Collapsible Hygiene Stall for the Deep Space Habitat

DESIGN CHALLENGE

Design, build, and test a scaled 1/6 size hygiene stall to be used on the Logistics Module for the Gateway Space Station. The following components are required in a final prototype:

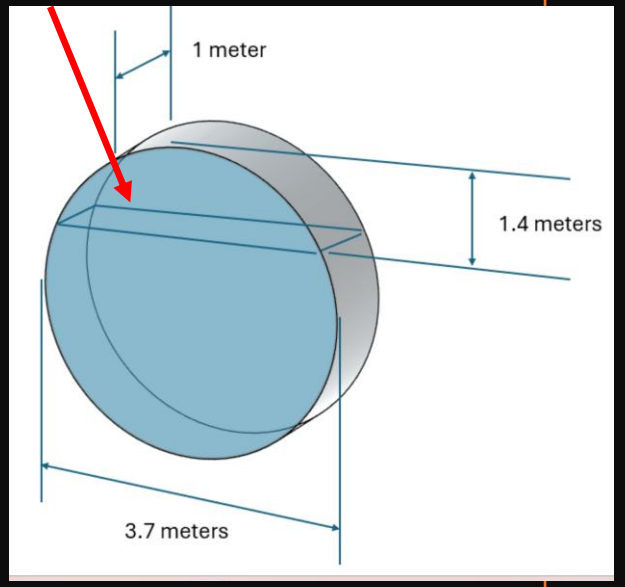
1. Provide privacy for an astronaut washing up. Material must be opaque to prevent casting shadows visible from outside.
2. Be easy to set up and put away
3. Collapse to a storage volume no greater than 1 cubic foot (scaled for your model)

   (the collapsing volume doesn't have to be a cube—it can be any shape but the internal volume should be $2ft^3$ or less-- 1 ft x 1ft x 2 ft)
4. Include permanent lighting. Additional temporary lighting is optional.

DESIGN CHALLENGE

5. Provide good air flow for breathing, as well as drying out.
6. Allow for ducting from a nearby vent
7. Attach to handrails/bulkhead to provide stability during use.
8. Have attachments for hygiene materials, e.g. soap, shampoo, washcloth, razor.
9. Internal restraint system for astronauts to use while washing up
10. Easy to clean
11. Dries quickly to prevent mold growth

Volume available for privacy curtain



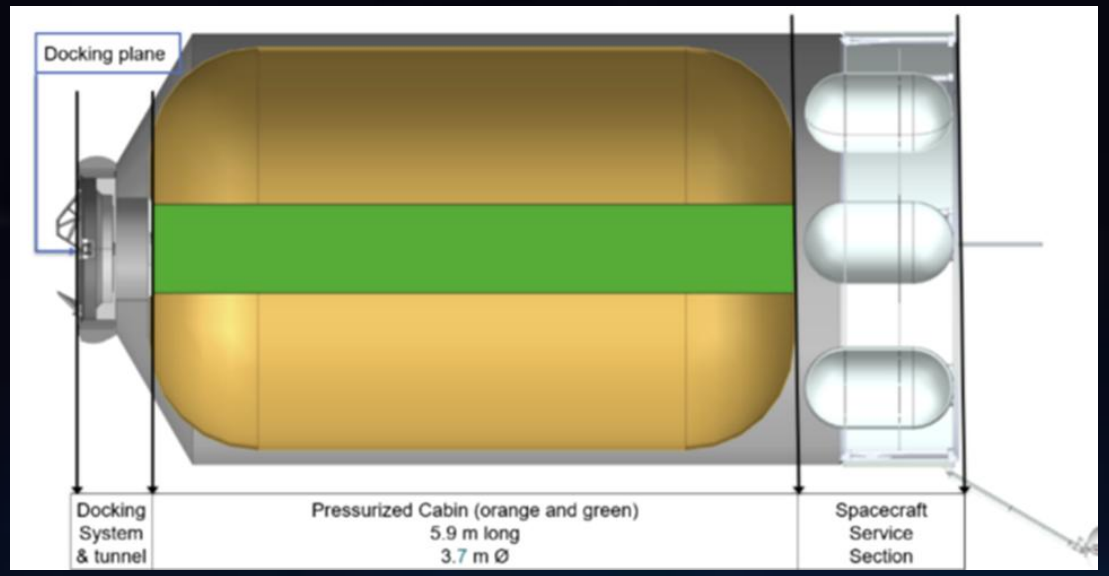
Overview

- Gateway is central to the NASA-led Artemis missions to return to the Moon for scientific discovery and chart a path for the first human missions to Mars and beyond. The small space station will be a multi-purpose outpost supporting lunar surface missions, science in lunar orbit, and human exploration further into the cosmos. NASA is working with commercial and international partners to build humanity's Gateway.

Overview

- The Gateway outpost will orbit the Moon and serve as a small space station to support Artemis missions to the lunar surface. It will fly in a polar orbit so that it can view the entire surface of the moon. The Orion capsule will launch on a Space Launch System (SLS) rocket and deliver astronauts to Gateway. A Human Lander System (HLS) will take the crew from Gateway to the surface of the Moon and back. To support this exploration of the Moon, an uncrewed Logistics Module (LM) will be needed to deliver cargo, science experiments, and supplies to Gateway arriving about a month before the astronauts show up. It will stay there while the astronauts are on the station and it will depart about a month after the astronauts leave.

