# Countering Objections to Space Settlement[1]

Al Globus, May 2021

Space settlement is moving from the fringe of space conversations towards the center. As this happens some will object to one or more aspects of space settlement. Most of these objections have been heard before. Indeed, since space settlement became part of the discussion with Gerard O'Neill's work on free space settlements in the 1970s, many of the same objections have surfaced again and again. The space settlement movement, including this author, has some experience responding to these attacks. This paper is intended to be a place to find rebuttals to objections to space settlement. For each objection there are talking points and a brief discussion.

The objections are broken into categories: General objections, It cannot be done, Power plays, and Miscellaneous.

First, we must know what a space settlement is and why one might want to settle space.

## What is a space settlement?

For the purpose of this paper, a space settlement is a place to live beyond Earth's atmosphere, including raising families. This involves living on a planet or moon or in orbit, including co-orbiting with an asteroid. In-orbit settlements are often called free space settlements.

## Why settle space?

**Talking point:** To survive and thrive.

### Survive

Someday the Earth will become uninhabitable. Before then life must move off the planet or become extinct. While inevitable, this could be billions of years in the future. Much more near term threats include climate change, major asteroid hits, supervolcano eruptions, nuclear war, pandemic, nearby supernova, and technology run amok (for example, the Grey Goo[2] and Paper Clip Apocalypse[3] problems) many of which could happen at any time.

[1] This paper is derived from Facing Arguments Against Space Settlements published in Ad Astra in the Winter of 2021 by the same author and which shares a good deal of text.
[2] The Grey Goo problem is from the nanotechnology tradition. In it, a 'universal catalyst' embedded in reproducing molecular machines turns everything it can reach into grey goo.
[3] The Paper Clip Apocalypse problem is from the Artificial Intelligence (AI) tradition. It involves the construction of a very capable intelligent machine that is instructed to produce optimal paper clips. The machine then turns everything within reach into paperclips.

Space capabilities can reduce some of these threats. For example, spy satellites have played an important role in avoiding nuclear war thus far. Space settlement can prevent asteroid hits as an extensive space civilization would likely monitor all asteroids and comets as a potential source of materials for free space settlements and divert any objects heading towards Earth. Special purpose space settlements for developing potentially dangerous technologies can improve safety when used as laboratories isolated from the rest of humanity by hundreds of kilometers of vacuum and radiation.

In addition, in the event of a planet wide disaster not only might billions of people die, but recovery would be difficult since the whole planet is affected. If an extensive branch of our civilization is in space before any of these threats manifest, the unaffected space settlements can provide aid up to and including reseeding Earth.

## Thrive

Why build space settlements? Why do weeds grow through cracks in sidewalks? Why did life crawl out of the oceans and colonize land? Because living things want to grow and expand, to thrive, not simply exist. Alone of all species we have the ability to go to space by developing rockets, pressure vessels, space farms, and the hundreds of technologies necessary for living things to survive in space. Note that if we don't take the next expansion step there is no one else that can.

A key aspect of space settlement thriving is the ability to **build new land**, rather than take it from someone else. This allows, but does not guarantee, a thriving, expansive civilization without most resource wars or destruction of Earth's biosphere. In the space settlement era resource wars are unlikely and unnecessary because our Sun provides billions of times the energy used on Earth and the asteroids provide enough material to make new orbital land hundreds of times greater than the surface area of the Earth. Destruction of Earth's biosphere can be avoided by moving most environmentally damaging activities off of Earth. For example, a space solar power[4] system's space segment could be built from lunar or asteroidal materials without touching Earth's biosphere.

# General objections

This section contains general objections such as space settlement being too expensive.

## Objection: Space settlement uses money that could be better spent on housing, food, medical care, etc.

**Talking point 1:** Most resources should and do go to today's human needs, but a small fraction should be our seed corn, to be spent on the future.

[4] Space solar power refers to collecting energy in space and beaming it to Earth. Space solar power can, at least in principle, supply Earth with enormous amounts of very clean electrical energy.

