Martian Habitat

Group 1

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Overview

The Martian Habitat is a project developed during the course of the AR0122: 1:1 Interactive Architecture Prototypes elective.

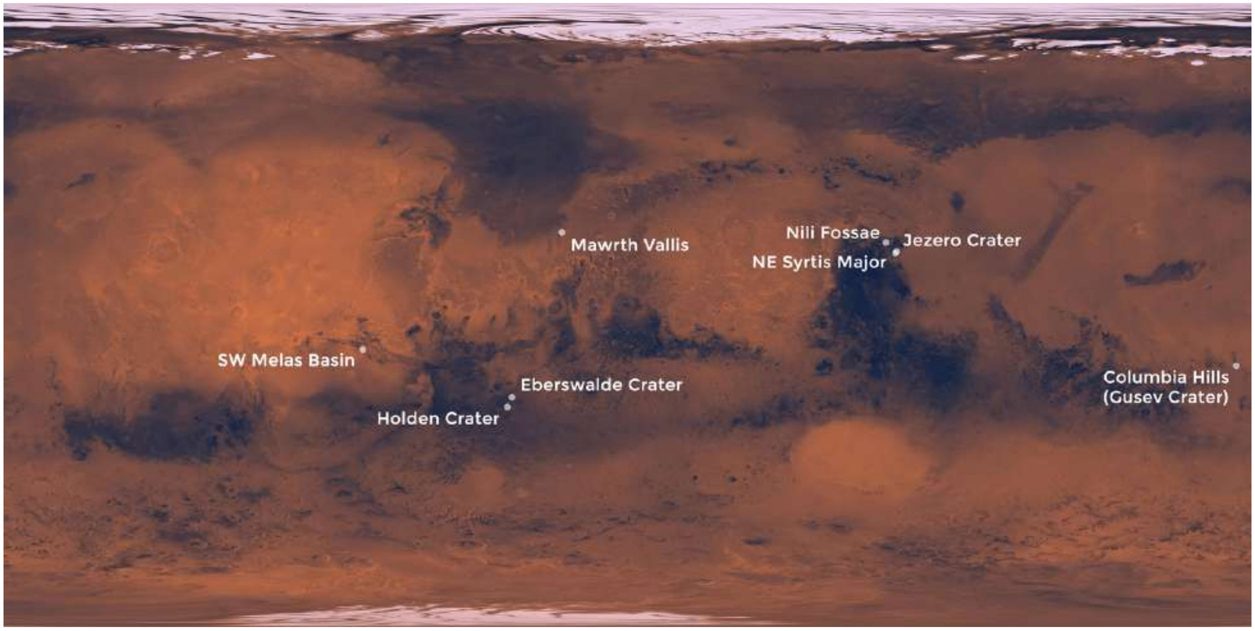
The concept envisions a dwelling for 2-3 research scientists seeking to establish themselves on Mars as part of their mission to research the existence of water on the planet, with the goal of contributing to its colonization in the near future.

In designing the habitat we were tasked with using ingenuitive ways of human robot interaction in the making of the structure. In doing so, we were able to create a habitat in a harsh environment that utilizes robotic assistance for increased efficiency, safety and modularity.

The Site & Brief Development

The Site - Nili Fossae

Before selecting our site, we researched identified potential landing sites by NASA and filtered them based on sites that had the highest volume of water. From this process we eventually decided on **Nili Fossae** as the site for our prototypal habitat.



Nili Fossae is a region on Mars that is known for its distinctive geological features. It is located in the northern hemisphere of Mars, near the equator, and covers an area of approximately 3,300 square kilometers.

There is evidence that suggests the presence of water in the past in the Nili Fossae region on Mars. Some studies have identified hydrated minerals, such as clay and sulfates, which are often associated with the presence of water. These minerals are thought to have formed in ancient lakes, rivers, and hot springs that existed in the region billions of years ago.

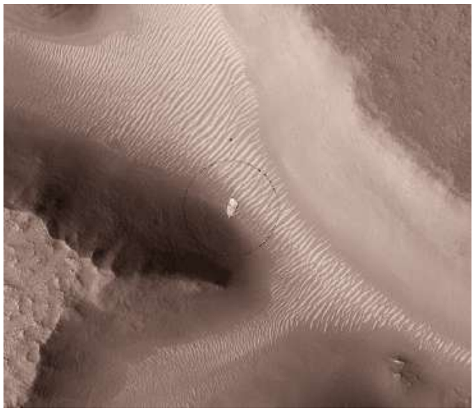
In addition, some recent studies have suggested that there may be subsurface ice deposits in Nili Fossae and other regions of Mars. These ice deposits could be an important resource for future human missions to the planet, as they could be melted and used for drinking water, irrigation, and other purposes.

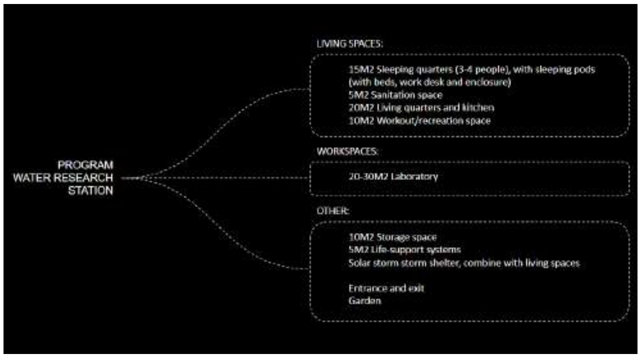
While there is still much to be learned about the presence of water in Nili Fossae and other regions of Mars, the evidence so far suggests that water played an important role in shaping the planet's geology and could be a crucial resource for future exploration and settlement.

For these reasons, Nili Fossae has been identified as a potential landing site for future Mars missions, due to its relatively flat terrain and easy access to valuable resources. Scientists hope that by studying this region in more detail, they can learn more about the geology and history of Mars, and perhaps even pave the way for future human exploration of the planet.

Our Brief - Water Research Station / Dwelling

As part of the development of our brief, we focused on creating a smaller, simpler martian habitat that would allow for 3-4 people. The idea being that this could be a node that would eventually expand as new settlers came in, with the brief being replicated for newer establishments.





