Asteroid Mining: Key to the Space Economy

by Mark Sonter
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The Near Earth Asteroids offer both threat and promise. They present the threat of planetary impact with regional or global disaster. And they also offer the promise of resources to support humanity's long-term prosperity on Earth, and our movement into space and the solar system.

The technologies needed to return asteroidal resources to Earth Orbit (and thus catalyze our colonization of space) will also enable the deflection of at least some of the impact-threat objects.

We should develop these technologies, with all due speed!

Development and operation of future in-orbit infrastructure (for example, orbital hotels, satellite solar power stations, earth-moon transport node satellites, zero-g manufacturing facilities) will require large masses of materials for construction, shielding, and ballast; and also large quantities of propellant for station-keeping and orbit-change maneuvers, and for fuelling craft departing for lunar or interplanetary destinations.

Spectroscopic studies suggest, and 'ground-truth' chemical assays of meteorites confirm, that a wide range of resources are present in asteroids and comets, including nickel-iron metal, silicate minerals, semiconductor and platinum group metals, water, bituminous hydrocarbons, and trapped or frozen gases including carbon dioxide and ammonia.

As one startling pointer to the unexpected riches in asteroids, many stony and stony-iron meteorites contain Platinum Group Metals at grades of up to 100 ppm (or 100 grams per ton). Operating open pit platinum and gold mines in South Africa and elsewhere mine ores of grade 5 to 10 ppm, so grades of 10 to 20 times higher would be regarded as spectacular if available in quantity, on Earth.

Water is an obvious first, and key, potential product from asteroid mines, as it could be used for return trip propulsion via steam rocket.

About 10% of Near-Earth Asteroids are energetically more accessible (easier to get to) than the Moon (i.e. under 6 km/s from LEO), and a substantial minority of these have return-to-Earth transfer orbit injection delta-v's of only 1 to 2 km/s.

Return of resources from some of these NEAs to low or high earth orbit may therefore be competitive versus earth-sourced supplies.
Our knowledge of asteroids and comets has expanded dramatically in the last ten years, with images and spectra of asteroids and comets from flybys, rendezvous, and impacts (for example asteroids Gaspra, Ida, Mathilde, the vast image collection from Eros, Itokawa, and others; comets Halley, Borrelly, Tempel-1, and Wild-2. And radar images of asteroids Toutatis, Castalia, Geographos, Kleopatra, Golevka and other… These images show extraordinary variations in structure, strength, porosity, surface features.
The total number of identified NEAs has increased from about 300 to more than 3,000 in the period 1995 to 2005.
The most accessible group of NEAs for resource recovery is a subset of the Potentially Hazardous Asteroids (PHAs). These are bodies (about 770 now discovered) which approach to within 7.5 million km of earth orbit. The smaller subset of those with orbits which are earth-orbit-grazing give intermittently very low delta-v return opportunities (that is it is easy velocity wise to return to Earth).
These are also the bodies which humanity should want to learn about in terms of surface properties and strength so as to plan deflection missions, in case we should ever find one on a collision course with us.
Professor John Lewis has pointed out (in Mining the Sky) that the resources of the solar system (the most accessible of which being those in the NEAs) can permanently support in first-world comfort some quadrillion people. In other words, the resources of the solar system are essentially infinite… And they are there for us to use, to invest consciousness into the universe, no less. It’s time for humankind to come out of its shell, and begin to grow!!
So both for species protection and for the expansion of humanity into the solar system, we need to characterize these objects and learn how to mine and manage them.
Once we learn how to work on, handle, and modify the orbits of small near-earth objects, we will have achieved, as a species, both the capability to access the vast resources of the asteroids, and also the capability to protect our planet from identified collision threats.
Since the competing source of raw materials is “delivery by launch from Earth,” which imposes a launch cost per kilogram presently above $10,000

per kg, this same figure represents the upper bound of what recovered asteroidal material would be presently worth in low earth orbit.

Future large scale economic activity in orbit is unlikely to develop however until launch cost drops to something in the range $500 to $1,000 per kilogram to LEO. At that point, any demand for material in orbit which can be satisfied at equal or lower cost by resources recovered from asteroids, will confer on these asteroidal resources an equivalent value as ore in true mining engineering terms, i.e., that which can be mined, have valuable product recovered from it, to be sold for a profit. Now, $500,000 per ton product is extraordinarily valuable, and is certainly worth chasing!

Note that the asteroidal materials we are talking about are, simply, water, nickel-iron metal, hydrocarbons, and silicate rock. Purified, and made available in low earth orbit, they will be worth something like $500,000 per ton, by virtue of having avoided terrestrial gravity's "launch cost levy."

These are values up there with optical glass, doped semiconductors, specialty isotopes for research or medicine, diamonds, some pharmaceuticals, illicit drugs. On the mining scene, the only metal which has ever been so valuable was radium, which in the 1920's reached the fabulous value of $200,000 per gram!

Platinum Group Metals (which are present in metallic and silicate asteroids, as proved by the "ground truth" of meteorite finds) have a value presently in the order of $1,000 per ounce or $30 per gram. Vastly expanded use in catalysts and for fuel cells will enhance their value, and PGM recovery from asteroid impact sites on the Moon is the basis of Dennis Wingo's book, *Moonrush*.

When will we see asteroid mining start? Well, it will only become viable once the human-presence commercial in-orbit economy takes off. Only then will there be a market. And that can only happen after NASA ceases acting as a near-monopolist launch provider and thwarter of competition, and reverts to being a customer instead.

A developing in-space economy will build the technical capability to access NEAs, almost automatically. And regardless of the legal arguments about mineral claims in outer space, once the first resource recovery mission is successful, what's the bets on a surge in interest similar to the dotcom-boom and biotech-boom?

The first successful venturers will develop immense proprietary knowledge, and make a mint. And some as-yet unidentified (but almost certainly already discovered) NEAs will be the company-making mines of the 21st century.

Mark Sonter is an independent scientific consultant working in the Australian mining and metallurgical industries, providing advice on radiation protection, industrial hygiene, safety, and remediation of radioactively contaminated sites. His career includes 2 years as a high school science teacher, 6 years as a University Physics lecturer in Papua New Guinea, postgraduate studies in medical physics, and 28 years in uranium mining radiation safety management, including 5 years as Corporate Safety Manager for a major mining corporation. Mark was a visiting scholar at U of Arizona in 1995, and during 1995-97 wrote a research thesis on the Technical and Economic Feasibility of Mining the Near-Earth Asteroids. He was granted funding by the Foundation for International Non-governmental Development of Space (FINDS) to develop concepts for mining the near-Earth asteroids.

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