Vision for an Analog Moon Base on Earth

By Peter Kokh

Excerpt from “A Pioneer’s Guide to Living on the Moon”

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What a Lunar Analog Research Station Should Attempt to Demonstrate Here on Earth

We have already had humans on the Moon exploring limited areas. Manned exploration is not something whose feasibility we still need to demonstrate.

- ***We need to determine which operations can be done effectively by teleoperation from Earth in order to dedicate precious man-hours on location for those things that can not be done as well by teleoperation***
- We need to demonstrate the ***methods and tools of expansion of an outpost into a settlement.***
- We need to demonstrate the ***options for using local lunar resources to accomplish that goal.***

Other things worth demonstrating at a Lunar Analog Research Station

- Teleoperable shielding emplacement systems
- Erection of shielded hangers within which to indirectly shield pressurized modules and/or to house supplies and systems that need to be accessed on a regular basis
- Greenhouse systems
- Early industries: cast basalt, glass fiberglass composites, concrete, metal alloys
- Arts & craft media using only lunar producible materials
- ***Refurnish the Analog Station with objects made in the above demonstrations.***

And on and on.

Evolution of the Analog Complex with regular "Updating Makeovers" as new technologies are demonstrated

Of necessity, the initial complex modules will be built with available terrestrial materials. However, right from the outset, floors could be finished with cast basalt tiles made in Czechoslovakia and marketed in the US out of West Virginia. We could also start out with interior walls constructed ***not*** of 2"x4" wood studs and drywall (as is the case at MDRS and FMARS), ***but of steel studs and duroc™ cement board.*** Not only would that be √ closer to what we might end up doing on the Moon, it would be √ a fireproof solution.

As we demonstrate new materials technologies, we could then replace more and more of the original materials, furniture and furnishings used in the station with those analogous to what we might be able to produce on the Moon out of cast basalt, carved basalt, and basalt fibers. In this manner, ***the quality of the "simulation" would keep increasing - proof that we are learning things worthwhile!***

A Lunar Analog Station as a Part of a larger Project

A Lunar Analog Research Station is but one part of a grander dream of the Moon Society, called Project LETO [Lunar Exploration and Tourist Organization] which would involve a major tourist and educational center. It is my opinion that the research facility should not be included in such a complex but located separately in an appropriate isolated landscape. However, a twin facility at the tourist center, evolving (expanding and upgrading) in step, would be available for regular tours. It would have monitors at each location to show web cam views of what is currently going on in the real research station.

The Mars Society relies on publicity for its analog stations for public support and funding. A sister complex open to tours with a peep hole into the actual one, if located in a high

tourist traffic area such as Las Vegas or Orlando, would greatly increase public exposure, public enthusiasm, and, equally if not as important, a steady flow of donations and new members.

For a diagram map of our proposed Lunar Research Station, see below

What's Next for such A Mars Society collaboration?

Another Crew at MDRS? Moving somewhere else?

We can do some of these things suggested above a**t the Mars Desert Research Station** in the a future Field Season - for example, **a first practice of operations through a complete lunar dayspan/nightspan cycle.**

The demonstration of "**a modular bio-spherics expansion architecture,**" as it involves the facilities themselves, would necessitate an independent operation on a separate site. It would be foolish to make major capital investments in a "temporary" facility not our own. And there is no reason to believe that the Mars Society would approve any such expansion plans.

If we want to do these things, we must find another site or, better, ***find a way that we could operate at the Mars Desert Research Station in Utah that followed the "2 week long "Dayspan"by a "2 week long Nightspan,"*** [if just before, or just after, the scheduled MDRS season, it would not interfere with Mars Society operations there.]

As for a new site for our new modular complex, locating it in a "lava sheet, lava tube area" would be optimum for silane and/or fuel cell based utilities, cast basalt operations and other materials processing and manufacturing operations we want to demonstrate.

Why at the Mars Desert Research Station?

It will take some time both to identify a new site and acquire access and use. To date, there is no such "Analog Facility" on basaltic terrain. We'd have to start from scratch.