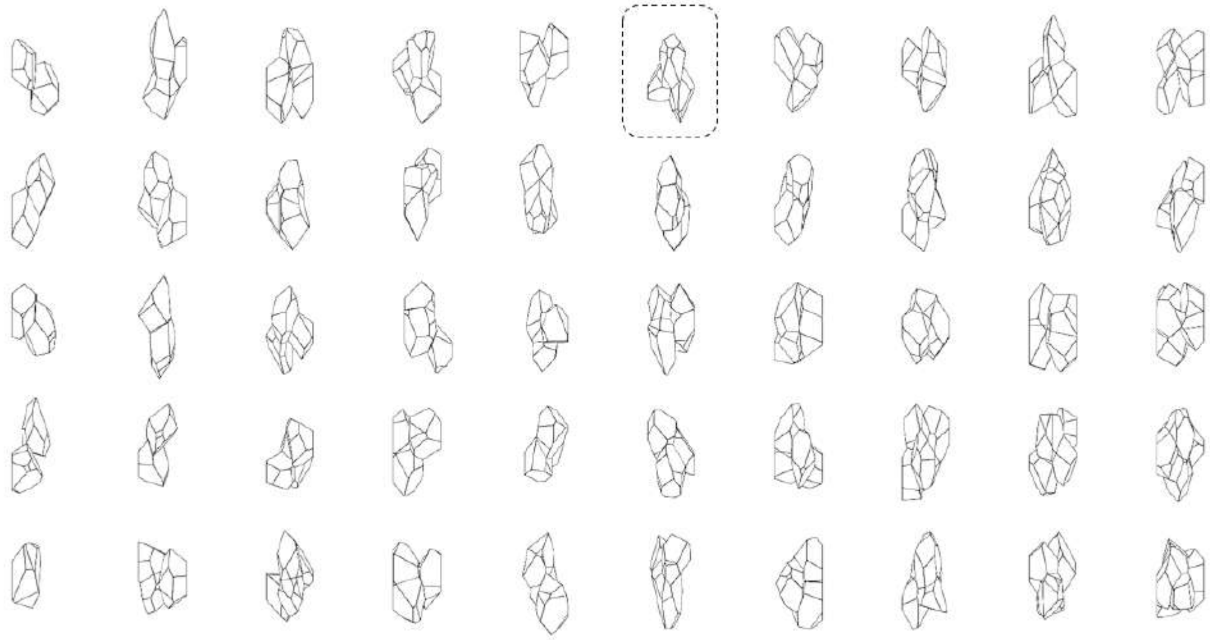
The Nili Fossae region on Mars was chosen as the landing site for our martian habitat because it offers several advantages for future human exploration and settlement. Firstly, as described earlier, the region is known for its rich mineral deposits, which could provide valuable resources for sustaining human life on Mars. Secondly, the region's relatively flat terrain and easy access to resources make it an attractive location for future missions and settlements. Finally, there is evidence to suggest that there may have been water in the region in the past, which could be an important resource for future human missions.

Given the focus on creating a smaller, simpler martian habitat that can be expanded as needed, the Nili Fossae region provides an ideal location for setting up a node that can eventually grow into a larger settlement. The habitat can be designed to be scalable and modular, allowing for easy expansion as new settlers arrive and the need for more space and resources increases.

Overall, the choice of Nili Fossae as the landing site for our martian habitat is based on a combination of factors, including access to valuable resources, ease of access, and potential for future growth and expansion. These factors make it an ideal location for establishing a small, sustainable human settlement on Mars.

Design Concept

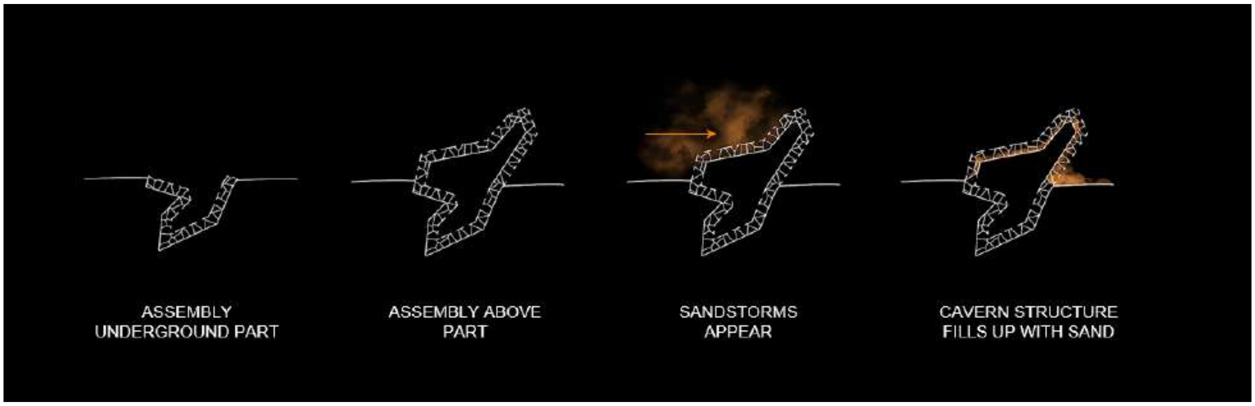
Form Finding



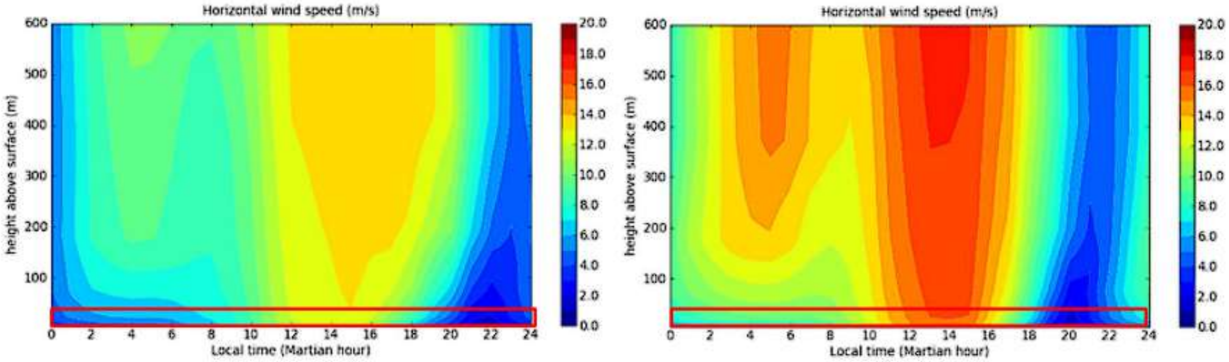
Since our construction method is based on the logic of voronoi geometry, in our search for a form that would work with our design, we ran through several iterations of the voronoi modules. These voronoi modules represented: Entrance, Workspace and Dwelling, respectively. Throughout the process we would seek a form that worked for us while at the same time modifying control points of the overall form to conform to our intention.