**Talking point 2:** Mature space capabilities can, and often do, pay for themselves and then some.

The first and most common objection to space settlement is that the billions of dollars of space money could be better spent feeding and housing people, providing medical care, etc. The simplest response is that most of society's resources should be, and are, expended on foods, shelter, health care, education, communication, transportation, etc. The United States has a multi-trillion dollar economy while NASA's budget is around $24 billion. You can think of this money as seed corn.

Every year a subsistence farmer must plant their crop. The seed for that crop comes from the same corn the farmer's family eats. If they eat all the corn grown they will starve as there is no seed the next season. So a small fraction of the corn crop must not be eaten, no matter how hungry they are.

Similarly, NASA uses a small fraction of the country's resources to develop new capabilities and products and improve existing ones. NASA is focussed on space and aero vehicles which has led to immense improvements in transportation, communication, understanding the Earth, protecting Earth from asteroids, location services, and much much more.

The second response to this objection is that mature space activities pay for themselves and settlement can do the same. The classic example is communication satellites, which are the single largest arena of commercial space development. Comsats have earned profits for decades, paying back in taxes the government money spent to help them develop many times over. Earth resources satellites can also be quite profitable in addition to their vital role in understanding Earth's environment. Location and navigation satellites enable a thriving economy in ground devices, such as smartphones, that use the government owned and operated space GPS (Global Positioning System) to help people get to their desired location.

## Objection: If we were meant to go to space, we would <fill in the blank>

**Talking point:** Our ability to make machines can take us into space.

The human body is poorly suited to space. If put in direct contact with the vacuum, radiation, and/or temperature extremes of space things will not go well and death is the usual result. However, the human body and mind are superbly suited to building machines, including machines that can create very livable worlds even in the hostile environment of space. Vacuum can be defeated by pressure vessels, radiation by mass or electromagnetic fields, temperature extremes by insulation, excessive heat by thermal radiators, and so forth.

## Objection: We will mess space up just like we have Earth

**Talking point:** Space is mostly rock, radiation, and plasma. There are no local societies to oppress or living environments to 'mess up.'

The cosmos, stretching 53 thousand light years in this galaxy alone, is almost all plasma, rock, and radiation. There really isn't much that can be ruined, and there is an awful lot of it (about 100 billion stars in the Milky Way). At least in this solar system, there are no native tribes that could be oppressed or have their land stolen. There is no living environment that can be destroyed except, perhaps, microbes on Mars or a few moons. Parts of the space environment should be preserved for posterity, for example the Apollo landing sites. However, much of space suitable for settlements, for example the asteroids, can be freely exploited without creating loss to any living thing.

A critic might note that we have polluted small but important bits of space, namely Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO). These have a debris problem in the form of derelict spacecraft, bits of junk, and debris from collisions and explosions. The situation causes no problems on Earth other than increased satellite operational costs. Furthermore, a number of missions to clear out the debris are in the works. There are also very large constellations (thousands of spacecraft) in development but considerable effort is being put into minimizing collisions. In any case, one can reasonably expect people living in space to be more concerned with the debris problem and in a better position to do something about it.

Life will change space as we move into it, just as life changes Earth.  There are already foot prints and wheel tracks on the Moon and more are on the way.  There are rovers and landers on Mars as well as thousands of working satellites in Earth orbit. Unless we abandon space development these changes will accelerate.

When life moved out from the oceans and onto land enormous changes took place on Earth. Changes that led to the existence of you, dear reader. There are those today who think changes are unacceptable; that any change is degradation and everything should stay as it is, or sometimes was, forever. Had this been the case in the past, humanity would be limited to Africa or, quite likely, extinct.

## Objection: Having an alternative to Earth devalues Earth

**Talking point:** Earth is, by far, the best planet. It cannot be devalued.

Some may justify damage to Earth's environment by thinking that humanity can simply escape to space settlements and leave the mess behind. This is a terrible and obvious mistake.

First, Earth is the best place in this solar system, and by an extremely large margin. There is no other place where one can breathe the air. No other place with large amounts of liquid water on the surface. No other place that grows any food at all. One could go on for some time. In short, Earth is the solar system's best planet.

