

Question 1:

Dear Cheap Astronomy – Is crashing asteroids really going to work Part 1

As we've discussed before on this podcast, crashing asteroids on the Moon might seem useful way to avoid a lot of tedious mucking about with drilling and explosives, but not only do they crash, they hit with such force as to completely disintegrate the object as well as disintegrating a big semicircular chunk of the Moon's surface and so leaving a crater.

A standard benchmark statistic is that a 100 metre asteroid that hits the Moon's surface at 10-20 km/sec will produce an energy output equivalent to a nuclear explosion, which will disintegrate both the asteroid and lots of lunar material, leaving a crater more than 1 kilometre in diameter. 10-20 km/sec is 10 to 20 times faster than a speeding bullet, but it's nothing special in astronomical terms. The Earth orbits the Sun with a velocity of around 30 km/sec. Anything sharing its orbit will be moving at about the same speed and in the same general direction around the Sun. Nonetheless when those things do cross paths the impact is still generally violent. It's estimated that most asteroids hitting the Moon do so with a velocity between 10 -20 km/sec though some may be slower and some may be as fast as 40 km/sec, those varying velocities being the result of both the Moon's and the asteroid's intersecting velocities, plus the acceleration of the Moon's gravity.

The reason we don't see lots of nuclear-equivalent explosions is that the Moon hasn't been hit by anything approaching 100 metres within the period that we've known asteroids existed. History has records of a number of visible flashes on the Moon's surface observed by the naked eye, but still probably nothing in the nuclear range. On a yearly basis there are probably only five objects approaching 10 metres in diameter that impact – there's just lots and lots of micrometeorites. It's guessed a 100 meter sized object might hit the Moon once every 100,000 years or so. Whenever that does happen the object would essentially vaporise in the nuclear equivalent blast. Smaller, less-massive objects would hit with less force, but still likely disintegrate, given those visible flashes we see indicate there's still a lot heat and energy involved. To date we've only found only tiny fragments of meteorites on the Moon, the largest known being a whole 3 mm wide – collected by Apollo 12 and generously called the Bench crater meteorite, although it was really just a tiny bit of shrapnel left over from the explosive impact of a larger object that produced the 65 metre diameter crater,

It's a different story on Earth where we often find quite large meteorites that appear to have landed relatively gently on the ground. Although when we say quite large, we are talking around 6.5 metres wide for the largest known intact meteorite, being the Hoba meteorite found in Namibia.

An asteroid plummeting towards Earth hits the atmosphere before it hits the ground. That initial impact is often enough to break an asteroid into pieces, which then keep falling up to their terminal velocity – meaning the speed at which they are unable to push any faster through the atmosphere despite the accelerating nature of gravity. So, in Earth's case most rock-sized asteroids don't achieve enough velocity to disintegrate on impact. If they produce a crater, it's really just a dent, not much bigger the object itself.

Of course Earth does have real impact craters, like Berringer meteor crater in Arizona, which is around one kilometre in diameter, thought to have been caused by a metallic 50 metre diameter object. Objects of this size and mass still get slowed by the atmosphere but the kinetic energy of the impact is influenced by mass as well as velocity so you can still get nuclear level explosive impacts from big asteroids

Back to the Moon though, the absence of an atmosphere is a problem. If deliberate lunar asteroid crashing is to be an economically viable method of asteroid mining, we need to do something to limit the destructive force of those asteroid impacts – even though a degree of contained destructive force might actually be a good thing. The first step to dealing with all that complexity is to have a part 2.

Dear Cheap Astronomy – Is crashing asteroids really going to work Part 2

In the previous episode we investigated how asteroid impacts compare between the Earth and the Moon, finding that smallish asteroids often land relatively intact on Earth due to being slowed to their terminal velocity by Earth's atmosphere, while equivalent-sized asteroids explosively disintegrate on hitting the Moon, since there's nothing there to slow them down. For example, if you dropped the Hoba meteorite, which is a roughly square 6.5 metre object with a mass of 54 metric tons from a high altitude, on Earth it would reach a terminal velocity of less than $\frac{1}{2}$ a km/sec. But if you dropped it from a high altitude on the Moon with nothing to slow it down the Moon's much weaker gravity would still be able to accelerate it up to more than 2 km/sec, ten times faster, before it hit. All that kinetic energy would explosively disintegrate the object and a big chunk of the Moon's surface as well, leaving behind a crater – and that's just from a passive drop. It's generally the case that asteroids will approach with relative velocities of between 10 and 20 km/sec before they even encounter the Moon's gravity.

So, if your asteroid mining strategy is to crash asteroids on the Moon, this is a problem. While there is benefit in having a crashed object break up in small pieces, having those pieces blasted outwards over square kilometres of the Moon's surface is not ideal. On this basis, we have previously suggested there is little point in just crashing one object. Instead, you want to crash around fifty in more or less the same spot to achieve a sufficiently rich spread of impact ejecta that then makes sifting through square kilometres of lunar regolith worthwhile. It's also the case that an explosive impact drives material into the ground as much as it flings it outwards. You'll probably only be left with a small proportion of an asteroid after from a highly explosive impact, but again after fifty impacts those left overs may become significant. Impact craters often contain impact glasses, being melted and resolidified silicates, or breccia – which is rock composed of a bunch of other rocks that have been fused together. Chicxulub crater, the dinosaur extinction one has 160 times normal background level of iridium, which still isn't a lot, but it does indicate some of the asteroid material did remain at the megaton level impact site.

Otherwise, you could slow each object's fall, finding the right fall distance for their mass that ensures they do effectively break up into small pieces but without those pieces getting spread too far. We are going to have to steer asteroids in anyway. That means it's likely we'll have

already ensured their velocity roughly matches the Moon's own velocity – but as we said earlier, even with a relatively passive drop to the Moon's surface, the Moon's gravity can still accelerate an object to over 2km/sec before it hits. For a 100 metre diameter object that's not a thermonuclear blast but it's probably still Hiroshima-level. However, with smaller, less-massive objects the impact energies would be lower. So, it may come down to consideration of how far you guide each asteroid in with retrofire before detaching a reusable rocket engine and letting them fall the rest of the way.

You could break up big objects into smaller pieces before the fall, remembering the kinetic energy of the impact will be a product of mass and velocity. But that's easy to say on paper – it's not like you can just slice an asteroid in half. If you use explosives bits will spread randomly and likely end up hitting the Moon's surface with more kinetic energy. So, this probably isn't worth considering

We can also think about the landing site. Soft ground is better than hard ground and maybe a mountain valley would limit the spread of the impact ejecta more than on a flat plain would. Or instead of a mountain valley, why not a pre-existing crater or even the same crater that just gets deeper and deeper the more asteroids that are crashed in it.

In the final analysis the cheapest option does look like crashing multiple asteroids at the same location. If that proves lucrative enough then there might be room for more investment in either slowing larger objects' descent and/or modifying the crash site to better cushion impacts and contain impact ejecta.