Wind Tests

To further elaborate, the design of the Martian Habitat was intentionally made to capture and utilize the build-up of dust during a storm. By allowing the dust to accumulate on the exterior, we can create a protective layer that can help shield the interior from harmful radiation. This not only provides a practical solution to a potential problem but also allows us to work with the natural environment of Mars rather than against it. In this way, the design of the habitat is not just functional but also sustainable, as it reduces the need for additional materials and energy to be expended in protecting the inhabitants from radiation.

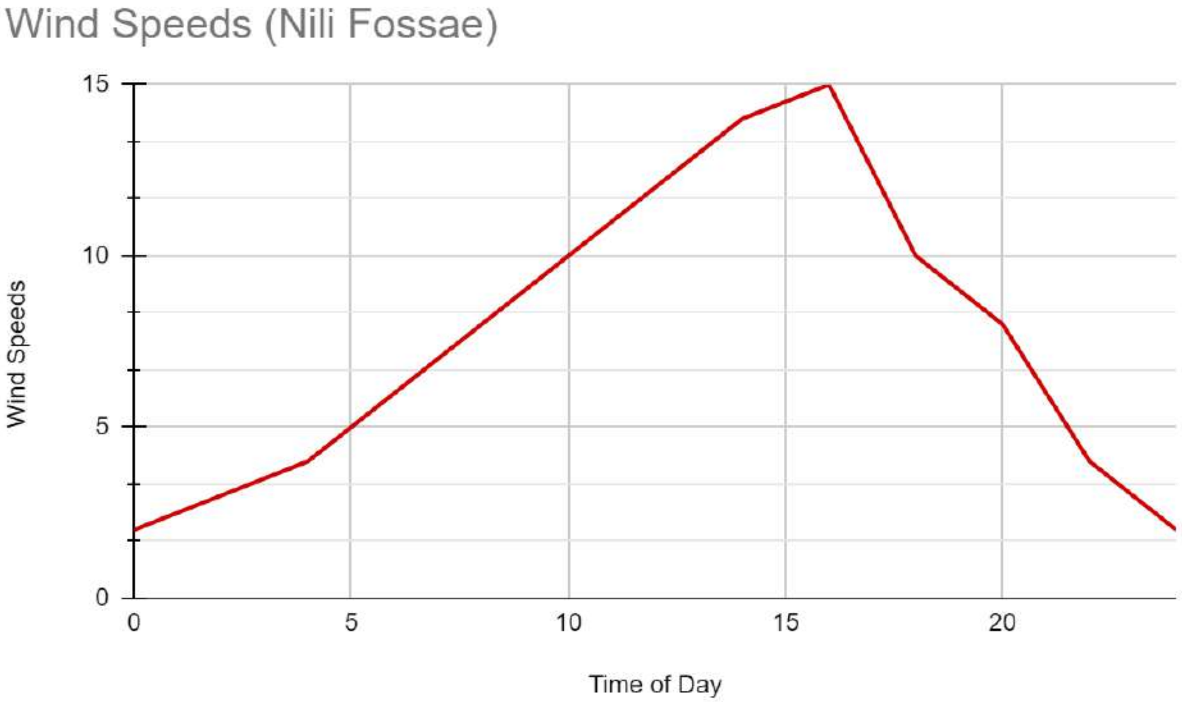


Design Research - Wind Testing

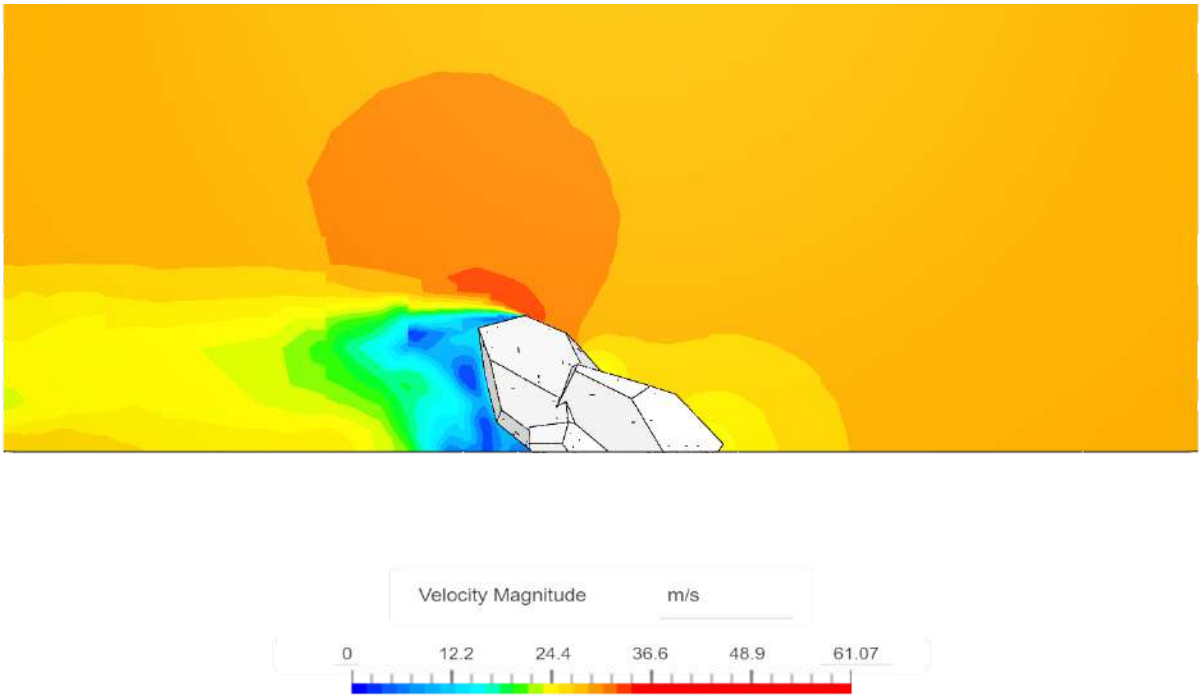


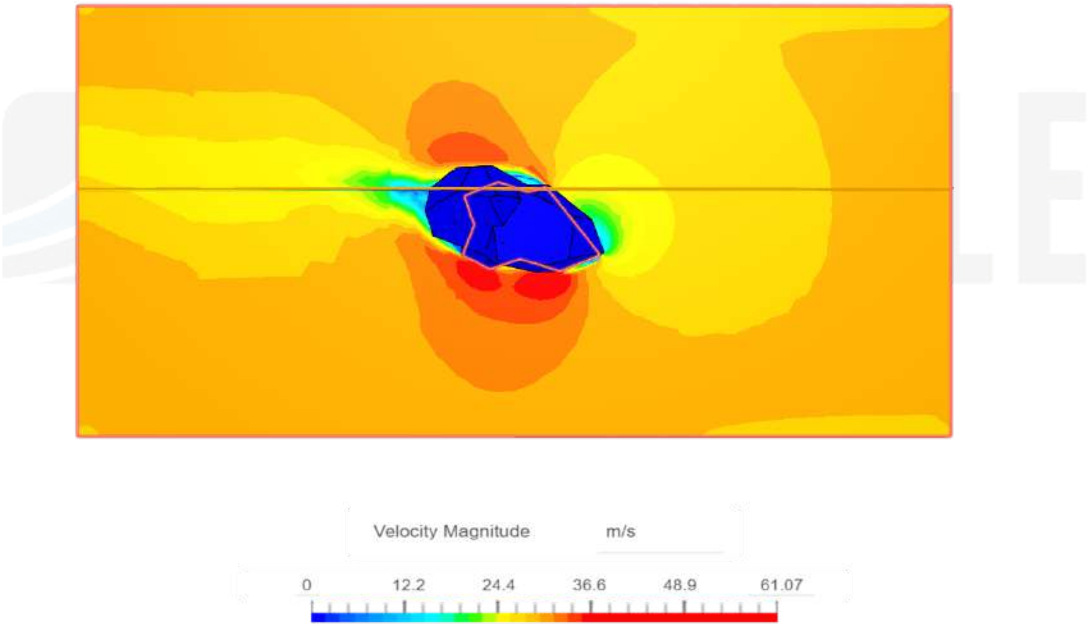
Martian Wind Speeds during different hours (Ouroumova & Schmel 2021)

As part of our research we looked into the data collected by a previous group in their paper 'Development of an Autarkic Design-to-Robotic-Production and Operation System for Building Off-Earth Habitats'. As part of their research they conducted an analysis on Martian wind speeds that would allow us to gain a clearer picture on wind conditions that our design would deal with on Nilli Fossae.



Using the simulation software SimScale, we conducted incompressible simulations specifically on Martian air in Martian wind conditions. By tailoring the simulations to the nitrogen-heavy atmosphere found on Mars, we were able to accurately model the behavior of