Second, there are over seven and a half billion people on Earth. Building sufficient space settlements for such an enormous population would take a very long time and transporting

them from Earth is an immense task. “Trash it and move on” is not a viable strategy for mankind.

## Objection: Earth problems must be solved on Earth

**Talking point:** This is simply untrue.

For example, besides the day to day problems solved by communication and GPS satellites, Earth observation satellites make a huge contribution toward the vital task of understanding Earth to minimize the critical risks we face with regard to the climate crisis and a host of other environmental challenges.

Space is used to solve problems on Earth every day. This is not in some far off time, it is now.

## Objection: Early settlers may become a resented elite (ala Elysium)

**Talking point:** It’s a movie, not a documentary.

In the movie Elysium (2013), by 2154 the masses live in misery and squalor on Earth while a privileged elite live in an enormous LEO space settlement with top notch health care, beautifully maintained estates, and a completely unrealistic, but vital to the story, illegal immigration problem. After a few centuries of space settlement, if Earth is allowed to degenerate, something similar could take place here.

The obvious solution is to not let Earth degenerate in such a way, which is a good idea in any case. It will be a long time before anything even vaguely like Elysium in the movie will be common in space. Given the proven track record of the last century or so in improving the human condition for billions of people, it is reasonable to expect that most people will be better off in 100 years than they are today, regardless of pollsters, if the environment is protected from the climate crisis and similar problems. While there may still be resentment, there should be a lot less squalor.

## Objection: Those who grow rich on space development may be resented

**Talking point:** How do you become a space millionaire? Start out as a space billionaire.

Outside of launch, communications, and Earth observation, people are mostly spending money in space, not making it, but this will not necessarily continue forever. However, resentment of the more fortunate is not limited to space endeavors and the response likely should be similar for space and non-space cases.

# It Cannot be Done

The second major class of objections is feasibility. Can space settlement be accomplished or is there some horrendous problem that cannot be solved?

**Talking point 1:** Space settlement is a massive engineering task, but there is no new physics needed and after decades of study no show stoppers have been identified. The necessary capabilities are within our grasp.

**Talking point 2:** Space settlement will be difficult but the rewards can be enormous.

## Objection: Space farms cannot work reliably

**Talking point:** A problematic but adequate space farm has been demonstrated on Earth.

Space settlements regardless of location need a farm to produce not only food but also clean water and oxygen, and must recycle wastes to become food again. This is an extraordinarily difficult task. Small settlements are particularly difficult to provide for because the life support system has small buffers of vital resources such as oxygen and water. If the space farm is very sensitive the whole system can become unstable and crash.

Fortunately there is one example of a ground based space farm experiment that, despite serious problems, was able to operate a mostly closed system supporting eight people in a three acre facility for two years. It was called Biosphere 2 and is largely considered a failure because they fell short of their original targets, had poor marketing, and did very unconventional science. But Biosphere 2 was an engineering success in that it more-or-less did what was hoped for on the first big try: keep eight people alive in an airtight system. An engineer's response to this situation is to try again, which they did for six months until outside pressures ended the experiment. So consider

1. Biosphere 2 was atmospherically closed. We know the atmosphere was recycled with very little loss because at about 16 months they had to import oxygen which was running low. If there was a lot of atmospheric leakage the oxygen level would have been the same as outdoors. The problem was that some of the concrete in Biosphere 2 was absorbing oxygen. Fixing the concrete, once the problem was understood, was easy.
2. The first large Biosphere 2 experiment (or closure) did not produce enough food. The biospherians ate some of their emergency food supplies because they were starving. Before closure they did not understand the amount of physical work, particularly weeding, required to operate Biosphere 2 and they set calorie targets much too low. A second closure featured more area devoted to food production, and Biosphere 2 was able to feed eight biospherians on the second try.
3. The $CO_2$ level varied wildly but by dint of a great deal of work was controlled well enough.

4. Importantly, the Biosphere 2 closure experiments both had the same water at the end of the experiment as in the beginning.

So, there is no doubt that Biosphere 2 was pretty much closed to both air and water. In the second closure neither oxygen nor food was in such short supply compared to the first. There was some leakage, of course, and some material came in and went out (for example, biological samples), but no more mass exchange with the outside than a space settlement might experience.

