

20 Questions on Lunar Resources

What is the Moon Made of?

Tests on Apollo Moon Rock samples showed that they contain high percentages of Oxygen, Silicon, Iron, Aluminum, Titanium, Magnesium and Calcium with lesser amounts of many other elements.

Aren't these elements common enough on Earth?

Yes, these same principal 7 elements are the major constituents of Earth's own crust.

Then what is the advantage of extracting such commonplace resources from the Moon?

There is no advantage at all if the idea is to bring them back to Earth. But because of the Moon's much lower gravity, 1/6th that of Earth's, it would take only 1/20th the fuel or energy cost to transport these raw materials, and anything made from them, all the way back to low Earth orbit (LEO) as compared to rocketing them up the short distance from Earth's surface. In LEO, we could then afford to use these building materials to do a lot of interesting things.

What sort of useful building products could we make from these few elements?

Eventually, we should be able to make high-quality metal alloys such as steel, aluminum, titanium, and magnesium. This would require an elaborate industrial complex, on the Moon or in Earth orbit. In the short run, it would be relatively easy to make useful sintered iron products, glass, fiberglass, and a glass-glass composite with the strength of steel. We can also make some ceramics and even concrete.

What things in particular would these cheaper lunar resources allow us to build in space?

Much larger Space Stations than we can now afford to haul up from Earth module by module is one example. Only with these cheaper raw materials could we ever afford to build orbiting factories to take advantage of vacuum and zero gravity to make useful things that can't be made on Earth's surface, or hotels and resort complexes for tourists to enjoy the spectacular views below, or the large orbiting Solar Power Satellites to provide Earth with ample clean power.

Given Earth's two most pressing problems, our deteriorating environment and Third World poverty, how can we justify the high up-front costs of tapping lunar resources?

Many things are contributing to our deteriorating environment; but the number one villain is electrical power generation from coal and oil-burning plants that fill the air with acid rain and greenhouse gasses that could eventually destroy the climate. Even if the developing countries switched to all nuclear-wind-geothermal-hydroelectric sources, people in under-developed nations will have no way to catch up to our

standard of living except by burning even more fossil fuels than we do today. Space-based power generation is ultra-clean and there is no end to the amount available where the Sun provides it free full-time. Without such a solution, Earth's environment and the World's poor will share in the same death sentence.

Besides these more abundant elements, does the Moon have any truly strategic resources?

A big surprise was that Apollo Moon dust samples contain 600 times as much of a rare form of Helium, Helium-3, as is found on Earth. This endowment is not native to the Moon, and is only to be found in the upper few feet of the loose powdery soil. It was apparently deposited there by the wind of particles streaming out from the Sun's hot atmosphere since the beginning of the solar system. If ever we succeed in engineering workable fusion power plants, He-3 would be the ideal fuel as burning it produces no radioactive particles, not even neutrons, just charged particles that can produce electricity directly. There is enough of this ultimate fuel in the Moon's surface blanket to provide Earth with all the power we want for the next thousand years or more.

What chance is there of unhappy side-effects of generating our electrical power in space?

Power from orbiting Solar Power Satellites (SPS) will have to be beamed down to Earth either by laser or by radio waves in the microwave range (not the same as those in your microwave oven as those would be absorbed by water vapor in the atmosphere!) Tests to date deliberately using insect and bird species that might be most vulnerable to such waves have flagged no ill effects. There are fail-safe ways of controlling the beam and keeping it on target to ground receiving stations. But some economic dislocation for coal miners and petroleum workers is the price we'll have to pay for either a solar power satellite grid or for a helium-3 fusion system. Yet putting these systems in place could employ even more people than those put out of work, by greatly increasing available power at low prices. A clean Earth and a chance for a decent standard of living for all could be the reward.

Where on the Moon is this wealth to be found and just how would we go about extracting it?

On Earth, slow geological processes have worked to concentrate much of the mineral wealth in scattered veins and lodes. On the Moon this did not happen and these minerals lie everywhere in similar concentrations. There need be no race to stake out rich claims. Eons of meteorite bombardment have "gardened" the Moon's surface into a "pre-mined" loose rock powder (regolith) 5 to 50 feet deep. All we need is here, and Nature has already done the dirty work for us.

Won't mining scar the Moon with open pits and unsightly piles of unwanted tailings debris?

