. Plain put, Mars did not enjoy its Spring and Summer long enough to have evolved any type of advanced life.

All the same, it is good to be back believing that we have a human-welcoming sister world in our own Solar System, back believing that Humankind will someday thrive on another world, that all our eggs will no longer be in one basket. Meanwhile, here is a toast to the overoptimistic visionaries that once stirred our romance with Mars! - *vive les Martiens!* We will be them. **PK**

Mars: *Exploring* Now, *to Settle* Later

By Peter Kokh

Robotic Exploration Goals: Guiding Principle

"Learning whatever we can now with robotic probes, so that when we are ready to send first crews to Mars, we will be able to send them to the most promising sites for starting (a) viable self-reliant settlement(s)."

- Good sites are not good enough. We need enough information to pick the best. *Optimization of our chances of success in establishing a second egg basket for humanity is at stake.*
- At present, there is no guiding principle for choosing instruments to go on Mars orbiters or landers. Prospective Principal Investigators make proposals, and a team of scientists, not settlement experts or designers, pick on the basis of weight, cost, and design readiness. We end up with good missions, *but not good enough to get the job done.*
- The Mars Society has not lobbied for needed instruments. *But it is in the Moon Society's interests, to make sure that the Mars Settlement(s) is (are) a helpful trading partner for the Moon Settlements, to take up this cause.*
- In short, the Moon Society owes it to our own goals and interests to pickup where the Mars Society has failed to take the initiative.

What kind of probes do we need to learn what we need to know in order to pick best sites?

1) **We need more complete mineralogical mapping of all elements** needed for settlement supporting industry
2) **We need ground-truth core samplers** in sediment areas of the presumptive boreal ocean bed, and of river systems to the south
3) **We need ground-truth core samplers** of suspected permafrost areas in order to design adequate water recovery systems
4) **We need superior altimetry data** of 10-meter vertical resolution to plan for future drainage systems and for road and railroad routing

Finding the best places to begin Settlement

There are many things to consider:

√ **water access:** is there handy subsurface ice or permafrost that can be tapped?

√ **Coastal areas:** areas near both ancient river tributary systems (exposed sedimentary layers: material of varying mineral composition) and the northern (presumably oceanic) basin whose mineralogy may be different and somewhat complementary

√ **Proximity to Pavonis Mons:** This shield volcano massif is known to be ridden with lavatubes and sits astride Mars" equator. *More on these assets below*

√ **Proximity to the deepest basin, Hellas:** once remedial climate change ("terraforming" or "rejuvenescence" of Mars, i.e. to an earlier friendlier state) has begun, this basin will always have the highest air pressure.

√ **Low equatorial areas (best climate)** Note that Mars northern hemisphere has shorter winters and longer summers than the southern hemisphere

Exploiting the Assets of Phobos & Deimos

Semi-officially, the Mars Society position would seem to be that Phobos and Deimos are irrelevant. The fear here is that a first manned mission might be to one of these mini-moons, delaying a manned exploration mission to Mars. But we do not need a Manned Exploration Mission! We should do all the exploration needed to determine a shortlist of settlement sites with orbiters and surface probes, so that the first manned mission to Mars will be "a Mission to Stay." Anything short of that runs an extremely high risk of being a one-time "Flags & Footprints" ("Kilroy was here") symbolic mission to be followed by more decades of nothing. We don't need another Apollo type dead-end repeat. Impatience always fails! Of course, the impatient never get that.

Phobos can help in two major ways:

1) **A forward base for the teleoperation in sub-second delay real time** of a whole fleet of ground truth rovers and core samplers, including lava tube explorers and polar cap miners. If we were controlling Spirit and Opportunity from Phobos instead of from Pasadena, the amount of productive exploration could be magnified a hundredfold or more. They go so slow because with a 6-40 minute time delay, we cannot afford to let them get too far ahead of us!
2) **If Russia's Phobos-Grunt mission should determine that Phobos is a carbonaceous chondrite,** rich in volatiles such as hydrogen, carbon, and nitrogen, an automated industrial operation to produce liquid methane and ammonia for export to the volatile-thirsty Moon could be a major source of income to any Martian settlement with which to pay for dearly needed imports. Given the lack of any other "identified" economic exports from Mars itself, this is not something to be dismissed.

Short-term goals of geological and exo-biological exploration are immaterial.

If this seems a brash statement, consider how much we would know about North American Flora and Fauna, about the continent's geology, its geological and paleontological past if only one or two "scientific expeditions had been sent (even with today's instruments and expertise) in comparison to how much we now know about the continent because continuous settlement has supported far more widespread, continuing, and in-depth scientific exploration of all kinds. Obviously, ***those scientists who dismiss settlement and want one or two scientific expeditions are willing to sell out the possibility of ultimate in depth exploration in order to get quick Nobel Peace Prize results now.***

Settlement of Mars is *the only way to support ongoing and thorough scientific research* on Mars of any and all types. Here as everywhere, impatience always backfires. The corollary is that settlement sites must be assessed not on the grounds of potential scientific yield but on the grounds of access to a complete suite of materials needed to support settlement should financial backing from Earth dwindle or disappear.

Those with scientific curiosity will arise in every settlement, just as on Earth, and eventually will explore every bit of Mars, and far more thoroughly. It is important to go to Mars for the right reason: to create another basket for humanity's eggs. Exploration will follow.

Long term, two sites on Mars stand out

1) Pavonis Mons:

"Peacock Mountain" astride Mars' equator, is an. enormous shield volcano, second to Olympus further to the NW. Its gentle western slopes offer **the ideal site for a launch track to orbit and beyond**. In Mars thin atmos-phere, the track may be able to launch directly into orbit, with a minimal course adjustment motor.

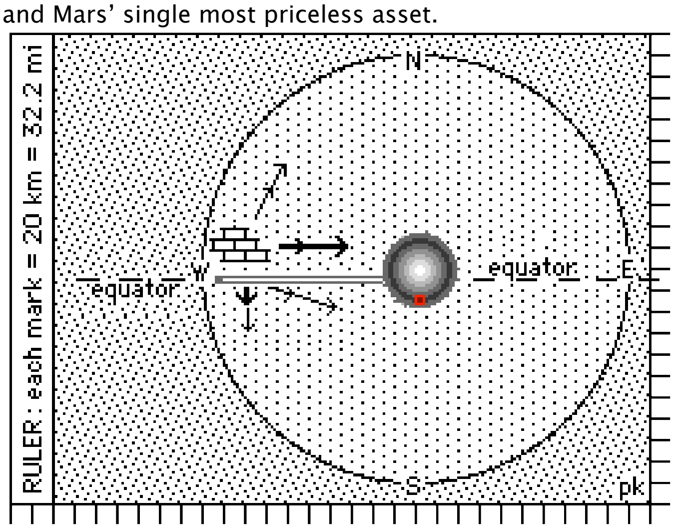
More, the crater rim itself is the best/only place on Mars to **anchor a space elevator** to Mars-synchro-nous orbit: a far, far superior site to anything similar on Earth, and requiring a much less massive cable.

Judging on the basis of the similar but much smaller northern California shield volcano of Medicine Lake, Bryce Walden, of Oregon L5, per our request [1994], deduced that Pavonis Mons

"has a volume 700-1000 times larger than Medicine Lake. (Pavonis is 7 times the diameter of Medicine Lake, covering 50 times the area and is perhaps 15-20 times taller). Taking the smaller figure and exten-ding the same argument, we might expect 10 billion cubic meters involving wider, higher, longer caves spaced further apart. If we postulate an average Martian tube interior ceiling height of 30 meters, that gives us a floor space of about 150 million square meters = 333 sq. km2 = 128 sq. mi., the size of an American central city in the 1,000,000 population range - in a host mountain with a footprint of 40-45,000 square miles, bigger than Iceland and comparable to the size of states like Ohio, Tennessee, Virginia, Mississippi, Louisiana, or New York."

Pavonis Mons is midway between the coast of the long-dry northern basin ocean to the WNW and the Valles Marineris canyonlands system to the ESE.

The western flank of Pavonis Mons would be our suggestion for the first major settlement on Mars, very possibly in a lavatube, with ample room for expansion into major urban complex. Pavonis Mons is arguably the most valuable piece of real estate in the system, by far, and Mars' single most priceless asset.



Plan of the Pavonis Mons Metroplex Area: The lavatube-riddled shield volcano slopes cover an area about 250 mi. in diameter. The corridor for the launch track up the west face of this equator-straddling mountain is shown, along with the site for a Pavonis Space Elevator Base on caldera rim. The brick-pattern area indicates the suggested site for the first settlement with arrows showing logical directions of early metropolis expansion. Eventu-ally, the entire base of the mountain could be occupied, attaining a population of up to a million citizens or more.

MMM Sources:

MMM Classic #2 pp. 37- 38 "Pavonis Mons: Possibly the most strategic mountain in the Solar System"

MMM Classic #8 pp. 11-13 "Pavonis Mons/Peacock Metroplex:" The site for Mars Main Settlement

Both issues freely downloadable from:
www.moonsociety.org/publications/mmm_classics/

2) The Hellas Basin:

Halfway around Mars in either direction from Pavonis Mons, and between 30-50° South of the equator, this major impact basin sits more than 8 km (more than 5 miles) below Martian mean ("sea") level. Mars' highest atmospheric pressure is now, and will always be, in this basin. ***Hellas will be the site on Mars where conditions will first allow Mars-hardened hybrid plants to survive out in the open.*** *Hellas will always be the front line of any effort to improve Mars climate* (e.g. by perma-nently melting polar ice cap carbon dioxide ice. In other words, once deliberate climate improvement projects begin, ***Hellas north "shore' will be the place to be.***

Hellas does have some drawbacks. As a basin it is landlocked, and thus any Hellas Sea will very slowly become salty, but over hundreds of millions of years. It will be subject to longer winters and shorter summers than equivalent latitudes north of Mars' equator. In sum, for the near term, Pavonis Mons is the place to start. In centuries to come, Hellas will grow in importance.

Another ancillary location: the edge of the north polar ice cap 50° west of the latitude of Pavonis Mons.

If there is no adequate permafrost or other subterranean aquifer handier to the Pavonis Mons site, an enclosed, pressurized, and insulated aqueduct could transport polar melt water towards the equator. There would need to be pumping stations along the entire route. Once the aqueduct reached the tropics, it would have to climb up the Tharsis ridge to Pavonis Mons. This would be no easy feat, and the energy to pump water all this distance, and then uphill, would be daunting. Sites still within the northern Boreal basin would have the advantage. We picked a point 50° west of Pavonis Mons for the easiest route south to the equator.

Liquid Subterranean aquifers?

We suspect that there may be a level below the surface where Mars residual internal heat is sufficient to keep subterranean aquifers in a liquid state. We would have to find such aquifers. Their depth below the surface may be intimidating to engineers. The best place to look for residual heat may be below the Tharsis ridge itself on which Pavonis, Arsia, and Ascraeus Montes all sit. If an aquifer is found, it could be a source not only of water, but also of residual geothermal energy for a metroplex. However, the expectation is that Mars" core has been cold for some time. Yet "cold" is a relative term. The much smaller core of the Moon may still be hot.

Summing up

We must prioritize science missions that will tell us where the clusters of needed elements needed to support settlement can be found. All other science goals are postponable. *Exploration can wait for settlement.* **PK**

Mars Analog Research Stations

Settlement-related research should have priority over geological and exo-biological research.

By Peter Kokh, member MDRS Crew #34 Season 4; Commander of MDRS Crew #45 Season 5

It has been a very special honor to have served on two Mars Desert Research Station crews and to have become a member of the very unique and privileged fraternity of those who have also been so fortunate. Both of these experiences will always be especially treasured for the rest of my days.

This participation would never have occurred were it not for connections made by my long-time friend, Ben Huset of the Twin Cities, who back in August 15, 1986 came to Milwaukee with others, in concert with a team from Chicago, to help launch what became the (Milwaukee) Lunar Reclamation Society.

I went to Hanksville, Utah in early 2005 to learn about the Mars Society operation and to prepare for a 2-week rental of this facility in the following year by the Moon Society. One goal was to identify any logical differences between a Mars Analog research program and a Lunar one. It was clear, that the Mars Society was trying to prove the value of human-robotic exploration of Mars, something the Apollo program had long since proved invaluable on the Moon. The Moon Society, if it had the opportunity, would concentrate on technologies and methodologies of expanding an initial outpost in the direction of settlement.

But while that difference seemed logical to me for some time, I now think that the Mars Society has been on the wrong track. Demonstrating the value of human explorers does not demonstrate either the importance or the value of human settlement, through which far more exploration would be done long-term. We now think that the program being designed for our proposed lunar analog research station would be a much better fit for Mars analog stations as well.

It has bothered me from my first visit that the Mars Society has not tried to expand beyond the original Hab and largely symbolic (ineffective) GreenHab. There is an observatory, but that does not expand the living space! In fact, at both the Arctic and Desert sites, the only expansion was made by the Moon Society on our time and dime: the framework of a "pretend pressurized" tunnel from the Hab to GreenHab that would allow crew members to pass from one to another without a "space suit" and preserving the useful pretense of being "in sim." But if you haven't been there, you wouldn't understand.

The sad thing is that the Hab has two airlocks which makes expansion out of one of them a real structural possibility. A ground-hugging "ranch" style one floor annex, perhaps to replace the crew quarters, could easily be shielded with sandbags for warmth in winter and for cooler temperatures in summer, making year-around operations feasible. And that would in turn make a real crop-growing greenhouse operation doable.

The two-story hab is a big mistake, both for Utah and for Mars. Two self-contained floors could ride the way to Mars on top of one another, then be connected side by side for better thermal management, and for safety. The ladder between floors is a major cause of accidents. The unshieldability of a tall vertical structure has exacted its price: a short field season.

Expansion of an original structure into a modular settlement should be a major vector of any Mars (or lunar) analog research program aimed at demonstrating the feasibility of settlement. This option has been totally ignored. *The effect is to reinforce the belief that the only reason to send people to Mars is to explore.* Yes, people and robots make a better team than people-only or robots-only. But strategically, it is far more important to the Mars Society's mission and goals to prove that settlement of Mars is possible, and that far more research by human-robot teams will be accomplished if settlement is the primary and fundamental goal, not something to keep hidden because of "the giggle factor."

No one wants settlement of the Martian Frontier more than Robert Zubrin. Yet no one stands more in the way of that happening than his strategic misdecision to support exploration alone first. On this point, the Moon Society is a stronger supporter of the opening of the Maritan Frontier as an essential trading partner for the Lunar Frontier in an interdependence, which will enhance the viability of both.

If the Moon/Mars Atacama Station in Chile becomes a reality, modeling modular expansion and modular biospheric systems will be a core vector of the program. The shift of the drive to settle Mars will be to this site in Chile.

Can MDRS be redirected? Absolutely. Rebuild the Hab with the two floors separated and then placed side by side with new modules being added at ground level, and insulated by sandbags or mulch bags in lieu of regolith. With a thermally moderate year-around season now possible, experiments with modular biospherics can begin so that as the physical complex keeps growing, its contained biosphere can grow apace.

While field research in geology and exobiology can continue, experiments with simulated lunar- and Mars-producible building materials should be a major focus. To better stretch expensive manpower on both worlds, experiments in pushing the limits of teleoperation should be a major focus as well.

Currently, by gambling everything on an Apollo-like one-time exploration mission to Mars, we risk selling out our dreams to those who do not share them. Yet we can't change or alter the MDRS/FMARS Research program and goals. You can lead a horse to water, but you can't make it drink. We can help by doing research at lunar analog facilities (and in Chile) that help promote settlement of both worlds.

The direction of the Mars Society is its own worst enemy. If any other MDRS/FMARS alumni/veterans would like to join us in developing a superior Mars Analog Research Program, please write kokhmmm@aol.com and tell us about your own experiences, interests, abilities, etc. If it is true, as we have long expected, that the Lunar and Mars Frontiers will either thrive together or both fail separately, an effort to salvage the Mars Society's analog program can only help support our own analog program.

Not all Moon Society members feel this way, and the Society is anything but a top-down dictatorship. But petty "either us or you" rivalry is self-defeating. We all owe it to ourselves to get out of the Moon or Mars mentality and into the Moon *and* Mars frame of mind. Start by reading this document:
www.moonsociety.org/reports/mars_conv2004/Moon_Mars_Similar.pdf

Beyond Moon & Mars! *On to the Stars!* **<PK>**

Mars Settlement-Preparation Research Outside of Analog Station Environments

By Peter Kokh

Some twenty years ago, Robert Zubrin revolutionized Manned Mars Mission scenarios by demonstrating that we could produce the fuel needed for the trip back to Earth from Mars' Atmosphere. This could reduce the total mass of the ship(s) setting out from Earth by as much as 90%. NASA eventually bought into a modified version of Zubrin's "Mars Direct" plan. See MMM #30, November 1989, "NIMF: **N**uclear rocket using **I**ndigenous **M**artian **F**uel: An Enabling Technology for Manned Mars Missions with Global Access in a Single Launch" by Robert M. Zubrin. Republished in MMM Classic #3 pp. 52-55 Available as a free pdf file download from:
www.moonsociety.org/publications/mmm_classics/

This was a historic and brilliant step forward, and he proceeded to build a working model of his adiabatic reactor, since duplicated by others. Unfortunately, in failing to pursue this research further, he/**we** have dropped the ball.

1. What besides Methane can we make from Mars Atmosphere?

Other fuels? Useful chemicals? Plastics? Shielding? Feedstocks for a basic aero-chemicals industry?

If our goal goes beyond manned exploratory sorties to real settlement, we ought to have been asking that question, and finding answers over the twenty years since! Mars' atmosphere is 97% Carbon Dioxide, 3% Nitrogen, some water vapor, and with a sampling of other elements such as argon and other noble gasses. Methane CH_4 is certainly useful. But so are its "upgrades" Ethane C_2H_6 and **Propane** C_3H_8, a liquid fuel.

Ethylene, C_2H_2 is the most produced organic chemical in the world. And its polymer, **polyethylene** is the most abundant plastic. Low density and high-density polyethylene resins (**LDPE** and **HDPE**) are extremely versatile and fully recyclable manufacturing materials, whose diverse products most of us use on a daily basis.

Polyethylene has also been shown to be a superior thermal and radiation barrier. On Mars, it might be more difficult to loosen up pulverized powdered regolith soil to use as shielding than on the Moon. Mars' regolith may be more densely compacted because if the planet's 2.25 times greater gravity. Use of an atmospheric product for shielding could be a desirable solution, and allow keeping outpost landscapes in a more pristine condition.

Here on Earth, polyethylene is produced from petroleum. While all the needed elements are present in Mars' atmosphere, we may need catalysts and reagents to produce it directly from the atmosphere. If these are recyclable, to be used over and over, then this alternative process may be a practical one. *We need to try!*

Beyond basic hydrocarbons, nitrogen is available from the atmosphere as well. But taking a Mars' based chemicals industry any further (introducing chlorine, sulfur and other elements) must await development of a mining industry. The point is, that ***the more organic substances and useful materials for which we can demonstrate the production from Mars' atmosphere, to stockpile in advance of crew arrival as a jump start to a basic level of self-sufficiency for the pioneers***, the more support and less opposition the idea of settling Mars will generate.

We may already know the basic chemical process pathways involved. *What we really need to do is to develop the lightest weight equipment feasible for a given amount of production output.*

We also need to develop lightweight storage systems so any atmospheric byproducts can be stockpiled on location. Inflatable containers with rigid bottoms would be our suggestion, *lightweight and compacted for shipment.* On Mars, the chance of micrometeorite puncture should be much less than on the Moon, where filled inflatable tanks could be placed under a pre-built shelter to provide thermal stability as well. Inflatable bladders for gasses, liquids, solids and substances expected to change state with the seasons could be developed.

Now if these bladders could be produced on Mars that would be even more helpful. Providing a "produced on Mars" stockpile of as many consumables as possible is the name of the game: not just fuel for trips home!

2. Experimental Mars Agriculture in Marslike Air

That we can grow crops in a carbon dioxide atmosphere at 10% of Earth normal pressure, and in turn ten times the pressure on Mars, suggests *an agriculture that meets Mars "halfway."* These are experiments that are easy enough to do here on Earth in a project we have dubbed "redhousing." See MMM Classics # 10, pp. 25-27, Available as a free pdf file download from:
www.moonsociety.org/publications/mmm_classics/

The greater the number and the variety of food crops, and of plants useful in other ways (fiber, spices, pharmaceuticals, dyes, etc.) that we can demonstrate can be successfully raised in "redhouse" conditions, the lower we will have reduced the threshold for successful Mars settlement. More, the idea of meeting Mars "halfway" will begin to look like a doable long range plan for settlers to go beyond subsistence to actual thriving on Mars. This philosophy should appeal to environmentalists and economists alike. Widespread support for establishment of a Mars Frontier will make everything easier.

And if a semi-automated, partly teleoperated food growth system could be set up so that the first crops were ready to harvest when the first pioneers arrived, what a welcome omen that would be!

We will get nowhere unless we dream what would seem at first to be absurd and impossible. It is not only the pioneers that need to have the right stuff. It is those who are preparing the way for them, maximizing the chances of success.

3. Finding Minerals for Martian Industries

We cannot live on organic substances alone! If we want Mars frontier settlement to succeed, we have to mount a campaign to skew the choice of instruments aboard future Mars orbiters and landers to include those that will identify not just those elements useful for a geological understanding of Mars' physical evolution, but also of elements necessary for industry. Taking a page from orbital exploration of the Moon, we need not worry about identification of areas rich in iron, magnesium, titanium, and thorium. But we need to know where best to look for many other vital elements as well.

This will take some campaigning! NASA (we might assume the same for ESA, China, Japan, India, etc.) goes through proposals from principal investigators and decides on the basis of which proposals are the most advanced, and which the least costly. How they fit the needs of would-be frontier-settlers does not enter into these decisions at all. While all science has some practical implications, as a constituency pushing to open the Martin and Lunar frontiers, we need to make the case for prioritizing practical applications and needs.

√ Instruments to map permafrost areas *and* to detect sub-surface ice and aquifers

√ Instruments to detect and map subsurface voids such as lavatubes and trapped gas pockets

√ Instruments to detect all industrially vital elements, such as copper, platinum, sulfur, phosphorous, potassium, and on and on.

The idea is to have data on which to base sound decisions on **where to set up industrial centers**. Not just anywhere will do, and certainly ***basing site decisions on geological and exo-biological curiosity alone is begging failure, and failure sooner rather than later.*** In the long term there will be immeasurably more geological and exo-biological exploration and research, if these activities are supported by a permanent and growing frontier population. Patience will pay off enormously!

4. Mars transportation systems

Mars is a big place, as big as all Earth's continents put together. We have already pointed out that the two most strategic places on Mars are half a world apart, some 7,000 miles or 11,000 km. Even if settlement of the northern part of the Hellas basin is postponed, we are unlikely to find everything we need for settlement self-sufficiency within short range of anywhere on Mars. And most certainly, monotonous appearances aside, one site is not as good as another!

There has been much talk about the feasibility of aviation on Mars. Enough talk! We need demonstrations and improvements and more demonstrations etc. We will need aircraft that can do reconnaissance but also carry passengers and some freight.

It would appear that ground-effects vehicles that could ignore the boulder-strewn fields of Mars and glide above the surface are unlikely. That doesn't mean we should not try to prove this assumption wrong. Railroads to haul cargoes and materials are a real possibility. How can we redesign them to suit the Martian climate and conditions?

The list of things we can do to demonstrate the feasibility of successful self-supporting Martian settlement is longer than we suspect. But we have to start making inroads if we are going to change opinions. There is a limit to self-sufficiency and the new Martians will need income-earning export options. Everything we can demonstrate that will give pioneers the edge, brings the day when we decide to open the Mars frontier *closer.*

Thriving Together vs. Withering Alone

How will future Martians pay for those things that cannot be produced (whether *not yet* or *not ever*) locally is the real question. It would seem that there is nothing Mars can produce that Earth cannot also make, except experiences. And very few will be able to afford the cost *and the time* for round trip tours of Mars!

We have seen science-fantasy suggestions such as life-saving pharmaceuticals (perfumes, aphrodisiacs, etc.) made from *special Mars' soils* that cannot be duplicated on Earth; or unique priceless gems made in the throats of Martian volcanoes. We have seen *no suggestions that are realistic* other than exporting things to the Moon at lower shipping costs than they can be shipped up (more quickly) from Earth.

On the other hand, building materials from the Moon, would be cheaper for building out LEO and GEO than equivalents rocketed up from Earth's surface. So helping make the lunar economy work is the key to making the Martian economy work.

Given its shallower gravity well, Mars will be a cheaper source of imports for the lunar frontier than Earth. Some items needed on Mars may be less expensive to import from the Moon. And this is our choice. Either prosper together, *Moon and Mars,* or face economic collapse apart. The Moon and Mars are logical trading partners. Those too proud to accept this will end up suffering the consequences.

In planning lunar industrialization priorities, it would pay then, to give some emphasis to those basic industries that could produce equipment and products of critical need on both Moon and Mars. Designing equipment for lunar and for Martian use may require some specific differences: but the two frontiers, in comparison to conditions on Earth, are similar in more respects those in which they are different. Equipment that proves out on the Moon may work on Mars with few adjustments, and if made on the Moon, for shipment to Mars, will cost less. And vice versa. It is only reasonable to expect one frontier to be ahead of the other in some respects, and the opposite in others. The most important thing in common is the need to become *as self-sufficient as possible as soon as possible*, should financial and other support from Earth decline or be interrupted.

There is much homework ahead of us. Leaving it to the government is not the answer. Working hand in hand (Moon and Mars supporters) should yield practical solutions and pathways for further investigation! If we spawn outposts on either or both worlds that could not survive collapse of civilization on Earth, or even an indefinite pause in support, then our effort to create additional baskets for Gaian and Human eggs will have failed. While such a level of survivability will be hard won at best, it is a goal that must be pursued in earnest from the outset. Dependency by design, intentional or not, is unacceptable. If we are going to expand the human world beyond Earth orbit, we need to do it right, and that means no half-measures.

In this respect, ***neither*** the Return to the Moon nor the push for a Mission to Mars, have been on the right track. We cannot assume that either NASA or any government bureaucracy, focused on exploration only, will understand these things. If it is our dream, we must take responsibility for getting it on the right track and keeping it there.

It is in the interests of Lunar Frontier enthusiasts to promote pre-development of any and all technologies that will help open the Martian frontier. Whether Mars frontier enthusiasts return the favor is immaterial. For us Lunans, this is a win-win situation. In time, "Mars only" advocates are bound to understand this. **<PK>**

MMM #234 - APR 2010

Lunar Thermal Wadis

MMM Special Report by Peter Kokh

Lunar Thermal Wadis & Exploration Rovers
NASA Lunar Surface Systems Concepts
February 25-27, 2009
http://www.nasa.gov/pdf/314555main_AIAA-2009-1339-125_Thermal_Wadi.pdf

"**wadi**" is an Arabic term common in Syria and Northern Africa for a watercourse that is only intermittently flowing with water, and is otherwise dry, often with wet soil below a dried surface. An oasis. The Sudanese city of Wadi Haifa gets its name from such a feature.

Here the term is applied by analogy.

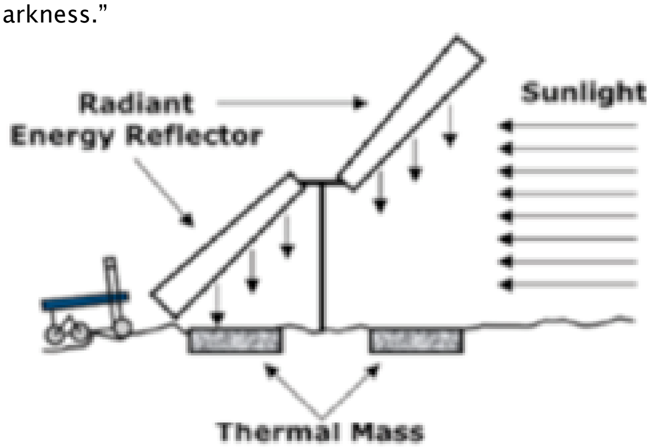
Source: Analysis of Solar-Heated Thermal Wadis to Support Extended-Duration Lunar Exploration
AIAA 2009-1339

Excerpt from the above:

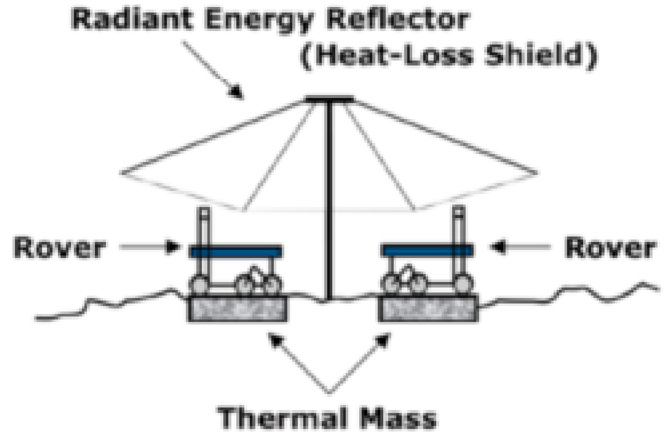
"Among the many challenges that renewed exploration of the Moon is the survival of lunar surface assets during periods of darkness when the lunar environment is very cold.

