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Mining Asteroids for Precious Metals

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Special points of interest:

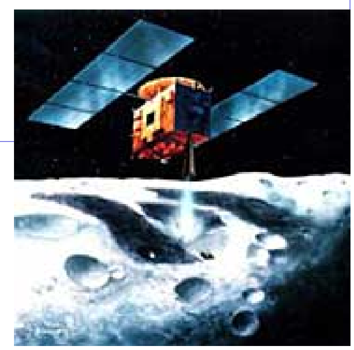
- Metals from space
- Triton Fun stuff
- Superfluous questions

Getting into space is expensive: a single launch of the Space Shuttle currently costs between 750 million and a billion US dollars. There are cheaper ways to put a payload into orbit, such as the launch systems of various other governments, the Shuttle-replacement *Ares* vehicles, and the SpaceX Corporation's new *Falcon* rockets. However, the reason spaceflight is limited to military and communications satellites and government-sponsored science and human programs remains strictly economic. Even SpaceX's rockets cost over $3000 for every kilogram they can put into orbit.

Given the high cost of spacecraft, there must be a compelling monetary profit for any corporate activity. Currently, the only product from space is information about the Earth: GPS navigation, satellite television and telephones, weather forecasts and pictures for GoogleEarth. There is no incentive to build any spacecraft that go beyond Earth orbit, or carry large payloads such as people. The latter may eventually change with space tourism, but there is a big difference between Virgin Galactic's SpaceShipTwo putting a pilot and three passengers into the upper atmosphere for five minutes of zero gravity and a *2001: A Space Odyssey*-style commercial flight to the Moon.

To break spaceflight out of the satellite-data monopoly, we need a new product. It must be very expensive per unit mass, and have a guaranteed market. This is not a new idea: plans have been considered at least since the early 1970's and in science fiction far before that. Two possible products have essentially no mass: information and power. One early plan for making money off of space was *"The High Frontier"* by Princeton professor Gerard O'Neill, who proposed building very large solar arrays in orbit and beaming the power to the ground using microwave lasers. The sheer scale of this project (~ a *trillion* dollars) and various technical problems with beamed power consign it to science fiction. With information and power off the table, we are left with extracting, shipping back, and selling resources available in space: in a word, *mining*.

Harrison Schmitt, the last astronaut to walk on the Moon, and representatives of the Energiya corporation, which builds Russia's rockets, have advocated mining the Moon for *helium-3*, which is present on Earth in small quantities but much easier to extract from the surface soil of the Moon, which is deposited there by the solar wind. However, helium-3 is only useful for experiments in fundamental physics and in some designs for fusion reactors.



Landing on asteroids like the Japan probe Hayabusa (above) did, will become routine if mining operations can be made profitable

Without fusion as a useful power source, there is no market for material extracted from the Moon. Prospective space miners must go elsewhere.

Surprisingly, the Moon is not the easiest object to land on after you leave the Earth. It is the closest, but the Moon's gravity means that a lot of fuel must be used to land safely and leave again. A much smaller object on an orbit around the Sun sufficiently close to that of the Earth requires less fuel to get to and return from compared with landing on the Moon, because you can 'dock' rather than land. Less fuel means a smaller spacecraft initially, which costs less money. Fortunately, there are many objects, a subset of the *'near-Earth' asteroids* or NEAs, which meet these criteria.

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Mining Asteroids: *continued*

Photos/Info: NASA/JAXA

NEAs aren't necessarily near the Earth at any given time, but are on orbits that pass near the Earth in an astronomical sense (less than 20 million km).

Asteroids are small objects that never accreted onto each other to form planets and are made of mostly mundane materials: rock, water-bound minerals, a tar-like sludge of carbon-bearing compounds. We might consider shipping water from an asteroid to Earth orbit, and selling it for 2000 dollars/kilo, comparable to some very expensive wines, if there were more possible consumers than the 3- to 6-person crew of the International Space Station. But there is a far more valuable product from some asteroids: *platinum group metals*.

In addition to rock, water, and organics, the Earth contains a large quantity of metal, which forms the Earth's core and is therefore not accessible. Among the asteroids, there are a few objects that are nearly pure metal. Based on studies of meteorites, the alloy is nickel-iron, typically about 90% iron and 9% nickel. The rest is mostly cobalt, with small amounts of rock, organics, most of the rarer metals, and most importantly for this discussion, up to *20 parts per million of platinum, 10 parts per million gold*, and *20 parts per million of other platinum group metals*. 20 parts per million may seem to be a trace, but the largest platinum mines on Earth are in the Bushveld Complex of South Africa, working ores which are typically about 5 parts per million. To extract those 20 parts per million does require a lot of work, but there is as much platinum in the 1-kilometer-wide NEA called *1950 DA* as there is in the entire Bushveld.

Platinum is expensive for three reasons: it is incredibly hard to corrode, so it is used in working with acids and as electrodes in fuel cells; it catalyzes certain reactions, so that it is essential in making clean-burning internal combustion engines; and it has been promoted for use in jewelry, although the last is probably due more to its already high price. Currently, platinum costs about $30,000 per kilo and over 200 tons are mined every year, so the total annual revenue of the industry is about $6 billion, with the other platinum-group metals, except gold, together totaling about the same amount. Adding more metal to the market by mining an NEA, such as 1950 DA, would drop the prices somewhat, but not dramatically, unlike gold, where the price is driven by speculation trading of gold reserves. In any event, the potential market for asteroid mining of platinum-group metals is several billion dollars per year for a couple of hundred tons of material returned to the Earth.