It would take more time, and money, to deploy our desired complex. However, ***we could start with a mockup complex of rented or purchased used old camping trailers, replacing them one at a time with new construction.*** This plan that would minimize interruption in annual simulation exercises, a plan that would operate in a basaltic area.

Picking a basaltic site: I would prefer Southern Idaho (a site adjacent to Craters of the Moon National Monument where visitors can explore lava tubes. Note: lava tubes on Earth

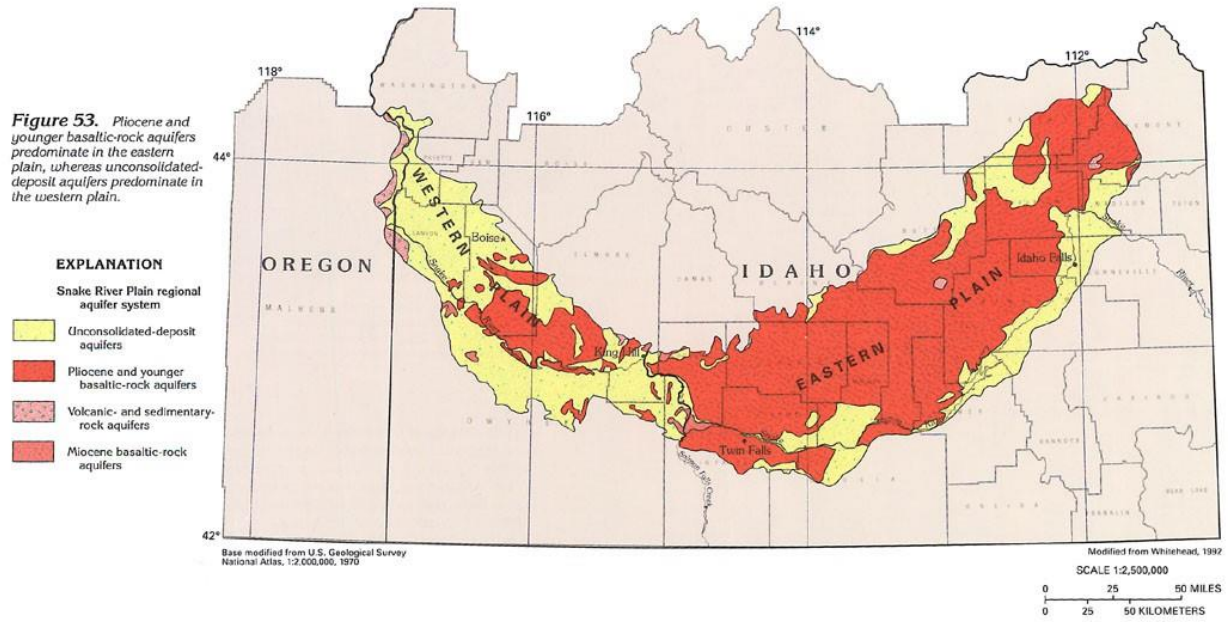
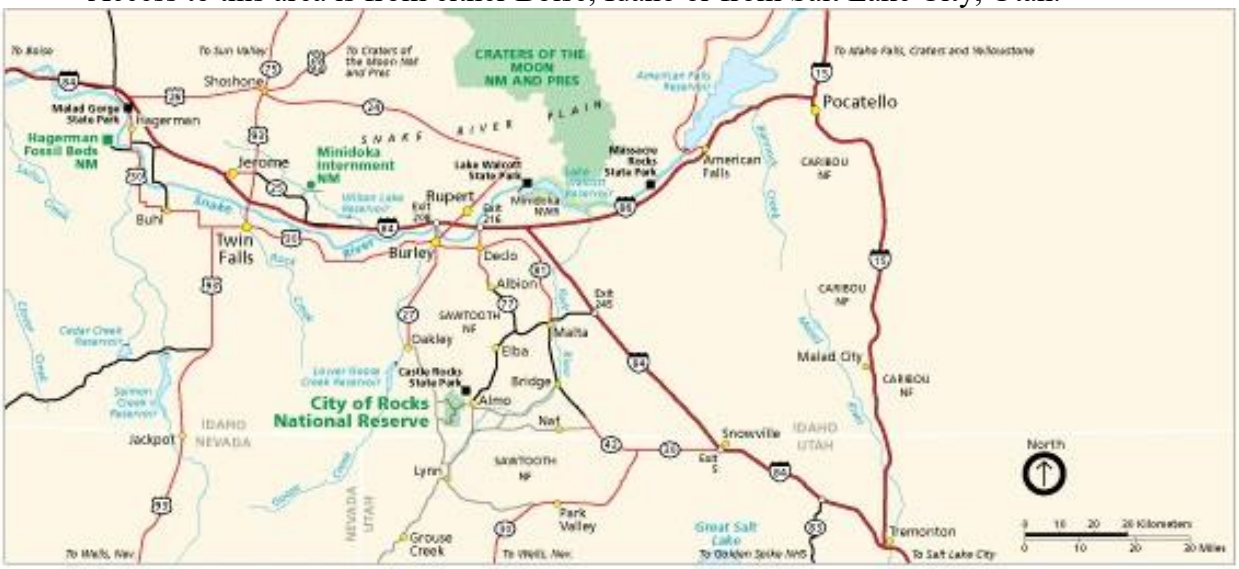


