Hi, this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *CubeSats*.

Remember how a few geeky nerds got computers – and then everyone got computers? And then a few people got smartphones – and then everyone got smart phones? So, maybe it's a bit of a stretch to suggest the next big thing will be CubeSats, but they are now definitely a thing. Indeed, CubeSats are currently leading what's called the democratisation of space.

A CubeSat is a small satellite, built around some rigidly-defined design parameters. So, a 1 unit CubeSat is a cube 10 by 10 by 10 centimetres and its mass must not exceed 1.3 kilograms. Larger CubeSats then come in 3, 6 and 12 unit sizes – where a 3 unit CubeSat is built from three 10 centimetre units joined into a line and a 6 unit CubeSat is two lines of three units joined side-by-side and 12 units may be two lines of 6 units joined side-by-side. So, although a 1 unit CubeSat really is a cube – the rest are generally rectangular, although you can go way up to 27U, which is a cube of 3 by 3 by 3 units – in other words, 30 by 30 by 30 centimetres.

Anyhow, over 700 CubeSats of various sizes have been launched since the first one went up nearly fifteen years ago back in 2003. And since over 600 of those 700 have gone up in the last five years, the pace is clearly accelerating. Indeed, in February 2017, the Indian Space Agency set a new world record by launching 103 CubeSats on board its Polar Satellite Launch Vehicle.

A good example of a CubeSat is the Planetary Society's Light Sail-A spacecraft which is due to be launched in early 2018. It's a 3U CubeSat, which means it's around 30 by 10 by 10 centimetres in size with a mass of less than 5 kilograms. Two of the CubeSat units hold the stowed solar sail and its mechanism which will unfold the sail when it's in orbit. The remaining third unit of the Light Sail-A CubeSat holds the satellite guidance and support systems.

The modular standardisation of CubeSats is useful in planning launch payloads – since a launch vehicle, either built or on the drawing board, will have a fixed volume in its nosecone and a fixed payload mass that it's able to get into orbit. And a launch is a launch, with a fixed and huge cost involved. So, the last thing you want to do is to launch with unused capacity. For example, if a rocket is to launch a communication satellite of known mass and volume – the rocket owner can announce there is room for, let's say, 36 CubeSat units – because the owner knows what volume that involves and the owner knows that it won't represent more than 50 kilograms of mass. Then, various agencies with CubeSat interests can bid for places on board. Many rockets payloads are determined in this way more than a year before their launch – sometimes even before the rocket has been built.

So, this all means that CubeSats are very good for the rocket business. And with economies of scale and competition driving prices down, CubeSats are becoming more affordable to consumers, if you call a couple of hundred grand affordable. It is at least affordable for some small to medium sized enterprises, including universities.

In recent years, CubeSats have also been launched from the International Space Station and this may hint at how things will evolve in the future. Deploying CubeSats from the ISS is much more forgiving as you can launch them all wrapped up in cushioning. Once at the station they are then unwrapped by the astronauts who can also do a pre-deployment check before they're released into space. The next step will be to build CubeSats from components – or even 3d-print them from scratch. This will bypass all that tedious mucking about with launching and you'll be able to build them with much more delicate components.

But, whatever the future may hold, CubeSats are a happening thing, right now. There are commercial websites out there where you can custom-build your own CubeSat, starting with a base unit of 1U or 3U or whatever, where a 1U base unit will set you back around 10 thousand bucks. This base unit is just the skeletal frame, a motherboard and processor and various adaptors and connectors. To make a fully functional satellite, you'll then need to buy various add-ons, most of which are essential components, but you can mix and match on price to achieve your preferred balance of cost versus functionality. There are solar panels and batteries and communication systems and antennae – and you can also add in attitude control and even a propulsion system and there's a ton of emulators and connectors available to ensure all the various subsystems can talk to each other.

What you do from there depends on what you actually want your CubeSat to do. For maybe 20 thousand bucks you could have a CubeSat with electrical power and computing and communications capacity. But if you want it to do more than just orbit the Earth sending Sputnik-like location beeps, you'll need to make your CubeSat steerable and add cameras or detectors so that it can go and investigate some interesting phenomena.

So, at the end of the day, it's more likely you'll end up spending around $50 grand just for a 1U CubeSat. There are a few economies of scale if you want to ramp up to a 3, 6 or 12 U CubeSat, but 50 grand per unit is a reasonable ball park figure to run with.

Once you have your completed CubeSat, there are also service providers who will help you to get it launched. There's one with the unfortunate acronym of ISIS – which is neither a terrorist organisation, nor Sterling Archer's former employer, but rather *Innovative Solutions In Space*. ISIS can organise you a slot on a launch schedule, as well as manage your *pre-launch deployer integration campaign* – which mainly means making sure your CubeSat will actually fit in the launch vehicle. That mostly involves matching your CubeSat with a P-POD, a *Poly Picosatellite Orbital Deployer* – which can deploy CubeSats once in they're in orbit.

You're still probably looking at more than a million bucks to launch a 12U CubeSat, or anything bigger, but if you are happy staying small, the total cost of *both* building and launching a 1U CubeSat is a bit under $200 grand and falling. Of course most of us don't have that kind of cash at hand, but with enough determination you could enrol in a university, do an advanced degree or two and eventually find yourself working on a CubeSat space mission. And, just maybe, over the next decade or so, *massification* might occur – where growing demand and competition keep on pushing the price down until suddenly an average middle class person can afford their own CubeSat – and that's when the whole industry could go through the roof.

This really could happen if there's a compelling reason why everyone would want their own CubeSat up in orbit. It is difficult to see what that reason might be just now. But then the early adopters of integrated circuits, computers and modems, were all just backroom nerds doing things that no-one really saw the point of.

Ofcourse if CubeSats do become the next big thing, we need to mindful that lots of solid booster rocket launches will add a lot of pollution to the atmosphere – and having a lot of amateur CubeSats in orbit could risk triggering a space junk apocalypse.

On the bright side though, there's no reason to assume that all CubeSats are just going to orbit the Earth. The May 2018 launch of the *InSight* Mars lander will include two CubeSats that will fly to Mars alongside *InSight* to provide backup communications relay from *InSight* back to Earth during its Mars landing in November 2018. The CubeSats, also known as the MARCO mission, are each 6U CubeSats and will launch on the sme rocket as *InSight*, but then detach and fly independently to Mars. They both have a rudimentary propulsion system that will enable some minor manoeuvring to get them on the right trajectory for a flyby of Mars just as *Insight* is landing on the planet. So, for CubeSats, the sky is not the limit.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website, where space really is getting cheaper. No ads, no profit, just good science. Bye.