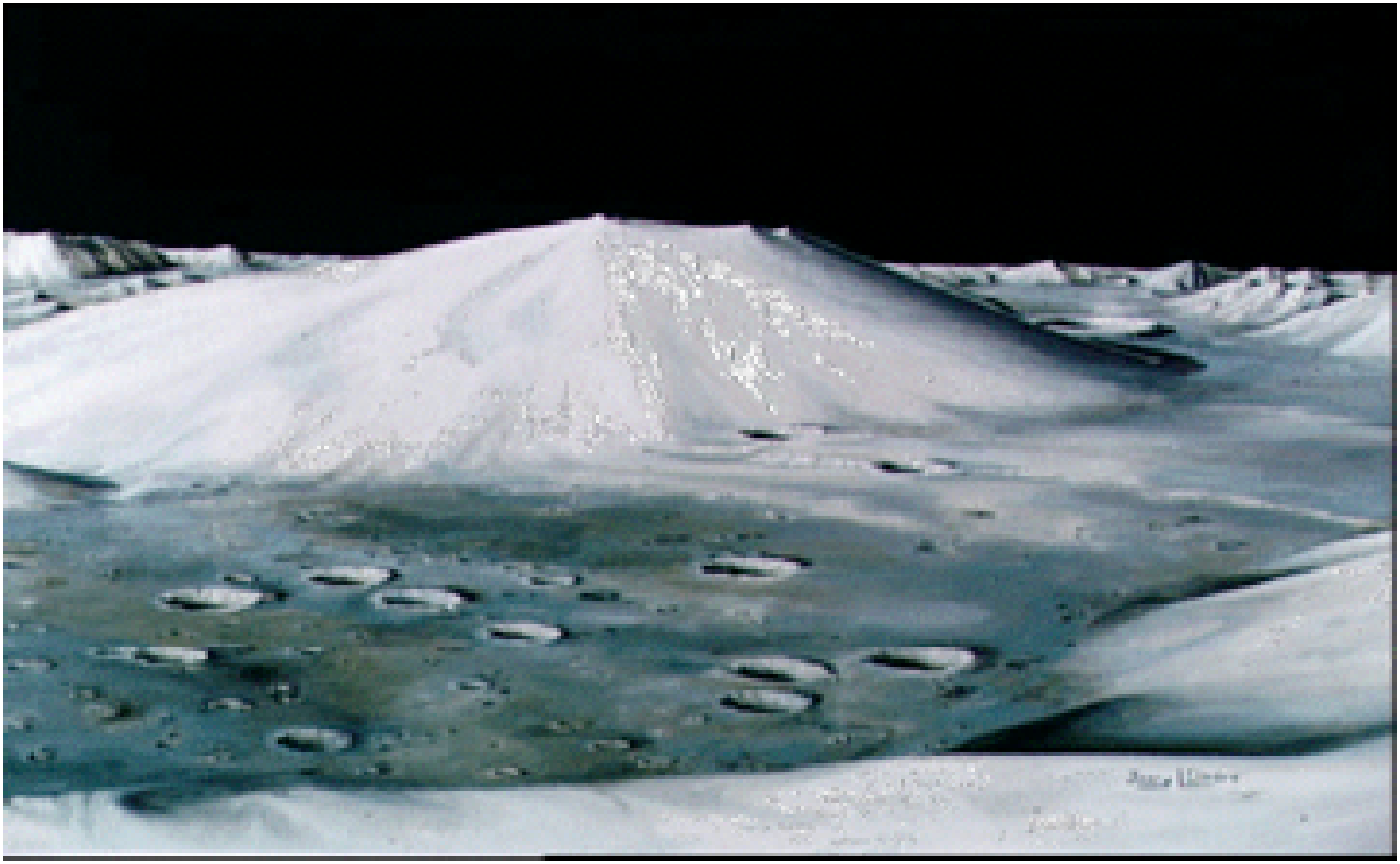
A Modular Analog Lunar Research Station Proposal

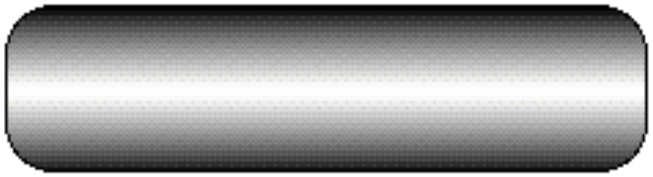


Peter Kokh - December 9, 2006 - Lunar Reclamation Society

Several slides added or modified: November 23, 2009

Vertical? -- *or Horizontal* *- Our Design Philosophy is "Modular" as a "real" outpost would be constantly expanding in space and functionality*

Ranch Style Cylinders are easier to shield than multi-story vertical stacks, and safer, because ladder use is reduced



An Analog Outpost should be Modular just as a real Lunar Outpost would be, able to grow *in open-ended fashion*

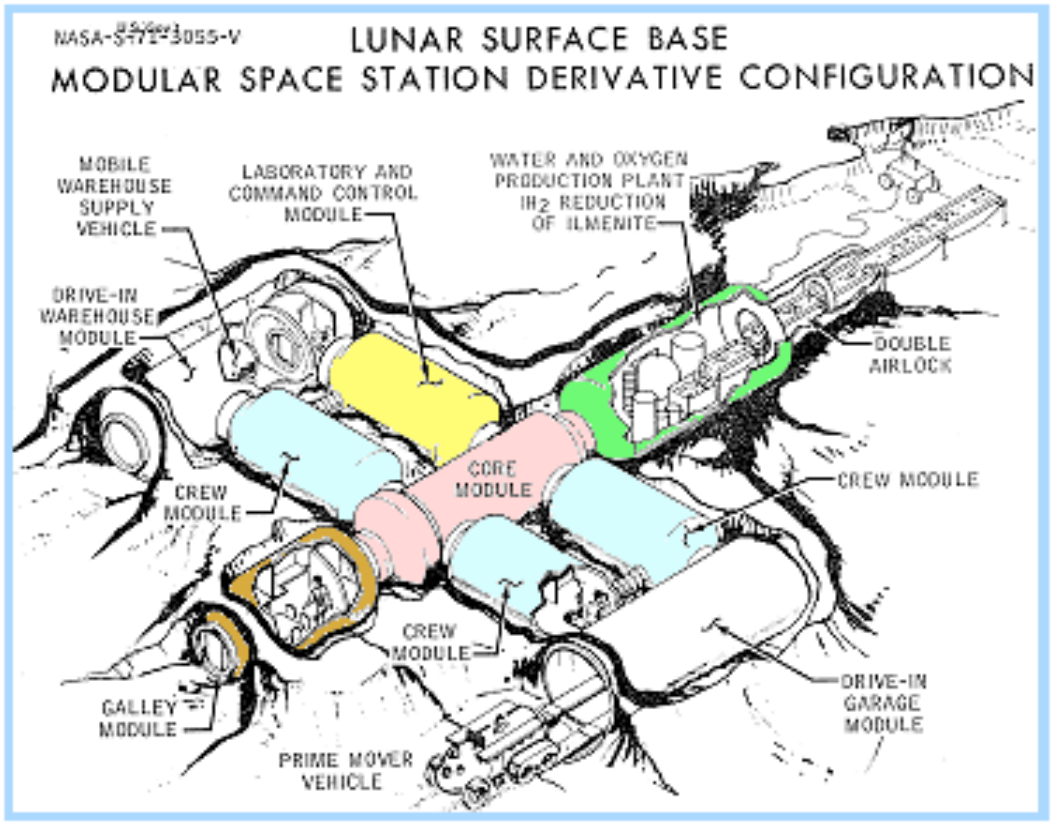
This **NASA sketch** shows one kind of modular layout.

Color added

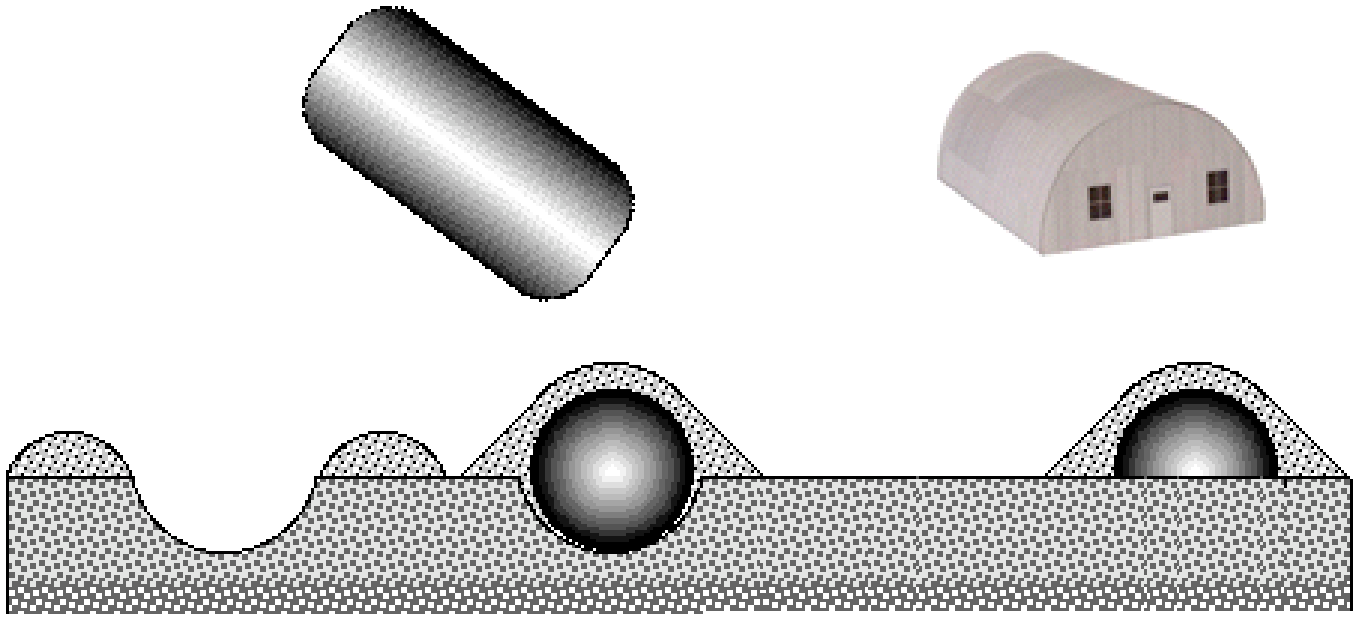
In this arrangement, the various modules, sized to fly in the **shuttle payload bay**, are connected directly to one another.

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.

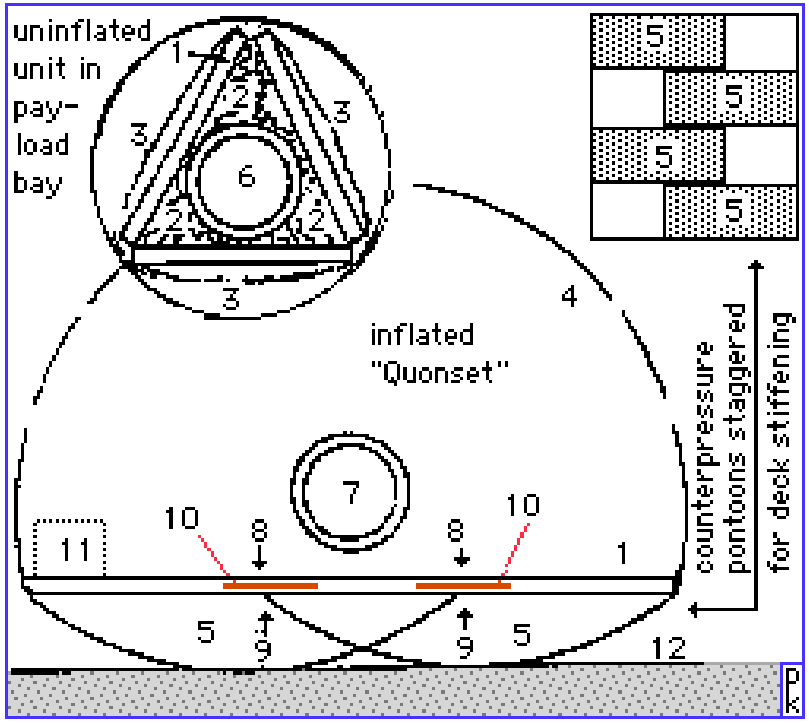


a Regolith-covered Cylinder and
a Regolith-covered Quonset Hut
look very much alike *from the outside*



Appearances can create an effective sense of realism that will motivate research crews.

