Hot Idea

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Mining the Moon, Mars, and Asteroids


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An international group of scientists, mining and aerospace engineers, policy makers, and other specialists met in Golden, Colorado to discuss the use of space resources. Space Resources Roundtable II was held at the Colorado School of Mines, and was sponsored by the School of Mines, NASA, and the Lunar and Planetary Institute. Participants discussed lunar, martian, and asteroidal resources, along with economic and legal aspects of using extraterrestrial resources. This report focuses on lunar resources. Manufacture of useful materials on the Moon, Mars, or asteroids requires extensive use of what we know about those places through studies of lunar samples and meteorites from asteroids and Mars. It is applied cosmochemistry.

References:

Space Resources Roundtable II, 2000, LPI Contribution 1070. Lunar and Planetary Institute, Houston, 75 pp.

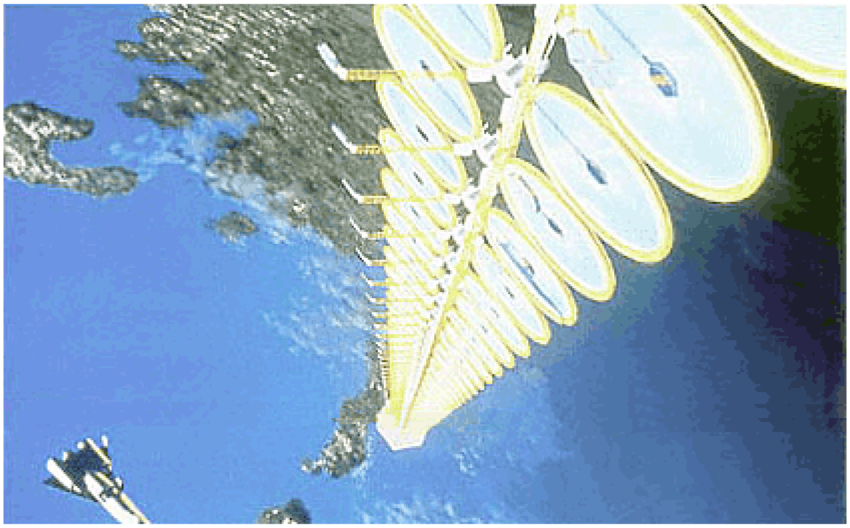
Abstracts also available at Space Resources Roundtable.

Lunar Solar Power

Energy specialists point out that we need alternatives to fossil fuels. They give several reasons. There are environmental problems with burning carbon. The traditional fuels will eventually run out. Perhaps most important, increasing the standard of living in developing nations requires a huge increase in the supply of energy.

Solar power has often been touted as an answer to the world's energy problems. However, it is not very efficient. A given place on Earth is dark half the time. Clouds and dust reduces the amount of solar energy by another 50%. And except near the equator, the low angle of sunlight causes loss to the air, cutting the amount of energy by yet another 50%. All those reductions amount to eight times less solar energy reaching Earth's surface than arrives from the Sun.

The obvious thing to do is to tap the Sun's energy in space. The idea of space power systems has been around since the late 1960s. New technology makes it more attractive than it was at first. Its biggest problem is the cost of launching lots of stuff from the ground to orbit. But suppose almost all the needed materials were already there? David Criswell (University of Houston) has been arguing for years that the materials are already there--on the Moon. It just takes some manufacturing facilities to produce the needed parts and pieces.

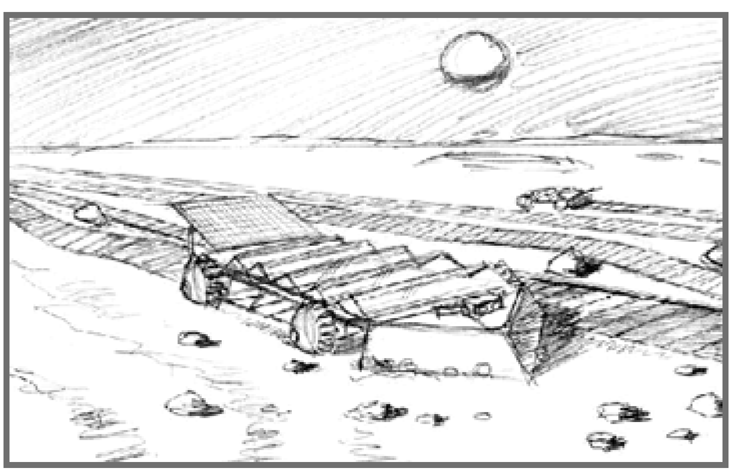


Solar power could be generated in space and beamed to the ground. The amount of material needed to construct a power satellite is large, hence expensive to transport from the surface of the Earth. It may be more cost-effective to bring the ingredients from the lunar surface--or even use the Moon to collect the solar power.

