Mars Trash Ejector

Glenn Johnson

On the way to Mars and the return trip to Earth, the astronauts will accumulate a significant amount of trash. The mass and volume of that trash could be detrimental to the crew's mental and physical health as well as be a significant impact on the fuel.

Having a plan for dealing with trash for a long mission will be essential to success. There are many considerations that need to be made so that that our first mission to Mars does not ruin a main goal with our trash nor damage current or future vehicles going to Mars.

Reasons for ejecting trash before arriving at Mars

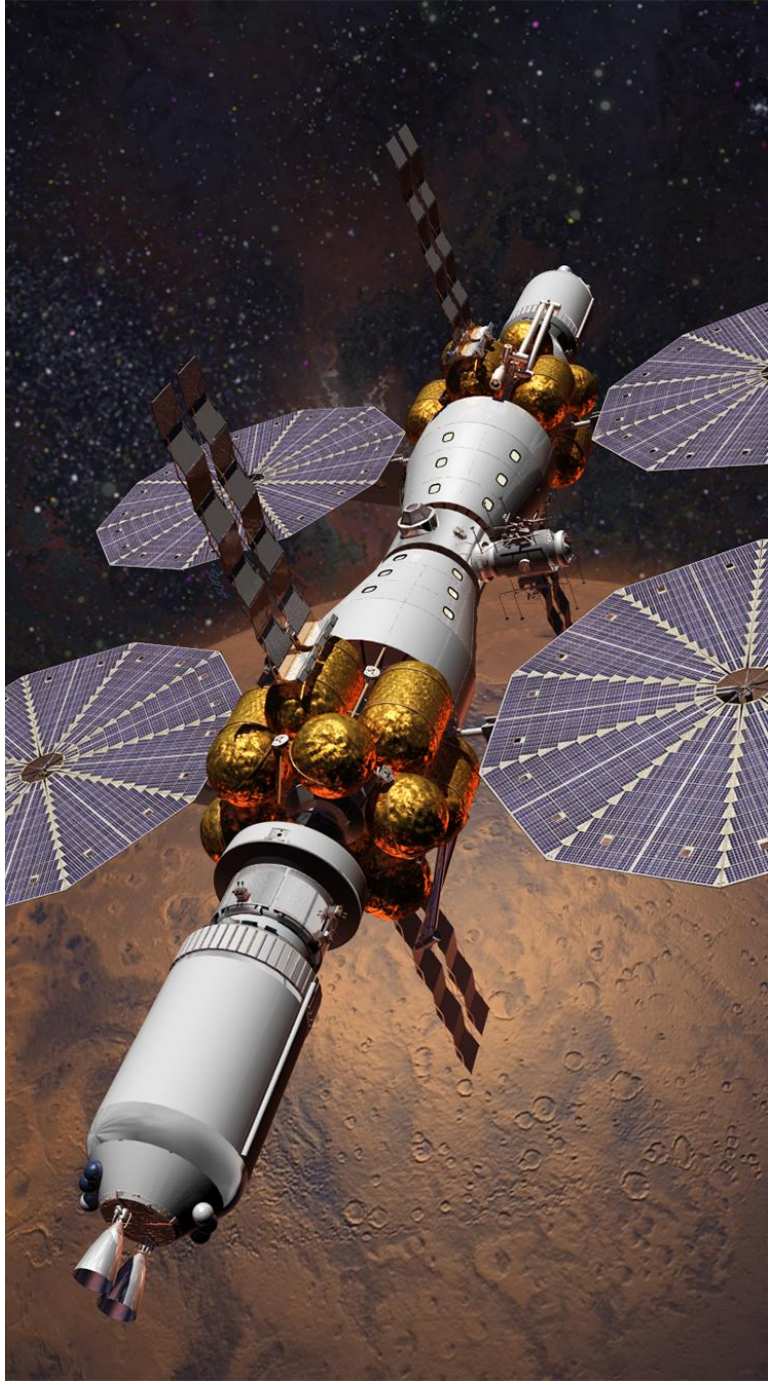
Save fuel for slowing the vehicle down when arriving at Mars/ when leaving Mars/ when arriving back to Earth

Minimize chances of bacteria build up inside with the crew

Increase volume inside the vehicle as crew consume materials

Minimizing stink---Save on operation of the trace contaminants system

Preserving mental health of crew



Design requirements

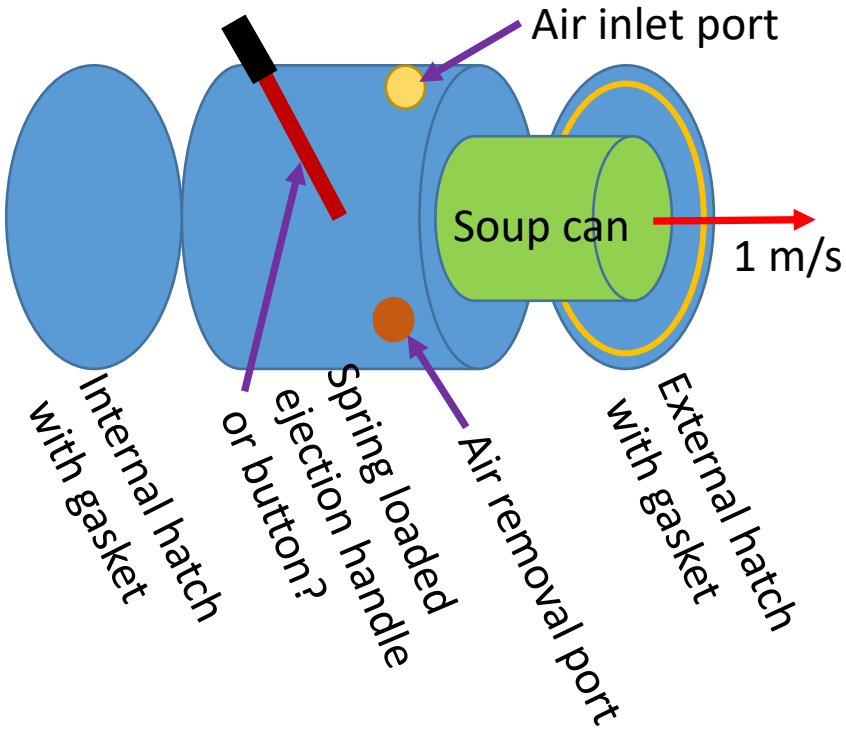
Problem:
On the way to Mars or any distant destination, the astronauts will be eating food, repairing the ship and accumulating trash. If they hold on to all of the trash, until they get to their destination, they will be smelling up the vehicle and taking up lots of space. They will also require more fuel to slow down than if they get rid of the trash on the way. We need some kind of trash ejector to get the trash out and away from the ship and, better yet, burn it up in the Martian atmosphere or Earth's if they are coming home.

