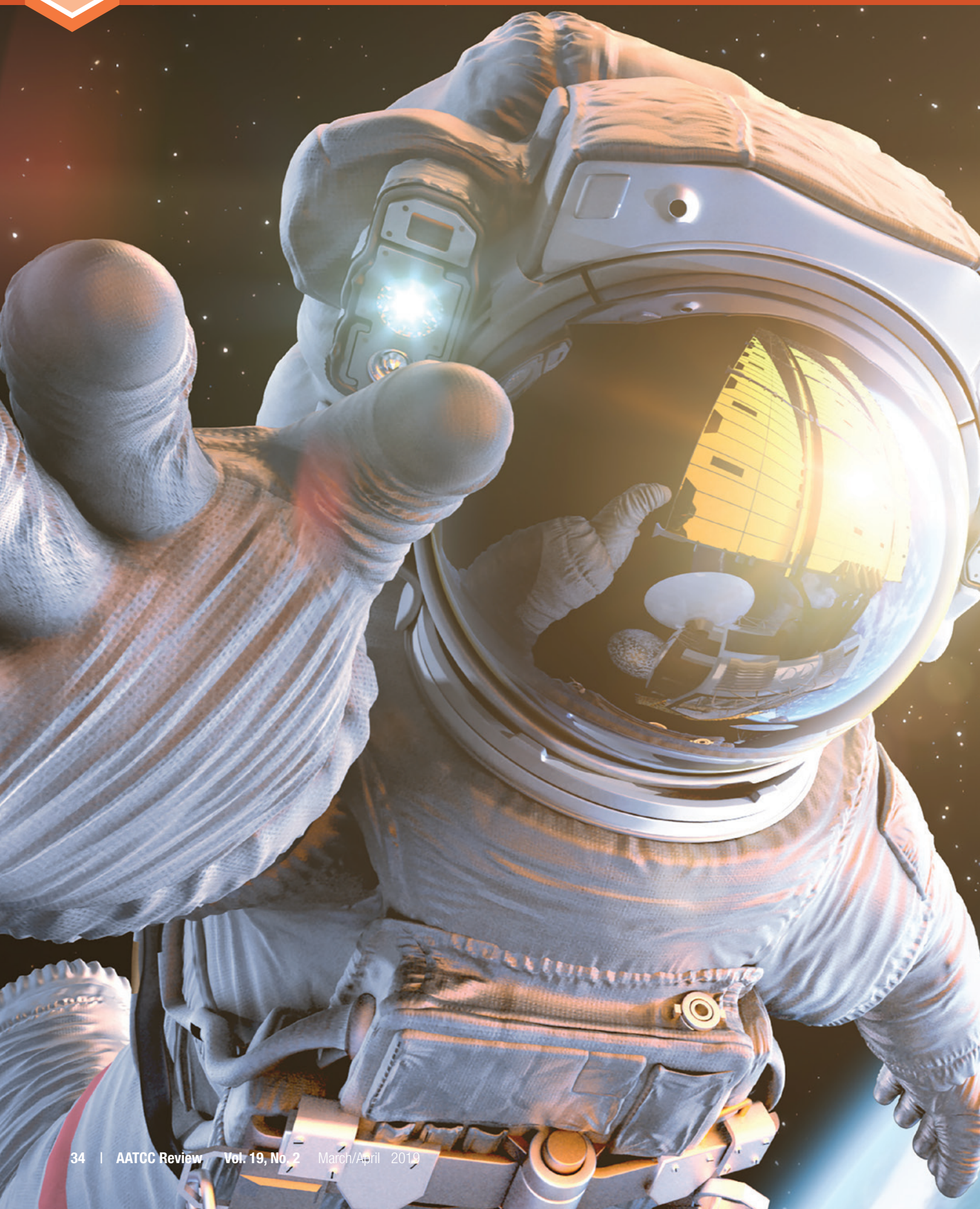

Bringing Space Textiles Down to Earth

By Fi Forrest

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Textiles are an essential part of the space industry. Every gram sent into orbit costs hundreds of thousands of dollars, so textiles must be lightweight as well as strong, and resistant to extremes of heat, cold, and ultraviolet radiation that they never have to experience down here on Earth.

