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Final Report for Project Starch Shield

Abstract

The present study explores the current development of **Project Starch Shield**, a practical and efficient solution to the problem of creating accessible, cost-effective, thermal and radiation shielding that will hold up to the extreme conditions of space. Our goal is to produce state-of-the-art Lunar Regolith Simulant Starch (LRSS) composite aerogel bricks for use as mass-efficient, effective passive heat and radiation shielding. The work we are doing is crucially valuable to all parties looking to develop space-based operations. Whether human-occupied or uncrewed, lunar settlements will require thermal and radiation shielding in order to have long-term practical and financial viability. The critical nature of this challenge, and the active need for a solution is evidenced by ESA’s recent allocation of a 174,999€ budget for “Aerogels for insulation and contaminant degradation in habitats and spaceships” (Esa.int. 2024). There are numerous other organizations spending time and resources attempting to develop similar

technology, as well as promising research that indicates a potential for in-space manufacturing of higher-quality aerogels than those that can be produced on Earth (Lab, I.N. 2023). There is a clear market need for our proposal, and our innovative approach provides a unique value proposition in the form of a design leveraging In Situ Resource Utilization (ISRU), and successfully tested cutting-edge material science solutions, for a mass-efficient, cost-effective, resilient, accessible In-Space Assembly and Manufacturing (ISAM) of insulation.

Introduction:

Space is extreme. Outside the cozy blanket of our atmosphere, there are vast isolated regions of resource-scarce desolation that are constantly assaulted by high-energy radiation. There are zones that have no atmosphere and little to no magnetic field, where all things are subjected to intense temperature oscillations and powerful cosmic rays that pose a serious obstacle to any and all future settlements and space activity. Even machines are not safe from this onslaught.

In order for humanity to create permanent settlements in hostile regions such as the lunar surface and beyond, we must develop specialized engineering solutions for the unique environments we will encounter off-world. Space is extreme, and so we must make it our goal to develop extremely robust solutions in order to survive and thrive beyond the safety of our Earth.

Operations Outline:

After conducting our trade study we determined that the following design best fit our requirements:

