Hassell/University of Toronto

Xavier DeKestelier – Hassell
Dr. Brady Peters – University of Toronto

Modular Robotic System for Lunar Applications

Executive Summary

In this project we investigated the design and digital fabrication processes that would be necessary to construct a lunar habitat. Because of the costs – both environmental and monetary – of bringing construction materials and equipment to the moon from earth, a strategy of in-situ resource utilization (ISRU) was a key starting point for the project. The project hinges on the use of lunar regolith for the construction of the habitat and so building sites with sufficient and accessible stores of lunar regolith were identified.

A construction system was determined through precedent analysis. Fifteen innovative architectural design and fabrication systems were identified and analyzed and through this a system of aggregate construction was determined to be a system that met required criteria for constructability, redundancy, precision, and reconfigurability while still achieving necessary protective characteristics for the habitat.

The habitat shell was the main focus of the research as it was assumed that lightweight inflatable habitats could be then placed within the protective shell. The form of the shell is based on the structurally efficient catenary form with smaller arched entry portals that enable personnel and machinery to enter and exit the habitat. One of the key benefits of the aggregate constructive system is that it does not require construction machinery or scaffolds larger than the habitat itself. The aim is that the habitat can be constructed using a series of small mobile robots that fabricate and place the aggregates to form the structure. Several robotic systems were investigated and a system where aggregates are launched onto a temporary inflatable scaffold was determined to be the best solution.

A primary challenge of the design and experiments was the drawing and simulation of the forms that the aggregates would take when launched and as they accumulate into the eventual form of the protective shell. This new paradigm of construction challenges current architectural design tools. We investigated several approaches to simulation and found that using the rigid body physics within the software Houdini VFX enabled us to predict launch trajectories, the effects of aggregate interaction, and scaled to the number of aggregates necessary to construct a shell – which was between 4000-5000 aggregates.

Material investigations were undertaken to understand how aggregate geometry effected form, how aggregates interacted with each other to provide a structurally stable shell, and how instructions from the design software could control the robotic launchers. Many scale model studies were undertaken with 3D printed aggregates. Two small robotic launchers were developed and different trajectory and launching positions were studied.

A key challenge was the fabrication of the large number of aggregates necessary to build a dome. To solve this challenge, we changed 3D printing technology from FDM printing to sand-printed aggregates. 4000 aggregates were printed and a new launcher was developed and constructed that would attach to a 6-axis industrial robot. A method of designing and fabricated an inflated formwork was developed, and a final 1:10 scale model of the proposed habitat shell was constructed.