A Quonset hut could also be interpreted as a special kind of hybrid rigid-inflatable



Hybrid Rigid "Quonset" Inflatable Fits in Space Shuttle Payload Bay

[1] Hinged 3-section floor deck.
[2] Uninflated Quonset roof/wall
[3] Uninflated floor support pontoons
[4] Inflated Quonset roof/wall
[5] Inflated floor support pontoons
[6] In transit position of docking module
[7] Docking tunnel in end wall
[8] Downward air pressure on hinges
[9] Counterbalance pressure on hinges
[10] Contingency stiffening bars
[11] Representative pull-up feature
[12] Ground contour before shielding

A Quonset Module Shell is *inexpensive*

20 ft wide, 10 ft high, 40 ft long
metal shell with front door only,
delivered to site

27 ft wide, 30 ft high
shell and legs only, at factory

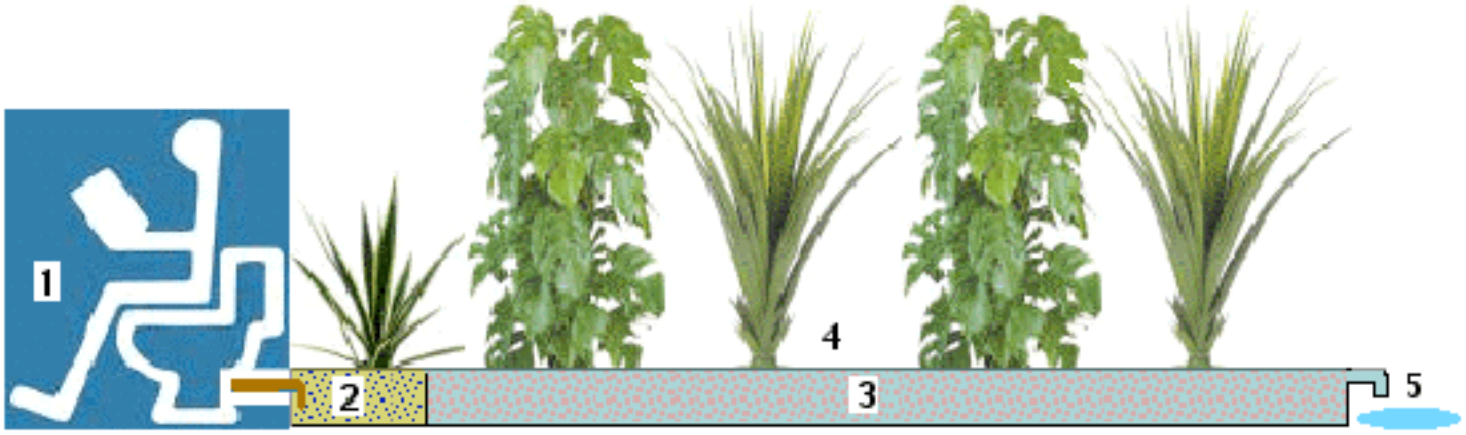
$7,000 (12 Quonsets = less than 1 of these) **$100,000**

An idea of the Quonset interior volume

Modular Architecture ==> Modular Biospherics:

Integrating biosphere components in every module, rather than as a closeted afterthought, allows the physical Outpost Complex & Biological Biosphere to grow ***in step together***

Each Habitat or Activity Module would have a Wolverton Black to Gray Water Treatment System



1 Side-flush toilet

2 blackwater tank with microbes to break down solids & destroy all pathogens

3 inert filler with irrigated soil

4 plants with roots in wet soil mixture

5 effluent water is 95% treated, ready to water plants in greenhouse and eslewhere

Odorless system fills each module with sweet fresh air and lush greenery

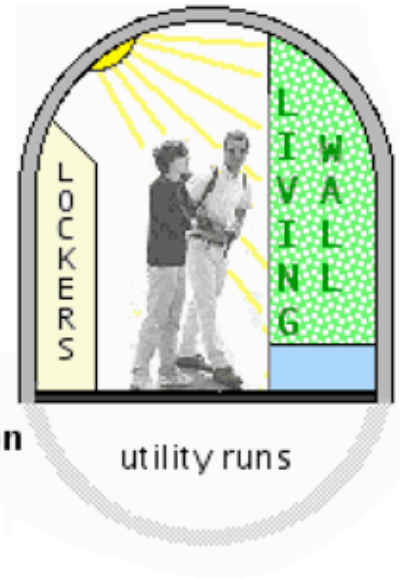
Modular Biospherics: Biosphere components can even be integrated into the hallways and connectors that tie the complex together as a living whole.

Living Wall installation, Baltimore, MD. This 110 sq ft (10 sq m) wall filters all the air for its 7,500 sf office building

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.



Modularity creates options to experiment with different utility systems as well

AIR QUALITY — Each module already comes with a Wolverton toilet graywater system to help maintain fresh air quality

ELECTRIC POWER

Enough solar panels and batteries to maintain minimum life support needs if main power is lost, for a period TBD

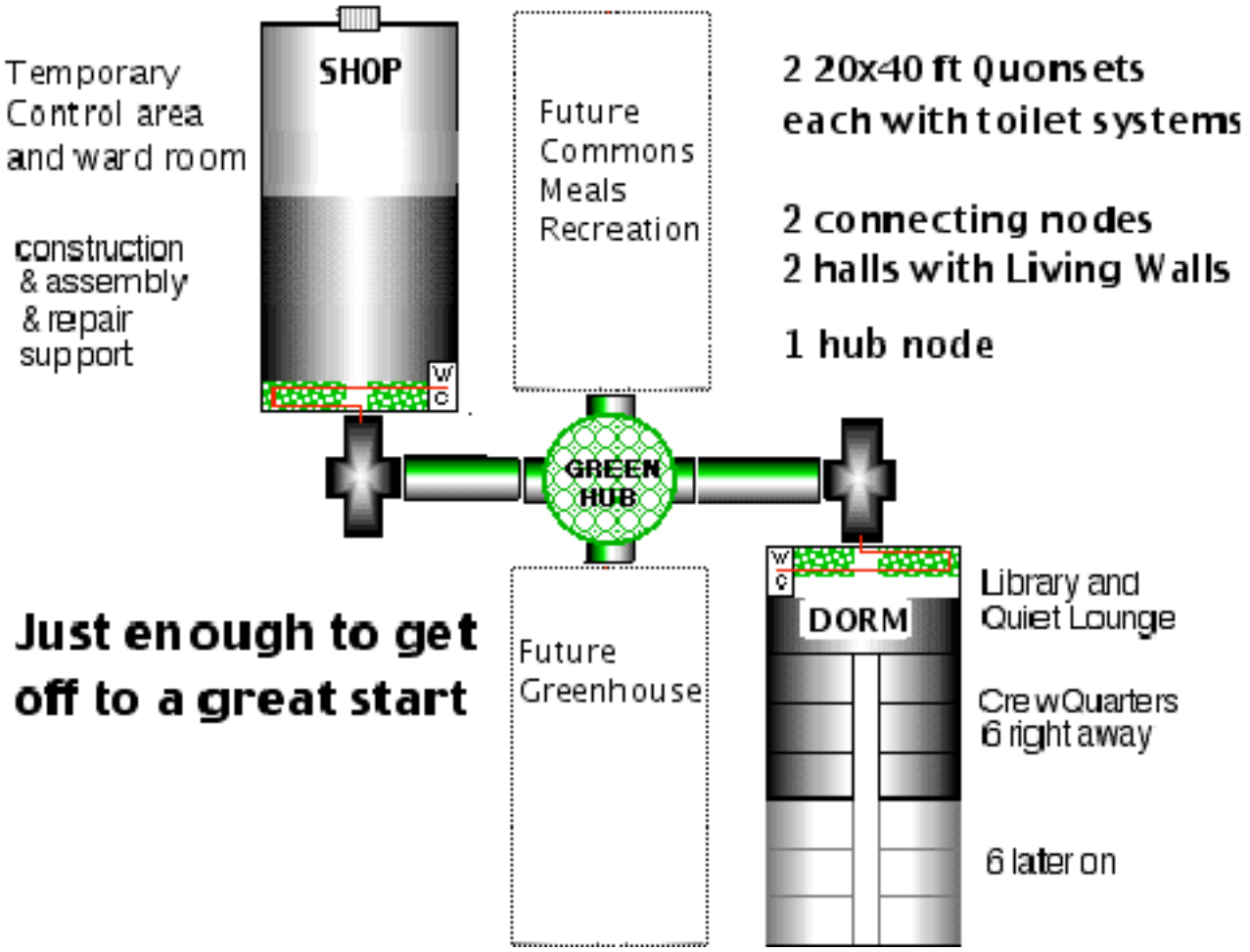
WATER STORAGE

Fresh water reserves and waste water holding tank to last for a period TBD

THERMAL SYSTEM — A system that would maintain internal temperatures within tolerable, if uncomfortable limits, should main power fail, for a period TBD

FOOD RATIONS — survival rations sufficient for a period TBD

Phase I of a Modular Analog Outpost



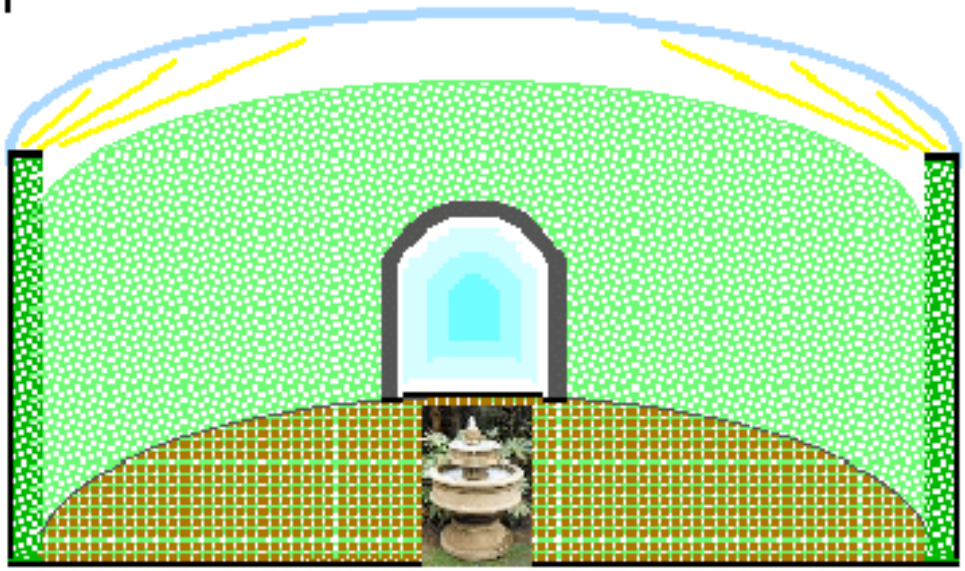
A “Green Hub” at the Station’s busiest intersection

START OF A CONCEPT

High Ceiling, higher than anywhere else in the outpost. It would be painted matte sky blue and brightly lit by hidden cove lighting to serve as a faux blue sky.

A vertical cylinder with 4 openings to 2 modules and to 2 hallways.

Cylindrical walls would be covered with plants. A fountain or water feature would be at the center



THE GREEN HUB would be a node through which everyone would pass at least three times a day, on their way to the dining area.

This suggestion is the result of feedback from Michael Bakk, Calgary Space Workers.

