GETTING A FEEL FOR SPACE

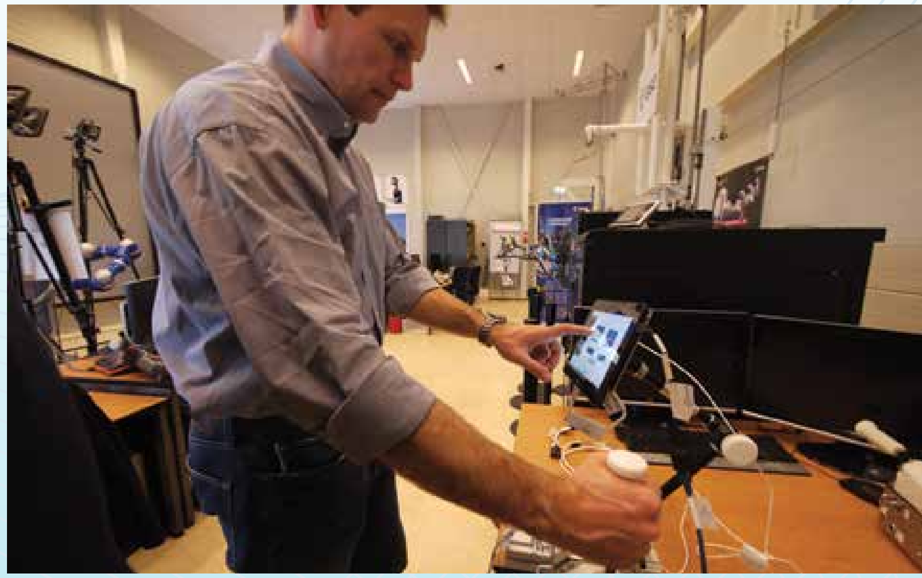
The way we use robots to explore the Solar System is about to change. **Elizabeth Pearson** looks at this new face of robotic exploration

From the surface of Mars to comets, robots have played a huge role in how we have ventured out into the Solar System over the past 60 years. In all that time, there has always been a control team on Earth, making decisions about where our distant emissary is going to travel to and what it will do. Now a new set of experiments on the International Space Station (ISS) could revolutionise the way humans and robots work together in the exploration of not only our own world, but many others as well.

In September, ESA astronaut Andreas Mogensen will take part in the Interact demonstration experiment, becoming the first human to pilot a robot on Earth from orbit. But not only will he control the robot; he'll be able to feel what it feels.

The experiment is being run at ESA's Telerobotics and Haptics Lab, where scientists have been investigating the orbital use of haptic technology – haptics being equipment that lets you feel forces and vibrations. A joystick sent to the ISS in 2014 has already allowed the crew to control a simple game-like experiment on a connected tablet, investigating how microgravity affects haptic feedback to astronauts. Already they have found that the weightless environment reduces astronaut ability to feel the joystick when it was mounted on the wall. In space, pushing on a stiff object causes you to move rather than feel resistance. Luckily this problem can be softened by attaching the stick directly to the astronaut via a harness.

Being able to feel what you're doing is very important to accomplishing fine tasks. Think about when you come in on a cold day and your fingers have gone numb; something as simple as tying your shoelaces becomes impossible. For the many robotic operators without haptic feedback, this is how they must constantly operate.



▲ Mogensen tests a model of the joystick he will use on the ISS to control the Centaur robot (below) on Earth for the Interact experiment

From remote control roving...

But the new Interact experiment will attempt to give robot operators some of the feeling back. It will see Mogensen attempt to operate a robot named Centaur, which has two robotic arms with hands that can be used to grip and manipulate tools. Using a tablet to display the terrain and controls, Mogensen will manoeuvre the robot towards a task board placed in an unknown location some distance away. Once there, he will pick up a peg and attempt to thread it into a hole less than a millimetre bigger.

"He can use the joystick to put a peg into a hole on the board, and if he is well aligned he should – in principle – receive very little force-feedback on the stick," says André Schiele, associate professor at Delft University of Technology and head of the lab. "If he is not well aligned he will instantly feel that he is blocked and can then use the tablet to finely adjust the robot arm."

The experiment is a stepping stone to a more audacious plan of controlling rovers on other planets such as Mars.