With the US National Aeronautics and Space Administration's (NASA) recent announcement of a lunar spaceport—the Gateway Project—and manned missions to Mars being proposed by Elon Musk, the next generation of space textiles are *GO*.[1,2]

In space you find textiles everywhere, from the straps that hold you in place during take-off to the parachute on your re-entry. Diapers are in your underwear, you might work in an inflatable module on the International Space Station (ISS) and even that flag on the moon was specially designed in nylon. In space everything acts, and reacts, differently. Whether in low-gravity environments like the moon, or micro-gravity on the ISS, even the way moisture wicks away from the human body is different.

Fitness and Exercise Wear

Dealing with Perspiration

When European Space Agency (ESA) astronaut Major Tim Peake decided to run the London Marathon via a treadmill on the ISS, he was surprised at the way sweat adhered to his body. Although drops were pulled down away from his arms and legs due to their movements, a large mass started to accumulate on his forehead, which he had to towel down every 20 minutes or so. Without the action of convection to move cool air around, heat stays very near to the skin.

Hygiene in a confined space like the ISS is important, not just for health, but also for morale. Astronauts wear clothes for several days, or even weeks, at a time, then simply dispose of them in the outgoing trash. Crews spend a lot of time exercising in space to keep themselves fit in micro-gravity. There is no laundry on the ISS and cleaning isn't simple, as chemicals can outgas within the confines of a space station.

Particles which shed during wear are also problematic, and so fiber properties are extremely important. Consistent manufacture is essential, as everything going up into space has to be carefully tested on the ground first, with safety paramount. In the event of a fire, fabrics must char, not melt, so natural fibers, such as merino wool and cotton, are currently favored.

A new type of sportswear, designed for astronauts to reduce sweating and remain fresh, was evaluated onboard the ISS by ESA astronaut Alexander Gerst (while he was aboard the space station in 2018). The Hohenstein Institute, with co-operation of ESA, conducted tests of this latest high-performance clothing as part of the *SpaceTex*2 experiment.[3]

In collaboration with Schoeller Textiles, project leader Jan Beringer, of the Hohenstein Institut für Textilinnovation, designed workout tees for astronauts to wear while exercising.

"On the ISS it's not about wicking—it's about evaporative cooling," says Beringer, who worked with astronaut Gerst. He describes how he went about the new designs for the experiment. "I looked at a new yarn and fabric constructions with superior wicking, lateral moisture transport, and thus resulting evaporative cooling. I found these fabrics at an innovative US company named Coolcore. They supplied custom manufactured fabrics with increasing evaporative heat loss especially for the SpaceTex2 experiment. The T-shirts were cut and sewn by one of my Hohenstein colleagues."

Beringer believes the collaboration has been beneficial. "I gained [a] lot of reputation and recognition in the space sector and made new contacts and

