Zero-g bulk transfer system

Glenn Johnson with Samantha Cristoforetti

Develop a system that will allow astronauts to transfer loose particulate from a bulk bag to a smaller bag in a controlled fashion to help minimize the packaging and trash in the space program.

Reducing trash in space

- Trash is a constant battle on the ISS. When launching equipment, supplies and hardware to the ISS, there is often foam packing to prevent materials from getting damaged from the vibrations of launch. Occasionally, wipes, clothing and food packets can be used as packing material but when dealing with a truck sized volume of supplies, that can be very difficult to keep track of all the materials. This means that there is a large amount of foam, plastic bags and other packing material—a significant amount of trash that flies to space and takes up a lot of volume.
- When an astronaut is preparing to go to the ISS, they might ask the Food Lab to send up a big bag of almonds because they really like almonds. But the Food Lab can't send up a big bag of almonds or other bulk food items because when the bag is opened, without gravity all of the almonds will be floating in the bag and the action of opening the bag pushes the almonds out the top of the ziplock bag. To avoid clouds of almonds, almond dust and salt getting into the astronaut eyes, nose and all over the space station, the almonds are packaged in single serving packages that contain around 15 or 20 almonds so they are easier to control. This means instead of one larger plastic bag there are now 15 or 20 little trash bags. This happens to a lot of food items (m &m's, jerky, peanuts, skittles, dried fruit,….) which means there is a lot of little food bags and a lot of trash.
- Astronauts work hard to pack away their trash as it is generated and pack it into as small a space as possible.

Normally these rounded Jettison Stowage Bags are used for holding much of the trash but other times any empty bag can be used for trash.

Notice how the m&m's float all over inside the bag.

Zero-g Bulk Transfer System

Problem:

The current solution to controlling the many little nuts, bolts, almonds, m&Ms, Leggos, … is to wrap them in small containers but all of these small packages add to a very large amount of trash. Is it possible to control the many, many particles that can be inhaled, float into eyes, clog up electrical connectors, obstruct air vents and cause many other problems in zero-g without sending more trash to the ISS or other space craft? Because of the lack of gravity, we end up having to send up many plastic packages to control the small particles. If we could come up with a system that would allow the transfer of small particulate from a large, flexible, bulk bag to a smaller container we could save NASA from sending up a lot of packing material that turns into trash and adds to other trash issues on the International Space Station.

Objective:

Design a systems that would allow the transfer of the contents of a large flexible bag of almonds to a smaller container in a controlled fashion in zero gravity.

Requirements:

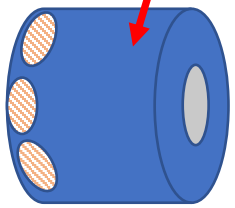
- Need to be able to control the amount of particles being brought into the new container
- Needs to be easy to clean
- Helpful if the new container is transparent
- Could be hand powered or battery powered
- The easier it is to operate, the more likely someone will want it.

Tips:

- This sounds easy but is complicated because most people have a hard time envisioning lots of particles floating around in space and controlling them.
- This will be difficult to demonstrate on Earth since we have gravity-----maybe try small Styrofoam balls or packing peanuts?
- Could small, low volume fans be used to pull materials into the smaller containers.
- Could this be done with centrifugal force with rotation pulling the particles in a controlled fashion?

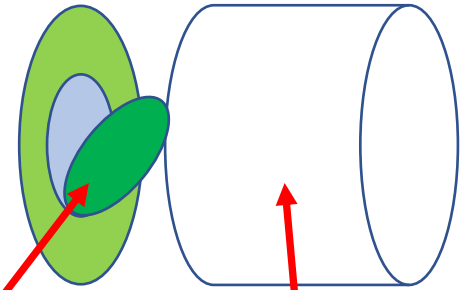
There are probably 10 different ways to solve this but this may give you some ideas of the complications and the needs of the crew.

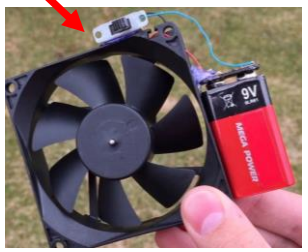
Adapter for the flexible bag to the smaller container with a restricting hole to help control flow of particles. May need air holes that will allow a mixed air flow to prevent all of the almonds from getting sucked in all at once.

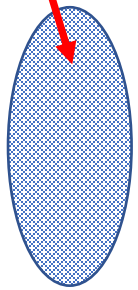


Small, battery powered computer fan with a switch (maybe rechargeable)

Screen to protect fingers from fan blades







Does there need to be air flow through the bag of particles to pull them into the smaller container? Gentle squeeze? Do you need to make a special bulk bag?

