Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Space elevators.*

Well folks - it's another small milestone in that less well travelled road that is Cheap Astronomy. Finally, a Mr Stephen De Souza purchased the 'commission a podcast' charity option, where every last cent goes to the Unicef Water for Life fund - and none of it goes to me because of the no ads, no profit thing (and how's that working out for you Steve - shoosh) - and as part of the deal Stephen gets to nominate the topic for this podcast.

So, it's space elevators. Which I'll suggest is a great physics thought experiment, but if we're going to do it, it's probably going to be on the Moon or on Mars. On Earth, the combination of strong gravity, a junkyard of orbiting space debris and a dense, highly litigious population living on the surface - adds up to a level of economic risk likely dissuade even Richard Branson from the multi-billion dollar investment that would be required. So, this is not to say it couldn't be done – it just probably won't be anytime soon. But a space elevator on the Moon or Mars - heck yes.

Nonetheless, let's start with the Earth model – since you know, it's Stephen's podcast. The whole idea of geostationary orbit is if you propel something at 3.07 kilometres a second it will fly away from Earth - at something approaching, but not exceeding, escape velocity. And if it just maintains that constant velocity, it will naturally end up at an altitude of 36,000 kilometres. But of course, to be truly geostationary you will have to maintain this exacting orbital velocity over the equator. If you say adopt a polar orbit – you could still stay at 36,000 kilometres altitude – but the Earth will rotate sideways beneath you.

Anyhow, the real problem with building a space elevator on Earth is that you need over 36,000 kilometres of cable. On Mars you can maintain an areostationary orbit at 17,000 kilometres altitude. So that's not only less cable – but less stress on the cable that you put there.

As is well recorded, there is potential to manufacture a very light and very strong cable of carbon – or even boron-nitrite - nanotubes. But it's worth stressing the word potential here – currently manufactured lengths of nanotubes are still measured in centimetres. Manufacturing 36,000 kilometres of flawless cable is well beyond our current capabilities – but OK, it is possible.

Next thing you'll need is a counterweight. Over 36,000 kilometres of cable – even nanotube cable - has a sizable amount of mass and something has to hold it up and keep it taut. It could be a manufactured satellite – or maybe a modified asteroid - although the latter is also well beyond current capabilities. But the satellite – well, sure we can do that now.

Despite the mass of 36,000 kilometres of cable – even nanotube cable - being substantial, the satellite doesn't have to match that mass as a counterweight. It just has to match it in terms of momentum which is mass times velocity, because remember it's moving at over 3 kilometres a second – which is around three times as fast as a speeding bullet on the surface of Earth. And this counterweight – although it's going to remain in geosynchronous orbit – is not actually going to sit at 36,000 kilometres – it's going to have to be quite a bit higher than that.

Here's why - imagine you start with your standard geostationary satellite at 36,000 kilometres. As you start lowering cable from it – that cable is going to add mass. This only has a minor effect on the satellite's orbit – since all you are changing is the mass ratio between the Earth and the satellite and hence slightly shifting the barycentre about which both masses orbit. Of more concern is that you are bringing the mass of the cable closer to the surface of the Earth. This means that the tip of the cable has a smaller orbital diameter to move around than the satellite does – so the cable is going to start moving ahead of the satellite and risk dragging the satellite down from its geostationary orbit.

So, as you start lowering cable, you've got to raise the orbit of your satellite counterweight – so it's always the centre of momentum of the whole structure that stays at 36,000 kilometres altitude. Then even if the tip of the cable is trying to pull it forward – the counterweight is pulling back – so you end up with a nice straight line of cable from the counterweight down to surface of the Earth. In fact, you could even substitute the mass of your counterweight satellite for just more cable – so that your elevator can achieve an even higher altitude – just as long as the momentum of the cable past 36,000 kilometres stays equivalent to that of the cable under 36,000 kilometres.

So, at this point you might be wondering what happens when the elevator cabin starts going up the cable – since the cabin also has mass. Once it's left the Earth's surface and is no longer being propelled around by the Earth's rotation, it will begin to drag on the cable – pulling it back. This shouldn't have much immediate impact on the cable which will have a very substantial forward inertia – and really the whole thing is a conservation of angular momentum story. The elevator cabin going up represents a skater spreading their arms out – so it very, very slightly slows the rotation of the Earth, while gaining angular momentum of its own. So the elevator cabin puts drag on the Earth and drag on the cable - while it is sped up – so everything pretty much stays in a straight line.

The only thing is, the Earth isn't a perfectly unchanging rotating system – there are constant fluctuations from lunar tidal effects, magma movement, tectonic plate movement and atmospheric movement – in other words, weather. So, it's probably a good idea to have an ion drive or something similar attached to the elevator cable's centre of momentum – or perhaps the elevator car itself – to enable tiny orbital velocity corrections when required.

But, like I say - who knows if we'll ever do it. More likely we will build a Mars elevator – where we've either got to deorbit Phobos – or use it as the counterweight – otherwise it's inevitably going to crash into a cable that's connected to Mars' equator. So, a bit of a technology push is required there.

Before that we might build an elevator on the Moon, where we also have interesting possibility of building a cable from the Moon's equator up to the Moon–Earth L1 Lagrange point – a substantial 50,000 kilometres altitude from the lunar surface – but with the Moon's one sixth G gravity the engineering issues become that much simpler – and you probably don't need nanotubes.

Both the Moon and the Mars elevators would still save substantial amounts of expensive rocket fuel which is currently required for use in landing and launching from the Moon or from Mars. So, there are still real and feasible economies to be made. And if we build an L1 lunar elevator to land – why not build another one from the dark side of the Moon up to the Earth-Moon L2 Lagrange point. Then you just launch from Earth to L1 – land on the Moon with the elevator – drive around to the dark side and then catch the L2 elevator up into interplanetary space.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website that's just all talk really – and there's 90 instances of that now. No ads, no profit, just good science. Bye.