NASA / HEROX SPACE POOP CHALLENGE ENTRY BY DAVID O'DELL, AUSTIN TX

Title

Space Sorbent Tubing - inspired by oil, to soil

Very short description

The SST system uses existing technology in a new manner for waste removal, cleaning and storage in one innovative parallel process.

Executive summary

An Earth-bound toilet performs several parallel processes. To reduce smell, transport waste, refill, clean the bowl we use liquid water as the waste bearing medium. The SST waste bearing medium is an innovative way to use existing products while performing collection, transport, cleaning and storage in parallel, with manual backup and while our astronaut is strapped into a chair in a tumbling spacecraft with no cabin pressure.

SST look and feel:

- SST is an absorbent tubing that glides between the legs of an astronaut upon defecation. The SST system acts like a reel-to-reel cassette player. SST is preloaded prior to launch onto a fresh reel then transported as needed between the legs onto a waste reel. The reels are found at the front pockets of SST shorts worn by the astronaut prior to donning the MACES.
- SST is made from thin-walled poly plastic the diameter of garden hose. Various diameters and lengths can be customized for the comfort of our astronauts.
- SST is filled with absorbent deodorizing beads. It resembles a long, soft bean bag that can conform to various shapes and glide paths.
- Hundreds of tiny perforations around the circumference and length of SST allow liquid waste to reach the absorbent material inside
- Raised fabric ridges around the circumference and length offer a wiping action.
- Embedded germicidal lubricant provides comfort during glide and guards against bacterial infections.
- Our astronaut would use up to 3 linear feet per day, assume 20 feet preloaded into shorts.

SST Shorts

The SST shorts have the look and feel of padded snowboarding shorts similar to these:

http://demonsnow.com/store/DS%201450.2%20Shield%20Short%20Hard%20Tail%20snowboard%20Padded%20short%20Hard%20tail

The SST shorts are different for men and women. The SST reels are mounted on the front. A semi-rigid plastic guide channel is sewn onto the pants forming a closed path for SST to travel through. Inside along the crotch the guide channel is U-shaped and holds SST tubing exposed to the genitals. When our astronaut defecates they can "bear down and spread" letting the SST absorb as much as possible. Our astronaut turns on the switch and SST glides along this channel wiping and disinfecting the genitals while absorbing and transporting soiled portions to the waste reel.

Power requirements

The SST system requires 12-18V and at least 1A current to run two dual direction DC encoder motors geared for slow speed and high torque. This is more than the 100ma of current available. Power is needed for a display that shows remaining amount of SST. Power is fed to the SST shorts by a lockable power-data cable located inside MACES.

Electric Controls

The SST system would be controlled using an external safety switch located on the front abdomen of the MACES, reachable by either hand with minimal effort. An upward-facing counter display would be located near the switch. The switch would allow for both forward and reverse action in the motors to allow a "back and forth" wiping action if our astronaut feels the need.

Manual Control

The reel motors will employ a clutch system that will allow them to be turned manually. Upon donning MACES, two flexible cables will be connected from the SST reel housings. These cables and their external knobs resemble the slow motion controls found on camera and telescope tripods. The MACES would need to be modified with two manual control knobs on the abdomen. The clutch release would need to be integrated into the control knobs, perhaps by pulling them.

Why should your Solution be chosen for an award?

The Space Sorbent Tubing (SST) system solves several waste problems for various size and genders of astronauts with minimal new technology and minimal modifications to MACES. By treating the waste like an oil spill instead of a waste-water treatment plant, we eliminate complex delicate “in series” processes and run all processes in parallel – collection, transport and cleaning all occur at the same time with one waste bearing medium. By keeping the SST system simple while offering manual control backups we can reduce the chances of failure and afford our astronaut a chance at surviving an emergency in health and in comfort.

How does your solution manage up to 1 L per day of urine for 6 days for women?

Our female astronaut will perform a ”bear down and spread” maneuver, pressing the guide channel into contact with the outer skin of her genitals and urinate freely onto the exposed SST material at any time. Once she has finished urinating she remains in the bear down position to allow the exposed SST in the crotch guide channel to absorb as much fluid as possible. She may need to perform a pelvic thrust to spread the fluid along the guide channel. She then uses the external SST switch on the abdomen of the MACES to activate the reel motors that will pull fresh lubricated SST material across her genitals, allowing the ridges to wipe them as it transports waste from front to rear to the waste reel. This process can be repeated as long as there is fresh SST material available. Even using soiled SST material is possible as long as it is not completely saturated.

