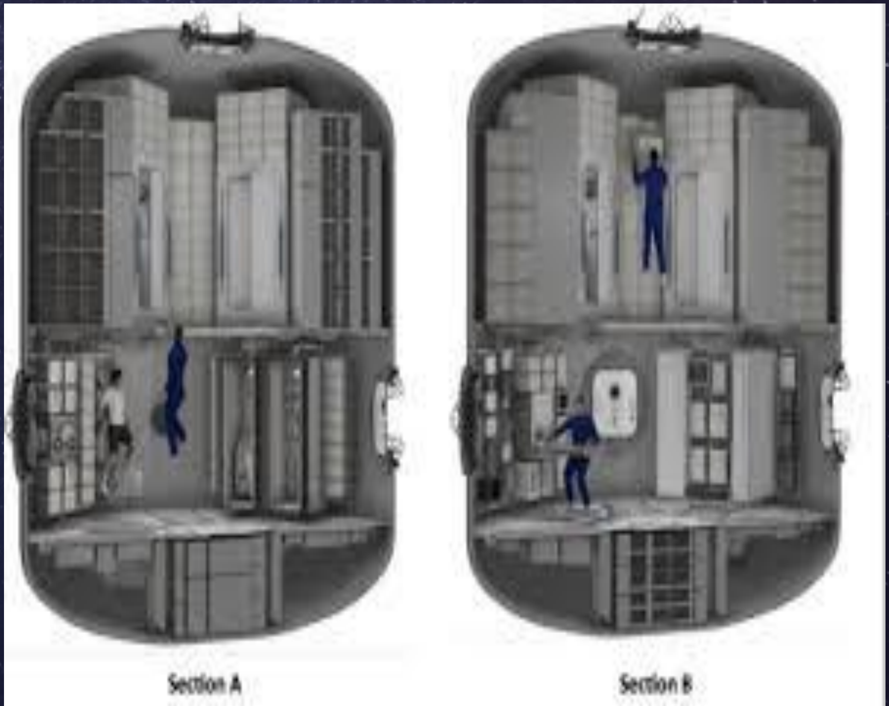
MARS TRANSIT HABITAT FOOD STORAGE

DESIGN CHALLENGE

- Design and build a prototype food storage module (freezer) **<u>that utilizes external cold temperatures</u>** and **<u>minimizes power consumption</u>**.
- Specific design and testing requirements are found on slides 13 & 14.

PROJECT OVERVIEW

- NASA is developing a strategy for sending humans to the Mars vicinity in the mid-2030s known broadly as NASA's Journey to Mars.
- A critical part of this campaign is the development of substantially capable habitation systems capable of extending human presence beyond LEO(Low Earth Orbit).
- The Evolvable Mars Campaign (EMC) feature in-space transit and surface habitats supporting crews for the ~1100-1200 day missions to Mars vicinity



1 https://ntrs.nasa.gov/api/citations/20170002219/downloads/20170002219.pdf

PROJECT OVERVIEW

- NASA will assemble its deep space transit habitat through a phased, modular aggregation process.
- Because of the immense mass and volume required for multi-year missions, the transit habitat (often referred to as the Deep Space Transport or DST) cannot be launched in a single piece.
- To meet payload mass constraints, habitats may launch in a "partially loaded" state. Critical subsystems and supplies are delivered on subsequent launches and installed in-space by crew or robotics.