Figure 53. *Pliocene and younger basaltic-rock aquifers predominate in the eastern plain, whereas unconsolidated-deposit aquifers predominate in the western plain.*

(and ion Mars) are smaller than those on the Moon in cross section, in an inverse relation to gravity: the more gravity, the smaller the lava tube.)

Access to this area is from either Boise, Idaho or from Salt Lake City, Utah.



Our Own Lunar Analog Research Station? What we'd do differently

Even before my last (of 2) two-week stint at the Mars Desert Research Station in Utah, I started keeping a file of ideas under the heading "**what we might want to do differently at our own Lunar Analog Station.**" (This is not a near term project. But planning ahead is good.)

Location: there are two schools of thought here:

• Put it in the heart of a high traffic tourist area such as Las Vegas or Orlando or Chicago.

• Choose ***a location where the terrain is suggestive of moonscapes: on a lava flow sheet***, with access to lava tubes, perhaps

I do not believe you can satisfy both objectives without serious compromise. Further, tourist traffic and serious research without tourist interference do not go hand in hand. We do need both, however. The answer is to **build two stations (two identical stations are cheaper than twice just one:**)

√ <u>One in a high traffic area for tourists and public education</u> - with only mockup equipment

√ <u>One in an isolated location where we can do serious work</u> - fully functional

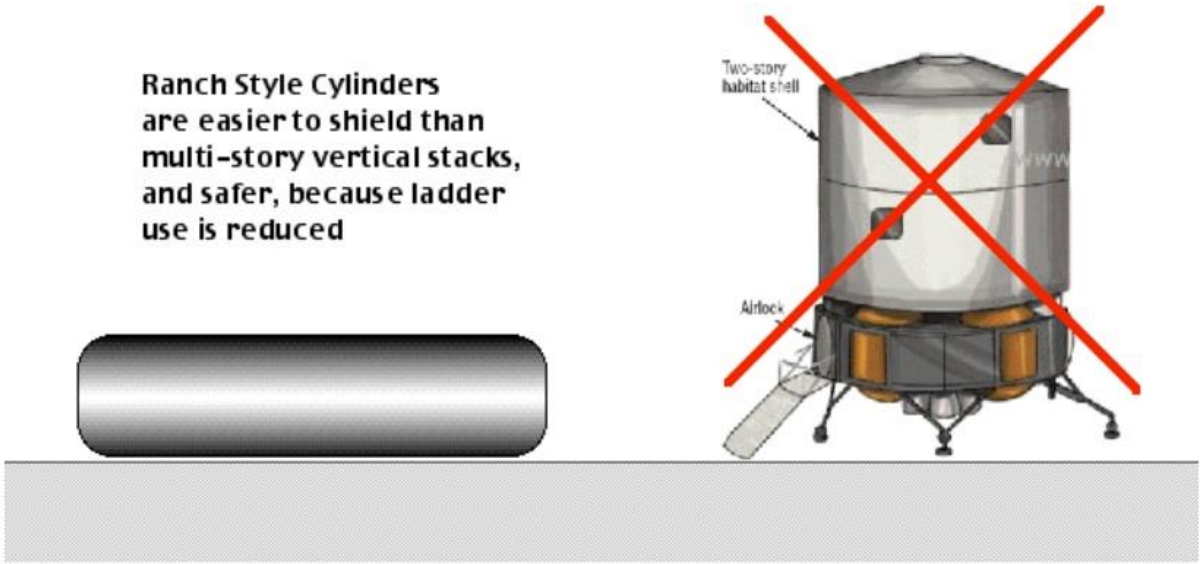
Web cams at the research station would feed monitors at the tourist facility.