Overview



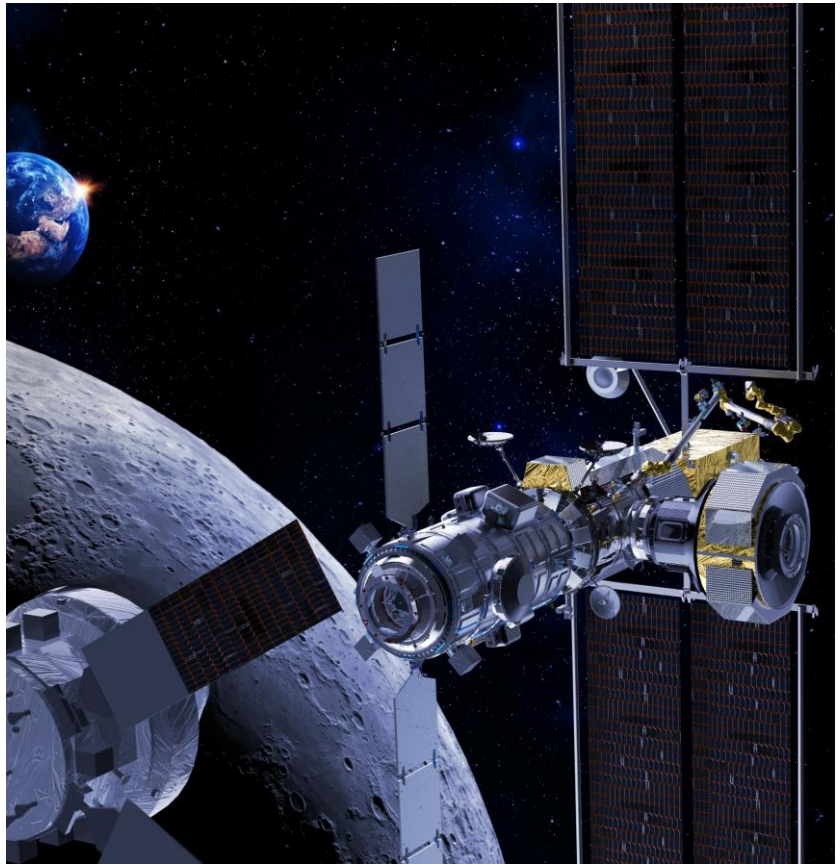
- Mission Scenario: A crew of four will launch on an Artemis mission in the Orion capsule atop an SLS rocket headed to the Moon for a three-week mission at Gateway. Two crew members will spend one-week on the surface of the Moon. One month prior to the crew arrival, an uncrewed Logistics Module will launch with a load of supplies and travel six days before autonomously docking at Gateway.
- Gateway is much smaller than the International Space Station (one bedroom apartment versus a six bedroom house). It is not large enough for the crew to store all the cargo from the Logistics Module after arrival. Cargo will remain in the LM, and the crew will access and use the supplies as needed. The LM will function as both a delivery vehicle and as a pantry, active storage room, and trash collection area.