How does your solution manage up to 1 L per day of urine for 6 days for men?

Our male astronaut’s SST shorts will require a custom fit expanded front and lower guide channel that sufficiently covers and cradles the penis shaft and testicles. This expansion resembles a semi-rigid athletic cup commonly found at sports stores, it also resembles the pelvic section of a Storm Trooper’s uniform from the movie Star Wars. The expansion should allow for flaccid and erect size changes of the penis. The SST tubing will glide along one side (left of right) of the front expansion, making contact with one side of the testicles and following through towards the anus and out to the waste reel. Upon urination our male astronaut will pee freely into the front expansion cup and then wait for a brief moment allowing some absorption. Our male astronaut will perform a pelvic thrust or side to side inertial wiggle to assist SST in making contact with free floating urine in the cup area. He then uses the external SST switch on the abdomen of the MACES to activate the reel motors that will pull fresh lubricated SST material around his penis and testicles. This process can be repeated as long as there is fresh SST material available. Even using soiled SST material is possible as long as it is not completely saturated.

How does your solution manage up to 75 g of fecal mass and 75 mL of fecal volume per day for 6 days?

For pooping, our female and male astronauts will both perform a ”bear down and spread” maneuver, pressing the guide channel into contact with the outer skin of their anus. They will proceed to poop freely onto the exposed SST material. Once finished our astronaut remains in the bear down position to allow the exposed SST in the crotch guide channel to absorb as much fecal matter as possible. Our

astronaut then uses the external SST switch on the abdomen of the MACES to activate the reel motors that will pull fresh lubricated SST material across the anus, allowing the ridges to wipe it as it transports waste from front to rear to the waste reel. Urination can occur at the same time with this system with no difference in process. Even a mixture of fecal fluid and urine can occur. As long as fresh SST is transported across the genital orifices and a proper wipe is accomplished, the health of our astronaut should be preserved. It is possible that some fecal matter will be pushed onto the upper furrow of the butt cheeks near the small of the back. The SST shorts will ideally be cinched along the waste to protect against waste material escaping into the MACES suit.

How does your solution remove up to 80 mL of menstrual waste over the course of 6 days?

It has not been proven or disproven that retrograde menstruation is an issue in zero gravity environments so the SST system does not propose a solution to this possibility. Unfortunately there have not been enough studies on reverse menstruation in zero gravity. Due to lack of data and the serious risk to the health of our female astronaut corps, it would be highly recommended that our female astronauts use some form of contraception that inhibits menstruation. Please refer to Varsha Jain and Virgina Wotrings article "Medically induced amenorrhea in female astronauts" (Nature Partner Journals Microgravity - 4/2016). http://www.nature.com/articles/npjmgrav20168

If our female astronaut is menstruating while wearing the SST system she only needs to perform a bear down and spread maneuver when she feels the need to. While performing the maneuver she can turn on the reel switch and allow the SST material to comfortably wipe away any menstrual waste.

Assuming there are no open cuts or sores the risk for infection from menstrual waste near the anus is minimal. Fecal material and menstrual blood are sterile to the astronaut that produces them. As more fresh SST is guided along cleaning genitals the risk of infection is lowered with every portion that passes.

How does your solution interface with the orange space suit? What changes, if any, would be required to the suit for implementation?

Five changes to the MACES suit would be required for the SST system to work as intended.

First, a separate higher current SST system battery will be required, or, allowing the existing 20V battery to operate at around 1A for short bursts of time to run the reel motors. This battery should be mounted externally in case it needs to be recharged or swapped out. It should not be incorporated into the interior of the MACES.

Second, an SST system control area would need to be given dedicated space on the abdominal area of the MACES. This area would house the SST reel motor control safety switch, the data display and the manual control knobs. This area would be rectangular around 6 inches tall and 10 inches wide or smaller depending on ease of sight and use.

Third, a power-data cable would need to be routed from an external SST battery to the SST system control area on the abdomen and then to the interior of MACES. This power-data cable will need be plugged into the SST shorts upon donning MACES. This would require suit penetration for the cable.

Fourth, to provide manual control backup in case of emergency, connectors from the SST system external control knobs on the abdomen of the MACES would need to penetrate the suit and be easily available to our astronaut. Upon donning MACES our astronaut would plug these connectors into each of the reel housings.