Objective:
Design, build and test a scaled **TRASH EJECTOR** for the Mars vehicle that will allow astronauts to dispose of their trash containers safely on their way to and from Mars.

- The trash containers on the ISS are similar to a 5 gallon bucket—that's too big for you to demonstrate with. Design yours to eject a **full can of Cambell's Chicken Noodle Soup as your demonstrator**. You should be able to demonstrate with either a rigid container or a soft container bag but it should be more densely packed (not a pillow).
- **Internal Hatch**--the crew will open to insert the trash container (your soup can)
- **External Hatch**--open out into space so they can shoot the trash away.
    - Method for opening and closing the external hatch from inside the space craft.
        - Rotate outward, rotate upward, slide?
- Some method of inhibiting both hatches from being opened at the same time (we want to keep all the air in the space craft).

- Be able to show a how air will enter and be removed from the trash ejector so the crew isn't consistently throwing away the air supply or fighting to put trash in. This does not need to be functional (no air pumps needed) but you should be able to show how you will let air in and remove it.
- Will it be spring loaded? Pneumatic? bungees can't handle the cycles needed or the exposure to space.
- Some kind of handle or button for releasing the trash.
- Trash needs to be held in place until the crew is ready to shoot the trash even if the outside hatch is open.
- Make it so the trash is **ejected no faster than 1 m/s. (don't dent the wall)**
- ~~Should be adjustable so that there are settings for .5kg of trash or less, 1.0kg kg of trash or less and 2.0 kg of trash or less. Its ok if you have more settings as well.~~
- Can you make the trash container spin (like a bullet or football) as it exits the ejector so that it is more likely to stay on the correct path? It doesn't have to be fast rotation. It would be best if it is not tumbling. **This is not a requirement just a thought to consider.**

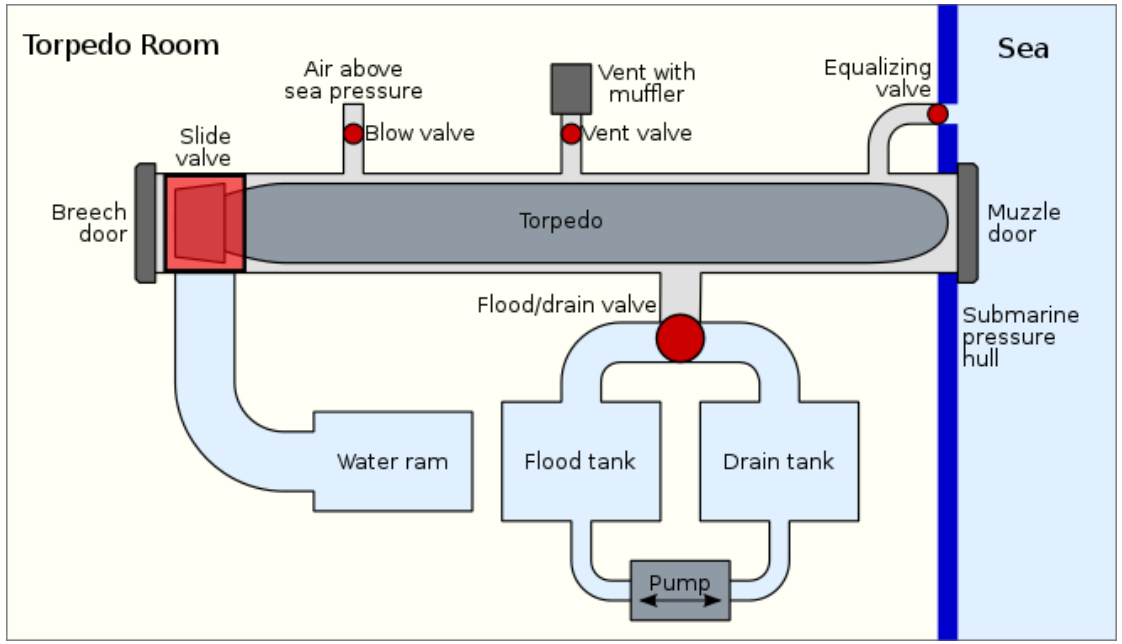
- It is ok to add structure to the outside of the soup can but you are not to remove soup from the can. it must still contain the soup. You may remove the label if you like but it still needs to be cambell's chicken noodle soup—consistent mass.



Torpedo tube

- This is a link to a tour of a submarine torpedo tube that has some similarities to what we are doing with a trash ejector. A torpedo tube is a lot more complicated than what is needed for ejecting trash but there may be some ideas worth understanding relating to the valves. Plus it's pretty cool.