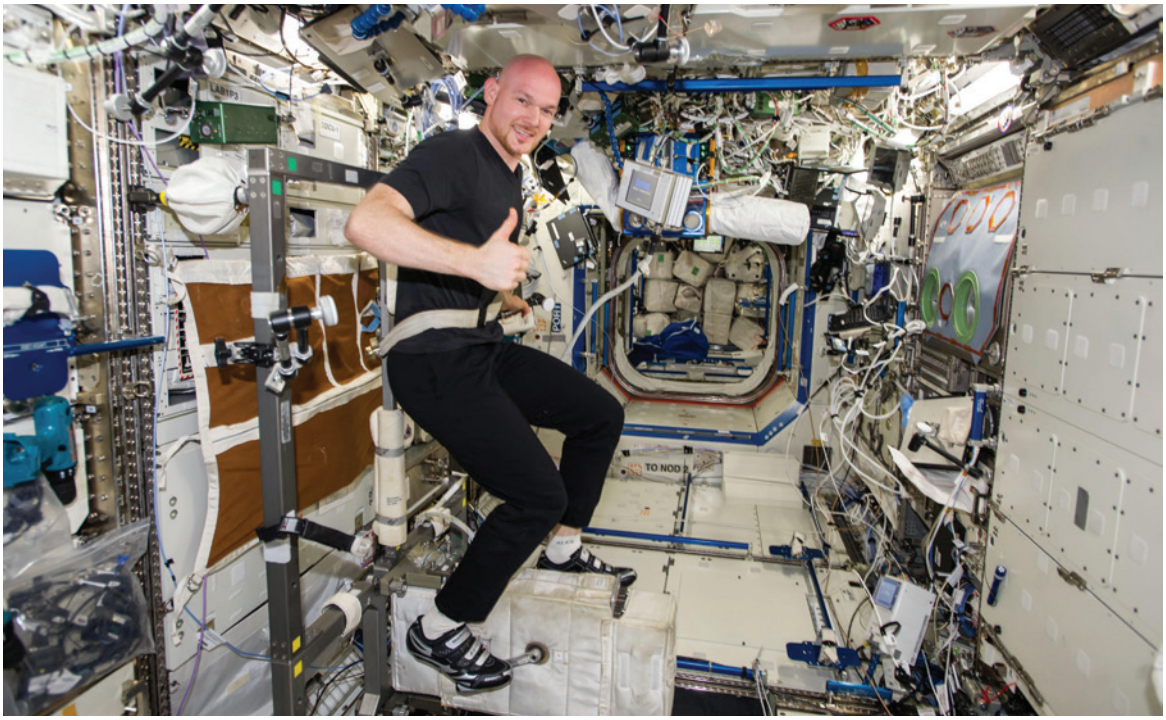

PHOTO CREDIT: NASA

Gerst exercising in the ISS, during SpaceTex.

research opportunities," he says. "And most of all I got to meet lots of amazing people including the German ESA astronaut, Alexander Gerst, who acted as my subject for the experiment."

Coolcore normally supply sports apparel, and it is their chemical free fabric that Beringer used (currently on the ISS). "We are really excited about partnering with the Hohenstein Institute and participating in the SpaceTex program experiment," says David Ludd, VP of Global Marketing at Coolcore. "We are looking forward to seeing what interesting data may come back concerning human physiology in space and how Coolcore can participate in the science of improving textiles for use in extreme applications."

"We are a chemical free thermoregulation fabric provider," notes Ludd. "Our key point of difference is our fiber and yarn technology (which is patented) and this allows us to have superior moisture transportation, distribution, and regulated evaporative cooling. Our moisture management system allows for expedited drying so that the wearer is comfortable and dry after periods of exertion preventing saturation. Our technology is mechanically inherent in the fabric and does not include any topical or additive treatments."

Dealing with the Effects of Gravity

Concerns over the loss of bone calcium density due to the lack of gravity over time has led to experiments using "skinsuits." These form-fitting garments simulate the effect of gravity through squeezing the body via a bi-directional weave design in the suit, operating from the shoulders down to the feet. ESA has been working with partners that include Kings College and University College, London, and MIT in preparing the prototypes, which have been tested onboard the ISS. It is hoped that such active textiles will help crew members maintain their fitness during long stays in space.

Spacesuits

The Original Spacesuits

This year is the 50th anniversary of man's first Moon landing and, so far, it is the only world humans have walked on—other than Earth. Learning from that experience will be essential as we look outward, possibly towards Mars.

The 1960s Apollo suits that went to the moon consisted of 21 layers of neoprene rubber, polyester, and other synthetics, including an additional outer layer of fire-proof Beta-cloth that could withstand over 1000 °F. (Made from twisted, Teflon-coated glass fibers, this layer was added after the tragic death of