"Thermal wadis are **engineered sources of stored solar energy using modified lunar regolith as a thermal storage mass** that can enable the operation of lightweight robotic rovers or other assets in cold, dark environments without incurring potential mass, cost, and risk penalties associated with various onboard sources of thermal energy."

"Thermal wadi-assisted lunar rovers can conduct a variety of long-duration missions including exploration site surveys; teleoperated, crew-directed, or autonomous scientific expeditions; and logistics support for crewed exploration. This paper describes a thermal analysis of thermal wadi performance based on the known solar illumination of the moon and estimates of producible thermal properties of modified lunar regolith. Analysis was performed for the lunar equatorial region and for a potential Outpost location near the lunar South Pole. The results are presented in some detail in the paper and indicate that thermal wadis can provide the desired thermal energy reserve, with significant margin, for the survival of rovers or other equipment during periods of darkness."



Above: a sun-tracking reflector directs sunlight onto a thermal mass during periods of solar illumination while rovers conduct lunar surface operations.



Above: rovers are thermally coupled to the thermal mass to stay warm during the nightspan, and further protected by a heat-loss shield to limit radiative losses to space.

Above: The setting sun illuminates a rover parked on its prepared pad of heat-retaining compacted soil under an umbrella that retards heat radiation to cold black space.

Excerpt: "The thermal property values of the thermal mass are critical to the effectiveness of the thermal wadi. In its native state, lunar regolith is a poor material for thermal energy storage. Due to its very low thermal diffusivity, ... per measurements made during the Apollo program, heat does not penetrate the lunar surface very deeply and is lost rapidly due to radiation during periods of darkness. It is this property that accounts, in part, for the large surface temperature swing during the Moon's 27-day diurnal cycle.

"However, the regolith contains the elemental materials needed for a reasonable thermal energy storage medium, and experiments on Earth have demonstrated that solar and/or microwave energy can enable the necessary conversion processes. Examples of regolith processing methods that can produce thermal masses with improved thermal properties include:

- Compacting and sintering
- Melting processed or unprocessed regolith, then solidifying the melt into a solid block
- Incorporating hardware and/or materials with high-thermal conductivity and/or high-thermal capacity.
- Reducing regolith, by thermochemical or electro-chemical means, to produce a metal-enriched product

The paper goes into details on the relative merits of these options, the practicality of their use, and makes recommendations. Using the moondust's own assets to combat the harsh lunar environment, is a win-win option.

MMM

Salvaging the Google Lunar X-Prize "Also-Rans"

By David A. Dunlop,
Moon Society Director of Project Development

Google Lunar X-Prize –
www.googlelunarxprize.org/lunar/about-the-prize/introductory-video
www.googlelunarxprize.org/lunar/about-the-prize
www.googlelunarxprize.org/lunar/about-the-prize/rules-and-guidelines
www.googlelunarxprize.org/lunar/teams

Opportunities, Incentives, and Tools For New Lunar Science Missions

Google Lunar X-Prize Teams

- Twenty teams are now vying for Google Lunar X-Prizes. While only two teams at best will win the 1st and 2nd prizes, the other team programs may offer potential options for further development. If so, their investments to date should not be wasted.
- Their merits with regard to technological innovation or cost-efficient models should be not go untested simply because they were not the first or second to land on the Moon.
- GLXP teams that do not win 1st or 2nd prize will require incentives and support to continue advancing their projects to flight readiness status and actual flight to the Moon.
- These also-rans *may present opportunities to "re-purpose" their lunar landers to deliver needed or desired science payloads to lunar surface.*
- Evaluation of each team's design should be made in terms of
  - Risk reduction,
  - Technical feasibility
  - Cost efficiency
  - Suitability as platforms for lunar science missions that should be supported by the various national space agencies for those teams open to a follow-on incentives program to the original GLXP program.
- NASA and ILEWG (International Lunar Exploration Working Group) partners should support lunar program approaches and incentives that foster both international and commercial collaborations.

Incentive Science Contracts are an example of how this could work

- $50M incentives should be offered for delivery of ILN (**International Lunar Network**) science packages comprising laser retro-reflector cube, seismometer, lunar radiation monitors, and heat flow probes – http://nasascience.nasa.gov/missions/iln

Technology Incentives

A. NASA and DOE should offer RTG technologies as a missions-enabling technology incentive to lunar rover missions that deliver long duration sorties on the models of Pathfinder, Spirit, and Opportunity, and which address high priority science objectives. This should be jointly competed by ESMD (NASA Exploration Science Mission Directorate) and SMD (NASA Science Mission Directorate). http://en.wikipedia.org/wiki/Radioisotope_thermoelectric_generator

B. Incentives should be created for technology demonstrations that use non- nuclear techniques to survive the lunar night cold temperature cycle, such as "Lunar Wadis" – see preceding article.

C. Incentives should be offered and competed for principal investigators and teams which can demonstrate achievement of *science goals that are on lunar science road map* so that the process of lunar science missions development is more "granular" and financial "assets can be brought to the table" in consideration of lunar missions proposals by science investigators and teams whose instruments have been competitively qualified.

Open-Source Student Lunar Lander Engineering Missions

As a means of driving down the cost of lunar transportation and creating opportunities for the next generation of lunar engineers and scientists, the ILEWG nations should supports University-based engineering teams and networks working on a transparent open source basis.

Following the precedents of the ESMO (European Student Moon Orbiter) and ASMO (American Student Moon Orbiter), and **cubesat** projects ILEWG partner nations should all support at least one "open source" and "ITAR free" student lunar lander missions. This would create a pool of shared designs and platforms for engineering support of lunar landers and rovers and the expansion of the "lunar robotic village" by 2020.

These student lunar lander platforms should be cost justified by the requirement to deliver lunar a greater volume of lunar science packages to the surface, the need for technology demonstrations on the lunar surface, and the support of engineering workforce development goals.

An Open-Sources Science Proposals Database

An open data base for lunar science missions proposals should be created which identifies principal investigator, sponsoring organization, proposed science instruments, Their Technology Readiness Level, Lunar Science road Map Objectives, mass, power requirements, cost, so that the lunar community of interest is easy to identify and the lunar mission "market" potential for lunar science is transparent. This database should build on the Lunar Orphans Flight Test (LOFT) list of NASA Lunar Commercial Services Commercial Crew and Cargo Office and the ESA Lunar Science Proposals Solicitation lists. All ILEWG member agencies should be invited to support this database. **DAD**

LUNAR BASALT

What, Where, and its Critical Role for Lunar Industrialization and Settlement

By David Dietzler
With contributions from Peter Kokh

1) Technical Terms and Chemical Description of "Basalt," "Gabbo," "Lava," "Magma"

Basalt is hardened surface "lava. Hardened subsurface lava is called gabbro. Molten surface rock is called lava and molten subsurface rock is called magma.

The lunar mare areas are covered with basalt pulverized into a fine powder by eons of meteoric bombardment. This material will be relatively easy to mine with power shovels.

This regolith consists of pyroxenes (iron, magnesium, and calcium silicates: SiO_3), olivines (iron and magnesium silicates Si_2O_4), ilmenite $FeTiO_3$, spinels and plagioclase $CaAl_2Si_2O_8$.

Lunar basalts are classified as high, low and very-low titanium basalts depending on ilmenite and Ti bearing spinel content. **They differ from their terrestrial counterparts** principally in their high iron contents, which range from about 17 to 22 wt% FeO. They also exhibit a range of titanium concentrations from less than 1 wt% TiO_2 to 13 wt% TiO_2. A continuum of Ti concentrations exists with the highest Ti concentrations being least abundant. Lunar basalts differ from terrestrial basalts in that they show lots of shock metamorphism, are not as oxidized and lack hydration completely.

See: http://en.wikipedia.org/wiki/Basalt

Olivine contents range from 0% to 20%. Basalts from the mare edges or coasts probably contain more plagioclase, the mineral that makes up most of highland soils, than basalts closer to the center of the mare.

Types of Processed Basalt

● **Cast Basalt:** Basalt can be melted in solar furnaces, *cast into many forms*, and heated again and allowed to cool slowly (annealing) to recrystallize and strengthen the cast items. It can be cast in iron molds and possibly in simple sand molds dug into the surface of the Moon.

Iron could be obtained by harvesting meteoric Fe-Ni fines that compose up to 0.5% of the regolith with rovers equipped with magnetic extractors. Iron molds could be cast in high alumina cement molds. The high alumina cement could be obtained by roasting highland regolith in furnaces at 1800-2000 K to drive off silica and enrich CaO content. This could be hydrated in inflatable chambers with condensors to recover water vapor. It might also be cost effective to upport iron molds to the Moon since they would have a very long lifetime.

● **Sintered basalt** is not fully melted. It is placed in molds, pressed, and heated with microwaves or solar heat just long enough for the edges of the particles to fuse. This will require less energy than casting. Sintered Basalt can be used for low-performance external building blocks, pavers, and other uses.

● **Drawn basalt fibers** are made by melting basalt and extruding it through platinum bushings.

● **Hewn basalt** is quarried from bedrock, road cuts, or lava tube walls. It can be cut with diamond wire saws.

2) Uses of Basalt: source:

http://en.wikisource.org/wiki/Advanced_Automation_for_Space_Missions/Chapter_4.2.2

Table 4.16 Lunar Factory Applications of Processed Basalt

Cast Basalt - Industrial uses

- Machine base supports (lathes, milling machines)
- Furnace lining for resources extraction operations
- Large tool beds
- Crusher jaws
- Sidings
- Expendable ablative hull material (possibly composited with spun basalt)
- Track rails reinforced with iron prestressed in tension
- Railroad ties using prestressed internal rods made from iron
- Pylons reinforced with iron mesh and bars
- Heavy duty containers (planters) for "agricultural" use
- Radar dish or mirror frames
- Thermal rods or heat pipes housings
- Supports and backing for solar collectors
- Cold forming of Metal fabrication with heat shrink outer shell rolling surfaces

[Current industrial uses omitted above]

- Abrasion-resistant Pipes and conduits
- Abrasion-resistant Conveyor material (pneumatic, hydraulic, sliding)
- Abrasion-resistant Linings for ball, tube or pug mills, flue ducts, ventilators, cyclers, drains, mixers, tanks, electrolyzers, and mineral dressing equipment
- Abrasion-resistant floor tiles and bricks

Cast Basalt - commercial, agricultural, & residential uses (omitted on source list above)

- large diameter (3" plus) pipe for water mains and for toilet and sewer drainage systems
- floor tiles
- countertops, tabletops, backsplashes
- planters and tubs of all sizes, flower pots
- possibly contoured seating surfaces (contoured seats lessen the need for resilient padding, cushions)
- lamp bases
- many other commercial and domestic uses

Sintered Basalt (from URL reference above)

- Nozzles
- Tubing
- Wire-drawing dies
- Ball bearings
- Wheels
- Low torque fasteners
- Studs
- Furniture and utensils
- Low load axles
- Scientific equipment, frames and yokes
- Light tools
- Light duty containers and flasks for laboratory use
- Pump housings
- Filters/partial plugs

{Logical lunar uses omitted from above list]

- Blocks for shielding retainer walls
- Slabs for airlock approaches, external paths and walks
- lightweight light-duty crates and boxes
- Acoustic insulation
- Thermal insulation
- Insulator for prevention of cold welding of metals
- Filler in sintered "soil" cement
- Packing material
- Electrical insulation
- “Case goods” furniture as we might use wood composites such as OSB, MDF, etc.

Basalt Fiber – Uses (in place of glass fibers)

- Cloth and bedding, pads and matts
- Resilient shock absorbing pads
- Acoustic insulation
- Thermal insulation
- Insulator for prevention of cold welding of metals
- Filler in sintered "soil" cement
- Fine springs
- Packing material
- Strainers or filters for industrial or agricultural use
- Electrical insulation
- Ropes for cables (with coatings)

[In Gujarat at M .S. Univ., Kalabhavan, Baroda, basalt fibers are used as a reinforcing material for fabrics, having better physicomechanical properties than fiberglass, but significantly cheaper than carbon fiber.] www.fibre2fashion.com/industry-article/3/256/new-reinforced-material1.asp

- basalt brake pads? (no asbestos on the Moon)
  http://www.technobasalt.com/news/?id=14
  http://www.basalt-tech.ru/en/prospects

Hewn Basalt (MMM’s list)

- Heavy duty Building blocks
- Road paving slabs
- Heavy duty floor slabs
- Architectural pillars, headers, arches
- [a] Carving blocks for sculpture statues, other artifacts
  - lamp bases, mancala/oware boards, etc.
  - fountains, bowls, table pedestals, vases, etc.
  - statues, plaques, beads, bracelets, endless list

3) Properties of basalt From--
http://www.islandone.org/MMSG/aasm/AASM5C.html

Table 5.9.- Properties Of Cast Basalt

Physical properties Average numerical value, MKS units

Density of magma @ 1473 K 2600-2700 kg/m3

Density of solid 2900-2960 kg/m3

Hygroscopicity 0.1%

Tensile strength 3.5X107 N/m2

Compressive strength 5.4X108 N/m2

Bending strength 4.5X107 N/m2

Modulus of elasticity (Young's modulus) 1.1X1011 N/m2

Moh's hardness 8.5

Grinding hardness 2.2X105 m2/m3

Specific heat 840 J/kg K

Melting point 1400-1600 K

Heat of fusion 4.2X105 J/kg (+/-30%)

Thermal conductivity 0.8 W/m K

Linear thermal expansion coefficient
... 273-373 K 7.7X10-6 m/m K
... 273-473 K 8.6X10-6 m/m K

Thermal shock resistance 150 K

Surface resistivity 1.0X1010 ohm-m

Internal resistivity 1.0X109 ohm-m

Basalt magma viscosity 102-105 N-sec/m2

Magma surface tension 0.27-0.35 N/m

Velocity of sound, in melt @ 1500 K 2300 m/sec (compression wave)

Velocity of sound, solid @ 1000 K 5700 m/sec (compression wave)

Resistivity of melt @ 1500 K 1.0X10-4 ohm-m (author's note--this is of importance to magma electrolysis which requires an electrically conductive melt)

Thermal conductivity,
... melt @ 1500 K 0.4-1.3 W/m K
... solid @ STP 1.7-2.5 W/m K

Magnetic susceptibility 0.1-4.0X10-8 V/kg

Crystal growth rate 0.02-6X10-9 m/sec

Shear strength ~108 N/m2

4) Gallery of Basalt Products

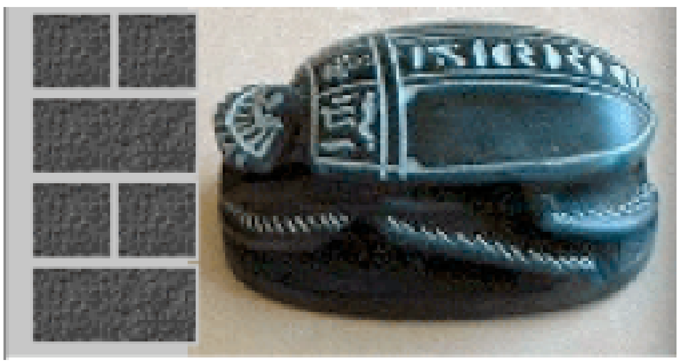
Cast Basalt Pipes

With unequalled abrasion-resistance, such pipes *and chutes* will be **pre-requisite** for all moon dust handling industries, even for oxygen production.

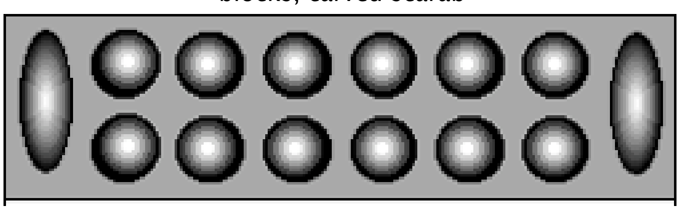
Cast Basalt tiles (from Czech Republic)

Cast basalt planter

Hewn and carved basalt:



blocks, carved scarab



A Mancala or Oware game board

A bathtub

Note: The above are individually crafted items. Production items include pipes and tiles of various kinds.

Basalt: What Does All This Mean?

By Peter Kokh and Dave Dietzler

The cute things such as what you can carve out of solid basalt, aside, the essential message is in the abrasion resistance of basalt vs. the very abrasive nature of moon dust out of which we are going to have to make as much as possible. The name of the game is to produce locally on the Moon as much as possible of local frontier needs, and to develop export markets for those things, to defray imports on the one hand, and to earn credits to import what they cannot produce on the other hand.

Our Thesis: A lunar basalt industry is **pre-requisite** to any other lunar materials industry. Unless we prefer to bring from Earth, all items needed to handle abrasive material such as moon dust,

Lunar industrial settlement must have access to basalt

We believe that we must start in the maria, preferably along a mare/highland coast with access to both major suites of lunar material. The Lunar North Pole is some 600 miles from the nearest such coast - the north shore of Mare Frigoris. The Lunar South Pole is more than twice as far removed from the nearest such coast, the south shore of Mare Humorum.

Despite the advantage of more hours of sunlight, and eventually recoverable water ice, starting at either pole could be an industrial dead end.

Yes, access to water is essential, but most of us interested in lunar settlement, *before the possibility of finding water ice at the pole became a common hope,* were determined to launch lunar settlement anyway. We would harvest solar wind protons from the moondust and combine them in fuel cells with oxygen coaxed from the same soil, to make water and extra power.

Having to do this, despite the now-confirmed reserves of water ice at the poles, may be a good thing, as it will prevent the rape of water-ice for the production of rocket fuel, and thereby preserve it for future lunar settlement needs including agriculture and biosphere. Yes Liquid Hydrogen and Liquid Oxygen are the most powerful fuels now in use. But 1) we don't need that much Isp to rocket off the Moon, or to hop from here to there on the Moon, and 2) we should be more concerned with developing more powerful fuels anyway, including nuclear fuels.

The polar water ice is at cryogenic temperatures, and extremely hard. Harvesting it in darkness at the bottom of steep crater walls will not be easy, and unless done entirely robotically, could be a very risky occupation. That it will be easy to harvest is myth #2. Myth #1 is that the sunlight at the poles is eternal. Honest estimates are that sunlight at any one spot is available only 76% of the tie at the South Pole, and possibly 86% of the time at the North Pole. That means for 52% of the nightspan at the South Pole and 72% at the North Pole. We must still bite the bullet and learn to store dayspan power for nightspan use for 100% of the nightspan, a factor of 2 times as long at worst. Then we can go anywhere, including places where a more complete suite of mineral assets are available, including possible gas deposits elsewhere.

The critical role of basalt is so fundamental to success that we must rethink our destinations. **DD/PK**

"Manned Space Exploration is Worth the Risk"

Our Apollo 13 40th Anniversary Essay Contest

[To insure judge neutrality, all the submitted essays bore only a ***code name*** and not the author's real name]

Above: the A13 Service Module Explosion captured in the imagination and art of Apollo 12 astronaut Alan Bean

A Focused Advocacy for Human Space Exploration

By Edward N Brown, Lakewood, California

Code name *Graystone_ebck*

Contest 1st Prize Winning Entry

It is generally agreed by most people that exploration and discovery are good and beneficial for future life and wellbeing. What are not in universal agree-ment are the approach that should be taken, the cost/ resources that should be allocated, and the Risk that should be allowed. As we acknowledge and appreciate this year the heroic efforts involved in the rescue of the Apollo-13 astronauts 40 years ago, many people are asking, "Is human space exploration worth the Risk?" If we are to answer 'Yes' to this question, we must be prepared to provide a convincing argument to support that position.

It is said that beauty is in the eye of the beholder. The same can be said about Risk. The degree of Risk involved in undertaking an activity can be estimated reasonably well by experts. Complexity, resource availability, and timeframe drive the estimate. But the degree of Risk that is tolerable by an organization or an individual is a much harder thing to ascertain. So when asked the question "Is it worth the Risk?", the answer is not straightforward. It depends upon the Risk tolerance of the evaluator. Four well-known factors drive the Risk tolerance*. Furthermore, the relevant tradeoffs are different for an individual considering undertaking an activity, an advocate proposing that someone else undertake an activity, a commercial establishment contemplating the prospect of starting an activity, and a governmental organization deciding whether to pursue an activity. Each has their own set of needs, desires, constraints, fears, and avoidances (henceforth abbreviated NDCFA) that influence their tradeoffs regarding Risk tolerance.

Let's look at the case of the advocate. To successfully advocate for something, you have to know your target. Then you have to "see-through-his-eyes"; to figure out what his NDCFA are, so you can try to persuade him to align his thinking with your own. Now let's consider the question of whether manned space exploration is worth the Risk. As an advocate, we believe that it is, but who are we trying to convince, what are their NDCFA, and how should we proceed? It is important to note that we are talking about "exploration" and not travel, commerce, or pioneering. This will steer our approach.

"Exploration" can be defined as the search or investigation of the unknown, with the aim of making discoveries that will maximize the tradeoff of self or group NDCFA**. There are three relevant types of travel-based "exploration"***. The Experimental type may have instances where human-tended experiments have value, but in general, manned programs compete poorly with unmanned robotic programs because of the high cost and safety disparity. The Geophysical type may be applicable to small-scale proof-of-concept efforts, but these niche programs always have environmental and popular ramifications. However, the Experiential type is driven by the desire to affect the tradeoff of NDCFA by improving sensory awareness of the surrounding environment. At the group level, these programs are usually under the purview of government organizations, and this is where we should concentrate our advocacy. Space tourism, adventure, vocation, or settlement might be applicable at the individual level (which has a very different NDCFA set), but large-scale experiential-type exploration is applicable to the government realm because the NDCFA are nationalistic.

A good place to start to understand the US Government's NDCFA is to review the current US National Space Policy. Of the seven Goals stated, Goals 1, 3, and 5 are very relevant to human space****. Although it is hard to pinpoint, I'm betting that the Goals that contain the words "strengthen leadership" are the key needs and desires. These Goals also give insight into the fears and avoidances, which must also be considered. Thus the central argument around which we formulate an answer to the original question must involve the concept of retaining US world leadership in space*****.

The advocacy argument is this: The nation that leads the world in human space exploration will lead the world in the projection of its political, economic, value, and belief systems. It would be unthinkable to allow another nation with a different set of priorities to be the world's leader in the projection of those systems to the rest of the world. This was the driver behind President Kennedy's challenge to the nation in 1961 and it is still valid today. The most important sentence in his May 25 Message to Congress is "We go into space because whatever mankind must undertake, free men must fully share." That says it all. To insure that freedom, and not tyranny, will be the predominant social institution as mankind explores the space frontier, the US must be the world's leader. That is the overarching reason why human space exploration is worth the Risk. Loss of leadership could result in loss of freedom and diminution of our hard-earned values, beliefs, and economic well-being. Our foreign policy is based on that precept. It is the overriding need of the US Government.

There are a lot of catch phrases that can support the argument. "Oh, by-the-way, human space exploration will also _____". You can fill in the blank: "improve economic prosperity by creating jobs, enhance national security by providing in-situ observers, increase the future science/engineering workforce by inspiring youth, improve civil operational efficiency through maintenance/ repair of space assets (Hubble)", come immediately to mind. There are others, and they are all important.

Finally, it is sometimes tempting to wax eloquent about how human instincts (curiosity) or human destiny (species survival) compel human space exploration. While this may gather emotional support among the already-converted, it won't get you any political-sway in Congress or the Executive branch.

In conclusion, by following a focused approach to advocacy, we can maximize its efficacy. We can respond 'Yes' to the question "Is human space exploration worth the Risk?" with a specifically tailored answer that targets the key NDCFA (along with supporting arguments) of US Government leadership. Of course, a good advocacy would also have prepared counter-arguments to respond to critics, lobbyists, and anti-advocates. But that is the topic for another essay.

Footnotes:

* Risk tolerance is a complex function of 4 factors:

1. What you want at the end of the day
2. What it may cost you to get it (which may not be just monetary)
3. What it may cost you if you don't get it (which may include loss of human life)
4. The uncertainty (probability, likelihood) in the activity that is hoped to get you what you want, actually coming to fruition (the degree of Risk)

** The Needs and Desires are also known as Goals and Ambitions in the "literature" (reports, articles, books, magazines, etc.)

*** The 4 types of discovery-based "exploration" (2, 3, and 4 may be travel-based):

1. Conceptual/Philosophical - special religious, cultural, or personal focus - analytical orientation - result is intellectual gratification - driven by desire for insight into life and existence, or personal fulfillment
2. Experimental - scientific focus - research orientation - result is data and understanding of the data driven by desire for knowledge or understanding of natural physical phenomena throughout the universe
3. Geophysical: topographic focus, prospecting orientation: result is location of minerals or natural resources driven by desire for accumulation of raw materials useful in the manufacturing of products which can be profitably distributed to create wealth
4. Experiential - geographic focus - mission orientation - result is maps, organized observations/descriptions, territorial claims - driven by desire for sensory awareness of surrounding environment to fulfill organizational (e.g. sovereignty, prestige/power projection) or community/individual (e.g. survival, comfort/happiness) needs and desires

****Goals of US National Space Policy (31 August 2006):

1. Strengthen the nation's space leadership and ensure that space capabilities are available in time to further U.S. national security, homeland security, and foreign policy objectives;
2. Enable unhindered U.S. operations in and through space to defend our interest there;
3. Implement and sustain and innovative human and robotic exploration program with the objective of extending human presence across the solar system;
4. Increase the benefits of civil exploration, scientific discovery, and environmental activities;
5. Enable a dynamic, globally competitive domestic commercial space sector in order to promote innovation, strengthen U.S. leadership, and protect national, homeland, and economic security;
6. Enable a robust science and technology base supporting national security, homeland security, and civil space activities; and
7. Encourage international cooperation with foreign nations and/or consortia on space activities that are of mutual benefit and that further the peaceful exploration and use of space, as well as to advance national security, homeland security, and foreign policy objectives.

** In May 2009, President Obama issued Presidential Study Directive PSD-3, calling for a broad review of the U.S. national space policy of former President Bush.

Manned Space Exploration is Worth the Risk

By Jared Treadway, Amelia, Ohio

Code name Emmacup

Contest 2nd Prize Winning Entry

Apollo 1, Soyuz 1, Soyuz 11, Challenger, Columbia:

To date, twenty-one brave space explorers have lost their lives while pushing back the frontier of humanity. When they died, not only did their families enter a black period of mourning, but entire nations grieved. In that grief we heard the rumblings of those who argued the futility of manned space exploration. They insisted that the deaths of these brave astronauts and cosmonauts were unnecessary, and that manned space exploration was not worth the risk of losing our sons and daughters, mothers and fathers, husbands, wives, and dear friends. Perhaps they have a point… perhaps.

Fear of loss is a powerful incentive to play it safe. Nature has provided us with a deeply-rooted instinct to protect those whom we love, and this feature has helped us to survive as a species in the face of countless dangers. Yet, fear isn't the only mechanism by which humanity has survived. Our mobility and vision have again and again drawn us to the horizon in search of greener pastures. Our will to survive led us out of Africa, across Asia, into Europe, and into the Americas. Our adaptability to a variety of environments laid the world at our feet. And even when the horizon had been conquered, the sheer challenge of diverse landscapes compelled brave women and men to scale Mt. Everest, race across Death Valley, swim the English Channel, or dogsled across Antarctica. Tackling a challenge brings out the best in humanity, plays to our strengths, strengthens our weaknesses, and strangely fulfills an oft-ignored void. Nature threw down the gauntlet, and humanity answered.

Yet, for restless humanity, another challenger now taunts; one that is akin to past challengers, yet dwarfs them by its vastness. The vacuum of space is monstrous, unforgiving, harsh, and takes no prisoners. Hitherto our challenges have taken place on our home turf, *terra firma*, where adaptability, though challenging, is possible. In space, however, humanity must rely solely on its ingenuity even to breathe. Like Sirens, other worlds call across unfathomable distances, beckoning to be explored. Humanity hears the call, feels the instinct to answer, but is intimidated by the danger. Having tamed nature, humanity has fallen prey to complacency and fear, and has excused itself from the call reverberating from its own nature by appealing to the twin chimeras of expense and danger. But the call cannot be thus ignored.

The risk of *not* exploring space with a robust manned program is *greater* than the risk of losing our astronauts. Environmental concerns, energy production, the population explosion, and the risks posed by earth-crossing asteroids are all potential dangers to the human race *as a whole*, and are best answered through an aggressive program of manned exploration and settlement of the solar system. These problems simply cannot be solved through robotic exploration alone.

