Hi, this is Duranee for Cheap Astronomy www.cheapastro.com. This is SISS, Science on the ISS – and today's episode is *SPHERES 2.0*.

Welcome to Season two of Science on the ISS and what better way to start Season 2 than by revisiting the fabulous SPHERES robots on board the ISS, which we first got to know back in episode one of Season 1. If we didn't manage to give you the impression back then that these robots are evolving, then hopefully this episode will make it a bit clearer.

You may recall that SPHERES is an acronym for the Synchronized Position-Hold-Engage-Reorient Experimental Satellites. They have been aboard the ISS since 2003. Operating in microgravity, the three SPHERES are able to propel them around the ISS using small puffs of CO_2 that come from pressurised canisters that need to be installed by an astronaut and the SPHERES draw power from double A batteries that need to be installed by an astronaut.

There are now moves afoot to implement an ISS-wide rechargeable battery system. Once implemented the SPHERES robots could then be recharging themselves from power drawn from the ISS solar arrays. This will eliminate the cost of ferrying packs of double A batteries up from the Earth. More importantly though, it brings the SPHERES a step closer to becoming genuine space-robots, able to operate independently from the planet of their birth. No-one's yet came up with an independent propulsion system for them, so we are still ferrying up the little compressed CO_2 canisters, but give it time and who knows what might come next.

Of course, another thing that any independent space robot will need is a universal docking port. To date, the SPHERES robots have practiced various docking procedures within the confines of the ISS by using Velcro pads so they could at least stick to something, including a fellow SPHERE. The problem with Velcro was that an astronaut was then needed enable undocking. With the new universal docking ports, or UDPs, two SPHERES will be able to dock with each other and then undock again with any direct human intervention.

As well as being installed on a SPHERE, a UDP can be installed on some other object, or just on a wall so a SPHERE can practice docking an undocking. Sure, it's just practice, but it's a step closer to space robots that can fly about servicing spacecraft.

And speaking of fixing spacecraft. There's a new SPHERES experiment underway called SLOSH – which isn't actually an acronym, it's just SLOSH. The SPHERES-SLOSH experiment will examine the effects of liquid movement, that is, *sloshing*, in microgravity. Rockets that climb from the surface up into Earth orbit enter a microgravity environment in which the behavior of the liquid propellant they are carrying is not well understood. So, having the SPHERES studying how liquids behave inside containers in a microgravity environment will increase the safety and efficiency of future rockets.

And then there's HALO, which isn't an acronym either and, if it becomes standard issue, will represent the biggest SPHERES upgrade so far. HALO is a 3D-printed structure designed to exactly fit around a SPHERE robot, without blocking the SPHERES' thrusters or sensors. The ring-shaped Halos interface directly with the SPHERES via their single expansion port, but once attached, a HALO provides the SPHERE with six additional expansion ports, as well as additional computing power and hard disk memory storage. HALO runs off its own power source and can also distribute that power to its expansion ports. So, with the basic SPHERE units providing mobility, an attached HALO can enable a whole range of new experiments, For example, with a HALO attached, a SPHERE can support more than one UDP, making it possible for *three* SPHERES to dock together and maneuver together as a single unit.

The first multifunction system to be attached to a HALO is called INSPECT, which you will be pleased to know *is* an acronym, standing for the Integrated Navigation Sensor Platform for Extravehicular Control and Testing. One of the most interesting components of INSPECT is ORF, the Optical Range Finder, which is essentially a binocular video camera. But we could stretch that a bit further and call ORF a pair of robotic eyes, since ORF processes optical data to build a 3D map of the SPHERES' immediate environment.

INSPECT includes a thermal camera to monitor infra-red outputs from its immediate environment. Also, INSPECT has what is known as a control moment gyroscope – a CMG – which works a bit like the reaction wheels built into many of our robotic spacecraft. Running off the Halo's power supply, the CMG will let the spheres to alter their orientation in space without needing to expend any of their limited CO_2 propellant.

So, with all these components working together, INSPECT will allow the SPHERES to have their first look around their ISS home and get a feel for the place, at least with respect to the surrounding temperature. And, after INSPECT has been trialed, who knows? The HALO system may enable the functionality of the SPHERES to be further expanded in directions we are yet to imagine. Or, just as likely, the HALO expansion systems might be superseded by a HALO Mark 2 or a HALO Mark 3 system that will enable even more new functions. The only fixed and fundamental components in all the possible options we are yet to explore will be the SPHERES units themselves.

In the meantime though, the US Department of Defence is taking the SPHERES in another direction with the RINGS – that is, the Resonant Inductive Near-field Generation Systems. The RINGS aren't adaptable enhancements to the SPHERES, they are purpose-built systems that have been made to test just two new technologies. Fitting around the SPHERES like a bicycle tire, the RINGS are large magnetic coils. If you fly two SPHERES with RINGS fitted in close formation, they can each bounce off the other's magnetic field, meaning that that they can work together to reorientate each other in space without either one wasting propellant fuel.

The second thing the RINGS will test is wireless power transfer. This will be achieved by using the RINGS magnetic coils again, but this time using the principles of magnetic induction. Much like the way steam turbine uses a magnet to convert the energy of motion of the turbine into an electric current, the motion of one RING, which is expending energy to actively drive a current through its magnetic coil, can induce a current through the other RING, without the other RING expending any energy. Indeed, the current induced that other RING represents useful energy that it can then store in its batteries.

This energy exchange process is only effective when the two RINGed SPHERES are in close proximity, so it does leave you wondering whether the whole process wouldn't be more efficient if the two SPHERES just docked and exchanged energy via a direct connection. But hey, this is science – we never really know what we're going to find out until we give it a try.

All these ideas and experiments envision a day when lots of SPHERES might be flitting around in Earth orbit making spot checks and repairs to orbiting spacecraft, including the ISS, or one of its future counterparts. Such space-borne droids might also play a role in refueling spacecraft, as well as deorbiting defunct ones. Indeed, it is possible, even likely, that the eventual solution to our current space junk problems will be a technological advance that will come from all this mucking about with the ISS SPHERES.

And it might also be that whenever we do get around to building the USS Enterprise, it will carry with it a collection of basketball-sized droids. During rest periods, those droids will go out and flit all around the ship, carrying out a regimented series of minor repairs and upgrades, as well as following pre-emptive algorithms to identify and fix any unexpected problems they find. This seems the most likely solution to keeping a ship in prime condition over a five year mission out in the harsh environment of space.

And if there is ever a Season 3 of Science on the ISS, we hope we will be able to tell you how much closer we are in getting to that goal.

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