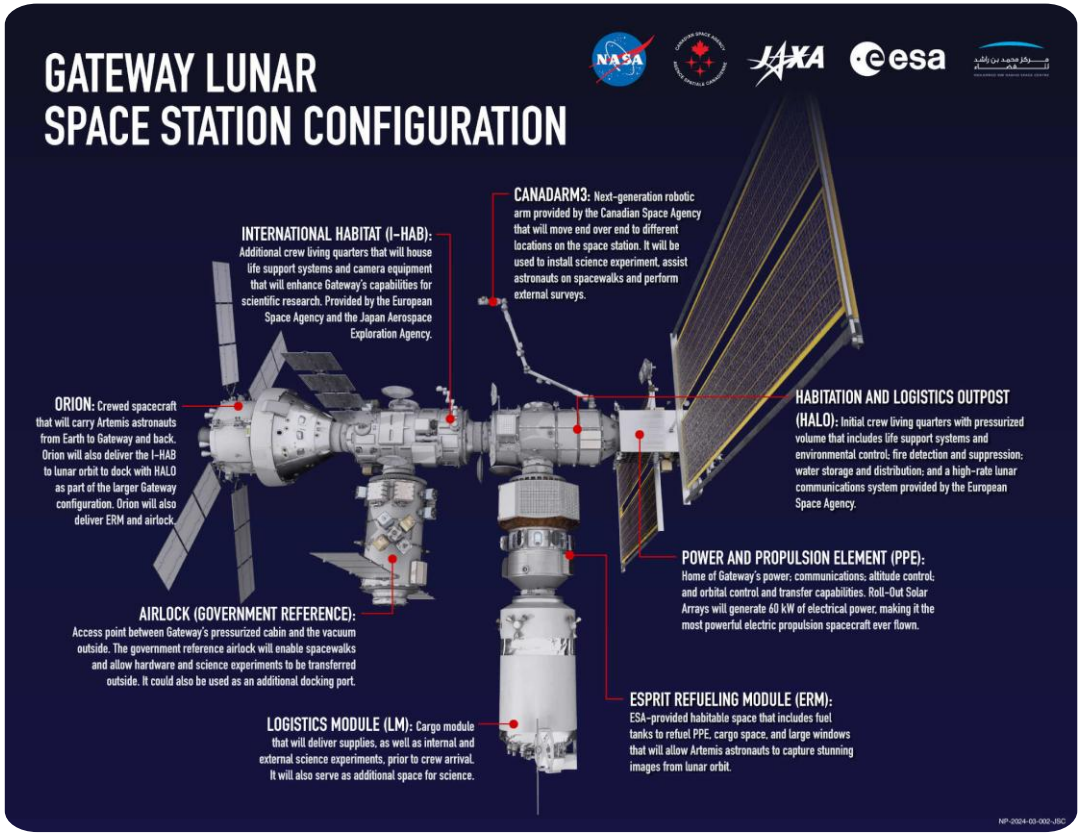
Overview

- Launch phase: For launch, the module will be used as a delivery vehicle, and the critical factors are securing the cargo (primarily stored in flexible cargo bags) against launch loads (6 g axial) and vibrations, maximizing use of module volume, and minimizing the storage system mass (to preserve cargo up-mass capability).

Overview

- Docked phase: Once the LM is docked at Gateway and the crew arrives, the LM hatch will be opened, and the crew will use the LM like a pantry, closet, and active storage room. Heavy duty securing and restraining systems required for launch are no longer needed in zero-gravity, but items must be restrained to prevent them from moving around the module. In this phase, providing quick, easy crew access to the cargo is critical because crew time is incredibly valuable and limited.
- Disposal phase: Throughout the mission, the cargo volume will be gradually repurposed for trash stowage. A solution for trash is not a goal of this challenge.





Overview

- After undocking from the Gateway, the logistics module will be on a long pathway to burn up in the Sun (maybe 100 years). There will probably be some long-term experiments for this longer mission (not for you to worry about).
- Part of the purpose of the Gateway is learn how to make a space craft for traveling to Mars:
- Astronauts are exposed to more radiation than the ISS around Earth,
- Maintaining fuel for longer periods of time without resupply,
- Long distance resupply and docking,
- Smaller volume for astronauts,
- New life support systems.

1.

Logistics Module leaving Earth Orbit

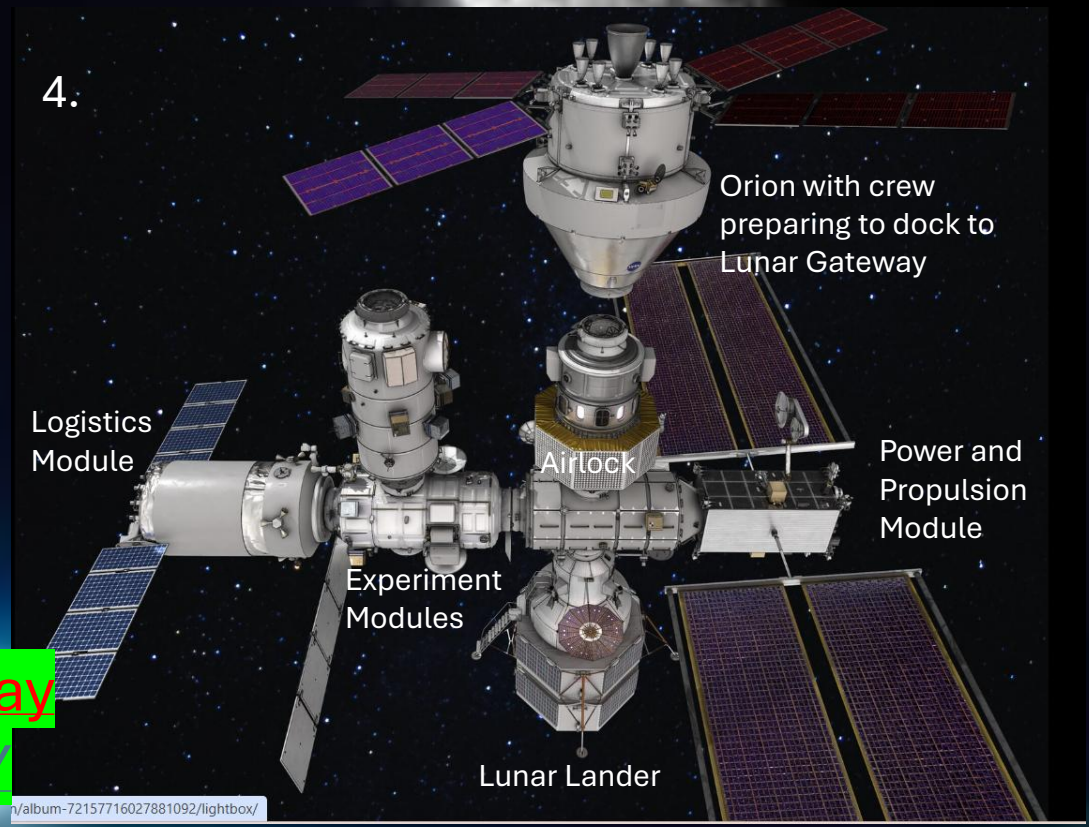
2.

