Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Asteroid mining… the long-term plan.*

This is the second of a two part series on mining resources in space.

In the last episode, we explored some options for extracting metals, like iron and platinum, from asteroids. But you can't eat iron or platinum, nor drink them either. This episode is all about all the other stuff we'll need to find to help us stay alive and afloat out there on the cosmic ocean.

So, let's say you want to live in space. First you should consider your requirements of daily living. You will need oxygen, water and food and also various construction materials for making housing, clothing and tools. You will also need other people, ideally people who want to work collaboratively to support a range of institutions – remembering that it takes a village to raise a child. If we are really going to live successfully in space, we need access to all the things that will enable us to both live individually and to raise children collectively – as well as having access to various diversions that will keep us occupied in our spare time.

The most abundant elements in the Universe are, in order: hydrogen, helium, oxygen, neon, nitrogen, carbon, silicon, magnesium and iron. Helium and neon, being noble gases, are largely chemical inert and so have limited use beyond a few specific industrial purposes. However, hydrogen, oxygen, nitrogen and carbon are the foundations of organic chemistry, making up not only most of us, but also most of our food - apart from a few trace elements. Silicon and iron, common in rock and metal, can be thought to represent the basis of our tool making and construction requirements.

So, not only are *we* star stuff, all the things that we need to live long and prosper are also star stuff and it conveniently turns out that our priority elements are the most abundant star stuff in the Universe. This is not luck. We are the way we are because the Universe is the way that it is. The Universe is not fine-tuned to ensure our survival. We have been fine-tuned to survive in the Universe that we evolved in.

The happy and abundant association of hydrogen and oxygen, the first and third most common elements in the Universe, gives us water to drink and water to support food production. Furthermore, water is also a readily dissociable compound that we can turn into oxygen and hydrogen rocket fuel – for example, by solar-powered hydrolysis.

Water is fabulously abundant on Earth, so there is little need for us to bring any water from space back to Earth in the foreseeable future. Our main reason for extracting water from space will be to stay in space.

We could start by extracting water from the Moon, assuming that enough water really is there in readily-extractable forms. India's Chandrayaan 1 and NASA's Lunar Reconnaissance Orbiter have both collected spectroscopic data that strongly suggest water is abundant enough to make extraction worth considering. Whether this water is in the form of hydroxyls, chemically bound to rock and regolith, or more-freely available as ice in permanently-shadowed craters remains to be determined.

But, even if we only manage to extract a few backyard swimming pools worth of water on the Moon, that still represents a lot of mass that we won't have to lift off the Earth's surface in order to to stay alive in space. There are probably quite a few swimming pools worth of water on Mars too, in the form of sub-surface ice, particularly around the poles, as the Phoenix lander discovered in 2008.

These recent findings of water on Mars and on the Moon came as a bit of a surprise since traditional wisdom has it that water should immediately sublimate into a gas anywhere sunward of the asteroid belt.

The oasis of Earth is an obvious exception to this rule, protected by its magnetic field and its atmosphere. But elsewhere in the inner solar system, unprotected water should evaporate or dissociate and be blown outwards by both solar heating and by the solar wind. It's not until you get to the asteroid belt that water should begin to settle.

In the asteroid belt we find the S-type, stony, asteroids that are closer in to the Sun. These S-types are relatively dry. But just a bit further out you find the more numerous C-type, carbonaceous, asteroids. We know from C-types that have crashed on the Earth that they contain constituents that must have formed in the presence of liquid water – for example hydrates, carbonates and clays. The water content of carbonaceous asteroids is estimated to be around 22%, which is something like potter's clay on Earth before it is fired. So, you couldn't easily suck the water out of a carbonaceous asteroid, but you could almost certainly evaporate it out with the simple application of heat.

These outer-belt carbonaceous asteroids might represent the next step after we are done with extracting any water from the Moon and from Mars.

After that, there is a line, drawn somewhere between the asteroid belt and the orbit of Jupiter, which we call the frost line. Beyond this line the Sun's warmth and the solar wind have diminished to such an extent that ices can form freely. These ices might be water or carbon dioxide or a mixture of the two, but either type form in great abundance out past the frost line. Remember that water and carbon dioxide are compounds of hydrogen, oxygen and carbon, the first, third and sixth most common elements in the Universe.

Out past the frost line, gigantic blocks of water and carbon dioxide ice are thought to have formed the gravitational centres about which the even more hydrogen gas accumulated – forming the gas giant planets. Although readily blown out of the inner solar system, hydrogen water and carbon dioxide utterly dominate the landscape of the outer solar system.

Out past the frost line, any objects smaller than the gas giants are liberally coated in solid water and carbon dioxide, including most of the gas giants' moons. So we won't be so much mining as melting what we need.

Carbon dioxide will be hugely useful in combination with water, since a photosynthetic organism – and perhaps an artificial process we may eventually make as efficient as the biochemical photosynthesis – can turn carbon dioxide and water into glucose and oxygen. Add some nitrogen fixing bacteria– or another artificial process we are yet to invent – and you can get amino acids from which you can build proteins. Nitrogen, you may recall, is the fifth most abundant element in the Universe.

All this starts sounding less like mining and more like farming, but there is a still a need for various trace elements, like magnesium, phosphorus and calcium which, being elementally rarer, you might have to carefully prospect for. You might have to carefully prospect for some of the rarer construction elements too, like copper, tin and zinc.

The dry inner S-type asteroids might be the most easily accessible source of such trace elements, since you won't have to dig through a thick shell of frozen water and carbon dioxide in order to get to them.

And if, at the end of this podcast, you are left wondering what we are going to do with the second and fourth most common elements, so fabulously abundant but so seemingly purposeless, just think helium balloons and neon lights. After all (sound byte)…

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where you can find the whole Universe in the periodic table. No ads, no profit, just good science. Bye.