"Some people want to send humans to Mars and leave them there," says Schiele. "We believe if we send humans there we have the responsibility to bring them back. The only feasible way to do that is to put them into orbit."

Instead, robots would take the risks of landing on another planet, controlled by the crew in orbit, a practice known as telerobotics, allowing the rovers to perform much more complex tasks than current Martian vehicles. Haptics is an important part of this control, for example allowing operators the ability to feel if a drill is sticking on a dense rock; they can then back off before causing damage. ▸

◂ ESA's latest full arm exoskeleton is controlled by the whole body and allows the user to feel what the robot can feel

ESA–A. LE FLOCH, ESA–J. HARROD, ESA TELEROBOTICS/TU DELFT

▲ Schiele waits to perform the landmark handshake from Earth to the ISS with NASA astronaut Terry Virts

▸ Theoretically this could be done from Earth, but it's made nearly impossible due to the time delay of several minutes involved in communication. If the controlling crew were in orbit it would only take a fraction of a second to send and receive signals. However, even this might prove too much.

"There is 0.8 seconds of time delay to the ISS," says Schiele. "Imagine you are driving a car and if you steered left it only turned 0.8 seconds later. It would be pretty difficult to drive."

The delay stems from communicating with a network of geosynchronous satellites that allows for complete global coverage. The length of the lag was tested during the Haptics-2 experiment in June 2015, in which NASA astronaut Terry Virts performed the first handshake from space with Schiele, who was in his lab in the Netherlands.

To mediate the delay, the team used modelling and software to pause the robot arm when it encounters a problem, stopping itself while it informs the user of the problem through haptic feedback, preventing damage. How much this small lag affects operational performance will be one of the things that Mogensen will be investigating during Interact.

If the problems of time delay can be overcome, this can have a huge effect on the capabilities of telerobotics when using the system closer to home. Haptically controlled robots are already being used in medicine, deep-sea exploration and emergency operations, such as those following the Fukushima nuclear reactor disaster in Japan in March 2011, but they often need to use the same satellite communication and suffer the same time delay.

... to a classic sci-fi exoskeleton

However, Interact is only the first step to beginning routine telerobotic operations in space and the next stage is already being planned – Schiele and his team are working on a more advanced control system than the current single-axis joystick.

"We are preparing a new experiment that will be launched in late 2016," says Schiele. "We've built a full arm exoskeleton that we will fly to the ISS."

This exoskeleton, the fifth generation developed by the lab, allows the user to control a robotic arm with their body, rather than just their fingers. The two are linked together so that when the user moves, the robot arm mirrors the motion. If the robot then comes across some resistance, the exoskeleton responds, making it harder to move.

During *Stargazing LIVE* 2015, Dallas Campbell was sent to the Netherlands, where he was able to shake hands with Brian Cox and Dara O'Briain at Jodrell Bank using a prototype exoskeleton and the Centaur robot.

"It's your classic sci-fi exoskeleton," says Campbell. "You are in complete control. You put your arm in, and you can wear it. It's not very heavy, it feels very natural. You get used to it strangely quickly. The great thing about it is the haptic feedback. It's not just saying, 'Hey I've got a robot arm!' You can actually feel what the other arm can feel."

Not only is the exoskeleton much more intuitive to use than a joystick and buttons, it's also a lot easier to use, especially in situations where you can't fully use your hands, such as during a space walk. Spacesuit gloves are notoriously difficult to work in, making even turning a spanner an ordeal. Being able to control a robot to perform these finer tasks could make dangerous extra vehicular activities (EVAs) much faster and easier.

"It would have been impossible to do something like this 20 years ago," says Campbell. "It's organisations like this that push the frontiers of technology."

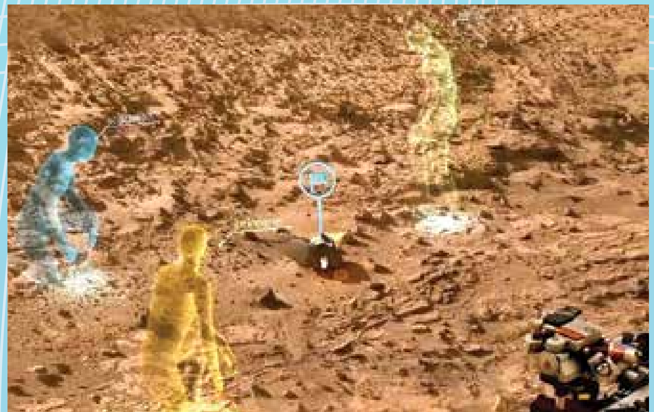
Now that both robotics and the computing power needed to control them is finally catching up, the lines between human and robotic exploration are beginning to blur. As the two begin to work closer together the way we explore the Solar System could be in for a big change.

