Question 1:

Dear Cheap Astronomy – Is there a new Venus mission coming?

Yes, although not before 2026 and quite possibly not before 2030. It's currently called Venera – D, where the D stands for what we'll pronounce as dolgozhivushaya, which means long-lasting in Russian and probably isn't pronounced anything like that. It's the first mission to Venus led by the Russian Federation, since all the other Venera missions were led by the Soviet Union.

The mission's objectives are to investigate Venus' atmosphere from orbit, on the way down and on the surface, as well as analyzing some surface material. Venus has a similar size to Earth and has a similar composition, but its closer to the Sun and rotates very slowly once every 243 Earth days and rotates the wrong way – all perhaps due to an ancient impact event. So, even though Venus has a molten iron nickel core much like Earth, its lack of spin means it has no appreciable magnetic field. So, even though it might have started out with an atmosphere similar to Earth – and perhaps even with liquid water on its surface, the lack of a magnetosphere has meant the solar wind literally blew away much of the contents of its early atmosphere but left the greenhouse gas carbon dioxide behind and the hotter things got the more carbon dioxide was leeched from surface rocks, which made everything get even hotter – and so on and so forth and hence the term runaway greenhouse effect.

There's still some uncertainty about whether the ongoing production of carbon dioxide is just from hot rocks or whether most of it actually comes from active volcanoes. It's likely Venus has a lot more volcanoes than Earth does, since it doesn't have water-lubricated plate tectonics that enables a steady-outflow of magma from mid-ocean ridges on Earth.

Venus' atmosphere is about 97% carbon dioxide and 3% nitrogen. The clouds of sulfuric acid you hear about are pretty much just that – clouds, representing a tiny proportion of the overall gas mix of the atmosphere. But unlike carbon dioxide or nitrogen those sulfuric clouds are opaque and completely obscure the surface.

The atmospheric dynamics of Venus are unusual too. Due to the planet's very slow rotation, it's almost like it's tidally-locked, with one face is in constant sunlight and the other not, so gas on the sunlit side expands pushing gas from the hot side to the cold side and creating a phenomenon called super rotation where a planet-scale wind moves the atmosphere around much faster than the planet itself is moving. We think this occurs mainly in the upper layers, while further down the temperature is more uniformly hot around the light and dark sides of the planet. So, down below there's probably more vertical rotation, where hot air rises from surface and then cools and falls back again. And there's an ongoing planetary loss of gas from Venus' ionosphere in the form of an invisible stream that's always pointing away from the Sun – like the tail of a comet. The gas lost is mainly charged ions of hydrogen and oxygen – and that's mainly in a two to one ratio, which is how Venus has lost its water, but kept all its neutrally-charged carbon dioxide

So, there's lots of interesting stuff to investigate on Venus. There are few details available yet on the spacecraft itself which is still largely a plan on paper. It is looking like NASA may join up to get some science instruments on the lander and possibly even load up VAMP, the Venus Atmospheric Maneuverable Platform which would detach from Venera-D on the way down and then fly around Venus upper cloud layers, by virtue of having wings, propellers and a balloon. VAMP would stay in the goldilocks zone between 40-60 km altitude where temperatures and pressures roughly match Earth at sea level. As well as observing the atmosphere's dynamics and analyzing its chemistry, VAMP would also look for bio-signatures. Given the likely absence of water, finding Venusian life seems like a long shot, but that's no reason not to have a look.

Question 2:

Dear Cheap Astronomy – What do you make of balloon missions in the Solar System

A balloon is an encapsulated space that has less density than the surrounding medium. Hence in a gravity field it will rise upwards, displaced by denser air pulled downwards by the gravity field. So for example in Earth's atmosphere you can have balloons filled with hydrogen or helium – or just with hot air, since the hot air expands more than the air outside the balloon and so is less dense than the air outside the balloon. The altitude the balloon rises to is partly about the differential density and pressures of the gas inside the balloon versus the gas outside the balloon, but it's also about the mass of the balloon and its payload, which might be a gondola full of people, or full of scientific instruments.

So, on Earth you need a balloon full of something that's less dense than the atmosphere outside. But, on Venus, a balloon full Earth's air could float since Earth's atmosphere is far less dense than Venus' atmosphere. So people could readily float in a spacecraft filled with breathable air if you get the balance of the spacecraft's mass versus the balloon's buoyancy right. Indeed they could float within Venus' goldilocks zone at around 40-60 kilometers altitude where the temperature and atmospheric pressure are about the same as on Earth's surface. Alternatively, if you did want a more massive vehicle – or one with more people on it, you could add a hydrogen or helium balloon – where helium can be a better choice since it doesn't explode. This extra buoyancy might be particularly needed on Venus since you may need a lot of radiation shielding if you decide to balloon on the sunlit side. Venus does have an ionosphere, but its absence of a magnetosphere leaves it mostly unprotected. On the upside the albedo – that is, the reflective nature, of Venus upper cloud layers means you could put solar panels on the top and bottom of your dirigible craft and both sides would collect about the same amount of energy.

And if that all sounds a bit science-fictiony, we did actually launch two balloons into Venus' atmosphere on the dark side back in 1985. The two VEGA probes deployed helium-filled balloons at an altitude of 50 kilometres on the night-side of Venus. Despite finding themselves in an aci- laced atmosphere with hurricane-like winds, both lasted for about two days over which time they both travelled around one-third of Venus's circumference.

It's speculated that on Mars, with its very thin atmosphere, which about 1% the pressure of Earth's atmosphere you can use a balloon with a vacuum inside. This would be hard to manage on Earth because the surrounding atmospheric pressure would just crush an encapsulated vacuum unless the container that held it was rigid enough to prevent that collapse, in which case the container would then be too heavy to float.

But on Mars the right balance can be achieved with a very lightweight balloon capsule, also assisted by Mars having only 40% of the surface gravity than Earth or Venus has. There are plans, at least on paper, to build zepellin-styled vacuum floatships on Mars. To carry payload, like a human crew and passengers, their balloon would need to be about the size of traditional zepellins and would probably have solar panels on their top surface to power air pumps that maintain the almost-vacuum within their balloons. Pump out the atmosphere and you go up, let some back in and you go down.

Given all the underlying physics we've mentioned, you can probably guess that one place you can't have a balloon is on the Moon, since there's no appreciable atmosphere that could displace a balloon full of anything, nor a balloon full of nothing. But on other moons that do have an atmosphere – like, you know, Titan, you could just apply the hot air balloon concept, which is going to be particularly effective in a very cold atmosphere like Titan's. After all for a hot air balloon to work, it just has to have air that's hotter, and hence less dense, than the surrounding air. And on Titan, the surrounding air is about minus 200 degrees Celsius, so just adding just a modicum of warmth to a balloon of that air would give you plenty of lift.