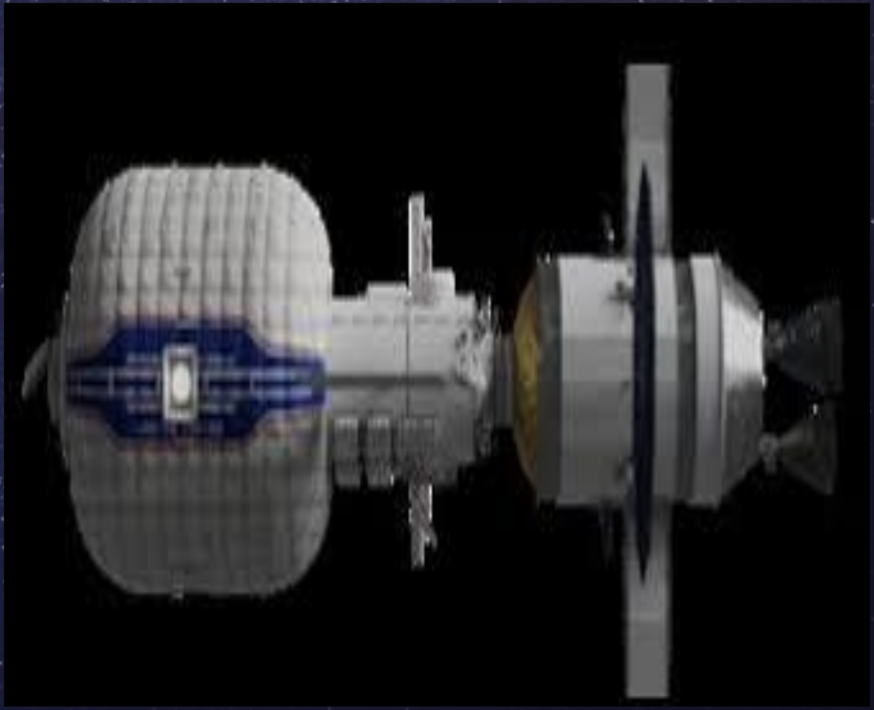
PROJECT OVERVIEW

A crewed mission to Mars will take 8 to 9 months. Resupplying consumables requires multiple spacecraft which is not currently planned. The majority of the food for the crew will be dehydrated, freeze dried, or thermostabilized. **<u>Some thermostabilized meals will require refrigeration or freezing. Providing sufficient refrigeration, while minimizing power consumption and volume involves unique design challenges.</u>**

PROJECT OVERVIEW

- Exploration missions such as Mars TH, where all food has to be launched in advance of the mission and sustain the crew throughout with no resupply opportunity, represents a fundamentally different scenario
- While powered refrigeration equipment technologies are being flown on ISS, these have high total power/cooling demands and facility volumes for food preservation that may not readily scale to a Mars TH scenario.
- A passive approach would leverage the external cold space environment to maintain a cold temperature for food.

4- https://ntrs.nasa.gov/api/citations/20220014734/downloads/1_11_version_with%20acknowledgments%20section.pdf



PROJECT OVERVIEW

- In addition to food storage for the crew a cold storage module can also preserve biological samples collected during the mission.
- This will require different compartments that maintain much colder temperatures than those needed for food preservation

CURRENT FOOD SYSTEM - ISS

- No refrigerators or freezers on board for food preservation although a small chiller was recently added on the International Space Station for chilling beverages.
- All food must be stable at room temperature for the required shelf life
- All food items are packaged in individual serving sizes.
- Food is thermostabilized and/or irradiated, freeze dried, vacuum sealed
- 18 month shelf life

2- https://ntrs.nasa.gov/api/citations/20100026032/downloads/20100026032.pdf

THERMOSTABILIZED FOODS

- Processed at high heat and then can be stored at ambient temperature
- For long duration missions refrigeration/freezing will help to insure viability
- High temperature removes harmful bacteria and enzymes that contribute to food spoilage
- They don't use up any extra water as the moisture stays in these packets
- Foods like fruit salads, stews, some desserts

3 – https://www.hunch-biohealth.com/uploads/2/2/0/9/22093000/acf_presentation_2024.pdf

FREEZE DRIED FOODS

- Moisture is removed from the food during packaging
- Food is checked for bacteria and can be irradiated prior to packaging.
- They are put into a -40 degree chamber until the drying process is complete via moisture sensors.
- Air is taken out by reducing the pressure with a vacuum pump

3 – https://www.hunch-biohealth.com/uploads/2/2/0/9/22093000/acf_presentation_2024.pdf

VACUUM SEALED FOODS

- Foods like candy, cookies, granola bars are sent up vacuum sealed.
- Vacuum sealing occurs when all of the air is removed from the packaging to keep the oxidation process from happening which reduces its viability.
- Most vacuum sealing can last safely up to two years.

3 – https://www.hunch-biohealth.com/uploads/2/2/0/9/22093000/acf_presentation_2024.pdf

DESIGN CHALLENGE

Requirements:

- ✓ Design a food storage module that will dock permanently to the Transit Habitat.
- ✓ Solid module, or inflatable is up to you.
- ✓ Cylindrical shape allows for large surface area to achieve heat transfer.
- ✓ Attach module to end of TH to minimize need for enter/egress.

5 - https://www.nasa.gov/humans-in-space/the-menu-for-mars-designing-a-deep-space-food-system/