Criswell believes that solar power stations should be located on the Moon. He proposes building them on the right and left sides of the Earth-facing side of the Moon. This ensures a continuous supply of power to the earth. Solar cells would collect sunlight and transmit the energy to microwave transmitters. The microwave antennas would beam the energy to Earth, where it would be received by other antennas on the ground. Criswell says that the solar cells on the Moon would not need to be highly efficient. Instead, they could cover a lot of real estate. The trick is to make the solar cells and antennas on the Moon.

Alex Ignatiev, Criswell's colleague at the University of Houston, proposed a solution. An expert in materials science, Ignatiev presented the basic design for a robotic solar-cell maker. It would roll over the lunar surface, leaving a trail of solar cells behind. As the surface passed beneath the rover, concentrated sunlight would melt the surface. This would cool quickly to make a smooth, glassy surface. Another system would extract silicon from the lunar soil by a vaporization process and deposit it in thin films on the glass surface. Depositing thin films requires a strong vacuum. The Moon provides such a vacuum. The flimsy lunar atmosphere has a pressure about a trillionth that of the Earth.

The result would be an extensive network of solar cells. They would probably not be very efficient, but Ignatiev suggested that covering a large area with solar cells would overcome that problem. Although Ignatiev has lots of work to do to prove that the concept will work, most participants thought it was a promising way to produce power on the Moon. Perhaps Earthlings will prosper during the coming decades from an inexhaustible supply of solar power from the Moon.



Pat Rawlings

This drawing by space artist Pat Rawlings shows Alex Ignatiev's idea of a rover making solar cells directly on the surface of the Moon.

Lunar Alchemy: Dirt into Products

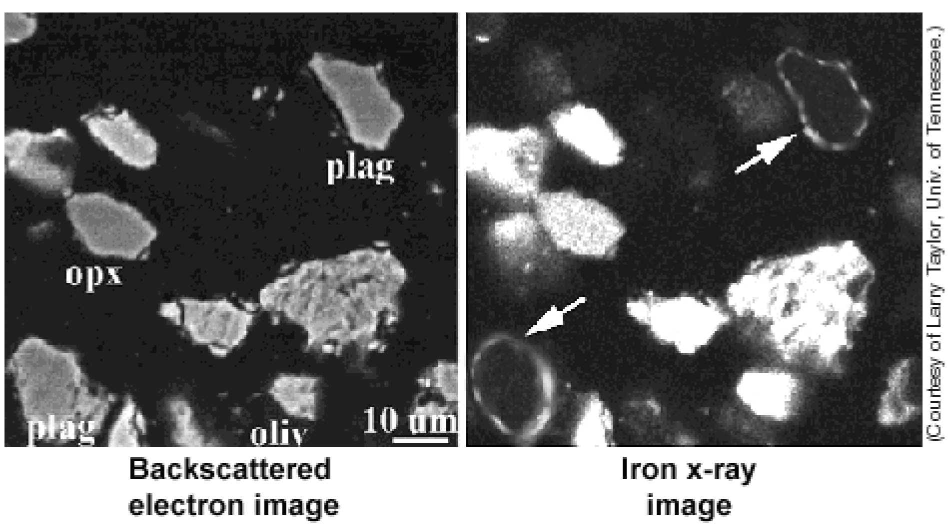
Schemes to extract oxygen from the lunar soil have been around for a long time. Almost all of them also produce other products as well, such as iron and titanium. Many require fairly high temperatures, hence a lot of energy. A few processes use hydrofluoric acid. These do not need a high temperature, but hydrofluoric acid is extremely toxic and corrosive.

Steve Gillette (University of Nevada, Reno) studies ways to separate elements on Earth. He suggested using organic chemicals to extract useful elements at a low temperature. Once lunar soil is dissolved into a mixture of organic liquids, useful materials could be separated. For example, silicon-based ceramics could be made at low temperature. These could be useful for many purposes at a lunar base, including making molecule-sized machines (so-called molecular nanotechnology). If the Moon becomes an important part of Earth's commerce, cutting-edge technologies will be essential.