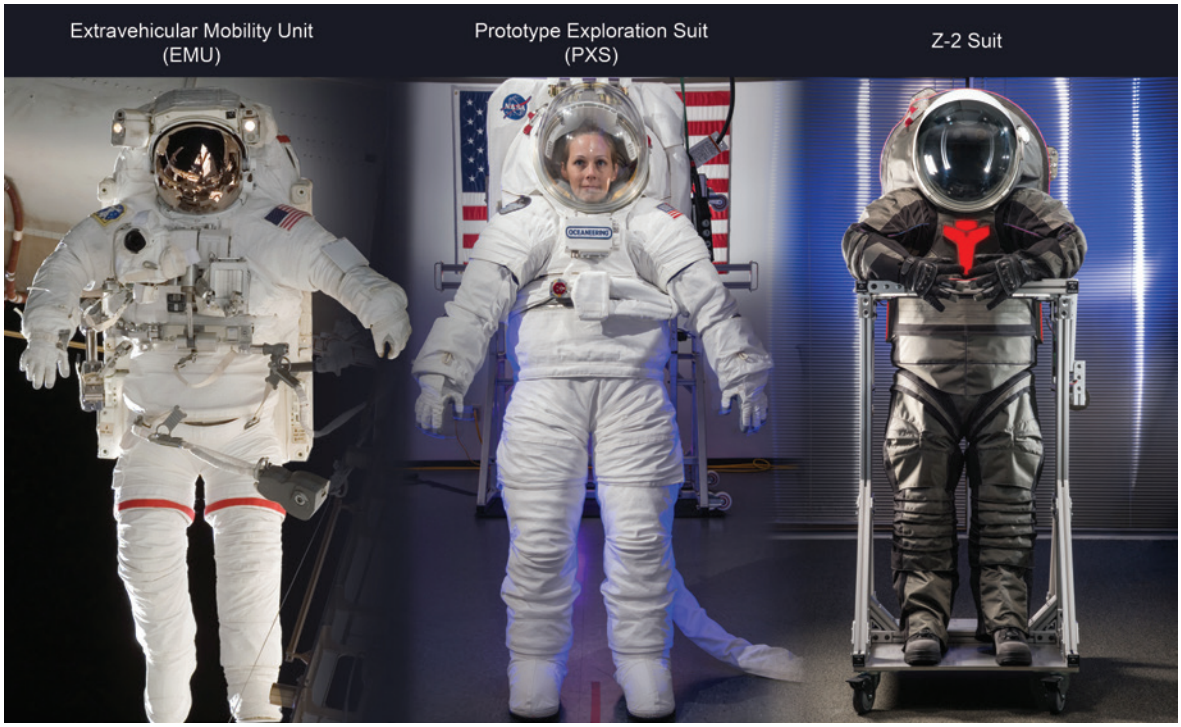

PHOTO CREDIT: NASA

The Importance of Outreach

The earthly reality of making textiles for space is not only the tiny amount of fabric actually required. Even small elements require extensive, expensive, and time-consuming testing. To offset such investment, there is the prospect of Earth-based uses; many companies see their innovations in space as a stepping stone to bigger things down here on Earth—whether by repurposing technology or by expanding their brand visibility. How can NASA and other space agencies encourage textile suppliers of the future to create the innovative components that will be necessary for large scale projects such as NASA's Gateway?

Extolled by US President Donald Trump in his *speech* back in December 2017, NASA's "new direction" is outlined in their *Strategic Plan* and emphasizes "Expand(ing) public-private partnerships to develop and demonstrate technologies and capabilities to enable new commercial space products and services."[5,6] Although the plan doesn't mention textiles specifically, NASA does recognize their value.

Outreach is one way to go. ESA partly addressed this during their 2016 "Couture in Orbit" initiative. Aimed at universities and schools, the project gave young textile and fashion designers access to established industrial fabrics and processes—with an eye to becoming some of Europe's space textile designers of the future. Cumulating in a fashion show in London, the event encouraged these young designers to think about space as a real opportunity for future research and industry.

