Study of Isokinetic Structures and Applications for Expandable and Adaptive Habitats using in-situ Lunar Resources for Future Moon Surface Missions

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1. Introduction

Numerous concepts for permanent lunar base structures have been proposed. Among these designs, some of them highlight expandability anticipating future growth at the expense of a detailed study of the lunar surface environment and the effects it may have on the structure and materials. Others concepts have the advantage of being structurally sound however, they do not consider the availability of lunar construction materials.

In this paper, we present a modular architecture for a lunar habitat taking into account the properties of isokinetic structures and the possibility of in-situ resources utilization. The overall concept would allow a mission crew of four to live and work on the Moon's surface, in collaboration with robots. The proposed solution presents the idea of an isokinetic expandable geodesic dome as the main and internal structure. It will contain a particular layer design to be covered by regolith and/or lunarcrete at the same time that allows future growth. This layer would provide a protection shield against outer environment. The layer is made from a pattern of empty triangular-based pyramids to be filled with regolith. At this stage of the work, the dimensions of the maximum expansion of the dome are 6 m diameter with 3 m height. However, we contemplate the possibility to have a bigger dome with an expansion up to 10 m diameter. Further expansions are yet to be studied.

A future mission scenario has also been studied for finding the best outpost for placing the habitat.
We have taken into consideration the lunar environment, construction methods and materials, structural systems and design loads among other parameters in the designing of the habitat. We also understand the role of human and robots, their performances and their interactions during the development and completion of the mission. Other aspects such as life-support systems, interior design, regolith processing and transportation will be studied within the next steps of the work.

This habitat requires achieved and available technology therefore, the lunar base idea may become a reality within the next decade, expanding our frontiers and open new opportunities for research.

Keywords: Lunar habitat, Space exploration, Manned missions, Geodesic dome, Adaptive habitat, Regolith, Human-Robot Interaction, Isokinetic structure

2. Overview

The Moon has been considered of special interest for exploration both because of its intrinsic scientific characteristics but also as a stepping stone to broader endeavours. The surface of the Moon provides with excellent opportunities for other scientific research such as astronomy, physics, astrobiology, human physiology and medicine [1]. According to the Global Exploration Roadmap (GER) humans will get to the Moon once again to achieve milestones in space exploration [2]

2.1. Habitat mechanism

Mechanism of isokinetic expandable geodesic dome (Figure 1.), the base will be placed in selected locations by means of a tele-operated rover (Figure 2.)

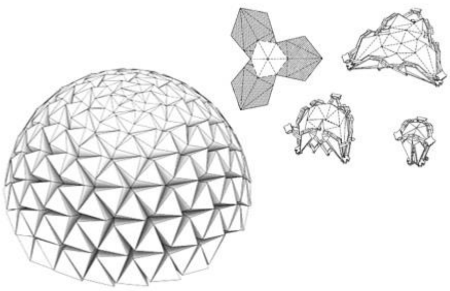


Figure 1. Dome concept based on origami pattern and hoberman sphere mechanism

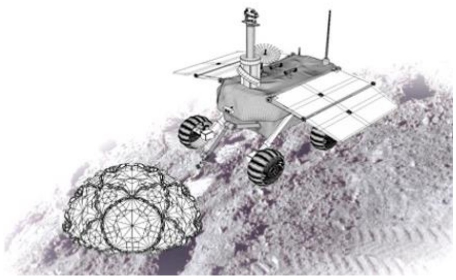
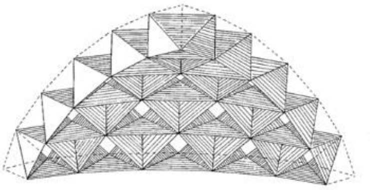


Figure 2. Illustration of the rover placing the 'un-expanded' dome



Once placed the dome will expand and the empty spaces of the triangular shaped patter (Figure 3.) will be filled by lunarcrete (Figure 4.) increasing the safety and efficiency of the structure.