Logistic Module arriving at the moon with docking hatch facing the camera

3.

Logistics module preparing to dock to Lunar Gateway

4.



Slightly old but valuable information about Gateway

https://www.youtube.com/watch?v=SVyrOQvRXrY

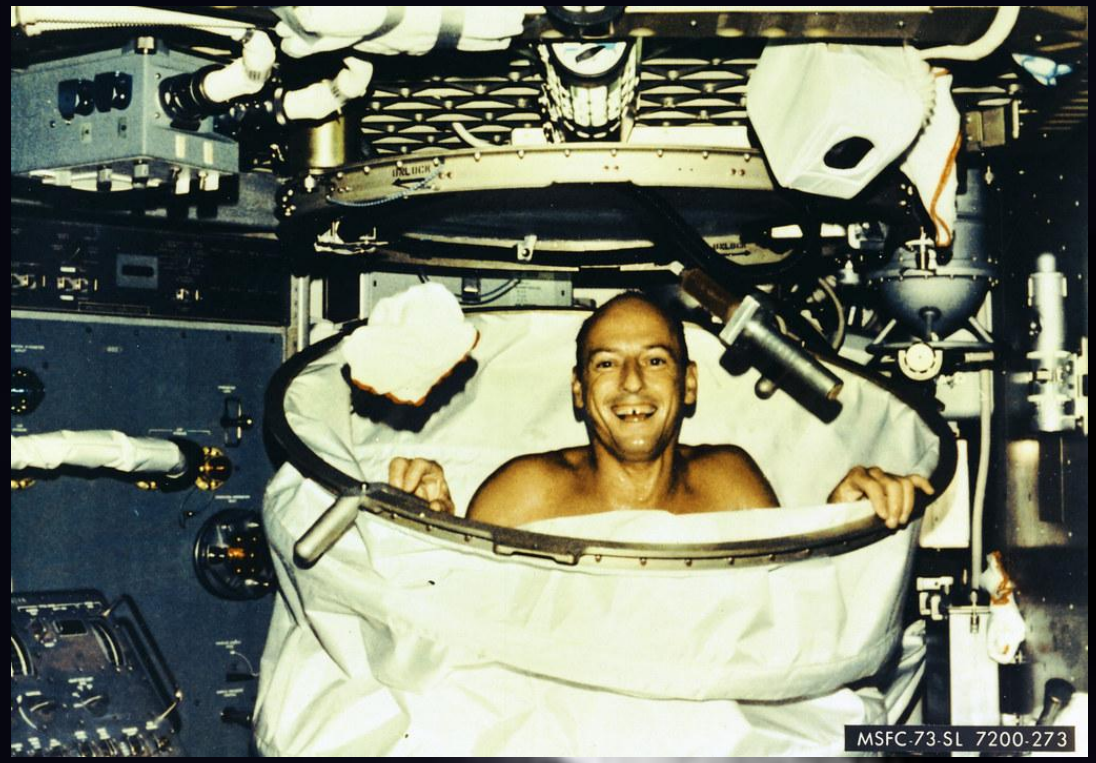
Hygiene in Microgravity

- Showering in space is challenging due to limited hot water and the effects of microgravity, which prevents water from flowing down as it does on Earth.
- Early NASA missions used sponge baths due to water limitations, while Skylab introduced a collapsible tube shower system (a lengthy and cumbersome process that many astronauts chose to skip).
- On the International Space Station, astronauts use rinseless soap and water pouches for cleaning, with every drop of water, including moisture from showering and breathing, captured and recycled by the Environmental Control and Life Support System.

