Comparative Factors for Structural Designs in Outer Space

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August 10, 2005
Introduction

A Martian Base
How can we make that and also send it to Mars?

A Lunar Base
Summary of Presentation

• All encompassing structure of a Lunar & Martian Base
• Factors involved in creating the structure (i.e., atmospheric/internal pressures, temperatures, etc.)
• Modifications necessary for a generic base used on both the Moon and Mars
Why? (Reasons for a Base on Mars or Moon)

- Limited resources necessary on Earth are abundant on the Moon or Mars (i.e., Helium-3 isotope, other fossil fuels)
- Travel to the external planets in the Solar System or other galaxies
- Allows us to learn more about the geological history of Earth
Atmospheric/Internal Pressures

**Moon:**
- Lacks an atmosphere
- Approximate atmospheric pressure is: $2.7 \times 10^{-12}$ millibars
- Contains a hard vacuum consisting of hydrogen, helium, neon, argon, sodium and potassium
- Dark atmosphere reflecting planetary bodies of the solar system

**Mars:**
- Very weak atmosphere compared to Earth
- Approximate atmospheric pressure ranges from 3.5-6 millibars
- Atmosphere consists of CO$_2$, N$_2$, Ar, O$_2$, CO, H$_2$O, NO, Ne, Kr, Xe
- Reddish atmosphere from the iron rich environment
Atmospheric/Internal Pressures

- Lack a strong atmospheric pressure against UV/cosmic rays
- More regolith shielding necessary for Moon
- Capable of containing Hydrogen (H₂), Neon (Ne) and Argon (Ar)
- Internal pressure would not be a problem since it only induces tensile strength
- CONCLUSION: A pressurized system needed with Moon getting more regolith shielding
Atmospheric/Internal Pressures

Notice the white on the top. This is why scientists are interested in Mars.
Temperature/Climate Differentials

Moon:
- Lunar climates are very consistent
- No or very little weather activity due to lack of atmosphere
- Temperatures range from -170 to 120 degrees Celsius

Mars:
- No common weather
- “cold, inhospitable, desert like place”
- Temperatures range from -120 to 62 degrees Fahrenheit
- Seasons similar to Earth due to its 25 degree tilt (spring, summer, fall and winter)
Temperature/Climate Differentials (Similarities)

- Harsh conditions with minimal atmospheric pressure, oxygen and extreme temperature changes
- Minimal seismic and volcanic activity due to lack of tectonic plates
- Heat dissipation an issue for both places
- CONCLUSION: pressurized inflatable structure can alleviate these conditions
Temperature/Climate Differentials (Conclusion)

Inflatable structure. [p. 353 Vanderbilt, Criswell, Sadeh in Johnson & Wetzel 1988]
Wind/Dust Problems

Moon:
- No wind due to lack of atmosphere
- Dust major issue (mainly remains on the ground, but can cling to equipment)
- Dust contains a charge. Intensity of charge makes it an issue.

Mars:
- Martian winds cause dust storms
- Dust storms most prevalent during the summer (can escalate to global dust storms)
- Dust contains a charge making it possibly toxic
Wind/Dust Problems
(Similarities)

- Dust is capable of contamination
- Can cause electrical failures delaying construction
- Water should be avoided (Water + Dust = Vigorous Reaction!)
- Cold press method should be used since parts of dust are valuable
- CONCLUSION: use the cold press method to get necessary parts of the dust and remaining parts should be kept away from the base
Wind/Dust Problems

Compare the Dusts.

Lunar Dust

Martian Dust
**Terrain/Environmental Factors**

**Moon:**
- Charcoal gray in color
- Very weak atmosphere so made up of debris
- Very consistent due to lack of weather/wind
- Rocks mainly found at the edge of craters or left over meteorite remains
- Ranges from dark gray to glassy-bead like remains

**Mars:**
- Made up of volcanoes or volcanic material
- Iron rich, red color
- Made up of: cratered, chaotic and flat featureless plains
- Very rough terrain with mountains and canyons
Terrain/Environmental Factors

Notice the volcanoes in the background.

Rocky, rough Martian terrain.
Potential Problems & Prevention of the Issues

Moon:
- Most problems arise due to lack of atmosphere
  - Solar radiation
  - Rough terrain/craters
  - Chemical activities

Mars:
- Natural Problems:
  - Dust storms
  - Lengthy solar eclipses (35.5–40.7 minutes out of the 117.64 minute revolution)
  - Cosmic rays
  - Solar flares
A Martian Dust Storm at Work

CONCLUSION:
Don’t construct anything during a dust storm.
Potential Problems & Prevention of the Issues (continued)

Moon:
• Biological:
  – Weightlessness
  – Fullness of the head
  – Bloodshot eyes for 24 hours
  – Round or swollen faces
  – Inability to relax

Mars:
• Biological:
  – Humans born on Mars would grow quicker due to lack of gravity
  – They would be very weak on Earth due to strength of gravity
  – “extreme” heat on Earth would also be an issue for them
Moon:
- Items sent to Moon need to be:
  - High tensile and compressive strength
  - Fatigue and crack resistant
  - Resistant to radiation damage

Mars:
- Goods on Mars:
  - No electricity (Mars lacks a supply of wires, cables, fiber optics)
  - Limited communication (no metal ores)
  - Obtaining liquid water difficult
  - In situ resource utilization problem (not factory approved)
  - Electromagnetic spectrum available and harmful
Potential Problems & Prevention of the Issues (continued)

- Solar flares, cosmic rays and radiation are major problems for the terrain
- Asteroid, comet and meteor protection necessary
- CONCLUSION: protection shelters necessary. Gradually less protection would be needed due to human presence.
Hospitable Places/Circumstances

