A RADICALLY EASIER, MARKET-DRIVEN PATH TO SPACE SETTLEMENT

BY AL GLOBUS

FUTURISTIC CITY, BASE, TOWN ON MOON.

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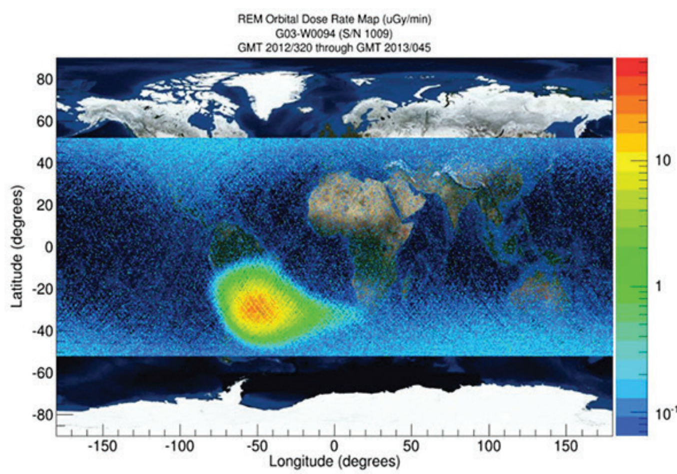
People have been dreaming about space settlement for decades, but these dreams have not come to fruition. Why? Because building traditional space settlement designs is extraordinarily difficult. Fortunately, there is a much easier way.

Location, Location, Location

The location for traditional space settlement designs include the Moon, Mars, asteroids, and the Earth-Moon L5 point (or other high Earth orbit). They all suffer from one very serious problem: They are very far away—anywhere from 363,000 to 400,000,000 km from Earth. This makes everything we want to do extremely difficult.

All space settlements need pressurized habitat, power systems, thermal control, communications, life support, materials recycling, and radiation shielding. As radiation levels in space are high compared with Earth, the mass of the radiation shielding dominates the mass of most space settlement designs. In orbits beyond Earth's magnetic field, radiation protection requires about seven tons of water per square meter of hull and a little bit less on Mars or the Moon. This amounts to millions of tons of material for a settlement big enough to really live in, perhaps 100 m across at least. If radiation shielding was not needed, space settlement would be a vastly easier.



Radiation measurements taken on the ISS (International Space Station). Note the very low levels (blue) near the equator. Image credit NASA.

It is our incredibly good luck that there is a region of space, very close to Earth, where radiation levels are much lower than in traditional locations. This is low Earth orbit (LEO) directly over the equator, called equatorial LEO (ELEO). The Earth's magnetic field protects this region from all but a small fraction of space radiation. Radiation levels are so low that below about 500 km it is possible—even likely—that no dedicated radiation shielding will be necessary. This means that a 100 m diameter cylindrical settlement in ELEO might have a mass of around 8.5 kTons—hundreds of times less than previously believed. This is not for a few capsules connected by tunnels, but an open living area comparable in size to a large cruise ship, with zero-g recreation at the axis of rotation, Earth-normal pseudo-gravity just inside the hull, and recreational space walks.

To get Earth-normal pseudo-gravity with a 100 m diameter, you need to rotate a settlement at about four rpm (revolutions per minute), which will make many people sick. Luckily, people adapt to rotation at four rpm within a few hours or days. Just like if you were to move to Nepal, you might experience altitude sickness for a few days (but Nepal is still a beautiful place to live).

Surface Settlements

Most Mars/lunar settlement schemes involve putting a module of far less than 8.5 kTons on the Martian/lunar surface. But that's the weight for a module a few meters across, similar to vehicles that have been in LEO off and on since the 1960s—not something big enough to enjoy living in. For a given size, the total mass of the material needed from Earth for ELEO and early Mars/lunar settlements is about the same as local materials can be used for radiation shielding. However, Mars/lunar residents will rarely leave their habitat due to radiation, and LEO development will continue to be much farther along. This is because ELEO is at least 100,000 times closer than Mars and 720 times closer than the Moon, giving ELEO a massive logistical advantage.

While space settlement may be vastly easier to get started in ELEO than anywhere else, it is still a huge task. Launch vehicle prices need to come down by a factor of perhaps 50. Reliable, nearly closed, large-scale life support must be developed. And a million engineering problems must be solved. Absent a gigantic pile of government money, how can this been done? One word: tourism.