- https://www.youtube.com/watch?v=UYEyhB0AGlw

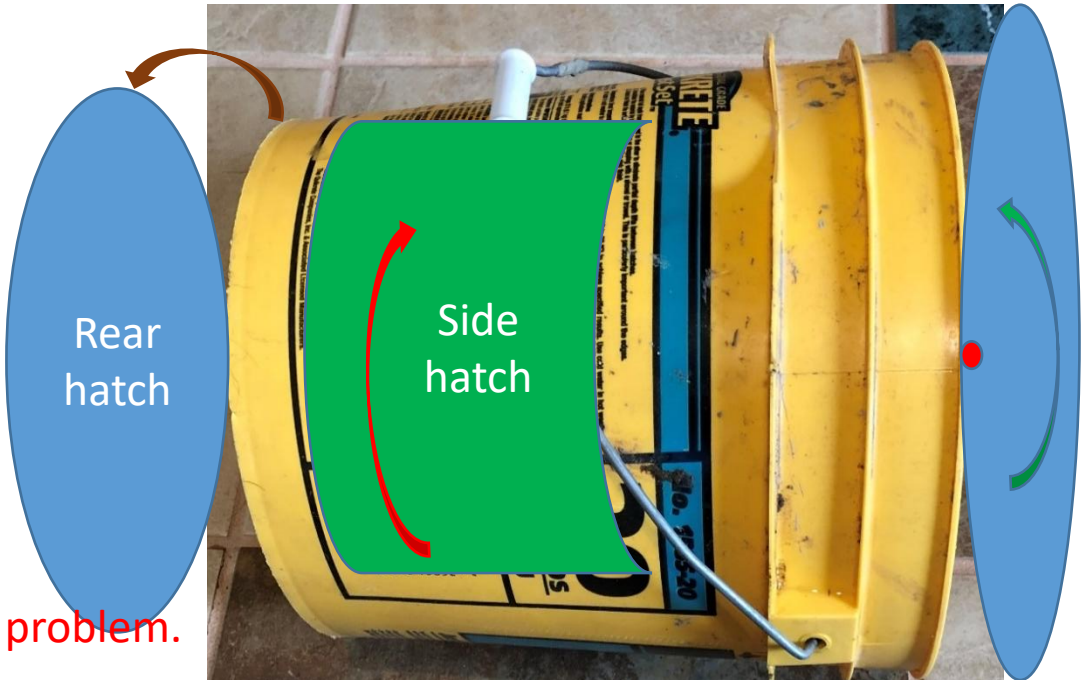


Two projects?

I could see this project being divided up into two different teams. Separating it into two different tasks can also help clarify what needs to be done.

- **Team 1**--develop the **trash can pusher**
  - Springs—one spring in the center to shoot the can like in a pin ball machine or one spring on each side
  - Motors and spinning wheels—hot wheels car shooter, football thrower, tennis ball shooter
  - Other option I haven't thought of
- **Team 2**--develop the **airlock** that holds the trash can pusher
  - Remove the bottom out of a paint can and develop doors for each side
  - Piece of pipe
  - Hinge rotates rear hatch open, pivot the exterior hatch on a pin?
  - How to open the exterior hatch from the inside?
  - Would it be better to have the internal hatch on the wall of the pipe or on the end of the pipe—depends on how you decide to position the springs or motors/wheels inside the airlock

Trampoline springs are much bigger than needed but could be arranged with a pusher plate to eject the can. The can could be place through a side hatch. A pusher plate hatch could be used to allow for rear loading of the can if a side hatch is not possible.



These are just ideas to help you think about how you want to solve this problem.

Problem description:

- On the way to Mars, astronauts will be generating a lot of trash. Some will be plastic wrappers from food, some will be solid waste from eating the food, some will be waste from experiments or broken parts that were replaced with good parts. At least 1 kg per person per day.
- This mission will be for 4 to 6 months to get to Mars. On the way home from Mars they will probably have a similar amount of time of travel. You can imagine they will produce a lot of trash. As they approach Mars, they will need to slow the vehicle down to enter a Mars orbit. The less mass their ship has, the less fuel they have to burn to slow down. If they have to hold onto all of the trash until they get to Mars, they will have to take more fuel to burn to slow them down. If they can get rid of some or all of the trash before arriving at Mars, the vehicle would have less mass and they would not need as much fuel to slow down.
  - If the crew is required to hold onto the trash all the way to Mars and back to Earth, this amount of mass would require over 300 kg of extra fuel to slow down the space craft than if they could get rid of the trash ahead of time. (page 15 and 16)
- However, they don't want to just throw the trash out. They don't want the trash to stay in any orbits that it might damage their ship on this mission or another future ship.
- One option is that the crew could burn up the trash and eject the combusted materials but to burn the trash would require having oxygen to burn the trash with. We would rather have oxygen for breathing.
- If instead they eject some or all of their trash before they start to slow down. It would be best if they could aim the trash so that it burns up in the Martian atmosphere to prevent the trash from staying in some kind of orbit that could be a problem later.
- The Martian atmosphere is much less dense than Earth's and is mostly carbon dioxide. Coming into the atmosphere at several thousand miles per hour will certainly heat up the trash but will the trash 'burn up' if the atmosphere is mostly carbon dioxide? Will there be a long enough path through the atmosphere to heat all the way through the container of trash to kill off any microbes before it hits the ground? These are questions that need to be answered before we send our trash there but not all of this is your responsibility.

Removing the last of the air

- We expect that the crew will be ejecting at least one canister of trash per week, maybe more. When ejecting trash, we don't want to lose any air from the vehicle or at least minimize the loss. The bigger the trash ejector compared to the trash canister, the more air could be lost.
- It should be a goal to keep the size down for both the loss of air and also the value of internal volume of the space craft for the crew.

Valves and vacuum pump?

- For the flight unit that flies, there will be a vacuum pump and a valve to remove air from the trash ejector before opening the external hatch to space. There will also need to be a valve that allows air to get back into the trash ejector so you can open internal the hatch to more trash inside. Your prototype does not need to have a vacuum pump but your prototype should have these two valves represented and labeled so reviewers can follow your plan.

How much air is left in the trash ejector once a trash container is installed? Reviewers will want to know.

- If you are able to size your ejector so that there is only 10% of the total volume of air is left when a trash container is installed, you wouldn't need to have a valve and vacuum pump to remove the remaining air. But you will still need to have a valve for letting air in.

Protecting for the possibility of Life on Mars

One of the most important parts of the mission to Mars is the search for life. We want to know if there was life or if there is life on Mars. If we find some kind of evidence of life, we will want to know if it is different from that on Earth, the same or similar. We want to make sure anything found on Mars truly originated on Mars. Therefore it is important that Earth does not contaminate Mars before we have a chance to look.

- NASA and other space agencies have been careful about sterilizing any landers or equipment they send to Mars. If we send people, we will have to not litter the planet with our (Earth) DNA.
- If we send our trash to Mars we have to make sure that the trash is sterile.
- Because the Martian atmosphere is very thin compared to Earth's (about $1/100^{th}$ as dense) and mostly carbon dioxide, any trash sent to 'burn up' in the atmosphere will certainly heat up as it approaches the surface but it may not 'burn' without oxygen. It also may not heat up long enough to sterilize the trash and then impact the surface and spread human and Earth DNA to the Martian surface—NOT A GOOD THING.
- One option that may help would be to design the trash containers specifically for the Martian atmosphere to aid in burning up and/or sterilizing the trash. There are some materials that can burn better in carbon dioxide than in oxygen. Lithium, magnesium, boron and aluminum will all burn in Carbon dioxide, some better than others. Magnesium burns even hotter in carbon dioxide than it does in oxygen. What if we made the trash containers out of magnesium or similar alloy so that as the trash enters the atmosphere of Mars, it burns hotter and sterilizes any trash contained inside. So even if some of the trash makes it to the surface, it won't interfere with the search for life. The size and shape of the trash containers would be important in making this work.
- https://www.sciencedirect.com/science/article/abs/pii/S0082078489801754
- **This is not a problem that needs to be solved by students but only some thoughts to be aware of.**

