Chapter 2
Water

Water is central to the design of spacecoaches. Conventional spacecraft based on the rocket and capsule paradigm treat water and other crew consumables as dead weight. In the spacecoach, water is the propellant, and because it is eventually used as propellant (we'll talk about propulsion in Chap. 3), it frees us to consider radically different, radically safer spacecraft concepts.

Water is a versatile material and can perform many functions prior to being consumed by the engines to produce thrust. Here are some of its other uses.

Radiation Shielding

Water is comparable to lead, on a mass basis, in terms of radiation shielding. Simply by storing water in compartments surrounding the areas where the crew spends the most time, spacecoaches will provide ample radiation shielding for their crews. In a radiation emergency, such as a solar flare event, additional water can be pumped into bladder-like shelters to provide additional shielding.

Heat Management

Due to the high thermal mass of water, it can also soak up excess heat when the engines or other systems are producing more heat than can be radiated away. This provides a stabilizing temperature regime compared to metal craft that must be rotated to relieve thermal stress. It can also soak up excess heat when the engines or other systems are producing more heat than can be radiated away. This heat management system will be mechanically simple and reliable.

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Life Support

It is the basis for a multiply redundant and fail-safe life support system, which will be discussed in detail in Chap. 5.

Consumables

It is a crew consumable, as both drinking water, and water-rich food. This water can be reclaimed via condensation, and from urine, subsequently to be consumed by the engines. In a spacecoach, even orange juice (or beer!) counts as propellant. In addition to human consumption, water is an important input for agriculture and biofuel generation.

Debris Shielding

It can be used for debris shielding, especially when frozen to form pykrete.[1,2] Pykrete is formed by freezing water and fibrous material. During World War II, the British investigated building an aircraft carrier out of ice mixed with wood pulp. This combination of water and fibrous material, once frozen, is as strong as concrete. Potentially, it is an excellent material for self-healing debris shielding. Gelatinous material, similar to ballistic gel, could also be incorporated into the design to further improve self-healing capability, at least for small debris strikes.

In a ship where water is abundant, agriculture and aquaculture both become possible, enabling crews on long journeys to grow at least some of their food *en route*, and also recycle carbon dioxide. The first ships probably will not be fully self-sustaining, but they'll be able to experiment with space agriculture and aquaculture early on, and gradually increase this capability with experience. Creature comforts that would be unthinkable in a conventional ship (hot baths anyone?) also become possible in a spacecoach.

Water is also important to the design because it is ubiquitous throughout the Solar System. There are many low gravity sites—the dwarf planet Ceres is an especially interesting place—that contain immense reservoirs of water-ice. Eventually it should become possible to extract water from sources like this and transport it to refuel spacecoaches wherever they fly. When spacecraft reach Jupiter, its icy moons offer a virtually inexhaustible source of water.

[1]Website (accessed April 6th, 2015), http://en.wikipedia.org/wiki/Pykrete.

[2]http://www.sciencedirect.com/science/article/pii/S0261306914008280.

And that is the ultimate goal of a system like this, to reach the point where we can scavenge most of the raw materials we need, especially water, to establish a continual supply chain and permanent settlements throughout the Solar System.

The Effect of Water on Crew Consumables

For a conventional spacecraft using cryo-propellants, the life support consumables are simply dead weight that must be accelerated and decelerated, requiring energy from the fuel or propellant. Given that deep space missions will require large quantities of materials for life support—e.g., water, food and oxygen—the spacecraft designer will try to limit their consumption to reduce the propellant required. An average person in the United States uses about 200 kg (440 pounds) of water per day, mostly for bathing and flushing the toilet.

When water is just a consumable, the mass cost is extremely large for deep space missions, and extremely costly if sourced from Earth using current rocket technology. NASA has determined that without recycling, drinking, water in foods and minimal toilet and bathing requires about 14 kg each day. The International Space Station reduces water demand by recycling water from bathing, waste recycling and respired water. This is about 85 % efficient in recreating water pure enough for drinking. This reduces the water demand to less than 2 ½ kg of water a day.[3]

For a 500-day Mars flyby mission that reduces the amount of water for an astronaut from 7 tons (7000 kg) to 1 ¼ tons (1250 kg). Even though this comes at a mass cost for the recycler, the overall saving in mass is very significant. There may be a certain "yuck factor" in drinking water recycled from the toilet, but in fact, properly treated, it can be purified to be cleaner than the water that comes from the municipal water supply.[4] In addition to water, the astronauts will need food and oxygen, estimated by NASA to require 1.8 and 0.84 kg per day, respectively. This would add 1.3 tons (1300 kg) for each astronaut on a roundtrip mission to Mars orbit and/or the Martian moons.

Ohio State University[5] recently estimated a mass budget for the proposed 2-person Mars flyby mission, Inspiration Mars,[6] estimating a 3-ton life support requirement of food, water and oxygen. This is broadly in line with a 5.1-ton requirement using NASA's guidelines, although it suggests even more minimal

[3]National Aeronautics and Space Administration, "Closing the Loop: Recycling Water and Air in Space", (n.d.): n. pag. NASA. Web. http://www.nasa.gov/pdf/146558main_RecyclingEDA(final)%204_10_06.pdf.

[4]"Reclaimed Water." Wikipedia. Wikimedia Foundation, n.d. Web. 03 July 2014.

[5]Gilligan, R et al. "Inspiration Mars International Student Design Competition" (n.d.): Ohio State University Web http://members.marssociety.org/inspiration-mars/semifinalists/ARES-M.pdf.

[6]Inspiration Mars website, http://www.inspirationmars.org.

water use. As Mary Roach so graphically wrote in *Packing for Mars,* after just two weeks in the Gemini spacecraft the astronauts' undergarments were literally rotting.[7] A 500-day camping trip in a spacecraft with no way to wash would be extremely uncomfortable. Clearly having the ability to create special chambers for laundry or personal washing would be a morale booster.

Because the spacecoach uses water for propellant, this water can be used prior to expulsion for consumption by the crew. Depending on factors such as engine efficiency and length of engine burn, the crew can use far larger quantities of water than a minimal ration in a conventional spacecraft. Even consumables such as frozen food and beverages count as propellant in a spacecoach, as the water content can be reclaimed from condensation and urine. This conversion of dead weight to working mass, in combination with modestly improved engine efficiency, results in order of magnitude cost reductions compared to conventional spacecraft.

[7]Roach, Mary. Packing for Mars: The Curious Science of Life in the Void. New York: W.W. Norton, 2010. Print.

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