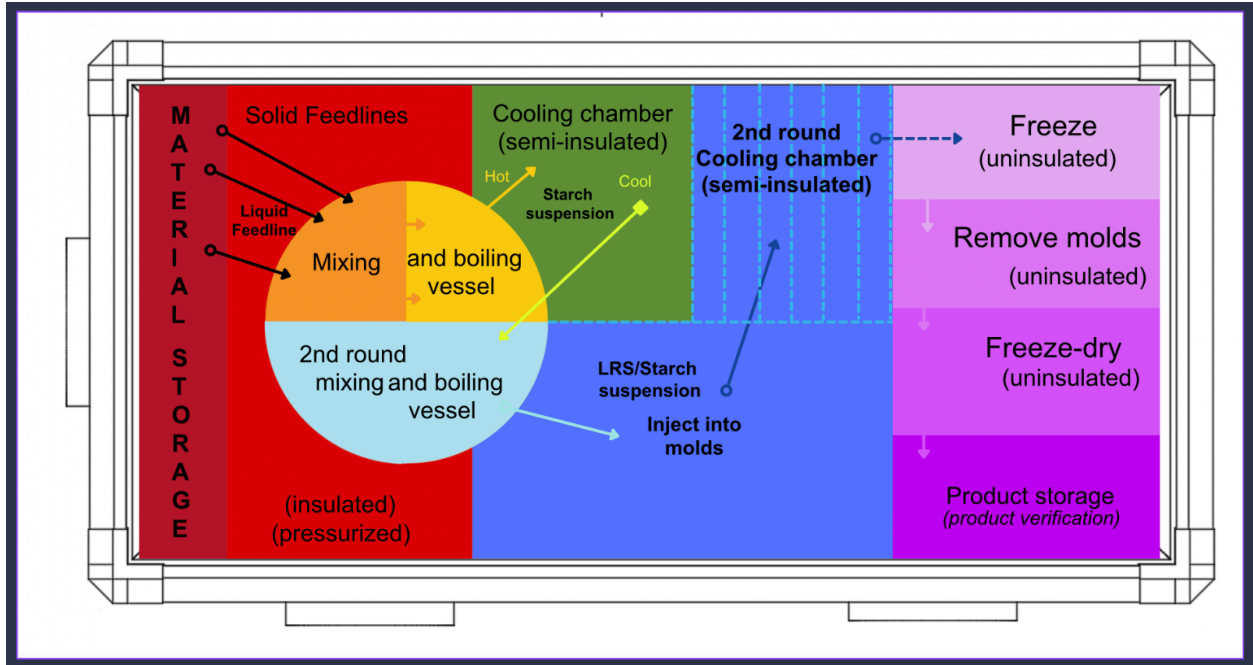


Figure 1. Preliminary layout diagram

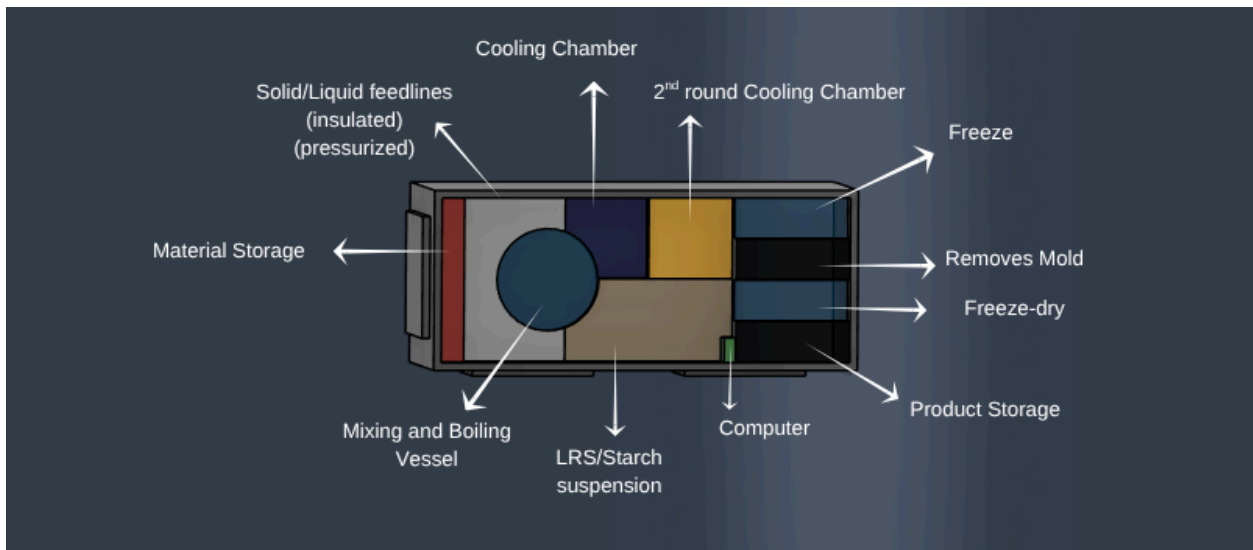


Figure 2. Layout CAD file

This is a diagram of the various chambers needed to manufacture the aerogel in the Bosuns Locker.

The Arkisys' Bosuns Locker will be internally divided into multiple chambers; a material storage section will feed into the first main chamber, which will be insulated and pressurized, containing a central vessel, into which three feed lines will terminate, and from which one exit aperture line will lead. The two feed lines for solid starch and LRS will employ extrusion pistons, in order to extrude the material into the vessel, and the liquid feed line for the water will use a pump operation.

Each of these feedlines will contain a flow rate sensor, and each line will terminate in a mechanically sealable door flush with the wall of the vessel. The vessel will be the space in which heating and mixing will occur. In sequence, the water and powdered starch will be delivered into the main vessel's bladder, and the stir bar and induction heating element will be activated.