If current projections hold, the habitability of the Earth will be drastically different within the next fifty years. Some scientists estimate that our environmental pollution has snowballed to the point of no return, and that much of this damage to the environment is irreversible. Technological innovation enabling life to survive in hostile environments will undoubtedly progress as humanity settles on other worlds–a progress driven by necessity rather than sheer profit. Although Earth's environment is not expected to become as intolerable as other worlds, such technological advances will surely provide solutions to later Terran environmental problems.

Energy production in space, though costly, is a long-term investment in our future. Space Solar Power is being taken seriously by some politicians as a clean, credible option,; and the ultimate benefits of such a program could be revolutionary. The late Gerard K. O'Neill had envisioned such space power stations as manned outposts where scientific research and station repairs and construction are carried out by ever-expanding manned crews. Such stations would someday become true colonies, essentially ensuring humanity's survival apart from the Earth.

As the population of Earth increases, problems concerning food production, sanitation, and clean water will also multiply. Such problems will have been dealt with in depth and from different angles by intrepid space pioneers, such as the first settlers of Mars or the moon. Fresh perspectives on such pressing issues will spawn equally fresh, innovative solutions.

Life on our planet has been molded by several planet-wide extinctions. The extinction of the dinosaurs was almost certainly caused by a rogue asteroid or comet that slammed into the earth 65 million years ago. The ability to maneuver and work in space is a necessity if we are effectively to deflect a potential planet-killer. And if a giant asteroid or comet should catch us unaware, it would be wise to have humanity spread throughout the solar system in order to ensure our survival as a species.

Above all, however, stands one truth: when humanity ventures among the stars, we will pass a fundamental milestone in our existence as a species. We wandered out of Africa, emigrated east and west, crossed oceans, conquered the skies, and harnessed the power of the atom. Now humanity will have reached a new level of existence, that of a space-faring species. Space is our manifest destiny, and will be hampered only by a lack of will power and imagination. The call has gone out, the challenge made, and we can feel the very marrow of our bones urging us onward, upward, and outward. It is time for us to fulfill our destiny as a species. It is time for humanity to take the sage advice of Polonius: "This above all, to thine own self be true." ###

{The 3 3rd Prize Essays will appear in the June MMM Issue]

Aspects of a Moon Society Lunar Analog Facility and How We Might Design One

By Dave Dunlop – dunlop712@yahoo.com
Moon Society Director of Project Development

The Challenge of Lunar Analog Environments

The Moon Society has long been interested in the challenge of developing lunar analog programs. First, the challenge of doing so on Earth has value as a test bed for understanding the "systems issues" in terms of the sequence of development and the processes that can be used. It is less expensive and less risky to try things out in an analog of the lunar environment than on the Moon. We could not afford to do otherwise. It is also a challenge to our imaginations. The Moon is a harsh and hostile and unforgiving environment. It will demand the best efforts we can muster to really go there and learn to live and work in that environment.

It is also a challenge to our learning and skills development It is one thing to write about or design something whether on paper or in virtual space; but it is quite another thing to carry out the process in the "real" world. Both stages of design are essential. We learn by trying things out. We learn by making mistakes, finding out what went wrong, and coming up with alternative solutions. We also derive pleasure from this process as physicist Richard Feynman wrote in ***The Pleasure of Finding things Out***.

Now we can develop and explore ideas in the virtual world and modify and learn at less expense and effort than if we had to physically build everything. We want to see how what has evolved in a virtual design environment will actually work in real world operating conditions. Rapid prototyping allows us to join these two aspects together so that new things can be quickly designed and produced. Testing them allows us to evaluate whether we have been successful and to what extent. This technology is used to develop fairly small object such as metal or plastic parts. On the other end of the scale Contour Crafting of liquid materials such as concrete is now proposed for large-scale structure and buildings.

The computer aided design and manufacturing process will be the critical core for the effective colonization of the Moon. It is exciting and transforming that the whole scale of lunar base development and operations is being opened and advanced by virtual efforts. A chapter of the National Space Society, the Oregon L5 Society has been exploring the use of Second Life soft-ware to create a lunar base environment, this effort led by Bryce Walden.

Society member Manny Pimenta is developing another exciting software project called Lunar Explorer. This software will open up the challenge of lunar design to the wider world. He is working with Google and NASA to provide a software program that will permit people all over the world to participate in designing lunar cities and developing design ideas and solutions to complex challenges. This will permit large number of students and adults all over the world to "take on the Moon" as they develop their science and engi-neering skills. The Moon Society welcomes this advance as a way of letting the world participate and anticipate the development of an Earth Moon economy benefiting enriching, and protecting the Earth by opening the resources of space.

It is no doubt as important to engage multitudes of people in the challenges of designing because of the impact on them and on Earth's society, as it is to solve the design challenges themselves. The process of engagement, the ideas, the educational benefits, the entrepreneurs and business that result from the process are the major benefits of undertaking on this challenge. Perhaps the best way to open the frontier of the Moon is to bring that frontier within the grasp of every student and everyone connected to the Web.

The Current International Interest in Moon/Mars Analog Research Programs

Analog programs seem to generate a great deal of interest, and attract many persons who would like to participate in them. Moon Society members and affiliated National Space Society chapters have many ideas and ambitions regarding analog programs. In Canada on Devon Island, the Canadian Space Agency with NASA as a cosponsor has a Moon/Mars analog program (The Haughton-Mars Project). This facility is situated just a kilometer from the Mars Society's Flashline Mars Arctic Research Station. These are probably the largest, best known and best-funded efforts.

The Calgary Space Workers in Alberta, under the leadership of Michael Bakk, is working on a portable modular approach to lunar base design. In Sweden MS member Niklas Jarvstrat is developing am underground lunar analog project using a former iron mine. In Mexico Jesus Raygosa has been advocating for a Mexican analog initiative, MexLunaHab, and has formed a new organization COMEXEBA to move forward this project and other efforts that can be a part of the New Mexican Space Agency AXEA initiative. In Chile there is also interest in developing a Moon/Mars analog program in the Atacama Desert region. The Moon Society has been requested to assist in the design of this program in collaboration with Maria Catalina of The Astronaut Teacher Association (TATA), a California based educational program. Shaun Moss from Australia has also initiated a new interactive website www.moon-mars.com.

In the US the largest private effort to develop a space analog was the Biosphere II program in Oracle, Arizona during the 1990's. NASA developed its own Bioplex effort at Johnson Space Center in the late 1990's but ended those for budgetary reasons as it did the complementary NSCORT program at Purdue and other institutions conducting controlled environment agriculture and CELSS systems. While NASA has left a research vacuum in the US for this type of work, its shortsighted program reduction leaves a vacuum, which provides an opportunity for other nations. The Moon Society supports forward thinking and research that will advance the agenda of settling the Moon and saving the Earth, no matter where in the world this research occurs, because nothing less is acceptable.

. The Mars Societies' Desert Research Station near Hanksville, Utah was leased for two weeks for a Moon Society Crew (MDRS Crew #45) in February-March 2006, after a prior 2-week stint by Moon Society President Peter Kokh on Mars Society Crew #34 the year before. The Moon Society does not yet have the resources to develop its own lunar effort in the US, but has given some consideration to potential sites, and has developed a multi-phase plan for an analog station of modular design.

The Urgency of Earth Applications of Lunar Analog Research

Now there is also another dimension to the issue of lunar base analogs that addresses the most urgent problems on Earth, the use of scarce resources and the management of the environment. A Moon base is a small village on the surface of the Moon. It must, because of transportation expenses, use the least amount of resources possible to meet the needs of its crew in safety and comfort, while recycling wastes, atmosphere, and water, and growing its own food and becoming as self sustaining as possible while also enabling a diverse ranges of research and commercial activity.

The disciplines and designs which will allow us to live and work on the surface of another planet will enable us to lift standard of living and preserve the environments of some of the poorest people on Earth. This is the payoff for a country such as India with some 600,000 villages whose productivity can be increased and whose people can aspire to a "Moon Standard" of living. Of course, India is not alone in this respect, as there are many people living in small village in rural poverty in countries across the world. But India deserves special mention because, from the very beginning of its space program, it has justified what they did in developing satellites and launch systems, which address the human problems of the country in agriculture, environmental remote sensing, meteorology, communications, and education. The ISRO could initiate a lunar analog program for the very same reasons and in the best of its scientific and educational heritage.

Design Elements of a Lunar Analog Base/Research Park

A. The potential locations of a lunar analog are many. We have already discussed virtual space as the first step. But many will not be satisfied to limit their efforts to the virtual world. There is also a case for proving and demonstrating in the real world and to have a real world simulator. As we have already discussed there have been a variety of efforts in a wide-ranging number of environments. Some might be selected because the natural terrain has a lunar look-alike quality. Where testing in a physical environment is important locations such as Devon and Island and Antarctica may provide some aspects of the extreme natural environment of the Moon. Others might be constructed entirely with the confines of a building in the middle of a city in order to reduce expenses in transport of people and supplies and to build a simulator environment that is also physically accessible to large number of people. The Bioplex effort at Johnson Space Center in Houston, Texas followed this strategy. Because there are many aspects to analog considerations there is value in encouraging a range of approaches and efforts. The following elements of design should be part of a comprehensive analog effort.

B. At the University of Arizona in Tucson, at the Controlled Environment Agricultural Center (CEAC) a prototype expandable Lunar Greenhouse is already in operation. CEAC is looking for more funding; the credibility of their systems could attract capital to a larger Analog Program which would have something no one else has: a working biological CELSS system growing food.

C. The CEAC system could be further improved by the inclusion of robotic or teleoperable capabilities. That would take another level of funding and engineering expertise focus on the operational of a Controlled Environment Greenhouse

D. What is also missing is an educational vision that could involve lots of students. CEAC has a good start on this. Synergies with the Lunar Explorer program might be explored. The proposed Moon Society Analog facility would attempt to involve students in many areas and in several ways, including teleoperation.

E. Another valuable contribution would be developing a working surface infrastructure system that shows how things will be landed, moved around, and protected from surface extremes by various methods of shielding, which would have the added advantage of managing thermal extremes.

F. We must demonstrate how tank farms can be assembled from empty landing vehicle tanks to enable ISRU demonstrations at first and then full industrial production.

G. We must demonstrate how curation-receiving facilities would operate collecting and dividing samples for shipping to Earth from those maintained and protected on the Moon.

H. We should demonstrate an architecture for extended surface exploration, which shows a progressive build up, and reutilization of what has here to fore been expendable equipment.

I. We should demonstrate the utilization of solar energy systems and not only PVC arrays but solar thermal turbine systems, and the utilization of "solar wadi" which use the latent heat stored in processed iron enriched materials derived from the lunar soils.

J. We should demonstrate the telerobotic operation of mining vehicles, which can process the surface regolith. The miner concept developed at the Fusion Research Institute at the University of Wisconsin was focused on the capture of solar wind implanted volatiles. Other materials process issues could also be coupled to these mining machines so that a cascade of materials processing events and process can be understood, designed, and prototyped. (See Q)

K. We should demonstrate the operation of solar power laser transmission systems to power lunar surface vehicles.

L. We should demonstrate a complete end-to-end system from harvesting of food crops to their preparation and storage using robotic and tele-robotic capabilities.

M. We should have modular habitation and lab systems perhaps using Bigelow inflatable modules or creating our own Moon Bagel Torus designs.

N. We should develop working models of the autonomous lander and deployment systems expanding Greenhouse systems tele-robotically proposed by CEAC.

O. We should partner with NASA to operate their exploration and surface mobility systems to see how they hold up in extended use and how well they can be maintained in a lunar simulation environment with missions "tasked" from an operating base.

P. We should explore the use of contour crafting construction technology in construction of lunar base structures and explore how this type of machinery could be designed, shipped, deployed, and tele-operated in the context of a lunar base operation.

Q. The development of feedstock for lunar concrete utilized by the contour crafting system is another aspect of in situ resource utilization studies, This aspect is also a significant systems development challenge based on the variability of lunar surface materials.

Now this list is not intended to be exhaustive but to merely illustrate the rich possibilities for research and engineering in a lunar analog context. We did not discuss the energy and resource systems management research alluded to in regards to the Earth-side applications. The limitation of page space leave much for discussion in future issues.

Links:

Haughton Mars Project
http://www.marsonearth.org/
Flashline Mars Arctic Research Station
http://www.fmars2009.org/
Mars Desert Research Station
http://desert.marssociety.org/
Moon-Mine (Sweden)
http://www.moon-mine.com
Moon Society simulation at MDRS
www.moonsociety.org/moonbasesim/moonbasesim.html
http://marssociety.com/MDRS/fs05/
[scroll down to crew 45]
Moon Society modular analog station presentation
http://www.moonsociety.org/moonbasesim/proposals/AnalogMoonbaseProposal.pdf
Mex Lunar Hab proposal
http://www.moonsociety.org/sem/mlh_Raygoza.pdf
Moon/Mars Atacama Research Station proposal
http://groups.google.com/group/moonmars
U-AZ/CEAC Lunar Greenhouse
http://www.moonsociety.org/moonbasesim/moonbase_analogs_net.html#sadler
Pisces Project on Hawaii Island
http://pisces.uhh.hawaii.edu/documents/LPSCAbstractFinal.pdf
Calgary Space Workers Project
http://www.calgaryspaceworkers.com/thehabitat.html
Aquarius Undersea Research Station
http://uncw.edu/aquarius/

Successful Opening of a Lunar Frontier Will Require More Than One Settlement

By Peter Kokh

An overwhelming percentage of lunar advocates, both professional and enthusiast supporters, assume that "the" lunar outpost will be at one of the Moon's poles, with the South Pole the current favorite. We have many times stated our objections to this location on these grounds:

- The **available sunlight** is *not* fulltime, and so we must learn to store power for use when sunlight is not available. So why not learn to do this for as long as two weeks, which would enable us to go anywhere
- **Water is essential** and would be costly to upport and at the poles water ice is available. In fact what is there is at cryogenic temperatures and not a resource that we can expect to tap near term
- The **temperatures at the pole** (excepting permanently shadowed crater bottoms) are moderate. But we have already endured "mid-morning" temperatures on the Moon during the Apollo days. Being "afraid" (let's call a spade a spade) of nightspan cold and dayspan heat is not a trait that bodes well for us as pioneers. We must learn to live in conditions that apply globally on the Moon, or just forget about it.

But from the vantage point of the Moon Society's declared vision statement,

> "*formed to further the creation of communities on the Moon involving large-scale Industrialization and private enterprise*"

the choice of "a" site is by itself "out of order." Why? Because the list of resources that will be needed for such an ambitious goal, are not to be found in any one location on the Moon: not at the poles, not at any other single location.

We owe it to our own stated commitment to start at a place from which we can easily expand. The South Pole is more highland-locked than is the North Pole, where twice as much water ice seems to be available. But we will want to tap resources that are more abundant in the maria as well as those more plentiful in the rugged highlands. But not all maria areas are equally endowed.

Some maria and mare-fringe areas are rich in KREEP deposits, that is, in Potassium (K), various rare earth elements (REE) and Phosphorus (P). Other areas are rich in ilmenite, an iron-titanium-oxygen mineral. Others are richer in uranium and thorium, which could support a lunar nuclear fuels industry. Then there are special places like the Marius Hills, which may contain volcanic volatiles, which could be exceedingly important Indus-trially and biospherically.

Helium-3, if ever fusion based on this isotope becomes a near-term reality, is to be found virtually everywhere, but seems to be especially concentrated in ilmenite rich mare areas.

It seems that for a really successful industrialization, one as self-reliant as possible (some imports will be needed), we will have to set up shop in several locations, and, yes, that includes at least one of the poles, the north pole being the most promising on at least three counts: twice as much hydrogen (implying) water as at the south pole, more water-ice as opposed to frozen regolith with a low water content, and less than half the distance to the nearest mare coast, the north coast of Mare Frigoris. There is reason to start outposts on the farside as well, both industrial reasons, and scientific ones.

We should factor in locations that will be highly attractive to tourists. At first, any place that is "on the Moon" will do. But as tourism grows, the demand will grow for especially scenic areas, and they abound. Some tourists will be content to land, look around, and leave. But more and more the demand for overland excursions will grow strong. New tourist targets will at first be handy to new industry-focused settlements. But in time, we will see them sprout up in non-settled areas. Different locations will offer different recreational opportunities as well as changes of scenery.

Now precisely because sites with special mineral resources will produce different products, they may also give rise to different arts and crafts, not just for frontier settlement enrichment, but to spur trade between settlements as well as to become more attractive to tourists, both those from Earth, and those from other lunar settlements - pioneers who need a vacation and change of scenery!

On Earth, trade was essential both for the development of local economies, and for slowly bringing all parts of the world into mutual contact. If we look back in history, trade has been absolutely essential, and probably the greatest single stimulus to the development and evolution of material cultures. Trade created incentives to build new highways, to improve transportation vehicles, to open new areas. Below is a map I found online of trade routes through Asia that have been key to the development of civilization.

What has all this to do with where we are now? A lot! The Bush-NASA plan was to open an outpost. Yes, NASA has always been aware of the potential for more, but it has not been tasked by the government to explore and develop those options. Thus the NASA plan was designed for a "low flight rate" transportation system in which cost was not an object, virtually guaranteeing that a first lunar outpost would remain the sole one, and that it might not even become truly permanent.

Personally, I have been greatly encouraged by the change in direction. While the government-focus may no longer be on the Moon, the technologies now to get attention will lead to better, cheaper, more efficient transportation systems, with considerable commercial participation, and even leadership. Now this is what we need to truly open a frontier. "A" lunar "outpost" has never been the goal of The Moon Society, nor of the National Space Society for that matter.

Yet there are many enthusiasts, who (a) would settle for a token outpost, and/or (b) are not confident of the abilities of the commercial and private sector to open the lunar frontiers. Face it. NASA cannot and will not open the Moon. Now we have a real chance that this will happen, and maybe even sooner. **PK**

Manned Space Exploration Is Worth the Risk

Tom Burkhalter, Hickory, NC

3rd place winner (3-way tie)

Since 1960, 101 people, mostly Russians and Americans, have died either during the course of space flight or in accidents related to preparations for space flight. According to NTSB statistics, almost that many people in America alone will die, in a single day, in automobile accidents. In a single week in this country, based on U.S. Labor Department statistics, more people will die in workplace-related accidents than have ever died in space flight related accidents. In a single year in this country, based on U.S. NTSB statistics, more people will die in airplane accidents than have died in space flight related accidents. Any argument that manned space exploration is physically “too risky” would therefore require us to ban, by the same argument, driving to the supermarket to shop for eggs, to work for a living or flying a Piper Cub.

Manned space exploration is without doubt expensive. Economists would ask, what is the benefit we obtain at the risk of the money spent? As for that risk, one spends money to make money. The technological spinoffs of the Apollo program alone created more jobs and economic opportunity - in short, made more money - than has ever been publicly acknowledged. Input the term “Apollo program spinoffs” on any Internet search engine and consider the ways in which our economy benefitted from that one program. As an humble example, today’s athletic shoes are based on materials derived for use in the space suits NASA astronauts wore on the Moon; at the other end of the spectrum, magnetic resonance imaging depends on digital signal processing techniques developed for Apollo. What is the economic value of early diagnosis of a brain tumor?

Arguing the technological benefits of manned space exploration, however, might be beside the point in assessing the relevant economic risks. Adjusted for inflation, the Apollo Program would have cost about 300 billion dollars in 2008. Congress, just before Christmas of 2008, gave over three times that amount to bail out a banking industry that made bad business decisions. The decision to undertake the risk and bail out the banking industry was made after only the most minimal debate of the risks and consequences. What benefit will we, as taxpaying Americans, receive for that economic risk?

There is risk and expense involved in manned space exploration but the risk appears to be no more than that present in those everyday activities described as “business as usual.” Perhaps, though, since it seems evident that even this level of risk is considered unacceptable by many people, one should identify what manned space exploration actually does for us as human beings.

Manned space exploration, by definition, takes us where no one has gone before. Perhaps it isn’t so obvious that it increases not only the store of human knowledge and experience, but the level of human potential. “Human potential” in this context means the scope of what we dare to dream of accomplishing, for ourselves and for our children. Manned space exploration is not only the stuff of dreams, but in a very literal and much more important sense, the stuff from which dreams originate.

Before Apollo “going to the Moon” was only a dream, an idea belonging to science fiction. But on July 20, 1969, we *knew* that human beings were on the Moon. “Going to the Moon” passed forever from the nebulous realm of science fiction into the factual realm of human history and experience. To look at the Moon during the Apollo landings was to *know*, and not merely to have *faith*, that *anything is possible to human beings*. What Apollo did for us then is what all manned space exploration does for us: When dreams are made real previously unknown dreams become possible. The human potential increases.

To explore, redefine and expand our full potential as human beings, to restore and maintain that spark of the heroic within not just some of us but each of us, is therefore the benefit conferred by manned space exploration, and that is worth the risk. Manned space exploration proves to us that whatever our problems, we can find a solution. Manned space exploration is the living, dynamic symbol of hope for the future, of that better tomorrow that is the fundamental promise of America. To acknowledge anything less is to deny our full potential - and what that potential might become in the future where no dreams have yet reached. TB

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Manned Space Exploration Is Worth the Risk

By **Dorothy Diehl**, Mt. Angel, OR

3rd place winner (3-way tie)

Exploring the unknown has always been fraught with risk for <u>Homo</u> <u>sapiens</u> over the last one hundred millennia. It is true that back then, humans lived in tribal societies and stayed on familiar terrain until environmental conditions changed and threatened their survival. Faced with doom if they stayed put or the possibility of survival if they explored the unknown, early humans left their homes on the plains of central eastern Africa and migrated south or north. In the north, subsequent generations pushed on westward or eastward across Asia eventually finding an Ice Age land bridge to the Americas.

Down through the ages this human willingness to take risks to escape hunger, poverty and/or persecution motivated many peoples to face what they did not know and, in spite of death decimating their peers, the survivors conquered that unknown. Sometimes, the driver for human exploration was the possibility of obtaining great wealth like gold and spices. Usually there was a comercial element lurking behind many expeditions of exploration, such as the great Lewis and Clark Expedition of 1803-1806. Yes, they drew maps of previously uncharted terrain and recorded many observations of previously unknown plant and animal species. However, the purpose of that expedition—to find a water route connecting the upper part of the Missouri River to the Pacific Ocean — was a commercial one. The ensuing wealth that would come to the United States, if a Northwest Passage were discovered, was more important than the many risks posed by such an expedition.

In our own time, the decision to send men to the Moon and return them safely to Earth was driven by the military threat of the Cold War when the Soviets successfully launched Sputnik, the first artificial Earth satellite. Our national prestige was ranked as more important than the personal safety of the astronauts. If the stakes are high enough, humans will run any risk that arises. The public did not vote for the Apollo Program; it was an executive order by President Kennedy.

Since the end of the Apollo Program, space exploration has been relegated to robots as cheaper and more expendable than human astronauts. Many robotic missions have been extremely successful. Now there is no driver to risk human lives to explore space beyond Earth. Of course, we are curious about what's out there, but the robots are slowly and partially satisfying that curiosity. And we are safe as clams on our lovely home world, the Earth. The fact that human explorers could, at great expense and great risk, make many more discoveries much faster in space than all the robots sent there has no traction with U.S. citizens.

However, if a group of people, perhaps from some other nation, decides to go to the Moon to explore ways to make a permanent settlement there and they succeed; then, the reports of that success will raise the possibility of new real estate and exciting jobs. Like the opening of the Oregon Trail in the nineteenth century, a permanent human settlement on the Moon in the twenty-first century will stir us to action. Those who come in on the ground floor of a new frontier not only acquire wealth but also make names for themselves in human history.

It is inevitable that new discoveries on the Moon will lead to new technologies, new ways of life, and eventually to Mars and the asteroids. Destiny will beckon to those who dare great achievements. The innate urge to explore the unknown that is buried in our genes will finally express itself again. We will relegate robots to support roles where they belong. Yes, we will consider the risks and take them in stride as the shuttle astronauts did when they assembled the ISS and repaired the Hubble Space Telescope. Instead of crawling centimeter by centimeter onto the Space Frontier exclusively with robots, we will finally sprint there with human explorers. **DD**

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The Case for Manned Space Exploration

By Valentin Peretroukhin, Toronto, ONT

3rd place winner (3-way tie)

"Space, the final frontier" has fascinated the minds of Mankind since antiquity. The 20th century saw great leaps of innovation that allowed humans to not only travel to space, but to also set foot on a completely different celestial body and return home safely. During incredibly unsettling times of war, violence, and social unrest, these audacious accomplishments were an inspiration to the masses and a true symbol of human ingenuity. At the climax of the "space race," the public's exuberant sense of hope and excitement for human space travel allowed governments to invest a considerable amount of money into fostering new ideas and technologies. In the decades following that era, the world's social dynamics and demographics evolved and many factors that initially promoted space exploration disappeared, along with much of the unified excitement for exploring distant frontiers. With the general public's support dwindling, it is now becoming exceedingly difficult for many developed countries to justify funding manned space endeavors.

Around the world, the American lunar landing of 1969 certainly marked the peak of public interest in space exploration. Over 600 million people, a record television audience at the time, watched as Neil Armstrong stepped down the ladder of the lunar module and uttered the iconic phrase, "One small step for man, one giant leap for mankind." Upon their return to earth, the astronauts reception was akin to the welcoming of renaissance explorers, filled with extravagant parades and glorious stories of strange foreign lands. The awe and excitement that surrounded this first trip slowly dwindled with later Apollo missions as the process was inherently repetitive and suddenly seemed entirely accomplishable. Beginning in the mid 1970s, the extent of human space exploration began to shift focus to creating inhabitable "stations" in low earth orbit and building various efficient ways of transporting humans to these stations. Though interplanetary exploration continued, it was, and still continues to be, fulfilled entirely by unmanned space probes.

As human participation in space exploration declined, so did the inherent public interest for any extraterrestrial missions. The reason for this can be found on magazine stands, in arenas and schools around the globe: Mankind is an incredibly social species. Our evolutionary supremacy on this planet stems from our competitive nature, our ability to work in groups and our ability to share information and pass on relevant knowledge. Furthermore, the intrinsic ability to put ourselves in the perspective of another person – the concept of empathy – is one of the key distinguishing factors that separate humans from other primates. For people to be able to relate to, and empathize with, the accomplishments of said space explorations there must be a human face attached to them.

One of the main arguments against human-based extra planetary travel, and perhaps why no country has attempted it since the Apollo missions, is the shear cost of developing technologies safe and practical enough to send humans to another world. The money for space endeavors is there, yet the public is extremely wary of spending billions of dollars on unmanned missions that often fail because of careless mistakes and miscalculations. In a manned mission where all decisions are scrutinized and much more rigorous precautions are taken, and the public is empathetic of the risk of human life involved, justifying high expenses is a much easier task. Additionally, more than just appealing to the public, astronauts bring an entirely different approach to exploring different planets and moons. Humans are incredibly dynamic and can perform many things that a robot simply cannot do. An astronaut can provide a holistic overview of a new unknown environment – in addition to the simple images, videos or other sensory data of a probe – that can be incredibly helpful in understanding its various characteristics.

Apollo 15 Astronaut James B. Irwin, staring back at our world through his command module window, described the earth as "a marble, the most beautiful you can imagine. That beautiful, warm, living object looked so fragile, so delicate…" From this incredibly unique and bonding view point, all of Mankind, no matter what race, sex or creed is a part of Earth: a beautiful, vibrant, diverse world in the dark empty abyss of space. In his book, *Cosmos*, the great astronomer and popular author Carl Sagan writes of this phenomenon, "if a human disagrees with you, let him live. In a hundred billion galaxies, you will not find another." In times of distress, a country's investment in exploring distant frontiers serves as an inspiration and a vital source of hope for many of its citizens. The best example of this occurred in the late 60s in the United States. This decade was marked by several prominent assassinations, a much disputed war in a completely different continent, the threat of nuclear annihilation, a struggle to eliminate segregation and a multitude of oncoming social reforms. Throughout all this turmoil, the Apollo Astronauts were seen as heroes, unifying the nation and providing hope when all else seemed to be in a state of disarray.

Thus, in just over 150 years after its conception, space exploration is now a crucial part of the development of Mankind. In a dynamic, multi-dimensional world it is imperative that we continue to challenge ourselves to explore distant frontiers and not be intimidated by the prospect of human space travel. Space is no longer simply a bragging right for the most developed nation – it may contain many answers to the daunting challenges our species will face in the next millennia. The future generations of Mankind will rely on our courage and our ingenuity. In the words of H.G. Wells, "life, forever dying to be born afresh, forever young and eager, will presently stand upon this earth as upon a footstool, and stretch out its realm amidst the stars." **VP**

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Thanks to these and other persons who entered our essay contest. Chuck Lesher, editor of our science-fiction publication, ***Moonbeams***, has now published these five and six more entries in issue #5. This is a free download from:

www.moonsociety.org/publications/fiction/

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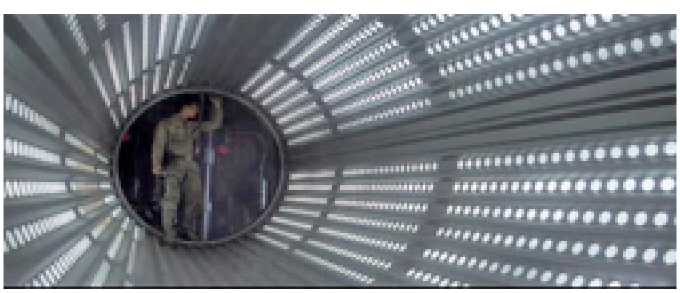
Some Hallways & Corridors of Sci-Fi Fame

Moonraker above, **Emprie Strikes Back** below



HALLWAYS & CORRIDORS

http://www.denofgeek.com/movies/313130/in_praise_of_the_scifi_corridor.html

By Peter Kokh

It is quite possible to build a modular outpost with no hallways, corridors, tunnels, skywalks, or other types of pedestrian passageways. To do so has a disadvantage:

- passing through one habitat or activity module to get to another one is disruptive and distracting to the activity and personnel in those modules. And the path, whether down the middle or to one side takes up valuable space.