As we have just noted, the mineral wealth of the Moon is lying loose on the surface. In essence, we need to simply rake the top few feet of loose regolith to harvest what we need. We will want to do this in

generally flat areas, going around craters of any size larger than a few yards cross. So there will be neither deep mines nor open pits, and the minerals not needed will be left in place. A visitor would have to come very close to tell that anything had been done while those on Earth will see no difference at all in the Moon's appearance. Earth mining companies have shown no interest in moon-mining proposals, but the prospects have enthused others who know what the Moon has to offer help solve problems on Earth.

How large a crew would be needed on the Moon?

Simple resource recovery operations could begin with perhaps a dozen people. Liquid oxygen to use for air, to burn in fuel cells to make water, and for rocket fuel would be the first product. With a few more people, we could begin making simple sintered iron products and glass-glass composites with much of the apparatus automated or remote-operated. Each step sets the stage for others, and as markets grow, there could someday be many thousands of miners and other workers and support personnel on the Moon. To house them, processing building materials will be a priority. These will become an export item also.

How could people live in such a barren place?

the first shelters will be compact space station type habitat modules brought from Earth, covered with a few feet of soil for protection from the elements (radiation, heat and cold, solar flares, etc.) But fairly soon the crews should be able to move into larger structures built from raw materials on hand. These spacious quarters could be flooded with piped-in sunlight, and filled with plants to keep the air clean and fresh and to provide fresh fruit and vegetables.

Would miners sign up for short tours of duty? Or go to stay and bring their families along?

Certainly the first volunteers will only stay or a few months at a time. But as the base grows, a point will be reached where it is cheaper to provide facilities for permanent settlers rather than keep shuttling personnel back and forth from Earth. As soon as possible, it will be helpful for some of the crew to volunteer as trial settlers, even going so far as to raise children. For until we can see how native-born children grow up, we cannot be absolutely sure that genuine settlement can be maintained indefinitely.

What long-term health consequences will there be for permanent pioneers and their children?

We can expect some loss of muscle tone and mass in adjusting to the lower gravity, but this should level off at an acceptable level. The longer we put off letting volunteers to stay long-term, the longer we'll have to wait to find out if this expectation is correct.

Wouldn't a settlement of any real size need a continuous infusion of very costly imports?

Lunar soil in general has very little hydrogen, carbon and nitrogen. Once we can tap the polar ice fields, these elements should be in sufficient supply to serve a population of as many thousands as the

diversifying economy can handle. By resourceful of elements that are economically abundant, imports can be kept to light weight complex sophisticated items and capitol equipment for manufacturing.

To build a healthy, diversified economy, what else could the colony export other than rocket fuel, building materials, and fusion fuel?

Almost anything the settlers could make for themselves to avoid unnecessary imports, should find a ready export market in Earth orbiting installations, killing two birds with one stone, so to speak.

Even if all of this development does not scar the Moon, won't it cause pollution there?

Any settlement would need to operate as a "closed biosphere" recycling its air, water, and biomass. As the pioneers will live "downstream" and "downwind from themselves," they will have strong do-or-die incentive to keep their little oasis of life fresh and clean. The Moon has no atmosphere, ground-water, or ecology of its own to pollute.

What about the suggestion that the Moon might be used as a dump for Earth's problem wastes?

Even if waste disposal authorities on Earth become desperate enough to pay to launch some wastes into space, it will be cheaper to let the Solar Wind slowly blow them out of the solar system altogether than to land them on the Moon. If, however, in the Moon's totally safe, sterile vacuum and biological isolation, it proves possible to "mine" such wastes for elements rare on the Moon, the settlers may welcome them.

How far off in the future is all of this and how much scarce money will we have to invest?

NASA has no plans to return to the Moon, per orders from Congress not to bring up the subject. Genuine settlement will need technologies that NASA has put off developing: closed biospheres and manufacturing under lunar conditions, for example. Some of these technologies could be developed by entrepreneurs now, simply for any profitable terrestrial applications. This "spin-up" approach would put such technologies "on the shelf" ready to use when needed, most of the cost already taken care of. A lunar settlement could eventually be a very profitable undertaking, given Earth's growing thirst for electrical power. In the end it will happen when business and industry are ready. Private investment is the key.

How inevitable is such an Earth-Moon economy?

Using present proven off-the-shelf hardware such as SpaceHab modules for lunar shelters, and existing vehicles, a start could be made within a decade. It will decades for the whole scheme to unfold, however.

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