our proposed habitat in the Martian environment. These simulations allowed us to test the viability of the concept of using dust accrual as a means of natural radiation protection, and to refine the shape and form of the building to better withstand Martian sandstorms. By analyzing the results of these simulations, we were able to identify potential areas of weakness in our design and make adjustments to ensure that the habitat would be capable of withstanding the harsh Martian environment over a prolonged period of time.



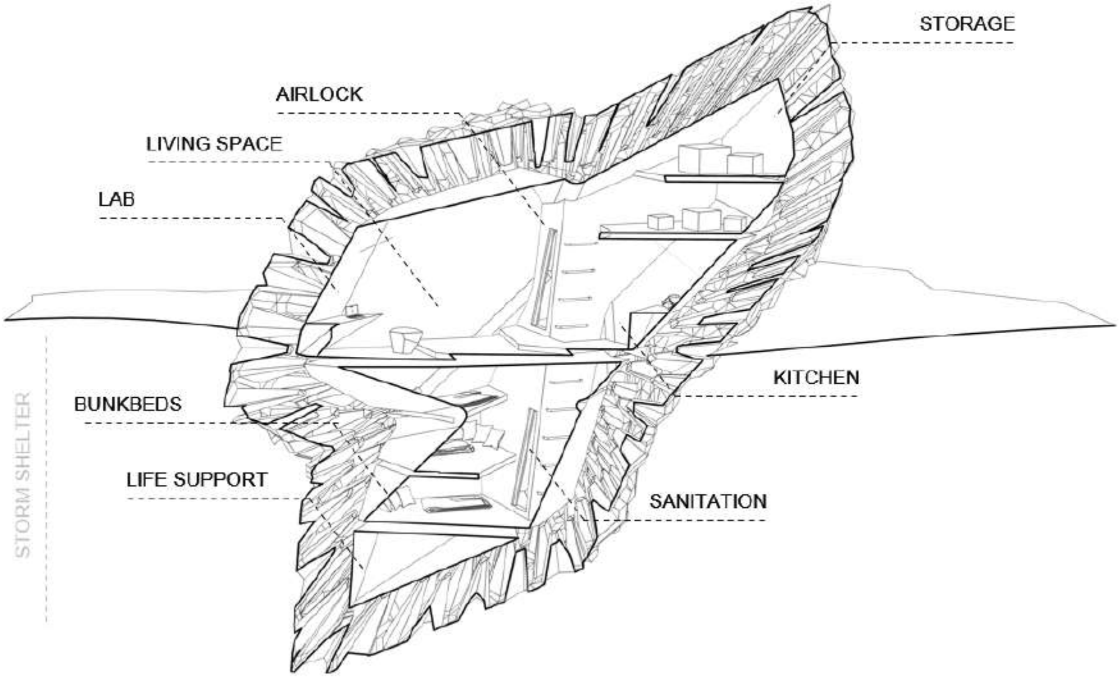


The outcomes of our study using SimScale showed that our proposed Martian habitat was able to significantly decrease the wind speeds from 30 m/s to 10 m/s or less, creating a lower velocity region that allowed for the build-up of dust. This was a crucial finding for our design, as it provided evidence that our proposed use of dust accrual as a means of natural radiation protection was a viable option. The simulations also allowed us to refine the shape and form of the building to better withstand Martian sandstorms and other environmental conditions. By taking into account the specific characteristics of the Martian atmosphere and climate, we were able to design a habitat that could potentially sustain human life on the planet for extended periods of time. Overall, the outcomes of the study were essential for the development of our Martian habitat design, providing valuable insights and data to support the feasibility and effectiveness of our approach.