Logistics: While isolation is great, logistics can be a continuing problem. The closest major airport to MDRS is 240 miles away in Salt Lake City. Travel is over good roads, but only a quarter of it is by Interstate. The nearest hardware store is 115 miles away, nearest home center 165 miles. Can we do better? Not sure. I checked out one site, the Black Rock Desert lava flow area in Utah 150 miles South of Salt Lake City, along I-15, but the terrain proved unsuitable.

Craters of the Moon National Park and surrounding Bureau of Land Management areas in Idaho is the basaltic terrain and a little closer to Boise, ID than to Salt Lake City, Utah.

Hab Profile: I understand the origin of the Mars Hab shape, but it is a mistake. The Mars Society has backed itself into a corner on this one. The two floor Hab would be difficult to shield (which we would want to do on either the Moon or Mars.)

Option 1: Have the two cylindrical floors separable, giving us 2 floor units that could be placed side by side - much easier to shield, and a lot less time spent on ladders of stairs.



I recommend we look for <u>some sort of Lunar Ranch design.</u> Such as ***a two floor horizontal cylinder.*** *(a pair of Quonset huts will do, one upside down, the other rightside up on top of it for a 2-floor cylinder)* ***Shielding is essential on the Moon (and on Mars), both for radiation protection and for thermal equilibrium. Dig a trench half the height of the Cylinder, set it in the trench and cover it with the soil that was removed. We would probably want more shielding on both the Moon and Mars, but the lesser amount suggested above would be sufficient to simulate what we would do on both worlds and equally important, make the "hab" (here on Earth) cooler in summer, warmer in winter allowing year around crew simulation studies. (or at least from early Spring through late Autumn).***

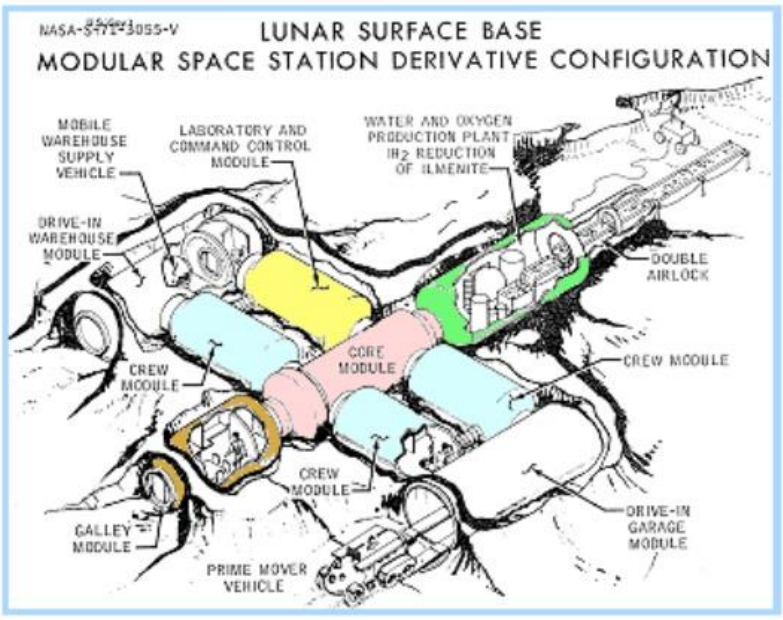
This **NASA sketch** shows one kind of modular layout.