Schiele controls the arm from the Netherlands as Buzz Aldrin and Brian Cox look on during *Stargazing LIVE* 2015

▼ It is hoped that this technology will make handling tools easier for astronauts

AUGMENTING **REALITY**

Bringing touch to robotics is important, but without visuals operators are blind



▲ This 3D simulation of Mars uses real data from rovers on the planet

▲ NASA and Microsoft are testing the HoloLens for use on the ISS

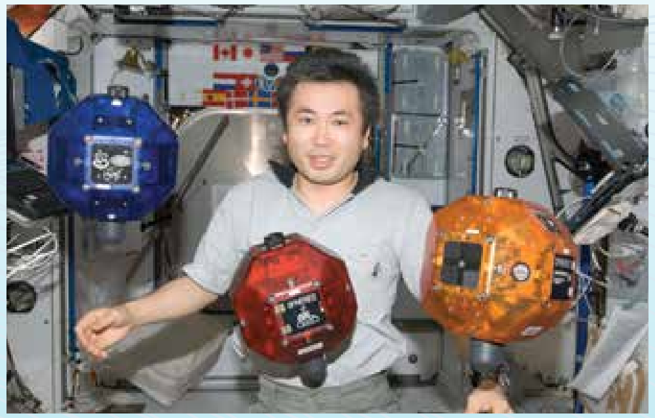
Video feeds in space are usually very bad. Suffering from low bandwidth speeds, videos are necessarily low resolution, come from limited angles and have little representation of depth. Performing complex tasks with only this would be like trying to fix a car in a darkened room, where you can't move your head and have one eye shut.

On the ISS, the problem isn't so bad thanks to an entire network of satellites providing internet speeds around the same as those found in the average UK home. But as exploration moves farther out into the Solar System, the quality of video is only going to get worse.

To make video clearer, ESA use augmented reality – overlaying information and 3D models onto real-world images to make them more understandable. 3D glasses can also be used to help gauge depth while information such as the predicted path of the robot arm can make tasks much easier. Meanwhile, NASA is experimenting with Microsoft's HoloLens, a headset that projects an image directly into your eye. Their goal is to allow planetary scientists to create computer models of objects and terrain imaged by Curiosity so they can examine them in a more natural way, helping to make decisions such as what direction the rover should go in. It's hoped that a set will be making its way to the ISS soon.

MEET THE **ROBOTS**

The ISS is already home to several robotic helpers



▲ The floating SPHERES propel themselves around the ISS via thrusters

▲ Robonaut 2 works inside the ISS, but could be upgraded for EVAs

▸ Kirobo can hold a conversation – but only in Japanese

For years there have been experimental robots on the ISS, prototypes for future helpers that can perform boring, repetitive or dangerous tasks and free up time for astronauts to do other things.

The ISS has been home to a mini-fleet of three floating orbs, called SPHERES, since 2006. The probes use carbon dioxide thrusters to propel themselves around the station and are used to test software and hardware that needs to move freely in space. They're already being adapted into robot helpers with the addition of a smartphone, making them mobile monitoring stations, checking the environment on the ISS.

A human-like helper is resident on the station in the form of Robonaut 2. The robot has human-like features and is highly dexterous, allowing it to use many of the tools astronauts can. Currently the robot is limited to life on board the station, but future updates aim to allow the robot to travel outside so that it can aid astronauts during challenging EVAs.

As well as maintaining the physical environment, robots could also help with keeping astronauts in peak psychological condition. A Japanese robot named Kirobo was sent to the ISS as space's first companion robot. The friendly looking robot is loaded with face recognition and cutting edge language software, which allowed it to chat with JAXA astronaut Koichi Wakata. With trips to Mars lasting at least two years, similar robots could help astronauts deal with the isolation of space travel, though Kirobo might have to learn a few more languages as it currently only speaks Japanese.

ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor, specialising in space science. She gained her PhD in extragalactic astronomy at Cardiff University.

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