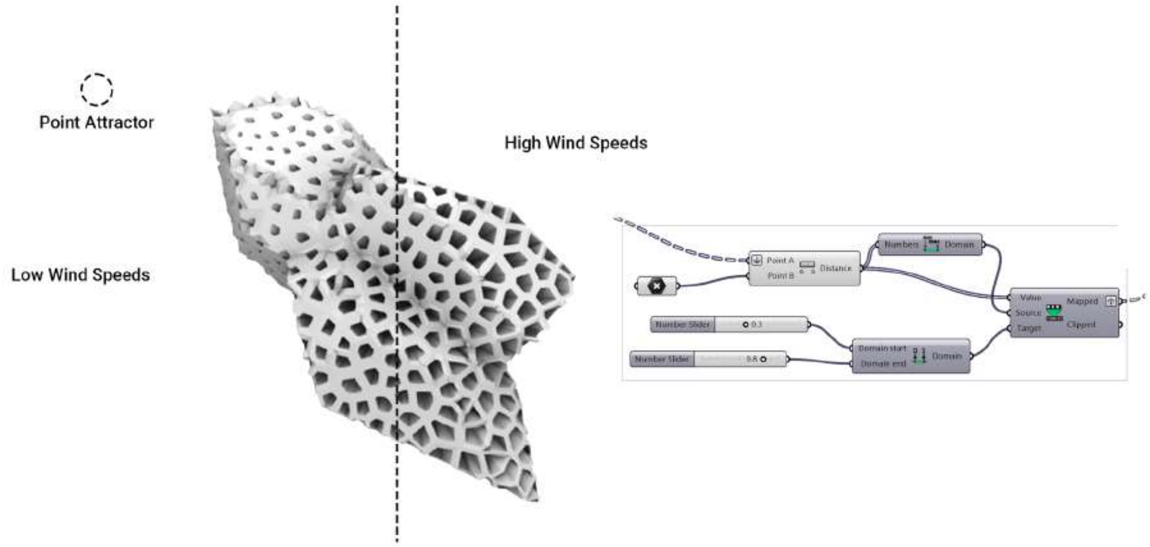
The full simulation can be explored and found here.

The Martian Habitat

The final result is a fully functioning and self-sufficient martian habitat that is fit for 3-4 inhabitants. The eventual goal with the habitat is that it can be the beginnings of a future community for the first settlers on Mars. The final habitat has three sections - Living, Working and Storage. This should provide the basic components for the first settlers to arrive in Nilli Fossae.

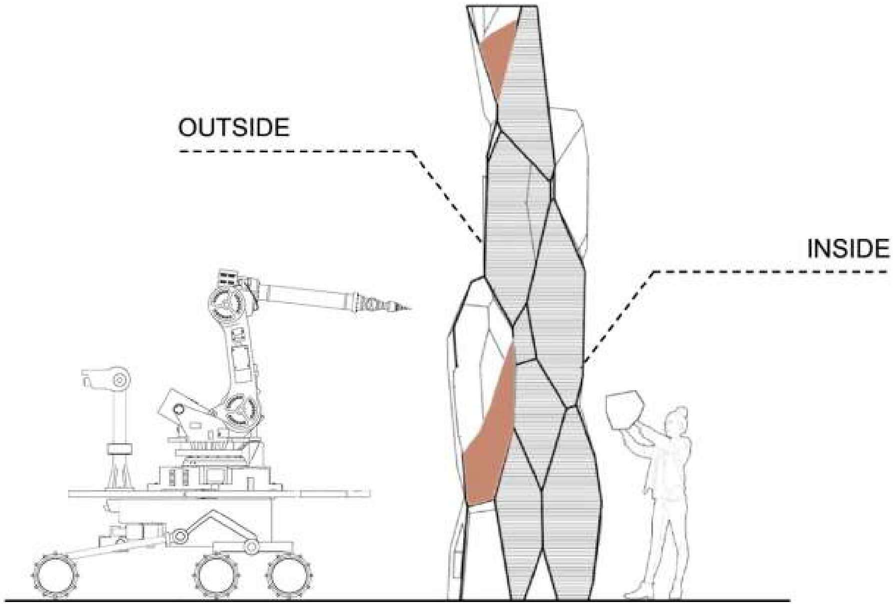


In addition to designing the martian habitat to withstand the harsh conditions on Mars, we also factored in the impact of Martian sandstorms on the building's outer skin. To achieve this, we incorporated a point attractor module into the grasshopper script used to create the envelope. This point attractor works by adjusting the size of the module holes based on their proximity to a specified point. In the case of our martian habitat, the point is the center of the building.



The point attractor module enables us to tailor the envelope to the wind conditions on Mars. In the case of high wind speeds, larger holes would be positioned towards the direction of the wind to allow for the capture of dust particles, while smaller holes would be placed on the opposite side of the building, facing away from the wind. This approach enables us to leverage the natural accumulation of dust on Mars as a form of radiation protection, without compromising the integrity of the building's outer skin.

Construction Strategy



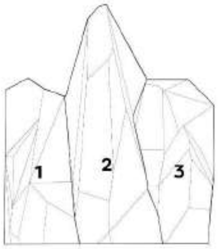
The design of the martian habitat was based on the principles of collaboration between humans and robots. The construction of the habitat will be carried out by robots that will be supervised and aided by humans. The robot-human collaboration will ensure that the habitat is constructed quickly and efficiently, while also ensuring the safety of the workers.