For an asteroid mine to succeed, it must also make money *quickly*. If it takes ten years for the first profits to return, there will be very little investment. A mine in the Bushveld or an oil well in Saudi Arabia pays for itself within two years or less. This tells us the engineering requirements of the mine. The cost of a spacecraft launched by an Ares heavy launch vehicle or a fleet of SpaceX Falcons is no less than $5000/kilo with extra costs of interest on debts, time lost flying to and from the target object, and payments on Earth-side resources. If we can sell the platinum group metals at $20000 /kilo, we must extract about 300 grams of product per kilogram of spacecraft every year to make money in two years. This means the mine must process its own mass of nickel-iron ore about *every hour*, since only the platinum-group metals can be profitably returned to Earth. This is a lower bound: the more mass that can be processed, the more metal we extract and the higher the potential profits.

It is very hard to engineer such a fast chemical separation process. Preliminary studies by different groups suggest the following: First, an automated sample return mission would validate the composition of a potential target. Then a large spacecraft is assembled in Earth orbit, containing a set of ion engines, a habitat for the crew, the processing plant, return-capsules for the product, fuel for the engines, and a large set of solar arrays.

At the target, the mining portion of the spacecraft 'lands' on the asteroid and is secured, while the crew habitat remains in orbit around the object. The material from the surface is scooped into the processor, sealed, and sliced into tiny particles using laser cutters. The chamber is heated to 200 C, to extract what little water, organics, and gases are in the ore. Then the chamber is flooded with carbon monoxide (CO). The iron and nickel react with the CO to form gaseous compounds called *carbonyls*, which are pumped off and decomposed at slightly higher temperatures (a trick currently used to make high-purity nickel). The CO is recycled and the spongy iron and nickel slag is unsealed and stacked someplace convenient. The remaining ore is now much less massive, and is more slowly reacted with a witch's brew of CO and chlorine to extract the platinum and other metals. This product is loaded into return capsules, launched on a trajectory to Earth, and, when the buyers have paid, they can pick up their orders from a salt flat in a convenient desert.

It appears possible to make large amounts of money by mining near-Earth asteroids for precious metals. But it is not easy: the engineering outline I have described has many details (for example, the carbon monoxide must not be lost to space and the habitat must be engineered for long stays, since it is very expensive to change crews). The cost of an asteroid mine is $10 billion, on a scale which produces about $6 billion per year of revenue, or half of the current market in platinum-group metals. This would be a very large project, but I think it is the best way to expand spaceflight until it becomes self-sustaining. This type of project is worthy of more thorough study. ###

TRITON FUN PRODUCTS

2009 has been declared the “International Year of Astronomy”. Events and activities to further the excitement of astronomy are being planned by IYA committees in over 100 countries. The logo for the IYA2009 is shown below. For more info on upcoming IYA2009 events, go to: http://www.astronomy2009.org

Triton Fun is an authorized distributor of T-shirts, sweatshirts and long-sleeve tees sporting this new logo. Part of the proceeds from the sale of these shirts will go to support astronomy clubs and astronomy activities connected with IYA2009 in California.

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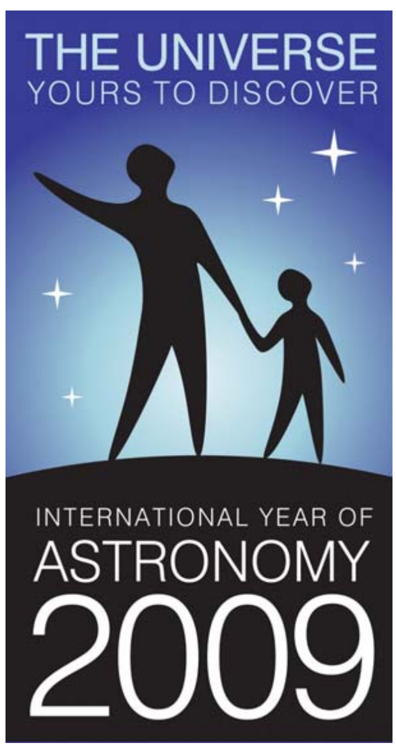

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Superfluous Questions:

1) In the movie *The American President*, who played the villain Senator who campaigned against the President ?

a) David Paymer b) Michael Douglas c) Richard Dreyfuss d) Martin Sheen

2) President Barack Obama was born *where* ?

a) Chicago b) Boston c) Hawaii d) Indonesia

3) Who was the shortest president ?

a) James Monroe b) Teddy Roosevelt c) John Tyler d) James Madison

4) Who was the first president to live in the White House ?

a) Thomas Jefferson b) Andrew Jackson c) George Washington d) John Adams

—> ANSWERS in next months issue of the Science Newsletter ! <——-

** ANSWERS to January's Superfluous Questions: 1. b) Buffalo 2. c) Hill Valley 3. a) Bromine 4. d) Sunset Limited