**Question 1:**

*Dear Cheap Astronomy – Is there anything special about New Horizons next target?*

New Horizons was launched in 2006 and completed its primary mission, a fly-by of Pluto in July 2015. Shortly thereafter, it was decided to set it on course to a smaller Kuiper Belt Object *2014-MU69*, which was discovered in 2014 using the Hubble Space Telescope. So, that's something special – it will be the first fly-by of an object that was discovered after the spacecraft doing the fly-by was launched.

MU69 is a cubewano. Cubewanos are a group of objects, also known as classical Kuiper Belt objects, all named after the first one ever discovered, QB1-0. Being a cubewano, MU69's orbit is unaffected by Neptune, unlike other Kuiper Belt objects that either cross Neptune's orbit (Pluto for example) or are close enough to Neptune's orbit to be perturbed by it (Haumea for example). Makemake is also a cubewano, while Eris - although also unaffected by Neptune's orbit – is far enough to no longer be considered part of Kuiper Belt – it's a scattered disk object.

Anyhow, apart from being one of several cubewanos, it's hard to say if there is anything all that special about MU69, since it is too far out to visualise any details from Earth. Being part of the Kuiper Belt, its orbital period is not too different from Pluto's, 294 years versus Pluto's 248 years, with a semi-major axis of 44 astronomical units versus Pluto's 39. If you don't know already, semi-major axis is a fancy way to describe the radius of an elliptical orbit.

MU69 is small as spacecraft targets go. Indeed this is the distinguishing feature that's got the scientific community interested. It's of intermediate size, around 30 kilometres by 45 kilometres, which is much bigger than *67P/Churyumov-Gerasimenko* – which is about 2 by 4 kilometres. But MU69 is much smaller than Pluto, which is over 2,000 kilometres in diameter. Being as small as it is, no-one is thinking that MU69 would have enough mass to achieve hydrostatic equilibrium – that is, no-one is expecting that MU69 will be round.

We should probably expect a cratered surface, since that is the normal appearance of a solar system object that doesn't experience regular resurfacing – think Ceres, Vesta, the Moon and Mercury as examples. We discovered last year that Pluto undergoes regular resurfacing events due to tectonic movements – that is, sections of its surface are regularly subducted and replaced by up-flowing fluid, which then solidifies into new surface. While the physics of all that is yet to be fully understood, it's probably because Pluto has an internal heat source and is composed of ices, which melt a lot easier than rock.

You can probably appreciate by now that we are filling out this podcast with details about other solar system objects, because we have no real idea what MU69 will be like. But we have given you this list of possibilities:

1) it's a cubewano, so presumably has never strayed far from its remote location of 44 astronomical units from the Sun, which means it's always been cold;

2) it's not massive enough to achieve hydrostatic equilibrium, so it will probably have a randomly-formed potato-shape;

3) it won't have had any resurfacing because it's too small and it's too cold – so it will probably be grey, since most things out there that aren't regularly resurfaced, do tend to be grey; and

4) it will probably be cratered because it isn't regularly resurfaced and there's always random debris out there to collide with. Even if there's only a minor collision every ten thousand years or so – a cold body in a vacuum that never gets resurfaced will retain a lasting record of every thump and bump it's ever experienced over its lifetime.

Anyhow, on the 1st of January 2019, we'll find out of any of that is right.

**Question 2:**

*Dear Cheap Astronomy – What do you make of the Mars helicopter plan.*

There are definitely plans to build the *Mars Helicopter Scout* and maybe even include it along with the Mars 2020 rover. The Mars 2020 rover will launch in the second half of 2020 and hence probably land on Mars in 2021, if all goes according to plan. The Mars Helicopter Scout has been proposed to act as a drone for either the 2020 rover, or some later rover, flying out ahead of the rover each day to plan the best route for that day. This would help to avoid obstacles, as well as identifying the most scientifically-interesting targets for the rover to head towards. If it all works out, this approach would save huge chunks of time, since, the way we do things now, every time the rover rounds a bend or tops a rise, Mission Control has to stop and assess a new set of images sent back by the rover's cameras.

But could a Mars helicopter really work? Could its rotor blades gain effective lift in the Martian atmosphere that has one per cent of Earth's atmospheric density? Well, let's start by saying – yes, it really could. The plan is to have something the size of a tissue box, with a mass of about a kilogram, powered by solar panels and with large rotor blades that spin at 2400 rpm, creating a spinning disk about a metre in diameter. Such a machine *could* manage a three minute flight each day which covered about a kilometre's distance – which is more than adequate to plan a forward route for a rover whose top speed is less than one kilometre an hour.

A prototype helicopter scout has been successfully flown in a vacuum chamber with the pressure reduced down to a Mars-equivalent atmosphere. Well, when we say flown, it achieved lift. There's a giant leap from achieving lift to managing multiple take offs, flights and landings on the surface of another planet. The helicopter scout will have to fly under largely autonomous control given the radio delay between Mars and Earth, which is anything from 4 to 24 minutes depending on where the two planets are in their respective orbits. So, about all NASA will be able to do is send an instruction to (beep *ah, OK today please head in that general direction for about 800 metres beep oh, and, ah, try not to crash OK?* beep).

So, the success of this plan is not just about the engineering challenges but about whether the risk-averse folk at NASA will launch such an unprecedented 'first' in 2020, when the helicopter is barely at prototype stage now.

The helicopter will need to have coaxial rotors – that is two pairs of rotor blades on the one mast, with each pair spinning in opposite directions. On your standard helicopter with a single pair of rotor blades, Newton's third law – the one about actions and reactions – should make the body of the helicopter start spinning in the opposite direction to the rotors as soon as the helicopter leaves the ground. Standard helicopters don't do this because of that smaller vertically-mounted rotor on the tail, which works to stop the body from spinning and keeps it pointing forward.

So if you want a flying box with no tail, you'll need coaxial rotors spinning in opposite directions – the spin of one rotor countering the spin of the other, so there's no net torque left to make the box spin. The Mars helicopter would steer itself just like any helicopter does – by tilting the spinning disk of its rotors, which would pull the helicopter in the direction of the rotors' downward tilt.

The helicopter's box-shaped body will probably be a kapton foil covered aluminium frame, on the top of which will be the solar cells and from the bottom of which will project four landing legs. Within the box will be the rotor motors, a solar rechargeable battery that will run the rotors and the cameras and it also trickle enough continuous charge to keep all the electronics warm overnight.

And of course the helicopter will contain a little black box with all the autonomous take-off, landing and collision avoidance systems. It's this not-quite-developed-yet component that's probably the deal-breaker for the 2020 launch. While there are a range of autonomous guidance systems available now, adapting any of them to the job of driving a coaxial rotor system in 1% of normal atmospheric pressure will be no small feat.

So it is quite possible that we'll be seeing a helicopter drone flying around on Mars one day – but whether you, or NASA, should put money on it launching in 2020 – well, that is another question.