The habitat is designed using Voronoi-shaped modules, which provide an efficient use of space and materials. The modules are designed to interlock with each other, allowing for easy assembly and disassembly. To aid in the assembly process, each module is equipped with a human and a robot hole. During construction, the human hole will be located on the interior of the habitat, allowing for easy access for workers. The robot hole will be located on the exterior of the habitat, allowing robots to easily grab and manipulate the modules into place.

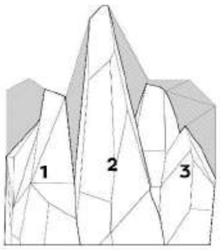
The holes in the modules also serve a crucial purpose after construction. They are designed to capture dust, which will be used to begin the dust accumulation process for radiation protection. The dust will be collected by the holes and gradually build up on the exterior of the habitat, forming a protective layer against the harsh Martian radiation. This innovative approach to radiation protection ensures the safety and health of the inhabitants of the habitat while also minimizing the need for additional materials and equipment.

The collaboration between humans and robots in the construction of the habitat, along with the unique Voronoi-shaped modules and dust accumulation system, makes this habitat design an efficient and innovative solution for future Martian settlements.

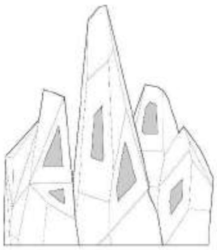
Prototyping



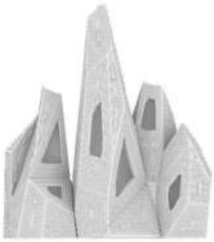
Carved Out Fragments



Shaping of Fragments



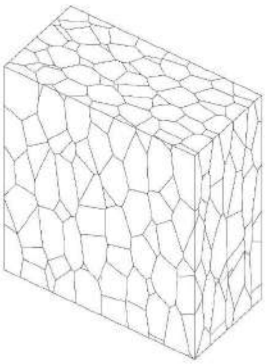
Insertion of Handles

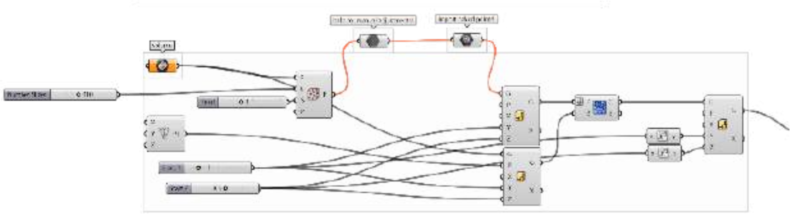


Final Preview

As part of our research, we were tasked with prototyping some of the fragments we would use in our design. This process involved creating sample fragments using the same voronoi geometry, then creating a preview before finally producing a print file. The print file would then be used with a robotic milling machine to produce the fragments out of foamboard.

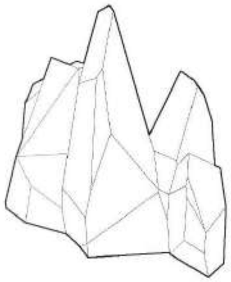
Stage 1 - Volume from Cells

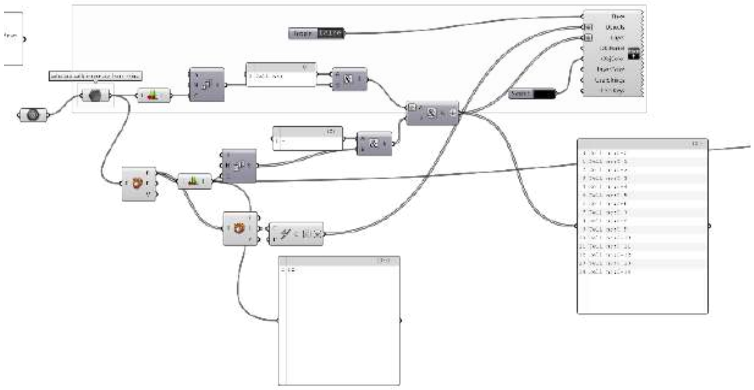




To begin with, we filled a defined volume with a voronoi geometry to simulate the assemblage of a chunk of the wall in our design.

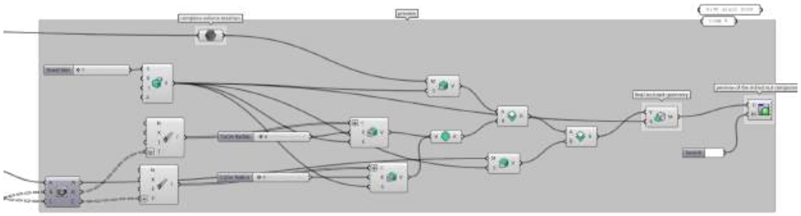
Stage 2 - Extract Fragments





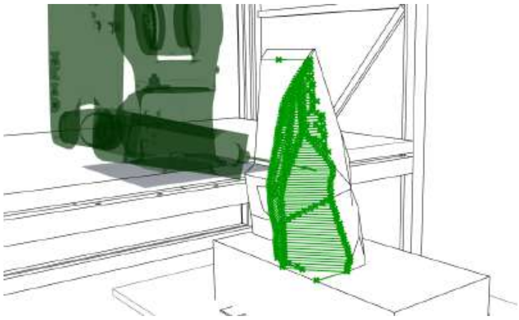
We then procured three conjoined fragment components from this volume. This would form the basis for our prototyping exercise.

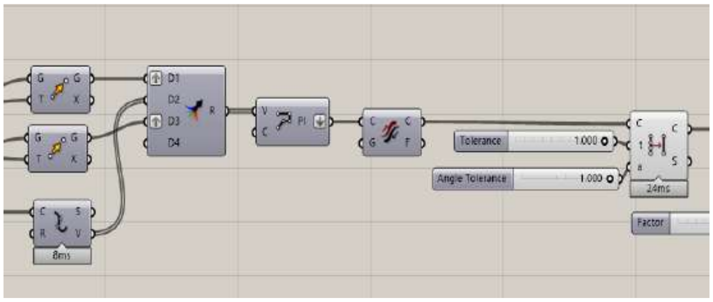
Stage 3 - Generate Preview / Input Holes



We then used Dendro in our grasshopper script to generate a preview of what the component would look like once it is milled out. From this we were able to allocate holes as handles and also visualize what the component would look like after being milled out.