On the other hand, the separation of modules that pedestrian passages afford offers these benefits:

- Isolation of decompression and other types of emergencies or catastrophes or;
- Opportunity to add additional biomass, in the form of living walls, for example; the opportunity to add storage in the form of lockers: a growing and busy complex can never have too much storage! Witness the International Space Station
- Vertical space to add galleries of paintings, photos, and other types of artwork;
- Corridor intersections can provide seating for conversation, snacks, reading, or simply people watching

All of the above benefits are important. In the current designs for a proposed Moon Society Analog Station and the proposed Moon/Mars Atacama Research Station in Chile, the opportunities for extra storage and additional Living Wall units two major drivers. The additional advantages are "frosting on the cake." The result will be a more pleasant place to live and work.

In contrast, he one-module MDRS facility, has no halls at all, discounting the open framework of the "simulated" Heinlein tunnel connecting the Hab to the Greenhab, built in 2006 by the Moon Society crew.

http://desert.marssociety.org/media/mdrs/fs05/images/crew45/c45d13str01.jpg

Hallways and other pedestrian corridors, as an opportunity for additional biomass in the form of Living Walls, are at the core of the "Modular Biospherics" architectural approach which is especially appropriate for a Modular Architecture, one that can expand and grow as the size of the crew (outpost population) and the variety of its research and activities grow. In contrast, one-size-fits all approaches to the mini-biosphere equation have all been dismal failures.

Living Walls, vertical arrays of vegetation with built-in irrigation systems, do not compete for floor space, save in a minimal way. Existing examples show an amazing variety in system design as in the variety of plants used and the way they are decoratively arrayed.

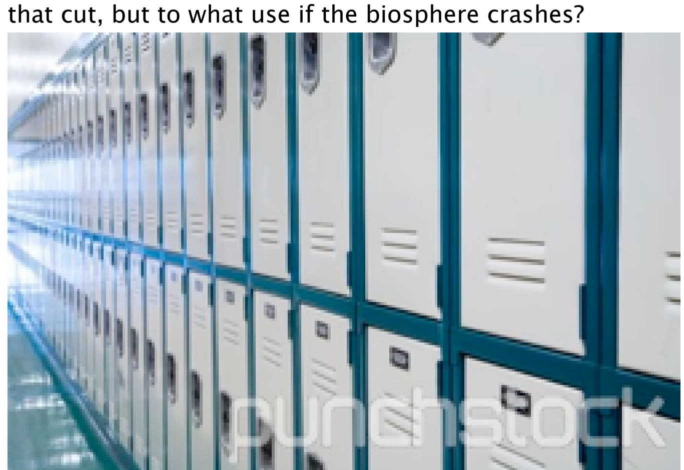
In an analog facility, with room for many such units in various hallways, provides an ideal opportunity to test many system designs and plant choices to see which do the best job of cleansing the air, keeping it fresh and pleasant, and which require the least care, Research of this kind is what an analog station should be about: not just a place to test field equipment and procedures, but to test modular outpost and biosphere schemes.

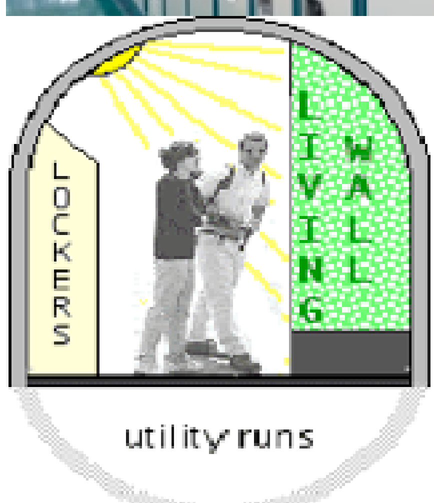
Beyond the Outpost: Settlement Pedestrian Ways

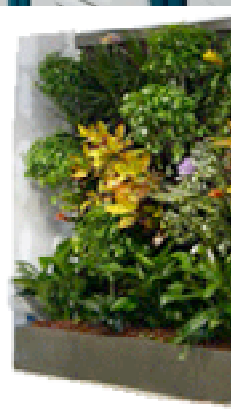
There will, of course, be pressurized settlement streets for electric vehicles, bicycles, and even mass transit. These two are likely to be generously vegetated, both along the curving sidewalls, and in traffic medians and pedestrian sidewalk borders. A settlement will have farm areas, of course, and these areas will contribute greatly to the overall biomass. But the contribution of plantings along streets and other pedestrian ways will add a significant extra. The more diverse and physically dispersed these biosphere contributions, the less likely any overall system failure due to blight or plant disease or other points of failure; *and,* the more "Earthlike" and reassuring the setting will be for day-in, day-out, outpost or settlement life; a*nd,* the happier outpost personnel and pioneers are likely to be.

That the principal benefit, more than sufficient to justify the expense involved, is the robustness of the contained mini-biosphere, is crucial. If the only advantages were pleasant surroundings and happier personnel, the budget weasels would quickly ax such features. We say that with contempt because these people overlook that the most important "system" of all is the human system. Kill or starve crew morale, and the most soundly designed physical structure will be for naught.

Now perhaps the locker row walls would survive that cut, but to what use if the biosphere crashes?







Above: cross-section of a minimal connecting hall.

Where lockers are not needed, as in areas too far from where the contents might be needed, art, photo, and sculpture galleries are an option. We see things like that in some urban metro/subway stations, though, more commonly such space is given to paid advertisements. Advertising, especially of cottage enterprise products, might be a healthy sign in those pedestrian connector intersections that have high traffice. Let's hope that we see both. And why not together? Paintings of fruit along side an ad for Mrs. Jones Jams and Jellies! A frontier is a place to start over. If ever ad sponsored an accompanying piece of artwork, how refreshing that would be!

A matter of words

We will see pedestrian passageways in many forms, and here on Earth we have many names for them: skywalk, tunnel, pedestrian bridge; Hall and hallway are rather generic. The Latin word, cunniculus, refers to an underground passage such as a rabbit tunnel or mine.

While there will be assembly halls and other recreational spaces in which people will mingle, it will be in the hallways that most people assigned to a lunar outpost, especially a multi-national one which is the center of research and innovation, will meet and strike up conversations. It will be in its hallways, that a frontier outpost begins to feel something analogous to home. Coffee or juice bars would help!

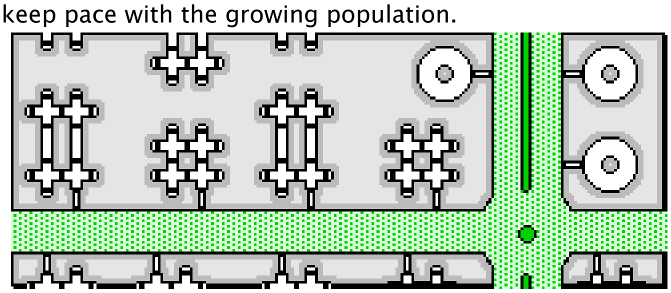
Pedestrian passageways, especially those that form a convenient loop, may also be frequented by walkers before they start their day's work. Indeed, these spaces will provide many of the perks of "being outside." They will be where one "gets out of the house," gets away from the office or shop. On a world where you just can't put on a jacket and cap and go "outdoors," these pedestrian networks will function as an "outside."

Some will be wide enough to have merchant kiosks down the middle, or at intersections, as do most shopping malls. Indeed, many a needed pedestrian trafficway might be expanded to include the mix of social and shopping needs "mall halls" provide, with shops to either side. As cottage industries arise in a young settlement, selling products produced in free time, something of the sort is sure to arise.

We've already mentioned scattered seating: for readers, coffee sippers; conversation, and simple people-watching. You won't see much of this if any at all in a small outpost; but within the more extensive framework of an International Lunar Research Park, it would be surprising if we didn't see these kinds of development. Here there will be people of many nations, who had not previously known one another, on assignments of different lengths of time. The social mix should be interresting, more so perhaps than at McMurdo in Anatarctica.

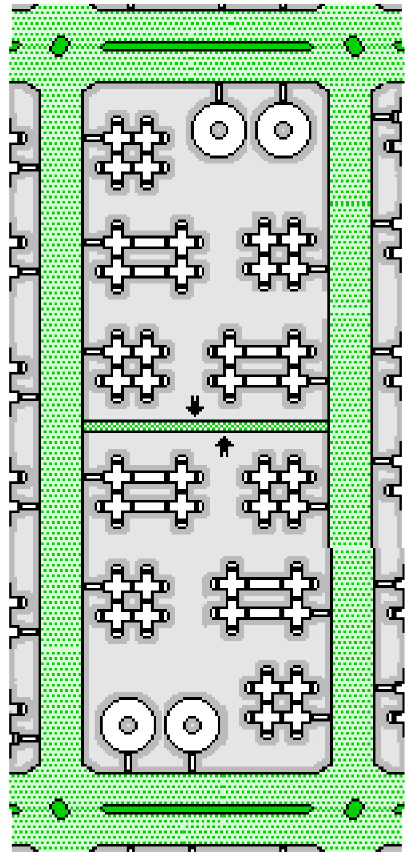
Hallway architecture

And once the settlement or the research park develops real "streets" with vehicles, park like sidings and intersections will take all this to the next level. There could be waterfalls, trout streams, and more. To the point they would ramp up the biosphere component to keep pace with the growing population.



Where would Pedestrian Passageways be bult?

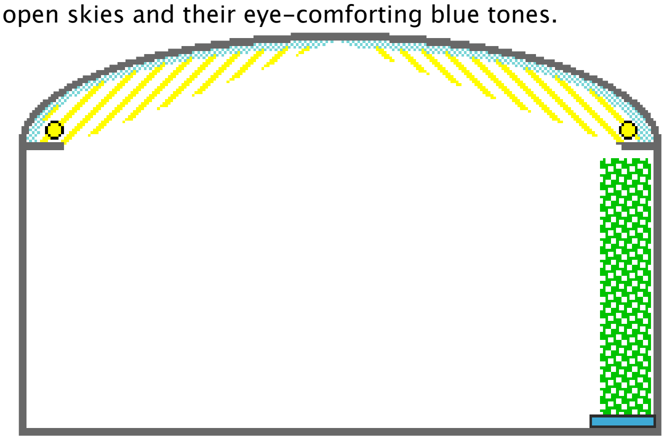
The answer is simple: wherever there is a need. They could connect office complexes, factories or schools and/or parks. They might connect street side-walks through the middle of long residential blocks, as is shown in this illustration ➔



In this "map" the green areas are the major hosts of biosphere support vegetation. Plantings could be ornamental and/or include fruit trees and bushes, herbs and spices, or other plantings to supplement what is grown in the main agricultural areas or "farms." This contribution to biosphere mass and air quality is significant.

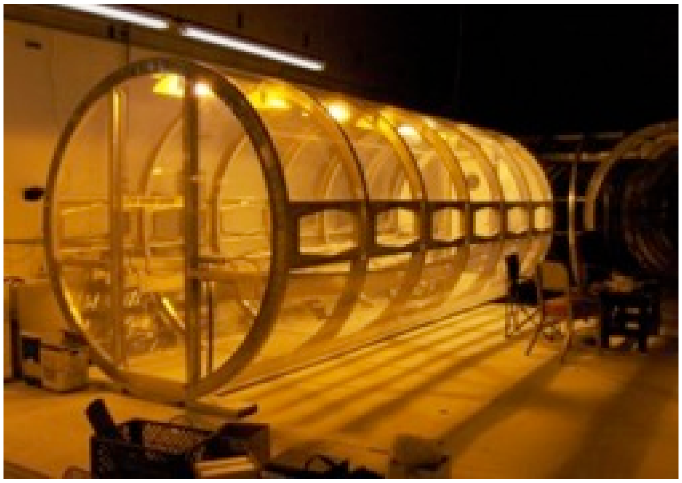
Ambience is essential

We've written before of "the black sky blues." In addition to the refreshing and reassuring inclusion of abundant vegetation in the form of "Living Walls" and the water features that could easily be incorporated in their hydroponics systems, hallways and corridors could be designed with arched or vaulted ceilings. Painted matte "sky blue" and uplit by cove lighting, they would bring welcome eye relief to those born on Earth and used to the open skies and their eye-comforting blue tones.



Pedestrian passageway construction

Pedestrian corridors or tubes could be assembled from fixed length cylinders: But they could also be made of inflatable sections: lighter, and thus more length for the shipping dollar. Phil Sadler had pioneered an interesting option. In connection with CEAC, the Controlled Environmental Agriculture Center at the University of Arizona in Tucson, he has designed an "expandable" circular framework for a lunar Greenhouse.



The unit travels compact, the ring frames up against one another, then pulls out to the desired length and is covered. Another idea would be an expandable slinky, as its continuous frame could carry electrical and other utilities. Much will depend on the pace at which new lunar building materials come on line.

ISS as an example not to follow:

The International Space Station has connecting passageways too. But with lack of foresight they are shorter than they might be, and narrower. Clearly, there is a market for inflatable corridors just as there is for inflatable modules. As a result, on ISS, every cubic foot not needed for a space to "swim through" is given to storage. No perks, no amenities, no décor, no plants, Just storage. Take a look at the following video [3 parts]:
http://www.youtube.com/watch?v=JgBgmw-2U8c

The lesson is to disperse the modules to be connected so that longer corridors are needed, and for the same or lower price (less weight per linear foot) wider inflatable corridors. This suggests a possible refit that would make ISS that much more livable.

Jumping back to large complexes on the Moon, it would be wise to design in a peripheral or self-rejoining corridor route for morning and evening walkers: one-way in the morning, other way in the evening?

Hallways and corridors are the lubrication that makes large complexes serve their purposes well. We tend to take them for granted, ignoring their potential to serve complimentary functions. Nor should the potential of corridor nodes or junctions be overlooked. They are natural meeting places so should have nooks were people can sit and chat, or just people watch; kiosks for coffee, tea, snacks and more.

As a complex grows, maybe there should be lanes for bicycles, or trikes with bins for groceries and other shopping loot. On the settlement level, there might be a pedestrian network as extensive or more as the road system, and complementing roadside sidewalks.

Pedestrian Passages & Galleries

Some of these passageways could become favorite places to post artwork and crafts, whether just for show, or for sale on consignment to an agent with the power to sell them. Such a setup would work to greatly increase the amount of arts and crafts activity in the settlement, as well as to personalize individual homes, apartments, offices, and more. They could also become places to show and sell other home enterprise products from home-canned preserves, herbs and spices, teas and other beverges, and even dyes and custom fabrics. Home made products assisted by this kind of exposure and sales opportunities could help accelerate the transition of some cottage industries into mainstreet businesses. And they could be a favorite hangout of budding pioneer musicians and singers, hoping to catch the ear of some booking agent.

Pedestrian Passageway wares and inter-settlement tourism

It is foreseeable that as passageway arts and crafts and home-grown and fashioned products, being highly individual, could become a major driver of inter-settlement tourism: "Shop the fascinating and ever-surprising passageways of Luna City, or of Shangri-Luna or of Port Heinlein!" While walkers and others "in transit" may be the main users during the workweek, on the weekends, browsers equipped with money or credits may be more numerous.

By including a spacious network of pedestrian passageways in settlement city plans, city fathers will be ensuring the development of a happy and healthy population of achievers and producers, and in general, of happy camper pioneers.

Passageway Intersections

We've talked of ships, kiosks, and places to sit down and visit at extra spacious passageway intersection. There might also be musicians, playing for donations, or just for the privilege of playing. Benches and other places to sit and rest may become a favorite arena in which to see and be seen. Here is a setting where dates can be made, as well as deals.

Pedestrian Passages & Exercise

Walking is not as energetic as running or cycling, but does do a lot, if pursued on a regular basis, to maintain overall health. If worked into one's shopping habits or used as an alternative to vehicular transport on short runs, negotiating a well-planned passageway system may add significantly to overall mental and physical health and sense of well being.

Regular walks would also reduce any sense of isolation and help foster a sense of community and good habits of socializing.

The risk of planners pursuing efficiency

Some settlement planners may see pedestrian passageways as unnecessary structures: "just put buildings cheek-by-jowel. Adding "miles of passageways consumes building materials, and other resources inefficiently." But they are wrong. Communities are vital complexes and amenities such as pedestrian passages will be both the grease and the stimulant of ever-increasing pioneer productivity and contentment. **PK**

Research and Development Projects For an International Lunar Research Park

By Dave Dietzler, Moon Society St. Louis
With contributions from others

The Industrialization of the Moon and Earth orbital space offers these R&D opportunities:

- Helium-3 fusion fuel
- Lunar power beaming systems
- Solar power satellites
- Trans-continental and trans-oceanic power relay satellites
- Large high-powered GEO telecommunications platforms
- Space-based defense systems
- Asteroid deflection systems
- Development of Mars exploration and settlement technologies
- Materials and propellant for ships to Mars and elsewhere in the Solar System
- Materials for orbital factories and settlements
- Scientific research including astronomy, planetary science and SETI
- Development of robotics and spacesuit technologies
- Tourism and sport
- Media production opportunities (space-based reality/documentary television)
- Advances in Mining, manufacturing and ISRU
- Advances in robotics/telerobotics for space and terrestrial applications
- Advances in compact/miniature industrial automation
- Advances in large-scale distributed systems automation
- Advances in nanotechnology
- Advances in artificial intelligence
- Advances in renewable energy technology
- Advances in fiber and wireless telecommunications technology
- Advances in microprocessor solid-state data storage technology
- Advances in modular building technology for space and terrestrial applications
- Advances in hydroponics, mariculture, microbe, insect and small animal farming
- New on-orbit manufactured products based on space environment processing
- Employment/economic stimulus through orbital industrial development
- New in-space remote data vault facilities

Investment

Investors are key to the success of space Industrialization. Private stockholders, banks and governments will not put up their money for space industrialization projects without solid proof of their viability. Theoretical or experimental devices shown to work on Earth, even in simulation chambers, are not going to attract the financing that machines tested and proved out in the real world of the lunar and orbital environment will.

We propose the creation of an International Lunar Research Park to test the limits of man and technology on the Moon and in outer space. Not only do we seek scientific and engineering data, we seek to determine the cost effectiveness of various technologies in the real world.

Governance

Any single government or corporation would not own the ILRP. An international body similar to a "port authority" would control an ILRP.

- Various entities would own or rent facilities combined with common facilities like life support, command centers, a landing/launching pad, power supplies, etc.
- The core of the base that supplies these basics - Life Support Systems (LSS), power, command, etc. would be owned and operated by the base authority that charges fees for services.
- Private contractors--governments, corporations, universities and perhaps even hotels would plug their laboratory, shop and habitat modules into the core structure.

This plan will reduce the up-front costs to the contractors who rent or own modules where they do their work. Wheeled vehicles and sub-orbital rockets would also be available to contractors by lease or rental plans, for exploration and prospecting on the Moon.

Research

At the ILRP research will be done to investigate whether mining and manufacturing on the Moon to make products for lunar and orbital industry rather than rocketing everything from Earth has more benefits than drawbacks, especially when finances are concerned. The technologies that are most cost effective will be determined before massive investment in large-scale space industry occurs. Research will also determine what the best kinds of lunar resources are, the cost effectiveness of their acquisition and their location.

Locations

There are several options with distinct advantages for different sets of research directions. Various goups of collaborating contributors might establish ILRPs at select locations. Any "The" in "ILRP' will hopefully be temporary

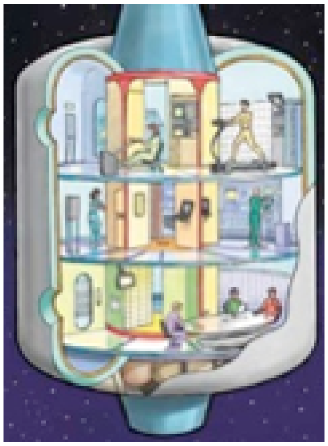
Areas of Investigation - Science

--Astronomy—telescopes could be built on Earth and rocketed to the Moon where they will have no atmospheric distortion to deal with. Eventually, huge telescopes would be built on the Moon from on site materials and these could be used to hunt for potential asteroid impactors and Earth-like planets orbiting other stars.

--Lunar geology/prospecting—ground truth probes into ice containing polar craters, deep bedrock core sampling, crater central peak sampling, seismic studies and drilling near volcanic domes to search for pockets of volcanic gas, lava tube exploration, investigation of magnetic anomalies like Gamma Reiner, Mare Marginus and Mare Ingenii

--Bio-medical—one of the chief areas of study will be the effect of low gravity on humans, animals and plants. Methods of coping with muscular and bone atrophy like sports, exercise, special diets, and medications must be studied.

[Editor's comment: The above is but a general report. To date, ILRP brainstorming has gone into depth on several topics. You can follow on this google group website; http://groups.google.com/group/international-lunar-resarch-park (requires google username, password) ###



The **TransHab** Project had been developing two concepts: an **inflatable envelope** & a **rigid core** carrying the bulk of the outfitting needs. Bigelow Aerospace has advanced the first, but not the second. That may prove to be a big blunder, and constrain BA sales.

Right: an illustration of the interior of a TransHab

Above: Horizontal version replaces earlier vertical one

Did the Bigelow team make a major blunder in deciding that TransHab's Rigid Inner Core was non-essential, and to develop only the Envelope?

When I first saw sketches of the TransHab design in the late 1990's, I noticed a striking resemblance to a design in a paper we had presented at ISDC 1991 in San Antonio, and subsequently published in the conference proceedings. Our Lunar Reclamation Society 'think tank' team dubbed Copernicus Construction Company, had presented the concept of a "Big Dumb Volume" lunar outpost structure which would be habitable only when an "amphibious" lunar lander Crew Cabin/surface coach, the "frog", was docked to it, sharing its life-support and power systems. "**The Lunar Hostel: An Alternate Concept for First Beachhead and Secondary Outposts**" http://www.moonsociety.org/publications/mmm_papers/hostels_paper.htm

The essence of our suggestion was that an inflatable envelope would be launched in an uninflated state around a rigid axial core that included an ***outfitting package that would expand as the envelope was inflated to provide a structured interior, complete with basic utility systems.***

As NASA was very present at that ISDC, It was natural to winder if our paper had been an influence on the TransHab designers. We also wondered how much an influence Lowell Wood's earlier concepts for inflatable space modules. These questions were settled in a Space Review Interview with TransHab developer William Schneider, conducted by Dan Schrimpsher, 08.21.2006.

http://www.thespacereview.com/article/686/1

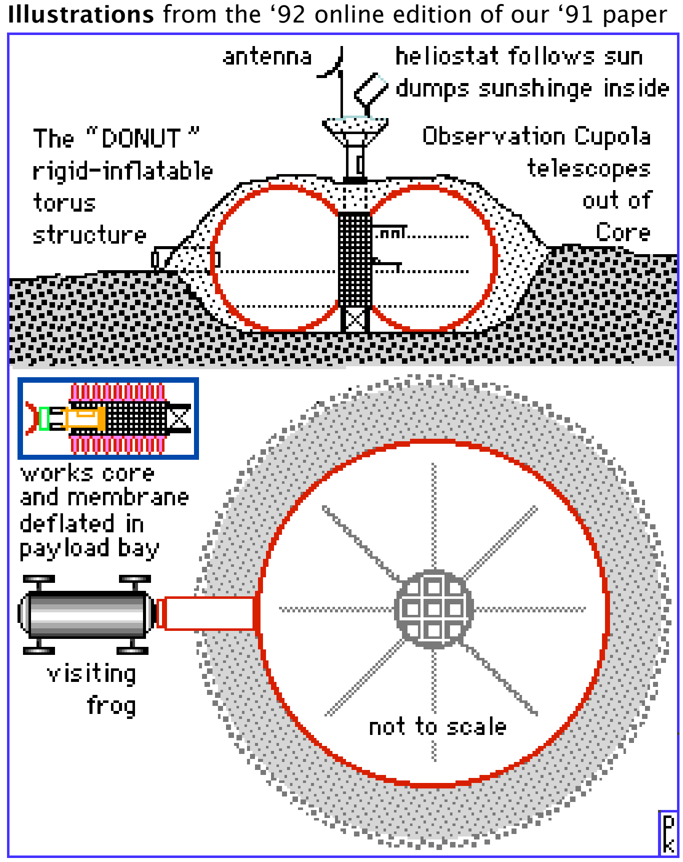
Excerpts from William Schneider's replies:

WS: "I am not familiar with the paper by Lowell Wood that you reference so it did not influence the design."

WS: "The original purpose of the TransHab design was for a Mars mission. The habitat for the Mars mission was required to be 600 cubic meters. For an aluminum shell structure—the type that had been conceived—to be that large while being launched (enduring high launch acceleration loads plus high launch vibrations) required a thick wall and heavy wall stiffening. Because of the large surface area the entire habitat became prohibitively heavy. An inflatable, however, could be launched in the collapsed configuration, *strapped tightly around a central core so that it could easily withstand the harsh launch environment;* once in orbit, where the acceleration and vibration loads are zero, it would be inflated to the required volume."

So this was yet another example of solutions so elegantly logical that they must inevitably occur to more than one person. History is full of such instances were an idea was conceived or invented independently by more than one person. We were content to be one of those.

Illustrations from the '92 online edition of our '91 paper



Note the illustration left center of the unit deflated in a Space Shuttle payload bay. Note also the observation and EVA dock tower that also rides in the rigid center core.

The "donut" torus interior structure pops out of the walls of a "works-packed" rigid cylindrical structure in the donut "hole". It was this TransHab prefiguring

hybrid-rigid-inflatable architecture that seemed to us to be the most promising way to get the most out of the shape/weight constraints of the Shuttle payload bay - or of an External Tank Aft Cargo Carrier etc.

The "donut" could be loaded with pull-out built-in features: top-mount central solar, visual, and EVA access, side-wall vehicle docking port, decking parts brought up in the core module's "basement', and a peripheral jogging track. The inner surface of the outer sidewall could be pre-painted or printed with a 360° panoramic mural medley of Earthscapes and Moonscapes.

Two extra coupling ports in the outer wall at 120° angles we would make possible clusters of individual donut units on a hexagonal grid for open-ended "organic molecular" expansion potential.

Small conventional instrument-packed canister modules brought up from Earth and coupled at unused ports would allow endless upgrades. [**Note:** Dave Dunlop had since rechristened our "donut" as the "Moonbagel"]

The "donut" was one of several "hybrid-rigid-inflatable" options illustrated in our 1991 paper.

Has Bigelow Aerospace made a potentially "Business Plan Crippling" mistake in scuttling this once "integral" part of the TransHab architecture? *We think so.* But we also think that *it is a mistake from which recovery is possible.*

Why it was a mistake

Bigelow Aerospace BA 330 units are currently advertised at $100M delivered to orbit. But the problem is that unless you want to use them as a free fall "gym," they are unstructured and definitely *not ready for use.* The question of "how much it will cost to structure the interior for use *after launch* (instead of before) is not addressed.

While Bigelow's Business Plan has had a very substantial boost form its recent partnership agreements with heavyweight Boeing, which will provide its Atlas 5 for launching BA 330s into orbit, and also provide a crew capsule for visiting them, the outfitting for usability question remains both unmentioned and unaddressed.

Now recovery from this potentially business-plan-torpedoing mistake is possible, and provides **a business opportunity for a third partner.** The new company would purchase a BA 330 airlock and design "slip thru" compact outfitting packages that once inside, would structure the interior.

This will be easier if the customer can settle for a vertical design as in the TransHab cutaway concept at the top of this article. But with enough ingenuity, horizontal outfitting packages are possible - for these, Bigelow's oversight is moot, as it does not seem *"as feasible"* to prepack a horizontal outfitting package in an uninflated BA 330 prior to launch. But most often, "where there is a will, there's a way."

Why attention to this oversight is urgent

We most definitely do want Bigelow Aerospace to succeed. Our criticism is meant to positively constructive, and to encourage formation of a third commercial partner company. At stake most urgently, are Bigelow's orbital opportunities, as potential additions to ISS and as, in clustered complexes, new space stations and tourist complexes, some of them in equatorial orbits. Then at last we can get read of *the stupid "The"* in "The ISS".