Also in this space would be park like benches, places to sit and rest in a beautiful envrionment and read a book or chat with others.

This is a place that should be designed in an open competition

It would be named after the winner in the design competition

Phase II Expanded Analog Moonbase

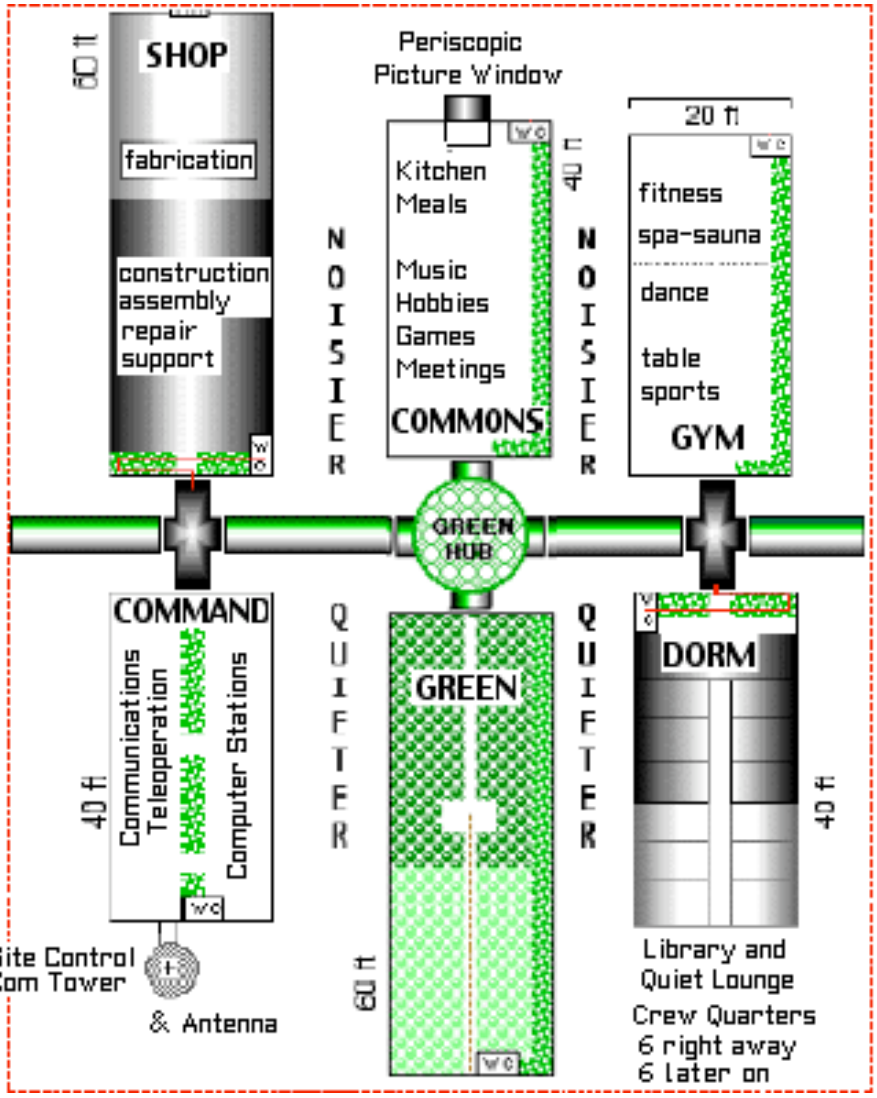
CORE of OUTPOST

Phase II

6,000 sq ft

vs MDRS

1,100 sq ft



L-R

SHOP

COMMONS

GYM

(noisier)

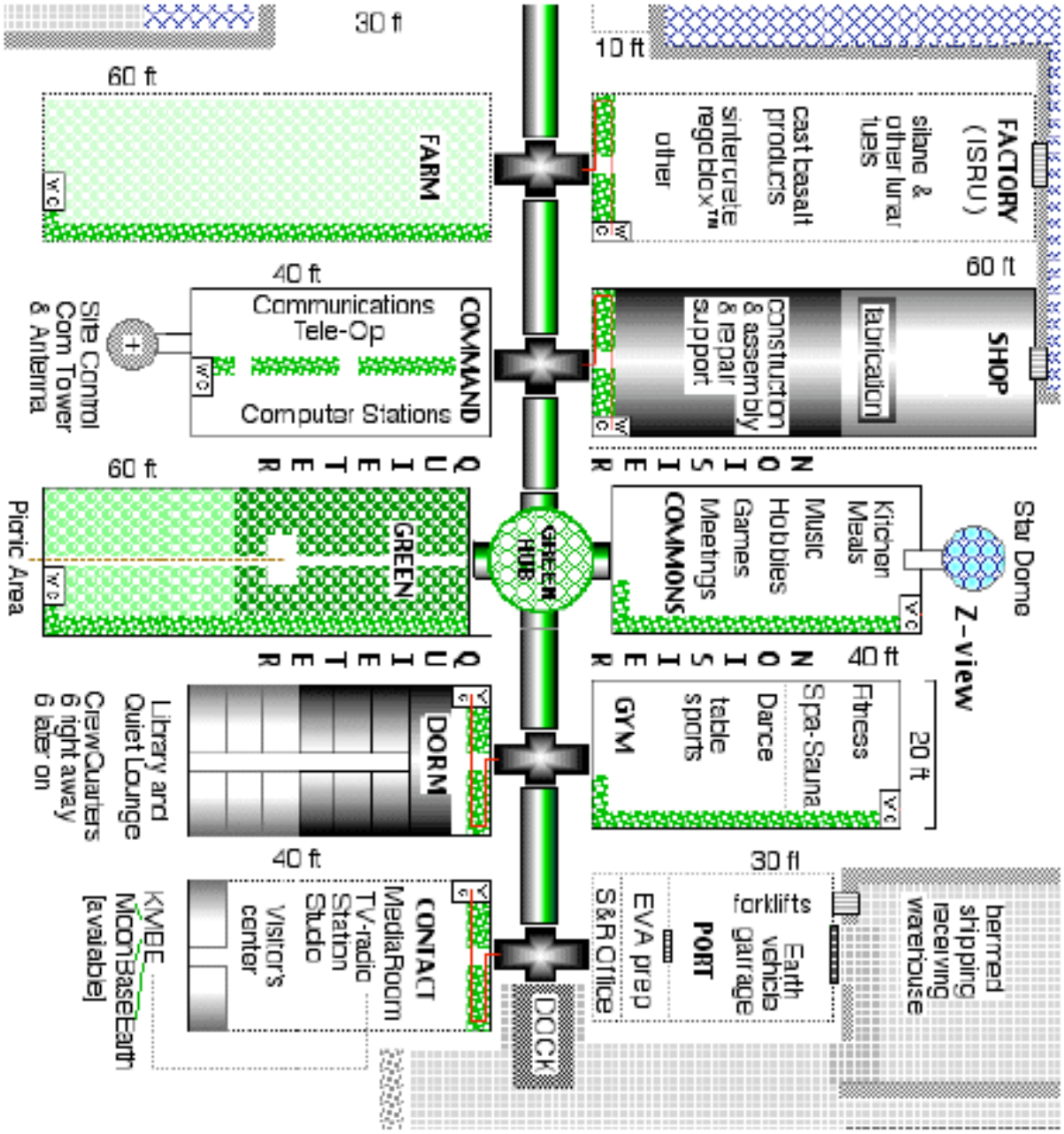
COMMAND

GREEN

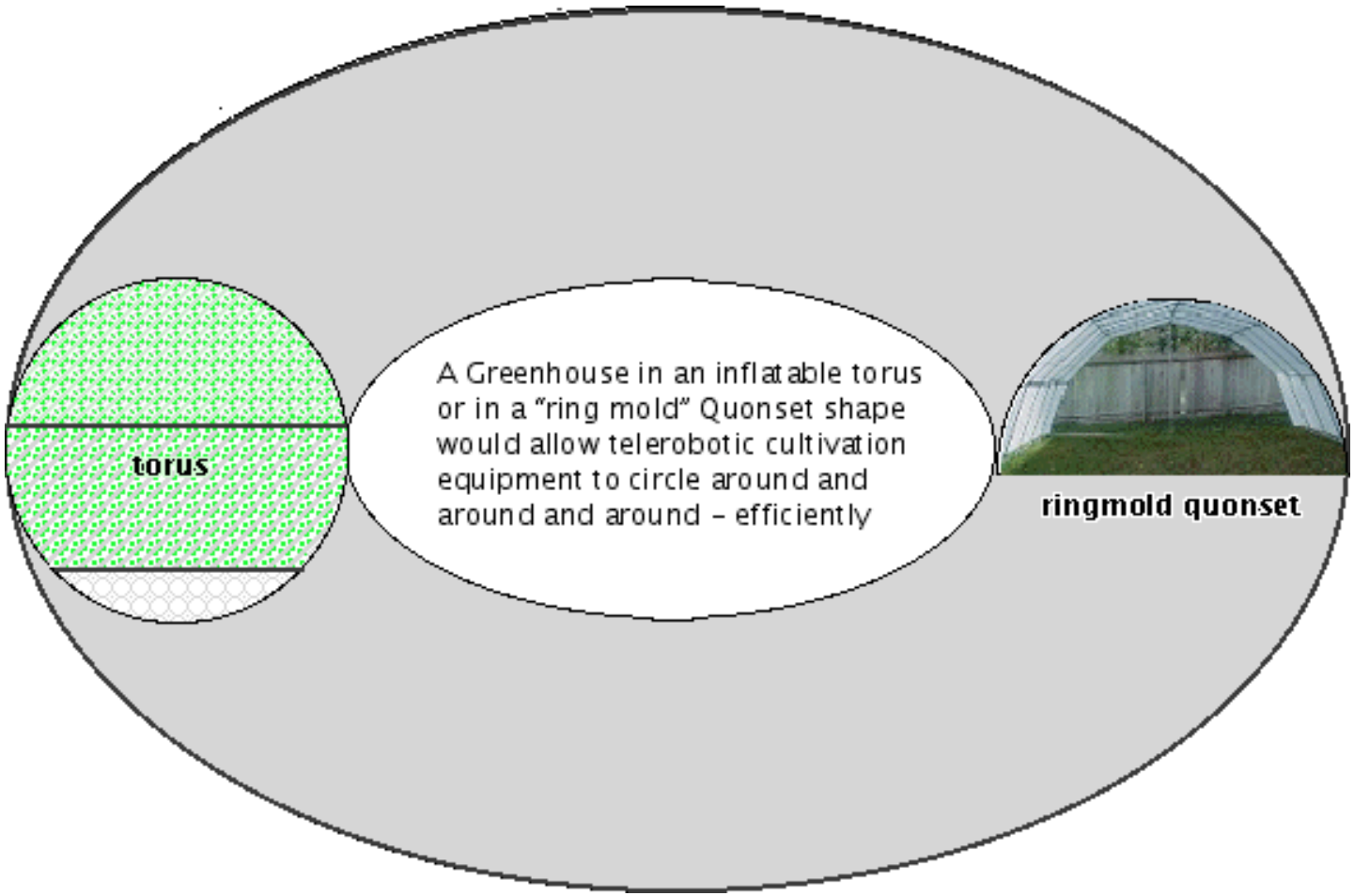
DORM

(quieter)

Phase III Expanded Lunar Analog Station



Phase IV: More Agricultural - Biosphere Space
A 2nd “torus” or “ring mold” Greenhouse



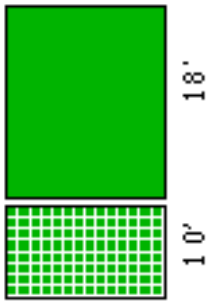
The South Pole Food Growth Chamber

This **"Food Growth Chamber"** has been in operation at the South Pole since 2003 providing **2 salads a day for 75 people.**

It uses **overillumination** and a **CO2-rich** atmosphere. On this side of those doors is an **Environment Room** with normal air and lighting. Here, crew can picnic, enjoy the lush setting, and even garden.