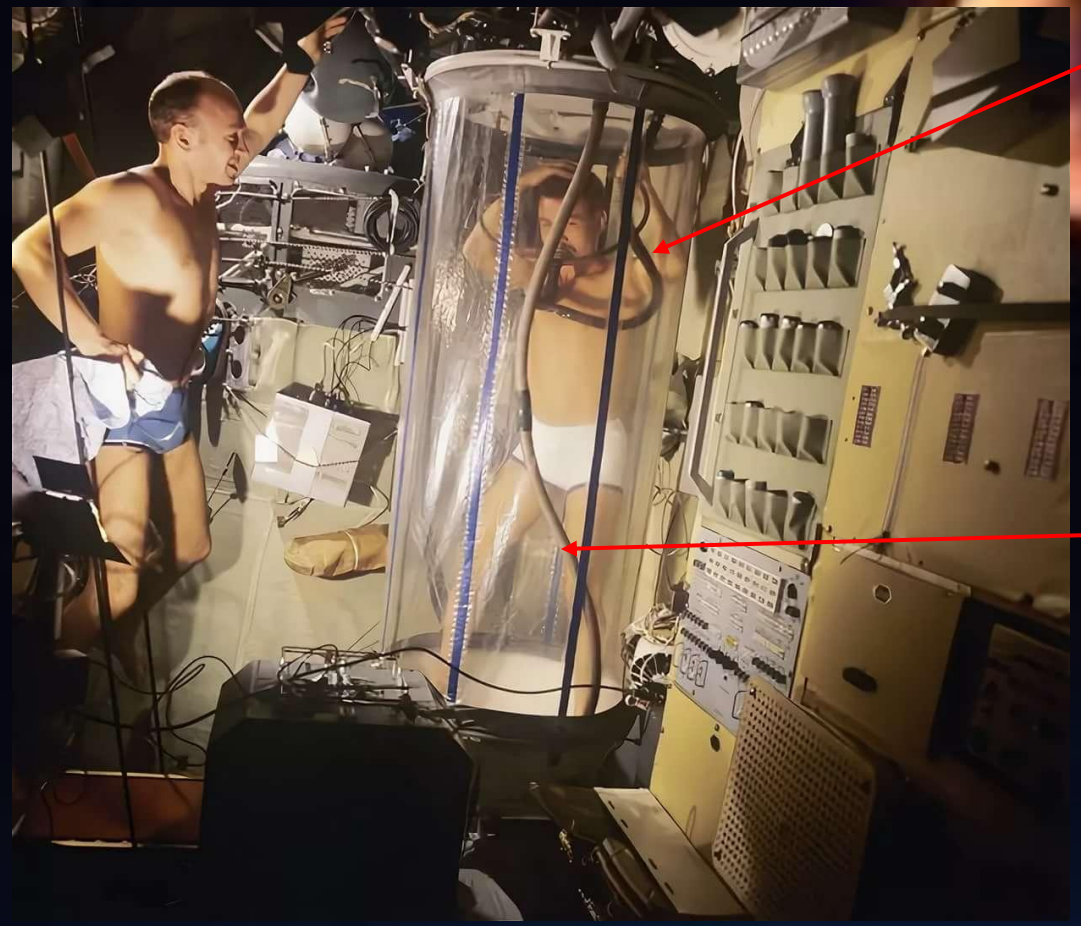
Skylab Shower Shower

SkSkylab was the first US space station in 1973. It was a large lab that was visited by 3 crews of three astronauts. They did lots of experiments with materials, new kinds of equipment, telescopes, photos of Earth but much of what they studied were the effects of being weightlessness on the human body and how to live in space for long periods of time. This included how to clean up in space. They had an enclosure for trying to keep the water from getting into the electronics. This one had more privacy even though, at the time, there weren't any women astronauts. It looks as though the snaps on the top would allow for it to be completely closed if desired. The crews said that it was cumbersome to take it out and put it away and preferred just using washcloths and pouches of water. ylab was the first US space station in 1973. It was a large lab that was visited by

https://www.google.com/search?sca_esv=cd63d47fa156149d&q=skylab+shower&udm=7&fbs=AIIjpHz30rPMyW