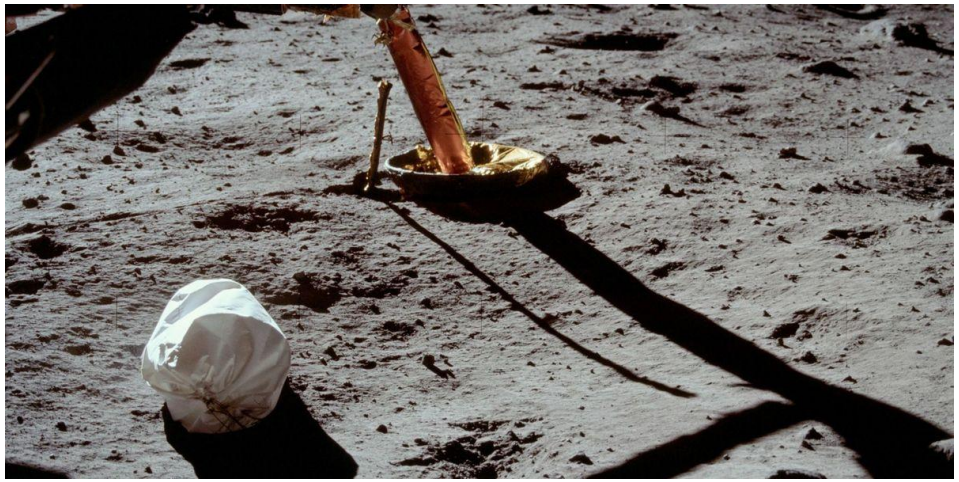
Plastic for Radiation Protection

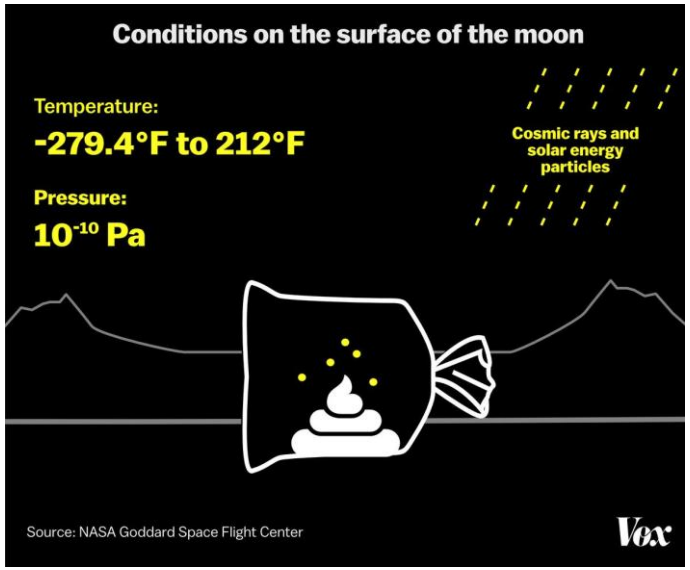
- Since the space craft will be outside the Earth's magnetic field, cosmic rays (high speed, ionized atoms) will be a significant problem on the way to Mars. The food and packaging contains a significant amount of water, organic material and plastics that are pretty good at absorbing some of the radiation that is coming through the ship. As the crew eats through their supply, they are losing some of their radiation protection. Some groups at NASA are working on ways to take some of the plastic food packages and compress and melt them into circular or square pucks that could be used as additional radiation bricks for protecting the crew as they continue their mission. These pucks could be placed around the crew's sleeping quarters or other areas where the crew spends lots of time to help absorb some of the damaging radiation before it impacts the astronauts. There will be lots of other trash that will be smelly and NASA will not want it in the space craft with the crew.

Plastic food packages, with some visible food residue, melted into a circular, plastic puck for potential use as radiation protection.

A little History of trash in space

- Apollo--In the Apollo program, the astronauts were very weight sensitive. Only essential equipment, supplies and samples came back from the lunar surface. Before they took off with the ascent vehicle, they would open the hatch and toss out a JSB (Jettison Stowage Bag—a big cloth bag) with all their trash in it and then take off with only their rock samples and as little else as they could. (The same style bag is still being used on the ISS today and are sometimes made by HUNCH students.)

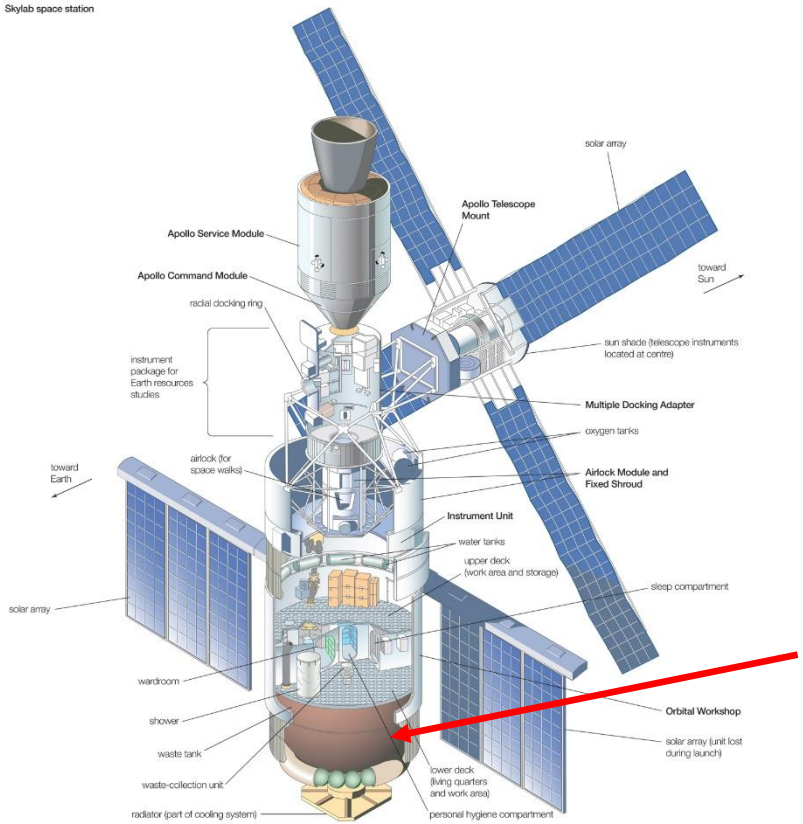




Skylab Trash

- Skylab was the first U.S. space station from 1973-1979. It was inhabited for over a year by 3 different crews but was then pushed up into a higher orbit in hopes that the Space Shuttle would be finished in time that it could dock with it and be a regular destination and research lab for shuttle missions. The Shuttle wasn't finished in time and Skylab burned up in the atmosphere. While the crews were on Skylab, all of their trash was placed in a container separate from the crew quarters at the back end of the ship. When Skylab eventually burned up, so did all of the astronaut's trash from all of the missions.
- When doing space walks, there may have been a few things that were released by the crew to burn up in the atmosphere but it was uncommon to release waste material.