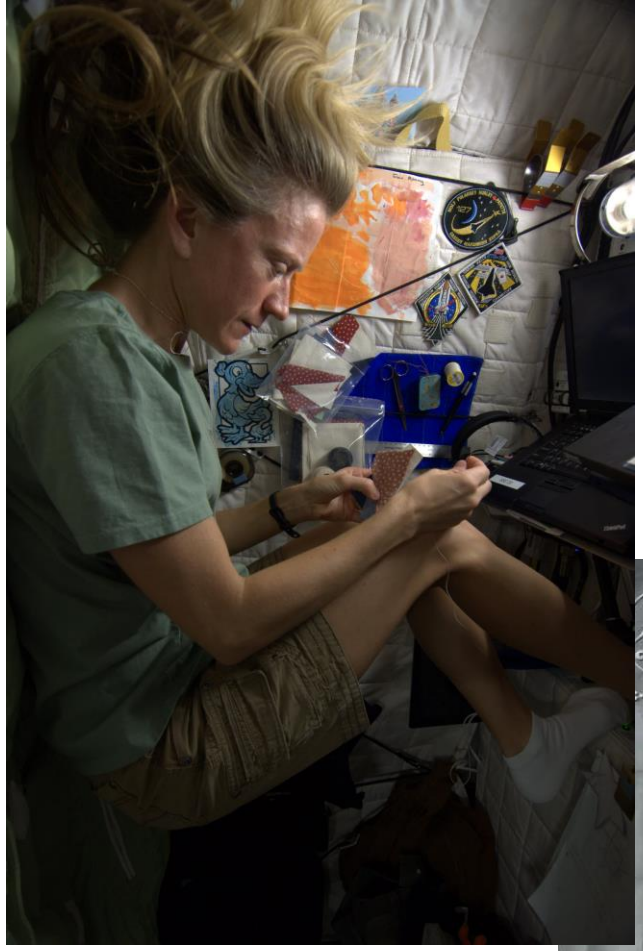
Self closing flap or lid that keeps the almonds inside once it is filled to desired amount

Rigid or semi-rigid transparent container that small particulate can be transferred into.

Replaceable/ cleanable filter—keeps the nuts out of the fan.

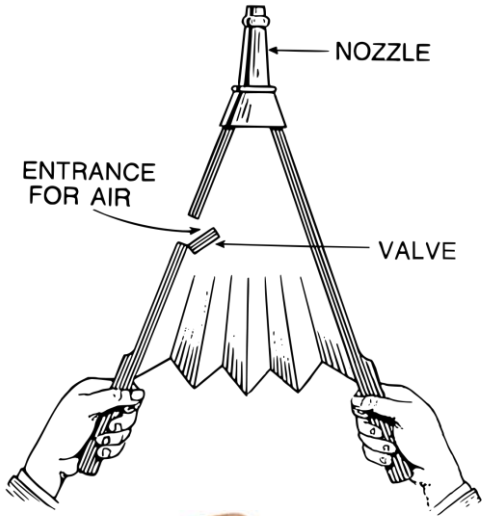
Controlling your space

- One astronaut told me that any time they open a ziplock bag, the motion of opening the bag will push items out of the bag in zero-g. It was very easy to lose parts if trying to get just a few things out of a bag. So if he had a bag of nuts and bolts or other loose items in a ziplock bag he would take it into his Crew Quarters (sleeping rack) that was a smaller volume and open the bag inside. This kept him from having to hunt all over a whole module to find the escapees.

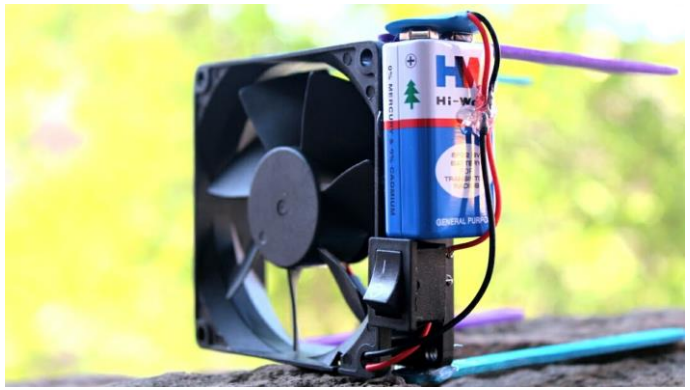


What can you use to for inducing air flow?

Could you use a cloth bag inside instead of a transparent container to capture your almonds.



Could you use a small bellows to pull the almonds from one bag to another instead of a fan?



