Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Asteroid mining… how it might actually work.*

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

Here at Cheap Astronomy, we have touched on asteroid mining before, but never actually devoted a whole episode to it, so now we're going to do two. Part 1 is about how we might mine metals, Part 2 is about how we might mine everything else.

If you need a compelling reason to go and mine asteroids, consider that many of the metal ores we mine on Earth actually came from asteroids. Any large celestial body, like the Earth, with sufficient mass and sufficient gravity, undergoes differentiation. During the Earth's dynamic formation phase, when it was still a molten sphere, heavier elements such as iron and iron-associating metals like nickel, iridium, gold and platinum all sank to the centre of that molten sphere. This is why Earth now has a dense inner core of mostly iron, but also those other less abundant iron-associating metals.

After that initial differentiation phase, the Earth's cooling crust was left composed of mostly silicon oxides, largely depleted of metals apart from aluminium, which is rarely found naturally in its elemental form, but instead is locked up in mineral compounds, such as feldspars, clays and micas.

So, many of the metallic elements we now get from the crust are thought to be the result of either post-differentiation meteor strikes or from materials occasionally brought up from the inner Earth, which may come straight up from the mantle or appear around subducting tectonic plates. The crust also has sedimentary iron ore deposits, which result from iron that was once dissolved in the ancient oceans, being later oxidised into rust that sank to the bottom, after some of the first photosynthetic organisms began producing oxygen.

So we've been a bit lucky with finding enough material in the crust to get by, but an awful lot more lies out in them there asteroids. Declaring that the sky is full of untold riches probably won't secure the capital needed for an asteroid mining venture. A convincing asteroid mining proposal will need to weigh up the cost of the mining process against the benefits that might be gained. Distance and delta V are the ultimate arbiters of any asteroid mining balance sheet.

Distance is well… *distance*. You have to expend a lot of fuel to cross the astronomical distances to get to asteroids and you have to expend yet more fuel to bring your mined ore back home. But, delta V is also a key factor. Delta V is the difference between Earth's velocity and an asteroid's velocity.

The Earth orbits the Sun at an average velocity of 30 kilometres a second. In accordance with Kepler's Third Law, anything orbiting the Sun closer in than Earth does so by moving at a faster velocity – and anything orbiting further out moves at a slower velocity. So since we are born on Earth and are already moving at a 30 kilometres a second velocity around the Sun, not only will we have to burn fuel to cross the distance to other objects in solar orbit, we will also have burn more fuel to either slow down or speed up in order to match those objects' speed.

So, our initial attempts at asteroid mining are probably going to focus on near-Earth objects. This is because, being near Earth, they aren't all that distant and they won't have a significant delta V disadvantage. It's a different story if you tried to mine a comet that comes screaming into the inner solar system for a brief perihelion, before screaming out again. Comet catching would require some extreme delta V corrections, something that might have to wait for the 23rd or the 24th century, after we've invented tractor beams.

Back here, today, we might first start an asteroid mining venture by sending some probe droids on one way missions to sample asteroids that have already been identified as likely mining candidates from long-distance spectroscopy. The probe droids would still only verify the surface composition of the objects, but in the early days of asteroid mining, surface extraction may be as much as we can manage anyway. If that surface extraction suggests there's more good stuff deeper inside we can always come back later, perhaps in the 22nd century after we've invented space drills.

The key to success in asteroid mining will be managing extraction and refinement. It's rare that we will find pure nuggets of platinum, iron or other metals out there – and you can't realistically base a multi-billion dollar mining enterprise on the hope of such a chance encounter. So, we will need to deal with the more-likely scenario of our probe droids finding high concentrations of desired elements locked up in some kind of mineral matrix.

Flying a huge chunk of asteroid back to Earth, to extract a small proportion of valuable material from it, is just not good economics. And, let's face it, who is going to agree to you flying huge chunks of asteroid back to Earth. Those pesky mass-extinction objects from Earth's ancient history continue to represent an almost insurmountable PR problem.

So, either we expend huge amounts of fuel flying a massive extraction facility, that we haven't invented yet, from one asteroid to the next, or we could just adopt the Cheap Astronomy CSOTM concept, that is Crash *bleep* (sorry, *Stuff*) On The Moon – which involves strategically crashing any potentially valuable objects and then extracting the riches from the rubble at our leisure.

If we followed the CSOTM method, then we will of course have to launch all the extracted material up off the Moon afterwards. But, because the Moon has only one sixth of Earth's gravity, the energy cost of launching the reduced mass of a concentrated extract won't be that much of an obstacle.

Indeed, the Moon's gravity will pay its own way by enabling effective extraction and refinement of the material that has been crashed on its surface. While heat and chemicals may play important roles in extraction and refinement, the time-honoured process of separating light materials from heavy materials will be an awful lot easier when there's gravity present. It's unclear how an extraction facility, roaming through space from one low-mass asteroid to the next, could manage this effectively – let alone, economically. Furthermore, if you keep the extraction facility close-by its easier to repair and to upgrade – and if it needs humans to run it, the Moon's gravity offers a healthier workplace than floating about in microgravity.

Another obvious benefit of CSOTM is that we would develop expertise in changing the trajectory of asteroids, an expertise that could end up saving not just our species, but also the pandas and the polar bears – and even the tree kangaroos.

We can forever envy Buzz Aldrin his view of the magnificent desolation of the Moon seen by Apollo 11, but the Moon is not exactly crawling with giant pandas, polar bears or tree kangaroos. It is magnificently-desolate real estate. So why not crash *bleep* on the Moon? After all, it’s been bombarded by random impacts for most of its history – what’s so wrong about adding a few more deliberately-targeted impacts?

Anyway, what exactly is out there that is worth crashing on the Moon? Asteroids can be c-type, which stands for carbonaceous, meaning they are kind of clay-like. Or asteroids can be S type, which stands for silicaceous meaning they are kind of stone-like. But there are also a smaller number of M type asteroids, which are kind of metallic. These much-rarer metallic asteroid types may be the remains of a larger planetesimal – which, like the Earth, *differentiated*, so that its iron and iron-associating metals sank into the middle as the object was forming. If such a differentiated planetesimal was subsequently involved in a collision, its metallic core may have become exposed, forming an M type asteroid. These are relatively rare, but hugely valuable.

It has been speculated that an M type asteroid of one kilometre diameter could contain more than two billion metric tons of iron-nickel ore, which is more than double the current amount that we extract from the Earth’s crust each year.

The biggest known M-type asteroid, 16 Psyche, is 200 kilometres in diameter and is believed to contain about 17 quadrillion metric tons of iron-nickel, which would meet our current production requirements for several million years to come.

Once we find one of these babies, the economics of asteroid mining will hopefully become a no-brainer.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we live in a world that really does have a tree kangaroo. No ads, no profit, just good science. Bye.