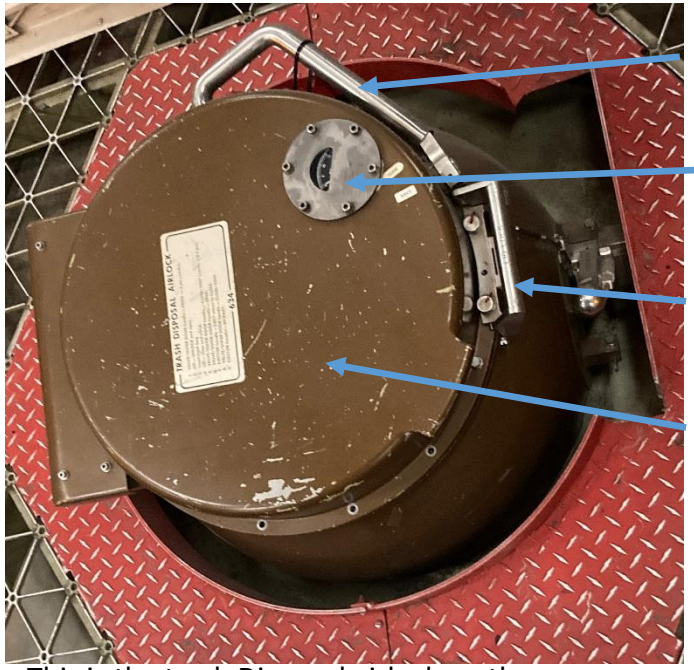
This is two Skylab astronauts in the living quarters with their heads next to the opening of the trash hatch.



The trash container is the brown tank at the bottom of the picture.

Skylab was a very large space station for its time and many excellent attributes.

Two astronauts are preparing to put trash in the trash airlock. It is pushed into a large tank at the bottom of the space station and stays there and burns up with the rest of the space station when it enters the atmosphere. The tank is at a vacuum.



This is the trash Disposal airlock on the Skylab trainer at Space Center Houston.

Ejector handle for pushing trash into the tank.

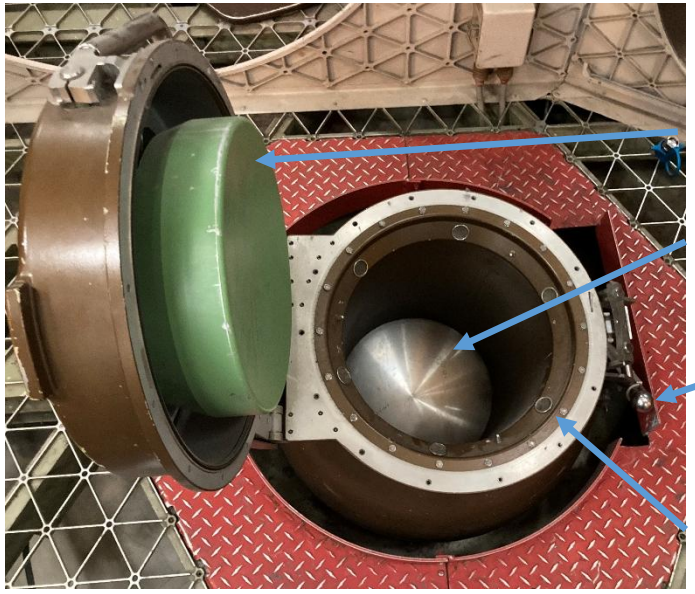
Pressure gauge

Latch for locking internal hatch

Internal hatch

Gasket for sealing internal hatch

Extension of the pusher plate



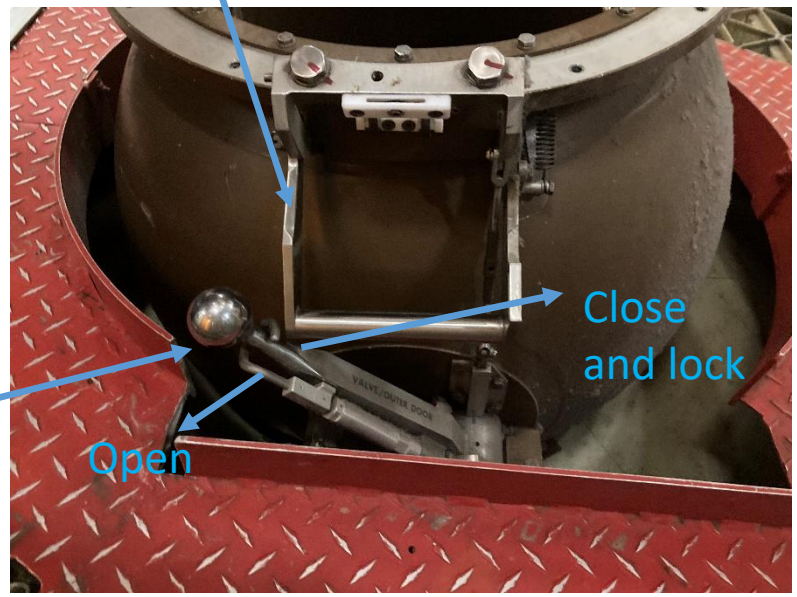
Trash pusher plate

Hatch to the tank (closed).

Lever for opening the external hatch to the tank.

Vents for equalizing pressure (6).