Continuous temperature readings will be taken via an external infrared detector, when the starch-water solution reaches its boiling point $\sim 100^{\circ}\text{C}$ (as monitored by the temperature sensor), an opacity detector will determine the point at which the solution becomes transparent, and then once the dissolution of the starch granules causes the viscosity to increase from its initial value of around that of water (which will be measured by the torque resistance experienced by the motor for the mixing mechanism), a signal will be sent to switch off the heating element.

The system will then be left to cool until the temperature reaches between $80\text{-}70^{\circ}\text{C}$, at which point the LRS feedline will dispense the LRS into the vessel's bladder and the mixing element will be reactivated. Once the LRS-S paste is formed (which will also be measured by the torque resistance sensor), the heating element will be reactivated and the LRS-S sample will be raised to its boiling point, under the continuous mechanical stirring, until finally the resistance

experienced by the motor for the mixing mechanism, measures a stable new viscosity indicating that the viscous LRS-S gel has been successfully formed.

The hot LRS-S gel will then be pushed by nitrogen gas released into the vessel (outside the bladder) and sent through the exit aperture line into the second main chamber of the locker, which will be subdivided into three sections: A) pressurized and semi-insulated, B) pressurized and uninsulated, and C) unpressurized and uninsulated. The production line from the vessel will feed into **Section A** of the second chamber, in which the LRS-S gel will be injected into molds attached to a sliding wall mounted rail track system, and left to cool to 50°C. Once cooled, the molds will be moved via the rails through the pressure lock to **Section B**, in which they will be exposed to the uninsulated external temperatures, in order to freeze down the LRS-S gel to -30°C. The frozen samples will then be removed from the molds via a servo pulling system, and lastly will be moved to the unpressurized, uninsulated **Section C**, where they will be freeze-dried using the vacuum of space.

Lastly, **Section C** of the second main chamber will be equipped with material property evaluation detectors primarily in the form of a laser flash method thermal conductivity sensor. The production and evaluation process will then be finished, and the finished LRS-S Aerogel bricks will be left in the final storage chamber.

Scientific Development

Science Goals

Science has of course played a critical role in directing all aspects of our design. There are numerous scientific principles and methods that we employ for the production and analysis of

the LRSS composite aerogel bricks. Moving forward with this project we will need to make use of knowledge in disparate fields, from material science to the effects of microgravity/freefall on fluid dynamics, to the specifics of multiple critical physical and chemical reactions. A great resource that we have access to in attempting to further refine our understanding of these fields is the help of Dr. Christophe Bliard and his colleagues at the French National Centre for Scientific Research (CNRS).

In order to eventually publish our work, we will need to test our understanding of the science requirements, and Dr. Bliard et al. have already helped answer many of the questions we have had related to the specifics of our seven-phase manufacturing process.

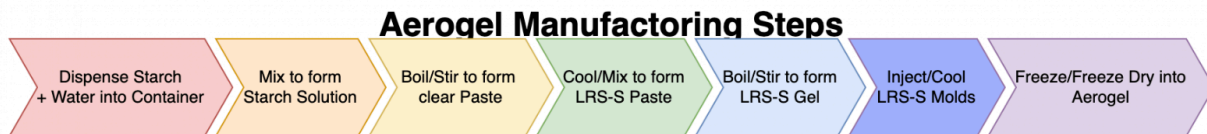


Figure 2. Flow chart of the steps to manufacture the aerogel.

The flow chart shows the different processes in the specific order needed to create the aerogel bricks.

Details

From correspondence with the researchers we now have useful information regarding volumetric yields as well as a baseline for the overall time frame of the production process:

“Volumetric yield was quite good since the resulting samples are very porous, so with 600 g of LRS with a skeletal density of 2 Kg/L we obtain +/- 1000 mL cube weighing roughly a little more than half a Kg.” said Dr. Bliard. He continued regarding the time frame:

“The total time of the process depends mainly on the freezing and freeze drying time which is directly correlated to the size and shape of the sample. The bigger the longer. For our 5x5x5 cm samples it could be down to 24 h but for several larger specimens (10x10x10 cm) it could require up to a week depending on the shape, the freeze drying time being correlated with the available evaporation surface.”

