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Habitation Systems Concept Studies

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Habitation System 1: Life Support

There is no human space travel and certainly no deep space travel without life support, it’s the most vital part of any spaceship meant to carry humans. Every part of the life support system, from providing clean air and water and protecting against radiation to the way it recycles human waste is as vital as any other. Deep space travel leaves a crew completely on their own and even crews while in lower earth orbit are still too remote to be resupplying quickly or often. Which means you need to bring everything you’re going to need with you and more importantly figure out how to recycle what you’ve already used and that includes human waste.

The International Space Station (ISS) uses the newest Universal Waste Management System (UWMS) which can recycle about 90% of urine, sweat and other used liquids into drinkable water for the astronauts (Elburn, 2020). However, when it comes to fecal matter, it’s all collected and thrown away. Being in such an isolated environment it is vital to try to repurpose solid matter and there currently isn’t a system in place to do so.

The UWMS is uses a fan to pull urine into a tank and solid waste into a baggy (Grush, 2020) so the system is already in place that separates the solid waste that makes it easier to mange for recycling.

Company:

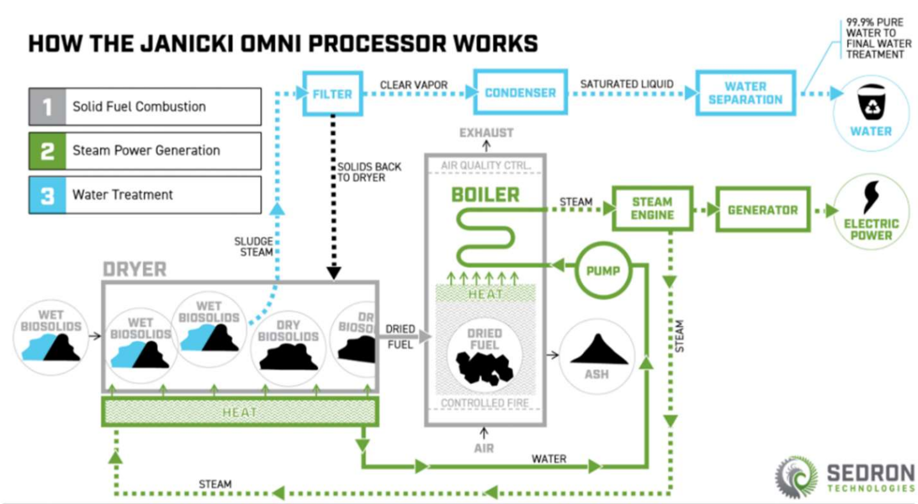
There is a system that does process poop for several uses, including as fuel and food, the Janicki Omni Processor. The system extracts water from human waste, making a dry mass, then it incinerates the dry waste into a non-toxic ash that contains phosphorus and potassium (Cashman, 2020), two crucial building blocks for fertilizer soil that could be used to grow food on a deep space mission or a planetary colony. A biproduct of the Omni Processor is that it produces clean water and extra energy.

Sedron Technologies is currently developing the Janicki Omni Processor, with a working unit operating out of Dakar, Senegal. (Cashman, 2020) With a footprint of roughly 567 sq. meters, (Sedron, n.d.) it's obviously not an ideal size to carry on a spacecraft for a deep space mission. The Processor works by intaking wet biosolids and putting them in a dryer system that produces steam and dry biosolids, the steam is then cleaned and separated and condensed back into water, which could be recycled into drinking water or water for other purposes. The UWMS on the ISS already separates urine and wet solid waste so the first step is already being done. After you have the dry biosolid from the dryer it can be transferred into a boiler where it's incinerated at super high heat and turned into an ash for use with crops being grown onboard.

One of the main benefits of the Omni Processor is that as a bioproduct of burning solid matter, it produces electricity via a steam engine, it provides enough power to sustain itself and still produces extra power that could be used for secondary purposes or even just as a backup power generator. The current system can handle the amount of waste produced by 100,000 people (Jewell, 2015), the average healthy adult produces about 128 grams per day (Emspak, 2015), so roughly 12,800 kgs per day, a system reduced in size to handle a typical NASA crew used in the Space Shuttle crew of five to seven (Wilson, 2006), it would only need to be able to process about 900 grams per day but it could be scaled up if this type of processer needs to be used for building a colony on another planet.

Next Phase of Component:

The Omni Processor would need to be scaled down to fit inside a spaceship and Sedron is currently working on a self-sustaining home-based toilet system (Sedron, n.d.). Since the processor doesn't need to be attached to a toilet but only have it fed by either the toilet or manually by the crew, the scaled down Omni Processor can accept the solid waste to store or immediately convert to water, ash and energy. The dryer and boiler section of the processor can use heat already being generated by the spaceships own engines and because it uses such high heat to incinerate the waste, it doesn't produce any foul odor (Jewell, 2015). The byproduct ash could then be used to enrich soil being used to grow fresh plants on a deep space mission. The steam from the boiler is used to create power via a steam engine so it also produces electricity that is vital for deep space missions, and because it's renewable the crew have another redundancy in place for power which is vital in deep space. The power output produced per day probably wouldn't be significant amount but since this would be for deep space missions or planetary colonies, the waste could be stored until you have a sufficient amount or store the produced energy in a battery for emergency backup power. The steam created could also be condensed to create more water.



(Sedron, n.d.)

Bridge the Gap:

A huge benefit is that the system is self-sustaining and on a deep space mission, that's incredibly important and because the system would be incorporated into current NASA systems instead of installing a whole new separate component, it would reduce the amount of parts that would need to be replaced should something go wrong. Two big drawbacks however are the heat needed for the incinerator and the steam created that drives a steam engine that produces the power output. Power or heat could be transferred from the engines. If they are using NASAs Solar Electric Propulsion (SEP) system which is being developed for deep space missions, the Ion engines burn nonstop to provide thrust (Mohon, 2021) so that's one way to get enough heat to use for the incinerator, and because of the scale of the system being used, it doesn't require that much heat for very long. The heat produced during this process could also be distributed among the spaceship to control for climate control.