Stage 4 - Milling Toolpath for Overall Shape



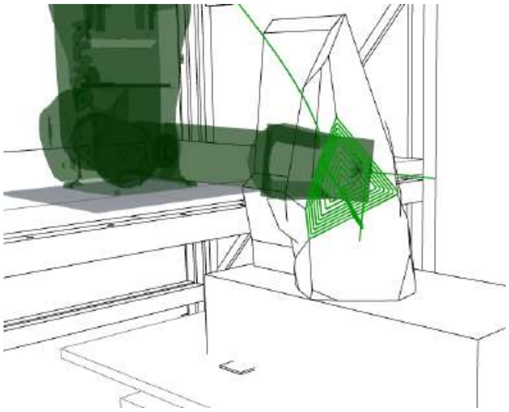


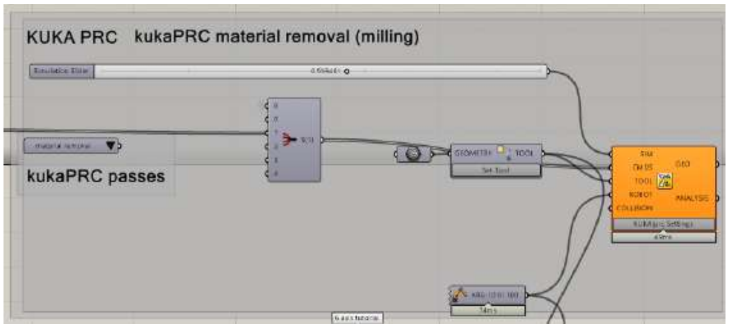
Tolerance 1.000

Angle Tolerance 1.000

We then created a grasshopper script with the aid of Arwin Hidding to generate toolpaths for the milling. The first part of the script would be the tool paths generated for the milling out of the fragment from a volume of foam board. This would produce the overall shape.

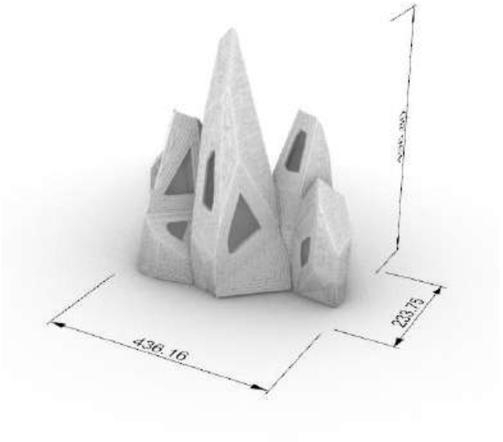
Stage 5 - High-Res Milling of Handles





We then generated the tool path for specific faces of the foam board to be milled out to a higher resolution. This would allow us to highlight where the handles would be located.

Final Result



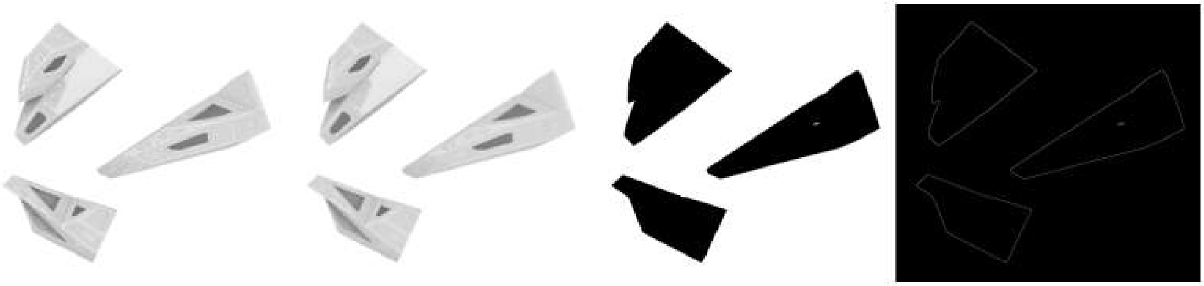
The final result is 3 pieces of foam board milled out and ready to test with human robot interaction. The fragment measures 500x436x273 mm in dimension and are 1:1 in scale. With these fragments we can begin testing how it can be used with human robot interaction to construct our martian habitat.

Computer Vision

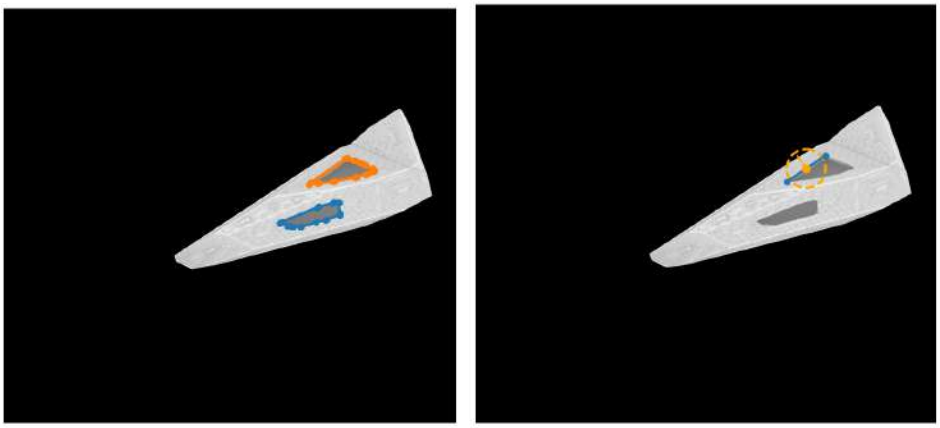
The purpose of this report is to detail the steps taken in creating an image processing application that identifies and extracts rocks from a Martian terrain image. The application was built using Python and the iacv library, and its goal is to assist future missions on the red planet by providing a means of extracting rock samples for analysis. In our case, we use it to prime the robotic hand in preparation for human robot interaction, by teaching it to detect and understand our fragments in space.

To achieve this, the application starts by retrieving two images; a foreground and background image. These images are then brightened and resized to fit the same size. They are also converted to grayscale and converted to RGB mode. A new image is then created by combining the two images using alpha_composite to form one composite image. This is done to incorporate a feature that allows the user to simulate an off-white background to make the program more realistic.