In addition, we now know that throughout the production process, dynamic viscosity should range from “0.005-0.01 pascal-seconds”. This statistic will be useful for better establishing the cutoff value that we will have the central computer monitor the torque resistance sensor for, in order to automatically verify when to terminate the mixing system once the desired viscosity has been reached.

Summary

As things currently stand, there are still many areas in which we will need to improve our understanding before we can finalize all the processes, such as identifying whether or not we will require a cooling system in addition to making use of the natural environmental temperatures, as well as verifying to what extent we can use the natural vacuum to aid in the freeze-drying process. Finally, it is important to note that we will need to clarify details regarding the prospects of water reclamation following the latter stages of phase 7 in the manufacturing process, as this will be critical to demonstrating the project’s long-term sustainability.

All these, as well as other points, we intend to address in subsequent correspondence with the researchers in the future, as well as through ongoing self-guided study. Although there is still much to finalize, we have a solid scientific foundation for our project, and from the Midpoint

Flash Talks last semester, we can state that Project Starch Shield would appear to be one of the most scientifically innovative proposals from C3 2025-2026.

Artemis integration & the potential scaled use of this manufacturing process

The following is a rough estimate of how our manufacturing process could be scaled up to a lunar facility, that could produce shielding for the Artemis Base Camp:

Our production process has the potential to be significantly simplified compared to what other shielding facilities may require. This is due to the fact that Lunar Regolith Starch Composite (LRSC) Aerogel, only requires a total of three ingredients:

-Lunar regolith

-Plant starch

-Water

Mass flows

In order to get a better understanding of the mass flows needed for a lunar factory to produce shielding via the Project Starch Shield method, we will need to do some rough calculations based on the information available to us at this point in the project's development.

Part 1: Mass of LRSC Aerogel

Regolith

It would appear from initial research that a coating of approximately 3cm (0.03m) of LRSC Aerogel integrated with other materials should be sufficient to achieve the required thermal insulation for the lunar environment(Veer & Mohite, 2023). As an analog for the amount of shielding needed for a lunar habitat, we can calculate the shielding required for a structure

with the same volume as the ISS, assuming minimum surface area. We can do this by seeing that as the ISS has a volume of approximately $388m^3$ (NASA, 2023), a very rough calculation of the shielding surface can be obtained by using the fact that a sphere with volume $388m^3$ will have a $Surface Area_{Sphere} = \sqrt[3]{36\pi V^2}$. Therefore we can say that the *minimum* shielding surface for a habitat with equivalent volume to the ISS would be approximately $A = \sqrt[3]{36\pi(388)^2} \approx 260m^2$.

Therefore the volume of LRSC Aerogel shielding we would need, per equivalent structure, would be $(260m^2)(0.03m) = 7.8m^3$ per structure. Let's say $10m^3$ per structure to make calculations easier. According to Bliard. 2025, the yield from 0.6kg of regolith was 0.001 m^3 of Aerogel.

Therefore if we do the math we see that we will need approximately 6 metric tons of regolith to produce enough LRSC Aerogel, to shield the entire surface of a structure with a similar volume to the ISS.

If we then assume the density of the lunar regolith is equivalent to that used by Bliard. 2025, that works out to just about 3 cubic meters of rock. So in summary, in order to produce enough LRSC Aerogel to thermally shield a structure with equivalent volume to the ISS we would only need to mine around 3 cubic meters of lunar rock (assuming the structure has minimal surface area to volume).

Mass of Starch

The LRSC Aerogel is 4% starch by mass therefore we would need 250kg of starch per structure, for thermal insulation.

Mass of Water

For the LRSC Aerogel water to regolith is 1-1, therefore we would need 6 cubic meters of water, or put another way we would need 6 metric tons of water for the thermal insulation.

Part 3: Total mass of shielding per structure

All this gives us a grand total of approximately **12.25 metric tons** of raw material needed for the total thermal shielding of a structure of minimum surface area with equivalent volume to the ISS. However, It is important to keep in mind that the mass of the water can be recollected and reused through the freeze drying processes. As such, we can state that the mass flow *in* per structure is approximately 6.25 metric tons of raw material, and the mass flow *out* is also approximately 6.25 metric tons of shielding (minus waste material) with a max of 6 metric tons of water staying in the system as water is recycled.