Space settlements will strive for closure and effective recycling but neither will ever be perfect. That means that over long periods of time settlements will have to be resupplied with at least atmospheric constituents (mainly $N_2$ and $O_2$)

## Objection: Humans cannot tolerate space radiation

**Talking point:** Settlers can be protected by radiation shielding.

Space radiation comes from a couple of different sources. One is our Sun, which emits dangerous levels of radiation from time to time requiring some sort of storm shelter for a few hours or days until the (space) weather improves. Without such a shelter the largest storms can kill an unprotected human.

There is also radiation trapped in certain orbits. The easiest mitigation approach is to avoid these belts (the van Allen Belts).

An important source of radiation is galactic cosmic rays (GCR) which come from all directions at levels that will not kill or even make you sick in the short term, but in the long term can cause increased cancer risk and other problems. This risk can be mostly avoided by using large amounts of water, regolith, or other material as radiation shielding. For example, in high Earth orbit seven tons of water per square meter of hull is needed to provide adequate shielding for settlers. However, in LEO near the equator (low inclination) radiation levels are so low that little or no shielding is required to get interior radiation levels acceptable for settlement[5].

In short, living with the radiation in space is quite feasible although for free space settlements getting sufficient radiation shielding materials (millions of tons in most cases) to the construction site can be a significant logistical task. On a planet or moon local resources can be used to bury settlements in several meters of surface materials.

## Objection: Humans cannot tolerate weightlessness

**Talking point:** Free space settlements can provide artificial gravity by rotating.

Free space settlements can be rotated to provide artificial gravity for settlers. This avoids a long list of problems astronauts have encountered being exposed to microgravity. The

[5] See http://space.alglobus.net/papers/RadiationPaper.pdf

fastest rotation that makes sense is about 4 rpm (rotations per minute) which corresponds to a 112 m diameter to mimic 1g (Earth normal gravity). Faster rotation rates correspond to smaller diameters and the living area becomes very cramped. When exposed to rotation rates of up to 4 rpm many settlers may at first become ill but will usually recover within a few hours or a day or two. Even better, experiments on Skylab suggest that rotation in orbit is much more easily tolerated than on Earth.

## Objection: Humans may not tolerate Lunar (1/6g) or Martian (1/3g) gravity

**Talking point:** Much more research is needed, and free space settlements can provide 1g.

Twelve men have experienced lunar gravitation levels (about 1/6g) for a few hours or a couple of days. Determining the health effects of reduced gravity will require far, far more experience and research for adults much less children. A spinning facility in orbit can provide any g level desired for such research. If it is determined that whatever problems are found can be mitigated adequately then the Moon and Mars may become appropriate places to settle.

## Objection: Free-space settlements will be hit by asteroids

**Talking point:** Asteroids big enough to be dangerous are rare and can be deflected.

By one estimate, in free space small meteoroids (<10 grams) will hit a settlement about once every two years. But the damage from small meteoroids should be easy to repair in plenty of time to save the settlement. Large meteoroids (asteroids) are expected to hit about once every million years. Tracking of asteroids is already routine although not as extensive as it should be and techniques for deflecting dangerous asteroids are already in development to protect Earth.

There is one important exception. Early settlements may be in LEO[6] below about 750 km where there is significant amounts of man-made debris presenting an existential threat to free space settlements. It is possible, but expensive, to clean LEO of debris.

## Objection: People need X

**Talking point:** People are incredibly varied in what they can live with.

X can be any of many, many things that people think they 'need.' This includes distinct seasons, a 24 hour day, sunshine, an immobile house to live in, contact with nature etc., etc. etc. The truth is that people can and often do live without all these things. Examples include Southern California which has no seasons to speak of, Northern Alaska where people live

[6] "Space Settlement: an Easier Way." by Al Globus, Stephen Covey, and Daniel Faber, NSS Space Settlement Journal, July 2017.

for months at a time with no sunlight, nomads who have no houses, city dwellers who rarely see a flower not planted by a gardener etc., etc., etc.

People live successfully in an amazing variety of ways, and space settlement will undoubtedly add more.