Centrifugal vs Centripetal

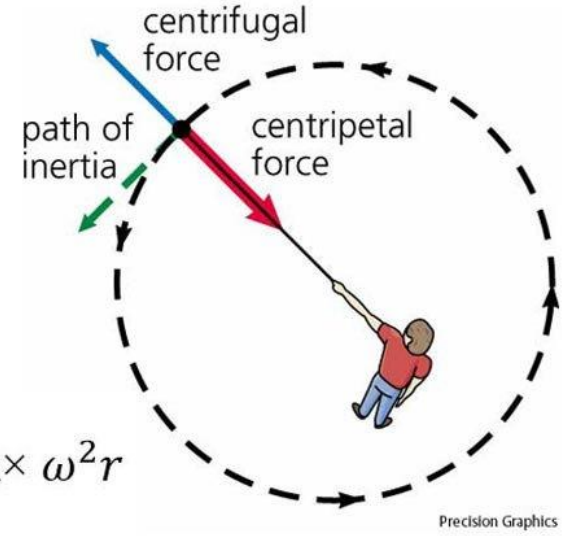
As a kid on the farm, I would swing a bucket of water in circles up above my head to see how to keep the water from falling on my head—sometimes I got wet. As I swung the bucket, the tension in my arm to hold the bucket is the centripetal force. The force that keeps the water in the bottom of the bucket is the centrifugal force. NASA uses both of these forces for a variety of equipment. There are several separators on the ISS that use centrifugal force to separate air from the liquids. This is used in the Water Reclaimation System, the Russian Electron System for generating oxygen from water and also in the Waste and Hygiene System for separating the urine from the air in the toilet system. All of these systems are rotating so the liquids go to the outside and the air is positioned in the center. This may be very different from separating almonds from a big bag to a smaller bag.

- https://www.youtube.com/watch?v=zdNH8gg2s-Y
- Notice how the banana peal separates from center of the banana
- https://www.youtube.com/watch?v=PPvHZAAGuW4
- Notice that the center of rotation determines whether the liquid goes to both sides or to one side.
- https://houstonpbs.pbslearningmedia.org/resource/npe11.sci.phys.maf.centripetal/teaching-from-space-centripetal-force/
- These are videos by Samantha Cristoforetti while on the ISS. This is a great example of how centrifugal force can be used to transport particulate to another container. The trick is making it easier for the astronaut and having the control to transfer only what you want. Notice how she is manipulating her feet to get the rotation she needs.
- https://youtu.be/6ywpnA_Wwh0
- https://youtu.be/RPCXAspbjEo