The Magic Bullet

Tourism can supply the two things essential to market-driven ELEO settlement development:

1. A very high flight rate to make fully reusable launchers economically viable. We estimate at least 10,000 flights per year is needed, compared to less than 100 today.
2. A market for ever larger and more sophisticated space hotels, starting with the International Space Station (ISS).

Seven paying tourists have flown to the ISS (one twice) on a 7-10 day trip, but right now no seats are for sale. The first few space tourists paid about $20 million and the most recent flight was on the market for $50 million. While this is discouraging (the price is absurdly high and headed in the wrong direction), surveys suggest that as prices drop, more and more people will want to go.

The best advertised price to fly into today LEO is $26.25 million, although the vehicle is still in development. If this is successful and makes a profit and more flights are booked, economies of scale can reduce the price, which in turn increases the size of the market, which enables a further reduction in price, and on and on. We need to get on this spiral of dropping costs leading to bigger markets leading to lower cost. If the cost is low enough, the market is measured in millions of customers per year, which is the sort of market needed for the kind of low-cost high-flight-rate transportation system necessary to settle space regardless of destination.

Tourists need hotels. The first space hotels may be small to keep up-front costs down, but if space tourism is successful, the desire for bigger, more sophisticated, and more luxurious hotels could drive constant improvement. Most of what is needed for settlements is also important for hotels: recycled air, water, and food, power systems, communications with Earth, etc. Hotels may even want artificial gravity so that guests need not learn how to use a zero-g toilet—which is difficult (and disgusting when you screw it up). Once hotels have developed most of the necessary technology and supporting infrastructure, building the first space settlement should be not much more difficult than building another hotel.

The First Settlement

The first settlement in ELEO might look something like Kalpana Two, about the size of a very large cruise ship.

In an internet survey of space enthusiasts, 30 percent of respondents said they would very much like to live in Kalpana Two in ELEO, including raising their children, and are willing to spend 75 percent of their wealth and lifetime income to do so. Only 10 percent of respondents would be willing to live in something smaller.

Artist concept of a small early space settlement. Note the curvature necessary to generate pseudogravity by rotation.

Although building Kalpana Two may be much easier after a few decades of space tourism development than starting from scratch, it is still a monumental effort requiring a great deal of money. Those funds will be easier to raise if Kalpana Two and later settlements have a mass-market product to sell to Earth.

To aid this effort, residents could assemble and test extremely large communication satellites—much larger than those launched today. These are attractive because the larger the antenna and the larger the solar arrays, the smaller the ground antenna and longer your battery lasts. ELEO is also a good place to manufacture ultra-light solar sails, as the sails need not be folded into a fairing, launched, and unfolded. While the market for solar sails is small, if one side is covered with power-producing electronics, you have extremely light power arrays comsats can use. Put fiber lasers on the other side of the sail can beam power, first for in-space applications and later to deliver power to Earth, for which there is a gigantic market.

Onward and Upward

The first ELEO settlement is the hardest to build. The second and subsequent ones will be easier because lessons will be learned and infrastructure developed. We estimate there is room for at least a few million people in a few hundred settlements in ELEO. This can provide the key requirement for commercially viable lunar and asteroid mining: a large market in space. ELEO settlement is a game-changer for lunar and asteroidal mining.

Once the mining infrastructure to deliver substantial materials to ELEO is in operation and ELEO fills up with settlements, it will be time for the next step: settlements in orbit beyond the Earth's protective magnetic field. These settlements will require millions of tons of radiation shielding, which can provide a market for a huge expansion of lunar and asteroidal mines. This network of settlements can then expand through the near Earth asteroids to Mars, the asteroid belt and beyond.

The next step, of course, is to send groups of settlements to Alpha Proxima and start the billion-year project of greening our galaxy. After all, if you have lived for 50 generations in space settlements, does it matter much if you are close to Sol or on the way to the nearest star? Probably not, at least for some, but that is a task for future generations. Our mission, should we decide to accept it, is to get space tourism on track to develop the technology and infrastructure necessary to build Kalpana Two in equatorial LEO. This tape will not self-destruct.

Al Globus has been developing space settlements since 1979 and has contributed to shuttle, Hubble, X37, Aerospace Plane, ISS, and cubesats.