Mir Space Station



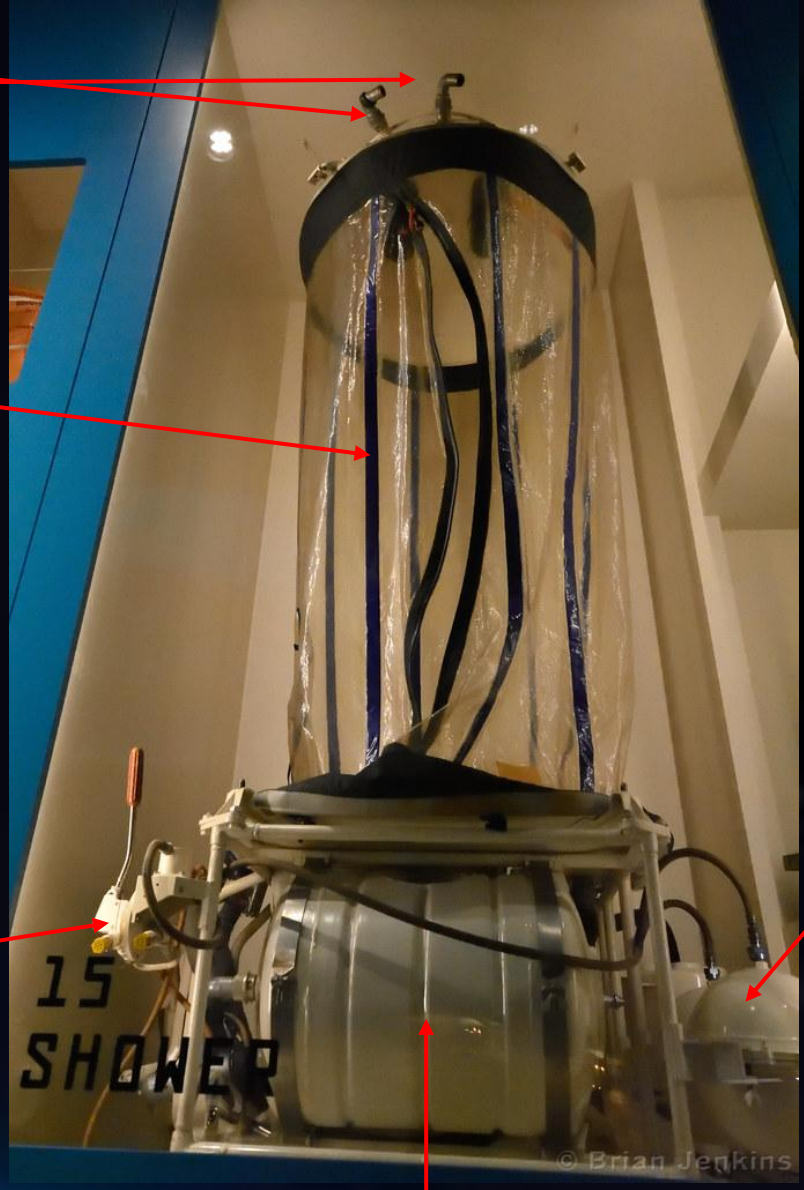
Water spray hose

Vacuum hose for cleaning up water after

Connectors for water and vacuum hoses

Rigidizers for enclosure (one is probably a zipper for entry)

Air pump



Tanks for soapy water

Water tank

This is the shower enclosure sent up on the Russian Mir Space Station. Notice that it is not for privacy (Russians didn't send up many women at the time). It allowed the cosmonauts to wash up with water they would spray from a tank that they pressurized with an air pump. After washing they would have to vacuum up any water inside the enclosure and then collapse the enclosure. It was very wasteful of the water and the clean up of the shower enclosure was time consuming and left them sweaty from the work. The crew ended up dismantling the shower and throwing it away. Afterward they used washcloths for sponge baths.

Shower in space?

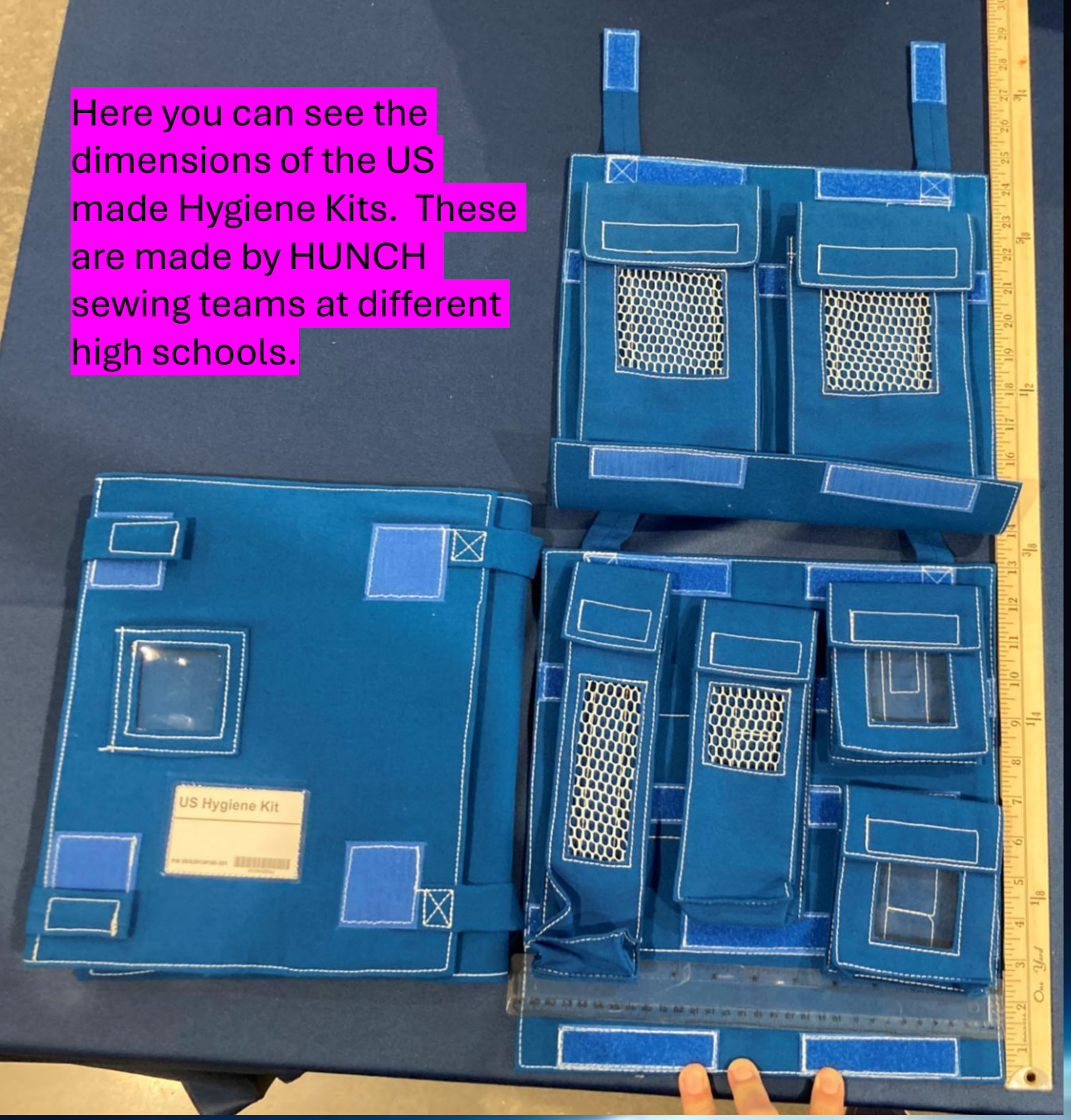
One of the main purposes of this is for privacy of the astronaut. The Gateway Space Station will be mix of male and female astronauts usually with a maximum of 4 people at a time. It will be important to have some space away from others while cleaning up.

