

Colonizing the Galaxy in Eight Easy Steps

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The Millennial Project: Colonizing the Galaxy in Eight Easy Steps by Marshall T. Savage, 1994

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The Millennial Project is a thousand year plan to colonize the galaxy. Yes, you read that right, no need to adjust the sanity controls on your computer.

The Millennial Project begins with the premise that mankind may very well be the only life in the universe; it is therefore our duty to see that life spreads and flourishes, that we fill the universe and make it live and breathe. As long as we are stuck on just one little clump of mud hurtling about the sun, all our eggs are in one basket. A single large meteor, nuclear war, or virulent plague might wipe us out. Even barring catastrophe, population density and longevity are increasing. Eventually we'll have to either stop breeding or find new places to put people. This book is an eight part, 1,000 year plan to solve these problems.

Marshall T. Savage's elegant and eloquently written plan begins with a simple step: establishment of a foundation to begin planning for humanity's diaspora. Since The Millennial Project was written in 1994, this actually has already begun, though it looks like it's in the early stages.

- [1] AQUARIUS – Space Colony at Sea

The meat of the plan begins with my favorite step – colonization of the Earth's seas. Aquarius solves today's problems in an inexpensive and ecologically sound way, and serves as a testbed for our later colonization efforts.

The first and most important part of each aquarian colony is an OTEC (Ocean Thermal Energy Converter), a revolutionary form of solar power. Thanks to the

sun, surface ocean waters are far warmer than in the depths, especially at the equator. An OTEC is a 3300 foot long pipe that sucks 40 degree (fahrenheit) water to the surface where it's 80 degrees. This temperature differential can then be used to power a steam engine. The lower the air pressure is, the lower the boiling point. At .43 PSI water boils at 80 degrees. The expansion of the water vapor turns a turbine which generates electricity. The vapor then condenses on a pipe that carries 40 degree water, which then lowers the pressure, which causes more water to boil, continuing the process.

A single OTEC will be taken by ship to a spot in equatorial waters, where the water is warm and deep and hurricanes are rare (thanks to the Coriolis force). A magnesium wire mesh will be placed in the water and using the electricity from the OTEC the water will be electrolyzed, creating a "seament". The same minerals used by shellfish to create their shell will be deposited onto the wire from the sea water due to the electricity. After 6 months of electrolysis a 5.5 mile diameter structure capable of housing 100,000 people should be complete.

The OTEC will pay many dividends. Excess energy can be converted and stored, or sold...water can be electrolyzed, separating the oxygen and hydrogen. Hydrogen can then be transported via large balloons for use in fuel cells in other parts of the world. More importantly, the water dredged from the depths of the sea will be rich in nitrogen which will promote plant and algal growth, making sea farming of fish and mollusks possible.

[2] BIFROST – 21st Century Launch System

Our bridge into space will be a revolutionary new system, far more economical than NASA's shuttles. A kilogram of payload onboard a Space Shuttle costs about \$8800 to send into orbit. The reason for this is that for every ton of payload (the stuff you actually intend to put into orbit) you have to use 25 tons of fuel and shuttle to get it there (20 tons of fuel, 5 of shuttle). Much of the fuel is spent, not lifting the payload, but lifting the rest of the fuel.

By contrast, Bifrost will be extremely cheap, perhaps as low as \$15 to \$20 per kilogram over the long term. The reason for this is that the Bifrost shuttle will carry almost none of its own fuel.

Bifrost begins with a 250 kilometer tunnel drilled out of a mountain and the surrounding countryside. The tunnel will be hyperbolic – beginning with a slight upward slope until it reaches the mountain towards the end, at which point it will be nearly vertical. Ideally the mountain will be one situated on or near the equator such as Kilimanjaro because objects at the equator are already moving faster than objects located at other parts of the world...the Earth has a circumference of about 25,000 miles, and rotates every 24 hours, so an object at the equator has an angular velocity of more than 1,000 miles an hour. By contrast, an object at the north pole has nearly no angular velocity. This extra velocity makes launches a bit cheaper (and explains why American launches have been done from Florida and Texas).