Fifth and finally, attach a small battery powered handheld flashlight to a spot on the exterior of the MACES using Velcro. From my limited research online it is believed that the only external light source are some colored glow sticks although there might be a flashlight located in the pockets. Either way, in an emergency inside the cabin I feel that unwrapping and activating glow sticks would take too long. The illumination that glow sticks provide would be colored and too diffuse to be useful during an emergency inside the cabin when seeing true color and intense directional light is required.

How does the crew member interact with your solution? Begin before the crew member dons your solution and walk through the entire process until the solution is removed after 6 days.

We will assume that the SST system components that need to be custom fit have already been fitted and the MACES and SST system are ready to use. I have outlined a possible emergency scenario which has guided the design of the system. We will assume our astronaut to be in the spacecraft wearing their normal work fatigues with normal fabric underwear on. In the case of a catastrophic emergency where the craft is dimly lit, tumbling, loud and losing cabin pressure, our astronaut will need to:

1. Move to the MACES storage area.
2. Open MACES suit, turn on the mounted flashlight in case cabin goes dark.
3. Locate SST shorts inside MACES, have them at the ready.
4. Remove all clothing from the waist down and quickly don the SST shorts.
5. Using a free hand check to ensure the genitals are not pinched or in awkward positions.
6. Cinch the leg straps, the guide channel front and rear straps and then waist straps for a snug fit.
7. Place legs into MACES suit, pull suit up towards abdomen.
8. Find the manual control cables in MACES, attach and lock to both reel housings. These will always be first. In case of lack of time, the system must be used manually without power.
9. Find the power-data cable in MACES, attach and lock to SST reel housing.
10. Open the safety switch on the SST external control area on the MACES, read the data display quick diagnostic (some sort of informative icon, green led or words that state the system is functioning as intended). If the diagnostic is OK, continue. If not OK, check the connections briefly. The system should have an a positive diagnostic prior to sealing the MACES suit, although manual control is possible.
11. We assume a positive diagnostic and finish the process of donning the MACES suit.
12. When the urge to defecate happens, perform a “bear down and spread” maneuver if possible.

13. After defecation allow the SST material a brief moment to absorb as much waste as possible.
14. Open the safety on the SST control switch on the abdomen of the MACES, this will turn on the data display.
15. View the illuminated data display to see how much fresh SST remains.
16. Press the SST control switch to "ON" and allow the SST material to wipe the genitals.
17. If necessary, the switch can be moved back and forth to allow a back and forth wiping action.
18. Our astronaut would continue life as usual in this emergency situation, using the SST system as needed for 6 days.
19. Upon re-entry our astronaut would check to make sure they have fresh SST material in position under their genitals in case they need to go during the re-entry / rescue process.
20. Upon safe recovery the MACES would be opened.
21. The interior manual control knob connectors attached to the SST reel housings from the MACES would be disconnected.
22. The interior power-data cable for the SST shorts would be disconnected.
23. Our astronaut would be assisted out of the MACES suit while still donning the SST shorts
24. Our astronaut would be assisted to a proper bathroom and allowed to remove the SST shorts and take a hot shower!

Please expand on how your Solution is set up and secured prior to sealing the space suit?

The SST shorts are similar to padded snowboard shorts and are donned as normal shorts. Our astronaut would need to remove all clothing covering the genitals prior to donning the shorts. The shorts have quick cinch straps much like mountain climbing belts at four areas: the waist, the lower part of each thigh, the front abdominal area, the rear above the butt crack. Upon donning the shorts our astronaut will cinch the thigh straps then adjust their genitals to ensure a comfortable position. Once a comfortable position has been attained, the front and rear cinch straps can be adjusted for a snug, comfortable fit. Finally the waist cinch strap is adjusted for comfort. Once the SST shorts are on, the astronaut will don the leg portion of the MACES and pull it up to their abdomen. The power-data cable and manual control knob cables will be found and connected to the SST shorts and reel housings. After these connections are made our astronaut will continue donning and then sealing the MACES space suit.

How does your Solution allow the crew member to move bend, fit through small spaces, and/or be seated and strapped into a chair?

The SST shorts are form fitting and allow our astronaut some freedom of movement but there will be sacrifices to comfort if the astronaut needs to be in a genupectoral position for long periods of time. A

long duration genupectoral position with the knees to the chest would result in potential discomfort due to a “wedgie” as SST material pushes against the crotch for too long. Short periods of this are acceptable, however the most comfort would be when our astronaut is either sitting, standing or supine.