Material Engineering

Materials: Goal

The primary goal of material engineering in Project Starch Shield is to find, evaluate, and decide on the materials used in the designed system. These materials must be able to survive the extreme conditions in space while efficiently completing the various tasks required in the manufacturing process. This role primarily focuses on understanding which materials can consistently provide both thermal insulation and radiation shielding with minimal offgassing while also being effective for in-space manufacturing needs. Material selection is driven by prior research and proven concepts that have been approved and recommended for use by NASA. By

using prior research and comparing different use cases to our needs, we are better able to select the ideal materials used in the construction of Project Starch Shield.

Research and Screening

Material selection decisions are guided by prior existing aerospace research, including guidance from the use of NASA's Nonmetallic Materials and Processes Selection List (NASA 2016). This list categorizes which electronic components used in the manufacturing system are allowed and recommended, as well as specifying the materials that are banned due to being incompatible with use in space. Additionally, we are using NASA's paper on the full comprehensive list of material standards (NASA 2020). Using this, we are able to better understand what the ideal composition of the system should be. This resource provides expansive insight into issues such as radiation damage, outgassing, thermal stability, and long-term material degradation. This outline and guide allows us to disqualify materials early due to their performance in environmental hazards. Furthermore, Project Starch Shield is looking towards the possibility of aerogel structures to fit our needs, in addition to the already proven alloys and compounds listed by NASA. The idea of aerogels being used for the project due to their established performance in a vacuum environment and relevance to our mission is backed up by previous projects using aerogels in a similar use case for mission insulation in space. (NASA 2019)

Outcomes

Using the best materials for the manufacturing process will allow us to have efficient power usage with minimal wasted energy, better enabling us to function with the limited power

available. In addition, universal use of well-rounded materials suited for all possible environments allows us to use unconventional processes in our cooling, such as allowing the aerogel to freeze-dry in a vacuum in order to reduce energy consumption and the time needed to complete the process. A comprehensive evaluation of materials allows the project to optimize the resources provided, and complete the goal of Project Starch Shield effectively.

Future Steps

Future material engineering goals will focus on continuing to refine material specifications during the final modeling phase of the project. This includes optimizing alloy types, electronic components, and aerogel substances, as well as addressing specific needs during various aspects of the manufacturing process, while also assessing long-term durability and function under the stresses of radiation and thermal conditions. We plan to use aluminum alloys for basic structure and lower stress functions; Titanium alloy for high stress processes; and copper alloys for conduction heating. In addition, continuing our investigation into fine-tuned material composition may provide additional performance gains and reduce redundancy. Continuing to follow the guidance of aerospace material qualification standards, including those outlined by NASA, will guarantee that the final materials within the system remain effective for usage in the project.

Mechanical Engineering

Mechanical Engineering Goal:

The main objective of Project Starch Shield in the focus of mechanical engineering, is to formalize all systems needed for each mechanical aspect of the manufacturing process. The mechanical processes include: the transfer of potato starch, water, and lunar regolith simulant, mixing these components, and injecting the resulting gel substance into molds for the freeze drying process. The types of mechanical systems proposed for the aerogel manufacturing are based on previous research and experiments which have been conducted in microgravity environments.

Research on Different Systems:

The transferring of substances and liquids in microgravity contains one of the biggest challenges as the formation of air bubbles occur in systems which contain liquids. Therefore, substances are moved by using various internal forces such as surface tension and capillary action. Capillary forces include the movement of pulls and pushes to move a liquid through narrow tubes. External mechanisms such as syringe pumps or heat pumps move and store liquids by relying on capillary action and surface tension. (NASA 2022)

