This is SISS, Science on the ISS, the International Space Station – and today's episode is *SPHERES*.

Humanity has been flying in microgravity since the late 1950s, but flying in microgravity is an expensive business. No-one has ever really had the chance to pull out all the stops and go a bit crazy – going left rather than right, fast rather than slow, that sort of thing. We haven't exactly pushed the edge of the envelope in *remote*-flying either. We can do it of course, like when we remotely launch and then dock unmanned supply vehicles with the ISS. But this is a huge undertaking, engaging both astronauts and ground personnel in a nail-biting and meticulously-orchestrated operation. Again, there's no chance of anyone just mucking about to try out a few new ideas.

So, wouldn't it be great if you had an orbiting laboratory that experienced microgravity 24 hours a day, seven days a week where you really could just muck about and test a few new ideas. Well, just look up folks – the future is now.

The SPHERES program, that is the **Synchronized Position Hold, Engage, Reorient Experimental Satellites** program is now in its 7th year aboard the ISS and has been one of the most successful ISS science programs to engage astronauts – as well as ground-based scientists, engineers and their students - in a highly-collaborative and kind-of-fun research effort.

The SPHERES are three free-flying vehicles that can move around inside the International Space Station providing an ideal test bed for developing theories and calculations to coordinate the motion of multiple spacecraft in microgravity.

You may not be surprised to hear that the SPHERES are spherical and since they fly around inside the space station you may not be surprised to hear they are only 20 cm in diameter - about the size of bowling balls. And they really can fly… at least in microgravity.

Well OK, *anything* can fly in microgravity – but the SPHERES can *maneuver* in microgravity. Each of the SPHERES has a propulsion system composed of a set of carbon dioxide thrusters and an avionic guidance system – that is, gyroscopes. Each of the SPHERES also has its own metrology subsystem which use ultrasound to determine its real-time position and its relative attitude. So, not only can they fly, but they can fly in tandem – all the while positioning, holding and engaging in activities like simulated-docking procedures, after which they can reorientate themselves before doing it all over again

The story goes that the SPHERES' principal investigator Professor David Miller from MIT really liked that scene out of Star Wars, where Luke Skywalker is aboard the Millenium Falcon, learning how to use a light sabre by defending himself from a 'laser remote', a floating droid that swished around while firing laser pips at him. (sound-byte)

Finally, in 2000 David Miller told his engineering students he wanted them to build him one – which they did. The first of the SPHERES, Red, was delivered to the ISS by an unmanned Progress supply vehicle in May 2006, the second, Blue was delivered aboard shuttle mission STS 121 in August 2006 and the third, Orange, was delivered in December 2006 aboard STS 116 – remembering that shuttle mission numbers don't always run in sequence.

Each of the SPHERES is powered by AA batteries, which deliver about 13 watts for about 2 hours running time. The SPHERES also have removable CO2 tanks which need refilling every now and again, depending on how much maneuvering they do.

The ISS crew only pull the SPHERES out for a test flight once every 3 or 4 months. Such a test flight generally has a set of pre-determined objectives and generates reams of data about each of the SPHERES' reaction to commands and the SPHERES formation-flying precision – as well as where things went wrong and why they went wrong. After a test flight, the ISS crew get on with the sorts of things that astronauts get on with, while the data outputs generated by a test flight are forensically examined by ground personnel over the next 3 or 4 months. Those ground personnel – scientists, engineers and their students – analyse the SPHERES program code line-by-line and the SPHERES telemetry second-by-second. This post-test evaluation may then inform what new maneuvers the SPHERES try out on their next test flight.

As well as receiving increasingly-sophisticated program coding, the SPHERES also have expansion ports. Back in 2000, when their basic schematics were first laid down, no-one was quite sure what those expansion ports might end up being used for, but these days the SPHERES have got smart phones. In fact Google/Samsung Nexus S smart phones – which first went on sale back in 2010 and were subsequently launched to the ISS aboard the final space shuttle mission STS 135 in July 2011.

When plugged into an expansion port, these smart phones provide each of the SPHERES with a camera, WiFi connectivity and a substantial amount of memory and processing power that was not available on such a small scale back in 2000. Ironically, the one thing the SPHERES can't do is make a phone call, as the phones' com chips were removed to avoid interference with ISS communications. The lithium ion batteries were also removed and replaced with AA batteries, since lithium ion batteries are a fire risk, while AA batteries are standard issue on the ISS – powering, amongst other things, the SPHERES themselves.

The current SPHERES may represent prototypes of more sophisticated droid-SPHERES that will assist astronauts with routine tasks around a space station. For example, conducting visual inspections of hard-to-get-to areas or maybe just delivering fresh coffee from the galley. But, in the longer-term, more sophisticated descendants of the SPHERES may be able to operate in the harsh vacuum of space.

The sophisticated formation-flying algorithms being developed in the SPHERES program today, may allow a range of complex engineering and construction tasks to be managed by a team of next-generation SPHERES. Anything from external station repairs to de-orbiting space junk. A team of space-going SPHERES might also support astronomical interferometry – creating multiple observation points for a radio astronomy array or even a gravitational wave detector.

SPHERES is one of those programs where you can *kind-of* see where it's going, but no-one is really sure quite where it might end up. And, no-one really minds either – at the end of the day, mucking about with three remote-controlled droids is teaching us important new tricks for working in space and it really is kind of fun.