With the first new space suit design for 30 years under construction at NASA, one of the designers tells *WSA* about the importance of material developments. Across the Atlantic, Hohenstein Institute and Schoeller Textiles have embarked on a mission of their own: sending textiles into space to boost understanding on earth.

One giant leap for textile innovation

Pixar film animators must have done a double take when NASA unveiled its first major space suit redesign in 30 years in 2012 – the Z1 looks strikingly similar to Buzz Lightyear's, and his catchphrase "To infinity… and beyond!" is echoed in its new mission statements. At the start of this year, more than 350,000 people voted on the latest design, an evolution of the Z1. It was a clever PR move to boost public interest and the winning design will be ready to test in November.

Although there have been numerous iterations, there have only been three distinct types of NASA space suit since the early 1960s: the Mercury, the Gemini and the Apollo, which was worn on the moon and which has been in use for decades.

But NASA's remit is changing – and therefore, the suit. Rather than focusing on space walks and working around the stations in orbit, it now wants to concentrate on exploration. It has set a new target of landing on the moon again by 2020, and is contemplating visiting other asteroids and Mars – and so its designers have gone back to the drawing board.

"We are concentrating on efforts associated with enabling planetary surface exploration," Shane McFarland, one of the engineers working on the Z-2 spacesuit, tells *WSA*. "Among the primary drivers for a suit to provide this functionality are reduced weight, dust mitigation and performing over a range of thermal extremes. Specifically, as it relates to materials, we are actively pursuing efforts associated with flexible aerogel formulations

'Technology', the new design of the Z-2, uses light-emitting patches to identify crew members on space walks.

NASA

and dust-tolerant seals to enable Mars missions." During EVAs (extra-vehicle activity - outside the spaceship) on Mars, there is the potential for dust to be retained on the suits and contaminate the ship when the astronaut returns from missions.

"We are also pursuing advanced composite structure materials and reduced-mass metallics," he adds. "The suit needs to be as mobile and comfortable as possible for EVAs on the Martian surface."

The Z-2 marks several milestones for NASA: the first surface-specific planetary mobility suit to be tested in a vacuum; the first use of 3D human laser scans and 3D-printed hardware; the most advanced use of impact-resistant composite structures; the first integration of the suit-port concept with a hard upper torso suit structure; and the most resizeable hard upper torso suit built to date.

One of the most noticeable differences is the rear-entry design, which NASA thinks will reduce the risk of shoulder injury – the astronauts crawl through a hatch at the top, rather than assembling the suits in a number of parts. It has added bearings in the waist, as well as in the hip and ankle, to make walking easier and has recently changed the shoulder design.

Weight is an important element. Tasks are more demanding in zero gravity as the body is always fighting against the air volume inside the suit: the astronaut must do extra work every time he bends a joint. The Z1 suit weighed 158 pounds (72kg), while the updated prototype weighs closer to 100. "Improvements in materials are enabling us to making future space suits better, more robust, lighter and more comfortable," says Mr MacFarland.

The suits have been through rigorous testing in the Arizona desert – the closest environment that offers the necessary rugged terrain. Amy Ross, a spacesuit engineer who took part in Desert Research and Technology Studies, says the weight reduction makes a big difference to the workload the subject can undertake. "They are able to bear the weight and move very well," she says. The astronauts are able to kneel to pick up rock specimens – something they were unable to do in the Apollo suit.

"The strategy we're taking now is to look at all the requirements of all our potential destinations and try to understand the most challenging of any aspect – for mobility, it's walking on the surface; for radiation protection, it's deep space," she says. "We're designing to be able to cope with the most challenging conditions, so that when we need to specialise for one specific mission, we already have the capability."

Over to you

NASA offered the public three choices. The 'Biomimicry' design mirrored the "bioluminescent qualities" of aquatic creatures and included segmented pleats at the shoulder, elbow, hip and knee, with electroluminescent wire across the upper torso. The bright colour scheme of 'Trends in Society' was designed to mimic sportswear, and was reflective of what everyday clothes may look like in the not too distant future, according to the creators from Philadelphia University and suit manufacturer ILC Dover, which is also working with Wolverine Worldwide on the project. 'Technology' – which won with 63% of the vote – features electroluminescent wire and patches across the upper and lower torso, exposed rotating bearings, collapsing pleats for mobility and abrasion-resistant panels on the lower torso.

NASA is not requiring that the finished Z-2 prototype be equipped with full outer-space capabilities, such as radiation shielding, as it will be only used for research on earth. A subsequent model, the Z-3, will be tested at the International Space Station (ISS).

Advances in unrelated fields are also helping: motion capture in the 1990s wasn't sophisticated enough for space suits design, but progress driven by the video game industry has meant

The Z-1, nicknamed Buzz Lightyear, is flexible enough to enable astronauts to stoop.

NASA

The arid climate, harsh winds and rocky terrain of the area around Arizona's Meteor Crater allow NASA to evaluate moon-like conditions.