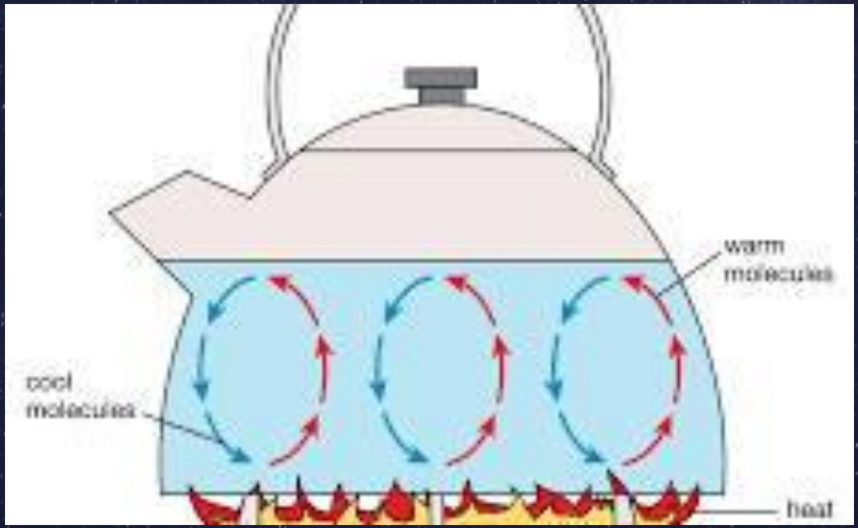
DESIGN REQUIREMENTS

- Space modules are complex systems that are beyond the scope of this project. Your prototype should primarily focus on the issue of refrigeration/freezing.
- Your prototype must be scaled and no larger than 2 cubic foot.
- You must have diagrams that illustrate the compartmentalization for food storage versus biological samples.
- You must include an inventory system
- Recommendations for specific materials used in flight hardware are required.

TESTING AND VALIDATION

- Dry ice in a Styrofoam container with adequate ventilation can provide a cold environment for several hours.
- Cool your prototype as much as possible before testing so that your internal compartment is as close to freezing as possible.
- Place packages of frozen food inside the prototype.
- Temperature measurements at point closest/furthest from access door are required.
- Take multiple temperature measurements at various locations inside your prototype
- Measure power consumption throughout the test period.
- Recommendations for specific materials used in flight hardware are required.

PROTOTYPE CONSIDERATIONS



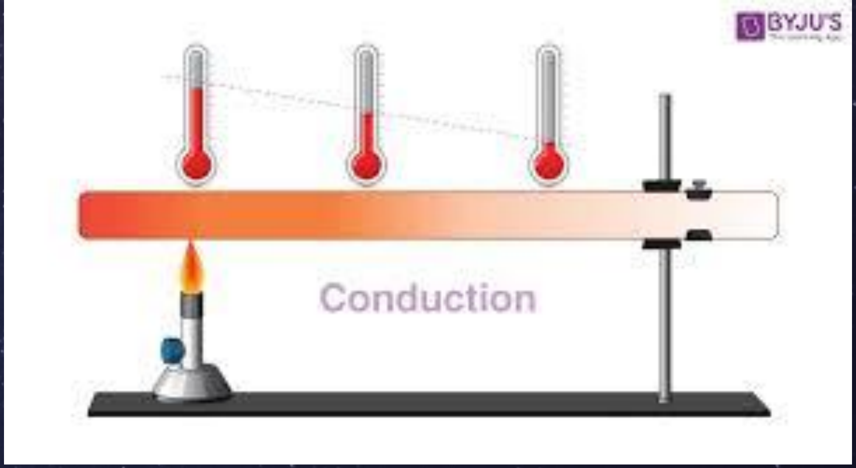
- Maintaining a relatively constant temperature for refrigeration/freezing requires heat transfer.
- The primary methods of heat transfer involve convection, conduction, and radiation.
- Convection typically involves the effects of buoyancy within a gravitational field. Microgravity significantly inhibits buoyancy making convection challenging.
- Some possible methods of utilizing convection are: Forced, Acoustic, or Marangoni convection. Each of these methods require additional power consumption.

6 - https://www.numberanalytics.com/blog/heat-transfer-in-microgravity-guide

PROTOTYPE CONSIDERATIONS

Conduction and radiation are two primary mechanisms of heat transfer that occur in microgravity. Conduction refers to the transfer of heat through direct contact between particles or objects, while radiation involves the transfer of heat through electromagnetic waves.

In microgravity, conduction heat transfer is unaffected, as it depends on the thermal conductivity of the material and the temperature gradient. However, radiation heat transfer becomes more significant, as there is no convective cooling to mitigate the effects of radiation.



7 - https://www.nasa.gov/smallsat-institute/sst-soa/thermal-control/

REQUIRED READING

1. https://ntrs.nasa.gov/api/citations/20170002219/downloads/20170002219.pdf
2. https://ntrs.nasa.gov/api/citations/20100026032/downloads/20100026032.pdf
3. https://www.hunch-biohealth.com/uploads/2/2/0/9/22093000/acf_presentation_2024.pdf
4. https://ntrs.nasa.gov/api/citations/20220014734/downloads/1_11_version_with%20acknowledgments%20section.pdf
5. https://www.nasa.gov/humans-in-space/the-menu-for-mars-designing-a-deep-space-food-system/
6. https://www.numberanalytics.com/blog/heat-transfer-in-microgravity-guide
7. https://www.nasa.gov/smallsat-institute/sst-soa/thermal-control/
8. https://www.ibiblio.org/apollo/Shuttle/Payload/STS-121%20MELFI%20User%20Manual.pdf
9. https://www.nasa.gov/wp-content/uploads/2015/07/coldstowage-ec7.pdf
10. https://techport.nasa.gov/projects/103155