Latch for locking internal hatch



Instructions of how to use the Skylab Trash Disposal Airlock

Engineering videos of Skylab (just interesting)

https://www.youtube.com/watch?v=ieav_xSonoQ
https://www.youtube.com/watch?v=rNLMpcH9Rqc
https://www.youtube.com/watch?v=WAjKiPfkpus
https://www.youtube.com/watch?v=vHVqFvHrFiI
https://www.youtube.com/watch?v=6YwoTWuLfzQ

Space Shuttle Trash

- All the trash from inside the shuttle, food packaging, experiment waste, old procedures,… ,comes home in trash bags and lockers and is later thrown away and disposed of. Solid and liquid waste in the space toilet is dealt with differently. All the urine is temporarily stored in a tank inside the shuttle. Once it gets filled up, the crew turns the shuttle and opens a valve to release the urine in the opposite direction of the shuttle's orbit (retrograde) so that it will re-enter the atmosphere sooner than later. The solid waste from the crew is kept in a container of the toilet and is removed once they return to Earth. The toilet is cleaned, refurbished and readied for another flight.
- If they were upgrading or repairing a satellite as part of their mission, the old parts might be released into space but it has to be released in a fashion where the parts will re-enter the atmosphere relatively soon to burn up and it won't be able to come around in a few orbits and damage the space shuttle. There had been times earlier in the space program when NASA and Russia were less worried about the trash they would release into space. But over time they realized they were having to track more and more dead satellites, trash, debris and other, nuts, bolts…. After many discussions, all of the space programs have realized the importance of minimizing their trash and are working to cut back on orbital debris. We don't need to add to the amount of trash that is in orbit.

It was important to compact the trash on the shuttle as much as possible to retain as much space as possible for the crew and the experiments.

Space Shuttle toilet contains all solid waste. Liquid waste was vented to space.

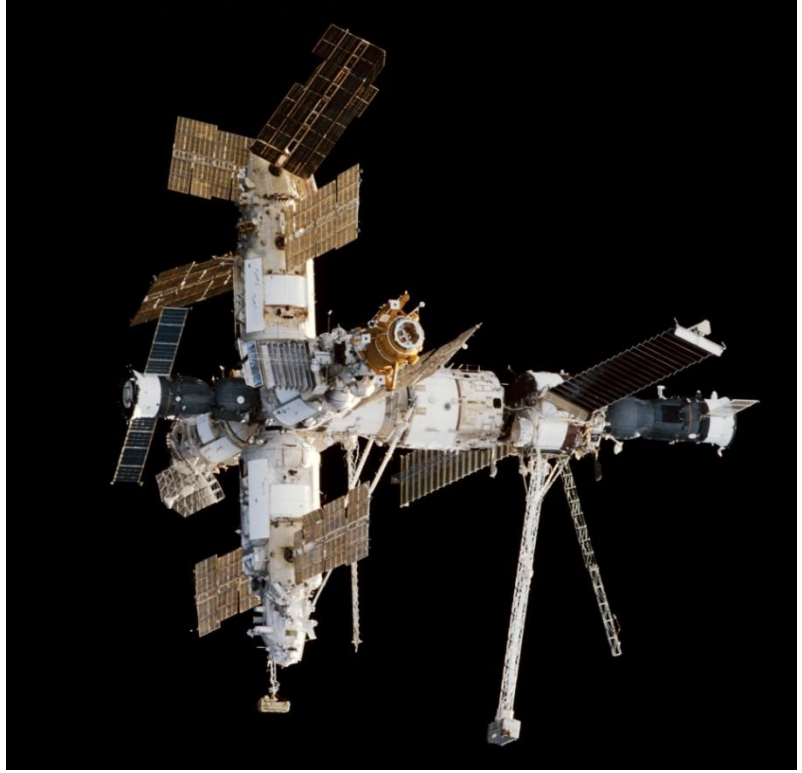
When the solar panels for the Hubble Space telescope were replaced, they let the old solar panels go so they could burn up in the atmosphere. Their large surface area and low mass meant they would fall into the atmosphere fairly quickly.

Mir Space Station trash

One time when I was at the airport preparing to fly somewhere with my family. I was waiting in the TSA line and a few people behind me was Shannon Lucid, the American astronaut who had stayed on the Russian Mir Space Station for 179 days—an American record for a long time. I had never met her but I knew that most of the astronauts were very friendly and usually didn't mind being approached as long as I could be discrete and not call attention to them. I turned toward her and introduced myself and told her where I worked at NASA and how I had recently come back from Russia where I had received training on many of the human related systems like the toilet and galley system. One item I didn't get training on but was interested in was the small air lock for disposing of trash. My colleague and I had glimpsed a strange aluminum tank with a long lever sticking up on one side in the corner of one of the training rooms at Star City. We asked our trainer what it was and he briefly described it as a spring loaded trash ejector for the Mir Space station but they didn't train it any more. He didn't tell us anything else and I wasn't smart enough to take a picture. We left the training with questions in our heads but too filled with other information swirling around in our heads and didn't ask anymore.

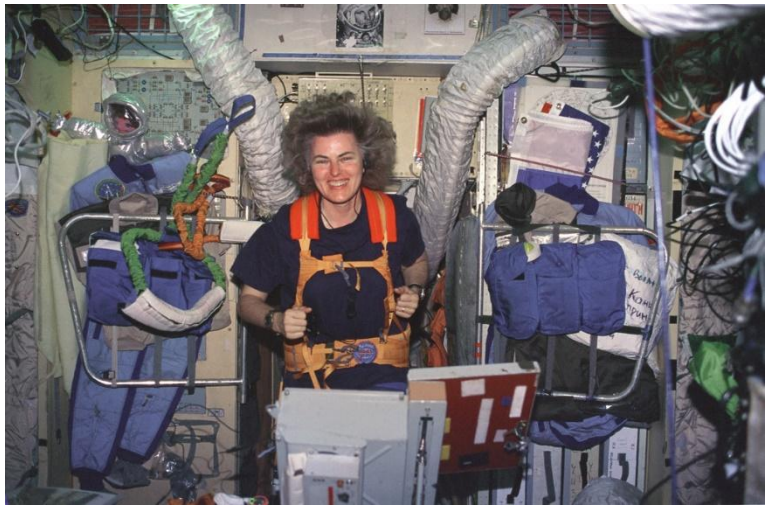
So here was my chance to ask someone who may have ejected trash out into space …"Shannon, Did you every get the chance to use the trash ejector?"

She looked at me with a big grin (I don't think she expected a trash question). "No I didn't." with a little bit of disappointment in her voice. "They had just stopped using it before I arrived." So she didn't get training on it either. We chatted for a few more moments while we waited in line about where we were going and what we were doing and then parted ways. I was no wiser but still glad I had asked.