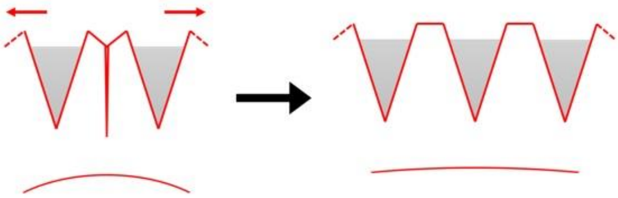


Figure 3. Detail of a triangular shaped pattern

Figure 4. Sketch of filling the empty spaces with lunarcrete

Mission Architecture

As a possible mission scenario we selected the Amundsen-Ganswindt basin (Figure 5.) as the landing site mainly for the presence of permanently shadowed regions, its position within the South Pole and its proximity to the Schrödinger basin making it a potential place to find cold traps and volatiles[2][3][4].

Four Traverses have been proposed for in this case study by analysing the slope (Figure 6.)

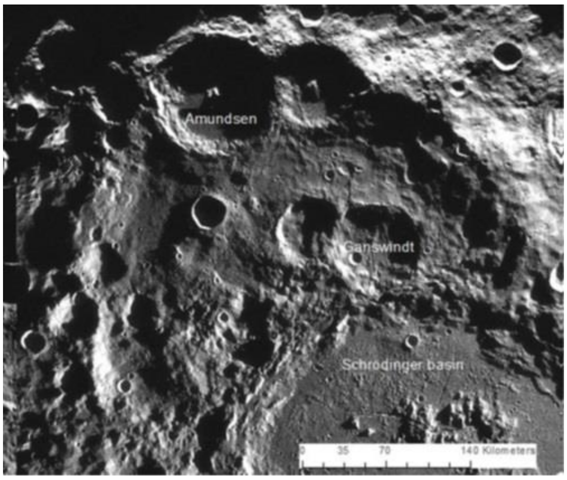


Figure 5. Amundsen-Ganswindt basin. LROC WAC image 100m/pixel of resolution

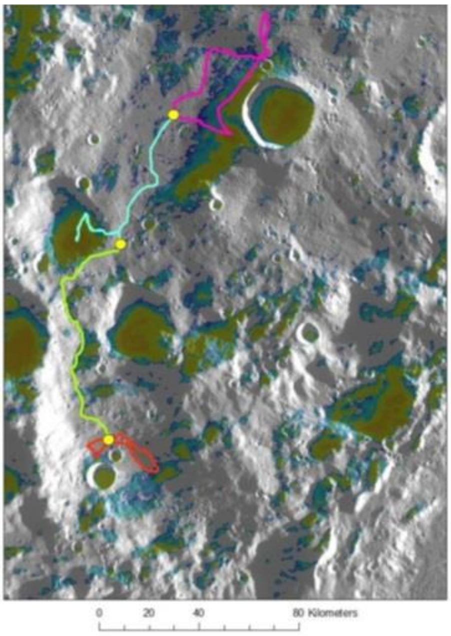


Figure 6. The orange areas on this image represent the locations where water ice may be cold trapped on the surface and the yellow and blue areas define the upper surface of the lunar ice permafrost boundary according to Paige et al, 2010. The pink, blue, green [3]

3. References

[1] Crawford, I. A., Anand, M., Cockell, C. S., Falcke, H., Green, D. A., Jaumann, R., & Wieczorek, M. A. (2012). Back to the Moon: The scientific rationale for resuming lunar surface exploration. Planetary and Space Science, 74(1), 3–14.
[2] ISECG. (2013). Global Exploration Roadmap
[3] Paige, D. A., Siegler, M. A., Zhang, J. A., Hayne, P. O., Foote, E. J., Bennett, K. A., Lucey, P. G. (2010). Diviner Lunar Radiometer Observations of Cold Traps in the Moon's South Polar Region. Science, 330 (October), 479–483 7. Hurwitz, D. M., & Kring,
[4] Committee on the Scientific Context for Exploration of the Moon. (2007). The Scientific Context for the Exploration of the Moon. Bulletin of the American Astronomical Society (Vol. 38).

Short Summary

A modular lunar habitat architecture, taking into account the properties of isokinetic structures and the possibility of in-situ resources utilization. The proposed solution is an isokinetic expandable geodesic dome with a particular layer design made from a pattern of empty triangular-based pyramids to be filled and covered by regolith and/or lunarcrete, allowing future expansions.