For Lunar applications, another *thick* bone to pick

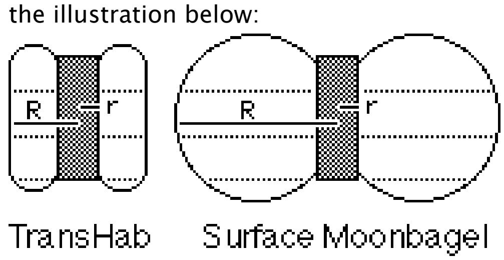
The BA 330 module is depicted in this Bigelow Aerospace tabletop model of a future lunar outpost concept

There are two things wrong with this picture:

1) It shows the modules "on" the surface, giving *the misleading impression that the one foot thick inflatable envelope,* designed to be puncture resistant to micro-meteorites and micro-space-debris, *is also sufficient protection against cosmic rays and solar flare radiation.* That would be very convenient, but it is an assumption that seems unreasonable on the face of it.

2) *If instead of an on-the-surface deployment,* we dig a trench, set the module in it, then cover it with 2 meters of moondust shielding, we would have enough radiation protection for personnel staying six months or so (but not a lifetime.) But then the one-foot thickness of the envelope becomes unnecessary. The envelope for a unit, meant to be covered with moondust, *need only be thick enough to contain the desired air pressure* (which for purposes discussed many times in other articles, we believe should be set at 0.5 ATM, all the reduction coming from Nitrogen, not Oxygen.)

3) Now *if Bigelow produces a separate thinner-walled unit for lunar deployment, the compacted for shipment weight and volume of the unit would be much less.* That saving can be spent in a much larger envelope! Consider the illustration below:



Left: thick wall unit

Right: thin wall unit shipped in same weight and volume

A deployed larger thin wall unit would occupy the same shipping space with the same weight. Now granted, the vertical design shown will be less easy to shield than the horizontal version, but it definitely can be done.

At least 2 Commercial Business Opportunities

The upshot then is that we need a new startup company to produce **"slip-in" outfitting packages** for Bigelow units to be deployed in orbit; playing "Roebuck" to Bigelow's "Sears." And a new company to design thin_wall Moon-bound inflatables pre-outfitted with interior structuring packages. *Calling all entrepreneurs!*

The Challenges of Dr. Abdul Kalam to The National Space Society & the World

By David Dunlop

Dr. Abdul Kalam, former President of India, addressed attendees at the 2010 International Space Development Conference in Chicago on May 30, 2010 via a teleconference hookup from India.

An Honor for NSS

Space Based Solar Power has been proposed for a long time, since the first advocacy of Solar Power Satellites by Dr. Peter Glaser in the late 1960s. It has undergone several significant technical and economic appraisals during this period. (1) But a new threshold for the National Space Society and SBSP was crossed in May 2010 at the International Space Development Conference in Chicago when Dr. APJ Kalam, former President of India on the topic "Harvesting Energy From Space", addressed the ISDC audience. (2)

This to my knowledge was the first time a former head of state of a major country had addressed the ISDC. Dr. Kalam discussed space solar power in the context of India's energy needs through the year 2052, not only as the former head of state in India but also as one of India's foremost rocket scientists. He called NSS "an enlightened audience for this address."

A Global Space Vision

Dr. Kalam did not stop with India's needs. In his ISDC address, He called for a World Space Vision and for action by Integrated Global Leadership through a Global Energy Technology Initiative for Harvesting Energy from Space. The Global Space Vision includes:

1. Large Scale Societal missions (including Space Solar Power Mission) required for and enabled by low cost access to space.
2. Evolution of a Comprehensive space security doctrine, policy, and program.
3. Expansion of Space exploration and current application missions.

The World Space Vision 2050 would enhance the quality of human life, inspire the spirit of space exploration, expand the horizons of knowledge, and ensure space security for all nations of the world."

A Challenge to NSS: Kalam stated,

1. "The organizers of the ISDC may address to the leaders of the G-20 a comprehensive paper on all aspects of space solar power and to request the participation of experts for a cooperative International Preliminary Feasibility Study project that would benefit all nations. "
2. "Meanwhile, an Interim Working Group could be set up to suggest the structure and content of the Preliminary Feasibility Study, and that should lead on seamlessly to the creation of an international steering committee and two or three International Study Teams of world experts."
3. "These Study Teams may cover among other aspects of space transportation and cost of access to space, efficiency of energy conversion, power transmission from space, possible collaborative mechanisms, experiments from nations and possible organizational mechanisms with potential sources of funding."

He made the observation that, "the present capabilities of **major space faring nations***** (my emphasis) are not optimally utilized and called for a 'certain paradigm shift' in international collaboration to bring the benefits of space to humanity as a whole." The launch vehicles, spacecraft, potential applications, space scientific research potential, and huge financial challenges call for a coordinated international approach. Dr. Kalam said his experience suggested this could be successful if each nation made substantial contributions in technology and resources.

"We are witnessing such phenomenon in other areas also. The countries of the world had come together to find solutions for the global economic turbulence. Issues like energy and water are in the realm of international community. **Then is it not an opportunity** for the space community of the world, which has played a key role to bring the world together, to think ahead and create a 'World Space Vision' and work out 'mechanisms' for taking up missions?"(Italics mine)

"Hence, it is a great challenge and opportunity for the world of nations, **particularly space faring nations** (my emphasis) to create imaginative mission mechanism(s) to take up global R&D program(s) and implementation so that the twenty first century can blossom to create SSP and its enabling technologies. I wish the Special Symposium a very special success."

A Potential National Space Society Response

I am proud as an NSS member, to belong to an organization not only recognized for its enlightenment by someone of the stature of Dr. Kalam but an organization also given a special charge to address a comprehensive paper to bring Dr. Kalam's World Space Vision Challenge to the forum of the G-20 nations. Our advocacy of Space Solar Power has been noticed by President Kalam who also specifically complimented our NSS Space Solar Power library on our website. The NSS collaboration with other organizational advocates of Space Solar Power has clearly paid off and been effective as an open advocacy effort.

The NSS has therefore received an historic charge and responsibility unique in our experience. NSS has experience in the US with annual advocacy efforts with the US Congress, but we have never before approached the forum of the G-20 nations or even the narrower group of all the space faring nations.

NSS membership however, is diverse as well as international. The President and Chairman of the NSS Board, of Directors is Mr. Kirby Ikin from Australia where there are several NSS chapters. Paul Swift of our affiliate organization, the Canadian Space Society, hosted the 1994 ISDC in Toronto. And one of the highlights of ISDC 2010 in Chicago was the Space Canada sponsorship of the dinner hosted by renowned Canadian broadcaster Bob McDonald with Space Canada's new film on Space Solar Power.

NSS chapters are found in seven other G-20 member nations such as Brazil, France, Germany, India, Mexico, and the Netherlands as well the US. We can therefore claim an international advocacy within our own membership, chapters, and affiliates. The NSS vision of space development is one inclusive of the interests of the whole world and our advocacy is consistent with the embrace of a World Space Vision and Global Energy & Space Solar Power Technology Initiative suggested.

Perhaps what I like best about Dr. Kalam's proposal is that while it is couched in terms of space technology, lowering the cost of space access, space energy supply, and yes, space exploration, its focus and strength of impact is clearly centered on our most important planet, the Earth. How could NSS advocacy be any more mainstream?

Geopolitical and Geocommercial Aspects

I find it interesting that Dr. Kalam focuses on two international groupings: First he discusses the opportunity for a paradigm shift and collaborative improvement of the major space faring powers, those nations with the national technology means. Then he proposes a Global Vision brought to the G-20, the most important economic members of the global economy, which also collectively represent 90% of the global economy, 80% of the global trade, and 66% of the global population. To this larger economic forum he would assign the development of 'mechanisms' for implementation that speak to both the economic and political process. The close ties of NSS to the Space Solar Power research community and to the Space Investment Summit are potential assets in the development of a comprehensive paper for the G-20.

Space Security

Dr, Kalam called for the evolution of a comprehensive space security doctrine, policy and program. This is very important arena, which implies a more active stance with regard to the topics of space security doctrine. Space security is a term which covers the national activities involving the national defense capabilities of every country as well as the safety and reliability of space assets and capabilities.

I think in the first instance space security involves principles comparable to the "freedom of the seas doctrine" in which all nations pledge to support the right of free access to space for all of the international community. This would also imply that international assets would be used in support of such right of access as well as assistance for assets in distress. It would also be important to constrain the waste of resources that could result from a militarization of space.

It must also address the poor international record with regard to the generation of space debris and the need to remediate both the threats posed by this growing problem and to develop proactive practices to prevent the growth of space debris. The "pollution of the commons" is what is at stake and the risks must be balanced and monetized in terms of insurance and remediation costs that are reflected in the price of market driven services. Space security is necessary for increased geocommercial space investments.

New Space Mission Applications & Global Growth

Space communications resources are part of vital infrastructure affecting the economies of every nation. Therefore the expansion of the growth of the space economy is threatened by the failure to come to grips with space debris. Proposals for increased development of space stations and human presence in LEO and cislunar space, for larger more capable GEO platforms, and for solar power satellites must address investment requirements, risk management, and the development of active measures to mitigate the risks of space debris.

The current $150 Billion annual global space economy is only a slight fraction of what could be orders of magnitude greater space-based economic activity in the next four decades. These additional space mission applications are the third element of his challenge and the call for study panels on: communications growth, Earth observation activities, space tourism, space manufacturing, and space solar power, and expanded space exploration. These study panels will underscore the economic and growth potential to create a truly Earth-Moon econosphere in cislunar space which will expand activities in LEO, GEO, Earth-Moon Lagrange Point 1, and on the lunar surface. Lunar in situ resources can be brought to bear on production of space solar power facilities and even space computation facilities.

Creating Mechanisms for Action

Dr. Kalam further calls for the appointment of an Interim Working Group and study panels. *International coordination could be facilitated by the formation of a* ***Space Solar Power Working Group*** *on the order of those such as ILEWG (International Lunar Exploration Working Group) and MEPWG Mars Exploration Group working programs.*

Members of such an Interim Working group might include some of the many international contributors to the Space Solar Power symposia and the International Academy of Astronautic study on space solar power represented from Canada, Europe, India, Japan, and the US and broadened to include both Russian and Chinese participation. The International Academy of Astronautics study group on space solar power, with the leadership of Drs. John Mankins and Nobuyuki Kaya of Kobe University has been working the past two and a half years to complete the first international study of space solar power. The first preliminary report should be completed by the end of this year with full publication expected in the Spring of 2011. This study should provide a timely foundation for expanded collaborative international research and additional recommendations originating from an Interim Working Group.

NSS, consistent with its free market values, would expect an Interim Working Group to develop into a more well-resourced Space Solar Power Working Group with formal participation and support from:

- COSPAR: Committee On SPace Research
- CCSDS: Consultative Committee for Space Data Systems
- National Space Agencies of major space faring countries
- The Commercial Aerospace sector
- The Commercial Power Industry
  (Electric Power /Research Institute would be a logical participant in the US)
- Representation of the Global Investment Sectors
  The World Bank.
  The Space Investment Summit group
  Regional Development Banks
- NSS: The National Space Society
- TMS: The Moon Society
- Other Space Solar Power Advocacy organizations

www.moonsociety.org/reports/space_solar_alliance.html

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Humans are 'teletropic' - drawn to far-off places, to the frontier, and to forever beyond

"In this decade" - JFK - 3 words that won us the Moon Race, but which have hamstrung us ever since

When JFK gave his famous "We choose to go the Moon" speech, these three fateful words torpedoed Wernher von Braun's plan. Sure he got to be in charge, but it was no longer his tune to which we would march. We could *not* delay achievement of the real goal, *beating the Russians, and Oh, by the way, we will visit the Moon ….* To set up a logical infrastructure along the way so that *if we planned to stay*, we could do so with an economical space transportation system. We were in a race, and the Moon was just a handy goal, dispensable once met. We would not delay the race to build an orbiting depot and assembly station. We would never have gone to the Moon as all, if it were not a way to trump the Russians big time, at their own game.

Those of us who were around at the time, when Nixon (not Congress) pulled the plug on *Kennedy's thing*, were disappointed to be sure. But Saturn V was not the right vehicle and transportation system on which to build a *sustainable* Moon venture that included a permanent and growing presence. To stay, we would have had to pull the plug on Saturn V, which we did anyway, and start with a transportation system that involved logical *nodes*. And so began the campaign to convince President Reagan to give NASA a new goal, building a space station.

Well, we lost that one too. We got a space station of sorts, but it was a "yoyo space" thing, downward looking at Earth, and not a outer-space oriented depot or assembly station. It was even put in an orbit unfit to serve as a transfer point. Yes, that orbit was necessary to get the Russians to agree to partner with us, Clinton's deal-clinching strategy to keep Russian scientists gainfully employed rather than out there looking for work in nations with mischievous intentions. Yes, the Space Station has done great things, and kept space in the public eye. But it is *boundary layer space*, not the outer space that includes the Moon and planets and beyond.

Once again the space community mounted an effort to get the government to consider going back to the Moon. Both Bushs came up with flawed plans. By then NASA only knew one way to do the Moon, the wrong way. So along comes Mike Griffin, who gives us a Saturn V substitute, a way to get to the Moon without building the infrastructure that might allow us ***to stay!***

Let's stop blaming Obama for halting what was a farce in the first place. Let's stop cheering on Senators who would reverse Obama's decision. If we want to return the Moon "to stay," we have to abandon **Space Transportation 1.0**. We have to start with a clean slate, and brainstorm **Space Transportation 2.0**

What we have been trying to do for over forty years has been a pathetic reenactment of the tale of Sisyphus, the mythical Greek figure who kept trying to push a big rock to the top of a hill, only to lose the battle and watch it roll back to the bottom, retrace his steps and try again to push it to the top. We did not settle the west that way. We did not set out from the East Coast with a gigantic 50 ft wide half a mile long Conestoga wagon pulled by a team of a thousand horses. No, we built places along the way, St. Louis, Kansas City, Omaha, Denver, Salt Lake City, etc. At these stops we could replenish all our supplies, even personnel. At each stop, we dropped off things (passengers too) needed there and picked up new supplies, fresh people. Every waypoint made the next waypoint doable *and at a reasonable cost*. Going from Sacramento to San Francisco, the last step, was no more expensive than going a similar distance much further east.

So how do we take a page from the mid-1900s, a century and a half ago? It is pathetic that it is taking so long to learn what is really an obvious lesson!

Waypoints on the Road to the "Moon to Stay"

Let's back up a bit. No I am not a rocket scientist. But rocket science is the problem. Why, because it is impatience that is always the problem. *Building bigger and more powerful rockets is just making it more expensive to go nowhere.*

It would seem that low Earth orbit is waypoint one. But I think it would pay to revisit how we launch from Earth. The most expensive thing is getting off the ground, and vertical launch is the most expensive way to do that. Fly back boosters, even rocket sleds, to launch horizontally to a level where the atmosphere is much thinner, need to be revisited. Always keep in mind that impatience is the enemy, the chief way we defeat ourselves in whatever we do. It simply should not take that much oomph to get us into orbit, or to the point where a smaller second stage could take over from a smaller first stage and successfully get the same payload into space. The masculine power trip way is not only not always the best way; it is almost always the worst way. So the first way point is the in transit level at which atmospheric resistance significantly drops off.

Low Earth Orbit

We all know how useful low Earth orbit is. It is a great place to study the Earth. Our remote sensing and weather and navigational satellites have given us a much better understanding of our home planet. And the International Space Station has helped as a platform. It is also a great place to assemble things to large and/or to heavy to be sent up in one payload. To date, except for the Space Station itself, which proves the point, we have tried to avoid in-space assembly by building ever-bigger rockets for ever-heavier and larger payloads.

What we haven't yet got right is that every part of a rocket that makes it to low Earth orbit, could have been designed "*transformer style*" to serve as components for something to be assembled in orbit. We just throw that "stuff" away: farings, spent stages, External Tanks!

For every ton of satellite mass in orbit, we have thrown many tons away that could not be integrated into something useful whether larger platforms, assembly and repair facilities, additional space stations or facilities for space stations. But then we are a throwaway people. Like our simian predecessors, who seemingly can't be house-broken, we apparently can't be planet-broken; it is easier to throw away and to trash than to reuse and reassign items and materials that have done their initial job. Had we not been so macho, and had been into husbanding everything that makes it into space, we could be decades ahead of where we are now, and probably without a space debris problem of such magnitude.

Impossible? If you think so, perhaps your imagination has become fossilized. Hold a design competition for ideas on what we can do with this or that throw-away item and prepare to be amazed at what still flexible minds can imagineer! Get with the program or get out of the way. We'd all still be in the stone age if it were not so.

Geosynchronous Orbit

Now we get to where it gets real fun! Perhaps most of us do not realize the scale of Geosynchronous orbit. At 23,000 miles above Earth's surface, 27,000 miles above its center, it is $2\pi r$ or 170,000 mi. (230,000 km) in circumference. Yet, it is limited. We don't need our communications satellites slowly drifting into one another, so international agreement limits "stations" to 2 degree intervals. Dividing 170,000 by 180 gives us a spacing less than a thousand miles apart. But we already have well over 180 objects in GEO. And if and when we start building solar power satellites in GEO, and these things will be large, the situation could become dicey.

One way to alleviate crowding would be to build giant platforms that could provide power, station-keeping and repair services to dozens, hundreds, or even thousands of individual communications and TV relay units. Where would we get the materials to build such platforms? We need not build more GEO-bound rockets, but only design their rocket casings in a way that, again, "transformer-style," can self-unfold into platform strut sections. Maybe we need to mandate our rocket scientists and engineers to watch more Saturday morning cartoons - some of them probably never heard of the "transformers." Well, the kids and toymakers all know, so maybe when they grow up, they can turn things around.

Ultimately, of course, building materials for GEO platforms and SPS stations, can be shipped down from the Moon at much less expense than up the shorter distance from Earth. IF GEO is to be the linchpin of the 21st century economy (up from $250 **b**illion per year of economic value to $250 **tr**illion), lunar resources will be the principle enablers. (Mars will contribute nada, zilch.)

The Earth-Moon L1 Gateway

This is the next waypoint, the "Sacramento" stage if you will. And in similar fashion, this gateway can be built up from components needed to get that far, but not going the rest of the way to the Moon's surface.

We will want an L1 Space Station with storage, even warehousing capacity, vehicle repair and maintenance facilities, fuel storage, cargo storage for transshipment, crew quarters for personnel in transit. L1 will grow apace with facilities on the Moon's surface, into a major transfer and service spaceport in the sky.

If L1 doesn't grow, neither will the lunar frontier. Reuse of every last item that arrives there not going further, is the key. See our slide show on L1 growth:
www.moonsociety.org/spreadtheword/pdf/LIphases.pdf

The Moon's Surface

Nor does our "transformer" routine stop at L1. Every part of a ship that lands on the Moon, and which is not needed for a return flight (100% if it is au unmanned cargo ship) should be designed for reuse or cannibalization on the Moon - down to the last strut, landing pad, fuel tank, --- everything, not just what's in the cargo hold - and that goes for packaging materials as well. To paraphrase a colorful description of rural southern cooking, using every part of the pig except the squeal (and maybe finding a use for that as well.)

Now I have just offended those who believe that reusability is the key to economy. No, not if you mean reusing the same thing over and over for its original purpose. To do that you have to get it back to its original port and that is wasting fuel. Second, by reusing as is, you do not benefit from the economy of mass production. We don't need ten reusable rockets that get used a hudnred times. We need a thousand rockets that get used only once, as a rocket, but then are put to permanent use taken apart and transformed into something needed on the frontier. Old timers will remember the World War Liberty ships, which we turned out cheap by the hundreds. Mass production and total reuse of materials at a destination - that's *economy on steroids*, if you will!

Yes things should be reused, but as materials, not as originally assembly components. We have to get into this new way of thinking avout things and their utility. Look at a lander's legs and pads, and see a mobile crane! We may have to tweak original designs to get the most reuse potential out of them. And this redesign may cost some, but the rewards for reusability will pay off handsomely. Let's sponsor and run contests annually for the most innovative reuse of all these things used only once in transit. Let the young people clear the cobwebs in our older brains! We will fail if we do not pass the torch!

Summing up "Space Transportation 2.0"

Every item that leaves Earth surface should be designed for reusability of its constituent parts or materials.

Components should be designed to serve some new function or purpose at the way station at which their original function has been achieved

Power is less important than economy and reusability

Nothing that can be used at a way station should be sent back down the line Earthwards. It is better in the long haul to keep sending up new rockets and rocket components that can be put to new use up the line, than to return them back down the line - false economy

Complete **H**ardware **U**tilization Mission **A**rchitectures = **"CHUMA"** (thanks to Dave Dietzler for this acronym)

Everything in the sacred traditional way of doing things should be reexamined in light of this new paradigm.

 # The goal is not to return to the Moon.

 # The goal is not to return to the Moon to stay.

 # The goal is to return to the Moon and keep growing a lunar frontier civilization which in turn will feed Earth's needs in GEO and elsewhere and help us all rejuvenate and preserve the Eden that Earth once was. We are going to have to travel a lot of light years to find another like it.

If this seems absurd, check out this report:
http://www.foxnews.com/story/0,2933,529059,00.html

We have to quit saying "we can't" when we haven't really tried. To the Moon, *to stay!* **PK**

Taking a Fresh Look at the SPACESUIT CONCEPT

By Peter Kokh

Background: in a previous article, "Engaging the Surface with Moonsuits instead of Spacesuits: Mother Nature has a Dress Code!" MMM #151 Dec 2001 [republished pp 2-5 http://www.moonsociety.org/publications/mmm_classics/mmmc16_July2007.pdf] we addressed some spacesuit issues. In this article, we take the discussion further.

The NASA Spacesuits developed for the Mercury, Gemini, and Apollo programs evolved quite naturally from high altitude aviation pressure suits. For use on the Moon, they had to be able to resist micrometeorite puncture and keep the astronauts cool in the rising mid-morning temperatures on the Moon. For short stays - the longest was only a few days - the radiation issue did not need to be addressed.

But it is clear that these suits had two functions: pressurization and protection. While the inner suit worn by astronauts did help contain physical body support, as they did not include a pressurized helmet or pressurized gloves, the outersuit with helmet and gloves was needed for both purposes: pressurization and protection.

Separating these two functions

However, if we separate these two functions, we might be on our way to a more rational design, more comfortable to wear, with greater freedom of movement, and yet with adequate puncture resistance and thermal management. We already have several experimental forms of the inner pressure suit: the "skinsuit," also known as the Mechanical Counter Pressure (MCP) Suit.

Mars Society Australia launched a "marsskin" project: http://www.marssociety.org.au/marsskin.php

> "An MCP suit would differ by exerting pressure on the body using form-fitting elastic garments. Webb and Annis published the concept and early experiments of a MCP suit in 1967, and in 1971 described the first demonstration that highlighted the many advantages of the MCP approach. MCP garments were found to offer dramatic improvements to gas pressurized suits in reach, dexterity and tactility due to the replacement of stiff joints and bearings with light, flexible elastics. Further advantages included safety (because a tear or hole would remain a local defect rather than cause a catastrophic puncture), lower suit costs and vastly reduced weight and volume. MIT conducted flexibility tests with basic MCP elastics during the mid 1980's and found MCP gloves to be measurably superior to gas-pressurized gloves."

While this prior research seems dated, one can understand NASA's on again/off again approach to space suit alternatives and development. The Return to the Moon has been an on again off again program: the first and second Bush space initiatives. And that is why space enthusiasts have taken the lead. In addition to the Mars Society Australia effort, we are proud to call attention to research done by crew member William Fung-Schwarz, Health & Safety Officer on the Moon Society's "Artemis Moonbase Sim 1" 2-week exercise at the Mars Desert Research Station, as Crew 45, Feb. 26 - March 11, 2006.
http://desert.marssociety.org/fs05/ (scroll down to #45)

The project goals, goal status, suit description, and costs are stated in William's report:
http://desert.marssociety.org/MDRS/fs05/0311/mcp.asp

Honeywell (LA), UC-San Diego, and Clemson U. have conducted physiological and design testing on gloves and arms. [from the Mars Society Australia page]

Lunar "Coveralls" - An MCP Skinsuit is not enough

There are additional links on the Aussie Marsskin page. As this page does not appear to have been recently updated, we can't be sure that this research continues. Be that as it may, it isn't to the point of this article. We think that it is a great start, but for use on the Moon, an outer suit that offers thermal management benefits as well as serving as a first barrier to micrometeorite and sharp rock punctures should be required outerwear in full exposure lunar surface vacuum.

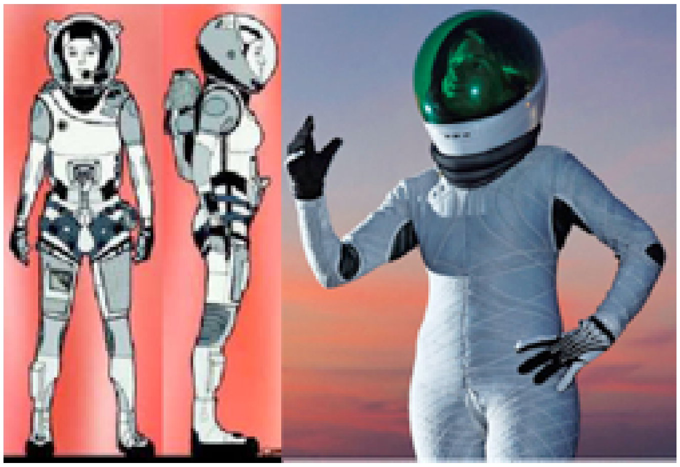
We have talked often about construction of shielded but unpressurized areas for storage of items that need to be accessed on a regular basis, and for equipment needing regular or frequent maintenance. We have dubbed these environments as "lee-vacuum" that is providing "wind" protection. "Wind?" We refer, of course to exposure to the cosmic elements: cosmic rays and solar flare protection as well as micrometeorite "rain." In such areas lighter weight pressure suits and skinsuits will be adequate, and reduce wearer fatigue as well as greatly improve mobility. Shielding will also deter overheating.

But for wear out on the not-so-protected surface, another layer, which need not also be pressurized, is to be strongly recommended. If this layer is loose, since it does not have to be pressurized, it should not hamper motion as did the Apollo mission suit. Those working on the surface could accomplish more with less effort, and less fatigue, thus reducing risk as well. Such suits might also reduce moon dust buildup on the inner skinsuit. They could also be shed before entering an airlock, and stored outside, thus reducing the migration of dust into interior living and working spaces.

In MMM #**225**, MAY 2009, pages 6-8, we wrote about "**Skinsuit 'Outerwear' for Surface Activities.**" In this article, we were addressing lee-vacuum environment use, in which one might choose to wear special outerwear, not for any extra protection, but either to hide unflattering body contours, or simply for "fashion fun."

Here we are talking about heavy-duty outerwear to be worn for protection not adequately offered by skinsuits when worn on the fully exposed lunar surface.

Left: an Apollo-like Moon suit. **Right:** The MCP skinsuit tested by William Fung-Schwarz at M.D.R.S. on crew 45.



Left: Illustration of the Australian concept
Right: Counter Pressure suit by 4 Frontiers Corporation

Again, in our opinion, a counter pressure suit, by itself, does not offer sufficient protection in the lunar environment. The Mechanical Counter Pressure suit research is an invaluable and essential first step. But we must mate it with an MCP compatible outer suit.

How much would an unpressurized outer suit resemble the Apollo Moon Suit? It might be about as bulky, and also have elastic wrist and ankle bands to deter moondust contamination of the inner counter-pressure suit. But by virtue of not being inflated, it would hang more naturally on the wearer and greatly reduce joint stiffening (and hence fatigue) that is produced by pressurization. I do not pretend to be able to draw such a suit with my low level of illustration skills.

Has there been experimentation along these lines? I am not aware of any. NASA has supported a number of optional spacesuit design programs in the past, but none are currently funded. And the design features these projects strove to realize were different: they were still pressurized.

It would seem a simple matter for a chapter to get hold of an aviation pressure suit, in lieu of a newer skinsuit, and then design and produce appropriately thick but loose outer suits with elastic sleeve and leg ends, in order to get across these concepts to the public as well as to the space-interest community at large.

If the return to the Moon is undertaken comer-cially (as well as by non-US national space agencies), it is possible that the commercial firms would be willing to part with tradition and try out and test such new double suit concepts. There is much to be gained both in mobility and in the length of time one could work out on the surface without fatigue.

There is a principle at stake here: if we want our lunar initiative to grow into something permanent, and we do all want that,

We must "do the Moon" on its terms, not ours!

As such a goal is a perfect fit for the Moon Society and for other groups such as the National Space Society – we both want commercial-industrial permanent lunar settlements – promotion of such projects should be pursued. It would be appropriate to provide seed money for modest research/engineering initiatives and demon-strations, if we find individuals or groups, lay or academic, who want to pursue these concepts further.