Color added

In this arrangement, the various modules, sized to fly in the **shuttle payload bay**, are connected directly to one another.

This makes it difficult to get at the exterior of any module should alterations or repairs be necessary.

In comparison to the all-in-one approach, it is a step in the right direction.



But to simulate a starter Moon or Mars settlement you would need say a half dozen of these units. And that would be far more educational than just "a" "Hab."

Meanwhile, one on our Moon could be as long as needed to provide all the living quarters, workshops, green space, recreational space we could want. And if we wanted to extend our simulation exercises, we could erect a series of such horizontal 2-floor cylinder units as we wanted, thus ***simulating growth of our outpost -*** which should be a major goal not only for educating the public, but towards learning what a first settlement should have from the gitgo. √ ***living quarters,*** √ ***vegetable gardens,*** √ ***work shops,*** √***communications/meeting room,*** √ ***recreational unit*** (games, indoor sports, exercise, etc. With this kind of Moon/Mars appropriate architecture, we can simulate more than a first landing, rather ***the beginnings of a first outpost that could grow into a first settlement.*** We could add more units as desired.

Utilities: It would be ideal to mimic the situation on the Moon as far as practical. Heavy use of photovoltaics (solar power) to run all the lighting (12 volt) and at least all the lower load outlets. Where we need appliances and equipment for which 12 volt versions are not available (yet) we will have to do with 117v AC power.

MDRS uses diesel-fueled generators. ***Fuel Cells might be better. Again, solar power is the optimum, and that means picking a site with a high percentage of sunny days***. No propane stoves!

Hab Design - Interiors: The first Moonbase structures will most likely be manufactured on Earth. But ***we have time to incorporate into our research station features that mimic what pioneers should be able to produce on the Moon.***

No wood 2x4s or sheetrock drywall when for little more cash we could buy steel 2x4s and Duroc (cement) panels on interior walls, and something like glassboard on exterior surfaces. If we are going to set the mood for simulating outpost life on the Moon, we owe it to ourselves to do it right inside and out.

Life Support:

We cannot expect to be able to simulate total life support on any reasonable budget. But we should work aggressively to go beyond the gray water (sinks, showers) treatment demonstrated at MDRS towards at least partial black water (toilet wastes) treatment combined with food production. ***The Wolverton system is a place to start. This ambitious goal implies year-around occupation or tending.***

Medical Systems:

MDRS has an excellent first aid kit and daily email contact with a doctor. Can we do better? It is worth discussing. In reality, many medical emergencies will have to be treated on location. On the Moon, transport to Earth is only an option for postponable procedures.

Crew Life Styles:

We need prior commitment from our volunteers to participate wholeheartedly in experimental ***pioneer vegetarian food preparation and menu development***. It's a matter of getting into the spirit and will generate good publicity. **Talapia** is a good tasting fish that would work well in troughs below "**Living Walls"** [serving as room dividers in the various units and in connecting hallways, where automated watering of the plants is recycled.

But we should also incorporate ***time, space, supplies and tools to experiment with pioneer-appropriate arts and crafts. What kind of arts and crafts can be pursued with the kind of materials that could be produced on the Moon/or Mars is a subject worth looking into.*** There are two sources: √***moondust/marsdust elements, and √garden stuffs.*** Most likely that kind of information is already out there.

