Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Living in microgravity.*

As we've all been learning from that fabulous podcast, Science on the ISS, there is a ton of good science to be done in the world's largest microgravity laboratory, the International Space Station – most of which has nothing much to do with space travel, although a bit of it does. But, as far as us becoming a space-faring species goes, these repeated missions to low Earth orbit just look as though we are dithering around on the sidelines, when we should be out there playing the game.

The main thing the ISS is teaching us about space travel is that microgravity is really bad for you. Indeed, this may be the main lesson to come from the space station era – if we are really going to live and work in space over lifetimes and over generations, we will need to take gravity with us. Otherwise, we might as well just send more robots.

The symptoms of long-term exposure to microgravity makes for a grim list. Loss of bone density loss, muscular atrophy and also neurovestibular dysfunction (which is dysfunction of the system that gives you your sense of balance and orientation). These symptoms can become quite troublesome over a period of six months.

Astronauts, who are some of the fittest and healthiest people of their age group, return to Earth after 6 months in space with scrawny muscles, osteoporosis, difficulty concentrating, nausea, vomiting, vertigo while walking, difficulty walking a straight line, blurred vision, dry heaves and general clumsiness.

Most astronaut training programs make a point of politely-excluding clumsy people who struggle to tie their own shoe laces and who are likely to throw up over someone else shoes without warning. But, this is just what we turn our long-duration astronauts into.

You might think that the first thing a returned astronaut wants to do after spending six months on a space station is to have a hot shower, but it's not that easy. On their return to Earth, the cardiovascular system of long-duration astronauts is so messed-up that simple vasodilation of the skin, in response to a hot shower, is enough to make them faint and risk cracking their head open on the bathroom tiles. So, returned astronauts need a shower chair and maybe have someone standing outside the bathroom door, who they can call out to if they get a bit dizzy – or if they aren't sure that they can get out of the chair unaided. This is what long exposure to microgravity does the prime of humanity in the prime of their lives.

Of course microgravity is something people can get over – and you could argue that as long as people stay in microgravity they seem to be OK, it's just the return to Earth that messes them up for a while. It's even possible that more work on the ISS might come up with just the right diet, exercise and medication regime to stave off the much of the bone and muscle degeneration – and we have made significant inroads in this area.

But, we are yet to fully investigate the longer-term effects of peripheral fluid retention, as well as immunosuppression, in microgravity – and it's unlikely that any of those effects are going to be good.

So, for now, we should assume microgravity is a health hazard, even though it is a dose-dependent health hazard. Short-bursts of it will do you no real harm, but long duration exposure of a year or more is likely to do you a good deal of harm. So, as if we needed yet another reason why a seven month flight to Mars and another seven month flight back might just be a tad dangerous… think microgravity.

Building a spacecraft with artificial gravity is technically-feasible today, but would be hugely expensive since you would need to build a rotating spacecraft on a very large scale. It's no good spinning a small spacecraft, since the difference in angular momentum from your head to your feet would make all your blood rush to your feet so that you'd keep fainting all the time. This: a) wouldn't do much for your bone density; and b) having astronauts who can only remain conscious while lying on the floor would considerably limit the parameters of a mission.

If you imagine a big bicycle wheel, the centrifugal force on an object at its outer edge is strong and that force declines steadily for any objects positioned inward along the spokes of the wheel – until that force reaches zero at the centre of the wheel. So, for a person to be comfortable standing, you will need something like a two hundred metre diameter wheel, which is set spinning fast enough to generate artificial gravity at its outer edge, with that gravity only declining slightly over the proportionally small distance of two metres – that is the height of a standing adult.

All that said though, you don't really need to build a wheel. You could just attach a spacecraft cabin to a two hundred metre long stick, or a cable, with a counterweight at the other end. You then set that whole structure spinning, where the centre of the stick is the axis of rotation. The counterweight might be a fuel tank, extra supplies or even a landing craft that won't need to be made operational until you reach your destination. The spacecraft's main thrust engine would probably be placed at the axis of rotation, while lateral thrusters would be attached to the cabin and / or the counterweight to start and then sustain the spin. Since the spacecraft will be spinning in a vacuum, sustaining its spin won't require continual thrust, probably just an occasional correction burn to maintain a steady spin rate and hence a steady force of artificial gravity.

Just how much artificial gravity you need to generate, to keep people healthy, is an open question. The faster you spin something, the more energy you need to burn and the more stress you place on the structure that is being spun. So, while 1 G may be ideal, 0.9 G, 0.5 G or even 0.1 G might be nearly as healthy. Just giving our bodies some idea of which way is up and providing an environment where fluids drop and warm air rises would eliminate many of the current problems involved in living and working in microgravity.

So, to find out the ideal proportion of G for good health, we should set up a Moon base, from where we can start observing whether people can tolerate one sixth of Earth's gravity, that is 0.17 G, for longer periods than we've ever managed on the ISS – ideally, for years at a time. This is certainly something we need to get a handle on ahead of sending people on a one-way missions to Mars, which has gravity of around 0.4 G – not that this podcast supports sending people on one way missions to Mars any time soon. This podcast thinks we should start sending people on one-way missions to Mars when Mars has a school, a hospital, several take-away restaurants and a police force.

Anyway, if we do find that living and working on the Moon with one sixth of G is sufficient to sustain reasonable health, then one sixth G may be all we will need to generate in our long-duration spaceflights of the future. If it turns out that we need Mars-strength gravity, of around two-fifths G, then that's what we'll generate instead – and if it really turns out that we need a full 1 G – well, so be it, we will just have to manage the energy cost and engineering challenges that go along with that.

The fact that we just don't know how badly a Mars mission might affect an astronaut's health is reason enough not to do it… yet. So, let's go back to the Moon and see how well we manage 0,17G over long periods. Sure we've *been* to the Moon, but we've tried to really live there. It is just another small step, but it's still a new step.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website that keeps your feet on the ground and your head in the stars. No ads, no profit, just good science. Bye.