Riches in the Rubble

By Michael Paine
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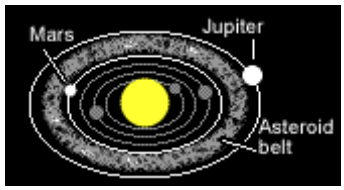
Thirty years ago, when the Apollo astronauts brought rocks back from the Moon, nobody rushed to stake a mining claim. Only traces of useful materials were found. The surface of the Moon turned out to be barren and unattractive for commercial development.

Asteroids, however, are another matter. Nearly all the raw materials needed to build a self-sufficient space colony are available on the most common type of asteroid. NASA plans to land a small robotic spacecraft on an asteroid within a few years, just one example of the belief that asteroids are both accessible and worth exploring.

Recipe for a Solar System

Most asteroids are made from the raw ingredients of the solar system, researchers believe. Those ingredients came from supernova -- exploding overweight stars. The solidified debris from these explosions contains mainly dust, rocks, water ice and iron (actually an alloy of iron, nickel and cobalt -- a natural stainless steel).



Nearly 5 billion years ago, under the tug of gravity, debris from supernovas gathered into a spinning disk. Most of this material fell into the center of the disk and formed our Sun. Further out the material formed many planets. As these planets circled the Sun they collided with each other and grew larger, until just nine planets were left. The debris from these collisions, together with other leftover rubble, was either swallowed up in further collisions or was mostly herded into planet-free zones like the asteroid belt between Mars and Jupiter.

Blast-furnace Planets

The inner planets (Mercury, Venus, Earth and Mars) likely started off as hot balls of molten metal and rock. Like a blast furnace used for making iron, most of the metal sank to the center of each planet and a thin, rocky crust formed on the surface. The crust material of these planets generally has much less metal than the raw ingredients of the solar system. Most crust is the equivalent of the slag, or discard, from a blast furnace, and there are just a few places near the Earth's surface where metal ores are concentrated enough to make mining worthwhile.

The good stuff is deep within Earth's interior.

What's in a Meteorite?

Iron meteorite	Stony meteorite	Earth's crust
Iron 91% **Nickel** 8.5% **Cobalt** 0.6% Source: Encyclopaedia Britannica	**Oxygen** 36% **Iron** 26% **Silicon** 18% **Magnesium** 14% **Aluminum** 1.5% **Nickel** 1.4% **Calcium** 1.3%	**Oxygen** 49% **Silicon** 26% **Aluminum** 7.5% **Iron** 4.7% **Calcium** 3.4% **Sodium** 2.6% **Potassium** 2.4% **Magnesium** 1.9%

Riches in the Rubble

Solar system rubble still collides with the Earth -- the smaller rocks reach the ground as meteorites. Some meteorites are nearly pure stainless steel, born in ancient supernovas.

Most of the asteroids are made of the same stuff as meteorites. They too are rich in useful metals and chemicals such as water and carbon, and hence their commercial potential.

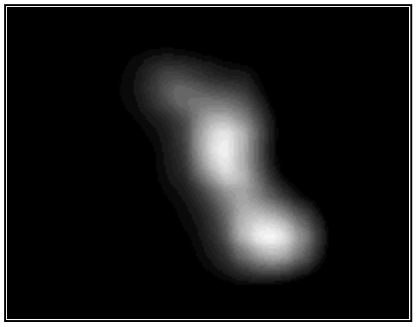
An example of the possible riches amongst this rubble of the solar system is the asteroid Amun. The orbit of this mile-wide object comes close to the Earth's orbit and, over millions of years, it could be a threat to the Earth. Before then, however, it is likely that mankind will have visited the asteroid and mined it away to nothing, because research indicates Amun is made from that primordial stainless steel. Planetary Scientist John Lewis, from the University of Arizona, estimates that the iron, nickel and cobalt in this single asteroid is worth about $20,000 *billion* at market prices.

Amun is unusually rich in metals and is typical of perhaps only 5 percent of asteroids. Most asteroids contain more rock than metal, but at least half of the material in these so-called stony asteroids could also be put to human use.

Let the Asteroids Come to Us

Some half a million asteroids 100 yards across or larger orbit the Sun along paths that cross or come close to the orbit of the Earth. In principle, it is easier to reach about 100,000 of these "Near Earth Asteroids" and return a payload to the Earth than it is to return the same payload from the Moon.

The recent Deep Space 1 flyby of asteroid Braille showed that we have the space technology to reach Near Earth Asteroids. By using material mined in space, mission planners could avoid the very high cost of launching materials from Earth.



The biggest technical difficulty in mining solid metal asteroids such as Amun might be the task of chopping chunks of metal from the main block. On Earth we have never had the luxury of mining a giant lump of pure stainless steel, so we don't even know how to do it.

Still, there is plenty of iron in common asteroids that could be mined using conventional techniques. These asteroids also contain water, which is not only important for surviving and manufacturing in space but also has potential as a rocket propellant.

A New Steam-powered "Rocket"

In 1829 George Stephensen won the first ever railway competition with a steam engine called the "Rocket." Although steam engines have now gone out of style on the surface of the Earth, there is great potential for steam-powered rockets in space.

In the vacuum of space a craft produces thrust by shooting matter at high speed out an exhaust portal. Conventional rockets burn exotic chemicals and the combustion products are forced out of a rocket nozzle to produce thrust.

An alternative to a chemical rocket is to heat a volatile material (a material which readily forms a gas) and expel the resulting superheated gas from the rocket chamber. The natural choice for this expendable material is water. Possible sources of heat are nuclear or solar power.

The main obstacle to steam powered rockets is the cost of launching tons of water into space from the Earth's surface. At a current cost of thousands of dollars per pound launched, we might as well send exotic chemicals into space -- the cost of the material becomes irrelevant.

But what if we could obtain water in space? The Moon's polar regions are suspected of holding frozen water, but the lunar poles are difficult to reach and launching payloads from the Moon is technologically and economically difficult. The obvious source of water is Near Earth Asteroids, because asteroids typically contain 10 to 20 percent water in the form of permafrost or saturated minerals. Dormant comets also orbit the Sun near the Earth, and these "dirty snowballs" likely contain more than 50 percent water.

There is another advantage to using water in space rockets. A thick layer of water ice around a manned spacecraft makes an excellent shield from radiation and small meteoroids. Water storage tanks could surround the habitable modules of spacecraft, like igloos in space.

The Next Giant Leap for Mankind

Our Earth-based technology for mining and processing raw materials needs to be adapted for use in space -- for mining the asteroids. If the dreams of science fiction writers are to become a reality and humans are to colonize space, then the next step is to tap into the vast resources of the rubble of the solar system.

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