Afterwards, edge detection techniques were applied to extract the edges of the image. This was followed by detecting the contours of the edges and obtaining the polygons from these contours. The polygons were simplified to remove noise, and the remaining polygons were then used to create a mask. The mask was then used to isolate the area of interest from the image, which in this case, were the rocks in the Martian terrain.



The application then proceeds to detect contours within the area of interest. The contours are then used to extract the handles and the largest edge in which the robot much reach in to.



Overall, the application was successful in achieving its goal of translating an image into something the robotic arm can comprehend. The iacv library provided a powerful toolset for image processing and analysis, and with the continued development of machine learning and artificial intelligence, the potential for further advancements in Martian image analysis is endless.

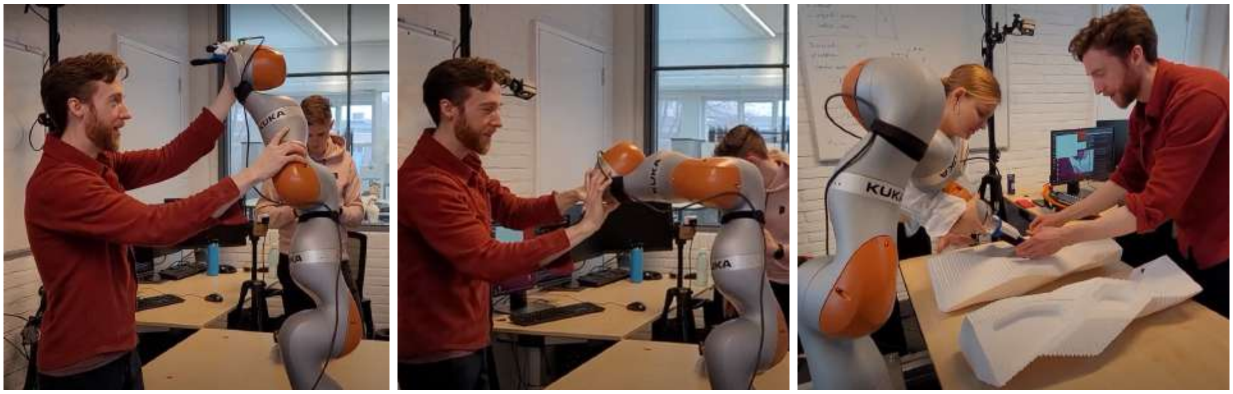
For further information, the code can be found here.

Human Robot Interaction

The final stage of the prototyping process involved simulating human robot interaction and how we can assemble these fragments using the aid of a robotic arm.

Calibration

Before we detect the fragments, the KUKA robot needs to be aware of where the physical obstacles are in the area as well as where it needs to start before the operation begins. This process is known as calibration, and it involves the manual input of a human.



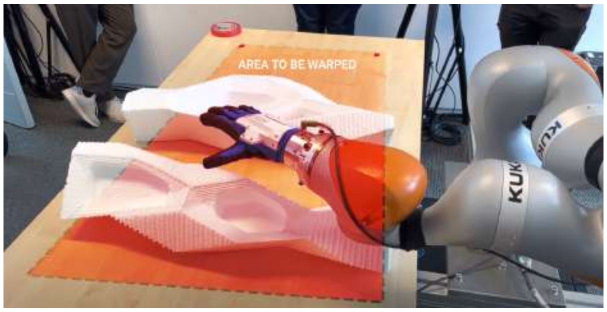
Left to Right: Point A, B, C (Table) in the calibration of the arm

The human guides the robotic arm to a specific point which will have a designated value assigned to it. These presets are important in guiding where the robot needs to be during specific points in the operation. It also helps the robot recognise where certain physical obstacles are in the lab, such as the table.

Fragment Detection

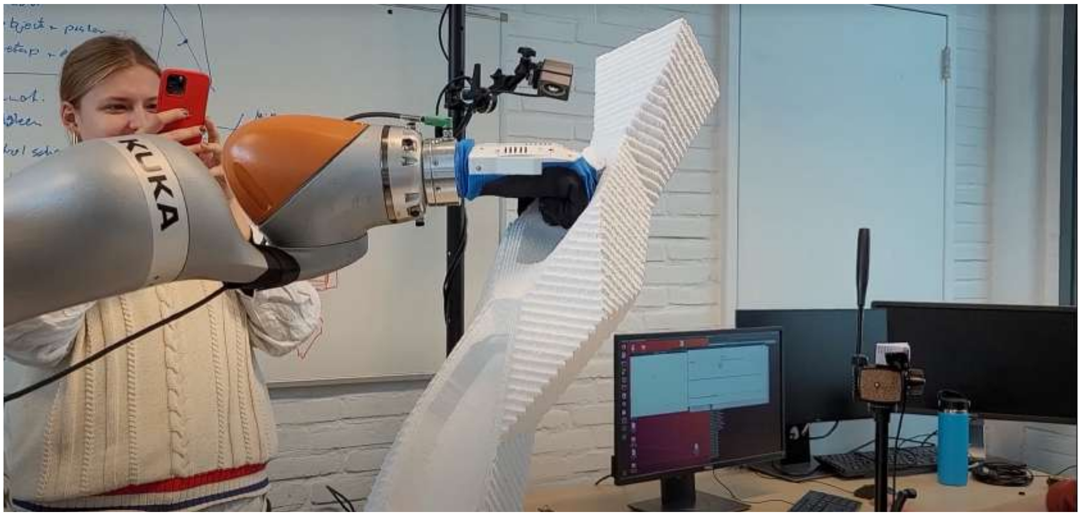
Before the actual assembly process can begin, the KUKA arm needs to be calibrated to ensure that it is operating within the required accuracy and precision.

In order to do this, we use computer vision to highlight the location of the fragments on the table. We then warp the image so that the KUKA robot is able to locate precisely where the fragments are on the workspace.



Assembly

The final step would be to use the KUKA arm to assemble the foamboard fragments by connecting them together using an adhesive or other joining method.



References

Schmehl, R., & Ouroumova, L. (202). Rhizome development: Autarkic design, robotic production, and operation system building on Earth. European Space Agency. Retrieved from https://nebula.esa.int/content/rhizome-development-autarkic-design-robotic-production-and-operation-system-building-earth