How does your Solution operate effectively for crew members of varying size and weight?

The SST shorts are custom fit for each astronaut and can be cinched for snug comfort upon donning. The SST material is custom made so that it is not too big and not too small as it glides between the legs. The guide channel is also custom fit to ensure comfort and proper coverage of the glide path of SST material. All this can be done prior to launch. Depending on an astronauts waste habits on Earth, different ratios of absorbent and deodorizers can be placed into the SST material for that particular astronaut prior to launch. The SST material should be manufactured with contents and size customization in mind.

How does the Solution ensure the conservation of gas in a crew member's suit?

The only gas that would be coming out of the SST system would be flatulence or odor from the waste reel. Powerful flatulence should be able to be expelled out of the SST shorts as this contact with the body is not air tight but rather "snug". Odor and flatulence in the suit body below the neck dam will be evacuated with other waste air from the helmet using the existing MACES backpressure regulator in open or closed loop positions.

How does your Solution protect the health and safety of a crew member?

Everyone lives with a partially dirty bottom. No one is 100% clean "down there". As best we wipe we still have fecal matter and urine on the genitals and underwear. We have lived thousands of years with a little waste on our bottoms. The SST system does not propose to perfectly polish our privates. The system is designed for safety, comfort and survival. The SST system provides a worry-free way to transport most waste away from sensitive areas that might become infected. Fresh absorbent SST tubing glides between the legs wiping most waste away while anointing the genitals with germicide and lubricant to prevent infection. As fresh SST is gliding along, the soiled portions of the SST tubing are pulled around a waste reel attached to the SST shorts.

How does your Solution protect the comfort of a crew member?

Our astronaut should wear a solution that allows them to "go freely" without having to deal with pinched catheters and other extremely uncomfortable penetrations or watery "wash cycles" that might put waste in the wrong places. The SST system should be near the comfort level of wearing a pair of padded snowboard shorts, only with a little more bulk to them. Range of motion might be affected slightly due to the bulk of the SST tubing reel housings located on the thighs of the SST shorts, but not to the point of endangering our astronaut. The SST shorts and internal guide channel are all custom made and fit prior to launch. The SST tubing that glides between the legs is also custom made and embedded with a gentle lubricant that might take a little getting used to but should not be too irritating over a 6 day period of time. All this would need to be tested on that particular astronaut prior to launch to make

sure there are no allergies or abnormal reactions to the tubing, the wiping fabric ridges, the germicide or the lubricant. All of these factors can be modified with existing materials and technology.

What is the Technical Readiness Level (TRL) of your solution? If your solution is requiring new and existing technologies, what is the TRL for each of these technologies?

The major systems and their proposed TRL are listed one by one, I am not a TRL expert but these are my initial thoughts. I used the TRL guide located at this page:

https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

SST tubing – TRL 3: While the components of SST tubing are readily available (absorbent beads, deodorants, lubricants, germicides, thin poly plastics, absorbent fabrics), all of them working in concert with each other would require testing absorbency in zero gravity, tensile strength and wiping capability. This would put it in the R&D phase with many predictable results, but still in need of prototype development and improvement.

SST motor controlled reels – TRL 3: These DC motors should be available off the shelf.

The reel housings the motors reside in will need to be prototyped once a suitable SST tubing can be manufactured. The reel housings will store fresh and soiled SST, therefore the motors will need to be protected from anything the SST tubing might induce. The motors would need to be modified in some manner to spin freely such that they can be spun manually. A clutch gear system might be required. A cable connection system would need to be prototyped and tested to ensure external manual control knobs can be integrated onto the MACES.

SST battery – TRL 4+: Batteries that provide current around 1A are readily available and could be externally modified with protective housings or circuitry for safety.

SST data display – TRL 4+: The external data display located on the abdomen of the MACES can be as simple as a backlit LCD screen similar to those found on LCD watches. These should be off the shelf and readily available.

SST shorts – TRL 4+: Padded shorts with a plastic guide channel and extra cinch straps can easily be prototyped using a pair of padded snowboard pants as a model.

Discuss any other considerations that informed the design of your Solution, as applicable, and any other benefits not described in your other responses.

I feel that the SST system can be used in other industries as well as a low cost, high benefit solution to long duration waste management. Industries like long-duration deep water deployment repairing or building energy or communication infrastructure at sea, or in hospitals where patient mobility is seriously hampered and moving them around to collect waste and clean them is putting them at harm.