Moon:
- Malapert Mountain:
  - S. Pole
  - Sun never sets
  - Line of sight with Earth
- Herodotus Chi & Schröter’s Valley
  - Low lying areas with low albedo and radar return

Mars:
- South Pole:
  - Availability of water
  - Polyurethane foam as an insulator
    - Moldable
    - Provides for more insulation
Hospitable Places/Circumstances

Aluminum is thought of to be the best material for both these places: South Pole, Moon, and South Pole, Mars.
A Prelude to the Inflatable Structure

The Most Ideal Structure for both Mars and the Moon... THE INFLATABLE
The Inflatable Structure

- Pressure vessel almost pillow-like in structure
- Tested and built on Earth and then inflated in the environment
- Consists of a roof and sub floor membrane, four sided membrane in 4 columns and a wall membrane
The Inflatable Structure

- Thickness of the Inflatable Structure =

\[ t = \frac{p_i R}{2\sigma_m} \]

where \( t \) = thickness, \( p_i \) = internal pressure, \( R \) = sphere radius and \( \sigma_m \) = tensile yield strength.

Suggested Values are:

- \( p_i = 10^5 \) psi,
- \( R = 240 \) in and
- \( \sigma_m = 10 \) psi

yielding \( t = 0.012 \) in
The Inflatable Structure

- Thickness of the Wall Membrane:

\[
t = \frac{\left( \frac{N_t}{\pi} \right) D + p_i \left( \frac{D}{4} \right)}{\sigma_m}
\]

where \( t \) = thickness, \( p_i \) = internal pressure, \( \sigma_m \) = material tensile yield strength, \( N_t \) = resulting tension and \( D \) = column diameter.

Suggested values are \( p_i = 752 \) KPa, \( \sigma_m = 690 \) MPa and \( D = 46 \) cm and \( N_t = 641 \) KN giving a thickness of 0.77 cm.
The Inflatable Structure
(Numerical Answers)

\[
t = \frac{N_t}{\pi D} \frac{p_i D}{\sigma_m} \frac{1}{4}
\]

\[
t = \frac{641000}{.46 \pi} + \frac{752000(.46)}{4}
\]

\[
t = \frac{690 \times 10^6}{443598.62 + 86480}
\]

\[
t = \frac{530078.62}{690 \times 10^6} = 7.68 \times 10^{-4} \text{ meters}
\]

\[
t = .77 \text{ centimeters}
\]

\[
t = \frac{p_i R}{2 \sigma_m}
\]

\[
t = \frac{10(240)}{2 \times 10^5}
\]

\[
t = 0.012 \text{ inches}
\]
The Process of Constructing the Structure

STAGE 1:
1. Excavate and shape ground to required depth
2. Lay structure on prepared ground
3. Secure structure in extended position
**The Process of Constructing the Structure**

**STAGE 2:**

1. Pressurize inside of ring girder to circular shape.
2. Inflate interstices with air or subtle gases.
3. Install airlocks and other penetrations.
4. Spray structural foam through injection parts.

The Process of Constructing the Structure

STAGE 3:
1. Pressurize inside SSMS.
2. Inflate interstices between air or subtle gases. Then spray with structural foam.
3. Fill bag with compacted soil.
4. Lay flooring.
5. Place soil cover.
Other Structures

A Modular Approach

Modules for a lunar base. [p. 397 Griffin in Johnson & Wetzel 1990]

Other Structures

- Erectable (construct on Earth and then settle it on the Moon within liquid oxygen tanks)
- Cable Structures
- Module Approach (developing a variety of modules and then assembling on the Moon)
- Tensile integrity structure for large surfaced areas
- Mobile structure (for evacuation in times of danger)
**Modifications**

- Moon would require more regolith shielding than Mars would since it has less gravity.
- Less regolith protection would be needed on Mars since it has some atmosphere protecting the terrain from meteorites, comets and solar flares.
- Regolith shielding will keep the radiation and micrometeorite effects to solely the top of the base.
- A structure on Mars would need to be self reliant since the position of Moon is within line of sight of Earth, but the position of Mars is farther away.
Construction of a Base (in Words)

Essentially, the structure, assuming that it is an inflatable, would be constructed on Earth. Then, when the base is constructed, it will be sent into space via unmanned mission and inflated on Mars or the Moon. If the structure is not an inflatable or rather an erectable or a modular base, parts would be built on Earth and then transported by space craft and constructed on Mars or Moon by robots or automated machines.
Conclusions/Recap

• Best Generic Structure: Inflatable
• Why?:
  – We know most about inflatable structures
  – Other structures can be applied. However, we would need to learn more about them
  – If we want to have a base up soon, inflatable would be best
  – Although we know so much about it already, we need to know more about it regarding materials and designs, since repairing a base would be time consuming and a challenge.
Conclusions

Hopefully, someday, we would be able to settle there and view Earth just as the people in the photographs are doing...
Acknowledgements

At this time, I would like to thank:

- **Professor Benaroya** for giving me the opportunity to learn more about the technological goals on the Moon and Mars,
- **Trisha Mazzucco** for making me feel more comfortable at Rutgers University,
- **Yuriy Gulak** for familiarizing me with various programming languages necessary in engineering,
- **Anja Garcia** for humoring me and familiarizing me with the assigned tasks this summer,
- **Everyone of you** for allowing me to learn more about you and Mechanical and Aerospace Engineering

I enjoyed this summer immensely and looked forward to every single day I was scheduled to come in. Thank you!