Question 1:

Dear Cheap Astronomy – Do we have the ability to measure the exact amount of heat arriving at the Earth from the sun?

Here on Earth, we often talk about light as being what we can see and heat as being what we can feel. But, really any wavelength of electromagnetic radiation can raise the temperature of something that absorbs it. A microwave oven heats things with high amplitude radio waves and even although high frequency ionising radiation, like ultraviolet, X and gamma rays, tend to destroy the things that they radiate, they will still heat them up as they destroy them. So, in a nutshell, it's best just to talk about the Sun's energy output.

When all electromagnetic wavelengths are taken together, the sun's surface emits about 63 million watts of energy per square meter. By the time that energy reaches Earth, after traveling 150 million kilometres and being spread out over that distance, that solar flux has diminished to around 1,360 watts per square meter when it hits the earth's upper atmosphere.

That figure of 1,360 watts per square meter is what's known as the solar constant – a measure of the solar flux that strikes one square meter of area positioned exactly one astronomical unit from the Sun and exactly perpendicular to the mean direction of solar radiation. So really the solar constant is a standard measurement and its actually never constant, because the Sun's output always varies slightly over time. That variation is mostly about the Sun's fluctuating magnetic field, which underlies the solar cycle, where it takes around 11 years to move from a solar minimum (very few sunspots) to a solar maximum (lots of sunspots) and over that 11 year period the strangely-named solar constant increases by about 0.1% and then drops by about that same proportion over the next 11 years. Beyond that, we know the Sun's output is very slowly increasing. When it first ignited around 5 billion years ago its luminosity was only 70% of what it is now. In another billion years from now it will be about 6% hotter than it is now – and that will be enough to evaporate the oceans and spell the end of Earth's habitability. Of course, all this is determined on paper, it's a barely measureable change – we just know it's happening and that the end is, very slowly, approaching.

Down here on the surface it does seem as though the Sun's output fluctuates wildly, even though it doesn't. Of most importance to our experience of temperature on the surface is the axial tilt of the planet. For example, at 45 degrees latitude, the Sun is up for 15 and a half hours at one solstice and just 8 and three quarter hours at the other solstice – which is a whopping 54% difference in day length. But, that's not actually what matters. If day length was what mattered then the hottest places on Earth would be the poles in their respective summer times, when they receive 24 hours of daylight. What actually matters is the angle of incidence of solar radiation. In those long polar summer days, the Sun is barely above the horizon, so most of its straight line radiation misses the Earth's surface. At the equator, despite there only being 12 hours of sunlight per day, the Sun is straight overhead, meaning its radiation is always directed right at the surface – and so it's always hotter.

Regardless of the angle of incidence, some of the solar energy that arrives at the Earth bounces off the outer atmosphere, some of it penetrates and then bounces off clouds and back into space and some of it interacts with and is absorbed by the atmosphere, thereby heating the atmosphere. As a consequence of all that, the surface of the Earth only receives about half of the incoming solar radiation that hits the upper atmosphere and even then a lot of that is reflected back from the surface. But that energy reflected back still has to make it back from the surface out through the atmosphere. This is why all that stuff about greenhouse gases really does matter. If you pump more CO2 into the atmosphere, it really does get hotter – and that is easily measureable.

Question 2:

Dear Cheap Astronomy – If we want a lunar orbiting space station, couldn't we just send the ISS there?

Well we could, but whether it would work is another question. There's a fundamental principle that things are built-for-purpose. Of course, you can re-purpose things, but that's only worthwhile if it makes practical and economic sense. The ISS was built for the purpose of orbiting Earth as a science laboratory. A lunar space station is more likely to work as a depot for lunar missions and potentially other space missions. It may still be a science laboratory, but that probably won't be its primary purpose. A lot of the science on the ISS involves Earth observations. On Earth you have weather and oceans and geothermal activity – and we've got complex ecosystems, not to mention a global civilisation. So while the Moon is jolly interesting, which we keep discovering from our orbiting robotic spacecraft, even with a crewed station in orbit, we might not find ourselves needing to observe it with such intensity, nor in so many different ways as we currently observe the Earth.

It's also the case that a lunar-orbiting space station will be well outside the Earth's magnetosphere, so it will need additional shielding to protect both crew and electronic systems from a level of cosmic ray bombardment that the ISS doesn't have to deal with. Furthermore, the ISS communication systems are only designed to handle two-way communication from low-Earth orbit, which is essentially a distance of 400 kilometres rather than the 384,000 kilometres distance between the earth and the Moon. And ISS life support systems are based on receiving regular resupply from 400 km away. While it's likely a lunar station would also receive regular resupplies, the added distance, travel time and cost means they might not be as regular or reliable. So to manage that risk, you'd want the lunar station to have a lot more storage and redundant systems – which translates to more infrastructure that serves a smaller crew.

And of course, if you are going to fly the ISS to the Moon you lose an Earth-orbiting space station. There is talk of retiring the ISS in 2030, at least the US side of it, but that's mostly because it's just getting old and needs to be replaced. Given we've already said a lunar space station is a riskier proposition, being exposed to higher intensity cosmic rays and it's three days travel-time for resupply or rescue, why add to the risk by using ageing infrastructure that was never meant to operate in that environment anyway.

And of course, getting the ISS to the Moon is not all that straight forward. There are currently thrusters on board capable of gently raising its orbit by tens of kilometres. If you want to get the ISS to the Moon in a matter of days, you would need to apply a much greater amount of thrust – applying thrust from one point puts stress on the whole structure to move it as a unit.

It might work better if you distribute the thrust across the whole structure, using multiple strapped on engines. This might also assist in manoeuvring, remembering the Moon is only tilted 5 degrees from an Earth equatorial orbit, while the ISS is tilted 56 degrees. So you not only have to get it to the Moon but also manage a complex orbital insertion manoeuvre once you are there. In any case, it would probably be best to use only gentle thrust - meaning the trip would likely take months rather than days. And while all this technically feasible, there'd be a lot of testing required using engines that may not be available off-the-shelf and to keep those engines fuelled you need to either carry the fuel with you – which means more mass and structural stress – or you need resupply craft to keep the ISS fuelled up throughout the journey.

The alternative to all that is to build on existing, or at least planned, lunar mission platforms. So, a heavy lifting rocket like the SLS or the Falcon Heavy could launch brand-new modular components of a lunar station, getting them to lunar orbit in a matter of days where they could be subsequently be put together by crew that has flown there with them. While we couldn't do this tomorrow, there are at least existing funded programs that do have these specific objectives. You couldn't fly the ISS to the Moon tomorrow either and such a high-risk strategy would divert attention and resources away from what is currently the main game plan in getting back to the Moon. While the whole Artemis lunar program does still does mostly look like a mission on paper, it is at least that much.