It is also important to keep from getting water all over a space station to avoid damaging electrical equipment. It is also important to not have water building up over time and allowing mold to grow in one location. Astronauts can't use a shower since spraying water would go all over in the zero-gravity environment. Mostly they will have a drink bag full of hot water and maybe soap with a washcloth. Water or soapy water will be absorbed from the drink bag into the washcloth. They will take a sponge bath with little water getting away from them.
https://www.youtube.com/watch?v=tDbbJWKKQu0

If they are washing their hair, water and shampoo are slowly transferred to their hair from the drink pouch. They slowly kneed and scrub their hair trying not to send droplets everywhere. It's easier to wash short hair without sending water everywhere. The longer the hair, the easier it is to send a spray of water every where. After washing, they absorb as much of the water and soap out of their hair as they can with a towel and then do a rinse with some water and absorb as much as they can into a towel again. The towel is then left in the open air to dry out. Their hair air dries, they do not have hair dryers on the ISS.
https://www.youtube.com/watch?v=uIjNfZbUYu8

Russian Style
Hygiene Kit

US Style Hygiene kits use the same kind of supplies.

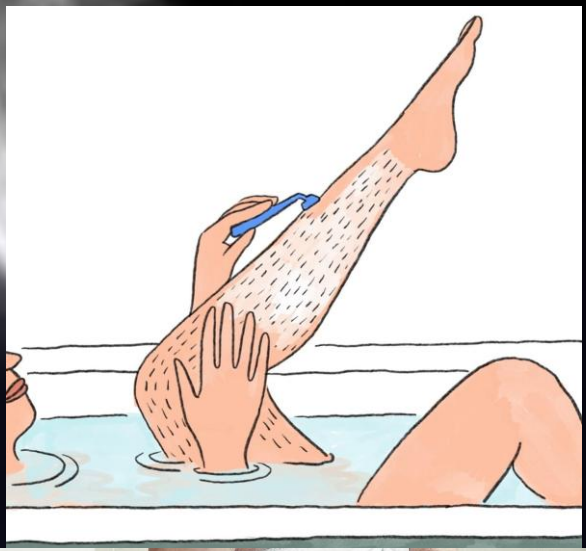


Here you can see the dimensions of the US made Hygiene Kits. These are made by HUNCH sewing teams at different high schools.

It may be helpful to mock-up part of the shell of the module to help with explaining how your hygiene stall fits into the volume of the module. Does your privacy stall need some kind of attachment to the shell or any structure around it?

Shaving in space

- Removing facial hair is important for safety since an oxygen mask needs to fit the face without leaking. (not a problem for most women)
- Shaving in space isn't very different for guys. You can imagine that if you hang upside down, shaving your face is pretty much the same.



- However, if people are shaving their legs, it **is** different—on Earth people use gravity to help them reach different parts of their legs. Imagine hanging yourself upside down and then reach to shave your legs—now you are having to pull your legs and your body into different positions to get to those different areas. This is an extreme example because you wouldn't be fighting gravity in space but illustrates the difference.
- Removing leg hair is not as critical as facial hair but it is a personal preference that some people may chose to do while in space (not a requirement).
- Does this affect your design of the Hygiene Stall?

- Removing hair from the razor is done by sliding the razor sideways through a wet cloth. Capturing the cut hair is very important so it doesn't float into eyes.

1/6th Scaling

We do not want full sized hygiene stalls. This saves you from buying lots of materials and taking up a large part of your bedroom or classroom.

You will be displaying your prototype on a table

Assuming the tallest astronauts are 6ft 3in and the shortest astronauts are 4ft 11in. Scale your prototype as best as you can for being 1/6th size. Choose a doll or action figure to demonstrate how a person will fit and use your hygiene stall

It would be wise to do some portion of a mock up for your own testing but your display must be 1/6th scale.

The 1cubic ft requirement for packing should also be scaled to fit your doll sized demonstration.

Design Requirements

- 1. Privacy

Select a material that prevents the silhouette of someone inside being seen. The material must also prevent water from seeping though. NASA also requires that materials used must not off-gas and no be flammable.

