Question 1:

Dear Cheap Astronomy – How will we build a lunar base?

The main issue with building on Earth is gravity – that is, if you'd don't build them properly they will fall over. With the Moon having one sixth of earth's gravity, stopping things from falling over is still important but it's a much easier thing to accomplish. The main challenge for building structures for people to live in on the Moon is that those structures will need to retain internal pressure against a vacuum. This will require a strong sealed membrane, so any thinking about in-situ resource utilization needs to stop here. There's nothing on the Moon that we could construct a large, sealed membrane from – at least not without some futuristic molecular reengineering technologies. In the twenty-first century, such a pressurized structure would be created on Earth, probably as an inflatable sphere or dome as these are the best geometries to withstand internal pressures. Then the structure would be flown deflated and folded up to the Moon, and then reinflated on the surface. Prior to such a building, astronauts may land and live in their spacecraft or in separate landed modules, but we anticipate an inflated dome will be first constructed habitation on the Moon.

Then of course you have to deal with another significant issue, micrometeorites. An inflated membrane won't stay inflated for long under regular bombardment by small and probably sharp rocks moving at high speed. So you'll need an extra shell around it – for bombardment and radiation protection. One option is a rocket body. Once we've got a colony going there'll be a need for as many uncrewed landings as there are crewed landings and when a robotic supply mission has delivered stuff to the surface – the only advantage in launching again is to return an empty rocket for re-use – so towards the end of their functional lives some of those reusable rockets might be left behind. Within the hollow tube of an old Space X Starship you could inflate a couple of domes and be safe and secure for a good long while.

But otherwise you could just cover your membrane shell with layers of regolith. This would work just as well for radiation and micrometeorite protection and is a practical use of in situ resources. Most of other ideas for in situ resource utilization look great on paper may be completely impractical in reality. For example, there's some calcium oxide in regolith so if we extract that along with some raw regolith for aggregate and you have yourself cement. But that extraction process needs an 800 degree celsius furnace and while it is in regolith it's not there in especially high concentrations, so it could mean a lot of energy input for low yield. And while it is cement, it's not like it's airtight – so people still have to live in the membranes we discussed, so any cemented structure would just be that outer shell we also discussed. So you could either scoop up regolith in a day or two or engineer an energy hungry plant that delivers pretty much the same outcome, only more slowly and at huge cost.

Of course, you could always place the dome membranes in a lava tube but the chances of a lava tube being right where you want it to be are low. Right where we want it to be will be at one of the poles and the current favoured site is Shackleton crater, the location of the fictional lunar base in season 2 of For all Mankind. It's big, at 21 kilometres in diameter, and it's right on the Moon's south pole. Its outer rim gets constant sunlight – unlike the 2 weeks or sun and 2 weeks of darkness experienced at the lunar equator. We haven't been able to visualize its interior, which being always perpendicular to the direction that sunlight bathes the rim is therefore in perpetual darkness.

There have been various hints from spectroscopic analyses that it might contain a lot of water ice and one of the early objectives of the Artemis missions, planned for later in the 2020s is to confirm if there really is a lot of water ice in there. Needless to say, having a substantial water source near to a location that receives constant sunlight would be ideal for a lunar base – so if Artemis does confirm the presence of water ice in Shackleton, we'll almost certainly build a base there.

Question 2:

Dear Cheap Astronomy – Will travel to Mars ever become routine

There is a view that whenever we do send astronauts to Mars, they won't fly there in one spacecraft. Their launch vehicle from Earth might dock with an orbiting deep space vehicle, which is built for deep space travel in a vacuum and would never have survived a launch through Earth's atmosphere. After the long trip to Mars this spacecraft might dock with an orbital gateway station in orbit around Mars, where the crew would disembark from their long distance craft, get their gear in order and then hop aboard a lander for the trip down to the Martian surface.

The advantage of this approach is that the launchers and landers can just be cockpits bolted onto a rocket engine. You don't need all the stuff that you will need on the months-long journey between Earth and Mars. Having the lander already in orbit around Mars means you don't slow down the astronauts by having them take all the mass of the lander with them – which will require more fuel and yet more fuel just to fly all that extra fuel.

And yes, there is a whole bunch of stuff that you'll need on the long journey to Mars. Ideally the deep space transport vehicle will have a crew module that is swung on a long arm around the axis of the spacecraft with a counterweight on the other end, to generate artificial gravity and keep the crew healthy. The crew's quarters will also need basic radiation shielding, plus there'll need to be a 'storm cellar' – a small and very heavily shielded room the astronauts can bunker down in when a big solar flare is headed their way. They also need enough water for the trip there and back – plus food and perhaps even a greenhouse to do something useful with all the waste CO2. On top of all that they 'll also need an engine and an absolute &^%$-ton of fuel, enough to first accelerate the substantial mass of this complex craft up to speed and then decelerate it back down when they get to Mars.

Unless of course… you turn your deep space transport into a 'cycler'. We currently fly robotic craft to Mars via a Hohmann transfer orbit – where you follow a solar orbit from Earth that takes you on a path to intercept with Mars' orbit just as Mars is passing by. That's usually where the story ends – but remember this is a Hohmann orbit, so if you don't stop at Mars you'll just keep on going around the Sun until you eventually intercept with Earth's orbit again – and if you don't stop there either, you'll eventually cycle back to Mars orbit again. So, although you burn a lot of fuel getting your deep space transport into a cycler orbit, you'll then just need occasional correction burns to stay in it. So all astronauts have to do is wait for the cycler to fly by Earth, hop onboard and eventually disembark when it gets to Mars orbit. They'll still have to accelerate up to get onto the cycler and then decelerate back down when they get off at Mars – and do all that in reverse when it's time to return to Earth, but for each of those end trips they can just fly in a cockpit on a rocket engine and hence need a lot less fuel.

If this all sounds a bit too good to be true, well yes it is a bit. Remember, the Hohmann transfer orbit just gets you from Earth's orbit to Mars' orbit and back again. It's not much help if neither planet is at that point in its orbit when you cycle past. However, since both planets move in constant cycles it does turn out that you do eventually meet up with each planet again. Each of the cycler's solar orbits takes a bit over two years and over a period of 15 from first leaving Earth's orbit it will fly-by Earth three times and Mars four times. So it's energy efficient but slow and it only makes economic sense if it's in regular use. So, it's something we might consider when travel to Mars becomes routine. A cycler is also known as an Aldrin cycler after Buzz Aldrin, Dr Rendezvous, did the first calculations – and since then various orbital mechanicists have proposed alternate cycler orbits and even multiple cycler orbits following different orbital angles so you might be able to hop across when they intersect to get to and from the planets a bit quicker.