# Power Plays

War and power politics will likely rear their ugly heads, but there is some reason to believe it will be less common in the age of space settlement.

## Objection: Space war may break out

**Talking point 1:** Resource wars are less likely as the available resources in space are so enormous.

**Talking point 2:** The fragility of free space settlements will limit some classes of warfare.

It is unrealistic to expect that space settlement will put an end to war if only because mankind goes to war for many different reasons. However two factors are expected to keep the level of warfare under some control: the fragility of most space settlements, particularly free space settlements, and easy access to truly vast quantities of energy and material resources.

Settlements and other facilities on a moon or planet (including Earth) can be buried under large amounts of rock making them difficult to destroy and limiting the options of an aggressor. The pressurized hull of free space settlements will usually be protected by several meters of radiation shielding giving it some toughness, but thermal radiators and solar arrays will be extremely exposed and vulnerable, making such settlements a poor platform for combat. It should be noted that if a lunar or planetary settlement uses nuclear power and cool interior temperatures for cooling, these vulnerabilities are much less.

As described in the section on thriving, the resources of this solar system are enormous: billions of times the energy budget of Earth, and asteroidal materials sufficient to build new land hundreds of times the surface area of Earth. However, that's for only one star and there are around 100 billion stars per galaxy. Thus, it is hard to imagine a situation where it will be easier to steal resources than to develop them. For example, by putting up a solar array one can access the Sun's energy. Alternatively one could attack someone with a solar array and steal theirs, but there are a wide variety of things that can go wrong and building one's own is expected to be a lot easier and more reliable than fighting over it.

## Objection: Space settlements may attack Earth

**Talking point:** Earth needs to know when to let go.

Early settlements will necessarily be an extension of earthbound organizations, probably governments and perhaps corporations. The number one most likely reason for space settlements to attack Earth is a desire for independence. The model most likely to avoid such wars is the Canadian, New Zealand and Australian models where independence was achieved gradually with very little if any violence. The American model, which involved years of full scale warfare, is not the ideal. Thus, Earth needs to let go of settlements and wish them well when the time for independence comes.

## Objection: A strong man may take over a settlement

**Talking point:** the right to leave is essential and may be sufficient.

It may be quite possible for a cult, probably headed by a charismatic leader, to take over a space settlement. This sort of thing happens on Earth all the time. Worse, it will probably be relatively easy to cut a settlement off from outside influences, at least for the small early settlements.

Takeovers are likely to be relatively bloodless as any serious fighting in a settlement may breach the pressurized hull (necessary on moons and planets not just in free space). Then the settlement would begin to lose atmosphere and everyone would need to deal with the hull or die.

An interesting question is: what is the smallest set of rights that settlers in a cult-run settlement need? Possibly just the right to leave. If this right were vigorously enforced (which may be quite difficult) then settlements with a repressive regime would tend to lose population, particularly among those critical settlers who know how to maintain and repair the settlement.

## Objection: Deudney threats

**Talking point:** a solar system with space settlement is far safer than one without.

*Dark Skies: Space Expansionism, Planetary Geopolitics, and the Ends of Humanity* by Daniel Deudney uses geopolitical theory to argue that space settlement would all but inevitably create threats that lead to war, destruction, and perhaps the extermination of humanity.  However, this book fails to compare the total threat with and without space settlement, minimizing the positive effect on survival that space settlement has -- the ability to help recover from global devastation. The threats Deudney examines are considered one at a time, not as the sum of all threats. He also grossly inflates the utility of asteroids as weapons. In any case, when the total threat is examined it becomes overwhelmingly obvious that the risks we face without settlements -- multiple paths to the extermination of civilization and even humanity with no way to recover -- completely overwhelms the risks with space settlements.

For a much more detailed critique of Deudney's *Dark Skies* see Not So Dark Skies published in Space Review July 2020.

# Miscellaneous

## Objection: People need nature

**Talking point:** City dwellers have little contact with nature today.

There are many people who live in a big city and rarely see a plant or animal that was not put there by a human hand. However, contact with nature is certainly desirable and many cities have large parks, for example, central park in New York, where city dwellers can get some exposure to something fairly close to nature.