Any crew member who wants a garden plot to grow whatever can have one.

http://www.southpolestation.com/trivia/00s/greenhouse1.html

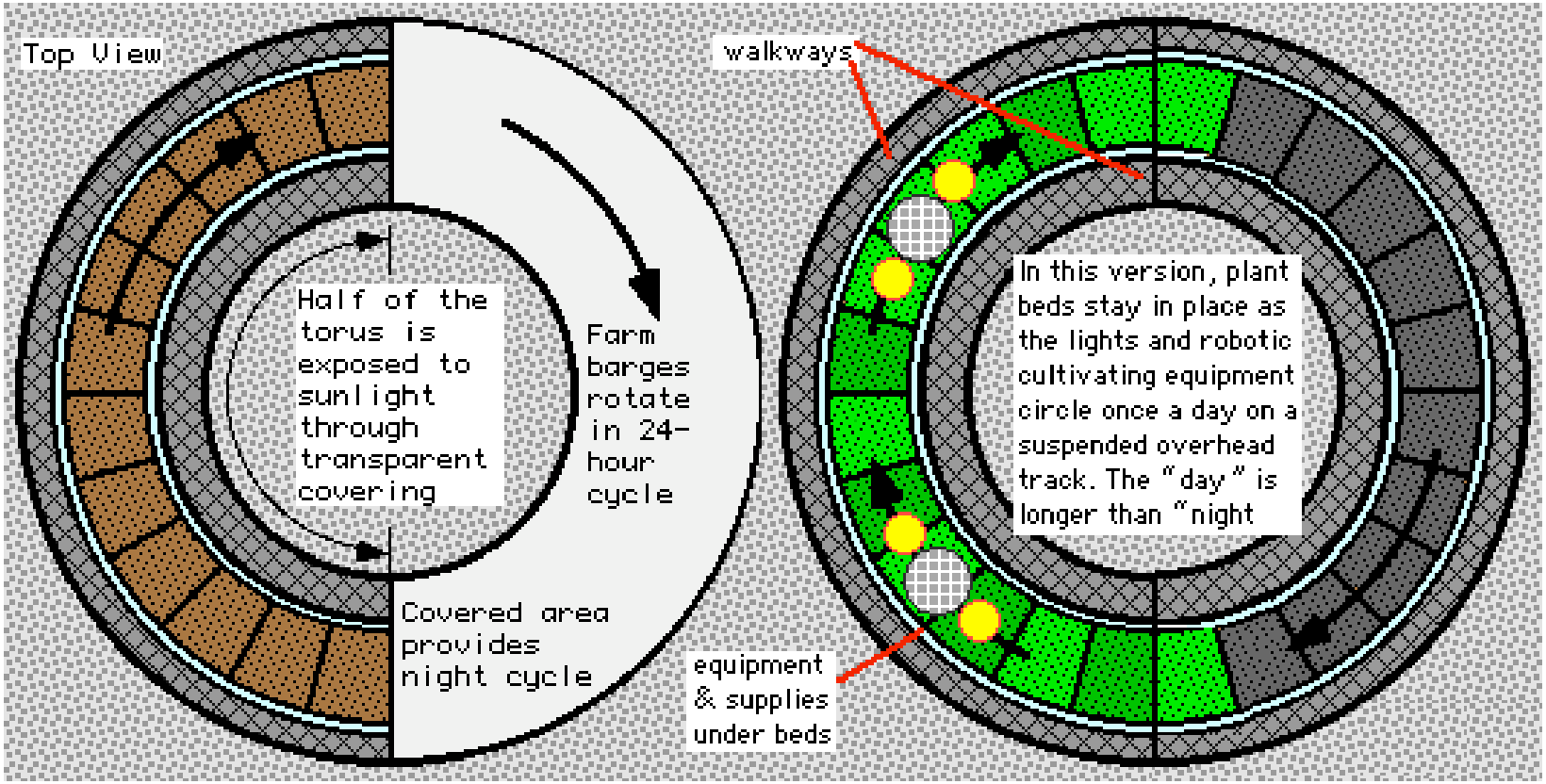


http://ag.arizona.edu/ceac/CEACresearch/International/004f.htm

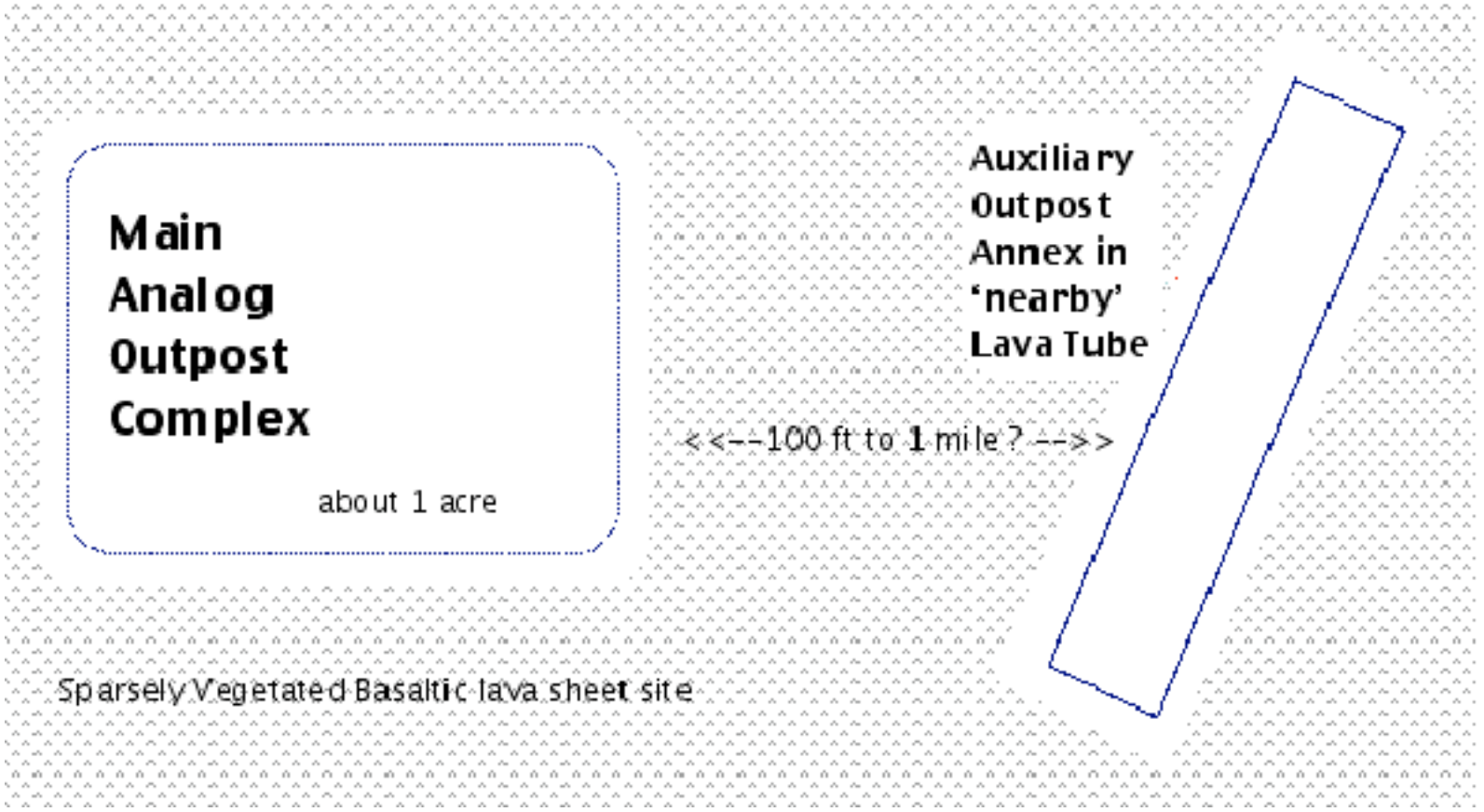
U of Arizona staff in collaboration with industry designed this successful model of what we could do on the Moon, and should copy at a lunar analog station. MORE pictures at the second URL above.

The challenge is to maintain this teleoperated system year around.

Tele-robotic “ring mold” Greenhouse concept
Would free lunar personnel for other duties



Overall Site Plan: a main “surface” outpost and an “annex” in a nearby lavatube or in an abandoned “dry” mine gallery



The Lavatube "Annex" would be used for Dayspan/Nightspan Operations Research

Wide Section of "Subway" in Young's Cave, Bend, Oregon

Lavatube is naturally pitch black, can be electrically illuminated on a lunar schedule, two weeks of light and 2 of darkness, cycling.

This "dome yurt" is a spacious 31 ft wide, 11 ft tall, 700 sq ft, lightweight, @ $2,100 incl S&H set up by 2 persons in 1 hr, comes compact to bring inside the tube.

Alternatives to an underground space for Dayspan/Nightspan Simulation

Cheapest-simplest way to simulate Dayspan/Nightspan

A shielded unit out-of-sight of the main outpost complex, could have fake windows that were brightly backlit by an electric "sun" during the simulated two weeks of lunar dayspan.

And be blacked out druing the simulated two-week-long nightspan portion.

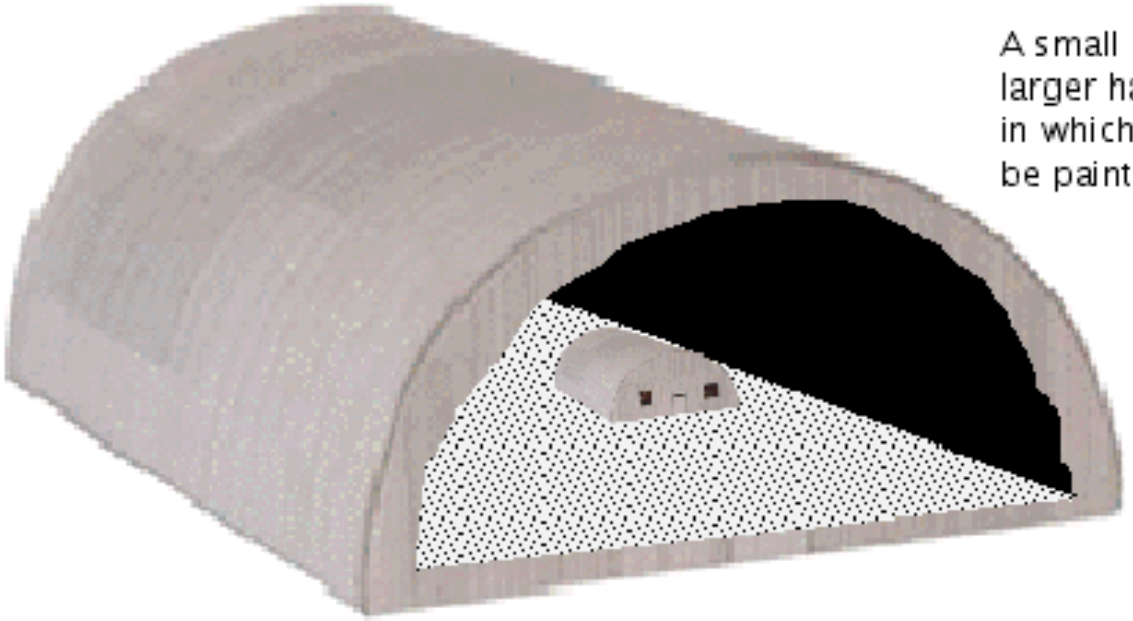
Crews would go outside during "dayspan" only during terrestrial daylight	**Crews would go outside during the "nightspan" only between local sundown and sunrise.**

This might be easier if the crew shifted their clocks forward six hours so that local 6 pm would become their "noon." Then they could do morning "dayspan" excursions in local daylight, and afternoon "nightspan" excursions after local sunset.

All visual clues would indicate around-the-clock sunshine for two weeks followed by around-the-clock darkness for the following two weeks.

A simulated "Earth" in the sky would help.