When mixing substances in a microgravity environment, there are various factors which make it much less efficient. There is a loss in buoyancy because of changes in density as the concentration of the substance changes. Therefore, the lost buoyancy will decrease the efficiency of mixing operations. NASA has conducted a paper on intravenous fluid mixing in microgravity. This paper proposed various methods for mixing with a focus on powders and concentrates with

sterile water for use on the International Space Station (ISS) and exploration missions. The constraints when choosing mixing methods included; mixing in a timely manner, and prevention of contamination as the solution had to remain sterile. The methods proposed were: built-in recirculation loop mixing, inline mixer during filling, magnetic stirrer bar mixing, stirring shaft with impeller mixing, ultrasonic vibrating rod mixing, container shape-change induced mixing, vibrating wall induced mixing, and acoustic streaming mixing. (NASA 2008). The various methods rely on pumps, an external moving rod, or the vibrating of an external surface in order to cause internal flow motions to mix the concentrates with the liquid.

Possible Solutions:

The main method to move the substances to each chamber of the locker would be through the use of pumps. These pumps would utilize capillary forces and enable fluids to move which is driven by surface tension and adhesion. The methods in the paper which were determined for further research were the magnetic stirrer bar and a vibrating wall induced mixing. The magnetic stirrer bar mixing method includes a magnetic stirrer bar placed into the bag and an external rotating magnet or a magnetic field would move the bar. As the moving magnetic bar will produce large internal velocities, it can quickly mix liquids with difficult powders. This method also prevents contamination as the bar can be sealed inside. However, one disadvantage includes dead mixing zones being created because the centrifugal force can distribute the granules along the outer edge of the bag. In addition, there is a possibility of electromagnetic interference with other technological components or the stirrer bar breaking free of the magnetic field if the

velocity is too high. In contrast, this stirring method is uncomplicated to implement conceptually and provides very efficient mixing with small mass requirements.

The other method that was selected is a vibrating surface. This method includes having one side of the bag being in contact with a surface that vibrates at a certain frequency to introduce internal flow. This method provides non-intrusive mixing at the expense of longer mixing times. The surface would vibrate at low frequencies of about 1 kHz to produce motion streams of fluids perpendicular to the surface. Therefore, in a closed container, this would produce internal motions to mix the components. There is a disadvantage however, as it is harder to adapt this mixing technique as it requires an optimal container shape. (NASA 2008)

Therefore, by using an injection system and a pump system, the potato starch and water can be moved into the mixing chamber. Then the mixing can be conducted either through a magnetic bar or a vibrating surface. The resulting paste created after being heated will be pumped into the next chamber. Once the resulting Lunar Regolith Simulant Solution is created, after a series of mixing and heating processes it can be injected into molds to be dried into the aerogel bricks.

More research will need to be conducted to find the most efficient systems to manufacture the aerogel bricks in a microgravity environment. These systems will then be designed to incorporate the other aspects of the manufacturing process.

Electrical Engineering

Role and Intent

The role of Electrical Engineering in Project Starch Shield is to design a robust, power efficient, and hardened electrical system capable of supporting a semi-autonomous manufacturing system in the Arkisys Bosun locker. The electrical subsystems must be able to safely distribute power, interface with sensors and actuators, and must be protected from radiation induced system failures, all while being able to communicate with a Command and Data Handling system. Given the power budget (300 W sustained, 1000 W peak), the electrical design must prioritize efficiency, modularity, and the ability to safely disconnect in the event of failures.

Power and Distribution Architecture

The power distribution is designed around a low voltage DC bus that is provided by the locker's interface. The primary voltage regulation will step down the bus voltage to standard levels (12 V, 5 V, and 3.3 V rails), using a DC-DC converter to minimize thermal losses and electrical noise and interference.

High power loads, including the heating elements and mixing motors, have to be electrically isolated from more sensitive logic electronics, through separate power rails and circuitry. A solid state relay or MOSFET-based power switch can be used to enable software controlled individual subsystems. This can allow non-critical components to be powered down during idle phases, and reduce the thermal stress and power draw.

Current and voltage sensors on each major rail can provide real time feedback to the control computer, which can enable the detection of any abnormal current draw.