NASA

NASA engineers can better understand how the suits move and make decisions about the next configuration. "I used to have to take photographs and physically measure the movements astronauts were capable of," says Ms Ross. "Now I can have them do functional tasks and understand which joints they use and how that joint contributes to the motion."

With the new suit deadlines approaching, NASA's engineers are ramping up their testing programmes. For Mr MacFarland, the onus is on material developments, which are "incredibly important". "There are many exciting capabilities that we would like to explore in a space suit, but advances in materials must be made first," he says.

European involvement

This is where textile researchers come in. Germany-based testing firm the Hohenstein Institute, university hospital Charité and DLR (German Aerospace Station) have partnered Swiss textile group Schoeller to fund an experiment they hope will improve their understanding of interactions between the body, clothing and climate.

On May 28, German astronaut Alexander Gerst took off from the cosmodrome in Kazakhstan, bound for the ISS. During the six-month Blue Dot mission, Mr Gerst will be responsible for 40 experiments including the Spacetex project, the first clothing physiology experiments to be carried out in a weightless environment.

"Due to the absence of gravity we will be able to look at the different processes of heat loss separately and therefore understand the single role in the whole process better," says Dr Jan Beringer, head of research and development at the department of function and care at the Hohenstein Insitute. "We know these processes here on earth, but in space this is a totally new territory that has never been explored before. We will be able to investigate the role of convective heat loss because, due to the absence of gravity, there is almost no convection in space."

Dr Beringer and Prof Hanns-Christian Gunga of the Center of Space Medicine at Charité attended a training session at the European Astronaut Centre in Cologne. Dr Gerst performed four intensive treadmill workouts.

What are space suits made of?

US-based materials science company DuPont was one of the early innovators; 20 of 21 layers of the Apollo moon suits in the early 1970s contained the company's products. Kevlar was used for strength and flexibility, Nomex made up protective layers while Kapton polyimide film was used in two layers because of its durability and thermal stability. Mylar polyester film was used in several layers because of its toughness and flexibility while Krytox was used as a lubricant.

Spacesuits today use a variety of structural and non-structural components: soft goods for the arm segments comprised of nylon, Gore-Tex and Spectra, among others. Composites are often used for structural elements like the upper torso or brief while metallics (stainless steel, aluminium, titanium) are used for rotating bearings, sizing rings, brackets and places where hard components interface with soft components.

"Many, many other materials go into the final design of any space suit assembly but these are the largest contributors," explains Mr MacFarlane.

Suit features

Primary life support subsystem: Worn like a backpack. Provides oxygen and removes carbon dioxide. Contains a battery for electrical power.

Helmet: Keeps the oxygen at the right pressure around the head. The visor is coated with a thin layer of gold that filters out the sun's harmful rays.

Liquid cooling and ventilation garment: Water is pumped through 90 metres of tubing to remove body heat. Sweat is recycled in the water-cooling system.

Bladder layer: Creates the proper pressure for the body and holds the oxygen in.

Outer layer: A blend of three fabrics: waterproof, impact resistant and fire resistant.

Simplified aid for EVA rescue: Uses nitrogen-jet thrusters to let an astronaut move around in space should they become untethered during a space walk.

During two, he wore functional underwear made of special polyester, and for the other workouts he wore a conventional cotton set. The aim was to assess how well heat and sweat were wicked away from the body and compare this to how well the garments will perform in space.

"In zero gravity, the breakdown of muscle and bone tissue begins very quickly," explains Dr Gunga. "To counteract that degeneration, working on special training equipment is extremely important for astronauts. The body tries to cool itself by releasing and evaporating sweat. However, due to the lack of gravity, neither the body heat nor the sweat are transported away on to clothing or into the environment. Instead, the heat envelops the body almost like an aura. The cooling effect is lost and the training imparts greater physiological strain than it does on earth, even for very fit astronauts."

After the testing, the textiles were packed in airtight containers and taken to the Hohenstein Institute to monitor odour formation and residual bacteria. Tenax tubes serve as the 'odour trap' where polymers absorb and preserve the molecules so they can be counted using a gas chromatography mass spectrometer. Performance functions such as antimicrobial finishes are an important element of these new textiles as garments cannot be washed after exercise on the ISS. Dr Gerst will deliver his worn clothing in air-tight packaging in November for comparison.

Schoeller Medical's CEO, Hans-Jürgen Hübner, says his company is hoping to help optimise astronauts' clothing for future space voyages and long-term missions, such as the three-year voyage to Mars planned for 2030. It is also hoping to use the findings to develop textiles for extreme conditions on earth, including sportswear, workwear and protective clothing.

"Moisture management, temperature regulation, comfort and protection are the areas where we are very interested in getting new ideas from Spacetex," he says.

"Future astronauts will benefit from this work. We'll also make sure that people here on earth who push the limits of their physical endurance or have to deliver peak performance in extreme conditions benefit as well."

On Expedition 40/41, flight engineer Alexander Gerst (foreground) will carry out textile experiments for European organisations and companies including Schoeller and Hohenstein.

NASA