A More Expensive Dayspan/Nightspan Simulation



A small habitat module inside a much larger hanger or high ceiling warehouse in which all interior "sky" surfaces could be painted matte black.

The floor would be simulated moonscape complete with mini-craters

During dayspan, a "bright sun," in the form of a sulfur lamp, could slowly make its way across the black "sky"

During nightspan, fiber optic stars could brighten the sky, along with a projected Earth to proper size and phase.

This could be done near the main base or at an altogether different location

An Alternative "Mobile-Modular" Approach
being pioneered by the Calgary Space Workers

- more realistic final appearance
- more realistic interior space
- no previous outfitting to remove
- clean slate interior design
- delivered to site

- can be outfitted where teams live
  …then trucked or towed to the site
- other teams can prepare other units
- includes flooring, interior surfaces
- includes RV wiring, RV plumbing
- realistic for a 2nd Lunar outpost

Mars Analog Research Program Goals vs. Moon Analog Research Program Goals

Demonstrate value of human-robotic Mars exploration at 1st landing

- The 6 Apollo Missions had already demonstrated this on the Moon
- Neither FMARS or MDRS has attempted to demonstrate modular expansion into a more functional outpost, use of local resources, the use of shielding against the cosmic elements and Mars weather, or of any kind of life support system.

Demonstrate the technologies needed to stay on the Moon, and expand

- Test modular expansion languages
- Modular biosphere expansion allowing comparison of differing graywater systems, living walls etc.
- Site preparation technologies
- Shielding technologies
- Incorporation of lunar materials
- Semi-automated food production
- Site maintenance, storage systems
- Mating production with lunar cycle

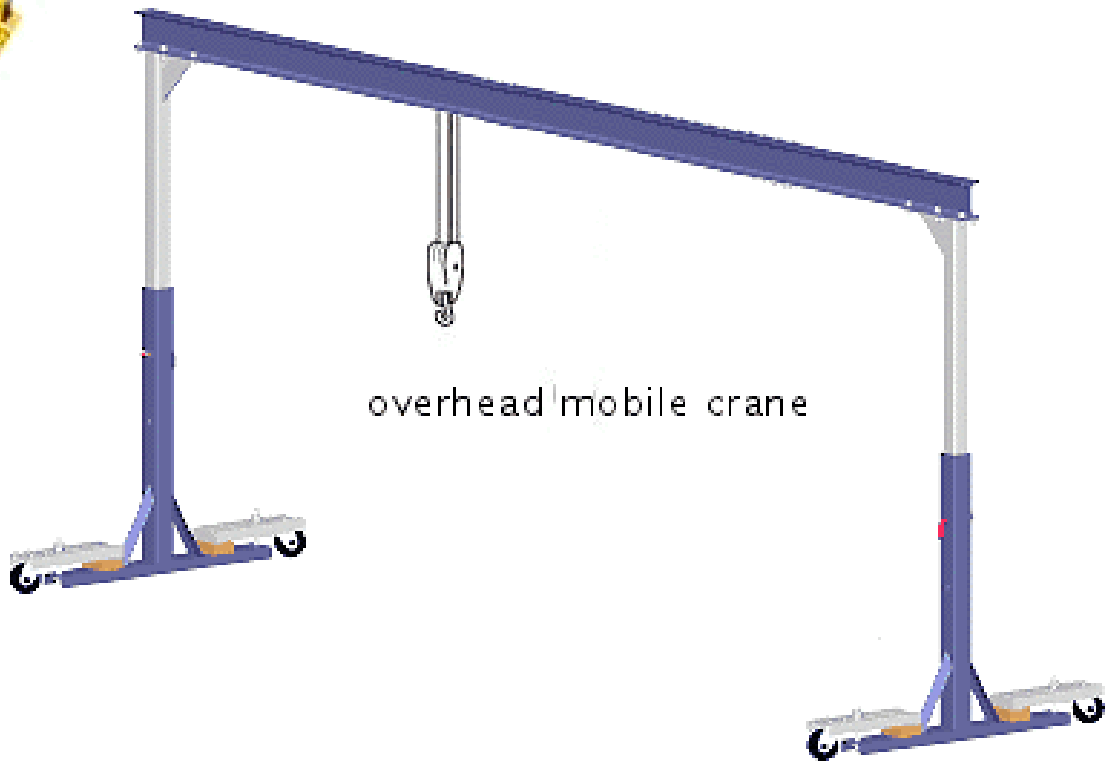
Some of our research program flows from our modular design philosophy. Other research vectors will depend on our site location.

- A vegetation free, rock, gravel, and/or a sandy location [a "big sandbox"] would allow practical experiments with site preparation, teleoperated equipment, shielding emplacement, and more.
- Proximity to basaltic areas would allow experiments with this early lunar industry.
- Proximity to a dry underground area like a lavatube or abandoned mine gallery would allow us to do experiments pegged to the lunar 29.5 day dayspan/nightspan cycle.
- Lacking a subsurface environment, the lunar dayspan/nightspan cycle could be simulated within a large building closed to external light.
- Any kind of terrain will demand development of appropriate warehousing and recycling systems
- No site is perfect, and, for practical reasons, we have to "pick our battles." Yet with ingenuity we can use most any available site to advance our preparedness for early operations on the Moon.

Analog Moonbase Research Program
Pushing the Limits of Teleoperation

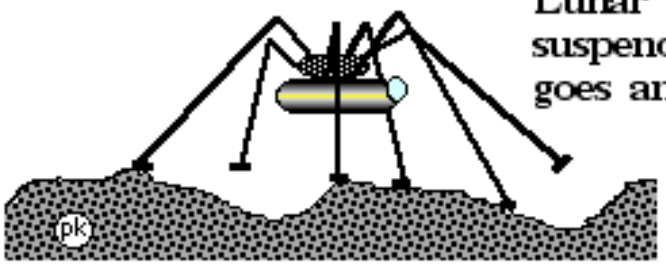
Bulldozer-backhoe

sandbagging system



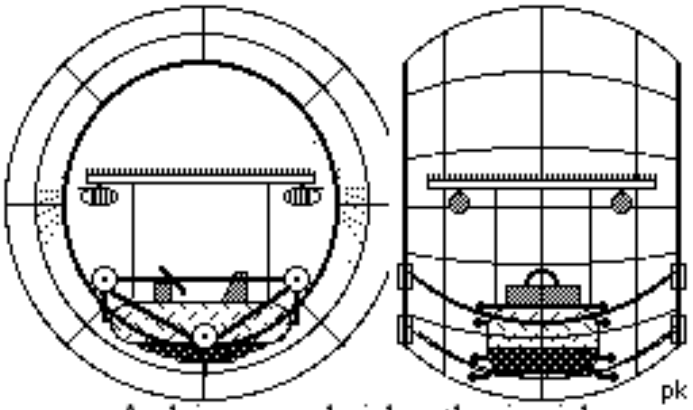
overhead mobile crane

Analog Moonbase Research Program
Experimenting with new type Vehicles



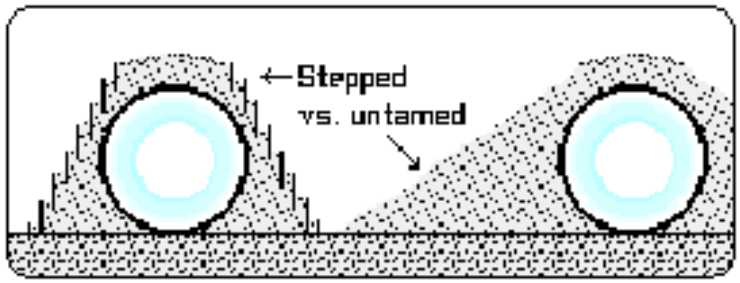
Lunar "Spider" with suspended crew cab goes anywhere

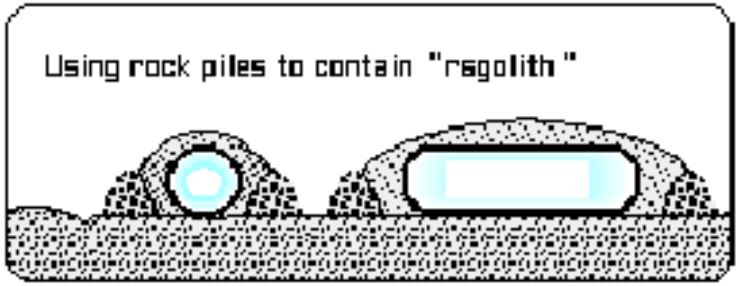
Much of the Moon's surface, especially in the "highlands." is very rugged. A vehicle modeled after a "Daddy Longlegs" or "Harvester" spider would be able to traverse such areas with ease, and probably at a respectable gait. The crew cab being perched well above the surface would provide a commanding view of the surroundings and allow a better choice of path ahead. A computer program would run the legs, allowing crew to concentrate on the surroundings.
One or more Spiders would allow explorers to visit much of the Moon's :"out-vac" back country without having to build roads, leaving visited areas in their pristine state.
Of course, spider excursions would be a favorite of tourists.

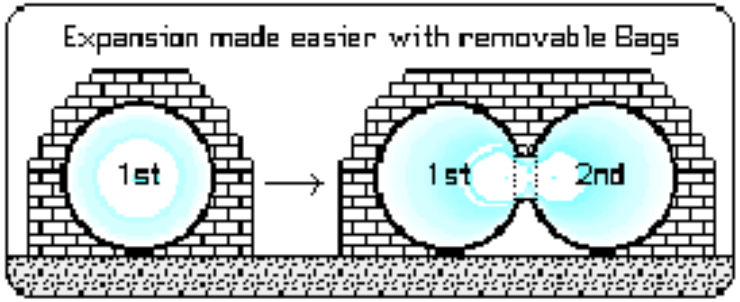


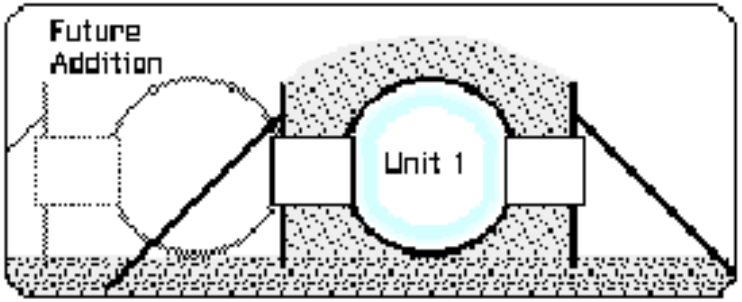
A driver pod rides the inside rails of a Lunar Squirrel Cagemobile tire-frame. Suspended above the weighted driver pod is a solar power array that also supplies some shade, and which is equipped with lights for night time operation. This unicycle can negotiate rolling terrain fairly well.