One of the fashion brands that took part in "Couture in Orbit" was 37.5. The 37.5 technology, that embed particles of volcanic sand and coconut shells into their yarns to increase the surface area in a patented technology invented by founder Gregory Haggquist. Their fabrics move moisture from the body while it is still in vapor form and are favored by snowboarders and climbers. "We were approached by the ESA for this project," says 37.5's Christy Raedeke. "They let us know that they were working with designers to think about future textiles in space, and that 37.5 came up as a fabric technology they were all interested in working with. So, we furnished the designers with fabrics in order to create their garments for the fashion show, and then we participated in the educational event afterwards where attendees and designers could come learn more about 37.5 technology. This event and the press that surrounded it certainly boosted our brand recognition."

three astronauts from a fire in the Apollo 1 module during testing in 1967).

The suits were manufactured by the International Latex Corp. (ILC Dover) and were stitched by seamstresses more used to making bras and girdles. ILC Dover still makes space suits for NASA and is also currently making airbags for the Boeing's Starliner return vehicle.

On the moon, reduced gravity and the electrostatic effect caused moon dust to jump up and cling to NASA spacesuits. Apollo astronaut and moon-walker Buzz Aldrin complained about the highly abrasive, glass-like moon dust sticking to his spacesuit, penetrating his boots, and then transferring into the landing module. NASA is currently examining "anti-stick properties" for the next generation of space suits.

New Spacesuits

With both a lunar space port and trips to Mars being discussed seriously as near-future projects, the new suits won't be just for an occasional space-walk, they will be designed to be more lightweight and flexible than ever before, allowing crews to live and work comfortably off-world for many months, even years.

Lunar and Martian soils have different properties, so suits will have to be flexible enough to cope with all conditions, be flame resistant for the high oxygen atmosphere of a space module, and provide protection against some forms of radiation. The suits currently in use on the ISS contain Ortho-Fabric—a blend of Goretex, Nomex, and Kevlar—but Beta-cloth is still used as a component of spacecraft heat

shields and sunshades. (Outside of the space industry, Beta-cloth has gone on to be a material used in buildings, such as the roof of the Palm Springs International Airport).

The ISS suits are a modular design to fit any astronaut and are kept on board the space station. They consist of a hard upper torso, a pliable lower torso, helmet, and gloves, with a liquid cooling garment worn underneath. First used in 1981, the current Extravehicular Mobility Unit (EMU) suit was designed to last 15 years and is seriously due a replacement.

Changes in political aims of NASA have already seen one new design, the Constellation, cancelled. Now, NASA is turning its focus to a suit that can walk on Mars, as well as the Moon. Material testing by NASA includes the use of abrasion tests using simulated moon dust. Using a rotary drum tumbler, testing also examines whether heat-sealed seams can prevent dust migration through the suit, as experienced by the original moon-walkers, Armstrong and Aldrin.

When testing gloves, strength and durability tests are joined by manual dexterity testing. When on a planetary surface, astronauts need to be able to change tires on a rover, use tools such as hammers and scoops, and operate science packages. If the gloves are too stiff, or become stiff with use, dexterity is lost and the astronaut tires more quickly. For a perfect fit, astronauts have their own set of spacesuit gloves which they take up with them to the ISS.

NASA's Commercial Crew Program—Boeing's Starliner, the replacement for the Space Shuttle—has its own launch and return suit prototype. With all-in-one shoes and helmets, the bright blue individually-tailored suits look sleek, incorporate touch-screen ready gloves, and are ten pounds lighter than current NASA launch suits. Elon Musk's black and white SpaceX prototype launch suit has already made it into space—albeit adorning a mannequin on board his Tesla Roadster sports car—launched into space in February 2018.


PHOTO CREDIT: HEATHCOAT

The "Invisible" Space Textiles

There are also new innovations for the many "invisible" technical textiles required in space, such as filtration membranes for air and water recycling. Water filtration manufacturer Aquaporin A/S has recently been sponsored by ESA to conduct testing of their water filtration system on the ISS. This new technology is based on how natural proteins use forward osmosis to move pure water through cell membranes. Testing on board the ISS is essential to see how the membranes fare in a micro-gravity environment. ESA hopes to use this technology in the lunar Gateway project, replacing heavier fabric membrane models that require filters to be constantly cleaned.