Crew Size: Given the much greater range of activities we would want to simulate and the more "village" size of a realistic Analog Outpost Station, there might be as much as **a few dozen volunteers involved at a time.**

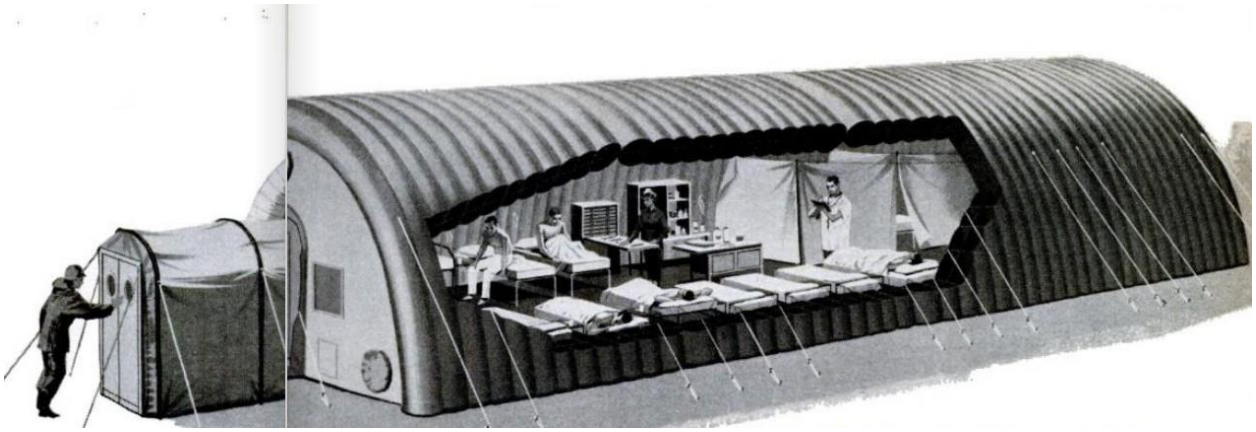
Facility supported research:

Geology and microbiology are big items at MDRS, and that is quite appropriate for Mars. On the Moon, there is no question of life: those into biology are better occupied developing our biospheric life support systems. And we have already done considerable geological investigation on the Moon. More remains to do.

Unlike a Mars base, where exploration is goal one, ***on the Moon, developing ways to tap local resources and start making stuff tops the list. From that point of view, the visible appearance of the host terrain is less important than its geochemical makeup.*** Basaltic areas that do not necessarily remind one of the Moon will still do fine. If we can have both, better!

The many aspects of what we want to demonstrate: √ shielding emplacement; √ regolith handling; √ oxygen production; √ cast basalt technologies; √ ceramics; √glass/glass fiber

composites (not yet an established technology, and something that needs to be developed here on



Earth so that it is a technology for us ready to use when we get to the Moon and Mars).

There is a lot of things we can do at a well-equipped, well-designed multi-unit Analog Lunar Outpost on suitable basaltic terrain here on Earth.

"Hab"s - we can **start with a pair of quonset huts, one inverted for the lower floor, the other upright on top of the lower unit for a 2 floor unit.** Connecting tubes can be smaller with utilities under the floor, Living walls on one side, lockers on the other.

The layout of an Lunar Analog Site, phase one would be the Farming and the Crew Quarters modules and the Commons and Gym modules above them, gradually expanding to the complete multi-function outpost covering an acre. ***All of the above benefits are important.*** In our design for a proposed Moon/Mars Atacama Analog Research Station in Chile, the opportunities for extra storage and additional Living Wall units were two major drivers. The result would be a more pleasant place to live and work. ##

√ check out MMM #227, August 2009, page 6,7

[from a study for a Chilean "Moon/Mars" Analog Station in the Atacama Desert in Northern Chile, to be built around a C130B Cargo plane to be donated by the Chilean Air Force, with Paul Graham and myself heading up the project. Alas, the University in the nearby port city of Antofogasta, said "Great Design! But we will build it, you guys can stay in the U.S. (after countless hours of brainstorming by Paul and myself.)

Unlike the MDRS, we'd simulate a small outpost not just one visiting craft.