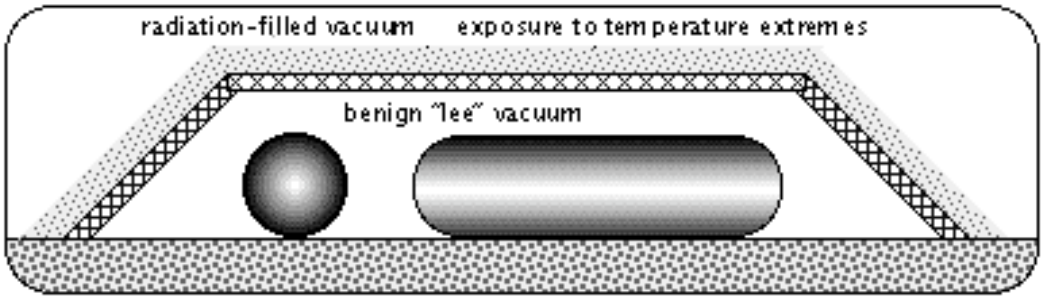
Analog Moonbase Research Program
Testing various Shielding Options



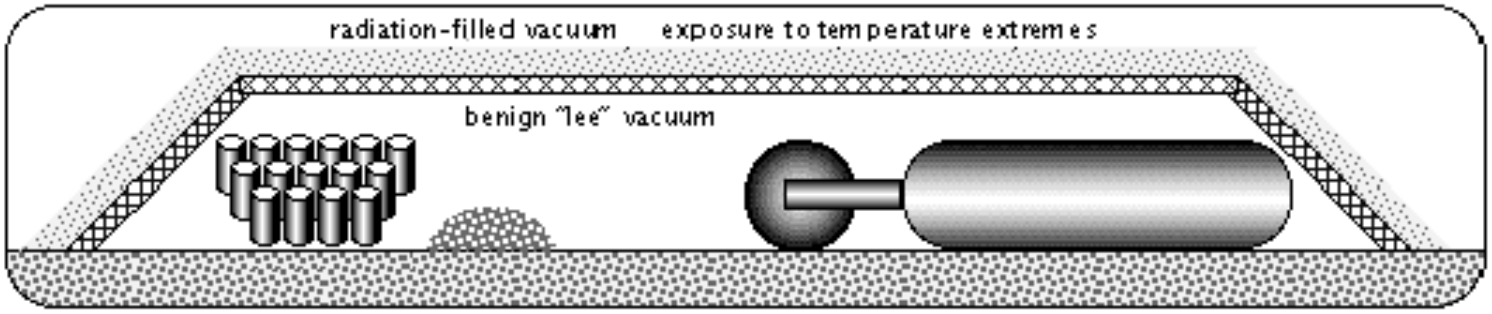








Analog Moonbase Research Program
Shielded Canopies, Hangers, "Ramadas"



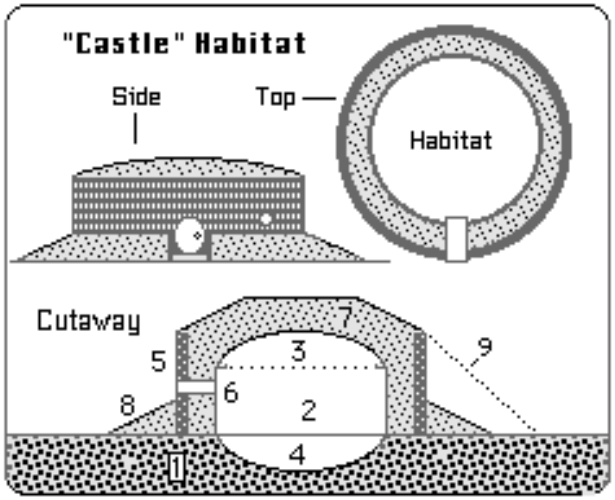
A shielded hanger or "ramada" (SW US = sunshade canopy) would be ideal for **warehousing items and equipment that must be accessed frequently**, as well as for simulated lunar or Martian materials to be used in experimental fabrication. In which case **the associated workshops might be best collocated within this protected areas as well.** Garage space for vehicles of various types might be included.

In a real Moon or Mars situation, the protection offered within would mean that personnel could wear simple lightweight pressure suits, providing much greater freedom of movement, and allowing working longer periods without fatigue.

The canopy istself is "shielded", on the Moon and Mars providing ample protection from cosmic rays, solar flares, micrometeorites, dust storms etc. and offering some thermal protection from the extremes, though not as much as within a directly shielded structure.

Analog Moonbase Research Program

Shielding: from blending in to "standing proud"

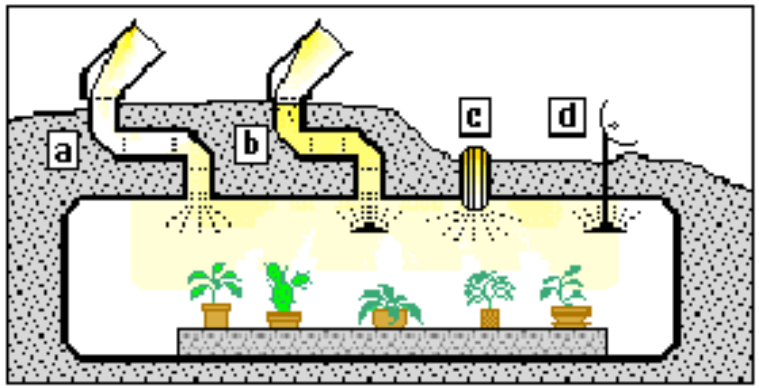


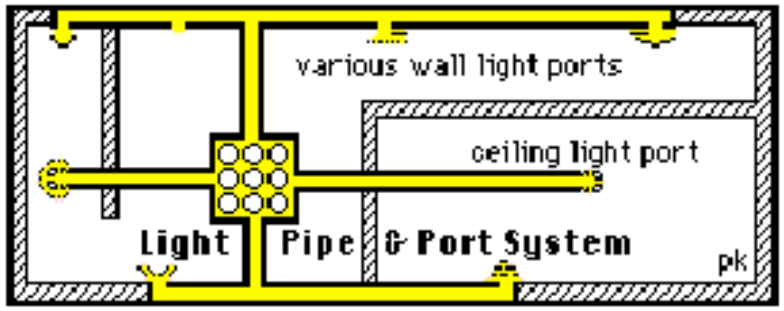
Shielded Habitats that "stand proud"

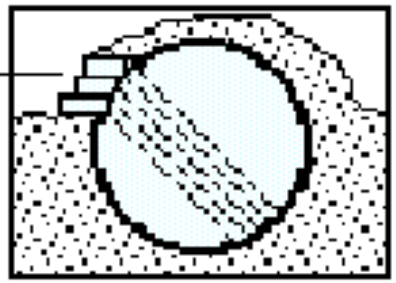
Early habitat structures, simply covered over by moondust to shield them from the cosmic elements, will blend into the moonscape. While some pioneers may prefer to pay respect to the Moon's natural beauty in this way, especially in very scenic areas, others may feel that they equally respect the Moon, as their new homeworld, by finding ways to design living spaces that "stand proud" as human contributions to the moonscape. **Key**: **1** the original surface; **2** living space interior of a short vertical cylinder; **3** cove-lit dome ceiling; **4** basement storage; **5** sculpted concrete retaining wall; **6** window; **7** contained moondust shielding; **8** berm **9** slope of moondust berm otherwise needed

- **Putting shielding directly over habitat structures** allows the "mole-hill" complex to blend into the moonscape, as if it belongs.
- Another way to say "we belong" but with "pride" is to create a wall of textured panels (basalt, concrete, etc.) that by origin and coloration will also "belong" but at the same time bear the stamp of our arrival.
- Inspired by cliffs in Utah, a talus slope berms the base of the structure and a mound of moondust covers the top
- This treatment might be just right to showcase and identify **the Command & Communications Structure**

Analog Moonbase Research Program
Testing various “sunlighting” systems

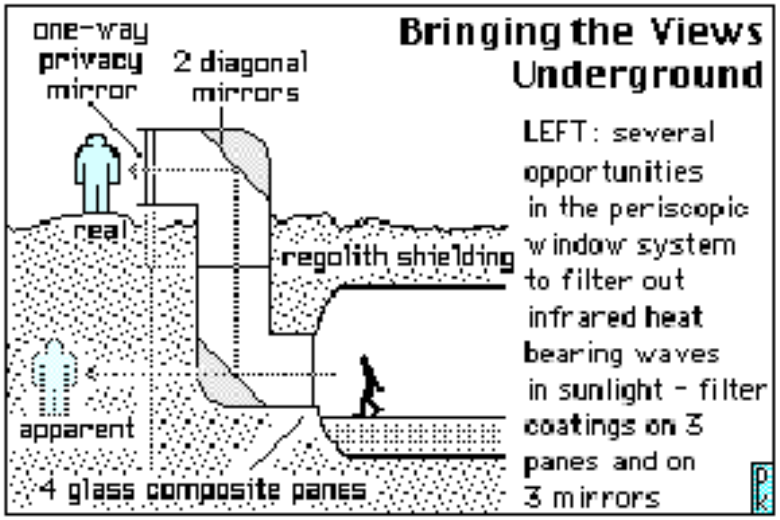


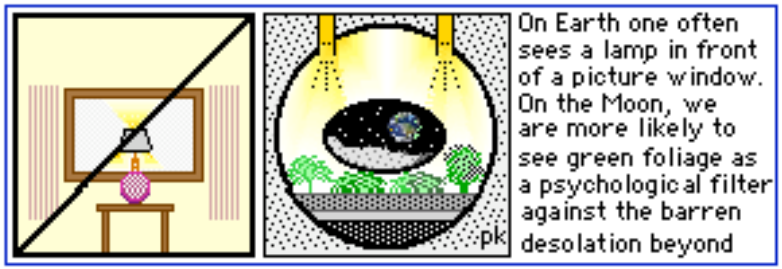




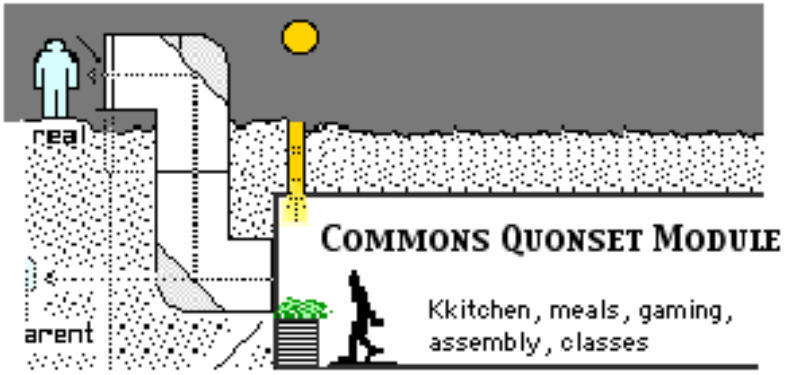
During the two-week long Nightspan, sulfurlamps could replace the Sun, feeding the same light pipe system

Analog Moonbase Research Program
Testing Periscopic Window Systems



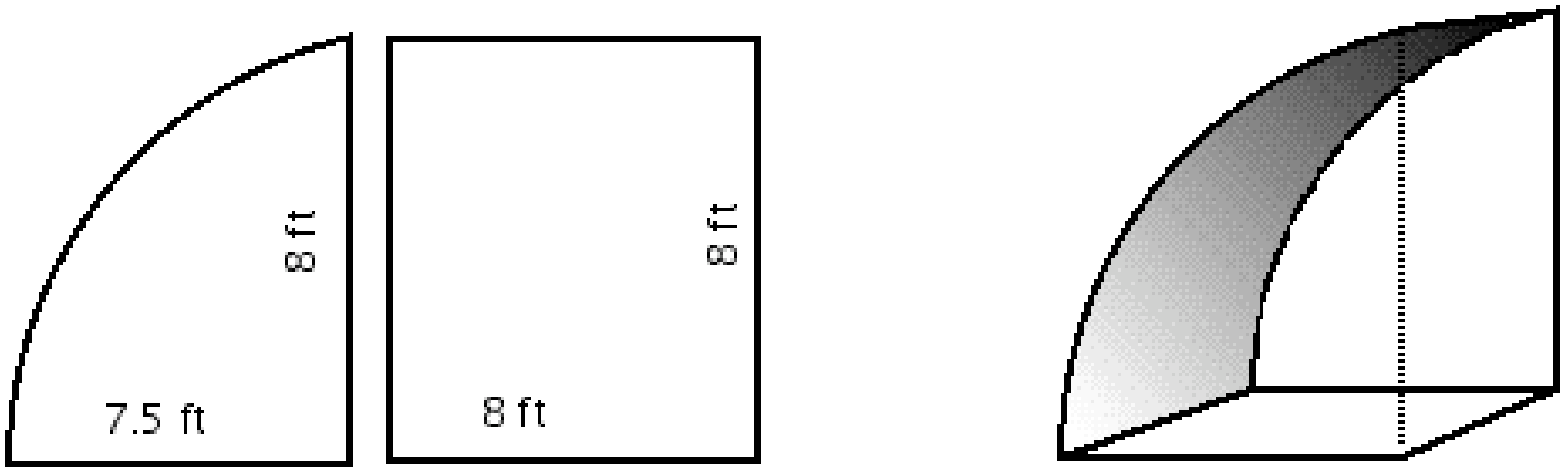


Such a "periscopic" picture window, or "Z-view" could be put in one end of one of the Quonset modules, e.b. Commons.



