Question 1:

Dear Cheap Astronomy – What the best solution to the space junk problem?

Well, good question. Without meaning to get too alarmist here, it is fair to say that no-one is anywhere close to solving this one. There's plenty of theoretical solutions proposed and some are being trialled, but for now there's nothing that looks remotely like a working solution and there are a swag of economic and legal issues that are likely to scare off anyone from implementing a solution any time soon.

Consider that deorbiting space junk may be for the collective good, but it delivers no immediate gain to a mission operator, and like anything in space, that mission will be gob-smackingly expensive. And you have to be mindful that all that stuff up there belongs to someone, even the stuff that's in pieces.

So, on the one hand, people will be saying: *why should I pay to move someone else's junk*? And, on the other hand, people will be saying: *hey, that's my junk!* For example, imagine country A has taken it upon themselves to clean up space, but in doing so accidently knocks a piece of junk owned by country B into a working satellite that's owned by country C. According to the Outer Space Treaty, it's the launching country's fault, country A. So country C would seek compensation from country A, while country B, might reasonably sue country A for reputational damage. So, if you are country A, not only is it hugely expensive to do anything about space junk, but also you could find yourself wrapped up in decade-long law suits as a consequence of doing anything about it.

But OK, let's get some context. It's thought that there may be more than half a million bits of space junk up there that are bigger than a centimetre in diameter. Of those, about 21,000 objects are larger than 10 centimetres in diameter, and we think (or hope) that all of those 10 centimetre-plus objects are being tracked by the U.S. Space Surveillance Network and other agencies. That tracking information allows any active missions up there to avoid those larger pieces of space junk. So, for example, the ISS (the International Space Station) shifts its orbit once or twice a year for this reason.

What's important to appreciate though is that space junk is distributed over many altitudes – and the higher the altitude, the longer the junk will remain up there. Anything that's below 600 kilometres altitude will be steadily slowed by atmospheric drag and usually re-enter after a few years. Any stuff that's currently between 600 and 1,000 kilometres altitude may remain up there for decades yet. Any stuff that's between 1,000 and 2,000 kilometres may stay up there for centuries – and anything that's above 2,000 kilometres, which is the limit of what we call low Earth orbit, is expected to stay up there for millenia.

So, it's not like there's just one orbital plane to worry about. In fact there's a huge volume of space up there with space junk going around in all directions at all different altitudes. So most of the catch and grab ideas you've heard of would need decades to chase down all the stuff that's up there. If instead you go for some kind of passively-floating net device, it might take that device centuries to make any substantial impact. After all, the football-field-sized ISS only has a few significant space junk encounters each year.

And of course, there's not much point spending a decade or more cleaning up stuff around the ISS' altitude when you know all that stuff is going to naturally deorbit in a few years

anyway. So the only logical thing to do is to work at higher altitudes, but as you go higher you have to cover an increasingly larger volume of space, which has a lower density of space junk. So, sure there is a lack of political will to do anything about space junk, but when you look into it, the practicality and feasibility of really doing anything substantial does look a bit dubious.

Being Cheap Astronomy, we love the idea of just blasting everything that's up there with ground-based lasers. This would be a vastly cheaper strategy and you could readily target objects at different altitudes. The idea is that you fire at the front of the object which then throws off an ablative retro-blast of material that slows the object down and eventually deorbits it. It's a nice idea that awaits serious testing and there's all sorts of reasons why it might not work all that well and there's all sorts of ethico-legal reasons why you might not be allowed to see if it works all that well. But, it is always reassuring to know that when we're faced with a problem that just looks too hard to deal with, they are always frickin' laser beams.

Next week, we'll look at how we might stop adding to the space junk problem, because here at CA we might be cheap, but we're not nihilistic.

Question 2:

Dear Cheap Astronomy – Well OK, how do we stop creating more space junk then?

This is the second half of a question we'd attempted to answer last week on how you clean up space junk – where last week we reached the conclusion that it's just plain impractical, economically, if not technologically, to think we are going to make any serious headway on fixing the existing problem any time soon.

So, perhaps the best way forward is to acknowledge that prevention is better than cure – that is, we should work on stopping the problem from getting worse. Because if we do stop adding to the problem, the existing junk, at least in low Earth orbit, will eventually undergo orbital decay over years or decades, or at worst centuries.

What everyone's worried about is the Kessler Syndrome, where an orbit becomes so crowded that collisions become inevitable and two pieces of space junk collide and break up into four pieces of space junk which then collide with more space junk to become eight or sixteen or sixty four pieces – and eventually you end up with an impenetrable cloud of space junk orbiting overhead.

So, what we can do now is to launch things that have an end-of functional-life deorbit strategy. This might apply almost immediately to the upper stages of launch rockets which usually run out of fuel just after they get their payload up to its target orbit. But, if you were willing to add a little operational excess to your launch system, that final rocket stage might retain just enough fuel to deorbit itself after its job was done.

And you could do a similar thing with your payload satellite, ensuring the satellite keeps a bit of hypergolic fuel in reserve near the end of its mission. So these approaches are totally feasible and don't require any major technology leaps. But launching with more fuel than you

really need adds to your launch cost, reduces your payload mass and deorbiting your satellite before the end of its functional life means your reducing its functional life.

So, it's all very expensive and you can't really recycle anything that's already above the atmosphere, because it's going to burn up when it re-enters. So no-one is wildly enthused about any of these ideas and any new countries entering the space game might be reasonably thinking how come they have to clean up after themselves when everyone who went before just left all their junk behind.

A viable alternative might involve employing electrodynamic space tethers that might just add a few thousand dollars to your launch cost. These will be a the subject of another podcast question coming soon, but just quickly, these kilometre length tethers can be unfurled and then act like a wire being dragged through a magnetic field, creating a genuine physical drag that will reduce the orbital velocity of a satellite or even a rocket stage – so as to hasten their deorbit.

Like most things that get talked about in the space junk world, it's an interesting idea that no-one has seriously implemented yet and who knows if it's really going to work and be any easier or cheaper that just retaining a bit of reserve fuel and deorbiting with your existing rockets and thrusters. At the end of the day, whatever strategy you employ, it's going to cost money – which means we may have to wait for some space collision disaster to spur people into action, or maybe we'll just keep getting away with it. Space junk tracking technologies do keep getting better which may be enough to allow spacecraft missions to plot a safe path through the increasingly-congested heavens for many years to come.

So, space junk is a very human problem. It is slowly and steadily accumulating up there and clearing away what's already up there is just wickedly difficult. Sure you can run a few demonstration projects that bring a couple of pieces down, but scaling up those kind of solutions to make any serious impact on the whole global problem borders on science fiction. So, it is undoubtedly true it's definitely better to concentrate on how we can stop adding more space junk. And, even today, that is looking quite feasible – and indeed many missions do now deorbit their various bits and pieces – wearing the economic impost for the sake of strengthening their professional reputation.

So, on the prevention side, the space junk problem is totally fixable, it's just going to cost a whole lot of money and reduce people's profit margins. So, the issue is really about people rather than science and technology – and sorry, this podcast focuses on science and technology. Good luck.