After many generations of space settlements growing bigger and bigger, settlements could have large open spaces that are let run wild. Although the starting seed may be distributed by mankind, the evolution of the area could provide some valuable natural-feeling spaces.

## Objection: People cannot get along in tiny initial space settlements

**Talking point:** Some people do get along in small spaces.

The island of Santa Cruz del Islote off the coast of Colombia has 1,200 inhabitants on an island the size of two soccer fields. Locals say the island is peaceful and calm, there are no police and essentially no crime. Everybody knows everybody and the residents reportedly love it.

That said one should expect problems when people are crowded together in a small space. Space settlements will be a nearly ideal environment for investigation of various ways to 'get along' so in time we may be able to substantially improve our ability to work together.

## Objection: Aliens

**Note:** With an estimated 300 million planets in the habitable zones[7] of this galaxy alone the possibility of alien space faring civilizations cannot be ignored. Contact with such a civilization is incredibly dangerous.

**Talking point:** Given enough time, a space settlement based civilization may become strong enough to survive encountering an alien civilization.

In the early millenia of creating an interstellar space settlement civilization we run an increased risk of being noticed by an alien civilization (if they haven't already found us tracking our TV and radio broadcasts). Once noticed there are a number of paths forward

[7] The 'habitable zone' around a star is where liquid water can exist on the surface. Planets in this zone have at least some chance of supporting the development of life.

most of which end very badly for us. Consider the fate of many indigenous peoples on Earth. However, this assumes the alien civilization is much stronger than ours which may only be true early on. After sufficient interstellar space settlement construction (millenia or more) it is we that may be the strongest party in such contact.

If there is a malevolent civilization among the stars we had better find it before it finds us and we need to be as spread out and strong as possible. In this case vigorous space settlement development is vital. In scenarios where the aliens are tolerant or even well disposed to newcomers it is essential to treat the aliens with respect and kindness to hopefully avoid being squashed like a bug. If there are no alien life forms out there then we have a duty to protect the only life in the universe, ours. That means building space settlements and lots of them!

## Objection: Space settlements may crash into Earth

**Talking point:** The vast majority of space settlements cannot come down on Earth.

The vast majority of space settlements are expected to be much too far from Earth to crash into it under any plausible scenario. However, in the early days of space settlement, settlers may take advantage of parts of LEO that have low radiation levels[8].

The radiation protective effect is particularly strong very close to the equator. This area is called equatorial low Earth Orbit (ELEO). ELEO settlements will be low enough that they cannot simply be abandoned because they would come down to Earth in a spectacular but devastating display.  They will need reboost, which is a straightforward task. At the end of life they will need to be recycled as even a small space settlement will weigh thousands of tons.

## Objection: This space settlement picture has a flaw

**Talking point:** Such pictures are artist conceptions, not engineering designs.

It is common to create beautiful images of life in a particular space settlement design. While these images serve an important function they often have technical problems. They are not engineering design documents! It is reasonable to ask that they are more-or-less right for some aspects of settlement life; however, there are usually substantial imperfections with regard to technical accuracy and often the design was to illustrate a particular partial solution anyway. This does not mean the settlement is doomed to failure. Usually it just means the design is incomplete. The only  issue is whether these problems can be resolved, which they usually can be. In those cases where they cannot be resolved at a reasonable time scale the design can be abandoned and another substituted in its place.

## Objection: Space settlements are not natural

**Talking point:** To the kids their space settlement will be perfectly ‘natural.’

[8] "Space Settlement: an Easier Way," by Al Globus, Stephen Covey, and Daniel Faber, NSS Space Settlement Journal, July 2017.

A space settlement is an unnatural place -- to those that don’t grow up in one.  To kids born and raised there they will be as natural as 1,2,3 just as kids living in the mountains or a big city will think of their wildly divergent environments as being natural.

# Summary

In short, there are many potential objections to space settlement, but there are valid responses to each of them. While some responses are more robust than others, the evidence points to vast benefits from our expansion into space. Talk openly and intelligently to the doubters, listen to them closely, for it is time to begin our greatest journey yet—our expansion beyond our home planet.