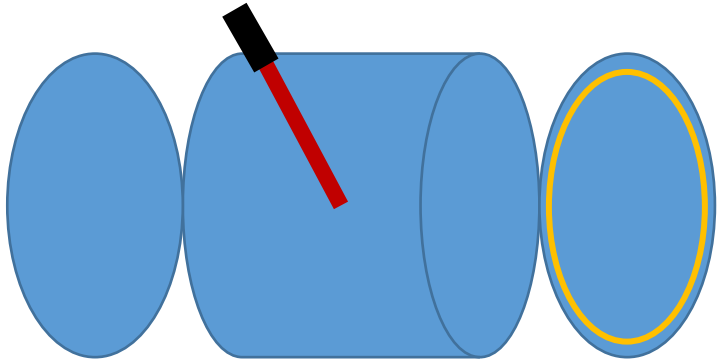


Mir Space Station with a Progress supply ship docked on the right side and a Soyuz docked on the left.

The majority of trash on the Mir Space station was placed in the Progress supply ships and burned up when it re-entered the atmosphere. Some trash was ejected through their trash ejector (mostly poop and urine cans) in the early part of the program but was discontinued to cut down on the amount of orbital debris.



Shannon Lucid running on the treadmill during her stay on the Mir Space Station



ISS trash

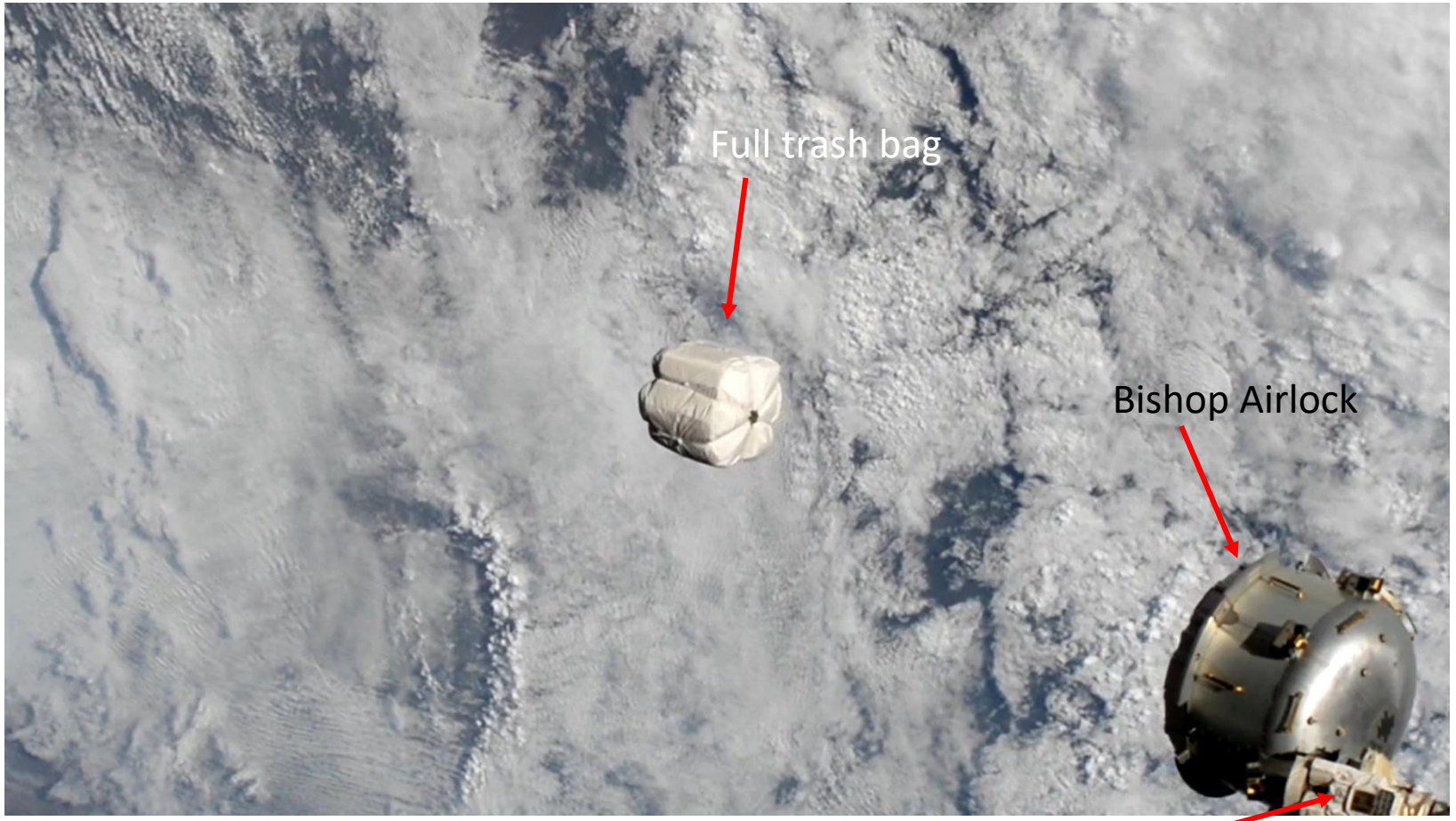
- Currently on the International Space Station, unmanned supply ships bring supplies of food, batteries, air, water… to the ISS and once it docks, the astronauts take all supplies and experiments out of the supply ship. As soon as they have cleared some space inside the supply ship, they start filling it with the trash they have been accumulating. Since supply ships only come every 1 or 2 months you can imagine they have a lot of trash they need to get rid of. (what would it be like if you had to keep all of your trash in your house for two months while you waited for the trash truck to show up?) Once they have filled the supply ship with trash, it undocks from the ISS and then is put on a path so that it burns up in the atmosphere somewhere over the south Pacific (even the ship). Most of the materials burn up easily, if there are any large pieces, they land in the Pacific ocean where there is very low likelihood of impacting any people. Occasionally there are pieces of the Station, usually on the outside, that are being replaced and are too big to bring inside and be thrown away in a supply ship. If it can be thrown in the opposite direction the station is traveling (retrograde) without damaging the space station, NASA is preparing to boost the station up to a higher orbit and the object is expected to fall into the atmosphere fairly soon, the astronauts will be given permission to literally throw it away. This doesn't happen often but it does happen sometimes.