Larger Crews, Longer Exercises: Talented volunteers or ....? The Mars Society has done a splendid job of attracting talented students with masters and PhD thesis projects worth demonstrating at MDRS, projects in the fields of geology, biology, and astronomy (astronomy is the least relevant for our main goal of simulating how exploratory crews would house themselves, etc.) While we can attempt to do the same, changing the stress, however (especially in biology), ***what we want to do*** **in the area of demonstrations suggests that we can prime the pump by** ***organizing engineering competitions on the college level for automated or teleoperated shielding emplacement systems, for example, with the winning team getting to do the final demonstration at our location. Such an effort would build enthusiasm and provide plenty of publicity.***

It also builds local cores of support. Summing up: I have been a very strong, ardent and outspoken supporter of the Mars Society's analog station program from the day it was first

announced. They have done wonders on a small budget with volunteer resources. Their program deserves respect. Even after 2 two week stints (2004, 2005) spent at MDRS in Utah, and seeing all the room for improvement, I am still a strong supporter.

However, we have the benefit of time on our hands, and can afford a more deliberate, patiently methodical approach. Our needs differ. ***We can do it, given time, but only if we don't wait until we have the money to start brain-storming and planning.***

It will be easier to find money to expand such an analog facility, than it is to get one started. The sooner the better, and our research will ultimately benefit the first pioneers.

Length of crew stays: we would definitely want to simulate a pair of "sunths:" 2 dayspans, 2 nightspans: (or 27 days plus one day for one crew to leave, the next crew to arrive.

More Considerations: the need for connecting passageways

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:

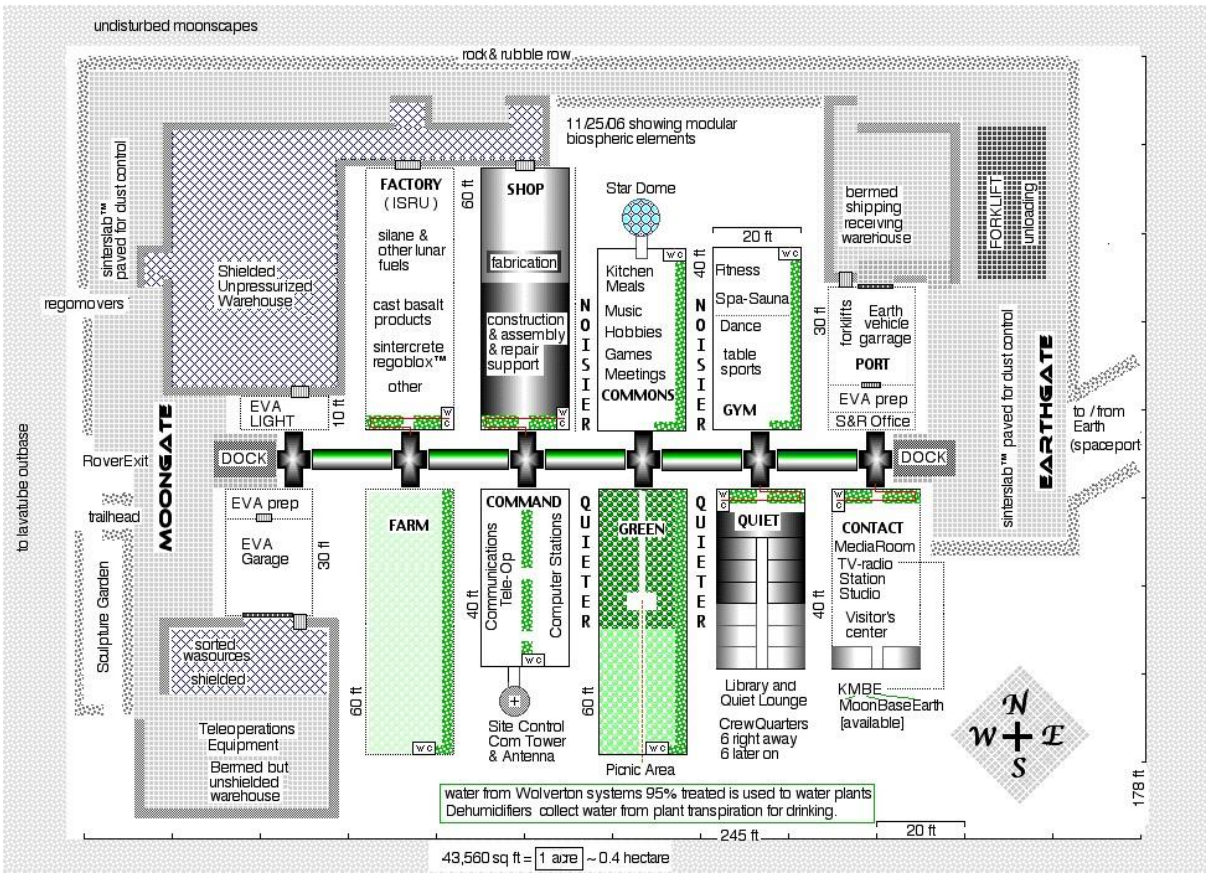
• passing through one habitat or activity module to get to another one is disruptive and distracting to the activity and personnel in those modules. And the path, whether down the middle or to one side takes up valuable space.