Control Electronics and Processing

The preliminary choice in system architecture for control, sequencing, and data handling is a Raspberry Pi system. NASA's *Raspberry Pis for Space Guideline* indicates that Raspberry Pi systems have demonstrated acceptable performance in space when appropriate system-level protections are implemented – particularly for non-flight-critical applications

Key mitigation strategies from this guideline include:

- **Power cycling capability:** The Pi will be connected through a controllable power switch to allow rebooting in response to single-event functional interrupts (SEFIs).
- **Fusing and current limiting:** Overcurrent protection will isolate the Pi in the event of radiation-induced high-current conditions.
- **Conduction cooling:** Thermal energy generated by the Pi will be conducted to the spacecraft structure, as convection is unavailable in vacuum.
- **Watchdog monitoring:** External hardware or supervisory software will detect non-responsive states and trigger safe recovery procedures.

The Raspberry Pi will not directly control or drive actuators. It will instead issue low power control signals to dedicated motors, pumps, and heating control modules, which will reduce the risk of a cascading electrical failure.

Sensor and Actuator Interfaces

The subsystems must support a diverse sensor suite, which includes temperature sensors, torque or current sensors for viscosity inference, flow rate sensors, and optical or opacity

detectors. These sensors have to be able to interface with digital protocols such as I²C, SPI, or UART, which were chosen because of noise immunity and simplicity.

Actuators which include extrusion pistons, pumps, mixers, and heating elements will be controlled using electrically isolated driver circuits. Motor drivers will include current sensing to detect stalls or overloads, while heaters will be regulated through closed-loop control using temperature feedback.

All interfaces have to be designed with shielding, grounding, and proper cable management to minimize electromagnetic interference.

Radiation and Fault Tolerance

Radiation effects present a significant problem for electrical systems operating beyond the magnetosphere, Total Ionizing Dose (TID) and Single-Event Effects (SEE) can induce bit flips, latchups, or permanent damage in electronic components. According to the NASA article, Raspberry Pi units have demonstrated functionality up to 10krad without significant degradation.

To mitigate these risks Project Starch Shield will employ a system-level fault-tolerant approach:

- Redundant sensing where feasible
- Software error checking and state validation
- Power isolation and reset capability for critical electronics
- Conservative operating margins for voltage, current, and temperature

Integration and Future Development

Electrical Engineering integrates with Mechanical, Thermal, and Computer Engineering. Electrical routing and component placement will be determined by thermal modeling to ensure good heat dissipation, while mechanical constraints will guide connector selection and harness design. Future development will refine the component selection using the NASA Parts Selection List and NASA-STD-6016 material and process standards.

Thermal Engineering

Goal of Thermal Engineering

The primary goal of Thermal Engineering is to ensure that a system maintains the required temperature ranges to allow all components and processes to function safely and efficiently. For Project Starch Shield our main focus is on the movement and transfer of heat energy throughout a system in a harsh environment such as the vacuum of space. In this context, Project Starch Shield posed quite an engineering challenge. It is essential that repeated heating and cooling cycles be carefully controlled for consistency and reliability, while preventing interactions between other supporting mechanical and structural systems.

Challenges

One of the primary challenges for Project Starch Shield is the environment. In the vacuum of space, convective heat transfer is essentially non-existent due to the absence of air

molecules. As a result, these methods cannot be utilized. This limits heat transfer down to a few methods, namely conduction and thermal radiation. Another challenge found is power consumption; In Project Starch Shield there is an available sustained power of 300W, with a peak available power of 1000W. These power supplies are for the entirety of the project, so it is imperative that heating elements be minimally power intensive while as effective as possible.

System Requirements

Project Starch Shield requires liquid water to be repeatedly heated and cooled at various temperatures and throughout the stages of multiple operations. This requires a heating system that has the ability to operate with consistent and controllable thermal input without interacting significantly with the mechanical mixing system.

Thermal isolation is another key requirement for the system. The heating mechanism must operate with minimal interactions with other systems. Unwanted heat transfers could impact performance and or structural integrity of the project, skewing the outcome of the end product. Unintended heat transfer would also affect power consumption as it would force more power to be consumed wastefully instead of being efficiently used for heating liquid water.