The shuttle is a "wave-rider", a delta wing craft (triangular) that coasts on its own shockwave and makes an excellent glider. The wave-rider will be accelerated through the tunnel using superconducting rings in the walls – magnetism will drag it along until it's attained much of the velocity necessary to launch it into orbit.

The wave-rider carries only about 4 tons of fuel. Ice, to be precise. When the wave-rider bursts free of the tunnel, powerful lasers on the ground will vaporize the ice on the rear of the wave-rider, which will give it the extra boost it needs to get into space.

The only fuel needed is a small chunk of (non-polluting) ice, so the electricity needed is rather low.

[3] ASGARD – Space Colony in Orbit

Our next stepping stone will be a colony in geosynchronous orbit about the Earth. Much like Aquarius, Asgard will house about 100,000 people. Also, much like Aquarius, Asgard will be modular. Aquarius will be composed of many hexagons joined together to allow for easy expansion and provide stability against sinking; Asgard will be Aquarius taken to 3 dimensions.

Asgard will be composed of a number of silicon bubbles – balloons, really. A house or office will be a bubble with a 6.66 meter radius. This bubble will be surrounded by 12 other bubbles of the same size; these 13 will be held by a large bubble. This in turn will be another dozen similar large bubbles, and these 13 will then be held by the largest bubble (300 meter radius), the outer wall of the colony.

Each bubble will be inflated by oxygen at 1/5 the air at sea level. On Earth, air is about 80% nitrogen, 20% oxygen (with a few other gasses thrown in). Removing the nitrogen will allow us to have less pressure in our bubbles which will exert less stress, yet still give us the same "partial pressure" of oxygen for breathing.

The outermost bubble will actually be a double-bubble – one surrounded by another slightly larger one. The space between these two bubbles will be filled by a 5 meter thickness of water, which will serve as a shield against radiation and micro-meters as well as drinking water and a space for farming of algae and other things to eat. Also, like Aquarius, our power needs will be satisfied by solar power.

[4] AVALON – Ecospheres on the Moon

>From the orbit about our own planet, we'll jump to the next most convenient place – the Moon. Despite its barren look, the Moon can easily be made hospitable for life. It has millions of craters, ranging up to hundreds of kilometers in

diameter. These will be domed over; larger ones will make cities, smaller ones perhaps just single family homes. All together, the craters cover as much area as California, Texas, and Montana combined.

About 90% of the elements we need are available right there on the Moon. The remaining 10% can be rounded up from other places such as meteors. One type of meter especially, "carbonaceous chondrites," have exactly what we need, including (of course) carbon, and water.

Once we've established a presence on the Moon, we'll repeat one of the previous steps: Bifrost. A similar system on the Moon will work tremendously cheaply, both because the Moon has just 1/6 the gravity of Earth, and because the cooler temperatures make cooling the superconductors easy. From there we will launch our way to the next step...

[5] ELYSIUM – Terraforming Mars

Our first target won't actually be Mars itself, but its tiny moon Phobos. Phobos is a 26 kilometer diameter rock circling Mars, barely big enough to call a moon. One thing in its favor is that, again, with very little gravity it makes an excellent space station, because launches are cheap. You can actually throw a stone from Phobos and hit Mars.

Phobos itself isn't nearly large or hospitable enough, so from there we would head to Mars. Fortunately, all evidence points to Mars once being a world much like Earth. There are mountains, dry river beds, empty oceans. At the poles there are frozen reservoirs of carbon dioxide. There may even be vast frozen seas beneath the surface. It will be our job to melt the polar caps of carbon dioxide and let the greenhouse effect take over (with a bit of help from us). Amazingly, Mars has a day that's only 33 minutes longer than Earth's and in fact fits human circadian rhythms more closely than Earth's, so we should feel right at home, though sunlight will be a bit less than half as bright as on Earth.