This research is vital! **PK**

For the Sake of Science, Science should not be in the driver's seat on the Moon

By Peter Kokh

IT may seem irrelevant now that NASA has been redirected away from establishment of a perm-anent structure on the Moon, it begs discussion. The lunar science community has strongly favored a south pole location because it lies on the rim of the vast South Pole-Aitken basin, the deepest on the Moon, most of it in the farside southern hemisphere, These scientists see a South Pole site as a jumping off point for overland expeditions that would probe the SPA's secrets. What's special about the SPA other than it being the Moon's deepest basin? There is an expectation among some that there are mantle materials to be found here and there on its surface. On the nearside, the mantle lies miles below the surface. What seems puzzling is that scientists are supposed to be "smart." The Apollo crater in the NE part of the SPA, where the deepest areas are to be found, is o a thousand miles from the pole, across rugged terrain. As moths that need the mythical "eternal sunshine" they would not get far from the pole before they would have to turn around to get back *before dark.*

That is not our point. To these scientists, estab-lishment of a permanent lunar frontier is a low priority if it has any priority at all. Yet, *the more people on the Moon, in the more places, for an open-ended period, the more science will be supported and in the more places.* If Europe had sent a dozen science expeditions to both North and South America each, but never settled, how much would we now know about these two continents compared to what we, as inhabitants, have learned over the centuries? These scientists, brilliantly focused in the short term, are obviously myopic when it comes to looking further ahead, their advice needs to be weighed against other more practical considerations.

We do need lunar science to help identify key locations on the Moon with the various resource concen-trations that would make them ideal for industry-based settlement. No spot on the Moon has all the needed mineral resources. The lunar frontier must be global in character. The South Pole, as attractive a site as it seems to be, has some severe drawbacks. The polar ice may not be a *near-term* resource. That some very rocky anything-but-flat areas get a lot of sunshine is irrelevant if there are no "buildable" locations nearby, locations large enough to support considerable expansion. And as the pole is so atypical, learning how to erect and maintain a base there does nothing to help us globally.

Some destructively impatient lunar mission advo-cates have convinced some U.S. senators that the Constellation program should be rein-stated. This effort is seriously misguided. Why spend our limited funds on a program to "fly & flunk" when we should be laying foun-dations for a Moon Program that will patiently and deliberately phase in permanent human settlement based on industries that will help tackle Earth's most important problems: environmental degradation and limited clean energy reserves.

It has become more important to some lunar enthusiasts to see something happen in their lifetime than to face death, *not having seen the favored frontier open, but knowing that we are on the right track to doing it right, doing it to last, doing it to fulfill all its promised potential.* **PK**

Conquest of Moon's Cold Traps Is the Key to anywhere in The Outer Solar System

By Peter Kokh

We always knew that the floors of the Moon's permanently shaded polar craters would be cold. After all, the brightest thing in their heavens, except for a rare passing comet, would be a star less brilliant than Sirius.

We always knew that we would have to bit the bullet and develop such cryo-materials, cryo-lubricants and other systems, that is, if we wanted to land rovers and long-operating probes on the fascinating moons of the Outer Solar System. But we thought that was a long way off, a challenge for another generation. Now it is suddenly our challenge.

Perhaps most writers and planetary scientists and lunar enthusiasts, see the availability of water-ice as an overriding reason to set up shop first at one of the Moon's poles. But now it seems that the challenge of learning to store power so that we can get through the lunar night, and to scavenge volatiles from moondust, may be the less daunting challenge. After all, the reward for doing so is to open the Moon globally, not just at the extremely atypical poles.

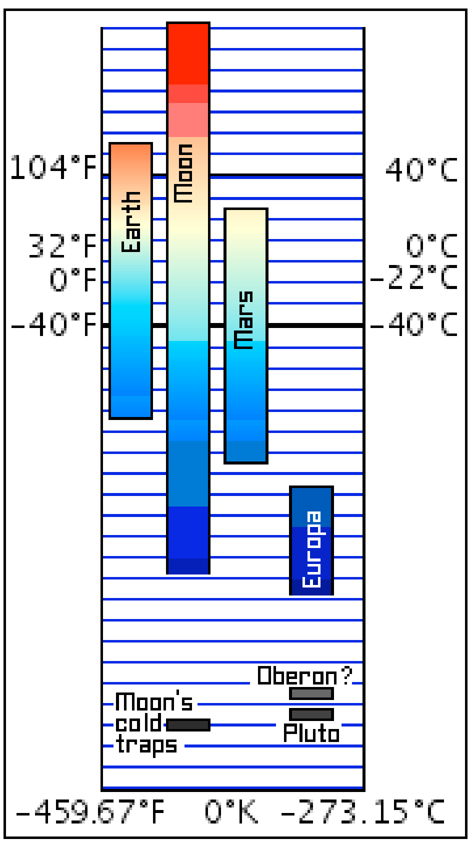
Yet, while the priority of "doing the poles" might now see to be a peg or two down the line, we do need to get busy developing the materials and systems that will allow us to study the lunar cold traps, and study their frozen bounty in depth. Will we need to use super-magnetic bearings instead of still science-fictional cryo-lubricants? Won't the recently discovered fact that these craters are electrically charged rule that out? We have a lot of homework to do, and the "readiness state" of the needed technologies is about 1, if not less, on a scale from 1-10.

But think! If we meet this challenge, suddenly the Outer Solar System is ours as well, decades ahead of the wildest expectations! The Moon is suddenly the key to the Outer Solar System! Not Mars, not Ceres, not even Europa or Callisto. The Moon? Suddenly planetary scientists bored or disinterested in the Moon, have a very big stake in the next decade of lunar exploration. The Moon will become the proving ground for outer system rovers.

But at least most of us were surprised at the recent finding that these pitch black areas were colder, by about 10° Celsius, than the poles of Pluto! Many voices have long been calling for "ground truth probes" that could sample the ice or permafrost regolith soils in these dark craters to quantify and qualify the nature of this frozen resource. What other volatiles are present? If the source is cometary, we'd expect carbon and nitrogen oxide ices and other volatiles.

These could be as strategically important as water-ice itself. What kinds of equipment and what methods would we need to harvest these resources? Enough with these orbiters and impactors! We needed to get equipment down there to find out what we really have, and how practical a near term resource these polar ices are.

But whoa! Metals are brittle at those temperatures. Nor do we have the electronics or even the lubricants that can operate there!



Even Mars people may see the benefit, for Mars is Antarctica in red, with less ice so that it only looks like Arizona or Utah: Mars shares the same temperature range from somewhat over freezing in a very few areas to bitter cold almost everywhere.

David Dunlop, the Moon Society Director of Project Development, has for some time now, been focusing on the potential for using the Google Lunar X-Prize program to put more rovers, and more badly needed instruments on the Moon.

His idea is to extend the options for the eventual "also-rans" to keep their teams intact by having NASA establish new prizes for fielding needed instruments on the Moon, and for landing in areas in which our scientific curiosity is very high. He would also like to see a new round of NASA engineering challenges to develop all these cryo-engineering technologies.

And now NASA seems to have gotten the idea as well.

What we could see sooner in the Outer Solar System

What we have learned with orbiters has been nothing short of amazing, and it continues to get more so. Scientists find ever more elaborate ways to coax more significance our to readings that once might have been considered noise. This is nowhere more true than with the Cassini team and the ongoing investigations of Saturn and its extensive family of moons and moonlets. What they continue to discover beneath the clouds of Titan, which vies with Europa as the most intriguing world beyond Mars, brings startling new information month by month as the extended mission continues.

That said, capable rovers on Jupiter's Europa, and on Saturn's Titan, Iapetus, Enceladys and other moons around the ringed giant could tell us more. Now that the need to develop some of the needed cryo-technologies is urgent because we need those materials and systems to unlock the Moon's tightly held secrets, can but advance the day when we can send similar cryo-hardy instruments to the icy outer worlds.

Ceres, Pallas, Vesta

Dawn is on its way to Vesta. The plan is to orbit the brightest of all asteroids, as seen from Earth, for 12 months, then move on to an eventual visit to Ceres where it will go into polar orbit around it. Such an orbit will allow very thorough mapping as Ceres rotates below.

Ceres is the only asteroid massive enough to reshape itself into a really spherical body. Its surface likely hides an ocean, and as the first planet or moon to reach this stage, just might have been the first place in the system to give birth to some form of life.

Ceres dominates a significant area: almost *15% of all Main Belt Asteroids lie within 60° of Ceres at any given time and remain there for fifteen years or longer before drifting out of range*. It will someday be the primary center of population, industry and services for the belt. And many of the technologies developed there will be useful in opening up the Jovian system. Ceres' temperature range is lower than that of Mars, but higher than that of Jupiter's four great moons. We look forward to Dawn's visit in 2015.

Pallas orbits at a similar distance from the Sun, but has a unique vantage point for study of the Sun and the inner solar system. Its 35° inclination to the ecliptic gives it a high perch both above and below that plane.

Vesta may be the biggest object in the system with a cold solid core. At Vesta's center of gravity, you would have a "negative zero-g" as the masses overhead would cancel each other out. That could make that point a unique physics lab. This world may also have lavatubes.

Oberon and Miranda

I have singled out the moons of Uranus, because along with their mother planet, their plane of rotation is almost perpendicular to the plane of their orbit around the Sun. That means that for half of Uranus' 84 year long circuit around the sun, alternately the north and south poles of its moons are pointed not just perpendicular to the sun, but away from it. Vast circumpolar areas on Oberon, Titania, Umbriel, Ariel, and Miranda will be in darkness for decades, which could lower temperatures below those experienced on Neptune's moons twice as far out from the Sun. But that is a very uneducated guess, and we welcome a real calculation.

Pluto & Charon

The calculated temperatures at Pluto's (and Charon's) poles are some 10° C, 6° F higher than those recently measured in permanently shaded lunar polar craters. But to be honest, we must keep in mind that Pluto is still not too far past its closest point to the Sun, and that in its very eccentric orbit, it will receive less than half the amount of sunlight it now gets, before it rounds the "aphelion" corner some 120 years from now and starts the slow arc back inward. Given this consideration, Pluto's poles may become as cold as the Moon's. Yet the Moon's cold trap craters may not have seen sunlight for billions of years. So Pluto might still be second.

The Pioneers and the Vikings – are RTGs the answer?

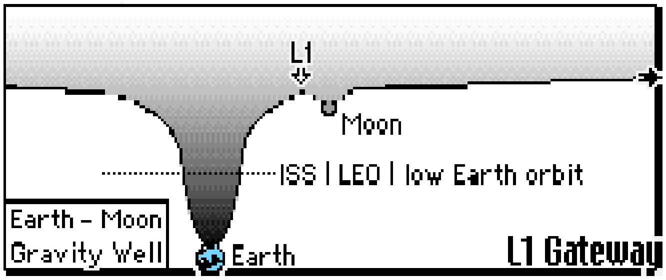
These probes are significantly beyond the traditional "outer limits" of the solar system and just keep on sending back data. But they do not have moving parts, or, if any, they are warmed by an RTG, a radioisotope thermoelectric generator, a marvelous device without which much of what we have accomplished in space would still be on the science-fiction wish list. Are they part of the answer to the challenge of ground-truth probes in permanently shaded craters at the Moon's poles? Maybe – if we can shield the surface we want to study from the heat output of the RTG. Remember Heisenberg's uncertainty principle. What we observe is altered by our observation of it. Now that principle may be the case for quantum dimensional investigation. But a parallel effect may hamper ground truth probe whose instruments and "claws" and "drills" are kept warm enough to operate by any kind of heat device.

So we think, that this is not the answer if we want unstilted results. Heat may or may not be a problem for harvesting polar ices; but it will be for studying them. TTG powered instruments will do to the icy moondust what the scalpel does to the frog in order to learn from dissecting it. So we think that the best approach is to take the plunge and by trial and error, challenge after challenge, in one area after another, develop true cyro-materials and cryo-technologies. The rewards of doing so will be to advance the pace of Outer Solar System science, and to telescope the time it takes us to go from being an intercontinental species to one that is truly interplanetary, and interplanetary with interstellar dreams.

Suddenly, the Moon becomes important for more than those who have been interested in uncovering its secrets and putting to use its resources for the benefit of human survival on a cleaner, greener Earth.

In a future article, Dave Dunlop will tell us how we can accelerate our development of cryo-technologies through X-Prize type programs and NASA engineering challenges. At the very early stages of this process, there may be groundbreaking advances that will prove to be within the scope of student and university scale projects.

It clearly falls within the Moon Society's mission to instigate and encourage this type of research. On the Moon in general, we need lubricants that will perform well at both colder and hotter tempera-tures than normally encountered on Earth. Looking down "paths not taken" during the development of silicones and silicone technologies, we may make some useful advances that will help in "ordinary" lunar hot and cold conditions, but not at the poles. Here we may need to start from scratch. Breakthroughs may come slowly at first, but we need to tae the plunge and keep on plunging. **PK**



An L1 Space Station: Gateway to the Moon, Part 2

By David Dietzler

Introduction

In MMM #232, February 2010, the article "An L1 Space Station: Gateway to the Moon" was published. Several points deserve further elaboration. It is also at:

http://groups.google.com/group/international-lunar-resarch-park/web/l1-station-gateway-to-the-moon

[requires a google username and password]

Manned Transportation

Since it takes less delta V to reach L1 from LEO than to reach escape velocity from LEO, retro rocket into LLO (Low Lunar Orbit) with a fully fueled lunar descent/ ascent vehicle and then rocket back to Earth, Apollo style, a much smaller Earth launch rocket is needed. Instead of the Ares V monster rocket, I suggest using a SpaceX Falcon 9 Heavy with a new cryogenic upper stage. This rocket could put 65,280 lbs. in LEO.

Time for some not too heavy math

Rocket engines burning LH2 and LOX could have a specific impulse of 460 seconds and an exhaust velocity of 4.5 km/sec. As the dV from LEO to L1 is about 3.15 km/s, we can use the rocket equation to determine: e^(3.15/4.5)=2.01375 65,280/2.01375 = 32,417 The mass of rocket and payload after all propellant is burnt. 65,280-32417= 32,863 propellant mass. Tankage and motors 15% of propellant mass (conservatively, tankage and motors might only be 10% of propellant mass) 0.15(32,863) = 4929 lbs.

So the mass of the rocket and payload dry minus the mass of the rocket itself (tankage and motors) gives us the payload mass, in this case a crewed module of 32,417 - 4929 = 27,488 lbs or 13.7 English tons.

A 13.7 ton spacecraft is very respectable. The Apollo Command module amassed 12,800 lbs, the Soyuz 14,350 lbs. and the Orion CM 19,000 lbs. Here's where some elaboration on points overlooked in the first article is called for. The crewed module does not need a massive service module consisting mostly of propellant for braking into LLO and then accelerating to lunar escape velocity for return to Earth and aerobraking; however, it does need rockets for thrusting out of L1 and going on a trajectory back to Earth and aerobraking then parachuting back to Earth's surface. Since L1 is not stable on the axis that lines up with Earth and the Moon, it won't take a lot of rocket power and propellant to get out of L1 and fall back to Earth; however, the re-entry angle would probably be too steep if the capsule fell along this straight line and it would probably burn up. So rockets and propellants will be needed to move the capsule onto a better trajectory. Since the vehicle would amass 27,488 lbs. and the Orion CM was to amass 19,000 lbs., we could make the manned portion of the vehicle as large as the Orion CM and have 8,488 lbs for the propellant. If the tankage and motors are included in the 19,000 lbs. of the vehicle itself (about 1300 lbs.) and 460 second LH2 and LOX burning motors are used, this craft will have a dV capacity of 1.66 km/sec. Is this enough for maneuvering out of L1 and onto a trajectory back to Earth and atmospheric re-entry? I cannot solve this problem. I call out to readers for answers. If there are real rocket engineers reading this issue and graduate students looking for a research project-- here is a challenge for you!

Robotic Transportation

Landers, or Moon Shuttles, would be sent to L1 with electric drives and fueled at L1. I envision reusable single staged vehicles powered by LH2 and LOX. Water would be transported by highly efficient electrically propelled vehicles to L1, then cracked to hydrogen and oxygen and liquified. To prevent problems with cryopropellant boil-off while on the lunar surface, robot-tended reliquifaction devices would be landed ahead of time.

In the first article we noted that a propellant depot in LLO would probably not be a good idea because lunar orbits are not very stable due to mass-cons. So the L1 location is superior. Also, with high performance LOX burning rockets, as much cargo can be landed from L1 as can be landed from LLO with lower performance space storable propellants like MMH (mono-methyl-hydrazine) and NTO (nitrogen tetroxide) even though the dV from L1 is higher than from LLO. In addition, less electric drive propellant would be needed to reach L1 because the dV to L1 is less than to LLO and just as important, less time would be required, and time is money.

So there is an advantage to sending cargo to the Moon via an L1 way station. Moreover, landers designed to run on LH2 and LOX could eventually be fueled on the Moon with propellants derived from lunar ices, if we can get them. This deserves some elaboration not included in the first article. I can already hear the voices of some fellow Moon Society members crying, "No! Don't waste that precious lunar hydrogen!" But I don't want to waste that hydrogen by using it as rocket propellant either. So what do we do? The next section contains the answer.

From L1 to Lunar Surface:

• Reusable single staged manned landers using LH2 and LOX. Initial propellant for first descent sent to L1 with SEP in the form of H2O, processed to LH2 and LOX at the L1 station. These vehicles will load up with enough LH2 and LOX to descend to the lunar surface and return to L1. Cooling equipment to keep the cryogenic propellants cold during a prolonged stay on the Moon will be landed ahead of time. Doesn't this mean transporting propellant from Earth to L1 at great expense? Using hydrogen mined on the Moon to fuel these vehicles is undesirable because lunar hydrogen resources are so scarce, and mining for hydrogen will also be expensive. As oxygen is abundant in regolith it would be possible to land these vehicles with only enough LH2 for return ascent to L1 and tank up on LOX produced on the lunar surface. Eventually, other fuels like aluminum powder will be produced on the Moon. One-way LH2 and LOX fueled cargo landers will be "cannibalized" on the Moon. Nothing will go to waste.

More discussion and calculations pertaining to Moon Shuttles and their propellant requirements is found at:

http://groups.google.com/group/international-lunar-resarch-park/web/propellant-for-moon-shuttles

http://groups.google.com/group/international-lunar-resarch-park/web/propellant-masses-for-moon-shuttles-2

Calcium Reduction for Processing Lunar Regolith

Geoffrey A. Landis
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A lunar base, and eventual long-term lunar settlement, will require the ability to process available lunar resources to produce useful product to reduce the requirements for resupply from Earth. It is well accepted that the most useful product that can be produced from lunar regolith will be oxygen. Oxygen is the major, by mass, component of rocket fuel; it is also required for life support, and finally it is the main (again by mass) component of water, which is also required for life support. Oxygen is an abundant component of the lunar surface; lunar rocks and regolith consist of about 45% oxygen by mass. However, the oxygen is tightly bound in the form of silicates. Because of the network-forming properties of the silicate, silicate rocks have high melting temperature, and reduction of the rock to produce oxygen (and byproduct metals and silicon) is difficult.

While the first material to be produced from lunar regolith will certainly be oxygen, in the long term development of lunar industry, it will be necessary to produce other materials as well. Some volatile materials, the gaseous elements adsorbed onto the surface and implanted into grains of regolith (presumably originating from the solar wind), will be easily produced by heating the regolith, although in small quantities. These will be of considerable use for replacing life-support consumables. In addition, hydrogen (in the form of water) is known to be available in cold-traps near the lunar poles.

In the longer term, other desirable elements to be produced from regolith are aluminum, iron, and titanium for use as structural metals; silicon for use as a semiconductors; aluminum for use as an electrical conductor, and oxides to be used in glassmaking. It may also be valuable to produce metals or silane [SiH4] for use as a rocket fuel. Thus, we anet a regolith reduction process that produces highly-reduced byproduct that can be further refined to useful materials, rather than a slag material of mixed tightly-bound oxides.

Many processes to produce oxygen from lunar regolith have been proposed. The most well-developed, hydrogen reduction of ilmenite, has the disadvantage of requiring high temperature. and reducing only a small fraction of the oxygen available in the soil, requiring a separated feedstock. Another problem is that it produces as byproduct a partially-reduced iron titanate slag that is not a useful material for futher materials production. Other proposed processes, such as carbothermal reduction, have similar problems. Is it possible to suggest a new process that uses lower temperatures, extracts a higher fraction of oxygen, and produces reduced materials in a form that can be used for later refining into useful product?

In earlier work, I had suggested that regolith reduction might be done using fluorine substitution reactions, converting oxides (primarily silicates) into fluoride salts, with oxygen as a product. The fluorine reactant must then be recovered by molten-salt electrolysis of the fluoride. That process has several advantages over other proposed reduction methods, but also has some disadvantages.

Another process, which has considerable advantages over existing processing, is calcium reduction. This process proceeds in two steps:

(1) *Metallothermic reduction*. This is done by heating the regolith in the presence of (liquid) metallic calcium, converting the silicates into metals plus calcium oxide.

(2) *Molten Salt Electrolysis:* The oxygen is produces in the second step, electrolysing the calcium oxide in a molten salt at 825-900 °C, recovering the metallic calcium for reuse in step 1.

These processes require considerably lower temperatures than direct electrolysis reactions, and produce oxygen with considerably higher efficiency than hydrogen or carbothermal reduction methods.

Metallothermic reduction has been used on Earth, for production of rare earth elements, manganese, chromium, vanadium, zirconium, and niobium. Following the reaction, the oxygen is chemically bound in the form of calcium oxide. To generate free oxygen (and recover the reactant calcium), this oxide is electrolyzed:

$Ca^{+2} + 2\,e^{-} \rightarrow Ca$ (metal)

$O^{-2} \rightarrow 1/2\,O_2$ (gas) $+ 2\,e^{-}$

This can be done in a molten calcium chloride/calcium oxide mixture, with a eutectic point of 750 °C, commonly done at temperature from 850 to 900 °C.

The two steps need not be done separately: a single reaction crucible can be used to accomplish both steps simultaneously, in the same molten-salt solution. This combined processing describes the FFC ("Fray, Farthing, Chen") electrochemical reduction process, which has been used to produce metallic titanium, molybdenum, and tungsten from oxides.

Such a calcium sequence has the advantage over many other proposed reduction processes that it does not require beneficiation or selection of a particular mineral for feedstock (although it would be desirable to use lunar fines for feedstock, rather than bulk rock, since the reaction rate is proportional to surface area) but is able to remove the oxygen from all the mineral components found in average soil. This means that it has very high oxygen yield. And the primary reactant, calcium, is itself a component of lunar soil, and thus reactant that is lost in processing can be replaced by material generated from local resources.

More importantly, though, since the reaction should result in nearly complete reduction of oxides to metals, the byproducts will be highly reduced alloy of metals and silicon, and hence suitable feedstock for further refining into materials of industrial use.

References

Fluorine substitution: Geoffrey A. Landis, "Materials Refining on the Moon," *Acta Astronautica, Vol. 60,* No. 10-11, 906- 915 (May-June 2007). See also *NASA Technical Memorandum TM-214014*, December 2005.
Calcium reduction: Geoffrey A. Landis, "Calcium Reduction as a Process for Oxygen Production from Lunar Regolith," to be presented at the AIAA Aerospace Sciences Conference, 4-7 January 2011, Orlando, FL.

About the Author:
http://en.wikipedia.org/wiki/Geoffrey_A._Landis

Landis is also a member of the Moon Society Board of Advisors

Casting Metal on the Moon

By David Dietzler

Engineering details might seem dull or trivial, but they can make or break us. There won't be any ISRU and bootstrapping on the Moon without metal casting. Three dimensional printers that use lasers or electron beams (which require vacuum, free on Luna) to fuse powdered metals, glass and/or ceramic into small parts that can fit in the hand and medium size parts with dimensions of one or two feet will be used to produce all sorts of parts on the Moon. Barring the creation of giant 3D printers we will need to cast large metal parts on the Moon like vehicle chassis frame members, axles, wheels, struts, etc. When we can we will use rolling mills and/or extruders to make things, but we might want to cast up the rolling mills and extruders with lunar materials rather than ship these massive devices to the Moon!

Aluminum and magnesium are often sand-cast but they might also be cast in plaster molds with plaster obtained by sulfuric acid leaching of highland regolith. Plaster, $CaSO_4$, is also a cement setting time retardant and Portland cement contains up to 5% of this compound by weight. Iron, steel and iron alloy (e.g. iron-aluminides, iron-silicon, iron-manganese, iron-nickel) casting is going to require sand molds. Foundry sand, also called green sand, is made of either silica or olivine sand, two substances we have on the Moon, water that can be obtained in various ways and rigorously recycled, bentonite clay and sometimes pulverized coal (forget coal on the Moon). We will have to do casting in pressurized chambers with dehumidifiers to recover water vapor from the drying sand mold and powerful cooling systems because it will get very hot inside when working with molten metals and interior pressure will increase as temperature increases. Casting chambers will be built of metal and concrete, not Kevlar!

Here's the detail I am hung up on; there is no clay on the Moon because there was never any water for the hydrological processes that produce clay to occur. Clay is essential to bind the sand mold. We might be able to synthesize clay on the Moon. At:
www.patentstorm.us/patents/6565643/description.html
we read that, "U.S. Pat. No. 3,803,026 describes a process for preparing a clay-type material in which an amorphous gel comprising silicon oxide, aluminum oxide, and, e.g., magnesium oxide is subjected to a high-temperature ageing step in an autoclave.

C.R. Acad. Sc. Paris 7 292 describes a process for preparing, int. al., clays comprising aluminum, silicon, and, e.g., magnesium by way of a co-precipitation process." Silicon, aluminum, magnesium and their oxides exist on the Moon. I suspect that it will be more practical to synthesize clay on the Moon than upport it from Earth! It is also possible to bind foundry sand with resin. At http://en.wikipedia.org/wiki/Shell_molding we read:

""Shell molding, also known as shell-mold casting, is an expendable mold casting process that uses a resin covered sand to form the mold. As compared to sand casting, this process has better dimensional accuracy, a higher productivity rate, and lower labor requirements. It is used for small to medium parts that require high precision. Examples of shell-molded items include gear housings, cylinder heads and connecting rods. It is also used to make high-precision molding cores."

The Wiki article states that this is used for small to medium sized parts so we might still need clay for large part casting. Resin could be made in lunar labs and we would need some way to recycle it possibly by leaching unused resin out of spent molds with an organic solvent and by extracting vaporized resin from air and CO_2 from burnt resin. Resin will contain rare lunar elements like H, C and N, and we cannot afford to waste these. If we cast in chambers with inert gas filled interiors the resin won't burn to form CO_2 and other gases.

If we can synthesize clay on the Moon, and i suspect that we can and must, and do it cheaply, then we could even work clay and fire it with electric furnaces into pottery and other desirable items. That would be a nice added benefit. An unconventional approach to metal casting on the Moon might be the use of microwave sintered regolith molds, but data is lacking. This should be investigated. **DD**

About the author:

Dave is a core member of Moon Society St. Louis and as the editor's chief co-brainstormer, has had quite a few articles published in MMM over the years. "Dietz" tries to figure out how we are going to do and make all the things necessary to found a civilian industrial settlement on the Moon. A member of the Moon Society Board of Advisors, he maintains his own website: www.moonminer.com, which is really worth exploring.

Dave is also heavily involved the google group – http://groups.google.com/group/international-lunar-resarch-park that focuses on "**R&D Projects for an International Lunar Research Park**" His efforts have attracted a number of heavyweight co-conspirators, including materials science people, planetary scientists and others. Dave is not afraid goof in breaking new ground. "If we didn't have him, we'd have to invent him."

Could the Best Place to Mine Asteroids be on the Moon?

By Peter Kokh

Hey, the asteroids are way out beyond the Moon! But how do you think the Moon got all its craters? Volcanic origins were ruled out long ago. Yes, asteroids are "out there." But now and then one is gravitationally dislodged into the inner solar system, and sometimes, the Moon or Earth itself is in the way and splat!

The amount of asteroid-sourced material in the moondust or regolith may be relatively small. Much of the impacting asteroid material may have been thrown out into space. But some must remain. Now most of the near Earth asteroid objects seem to be of the stony type, and we have enough rock powder on the Moon! What would be of interest are left-overs from metal-rich asteroids. In general, the Moon is deficient in some of the elements most needed for a technological civilization: copper, zinc, gold, silver, and the most prized element of all: platinum, involved in some 25% of all current manufacturing processes. It is the catalyst of choice for hydrogen-oxygen fuel cells, for example. Copper is so important that a 1% ore on Earth is considered "rich."

PGMs – Platinum Group Metals – are the focus of the recently published science fiction novel by Bill White, a Moon Society member: "Platinum Moon" which was reviewed in the August issue, MMM #237. PGMs were also the focus of Dennis Wingo's work "MoonRush."

Why not mine Platinum and associated metals on asteroids where they are concentrated? John Lewis and many others talk about this extensively. But there are a few awkward details that they aren't sharing with us.

