Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *3D printing in space*.

3d printing and space – it doesn't get much better than that, unless you can add some dinosaurs maybe. And 3d printing in space really is going to happen. In August 2014, NASA plans to send a proof-of-concept 3d printer to the International Space Station to demonstrate that the technology can work in orbit. And, assuming that all goes well, a permanent facility is expected to follow in 2016. That permanent facility will be able to create working spare parts for some of the space station's infrastructure. And in the longer-term, this new technology, also known as additive manufacturing, could be a real game-changer in our quest to become a space-faring species.

In the early days of 3d printing, objects were just sculpted out of a block of material, the printer working to remove excess material and leave a pre-determined shape behind. But these days, 3d printing is an additive process, where you build up a three dimensional object layer-by layer using printing jets that follow a pre-defined 3d digital model and extrude a layer of malleable material on each pass.

If you print objects by additive manufacturing not only can you reproduce shapes, but you can also create objects with intricate inner cavities, that a sculptor working on a solid block could never hope to reproduce.

So, why 3d printing and space? Well, think about Apollo 13. The CO2 scrubbers from the command module wouldn't fit the receptacles in the lunar module. So ground control worked up a way to jury rig an interface out of cardboard from the mission procedure folders, some sealed plastic bags that were meant to store moon rocks and, of course, duct tape. They did get it to work, but put a 3d printer into that story and ground control could have just built a prototype interface connection from modelling clay, scanned it in 3d, uploaded the digital model and the astronauts could have printed it out and breathed easy.

That is what the first stage of the 3d space printing revolution will be about. If something breaks on the International Space Station, rather than having to wait for the arrival of the next supply ship, the crew just print out a replacement based on a 3d blueprint uploaded by ground control. To make this work, we will still have to fly up the raw materials, the ink if you like, that makes 3d printing work. Such raw materials are commonly thermoplastics or metal alloys, although the range of raw materials that can be printed is steadily growing.

For example, sugar and chocolate can now be printed out into novelty dessert items – and, in the longer-term, more complex food items might be developed. It has been proposed that future Mars colonists will celebrate their first night on the planet by consuming a 3d printed pizza created from freeze-dried particles of carbohydrate, protein and fat, which have been printed out with just the right textures and colours to produce something will look, taste and feel a bit like a real home-made pizza. This kind of thinking leads people to suggest that 3d printers are the first step towards Star-Trek-type replicators.

3d printing in microgravity presents a few hurdles, but these are generally finicky problems rather than major barriers. Current 3d printing techniques rely on printer heads that extrude layer after layer of thermoplastic. But that layering is more dependent on surface adhesion than it is on gravity. Other techniques involving building up shapes from metal particles, generally depend on a process known as sintering – which involves heating the metallic particles up enough so that they adhere together without actually melting. Some techniques also employ lasers to orientate and even weld things into shape. None of these approaches are especially dependant on gravity either and so should require only minor refinements in order to work in space.

Perhaps the biggest issue to deal with will be heat transfer. When you heat something up in microgravity, it takes a lot longer to cool since hot air doesn't rise in microgravity it just hangs around. With 3d printing you need the new printing layers to be hot, so they will adhere, but you also need to ensure the already laid down layers cool down lest the whole object melts due to heat retention. But getting around this problem may be as easy as running a fan over the object being printed, which should then cool it down just as quickly as it might on Earth.

Having conquered this initial start-up stage, the second stage of the 3d space printing revolution will involve printing things that work just fine in space, even though they would just collapse under their own weight back on Earth.

For example, we might print out the components of light-weight interplanetary probes that would have never survived the stresses of a rocket launch from Earth. These lightweight probes could either carry more fuel or they might carry more scientific payload mass. Either way, these would be faster, better and cheaper space probes.

The third stage of the 3d space revolution is when we stop flying the raw materials for printing up from Earth and instead start using materials that are already out in space. For example, lunar regolith is largely silicon oxides. You just mix this with some magnesium oxide to create a pulp that can be then extruded into any shape you want and then set solid by adding a binding salt.

The plan here is to print buildings. They won't be airtight buildings but if you print out the inner and outer walls of a lunar apartment block and then fill all the cavities with inflatable membranes, made of Earth-derived plastics, they become airtight. The recycled regolith will give the building structure as well as protection from radiation, temperature swings and micrometeorites. So even though you still need to fly some specialised materials up from Earth, about 90 per cent of these buildings' mass will just be moon dust.

And it doesn't stop with the Moon. We know that some asteroids are rich in metals, including iron, titanium and platinum, while others are composed of semi-organic materials, like clays that might be modified into ceramics. And there's no shortage of water out there to act as a solvent if we want to get more chemically creative. And of course, we can recycle all of orbiting space junk too, just grind it down into particles and then build it up into something more useful.

In the very long-term, once we start sending people on interstellar voyages, Earth can just broadcast new design schematics to allow the interstellar explorers to print out upgraded components for their spacecraft. Indeed, as engineering requirements become increasingly sophisticated we will probably need to broadcast design schematics to allow them to upgrade their printers.

And that brings us to the fourth stage of the 3d space printing revolution – when the printers begin printing printers. As we begin to colonise space, the distance from Earth means it is just impractical to send out a new printer to a colony on Mars – and why would you bother when there are printers there that can print anything you like, including a new printer.

In parallel with those developments, we might create a kind of printer-consciousness. This will have simple beginnings as we build printers with a few logic protocols that enable autonomous operation, overcoming many of the inconveniences caused by the radio time delay from Earth. So, we will have created autonomous entities with the ability to reproduce themselves and with the ability to plan and with the ability to build anything in 3d. What could possibly go wrong?

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we just build these episodes up from nothing. No ads, no profit, just good science. Bye.