Presumably by this time we will have perfected use of fusion for power generation. It's fusion that powers the Sun, as well as certain kinds of nuclear weapons. Helium-3, a rare isotope of helium, can be harvested from the Moon and can be used together with deuterium (an isotope of Hydrogen very common in Earth's oceans) to start a fusion reaction.

[6] SOLARIA – Colonizing the Solar System

With just a 2% annual growth rate, there will be 1 trillion humans by the year 2250, about 166 people for every 1 person there is today, doubling about every 36 years. With an 8% growth rate typical of frontier settlement, this would be astronomically higher, doubling every 9 years. Where will we put all these people?

Our best bet is the asteroid belt, a big pile of rocks orbiting between Mars and Jupiter. Amazingly, there are ten billion asteroids larger than 100 meters in diameter. That's larger than a football field in all 3 dimensions, and weighs 1.5 million tons. The 32 largest asteroids are far larger, all over 200 kilometers in diameter, with Ceres, the largest, being 466 kilometers. Each asteroid, once hollowed out, could support a population of anywhere from thousands to billions of people. Beyond that, there are 100 billion asteroids between 10 and 100 meters in diameter, with enough matter to support anywhere from a few families to a small town.

Farther out there's an even more incredible resource: the Oort Cloud. The Oort Cloud is a ring of as many as 100 trillion comets, starting at about Pluto and extending about halfway to the nearest star. The mass of the comets in the Oort Cloud may be as high as ten times the combined mass of all of the planets in the solar system.

At this stage we'll want to increase our energy output to fuel our expansion. Again, we'll turn to solar power. In fact, it will be the ultimate in solar power – what is known as a Dyson shell (or Dyson sphere), named after the physicist Freeman Dyson who first came up with the idea in 1959. A Dyson shell is a 20.6 million kilometer diameter shell almost completely surrounding the sun, leaving a narrow band in the center so that light will still reach the Earth and other planets. The shell will be composed of an incredible number of thin solar collectors that will beam energy in the form of lasers or focussed microwaves to where it is needed.

[7] GALACTICA – Colonizing the Galaxy

Despite an exhaustive search by programs such as SETI and SETI@Home, no other star system has been proven to have life. It's in this step that we'll change that.

Our first star system for settlement will be the Centauri system, a system with three stars orbiting each other, Alpha Centauri, Beta Centauri, and Proxima Centauri. The closest is about 4.3 light years away.

A light year doesn't sound like much; science fiction flippantly throws the term around as if it's trivial, but really it's such an inconceivably large unit that travelling this distance in a reasonable amount of time will prove quite a challenge. A light year is the distance light travels in a year; light travels nearly 300,000 kilometers per second, or around the Earth twelve times in one second. Clearly we'll need a new form of energy and propulsion to reach the nearest star.

The answer is anti-matter. Anti-matter is very much like matter, except when combined with matter, both are annihilated and release pure energy. A kilogram of anti-matter is enough to launch 9,000 Saturn V rockets to the moon.

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Naturally you don't find anti-matter just lying around. We'll have to produce it, at incredible cost. We'll create electron / positron pairs by focussing together lasers operating at about 26 million times the power of the Sun, but fortunately for only billionths of a second at a time.

We'll need special craft to take us to the Centauri system. Our ship will be designed to travel at about half the speed of light, which means it will take more than a decade to get to the nearest star (since it will take time to accelerate half the speed of light). Travelling at this speed, even the smallest motes of dust can have incredible destructive force when they collide with the ship. Therefore, the ship will have a thick ablative shield in the tip, a barrier that will be expected to wear away over the course of the trip.

<http://www.4literature.net/story/2002/7/28/115247/145>

Forgot what step 8 was, dam, there goes the galaxy!