1. **There is an "inconvenient" Catch-22 in Orbital Mechanics that says the closer two bodies** (Earth and a target asteroid) **are in period** (the time they take to go around the Sun, **the farther apart on the average are the launch windows from one to the other**. The wait between launch windows between Mars and Earth in either direction is some 25+ months. Between Earth and a really close NEA or NEO that window may open every two decades or longer! The upshot is that NEOs are hit and miss "targets of opportunity" at best.
2. **But the delta V, the amount of change in velocity (or powered acceleration needed is very low**. Again a Catch-22 – **the lower the delta-V needed, the longer the trip from one to the other**.
3. **But you save so much fuel!** Well, that's okay if you are sending *robotic* prospectors and miners. But if you are sending humans, **the extra consumables you will need to send along will probably out-weigh the saved fuel.** The journey could take many months, and the wait for a window home could be years, and then the long trip back.

No one told you that? Hmm! I wonder why? We are not opposed to exploring, mining, and even settling the asteroids. In fact there have been many articles about asteroids and the possibilities for using them in past issues of Moon Miners' Manifesto. We have gathered them and republished them in a special Asteroids theme issue. This is a free PDF file download from

www.moonsociety.org/publications/mmm_themes/

Our point is that lunar pioneers can't afford to wait until asteroid mining has developed to the point where shipments from the Belt or elsewhere can fill the settlements' needs for these metals. There must be areas on the Moon where these metals are to be found in amounts worth prospecting for and extracting. No Lunar orbiter yet flown has been equipped to find these metals, especially in small local concentrations.

What do we need to detect and mine PGMs

Until now, the instruments chosen to fly on lunar orbiters have been selected to map concentrations of key elements we know to be fairly abundant on the Moon: iron, aluminum, magnesium, titanium, thorium; and it is fair to say that the driving curiosity has been what the geography of these concentrations says about how the Moon was formed and how it got to its present condition, rather than a search for "resources." Planetary scientists are in charge, and that is appropriate at this stage of the came. The only element that has *also* been the target of orbital mapping *as a resource,* is hydrogen, which together with overly abundant oxygen gives us water, water ice, and hydrates. But that is because, water is essential to outposts whether they get into the lunar materials industry business or not. Plus scarce water can be stolen from the precious lunar reserves for one-use non-recyclable exploitation as rocket fuel, when, in the Moon's low gravity environment, other more abundant options are available.

Now some of the targeted elements have usual partners: where there is thorium, there is probably uranium and lead, for example. So we know more.

Additionally, Apollo missions 12, 14, 15, and 17 all found KREEP deposits, rich in Potassium (K), Rare Earth Elements, and Phosphorus primarily in the Mare Imbrium splashout zone. Lunar Prospector in 1998-9 mapped these deposits at low resolution.

Could future lunar orbiter instruments detect PGMs and other valuable but less common elements on the Moon? Both the resolution and sensitivity of the needed instruments would have to be very high. But as so much is at stake, even sketchy indications of where best to look with on the surface techniques would be most helpful, by weeding out extensive areas where concentrations are lower. That said, to the extent that PGMs are a gift from the sky and not from the lunar interior, a statement that may not be totally correct, then their geographic concentrations should not follow well-known surface terrane "provinces" such as the highlands and/or maria. Nor will they be found in connection with certain types of craters, as crater types go by size, density, speed, and impact angle of the object creating them, and not by the object's makeup. That said, after a few PGM concentrations are found, it is possible that we will detect a pattern that will suggest where else on the Moon, the "prospecting prospects" are promising.

Do we need an army of human prospectors? This will be tedious work, and until definite concentrations that might be worth "mining" are found, expensive human efforts would be unwarranted and wasteful. So what can we do?

Orbiter instruments that successfully find some evidence of PGMs should be reflown on orbiters with eccentric orbits that carry them very close to the surface, say 10 kilometers (6 miles) or so, and keep adjusting the orbit until the entire Moon, farside as well as nearside, is mapped to produce the first crude map of PGM abundances. This map may suggest where to look on the surface itself. And here we need robotic rovers.

But because we will need many such assistants, and because there is an area as big as Africa and Australia together to cover, we suggest micro-rovers, working in teams, what I have called "robo-ants." I wrote about these handy critters way back in MMM #45, May 1991, almost twenty years ago. An updated version of this article was recently published in our Moon Miners' Manifesto India Quarterly, issue #5, a free download at:

www.moonsociety.org/india/mmm-india/ or directly at:

http://www.moonsociety.org/india/mmm-india/m3india5_Winter2010.pdf

We need to develop these handy "social mini-bots" anyway. They will come in handy as exospeleologist scouts, creating initial surveys of the interiors of lava tubes on Moon and Mars, and going elsewhere in terrain difficult for humans to traverse, and scour, whether in spacesuits or pressurized vehicles. Now of course, human guidance and teleoperation of these handy assistants from a nearby pressurized field vehicle is certainly an option.

PGMs have not been confirmed on the Moon and that is no surprise. We have not fielded the equipment and technologies needed. But we have every reason to believe that they are there, and that for the very practical reasons outlined above,

The Moon is the best place to mine Asteroid wealth!

The time to start planning how to do this is now! **PK**

An Asteroid Mission that Makes Sense

By Peter Kokh

Background: NASA's current direction

As of September 3, 2010 when I am writing this, NASA's marching orders are not yet set in stone, but all the indications are that the agency wants to concentrate on a Near Earth Object (asteroid) destination as the most feasible given the equipment resources likely to get the go-ahead for development.

Early in January, NASA released a **"Flexible Path" evaluation of a 2025 human mission to an asteroid.**

http://www.nasaspaceflight.com/2010/01/nasas-flexible-path-2025-human-mission-visit-asteroid/

This would be "a NEO mission in the mid-2020s, a full five to six years after the original target date to return to the moon, as outlined in the Vision of Space Exploration (VSE) – … no longer seen as achievable."

"Today, ~500,000 minor planets are known. Of that number, ~6600 are NEOs; of these ~1100 are PHOs (Potentially Hazardous Objects) – … objects that come within 0.05 AU (7.5 million km – 4.65 million miles) of Earth. PHOs are in orbits that have the potential to make close approaches to Earth, and are large enough to cause significant regional damage in the event of an impact."

So this is not a mission to identify mine-worthy objects and test mining methods. The primary motivation is Planetary Defense. The pace of asteroid discovery in general has accelerated enormously in the past decade and the list of PHOs is likely to mushroom significantly by the time such a mission is feasible.

As of January, NASA had narrowed the list of potential target PHOs to 38. Since then the list has shrunk by application of relevant mission constraints, to just two! But the list is likely to grow again as new PHOs are discovered, and shrink again as mission constraints narrow in on "doability."

http://www.foxnews.com/scitech/2010/09/01/nasa-narrows-targets-manned-asteroid-mission/

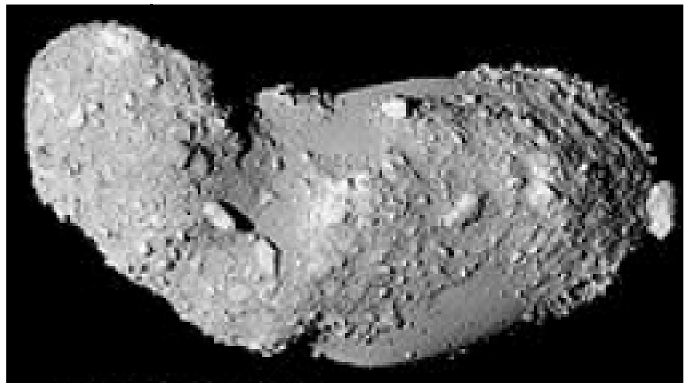
Candidate steroids are in eccentric orbits that do not bring them near to the Earth-Moon system on a regular basis, nor frequently. Of the 38 objects previously listed, only two will approach near enough to be visited on a round-trip of a few months time, within the 2020-25 timeframe. A third would come close enough in 2045. So very practical reasons help narrow it down.

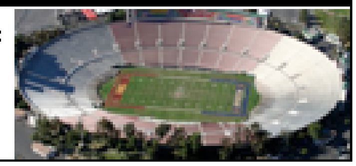
And should we not be ready by 2025, and no other PHO has been found that will approach within crew-reach before 2045, well, then all bets are off. So if the nation adopts this destination mission, there can be no delaying by the usual Congressional or Administration budgetary mischief. It will be "do or don't do" – period!

Another constraint is that the selected target must be viewable by large ground-based telescopes. So such a mission choice demands an irreversible commit-ment that was lacking in the Back to the Moon directive.

Background: initial mission & target constraints

The target must be an object of a minimum size, about 100 meters in longest axis. Yes, that does seem to offer a choice guaranteed to be *booooring!* But no larger, more interesting target that is also a PHO will come any where near Earth in the coming two decades. And as this is a human mission, it can't go too far afield if the mass of consumables taken along is beyond a certain limit.





The famous **Rose Bowl** is 880 ft long rim to rim, half the length of 1760 ft long **Itokawa** asteroid

Itokawa, visited by Japan's Hayabusa sample return probe, is the smallest asteroid visited to date. NASA's two candidate objects are significantly smaller and would easily fit on the Rose Bowl playing field. But for this purpose, *size does mater, only smaller is better.*

The smaller the size range, the more numerous these objects are. The odds on a really big object hitting us are far, far lower than those of one much smaller, but still able to pack a significantly disruptive punch.

Why we "Moon people" should care

Back in July of 2007, I put together a PowerPoint presentation and PDF Slide Show called "The Human Expansion Triway into Space"

The Human Expansion "Triway" into Space

I The point of this presentation is that far from not having our act together, the common impression of the media, of congress, and the public, Moon enthusiasts, Mars enthusiasts, and Asteroid enthusiasts have a common goal: preserving Earth and Humankind. There are three approaches to this directive and tall three need to be, must be, pursued. So while each group pursues different projects, these activities demand to be seen as complementary, not as alternatives.

As you go through the presentation, we show how each of these efforts can help achieve the specific goals of both the others. In other words, from a Moo Society point of view, the opening up of a human frontier on Mars is essential, as is the effort to preserve the Earth we all love from significant destruction by mindless errand astrochunks. Even if the asteroid contingency and the Mars contingency does not do us the courtesy of offering corresponding support to the establishment of a lunar frontier, that does not excuse us from doing the right thing. In short, while a mission to a PHO near Earth Object seems like a diversion and distraction, we sincerely believe that the Moon-enthusiast community should support it.

What we should *not be doing,* is to petulantly try to derail such a mission in favor of a Constellation type Moon mission guaranteed to end in "Flags & Footprints 2" but this is precisely what many well-known, and understandably disappointed lunar advocates are doing. It serves no purpose to name names. They are identifying themselves quite freely.

But let us go beyond tacit support of this limited asteroid mission, beyond vocal support, to activist insistence that the mission be done right! And that means that the chosen crew should be equipped to do a lot more than just "nose around!"

Mission Goals: Science

That the crew should "characterizes" the chosen object goes without saying. They would determine its **mineralogical makeup** and class (stony?, carbonaceous chondrite?, etc.) and determine its **physical character** (a solid chunk or a clump of loosely bonded rocks covered with dust - the "bean bag" type. Its basic shape and size and probable mass and rotational axes may have been determined by telescopic observations from Earth but will be determined with greater precision by the crew. The experimental value for its gravitational field will tell us its density and mass distribution (homogenous vs. clumpy).

We should also "tag" this chunk, placing a transponder, so that the object emits a signal that will help us determine its whereabouts with extreme accuracy. A complex multi-axial rotation, common to small objects, may well complicate the choice of a tagging site, as well as introduce some level of risk to crew movements, should there be a "whip" movement anywhere in such a complex multi-axial rotation cycle.

Mission Goals: Critical Experiments

But if these are the be-all and end-all of the mission goals, then we are wasting our money. The real mission, after these preliminary investigations are over, should be to put in place two or more experiments, to be operated in tandem, not concurrently, to test various theories of how best to alter orbits of objects of this size and type. "There are several ways to deflect asteroids, though none have ever been tried. The approaches fall into two categories - impulsive deflectors that nudge the asteroid instantaneously or within a few seconds, and "slow push" deflectors that apply a weak force to the asteroid for many years." http://geology.com/articles/earth-crossing-asteroids.shtml

Planting a nuke, the "macho" masculine choice, makes no sense if the object is not solid. Punch a bean bag and it just rearranges itself. It makes more sense to take two or three of the most promising "slow push" options and install the needed equipment to activate each in turn, not both or all at once, so we can measure the amount of deflection we get per amount of mass of the installed device(es) to enable us to judge with which system we get the most bang for our buck. Now some caution here: any given system may prove superior for a set size/mass range and set physical makeup of the object in question, but work poorly for other types of objects. Our choice of methods to test with this first visit will be affected by their total cargo mass, and ease or difficulty of deployment, as well as the need for time delays. Now none of these experiments will yield really good data, if we do not "tag" the object first so that we can follow orbital deflection changes with a very high degree of accuracy.

The Planetary Society ran a design competition, called "Tagging Apophis" with a significant $50,000 prize, and announced the three wining proposals in early 2008. It is notable that none of them decided to place the tagging device anywhere on the surface of the asteroid, but instead, all three chose to put the device in a stable orbit around the object. That avoids periods in which the tagging device might be out line-of-sight from Earth. So this gives us a jump-start on this mission requirement.

On the side of these options being adopted:

For once the curiosity of planetary scientists is not the only lobby to which NASA will listen. There is now a very vocal community of scientists and others, some of them within the agency, concerned about developing asteroid deflection options in the event that a NEO is determined to be a near-term threat, that is, on a course that could result in a near-future impact with Earth of a magnitude to cause significant regional or even global disruption and destruction.

I must admit to having been one of the "asteroid denialists" in the sense that *"the odds that Canada and Northern Europe and Russia will be 'wiped clean' by advancing glaciers at sometime in the next 25,000 years is significantly greater than the odds of a really destructive impact in that same period. But no one in Canada, or in northern Europe and Russia is losing any sleep over it."* I still feel that way. But that is not the point. ***The point is that affordable discretion is better than gambling.***

Asteroids and the Moon

Of course, an errant asteroid could hit the Moon and possibly wipe out a settlement. Actually, Earth's much deeper gravity well makes Earth a likelier target by 8:1 odds. But the lesson is that Planetary Defense is a good thing for a lunar frontier civilization also. So for Moon-enthusiasts also, there is something in this mission for us as well. So we should support this mission, and if we are going to do this, let's make the most of it, or let's not do it at all.

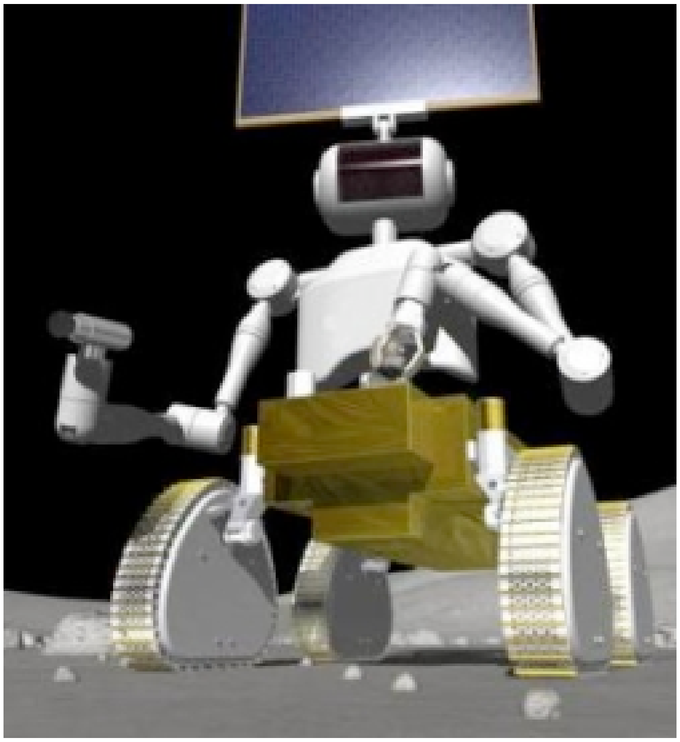
Further, even if we do not go to such a target near Earth object with mining in mind, we are bound to learn things that will prepare future asteroid miners for the conditions that they will face. Now while in the previous article I suggested that near term, we concentrate our asteroid mining efforts on the Moon first. Make no mistake that in time, asteroid sources of badly needed "Moon-deficient" metals and volatiles (notably Carbon, Hydrogen, Nitrogen needed for agriculture and biosphere) will be developed. Earth will need the metals; we will need both metals and volatiles. Trade will benefit all parties and lead to population growth on Moon, Mars, and asteroids as well as "space settlements" in Earth orbit or the Lagrange Points or amongst the asteroids.

Our movement into space cannot be addressed as a set of alternatives. We need to do it all, and each option we pursue increases the long-term viability of the others. The Moon is anything but the "end of the road." It is the key hub, if not in transportation terms, certainly in terms of trade and the Exo-Terrestrial Economy.

We must stop this adolescent infighting. We must all adopt the Human Expansion Triway to Space mindset. Separately, we will each fail. Together we will each win. The future of Earth itself, and of Humanity and Gaia, whether Earthbound or expanding through interplanetary space, even someday interstellar, is at stake. **PK**

AN AVATAR MOONBASE?

Japan & Russia have Separate Ideas



http://news.cnet.com/8301-17938_105-20006075-1.html - Above, a JAXA illustration from this report

By Peter Kokh

We have been talking for years about the need to automate and teleoperated as many "routine" tasks on the Moon as possible, in order to free humans on the scene to do what only they can do. Human labor on the Moon will be very expensive in terms of transportation logistics and life support. Workers on Earth, at the controls of teleoperation and telepresence devices will be considerably less expensive, and as they hand over the controls to relief personnel, the devices they control on the Moon can keep on doing their thing without relief.

Of course, there is a limit. Someone has to fix and maintain the teleoperated and telepresence-controlled devices on the Moon, and come to their assistance should they get stuck, or otherwise befuddled.

JAXA would go further, butting robotic avatars on the Moon that would allow scientists on Earth to see, pick up, and feel, and probe rock samples via telepresence. Humans would still be needed, and more of them than the devices they control, as they pass over the controls at shift rotations and for lunch breaks so that the work on the Moon can proceed "24/7." Telepresence operators would experience what it is like to be and operate on the Moon's surface, at least to some extent.

This kind of "takeover" may well happen for many occupations on Earth as well. No one will be laid off - they will just get to do their thing from the comfort of home or vacation settings. Less time spent traveling to and fro, less gasoline consumed. Of course, there will be some displacements. That is inevitable.

Background Reading
Some of these links include relevant videos

http://spectrum.ieee.org/robotics/industrial-robots/when-my-avatar-went-to-work/0

http://spectrum.ieee.org/static/telepresence

http://spectrum.ieee.org/automaton/robotics/industrial-robots/051810-anybots-qb-new-telepresence-robot

Call this development "**teleoperation 2.0**" if you will. The upgrade is that your eyes will see what your avatar sees; your hands will feel what it feels. For the teleoperator, this will at first be a thrill, then frustrating, as one gets used to the 2.5-second time delay - *light can only go so fast!* - But in time all this will become second nature. We get used to "magic" very quickly.

While it may seem that less people get to go to the Moon, more people will get to enjoy the "avatar experience." But as there is a limit to what can be done effectively and efficiently by telepresence, every task assumed by a telepresence operator on Earth, means that a human crewmember is freed for non-routine things. We won't be sending less people to the Moon, but the ones we send will get to do more exciting, less routine things. The upshot is that the same amount of humans on the Moon will get to do more interesting work, as the routine tasks will be teleoperated from Earth.

Now on Mars, telepresence type robotics will just not work, given the 6-minute minimum time delay (when Mars is closest to Earth) to a 40-min maximum, unless, of course, we have a forward base in Mars orbit: a space station or an outpost on one or both of Mars' two mini-moons. But more on how we will do this on Mars in our next **Mar**s issue (every **Mar**ch, of course), MMM # 243.

The Russians are planning a "robotic" moonbase as well. But this seems to involve teleoperated equipment only, tasked with base construction, and not telepresence tasked with scientific exploration.

Beyond Telepresence to "'Droids"

The next step is to make devices on the Moon autonomous, not only doing away with the time-delay, but substituting artificial intelligence for that of a tele-presence operator. But hopefully, Star Trek had it right, and the 'droids will be tireless helpers, rather than replacements for humans. We can leave to them those tasks that are boringly routine, as well as those that involve substantial risk or danger, and or unpleasant operating conditions (the heat of high noon, and cold of nightspan; treacherous terrain, etc.)

One thing I can't see, is droid replacements for my dogs! Or at least I hope to be long gone before that happens. I don't mind my dogs owning me! Lol!

Site preparation tasks

Current thinking sees involvement of robotic and teleoperated machinery for site preparation tasks such as spaceport construction, grading of the site, digging trenches to hold modules, then covering them with moon dust shielding, or with blocks made from moondust, etc. In short almost everything necessary will be taken care of by robots and/or teleoperated equipment so that when the first crew arrives, they have a ready-to-move-in outpost, and they can concentrate on scientific exploration and experimental production of building materials from moondust ingredients, needed to manufacture more living space for base expansion. **MMM**

From Lava Tube SKYLIGHTS To Lava Tube Settlements

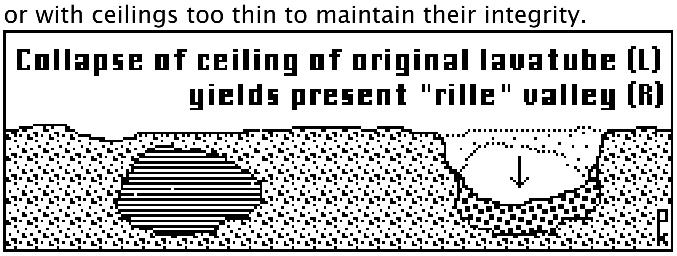
By Peter Kokh

Where we're at

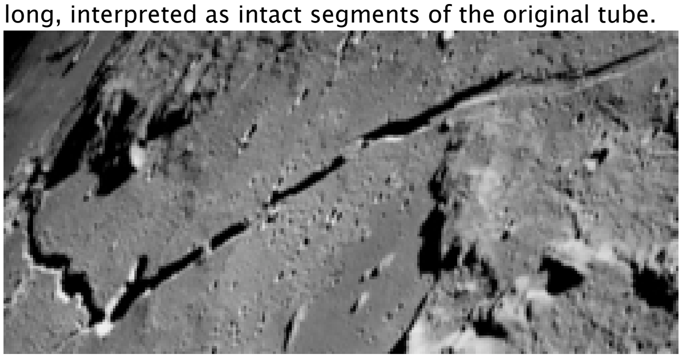
Chuck Woods (Lunar Photo of the Day, creator of http://the-moon.wikispaces.com) keeps track of all confirmed lunar lavatube skylights. To date (10.26.2010) there are 5 such sites, the first 2 found by Japan's Kaguya lunar orbiter, the last 3 by Lunar Reconnaissance orbiter. It takes very high-resolution photography to confirm such a feature, and LRO has found ten more dark spots around the lunar globe that need to be revisited with higher-res photography before they can be added to the list. Chuck suspects many more will be confirmed.

All of these locations are in lave flows, which spread by rivers of lava that soon crust over and as the lava flows out, create lava tubes. So we are finding these features in the lunar maria, frozen "seas" of lava. As the maria occupy 39 of nearside, and only a much smaller part of farside, we expect to find many more of these features on the nearside.

They are formed when a chance meteorite of sufficient size happens to hit right over a hidden tube, causing the tube ceiling to collapse. The reason we have been confident for decades that lunar lava tube networks pervade the mare areas, is twofold: that's the way lava sheets spread on Earth; and on the Moon we find many "sinuous rilles" for which the most logical explanation, given the basaltic nature of the terrain, is that they are the remnants of collapsed lava tubes: tubes too big and or with ceilings too thin to maintain their integrity.

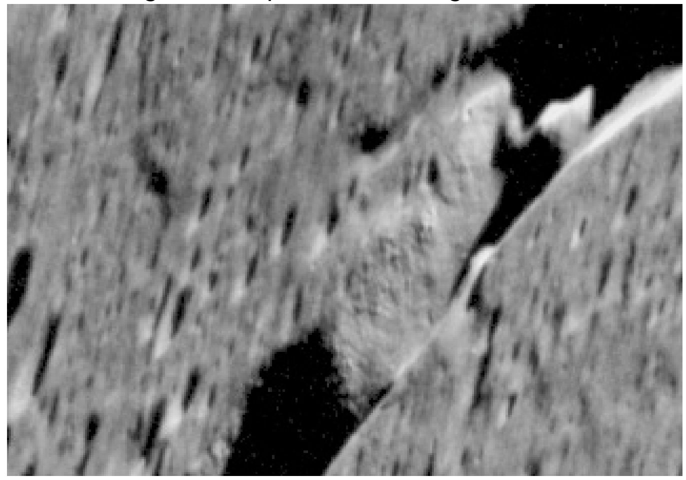


This argument is strengthened by the existence of long sinuous rilles that are "interrupted" by gaps miles long, interpreted as intact segments of the original tube.

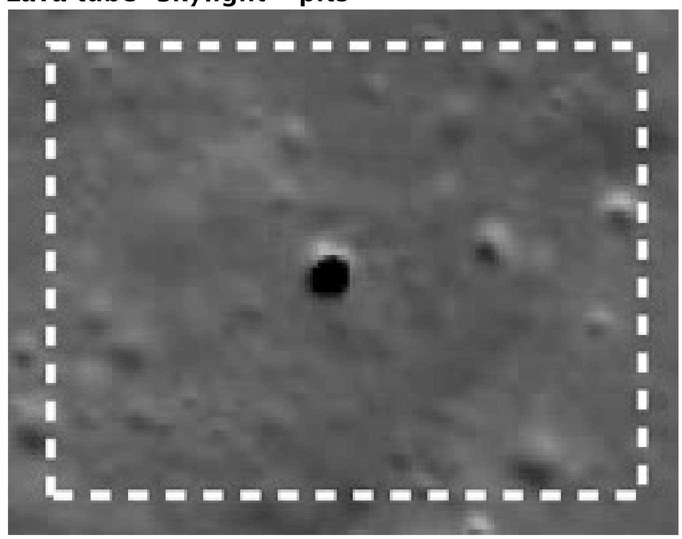


Starting at the bend to the left, 4 "bridges" are visible in this Apollo 10 photo of Hyginus Rille, central nearside.

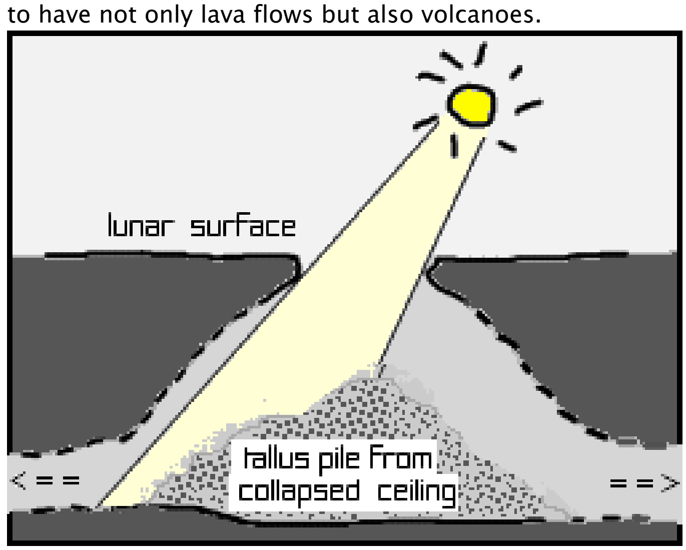
A very high-res 4.4 mb image of the above is at: http://spaceflight.nasa.gov/gallery/images/apollo/apollo10/hires/as10-31-4650.jpg Below is the area centered on the "bridge" interruption furthest right.



Lava tube "Skylight" "pits"



The first discovered, by a camera aboard JAXA's Kaguya (Selene) Orbiter is in the Marius Hills region of Oceanus Procellarum (Ocean of Storms) in an area known to have not only lava flows but also volcanoes.



This sketch, enhanced by to show the talus collapse pile, shows how these pit photos are to be interpreted

This webpage, maintained and updated by Chuck Wood, gives the current inventory of confirmed skylight pits.