Design Requirements

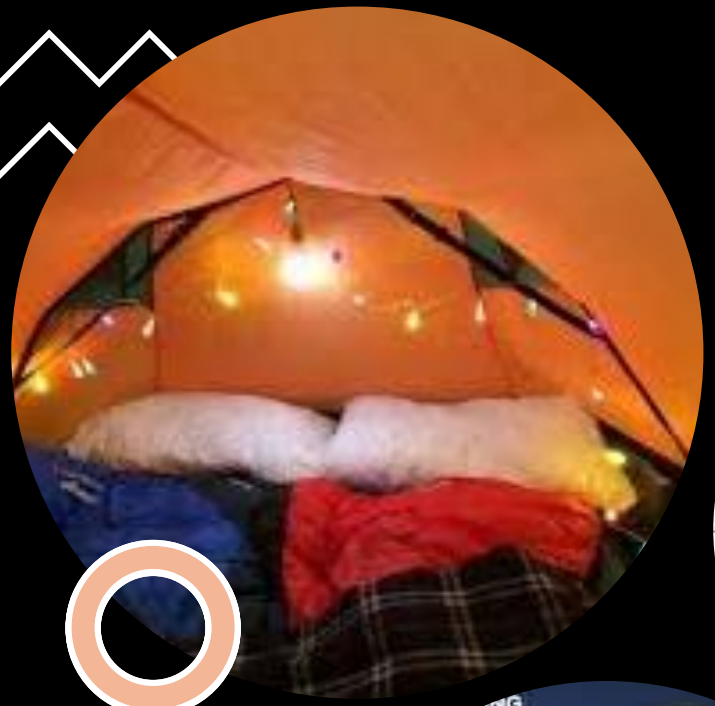
- 2. Assembly

Set up/breakdown must be accomplished by one person.

Process should take no more than 3 minutes

Design Requirements

- 3. Storage
- The entire system must collapse to a volume of 1 cubic foot, or smaller. A good analog is a backpacking tent, or camp shower.



Design Requirements

- Lighting
- Provide efficient lighting for bathing, shaving, etc.
- Can be integrated or suspended.
- Power from LM via USB
- Batteries on long duration missions are problematic. If you choose to use these, you will need a viable recharging system.

lighting

- **Don’t cast revealing shadows**
- Can have a combination of permanent lighting and moveable/portable lighting
- Placement of the lights can be critical
- Activities
- Sponge bath
- Shampooing
- Shaving legs
- Shaving faces
- Changing clothes
- What kind of restraints are needed?
- Consider the needs of people for shaving faces and legs

Design Requirements

- Ducting and air flow
- Closed spaces are problematic. Exhaled carbon dioxide can accumulate causing health issues. A continuous flow of air will also aid in drying the compartment, prior to disassembly.

Design Requirements

- Attachments
- Once the stall is assembled it will need to be secured to the LM. Attachment points may be hand/foot rails, or seat track. Integrating frames, or wires, into the stall may be useful. Make the attachments simple so a single astronaut can fully assemble the stall.
- In microgravity everything floats, including astronauts! Provide attachments, like foot straps, and everything the astronaut takes inside (soap, shampoo, washcloth, razor, etc.)
- Water is a precious commodity and astronauts will be limited on what they use. Water will need to stored in a collapsible container and dispensed a little at a time.

Flies up flat. Opens kind of like a pop-up tent. Rotates up from the bottom into the rack bay.

Something like a ZSR?


ISS017E018976

Each rack on the ISS is about the size of a family sized This A
About the size of a large refrigerator, a Zero-g Soft Rack (ZSR) is a large, cloth bag shaped like a rack on the ISS. The front side is an aluminum frame that give some rigidity and provides attachment points to the module. The inside can be one big open bag, or it can have smaller bags with cloth shelves that can be installed or removed for different configurations depending on the kind of supplies and equipment that it will be storing. There are small wires or thin poles to keep the bags in the expanded shape but there isn't a need for structural supports since there isn't gravity pulling on the stored equipment.

Design Challenge

- Maintenance
- Keeping the stall clean and dry is essential. Bacteria and mold can easily grow in damp environments. Water will not cling to the walls of the stall. It will accumulate in spheres (drops) and float. Any floating water will have to be captured and stored.
- Cleansers are prone to off-gas, so you will need to design mechanical methods of cleaning and drying the stall

1. https://www.nasa.gov/mission/gateway/
2. https://www.nasa.gov/gateway-deep-space-logistics/
3. https://www.nasa.gov/gateway-deep-space-logistics/about-gateway-deep-space-logistics/
4. https://en.wikipedia.org/wiki/Gateway_Logistics_Services
5. https://airandspace.si.edu/stories/editorial/how-shower-space

http https://www.flickr.com/photos/nasa2explore/53125157076/in/album-72157716027881092

Requirements for Collapsible Hygiene stall

Demonstrate

1. Prototype must be 1/6 scale model. Have a similarly scaled doll/action figure to show positioning of astronaut inside hygiene stall.
2. Your prototype must include lights, connections for ventilation hose (inflow and outflow), attachment for personal hygiene kit, restraint system to stabilize astronaut, method of cleaning interior after use.
3. Materials for the scaled Hygiene Stall may be different from the proposed final material –samples of the proposed materials should be shown if available. You must have a list of recommended materials for building a full-sized hygiene stall.
4. The proposed material must be opaque or not cast a significant silhouette of an astronaut who is inside.
5. Show that your hygiene stall collapses into a volume less than 2in x 2in x 4in
6. Must have multiple attachment points for securing the hygiene stall to handrails or other internal structure
7. Use a scaled portion of the shell of the module to deploy into and include any handrails or structural supports needed to hold your hygiene stall in position (keep it minimal, it is zero-g)
8. **You must demonstrate that the hygiene stall can be deployed from its collapsed position, and subsequently taken down, by one astronaut, within 3 minutes.**