Question 1:

Dear Cheap Astronomy – Is Helium 3 the future power source of humanity

Helium 3 is a proposed second-generation fuel for hypothetical nuclear fusion reactors. However, the hypothetical nature of such reactors should not be understated since first generation fusion reactors, that will use deuterium and tritium, are yet to be built. There are high hopes that such 'hot fusion' power plants will become a reality in the not too distant future, but while they are theoretically possible, it remains a major engineering challenge to turn that theory into reality.

Deuterium and tritium reactors pump out high energy neutrons. Those energetic neutrons can't be contained in any way, but you can surround the reactor with circulating water so that the neutrons heat the water and heated water than drives steam turbines. Second generation fusion reactors using Helium 3 will pump out high energy protons, which are charged particles and hence are totally containable. If we can engineer a mechanism whereby magnets direct a stream of those high energy protons then we should be able to generate a counter-current stream of oppositely-charged electrons. An energetic stream of electrons, passing through a wire, is what is commonly known as electricity.

So, in a nutshell, assuming first generation fusion reactors can be constructed, then second generation fusion reactors offer an even more efficient method of energy production. But, even assuming we do sort out all the engineering required, Helium 3 is a very scarce commodity – at least on Earth.

Helium 3, with one proton and two neutrons, is an isotope of Helium 4 – which has two protons and two neutrons. Helium 4 is what we normally use to inflate upwardly-mobile balloons and to make our voices go squeaky. Some Helium 4 and 3 was trapped within the crust of the primordial Earth, although more Helium 4 has come as a byproduct of the radioactive decay of naturally-occurring uranium or thorium. Most Helium 3 on Earth arises from cosmic ray interactions in the atmosphere, as well as from man-made sources, being nuclear bomb tests and nuclear fission reactors.

Although Helium 3 is being constantly pumped up out from the Sun, our magnetosphere works to protect us from the solar wind and hence also prevents us from obtaining all that Helium 3. However, since the Moon has neither a magnetic field nor an atmosphere, solar wind particles directly contact the lunar surface. And since helium is very inert, chemically-speaking, any Helium 3 captured in the surface regolith will just sit there, potentially for billions of years.

All that said, the slow and steady addition of Helium 3 over the last 4 billion years has resulted in a average regolith concentration of about 13 parts per billion, which is not a lot. So, to mine one metric ton of the Moon's Helium 3 reserves, you would need to process over 150 million metric tons of regolith. One ton of Helium 3 could be compressed into the volume of a small car and, on return to Earth, could then fulfil all the USA's energy needs for about nine days – at least once we've figured out how to build those second generation fusion reactors. Extracting all the Helium 3 that there is on the Moon's surface might power all of Earth's energy needs for more than 10,000 years – although in 10.000 years we'll probably have Dyson-swarmed the Sun and the Moon's surface will be more valuable as real estate than as an open mine.

But, well before all that happens, it is important to consider whether a small-scale operation will deliver economic returns – it's hard to argue for the value of going large-scale if small-scale does pay off some dividends first. Getting that first ton of Helium 3, requires strip mining an area of about 170 square kilometers and then heating the collected 150 million tons of surface regolith to about 600 degrees Celsius. While all technically-feasible, there's some substantial infrastructure required, as well a small workforce who will need somewhere to live. So, while Helium 3 might be a future power source for humanity, it probably won't be the only one – and if we find a more efficient power source in the meantime, we might never even use Helium 3. So, for now, Helium 3 fusion power looks like a future possibility, rather than a future probability.

Question 2:

Dear Cheap Astronomy – What do you think the first Mars mission will be like?

Here at Cheap Astronomy, we think the first crewed Mars mission won't be rushed. NASA's current plan is to land humans on Mars in the 2030s, although it is just a plan, that you wouldn't put money on – and nor has anyone. But, in any case, whenever we do land, current thinking is that our Martian astronauts will be welcomed by robots.

Given the massive investment of time and money required, it's unlikely the first Mars mission will be a brief, and largely symbolic, flag and footprints landing. There's an expectation that the first astronauts we send will have a long time on the surface, to do some kick-ass science and some kick-ass media – and they'll just be the start of an intensive exploration program, rather than a one-off history-making mission. So, to make all that possible, the thinking is that we should first land robots who have spent a year or more building habitats for the astronauts – so the astronauts can just land, drop their gear and get straight to work. Those habitats might be constructed in excavated caves for radiation shielding, although building inside caves comes with its own problems and risks – so some of that is still on the drawing board.

However, it must be said, the whole robot advance party idea is also still pretty much on the drawing board too. It's great that Robonaut 2 is aboard the ISS now, but it remains unclear when it will do any EVA time – in other words, to actually go outside the ISS. Robonaut 2 would require some major upgrades to operate in the vacuum of space. Of course, Mars' atmosphere is not a vacuum, but having only 1% of Earth's atmospheric density, it wouldn't be much use in heat transfer and the dust in the atmosphere would quickly clog any filters – so, on Mars, you are probably better off having some robots that are built to work in vacuums.

In any case, it's unclear why you would want all your Mars advance robots to be humaniform, the way Robonaut 2 is. For example, if you want to excavate caves or dig foundations for the habitats you probably want some semi-autonomous, front end loaders that have been adapted to operate in the Martian environment. But there, it's not clear if these ideas have even got onto the drawing board. So, there are quite a few things that you couldn't exactly call 'on track' for a 2030s landing.

Of course NASA could just do a footprint and flags mission without the advance robots, but no-one thinks the Orion capsule is big enough for a crew and all the equipment needed. NASA is now talking about building a spacecraft with proper living space suitable for the two to three year journey to Mars and back. It will presumably a non-aerodynamic craft that object that will be built (or inflated) in orbit and that will be big enough to swing quite a few cats. Orion will dock with it and become a part of the whole spacecraft that flies to Mars. And once it’s there, the astronauts will transfer to a Mars Excursion Vehicle that‘s either come along with the spacecraft or is already in orbit when the spacecraft arrives. The astronauts will land with it and then return on the ascent stage of that vehicle. Then the astronauts get back aboard the main spacecraft and fly back to Earth and finally land using Orion again.

And of course there’s always Space X, who recently announced their Interplanetary Spaceship, the first of which might be called the Heart of Gold, although here at Cheap Astronomy we’re quite fond of its earlier working title BFS – for Big %$#@ Spaceship. The BFS is planned to be around 50 metres long and 15 metres in diameter and will able to transport 450 metric tonnes of crew and cargo – if and when it’s built. It’s not clear how big the crew compartment might be, but it will presumably be big enough to also swing quite a few cats.

A date for when the BFS is built, let alone launches, atop a super-heavy lift rocket, which is also known as the BFR. Elon Musk says Space X can do it all without NASA contracts, but it’s hard to see them doing the whole mission off their own back, even with some crowd-sourced funding. At this point in history, it’s hard to believe that a Mars mission can get off the ground without one or more governments’ backing. So, once again, here at CA, while we do think the first crewed Mars mission will happen, we don’t think it will be rushed – and we also think there‘ll be robots involved.