Methods of growing your own food in space are currently being investigated with the "VEGGIE" vegetable production system on board the ISS. Fabric made from meta-aramid fibers (such as Nomex) is used to wick water from a reservoir to plant roots. Testing has concentrated on wicking consistency to prevent under or overwatering, and on water retention rates as the plants grow.

The calendered finish (pressure and heat applied by heated rollers) on Nomex initially caused problems with water retention, as this process reduces thickness by compressing air between the fabric threads. Uncalendered fabrics were found to retain water better. Research of this kind is vital if space crews of the future are to have fresh food available to them on long journeys, such as to Mars.

Getting Back to Earth—Parachutes

While most space components consist of only small amounts of textiles, the exception is the parachute, which contains vast swathes of fabric. Failure here is most definitely not an option. It is this imperative that drives Heathcoat Fabrics Ltd., who has been manufacturing parachute fabrics since the 1930s and make military and specialist parachute fabrics under the DecelAir brand.

"Heathcoat Fabrics Ltd. holds a unique position in the marketplace," says Peter Hill, director of woven fabrics at Heathcoat. "We are the only parachute fabric manufacturer to design and specify our own exclusive yarns, enabling us to produce the highest strength-to-weight ratio parachute fabrics."

Hill says that additional benefits for parachute manufacturers include Heathcoat's ability to design the yarn to meet the physical requirements of the parachute, which are not limited by standard specifications. The resulting parachutes have "exceptional heat and UV resistance, producing higher performing fabrics with outstanding retained tensile strength," says Hill.

"This resistance to heat is essential for space applications to ensure that fabrics retain their strength after the Dry Heat Microbial Reduction (DHMR) treatment that is necessary for the parachutes used in the space industry," notes Hill. "Our ability to provide bespoke fabrics in relatively small runs; and to design, weave, dye, finish, and test within our environmentally conscious site; is greatly valued by customers such as NASA."

Heathcoat supplied the parachute for the *ESA Huygens* probe, which successfully landed on Saturn's moon Titan in 2005.[4] Their next mission is to Mars. NASA's plans for a US$2billion mission in 2020 will mean a parachute that can withstand temperatures of -270 °C. The testing is rigorous, explains Hill, and only a select few companies can meet the extreme specifications of an organization like NASA.

E-Textiles in Space

Wearables—e-textiles that help keep space crew healthy and monitor astronaut vitals and cabin environments wirelessly—are among the technologies that the next generation is already using. Leap Technology, one of the sponsors of "Couture in Orbit," specializes in supplying electroactive polymer wearables, such as stretch sensors and actuators, to both NASA and ESA in partnership with other companies.

Sensors comprising a sandwhich of deformable electrodes and insulating layers of elastomer, register any deformation as change to the electrical capacitance, which can be measured. Such sensors can therefore measure strain, pressure, speed, angle, and g-force.

Leap has "previously executed a stretch sensor project for ESA/NASA through an Italian university, used for monitoring blood flow from the brain back to the heart," Alan Poole, director and partner of Leap Technology, explains. Their stretch sensor, placed on the neck and wrist of an astronaut, is featured on the official NASA website.[7]

Poole hopes Leap Technology will continue to play a part with another wearables project, not yet revealed. "In the coming months, we are expecting to take part in a larger ESA project as a sensor supplier—working with a company planning to utilize the technology to measure fluid shift in astronauts on the International Space Station. As well as in human motion capture, there are numerous potential applications for our sensor technology, both in space and on Earth," he says.

Onwards and Upwards

One solution now available to space crews is to make space textiles while in space. With a 3D printer already onboard, manufacturing can now take place on the ISS itself. NASA is currently testing making woven metal fabrics for possible use as flexible solar panels or shielding.

As manufacturing processes evolve, perhaps astronauts will need textile training! The first woman in space, Valentina Tereshkova, was a textile worker when she applied to be a cosmonaut—skydiving was a hobby. Perhaps she knew which skills would be *really* important.

Finally, how do you keep your spacesuit clean? Retired NASA astronaut and former ISS commander Chris Hadfield commented via Twitter: *"With wet wipes."*

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