Planned Solutions

To address these challenges, Project Starch Shield will rely primarily on conductive heat transfer, as conduction is the most effective and reliable method for heating available in a vacuum environment such as space. Heat will be transferred through copper piping, selected for its high thermal conductivity and ability for uniform temperature distribution. Copper's

predictable thermal behavior enables precise temperature control while minimizing formation of localized hot or cold spots during repeated thermal cycling.

Computer Engineering

Role and Intent

The role of the Computer Engineer is to enable the semi-autonomous operation of the manufacturing process of our LRSS aerogel brick, within the constraints of the Arkysis Bosuns Locker. While Arkysis (2025) provides a suitable environment for launching our payload, we are tasked to realize the discrete processes and operations necessary for the in-space manufacturing process throughout the mission cycle. Computer Engineering would enable the real world implementation and workings of the hardware and software identified through actual programming that fulfills all of C3's project requirements and the operational outline we have identified in the previous section.

Project Requirements and Future Considerations

A critical component for the Computer Engineer is developing the Command and Data Handling (C&DH) system that coordinates the required sequence of discrete operations. The Bosuns Locker is equipped with a suite of integrated, internal sensors available for our use and configuration. This potentially includes optical sensors, thermocouples, current/voltage sensors, strain gauges, and accelerometers. Data obtained from these sensors should be retrieved and communicated back to the ground station through the C&DH to allow us to monitor the current manufacturing process, course correct if necessary through manual user command signals, and

gain feedback from our payload. The discrete C3 project requirement is as follows: “3.3 Data handling & comms. Develop a high-level overview/flowchart of data management and ground communications needs.”

The Interface Control Document (ICD) from Arkysis (2025) provides in-depth technical specifications of the Bosuns Locker. To facilitate our payloads’ data protocol, Arkysis provides the Appliqué device for accommodating our C&DH. The Appliqué is a universal data protocol adaptor that accommodates our communication through any payload data protocol. We, as the customer, must disclose our chosen data protocol to Arkysis (e.g., RS-422, UART, I2C, etc.).

Additionally, we must provide specifications of our electrical and physical interface or have a physical interface connector recommended to us; Arkysis will supply a cable harness to connect from the Appliqué to our payload. This implies the Computer Engineer will need the coordination and integration with electrical and mechanical engineering to fulfill Arkysis’ requirements, and justify our anticipated level of remote interaction, clarifying any limited remote commands, e.g., initiating a sequence, confirming alignment before operation, or interrupting an operation.

Programming the process control flow will also be crucial to enable the operations of dispensing materials, mixing, heating, cooling, and extrusion for our identified manufacturing goal. We would need to generate signals to switch components on and off automatically, whether to terminate the mixing system when the desired material viscosity is reached or to activate the heating elements until the specified temperature thresholds are met; this works in tandem with feedback from Arkysis’ internal sensor suite. The software component should integrate within the constraints of the space environment, with hardware chosen based on the NASA Parts

Selection List (NPSL) to ensure the durability, performance, and qualification standards for our materials use; this implies the coordination with the Materials Engineer.

Preliminary research indicates that a modern Raspberry Pi would meet our project constraints in terms of power consumption, programming, and automation needs with electrical and physical interfaces, and space constraints within the Bosuns locker; further research is recommended to finalize the proposed concept hardware on which the software components will be built, upon coordination with the other engineers on the team. Future work will continue to build on and further develop diagrams/flowcharts stemming from the Concept Diagrams denoted in the [Project Star Shield Concept Diagram](#).

Conclusion

The diverse team of individuals who have already contributed to this project have helped to make a solid foundation which we will build upon moving forward into the future. As we continue to correspond with researchers and advisors, we will finalize budgets and TRL values of all components, in order to cement our solutions to all the engineering challenges of the project. We will finalize all mechanical processes, communication, and data systems, as well as finish a Single Source of Truth (SSOT) diagram/document for all future reviews. All of this will then directly contribute to our final publication.

There is still work to do, but it is clear that our innovative and wholly unique approach to this competition demonstrates a design for a potential solution to a fundamental obstacle that humanity will need to overcome if we are ever to put down roots on other worlds.

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