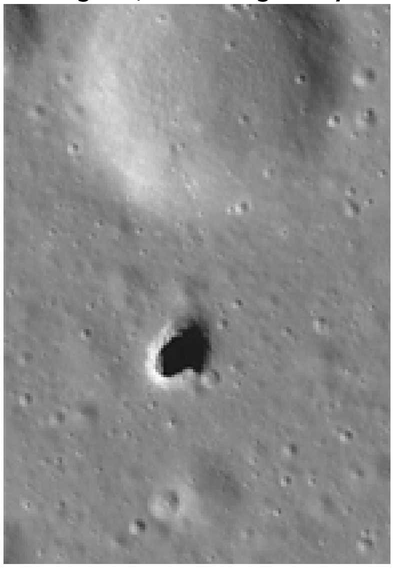
http://the-moon.wikispaces.com/Skylights

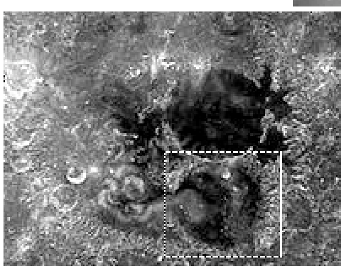
The Skylight found in Mare Ingenii, Sea of Ingenuity

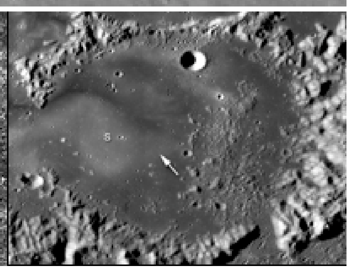
Left: Discovered by the LRO team, this skylight pit is the first such feature discovered on the the Moon's farside.

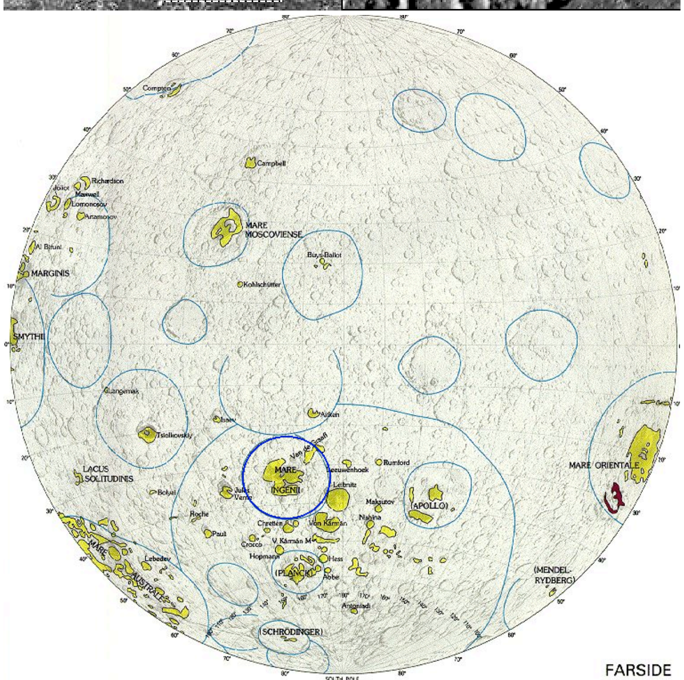
Below: Locaton of this feature within Mare Ingenii, at 33.7°S 163.5°E. This mare is about 318 km (.198 mi) in diameter.

Bottom: locaton of Mare Ingenii on the Moon's farside



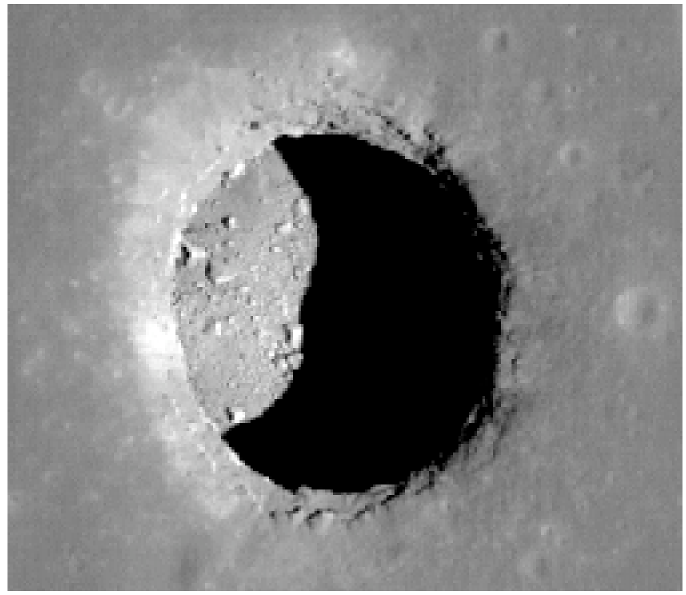






Three skylights found by LRO in M. Tranquilitatis

Yes, in the very mare in which humans first set foot on the Moon in the Apollo 11 mission July, 1961. The location of the first of the three found by Lunar Reconnaissance Orbiter is approximately 2° SE of the Sinas Crater and some 230 mi (380 k) to the Northeast of the Apollo site. This skylight has been unofficially named 'Sinas" by Danny Caes.



In this superb high resolution photo, what we are seeing lit by sunlight, is not the lavatube floor, but the tallus rubble pile from the collapsed lavatube ceiling. *See the illustration on the bottom of the previous page.*

Looking Forward

All those captivated by the implications of these recent discoveries look forward to the positive identification of more lunar lavatube skylights. Meanwhile, we must not deduce that these skylights mark the Moon's only lavatubes! These are lavatubes that, from a human point of view, won the cosmic lottery by being impacted just right to cause a local collapse. It would be more realistic to believe that we will find lavatube networks wherever there are lava plains. There may be hundreds, if not thousands of these features.

What's next – lunar lava tube skylight probes

The Moon Society is working on a design competition, which will be previewed at the **SEDS SpaceVision 2010** Conference at the University of Illinois Champaing-Urbana the weekend of November 5-7, 2010.

One design competition will be about modifying NASA's AXEL experimental rover (Google NASA AXEL for information and videos) which can winch itself down a crater rim, explore and then winch itself back. For our purposes, we need a much longer lighter weight cable, as well as some instruments that do not need sunlight to map and explore.

We will have a complementary competition for designs of probes that can enter the skylight and return data by means other than a cable and winch.

We are doing this in the hopes that NASA will consider fielding such a probe on both Moon and Mars. At stake is our need to modify public perception of both worlds as **dusty boulder-strewn rubble piles** to worlds with extensive networks of fascinating "**Hidden Valleys**" – the pre-shielded lava tubes ready for industrial parks, agriculture, warehousing, sports arenas, and archiving!

And, oh yes, lava tube Settlements!

Lavatubes: the possibilities

Please do check our earlier 1995 paper: "The Use of Lunar Lavatubes" – 2 parts

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

A favorite vision for many members who were with us during the Artemis Society days (1995-2000) was that of settlements inside pressurized lavatubes. But this does not appear to be a near-term option for 2 reasons:

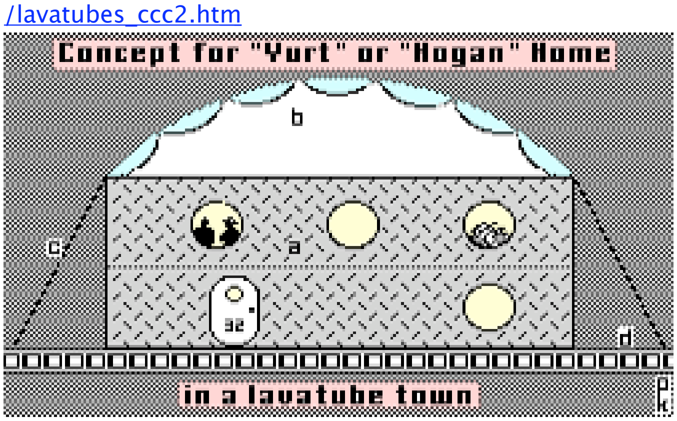
1. **Breathable atmosphere is 80% Nitrogen** - at 1 ATM - Earth-normal pressure. Of all the volatile elements most needed for biosphere purposes (Hydrogen, Carbon, and Nitrogen), Nitrogen if by far the least abundant in proportion to the amount needed. In the near term this will mean low ceilings and few pressurized "open spaces." One thing we can do to alleviate this somewhat is to try to make do with 0.5 ATM pressure, with all the hit (reduction) taken by Nitrogen, keeping the Oxygen partial pressure normal. Some point to disadvantages of this solution. But on the pro side, by simply reducing the partial pressure of nitrogen, the same tonnage of nitrogen will let us provide 2.73 times as much pressurized volume. For an article on this point, see pages 21-24, MMM Classic #16, a PDF file that you can download without username or password from www.moonsociety.org/publications/mmm_classics/
2. **Lavatube walls and surrounding basalt is most likely fractured.** If air moisture gets into these fractures and goes through repeated freeze-thaw cycles as the temperature inside the tube fluctuates, material is likely to spallate, break off and fall. We can probably deal with this on the lower walls, but spallation from the upper walls and tube ceiling could be a problem. So why not seal the walls? **Sealing a lavatube will not be easy.** Most suitable sealants involve scarce volatile elements. And they will be expensive for the pioneers to pruduce and use.

We are not saying "never," we are saying not in the near term. Our best bet and most practical nearer term option is to put pressurized structures inside the *unpressurized* lava tube. These "buildings" need not be shielded, unless we choose to do so for insurance against material breaking off the tube ceiling."

We should keep in mind that the most urgent need for pre-shielded space will be for industries and industrial parks, for protected warehousing, and maybe for extensive soil-farming. None of these uses will need the visual delight that would be provided by pressurizing the whole tube rather than the functional volumes inside. Residential areas can be more compact, but eventually we will move them into protected lavatube networks as well.

Brainstorming an early lavatube town

http://www.moonsociety.org/publications/mmm_papers/lavatubes_ccc2.htm

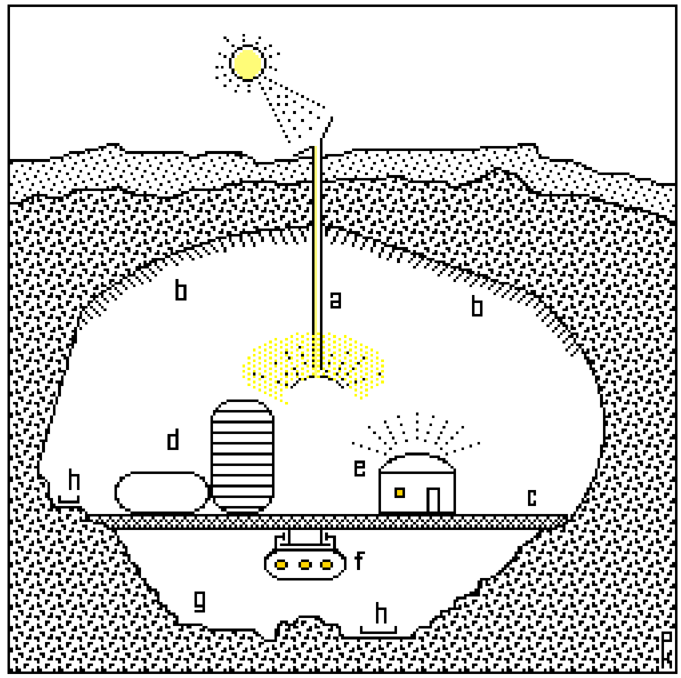


Concept for a lavatube single family home

KEY: (a) 2-story vertical cylinder section, bedrooms on the lower level; (b) lunar translation of the geodesic dome for a high translucent ceiling vault over the family room and other common areas including a central garden atrium; glass panes are neither flat nor concave, but convex; (c) cable stays prevent internal pressure from literally "blowing off the roof"; (d) the residential deck of the townsite, leaving the tube floor ungraded.

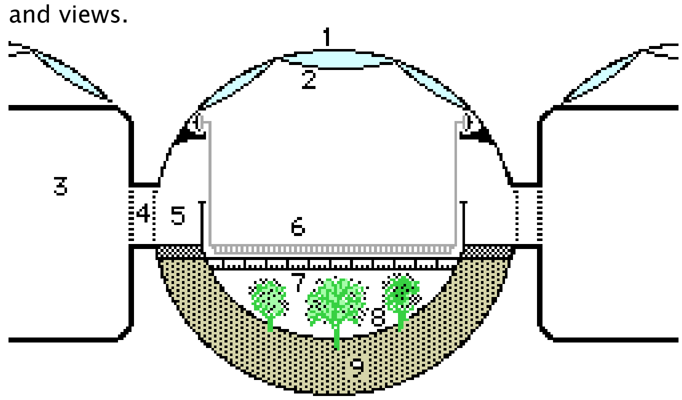
NOTE: upscaled, the yurt/hogan design will make a fine church, synagogue, or meditation chapel, with the simple use of stained glass convex panes in the roof dome. A dedicated shaft of directed sunshine on such a dome would surely help set the mood.

A variety of structures inside a lavatube



KEY: (a) sunshine access and defuser system; (b) white-washed "firmament" for best sunlight reflection; (c) "town deck" on tube-spanning beams; (d) assorted structures; (e) "yurt/ hogan" type home with translucent dome to flood interior with firmament-reflected sunshine; (f) monorail transit system; (g) lavatube floor left natural; (h) nature walks.

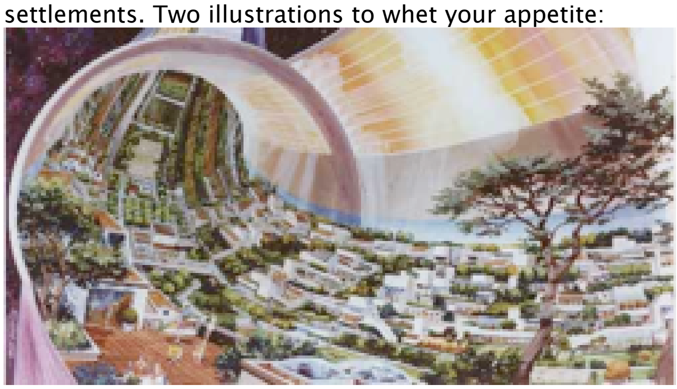
The early lavatube settlement will not be an assembly of individually pressurized buildings, but rather, like the in-surface burrowings, a maze of structures conjoined by pressurized walkways, streets, alleys, and parkways. In the netherspaces, roadway cylinders can be generously paned with convex windows to flood their interiors with ambient reflected and diffused sunshine and views.

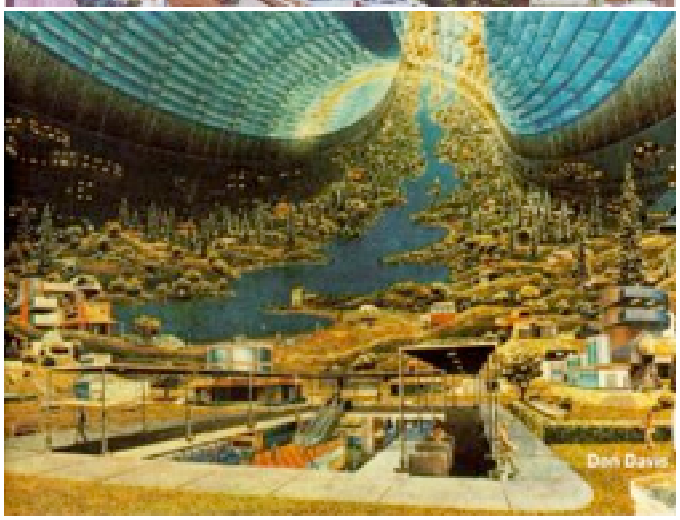


Fast forward to a can-do future:

Some maria experienced multiple episodes of lava sheet flooding. ***The walls of lower level lavatubes may be less fractured, and more easily pressurized.***

We did a thorough Google Images search for "lavatube settlements" and found nothing. There are sketches, from the pre-internet era, which apparently have not been posted online. However, our lunar lavatube cross sections are pretty much the same ballpark, size-wise, with cross-sections of Stanford Torus type space settlements. Two illustrations to whet your appetite:





If you find some suitable sketches, color artwork or just black and white line drawings, please send them to us, electronically at kokhmmm@aol.com or by mail to:

Moon Miners' Manifesto, c/o Peter Kokh,
1630 N. 32nd Street, Milwaukee WI 53208-2040

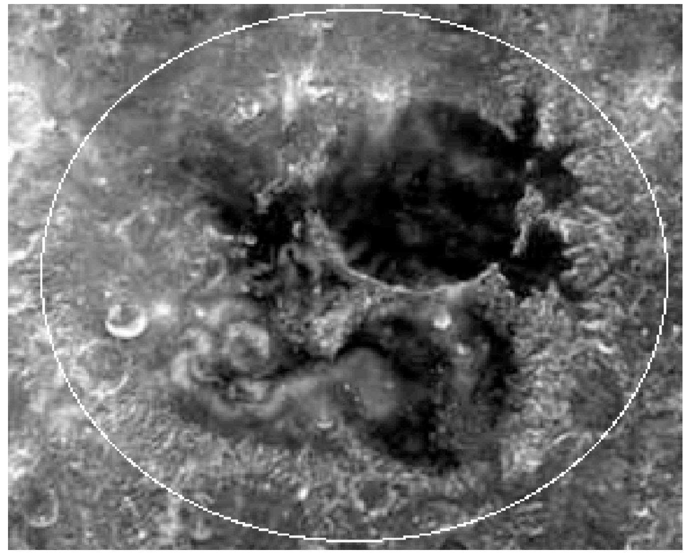
We need more appropriate artwork to enthuse the public at large about the possibilities that the confirmation of lavatube networks on Moon and Mars imply.

In the coming months, Moon Miners' Manifesto, and/or The Moon Society, may announce an art competition with several categories and attractive prizes. In the meantime, we look forward to additional confirmations of lava tube skylights on both Moon and Mars. We also hope for great entries to our AXEL-type probe design contest as well as for a wide open contest for practical lave tube skylight probes that NASA or other national space agencies may pick up, and build and fly.

To young people in the future, the possibilities of life on the lunar frontier will seem that much more interesting. There is more to the Moon than *"magnificent desolation!"* The Moon, and Mars too, have extensive and spacious protected Hidden Valleys that will one day be home to thousands, tens of thousands, and more pioneers. Keep the faith! **PK**

Mare Ingenii – "Sea of Ingenuity"
A Sweet Spot on the Moon's Farside

by Peter Kokh



The dark floor crater to the NE is 60 mi wide **Thomson**. Can one think of a better place for a very large array radio telescope complex devoted to S.E.T.I.? [Search for Extra Terrestrial Intelligence]

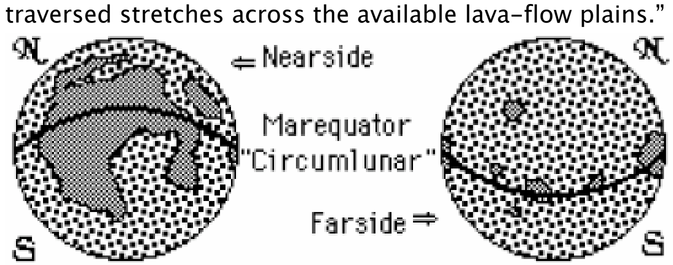
What's so special about Mare Ingenii?

Lunar Prospector detected strong mangnetic shields on the farside, at the antipodes of impacts that formed the Mare Imbrium basin centered on Mare Ingenii in south central farside, and the impact that formed the Mare Crisium basin, centered on the crater Gerasimovic in SE farside. What we think happened is at the moment of impact a magnetic plasma was ejected that surrounded the globe coming to a focus at the impact antipodes and permanently magnetizing the surface in those areas.

Such areas may be safer places for surface habitation, requiring less shielding for protection. On the other hand, there is new evidence that these areas also shield against the solar wind, so that the regolith in these areas may be relatively less rich in volatile particles attached to the regolith powder fines.

The "marequator" runs through Mare Ingenii

In MMM # 74, we coined the word Marequtor: "Some writers have proposed lunar equator-following roads, railroads, and even superconducting cables. The path of least resistance suggests a route that rises north of the equator on the nearside and south of the equator on the nearside to take advantage of the more easily-traversed stretches across the available lava-flow plains."



Unlike the crater Tsiolkovsky, which is another prime site, M. Ingenii is in the central farside slice of the lunar globe that is out-of-line-of-sight from both L4 and L55 Earth-Moon Lagrange positions where the Earth's and the Moon's gravities cancel out, the prime location for lunar communications satellites. **PK**

LUNARCRETE

Early lunar settlers will need an inexpensive, easy-to-use concrete for rapid construction of structures.

Introduction

The early pioneers who came to the "New World" brought with them all the tools they could afford. With this small initial supply of tools, they built homes, grew crops, hunted, engaged in trade, and produced new tools from the raw materials of the rich and virtually untouched wilderness. To build their houses, most early settlers used an axe and a great deal of muscle. The remainder of the building material came from the land around them: trees for walls and roofs; a mixture of mud, sand, and sometimes fine plant fibers for mortaring the cracks and joints in the wooden walls and roofs; dried vegetation for thatched roofs; and dirt for floors.

An early pioneer on the lunar frontier should also build his earliest structures using the least amount of imported tools and materials. The Moon lacks many material sources commonly used in terrestrial construction, such as water for concrete and brick mortar; trees for timber; organics and plastics for electrical wire conduit and plumbing; processed metals for load-bearing beams, reinforcing wire or grids, and electrical wiring; and processed concrete materials. The only major source of raw materials is the finely divided lunar regolith, or soil, which is most suitable for making ceramic building materials such as bricks, mortar, and concrete. Early lunar settlers will need an inexpensive, easy-to-use concrete for rapid construction of structures. For the widest possible use during this early development stage, the concrete must require only minimal initial processing and final placement time and effort. Since the lunar temperatures vary from well above the boiling point of water during the lunar day to well below the freezing point of water during the lunar night, a good concrete should be unaffected by these extremes of temperature during placement, curing and use.

"Concrete" usually refers to a mixture of aggregate, such as gravel; fines, such as sand; and hydraulic setting cement, such as Portland cement. These compounds are mixed together in many different proportions. Most mixtures are moistened with 5% to 25% water and cast into molds or forms.

Conventionally placed concrete mixtures must be kept in the very narrow temperature range of 40 to 80 degrees Fahrenheit for one To 21 days. Water content of the placed concrete must be held constant for this extended period of time to yield optimum strengths. If the concrete is allowed to freeze during the first day or two it will usually be very weak, and will crumble under very little stress.

During the early days of lunar settlement, water will not be abundant or cheap enough to leave large amounts tied up in housing structures. After a sophisticated and mature industrial base is established, conventional concretes may have limited application in some construction if a sufficiently large, inexpensive water supply is found. But, because of the temperature limitations caused by the water addition, conventional concretes will only have limited use in lunar and space habitats. Therefore, use of the term "concrete" to describe materials placed in a similar manner on the Moon would be misleading. It is proposed the term "lunarcrete" be used to describe concrete-like materials made from lunar raw materials and used as a building material in the settlement of the Moon.

Previous Proposals

Two feasible methods of constructing lunar dwellings largely from lunar raw materials have been proposed to date. One method 1 involves making precast and prestressed panels of lunar concrete bonded either with epoxy resin imported from Earth, with melted sulfur, or with fused rock. These types of building materials have many potential uses including lunar habitats, inside structures like floors and walls, industrial process equipment, and prestressed concrete for building a large space habitat. Sheppard? proposes using fused cast rock placed around steel reinforcing cables tensioned between anchorage points. Similar approaches to early lunar settlements would result in significant economy by reducing the use of expensive, highly processed materials such as various steel alloys. However, the first two binders are limited by the amount of resin that can be imported, and by the durability and strength of the sulfur concrete as well as the availability of indigenous sulfur. The third binder requires a great deal of energy, and a material to fill the joints between the panels to prevent loss of atmosphere.

A second method] involves driving heating rods into large piles of lunar soil. Fusion of the soil layer and subsequent removal of the underlying soil results in a "cave-like" structure. This type of structure also requires a great deal of energy to construct. Unless it is sealed, cracking of the internally fused structure could lead to slow leakage of some at mops here.

New Proposal

Table I lists the major requirements of a lunarcrete intended for widespread structural uses. This paper suggests an approach to development of lunarcretes that may satisfy the requirements in Table I.

TABLE I Requirements for a Lunarcrete

- Must be able to support its own weight plus the additional loads encountered during intended use.
- Must be able to contain air with virtually no loss.
- Must be abundant and therefore cheap.
- Must be easily and quickly prepared and placed.
- Must not require strict control of ambient temperatures during placement and curing.
- Must not contain water in any appreciable quantities.
- Must not fail catastrophically without warning.
- Must be structurally stable, environmentally stable, environmentally inert, impervious to external and internal stresses, such as micrometeriorite impacts.

In the terrestrial refractories industry, a novel type of material is gaining widespread acceptance. In many applications where monolithic construction is necessary and there is insufficient time for placement moisture to dry prior to use, dry vibratable compositions are gaining favor. These new products can be placed quickly and heated at rapid rates to very high temperatures, while yielding excellent strengths, densities, and low wear rates. Strengths well in excess of conventional, non-pre-stressed concretes are achieved every day, using many compositions of these materials. The terrestrial construction industry would have little or no use for such a product. However, a lunar construction industry would find substitution of energy for water and no strict ambient temperature dependence to be desirable features.

It is proposed that as-mined lunar soils be screened and recombined in the proper grain size configurations to create dry vibratable lunarcrete compositions. These mixtures should compact much more readily on the Moon due to lunar vacuum, since entrapped air is the main reason why dry vibratables sometimes densify poorly on Earth. Due to the great similarity between the particle configuration of the lunar soils and dry vibratable products, it may be possible to build the early crude structures using lunar soils in the as-mined state.

Internal and external metal forms are erected and loose-filled with the lunar soil. Conventional vibrations equipment attached to the metal forms is used to compact the soil to high density. Additional loose soil is added as necessary to maintain structural volume. Because of the lower lunar gravity, we may need further development of vibration technology for optimum distribution of compaction energy. Studies would also be required to determine the effects of pre-stressing cables on the vibration and compaction technique, if pre-stressed lunarcrete is to be used.

Use of variously designed inserts and different arrangements of internal walls should provide considerable diversity.

For a low temperature binder to give structures sufficient strength to support their own weight when forms are removed, silica glass separated from the lunar soil in fine particle sizes could be mixed with a small amount of imported alkali or with indigenous iron to form lower melting phases than the aggregate. Only a very small proportion of binder would be needed in any composition. Because powders form a harder, stronger mass in a vacuum when compared with powders whose particles are surrounded by air, it may be possible that, after compaction, the structures could hold together without need of a low temperature binder.

After the lunarcrete is vibrated in place,heated moderately, and forms removed, a simple focusing mirror could be used to heat the structure. Since the metal form is removed prior to fully sintering the structure, it must be collapsible-which makes it reusable indefinitely. If properly built, the form could hold an atmosphere and be used as temporary housing until completed structures are available. The rigid structure of the form would allow for radiation shielding by lunar soil even before compaction or sintering.

During the lunar night, heat could be supplied by electric heaters fed power from a solar power satellite or by aluminum-oxygen burners using lunar-derived aluminum and oxygen. Obviously, the earliest settlements should be planned so that the critical early heating requirements are supplied by focusing mirrors during the lunar daylight. Knowing the thermal characteristics and thickness of the lunarcrete, the proper size of the mirror and the time for heating can be readily calculated.

It should be possible to heat the structure from the outside so that the exterior surface will become molten and glazed, the interior surface will be moderately well bonded, and the central core portion of the lunarcrete will be fully sintered. The glazed exterior will be impervious to gases so no loss of atmosphere would occur. With increased understanding of the thermal characteristics of the lunarcrete, it may be possible to crystallize a glass ceramic in the glazed exterior and induce a compressive stress to the exterior surfaces of the structure, increasing its overall strength.

A moderately well-bonded interior surface will not crumble, but will be easy to anchor internal fixtures into because of its lower strength and penetration resistance. The well sintered central core portion of the lunarcrete will bear the major portions of the loads on the structure including some of the load-bearing for anchoring floors. This sintered region will also protect the glazed surface from damage from the interior by its high strength and penetration resistance. This structure should be less likely to leak atmosphere because cracks in the exterior could not propagate through to the interior to cause a loss of atmosphere. Similarly, cracks in the interior could not propagate through the sintered region and affect the impervious glazed exterior. Since only a part of the structure is totally melted, this approach should use less energy than the other methods mentioned above. 4.

A foamed or fibrous insulation could be *L-5 News, April /983 10* sprayed on the interior or exterior of the structure to even out thermal loads inside the structure. Insulating the exterior will protect the glazed surface from uneven thermal stresses during the lunar day-night cycle, and from meteorite damage.

The finished surface would be concrete-like in appearance and in its physical properties. The structure would likely be very resistant to chemical attack, water damage, fire, and explosion. Small cracks in the structure will act to warn of potential failure. Proper design and construction should prevent catastrophic failure. Repair of the load-bearing portion of the structure could be performed from the exterior in a similar manner to placement or from the interior using conventional concrete repair techniques and materials.

Reuse of the same forms would greatly simplify construction, but would give a company-town appearance to the settlement. However, use of variously designed inserts could alter the external appearance significantly and, combined with different arrangements of the internal walls and furnishings, should provide considerable diversity within the community.

Future Research

The Pittsburgh L-5 Society has initiated research into this novel concept for rapid construction of lunar dwellings using the vibration formed lunarcrete described above. This research will involve further literature reviews; computer design and modeling of the particle configuration, chemical or mineralogical structure, mirror size, heating profiles, and building structure; and limited laboratory testing to confirm technical details.

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