Centrifugal Force

$$F = m \times \frac{v^2}{r}$$

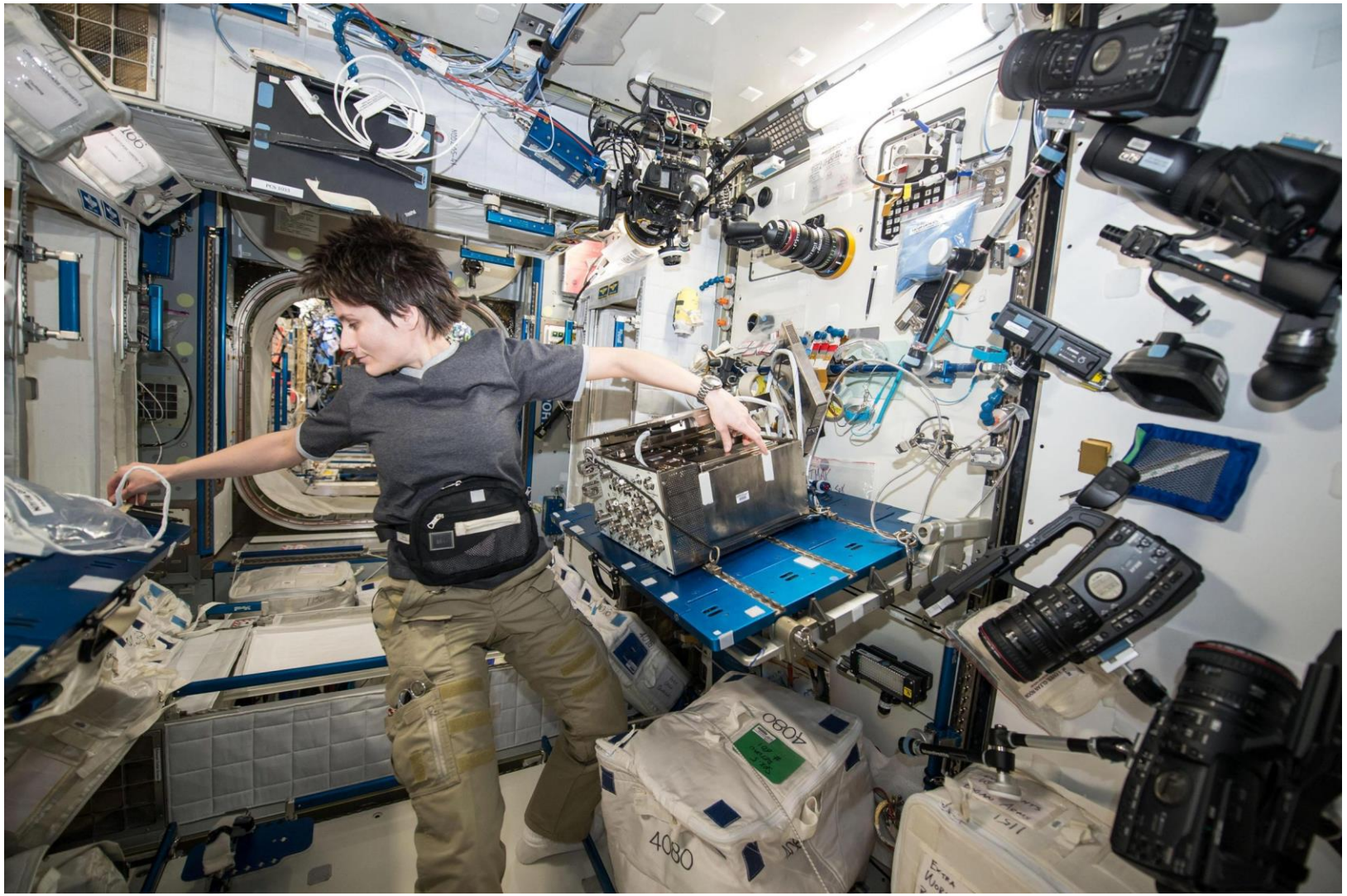
$$F = m \times \frac{(\omega r)^2}{r} \text{ or } F = m \times \omega^2 r$$



How can you control the amount of almonds flowing into the smaller container?

Besides high and low speed fans or suction, you can also control the door from the almond bag into the smaller container

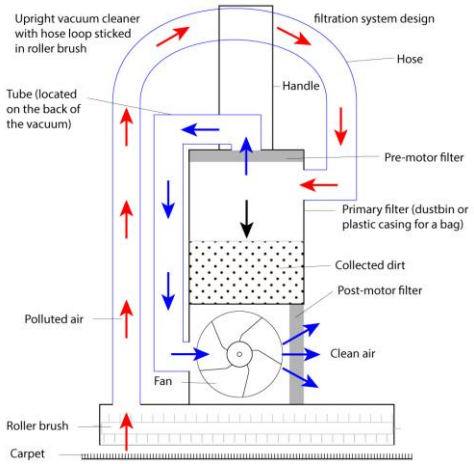
A major key to space flight is controlling your environment.