The steam presents a different challenge, after it's used to power a generator it needs a place to go. Obviously you can't have steam inside the cabin, it might be possible to use that steam and condense it into drinking water or you could just exhaust it into space, along with the exhaust created by the incinerator. The ash produced by the processor also needs to be carefully stored so that it doesn't escape into the cabin, fine ash particles could cause a lot of trouble with instrumentation, perhaps the machine can drop the ash into a secure bin with special access for when it's needed to fertilize plants. While these are serious problems that need to be overcome, the ability to recycle human waste, both wet and solid presents a great opportunity for the durability of deep space missions and space colonies.

Habitat System 2: Extra Vehicular Activity

The risks involved in deep space travel with human passengers is already extreme, even while inside a spacecraft and if you're sending humans far out into the cosmos, it's expected that they'll at one point leave the spacecraft to visit a planet or even just to make repairs or do maintenance on the spacecraft. Which is why the Extra Vehicular Activity suit (EVAs) is so important. When an astronaut leaves the safety of the spacecraft, they still need air, water, protection from radiation and every other safety that the spacecraft offers them but in a far smaller package.

Without an EVA Suit, any kind of space exploration would be impossible for humans, currently NASA deploys the Extravehicular Mobility Units (EMUs) for work outside the International Space Station (ISS) (Garcia, 2019) and for the upcoming Artimis missions they have the Exploration Extravehicular Mobility Units (xEMUs) which are far more advanced than the suits used during the Apollo missions. The xEMUs offer more mobility, including the ability to walk which is something the Apollo suits didn't really allow and with improved technology, the suits can last outside of the spaceship for over eight hours, (Gohd, 2019). While these suits offer the protection they need, these suits are still very bulky and while they offer protection for about an average workday, a more longer-term solution in case of emergencies especially while on a planet surface would be ideal.

Company:

EVA suits need to provide temperature control, airtight seals to keep air in while recycling it or removing the carbon dioxide produced, must also include radiation protection and be impact resistant against micrometeors or other damage an astronaut can sustain while exploring a planet or in the vacuum of space. For long duration missions it might also need to provide water and even a way to use the bathroom. Including all of this to a suit adds a ton of weight and bulk to EVA Suits. On Earth the EVA suit weighs about 280 pounds without someone in it (Dunbar, 2018). Of course in space it doesn't weigh anything but on another planet, such as mars where gravity is 1/3rd of Earths, the suit would way around 100lbs. Moving a lot of weight in a big bulky suit isn't ideal in an emergency situation where an astronaut might need to act quickly. D3O has developed a non-Newtonian fluid polymer that is soft and lightweight but hardens upon any impact called Super Goo (Rohrig, 2017). The material is incredibly light weight yet offers a lot of protection.

The product is already used in several commercial products that include extreme sports and military equipment that protect against concussions, sudden shear forces and even against bullets or shrapnel. D3O can incorporate Super Goo into existing equipment and can be tailored to work with other materials.

Next Phase of Component:

In its current form the material would already be lighter than the 14 protective layers used for the EMU suit, which include liquid cooling and ventilation, thermal micrometeoroid garment liners and pressure garment bladder. (NASA, 1998). All these layers provide the needed protection astronauts need to explore extreme environments. The D30 super goo cannot currently replace all these layers without being combined, however thanks to its flexibility as a material it can easily be combined with other materials that give it these properties while still maintaining its protection and light weight. Currently D30 can apply abrasion resistance, UV protection and fire retardancy, which can replace several layers with a single unified multi-protective layer that provides protection against micrometeorites, fire, works as an insulator to keep the astronaut at a proper temperature and is liquid resistant. The only other layers the EVA suit would need is radiation protection and pressure bladder with the liquid cooling garment worn underneath the EVA suit. That leaves the radiation protection that could be infused into the D30 layer, leaving only the pressure bladder and cooling garment to be worn, providing more flexibility in the suit while reducing the weight and more importantly the bulk which would increase mobility. Since these suits would be designed to be mostly used in space with no or low gravity, the suits weight could still be maintained at its current weight 280 pounds but because of the reduction of weight of the overall suit, you could use that difference in weight to include more oxygen, more battery or more water, which would extend the range or longevity an astronaut could stay in a harsh environment.

Bridge the Gap:

In order to get the D3O Super Goo into the needed state, the polymer would need to be woven with other material that would give it the needed properties. Areogel, which was created in the 1930s, is a material made from gel that has its liquid removed by a process called supercritical fluid extraction (Woods, 2017). The process leaves behind a super light, porous material that is also incredible strong. Areogel might be a good candidate, it’s already light so it wouldn’t add a lot of weight when combined with the Super Goo, since weight reduction is one of the main goals and a polymer based Areogel is incredibly strong and has incredible insulation properties since the space between the gel is at the nano level along with great heat resistance (Woods, 2017). The combination of Areogel and Super Goo would provide an EVA suit with strong resistance to impacts from micrometeors, thermal and vacuum protection and if the aerogels are created with a high hydrogen content it would provide radiation protection for EVA suits. (Incorporating nano technology to produce a combination of Areogel and Super Goo with monitoring sensors that could relay data to the onboard computers regarding status of the suit, including any impacts or tears, and using self-repair nano tech, could potential seal any small enough holes should they happen. Astronauts would have a thin, light weight, incredibly resistant thermal suit that allows for longer missions because of the increased room for battery, air and water and constant monitoring.

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