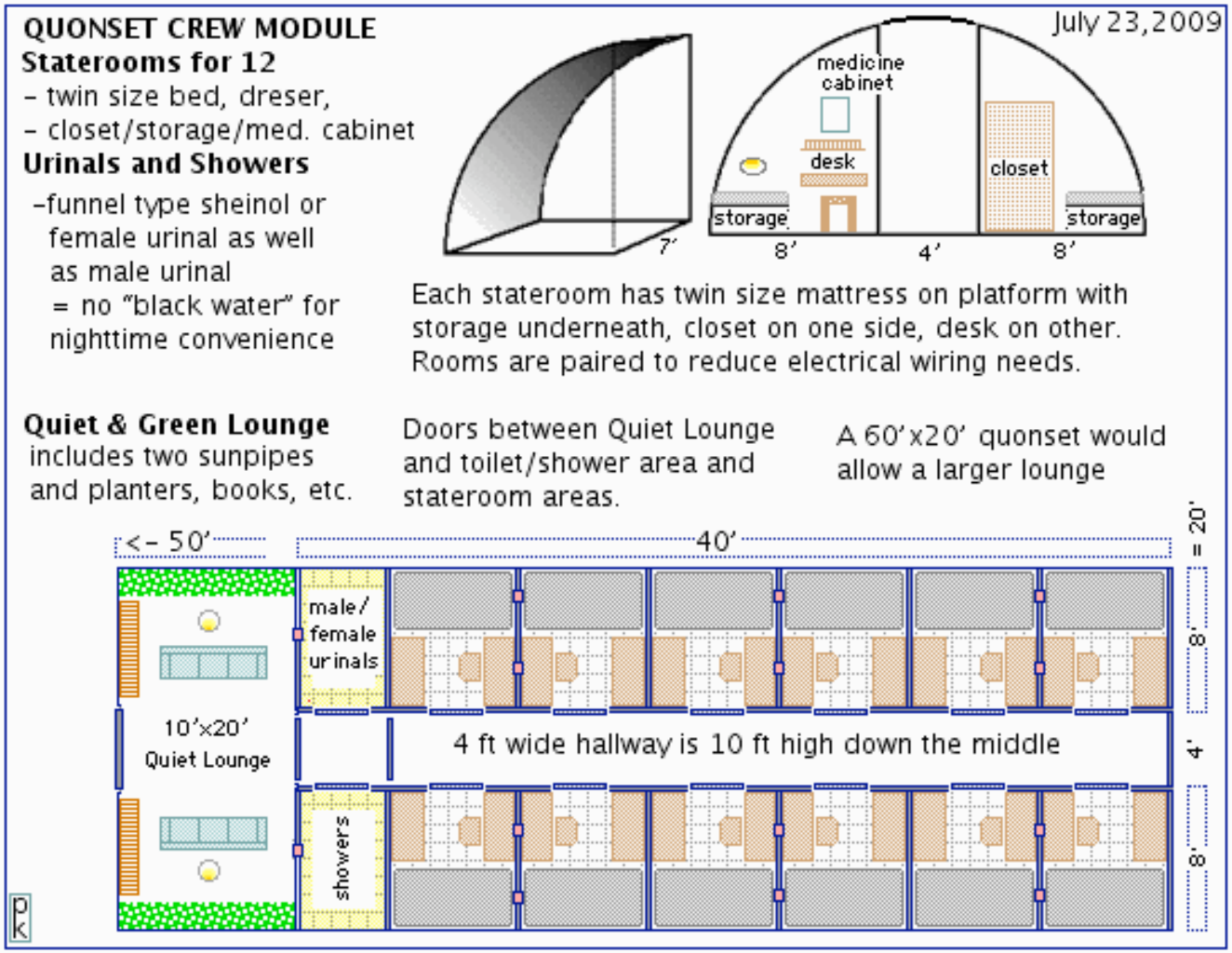
Everyone gathers in Commons for meals, gaming, and for meetings, chapel, movies, etc. Here would be a good place to see the surface outside, day or night, with or without Earth (or the Moon) in the sky. An initial experimental Z-vue design could be replaced with improved designs as new technologies made them possible. Seeing the barren surface through "living green filter" hastens the eventual acceptance of the Moon as "home."

Analog Moonbase Research Program
Ergonomics of various Layout Options



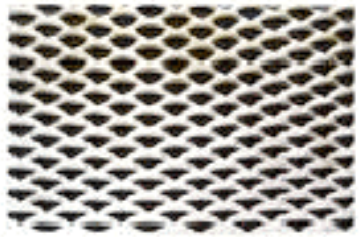
An Interior Design Competition to come up with 6 good ways to layout this space as a crewmember private bedroom/office

Outfitting a "Quonset" as the Crew Dorm with comfortable, quiet "staterooms"



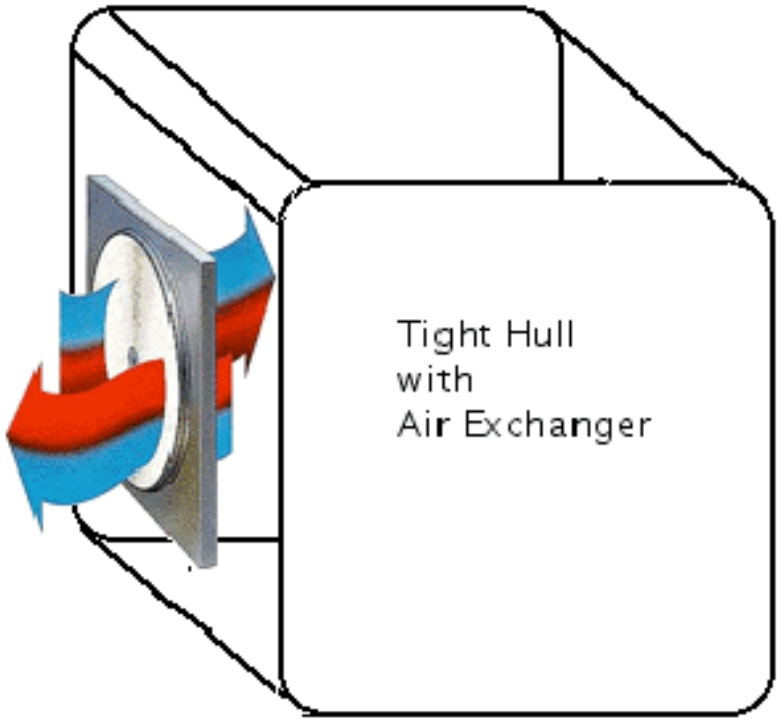
Analog Moonbase Research Program
Dust Control Systems & Dust Management

Paved Aprons around
Airlock Entrances



Expanded Metal
Grating for
Porches & Steps

Boot Cleaner



Analog Moonbase Research Program
Maximizing use of Early Lunar Materials

Cast Basalt abrasion-resistant material handling parts, tunnel liners, and paving tiles, slabs, tabletops countertops, planters, etc.

Experimenting with "raw" glass made from regolith simulant – dinnerware, tabletops, bud vases, many other household items and decorative accessories

What helpful items can we make from sintered basaltic dust?
Blocks to stack up to provide shielding?
Time to experiment!

Analog Moonbase Research Program
Early Lunar Materials for Decor

Rusting Regolith by lightly steaming it in a tumbler drum will rust the iron fines that pervade the sample. Putting the dried rusted dust in molds, and then sintering it, could create "**luna cotta**" flower pots, bowls for a fountain, sculptures.

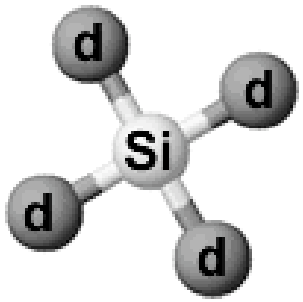
Raw Glass: a near-term, ready to go lunar technology

No doubt, we will find more ways to give our analog station an "at home on the Moon" ambiance.

Cast Basalt Tiles
made in the Czech Republic, are durable and abraison resistant (think moon dust) and are used on floors, walls, countertops, table tops, etc. They have a natural color variation similar to slate. As an early frontier lunar industry, cast basalt tiles may first be used in outfiting inflatable modules

Hewn Basalt Products: With cast basalt, we melt basaltic moon dust and cast it into useful products. But in the lunar "seas" or maria, below the pulverized moon dust blanket, lies solid basalt that can be hewn or sawn into building blocks. Some of these blocks can be carved/sculpted into art works.

Analog Moonbase Research Program
Experimenting with Lunar Fuels & Engines



Silane, SiH4 is a silicon based analog of Methane, CH4 and is a liquid fuel that we could make on the Moon.

Can we modify a propane generator to run on Silane?

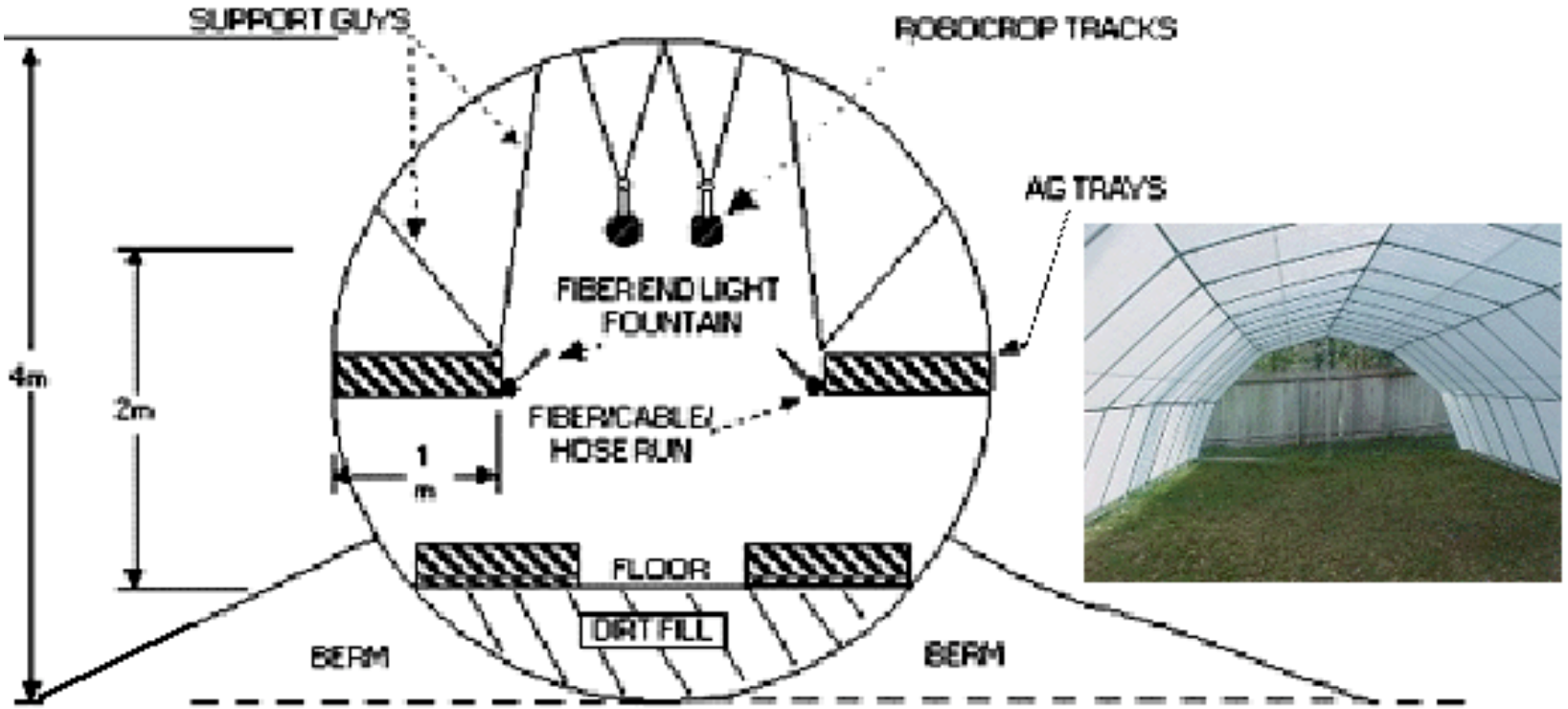
Can we use it to fuel our vehicles? Rovers? ATVs?