JSB's full of trash being readied for disposal in a supply ship.

Cygnus supply ship leaving the ISS filled with trash and preparing to burn up in the atmosphere.

Ejecting trash from the ISS

The ISS has tried using Bishop --the NanoRacks Airlock-- to eject trash as an experiment. Normally the airlock is attached to a hatch on the ISS and can be removed by the Canada robotic arm. This exposes anything inside the airlock to the vacuum of space. Engineers designed a specialized trash bag and a spring loaded ejector to fit inside the airlock. This allowed the crew to get rid of some extra trash in between supply ships.



NanoRacks Bishop Airlock

- https://www.youtube.com/watch?v=vQdkcDwyGZQ
- https://www.youtube.com/watch?v=A9KmZ_kZUlg&t=19s

Solid waste buckets

- KTO is a Russian acronym for a solid waste container. It holds about 10 days worth of poop and paper. Once it is filled up, the crew remove the white seat and close the top lid. Often they will shove as much hand wipes and other trash into it just to use up as much of the space as they can. They are not quite as big as a 5 gallon bucket (maybe about 4 gallons). Although they are mostly sealed to keep all the stuff inside, they are not perfectly sealed. The solid waste is not dry and is at room temperature so the microbes are still working on it generating methane. If the container were completely sealed, the pressure would build up and become a new hazard. Therefore some of the gas is able to come out making it better to have it away from where people are spending a lot of time. This is probably why the Russians wanted to be able to eject their trash from their earlier space stations.
- I do not expect that the solid waste buckets used on the mission to Mars will be the same as those used today but they will probably be similar in size, general dimensions and functionality.

KTO with seat and air hose attached.

Used KTO waiting for disposal.

Empty KTO without seat attached and lid open, hose attached

KTO with lid closed, hose attched

Soft container trash

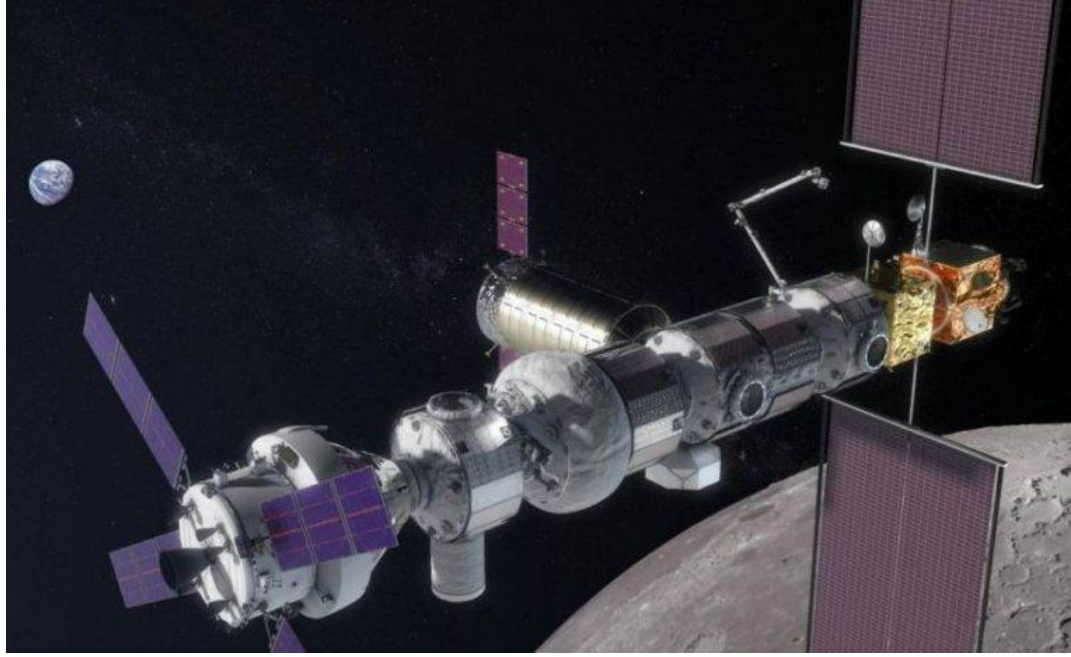
- The ISS uses 8L Sea to Summit green trash bags off the shelf but NASA changes out the closing clips and put in a draw string instead. The astronauts stuff it very full of plastic food packages (empty of most food but not clean), hand wipes, condiment packages (empty but not clean), Russian and ESA food cans, trash from experiments,….then it is usually placed into a Jettison Stowage Bag (JSB) where it will stay until the next supply ship is ready to be loaded for leaving. The sea to summit bags are tightly woven nylon that kind of hold the moisture and stink in but not entirely. When full these bags are a little bigger than a foot ball but can be different shapes depending on the contents.

Liquid waste containers

- All the water on the space craft will need to be recycled--including the urine. However, after cleaning the water, there are waste products that are left in a kind of sludge like liquid that will need to be disposed of. On the ISS, NASA recycles about 90% of the water. For the mission to Mars water recycling may get up to about 95%. The 5% they discard will be the sludge like material. Currently the ISS disposes of waste liquid in an EDV—a Russian acronym for a water container. These containers are sealed but there is a limit for how long they can hold the liquid (many months). These containers are similar in size and general dimensions to the KTO and would be disposed of in a similar fashion.

Going back to the moon

- Right now the plan for going back to the moon includes the Gateway space station that will be in orbit around the moon. This will be a location for supplies to be sent and stored before going to the moon. This means NASA and the other participating nations will have supply vehicles that will dock to the Gateway and could take trash back to an Earth orbit and burn up along with the trash, similar to how the trash from the ISS trash is dealt with. What we do with the trash on the moon is another story. I don't expect that the trash will be sent to Earth as that would take a significant amount of fuel to get it off the moon and back to Earth atmosphere. I suspect it may be buried to get it out of the way or it may sit on the surface until they have a better plan.



Requirements for Trash Ejector

Trash ejector

Demonstrate how your scaled trash ejector will eject a full can of Cambell's Chicken Noodle Soup at a speed of less than 1 m/s

1. Open interior hatch without being able to open exterior hatch
2. Load soup can
3. Close hatch
4. Show how air from trash ejector can be removed
5. Open exterior door from inside without being able to open interior hatch
6. Eject can of soup at less than 1 m/s
7. Close exterior hatch from inside
8. Show how air can be let into the trash ejector before loading another trash can