> On the other hand, ***the separation of modules that pedestrian passages afford 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
- 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 with seating for conversation, snacks, reading, people watching

Hallways and other pedestrian corridors are an opportunity for additional biomass in the form of Living Walls, at the core of the "Modular Biospherics" architectural approach 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. One-size-fits all approaches to the mini-biosphere equation have all been dismal failures.



Above: A complete Analog Facility (*start-up with the middle six units*)

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.

Putting such features 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.

Modular Biospherics: Living Wall Systems

Making the most of pressurized pedestrian & vehicular corridors:

"A living wall is a vertical garden. Plants are rooted in compartments between two sheets of fibrous material anchored to a wall. Water trickles down between the sheets and feeds moss, vines and other plants. Bacteria on the roots of the plants metabolize air impurities such as volatile organic compounds."

While this is the definition in the most technical sense, experimenters have made living walls in which plants are in pots anchored to a wall in a staggered pattern. They also found other ways to keep them properly watered, fertilized, and to recycle the drainage water. In a modular outpost, there will be connecting tubular passageways for pedestrians and carts.

On the Moon, the curved walls of passageways connecting homes in “neighborhoods” offer an opportunity to increase the overall biosphere mass of a lunar outpost (real or analog) by integrating a living wall feature along one side, for the whole length of (each) hallway. This will be in addition to the biomass contributed in any Greenhouse modules and any in the habitat and activity modules themselves.

Decorative Options: It is easy to work in rocks and planters, sculptures and other objects into a living wall system. These can be design accessories or fully functional parts of the plant holding and water irrigation systems. There are even automated ways to keep them properly watered, fertilized, and to recycle the drainage water.

www.verdirsystems.com/html/living-walls.html.

In a larger settlement, pressurized roads could have living walls to each side, and, down the middle, to separate traffic flowing in opposite directions, boulevard style.

If we continue to think in terms of floor space, then we will be put in competition with the plants we depend on - not a prescription for success. But plant areas can make use of otherwise empty wall space.

For photos of Living Walls, go to Google, and enter “**Living Walls**” - the variety both in plants used and in the way they are arranged is endlesss. You will find them indoors, against

walls or as room dividers, and along corridors, and even outdoors.

If our Lunar settlement homes and passageways sport a wide variety of Living Walls, this feature is the one that will most connect pioneer settlers with Mother Earth. ##

In a modular outpost, there will be connecting tubular passageways for pedestrians and small carts. Their curved walls offer an opportunity to increase the overall biosphere mass of a lunar outpost (real or analog) by integrating a living wall feature along one side, for the whole length of (each) hallway. This will be in addition to the biomass contributed in any Greenhouse modules and any in the habitat and activity modules themselves.

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