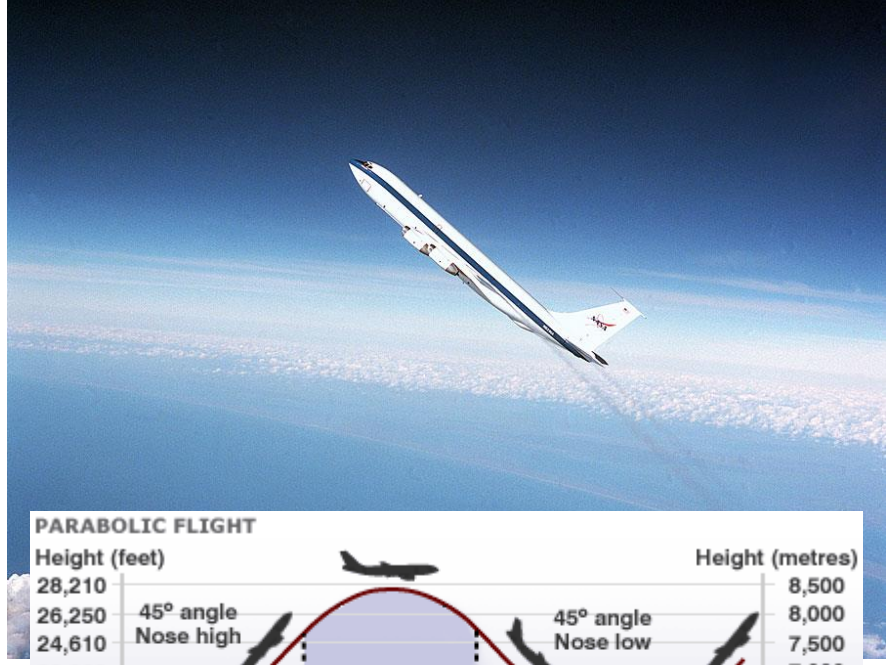


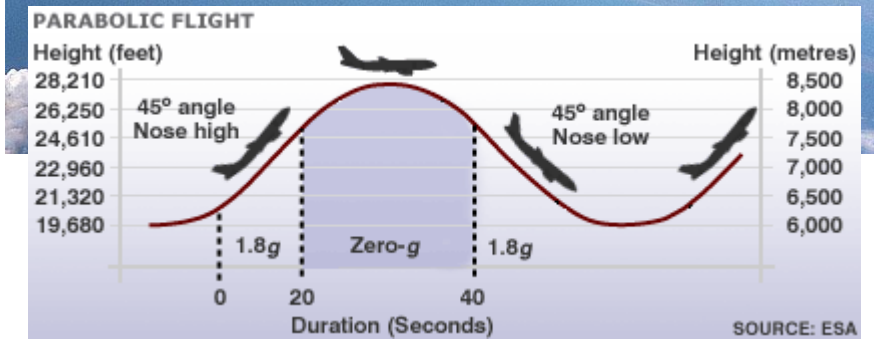
Although there is a lot of different tools and equipment all over this module, notice that it is all attached to the wall or ceiling in some fashion—Velcro, seat track, bungee, in a pocket. Nothing is floating around or getting away from her. It is all controlled—otherwise things get lost.

Testing

- Some equipment needs to be tested in zero-g before it flies to see if it performs they way we need it to. Sometimes this is done in an airplane that flies in parabolas to simulate zero-g for around several seconds before they have to pull back up. They can also do other flight paths that allow for the Moon's gravity or Mars' gravity. All of our testing for HUNCH would be better (and more fun) if we could do it in zero gravity but that won't be possible for most of us (even me).
- If you are using a centrifugal force to move your particles from one container to another, you might be able to do the testing by laying on a flat, smooth table and spinning it around. The smoother the better.
- If you are using air flow to transfer your particles, you may want to use something like Styrofoam packing peanuts to do your testing. You may want to cut them into smaller pieces to make them fit your needs. Different sizes may give you different results.
- If you are using some kind of other mechanical method to transfer your particles, you may be able to have it sitting on a table but you may need to do testing in one direction and then put it on its side or try it upside down as well.

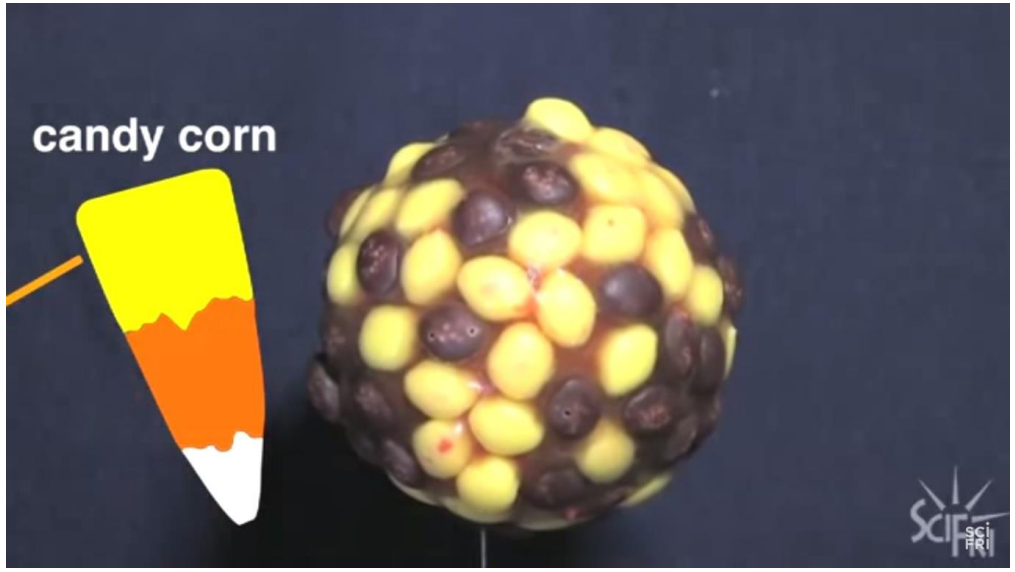






Candy and particulate related but just for fun

- https://ed.ted.com/best_of_web/nK6UUp2F



Controlling candy corn in zero-g

A soap analogy and a capstone analogy.