Analog Moonbase Research Program
Experimenting with Biosphere Options

- *Alternative* Black->Graywater Systems *in each Module*
- *Alternative* Living Wall Systems *in each Corridor*
- *Alternative* Plant Bedding/watering/fertilizing Systems in the Greenhouse(s) and Living Wall units
- *Alternative* nightspan Plant Lighting Schedules
- *Alternative* Plant Lighting Systems
- *Alternative* Plant Irrigation & Nutrition Systems

Analog Moonbase Research Program

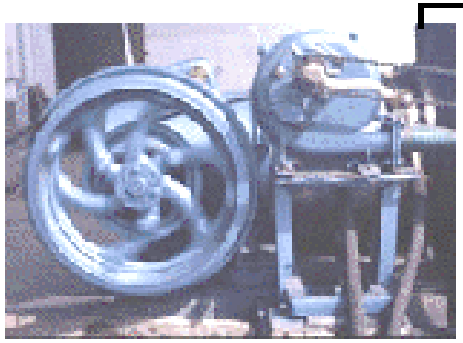
Testing robotic and teleoperated Agriculture Systems



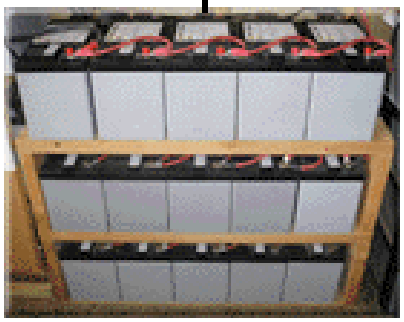
Analog Moonbase Research Program
Storing Dayspan Power for Nightspan Use

Dayspan Solar Power from
(L) Solar Concentrators &
(R) Solar Panel Arrays

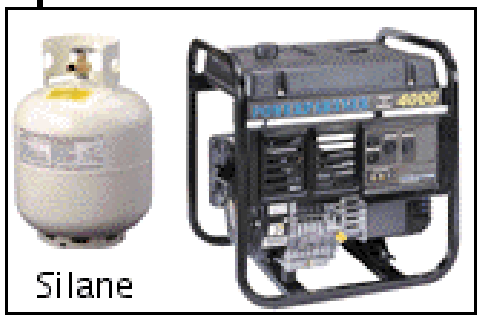
FEED



Flywheels



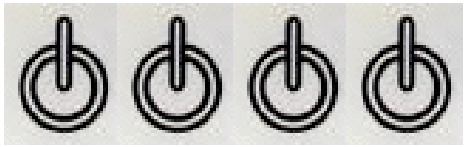
Battery Banks



Generator Fuel Production

Analog Moonbase Research System
Experiments with Operational Scheduling for Dayspan and Nightspan power availability

Activities Ideal For Dayspan (abundant power available)



- **Energy-intensive activities**
  - construction
  - soil moving
  - materials processing
  - manufacturing
  - power storage

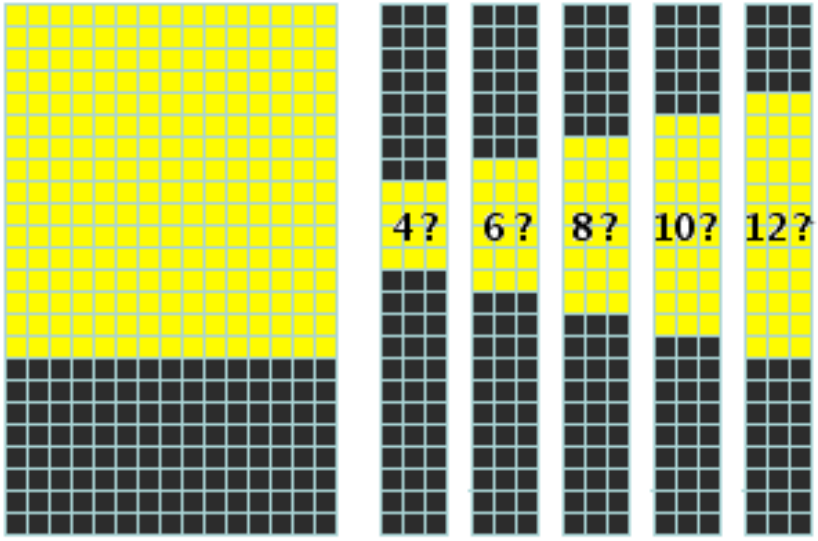
Activities Ideal For Nightspan (reduced power available)

- **Energy-light activities**
  - routine equipment maintenance
  - equipment overhauling
  - inventory & warehouse work
  - energy-light product finishing
  - packaging
  - design work
  - bulk of free time, long weekends
  - arts & crafts
  - extra time in the gardens

Analog Moonbase Research Program: Experimenting with Nightspan Plant Lighting

During Dayspan we can give the plants 16 hours of light a day

But how much light do they need during the nightspan not just to survive but to go on to harvest?



What Lighting System is most efficient?

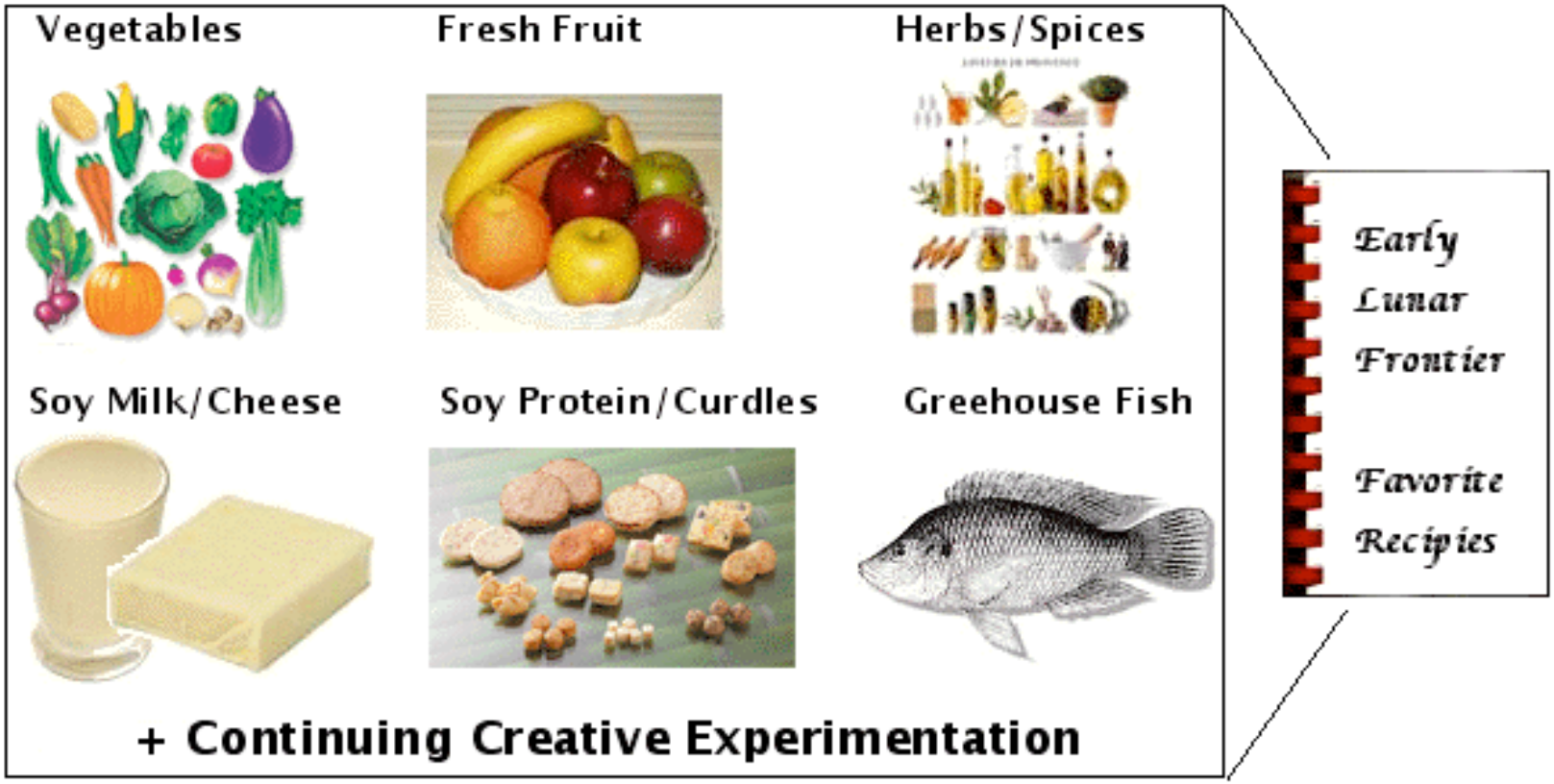
- Fluorescent Grow Lamps?
- LED lights, spectrum optimized suspended just over plant beds?

We need to get our plants through the two week long nightspan with the least power expenditure possible so that they continue to progress to a perhaps delayed harvest.

www.lunax.org

Analog Moonbase Research Program

Diversification of Early Frontier Vegetarian Menus.



Analog Moonbase Research Program
An Effort of Several Teams

Program Management Team

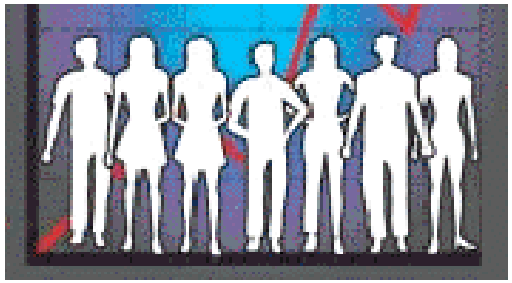
On-site Crews

Cap-Com Team

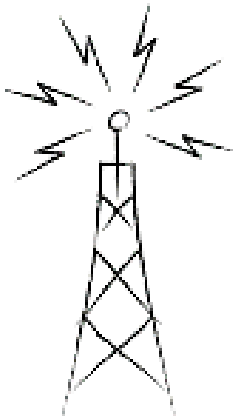
Teleoperations Teams

Remote Research Team

Analog Moonbase - Public Outreach
Student Involvement Programs



Student
Teleoperations Teams
Maintaining the
Greenhouse Systems



Student Operation
of on-site radio
and TV broadcast
Studio

KMBE
call letters
are available

Radio
Moon
Base
Earth

Student Design Competitions
could determine many
outpost features

Public Outreach Program - Visitor's Center

- Book Store
- Exhibits
- Theater
- Gift Shop
- WebCams
- Conference Room
- Walk-in Exhibits - Crew Bedroom
  - Lavatube Section - *other areas?*

- Wall display
  - current phase of the Moon
  - current phase of Earth (from Moon)
- Information on
  - how to apply for a crew slot
  - other ways to get involved
- Hiking Trail with several "duck blind" observation points of the moonbase complex
- Traveling Exhibits
- *What Else?*

Eventually, a Moonlight Motel
- rooms furnished in Lunar Frontier style

Analog Moonbase Research Program

What else can we do?

What else do we *NEED* to do?

Your suggestions are welcome!

This will be a *cooperative* project

Moon Society - National Space Society

Lunar Reclamation Society - Oregon L5 Society
and several other collaborating organizations

Your Comments & Feedback are Welcome

Peter Kokh - kokhmmm@aol.com
president@moonsociety.org
(subject line: “analog moonbase ideas”)

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