Science on the ISS_Robots

Imagine that a bolt has come loose on the outside of the International Space Station. It's a bolt on the Illudium Pew-36 Explosive Space Modulator and unfortunately you are the Illudium mission specialist.

Now, in order to tighten that bolt you are first going to have to spend several hours acclimatising to a 100% oxygen atmosphere, before you can even get into your space suit. The back story to that is that oxygen is only 21% of the air we breathe on Earth. The rest is mostly nitrogen – with a bit of water vapour and CO_2, none of which do anything much to keep you alive. So, in a spacecraft all you really need to stay alive is pure oxygen at 21% of 1 atmosphere of pressure. This is how all space missions up to and including the Apollo missions were run. It's easier to build a spacecraft that can hold 21% of 1 atmosphere of pressure than a full 1 atmosphere.

Trouble is, as we tragically discovered with Apollo 1, filling a spacecraft with pure oxygen is a major fire risk, unless you are *very* careful. The rest of the Apollo missions were *very, very* careful, but with the Space Shuttle and subsequent ISS missions, astronauts breathed an air mix of 21% oxygen, 78% nitrogen and the usual trace gases mixed in – all at a full 1 atmosphere of pressure.

But there is no way that you can work in a space suit filled with 1 atmosphere of pressure. You will be able to do a great imitation of the Michelin Man, but you will not have the strength to bend your arms or legs in for any length of time. Indeed you will struggle to make a fist – or to grip the torque wrench you will need to tighten that loosened bolt on the Illudium Pew-36 Explosive Space Modulator.

So, if you want to do anything in a space suit you have to go back to the old system of breathing pure oxygen at 21% of atmospheric pressure. This is a problem when you have been breathing the ISS cabin air at 1 atmosphere of pressure. The only solution is to go and sit in an air lock for an hour or more, breathing in pure oxygen and breathing out all the dissolved nitrogen that's in your blood. If you don't, all that nitrogen will come bubbling out of your blood when you shift to the 21% atmospheric pressure in your space suit – in other words, you would get the bends and you would probably die.

Anyhow, once properly acclimatised, you can get into your space suit and then get out into space. Out there you have to keep tethering and untethering yourself as you work over to where the bolt is, then you will need to confer with Mission Control – *uh, Houston, ready to tighten bolt now* – before deploying the purpose-built tool that you have brought with you.

If it now turned out that you had left that tool back in the airlock, there would be some mightily-pissed people down in Mission Control. But, of course a ground crew has been monitoring your every move, so when you reach down for the Illudium Pew-36 torque wrench, it is fortunately there. And so, you are able to fit it to the bolt, twist and tighten the bolt, check back with Mission Control that all is well and then slowly make your way back to the airlock. This whole exercise will have taken half a day and involved a ground crew of maybe six people, not only on the day, but also in all the detailed planning beforehand. And despite all the planning and all the safety checks, tightening that bolt will have been one of the most dangerous things that you have ever done in your astronaut career.

So, with half the podcast gone on discussing spacewalks, hopefully you can now see why having a space-enabled robot on the ISS might be a really good idea. For example, wouldn't it be great if you could just go: (*sound byte*).

Now, we probably need a whole lot more technological evolution before robots will understand that the urgent instruction *lock it down*, means:

> access the design schematics and then use the appropriate tool upon the fastening mechanisms in a manner that is sufficient to reduce the existing gap between the stabiliser and the bulkhead – but without damaging the stabiliser, the bulkhead or the fastening mechanisms. And do it quickly please, because we have an imperial TIE fighter on our tail.

Rather than using verbal commands, it's much more likely that we will operate the first generation of space robots using **telepresence**. Astronauts can put on video display goggles that will enable then to see through a robot's video camera eyes and they can put on sensor gloves to control the robots hands. Remotely-operating a humanoid robot with binocular vision and human-like hands means that human operators can make a robot exactly mimic their actions and hence do most of the things that a human might do on a spacewalk. After all, something that no-one really does on a spacewalk is *walk*, it is mostly about what you do with your hands.

Humans can currently operate the *CanadaArm* to do some pretty complex tasks outside the ISS. But, if we could remotely-operate a mechanism that responds to the intricate hand-eye coordination that most people have been trained with from birth – then that will take the concept of remote control to a whole new level. Indeed, if it all goes accordingly to plan, after 5 or 10 minutes astronauts fully-immersed in robot telepresence will begin to feel like they are actually outside the ISS, using their oddly-angular hands to turn the tool that tightens the bolt that repairs the fault on the Illudium Pew-36 Explosive Space Modulator. And 5 or 10 minutes may be all the time they need, to complete a task that previously required several days of planning and several hours of doing.

Robonaut 2, also called R2, has been on the ISS since February 2011. R2 has been powered up and put through a number of tests, to check that it can operate in microgravity just as well as it operated back in 1G of gravity on Earth. R2 has followed some pre-programmed manoeuvres, such as saying hello in sign language. A remote operator has also used telepresence to guide R2 to flip some fake switches and turn some fake dials and even catch a ball.

For the three years it's been in orbit, R2's torso has been attached to a post, but the ISS has recently taken delivery of a pair of legs, launched aboard a Dragon resupply mission in April 2014. The only thing faintly humanoid about those legs are that there are two of them. Otherwise, each are three metres long, have seven joints each and end with clamps, rather than feet.

As any astronaut will tell you, human legs are pretty much useless in microgravity and human feet are completely useless. So the main purpose of R2's legs is not to walk, but to reach out and fasten onto things around the station so R2 can move itself around while always keeping its two hands free.

In 2015, R2 will get a backpack, essentially a big storage battery that will allow it to move around without being plugged in. And after another round of testing, there will be another upgrade, that will then allow R2 to work in the cold vacuum of space.

Ironically, R2's main challenge, in working in the cold vacuum of space, will be staying cool, since its current system of cooling fans will be useless. R2 particularly needs cooling around its main computer, which is not in its head, but in its stomach. R2 also has several distributed processors around its body, to manage the data flow from its various cameras and sensors – and to coordinate the movement of its various servomotors.

To keep everything working optimally, R2 will probably be fitted with a water-cooled body suit which will not be all that different to what the astronauts currently wear on their spacewalks. So, in the end, astronauts and their space robot companions will have quite a lot in common. After all, when you work on the ISS, it's all about staying cool.