Several scientists talked about their experiments on extracting oxygen, using the more traditional high-temperature techniques. These included James Blacic (Los Alamos National Laboratory), Giovanni De Maria (University of Rome), and H. Yoshida and his colleagues (Tokyo Institute of Technology). All use some kind of mechanism to fluff up moon dirt to make it easier to react with hydrogen gas. (The experiments actually use simulated moon dirt. Real lunar samples are too precious to use until a technology has been tested thoroughly with fake moon dirt.) De Maria uses ultrasound to shake a column of dirt. The others use the force of flowing hydrogen gas to make the pile of dirt behave like a fluid. Blacic's apparatus ionizes the hydrogen, making it reactive. The others heat the gas and dirt.

All the approaches produced water by reaction of the hydrogen with the soil. On the Moon, this water could be used for life support. Most important, it could be split into hydrogen and oxygen to use as rocket fuel. The experiments also produced metallic iron. That could be used as a building material or for electrical cables, if we could figure out an efficient way to separate it from the rest of the dirt.

Larry Taylor (University of Tennessee) has been working on lunar samples since the first batch was brought back from the Moon. He has also worked on ways to remove oxygen from lunar soil. Recently, he has been working with a team on understanding the optical properties of the lunar surface. This is important to understanding many remote-sensing observations of the Moon. While doing that work, he learned that the smallest soil grains, those smaller than 20 micrometers, are coated with tiny particles of metallic iron. The particles are only 10 to 100 nanometers across.



These two images show the distribution of iron in a collection of tiny lunar soil grains. Those labeled 'plag' and marked with arrows (for plagioclase) do not contain iron in their interiors. This is expected because lunar plagioclase contains very little iron. However, the edges of the plagioclase grains are decorated with blebs of metallic iron. This makes the plagioclase magnetic. Arrows in the righthand image point to two plagioclase grains coated with metallic iron which show up as bright rings. The other mineral grains also contain iron blebs, but the coating is indistinguishable from the iron oxide in the interiors.

What's that have to do with lunar resources? It is important for two reasons. First, it may make it possible to filter out the finest lunar dust. Rocky dust can be a health hazard to future workers on the Moon. It also can collect on door seals, allowing air to escape from pressurized houses. The minute iron particles make all tiny lunar grains magnetic. So, magnets will be able to remove the dust from the air and could be used to clean surfaces.

Second, the magnetic properties of the tiny grains give us a way to concentrate the finest dirt. By heating, the tiny iron grains will combine into larger grains that can be separated. Also, hydrogen is a useful element in lunar industry. Because it is delivered to the Moon by the solar wind, it occurs in the surfaces of soil grains. A pile of small particles has a greater surface area than a pile of large ones, so hydrogen is more abundant in small grains than large ones. Thus, separating small grains also concentrates hydrogen.

Drilling Holes in Planets

Some mining engineers are making important contributions to understanding how to explore the subsurface and how to mine asteroids. Others are trying to determine how to drill for water on Mars. Those places are very different from Earth, so the engineers must modify their equipment and techniques. Dale Boucher (Northern Centre for Advanced Technology, Sudbury, Ontario) has used his vast experience in mine construction to devise a lightweight, power-stingy drill to use on Mars. Jim Blacic has also been working on how to drill on Mars. He and his colleagues have identified many components of terrestrial drilling rigs that could be easily adapted for use on Mars. He pointed out, however, that no existing drill could be used as is.

Leslie Gertsch (Michigan Technological University) described how an asteroid could be mined, once a resource was identified on it. She brought up the important point that the approach depends on the make-up of the asteroid. For example, it might be composed of a mixture of ice and rock. The asteroid might be weak, easily broken rock, or very strong rock. It might even be made of metallic iron. This shows how important it will be to thoroughly characterize an asteroid before deciding how to mine it.

The Future

People are eventually going to be working and living in space. Construction and operation of lunar solar power stations may make that happen. Or perhaps it will happen to support a thriving space tourism business. Whatever drives it, there will be a need to use the resources available in space. It is too expensive to drag all the needed ingredients up from the Earth. The resources are available on the Moon, Mars, and asteroids. Participants in the Space Resources Roundtable agree that we need to explore extraterrestrial bodies for resources and to learn how to extract those resources from them. Experts in the mineralogy and chemical composition of extraterrestrial materials will play important roles in the search and mining of space resources. Like Earth explorers through the ages, we must live off the land and a new breed of scientist, the applied cosmochemist, will be there to see it happen.

Additional Resources

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