Space Life

When I grew up the main thing you could see in the night sky was the dirty orange of light pollution, maybe a few bright stars and the moon. Now the skies are black again as people moved into the biarks, got night vision or left. You can see stars, but they take second stage to everything else. I can see at least a dozen habitats, energy grids and reflector stations gleam brighter than Venus ever where. Some drift across the sky, others lie along the unchanging arc of geostationary orbit in the south. Sometimes a reflection from their panels makes them flash bright enough to cast shadows. I can make out several bright points over the dark side of the moon, the lunar internationalist paradises. Another cloud of lights are L5, where diffuse cast-off from the tethered and foil-wrapped ice give off a perennial greyish glow. The sky is always dominated by one or two ships being accelerated – the vapour exhaust lit up by transport lasers and sunlight form shining comet trails stretching across the sky.

When I grew up the Earth was busy and the sky quiet. Now it is the reverse.

Life in space is unremarkable and normal for its inhabitants; only earthlings find it unusual. But then again, they live on a dense ball of mud and dragons.

Outside

Figure 1: Space sickness bag (Rebecca Smith Hurd, Wired)

> *Space is not about resources or frontiers - there are plenty of those on Earth. Building anything is always going to be more expensive in space than on Earth. No, space is about* space. *We provide *isolation*: guaranteed nothingness, great distances and easily monitored transports. All habitats will be hermetically sealed, easily defended from incursions and excursions. We can provide you a kind of safety not possible on Earth.*
> *- Lauren O'Malley, Phoenix Space Development marketer, 2049*

The dominant factor of space is distance and speed. Everything is far apart, everything is moving at several kilometers per second at least. This means that navigation tasks tend to be either faster than humans can perceive or occur at a very leisurely pace.

Space habitats tend to be located in habitat constellations, several habitats keeping in formation in the same orbit a few tends of kilometers apart. This enables simple transport between habitats using small shuttles relying on habitat launchers for propulsion. A trip takes at most an hour, and often far less.

Transport between habitats further away requires a more robust shuttle, usually laser-propelled. Any trip requiring a significant delta-v, like going to another orbit, tends to be expensive (although compared to pre-space colonization prices, the costs are minuscule).

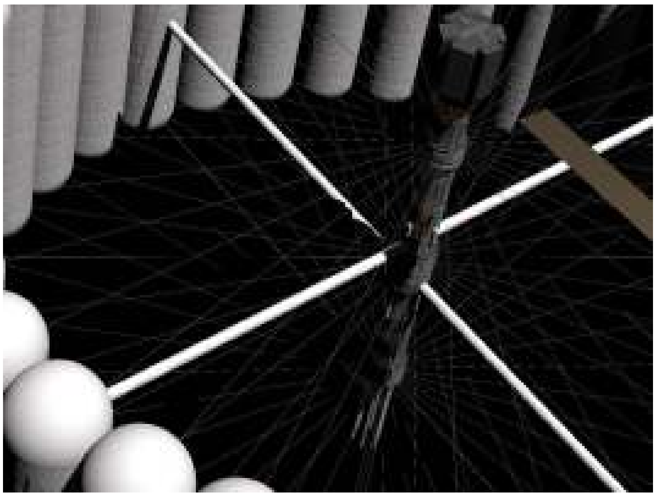
Most habitats have extensive arrays of antennae, energy collectors, protective shields and microgravity factories. Most activity in the "halo" is telepresence work; to actually do a spacewalk is rare.

Habitat types

The main types of habitats are:

- Zeros: structures built with no rotation, and hence no requirements beyond radiation shielding. Also known as "birds nests" and "building sites", since they tend to be messy and extended structures of trusses, panels, modules and inflated sections.

- Bolo habitats: two cylindrical habitats connected by a tether. Since they rotate around the shared centre of mass, they get simulated gravity. Using strong tethers large habitats can be constructed with little Coriolis force. The downside is the relatively small "floor space".



- *Heaven*-type toruses: a torus of connected modules. These days old-fashioned and somewhat quaint. They are popular among private habitat-owners and asteroid homesteaders.

Figure 2: (NASA)

- Donuts: larger torus habitats, shaped like a rotating wheel. Unlike Heaven they do not consist of modules and instead have one or more floors of living space inside.


Figure 3: (Don Davies)

- Cylinders: a rotating cylinder with flat or rounded ends, held together by fullerene cables. The most common form these days. Often paired with a counterrotating habitat to avoid angular momentum trouble and to keep the axis from precessing. The earliest cylinders had large and vulnerable windows, but modern cylinders are all "bottles": the rotating part rotates inside a non-rotating shielding layer and sunlight is either artificially produced or projected using light-tubes and nonimaging optics.

- Waterdrops: A version of the bottle cylinder habitat, but using a shield made of water kept inside plastic shielding. Only a few have been built, benefiting from larger hydrospheres and the chance to run enormous algal farms on the outside.

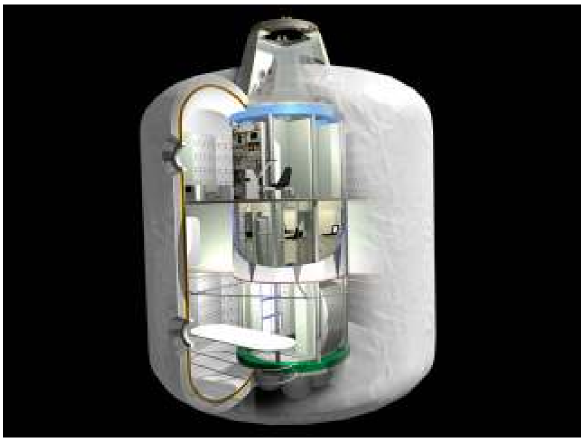


Figure 4: NASA Transhab module

- Transhabs: Smaller habitats used for transport. Often inflated or origami-unfolding. Often modular and possible to string together into various structures. Transhabs are often used when habitats need to be evacuated or large groups of people moved about.

Inside

Figure 5 (Foster + partners)

Practically all habitats use rotation to simulate gravity. This requires them to be large, since the rotation rate would otherwise have to be high and the Coriolis force would cause disorienting effects. Most habitats today are larger than a kilometre across, and many are much larger. This gives ample space for internal ecosystems, but also makes them large targets.

Most habitats either function as cities, or as networks of small "villages" of 150 inhabitants, often grouped together according to the latest sociological fad (right now neo-Dunbar fractal scaling is hot). In practice a single habitat works as a political city-state.

Space is always limited, so living space tend be cramped/cozy. Design and lifestyle often have a tinge of practical Japanese-style minimalism and compactness. High-rise buildings, arcologies or terraces near the sides of habitat cylinders are common, as are “underground” apartments. On the other hand the weather tends to be mild and manageable, so many spend much time in parks, cafes and other public spaces.

Similarly matter is expensive, so people rarely own much "stuff". Instead they make do with very reconfigurable materials – morphing furniture, origami equipment, inflatable bonsai, claytronic objects, surfaces that switch properties and spaces with multiple uses. Not to mention with holographic, augmented reality or purely neural possessions if they live Lunaside. While the better habitats have plenty of "outdoor space", a large number of people live in cramped conditions that would have been inhuman without flexible technology and deliberate escapism.

Space food has diverged markedly from terrestrial and lunar food. Vat-grown meat is old news; to many spacers the idea of eating even hydroponically grown vegetables sounds like an old-fashioned luxury with decadent overtones. Instead they like the distinct flavours, texture, shapes and fashions of their favourite styles of printed food. While it provides just as complex experiences as traditional food it has almost nothing to do with meat, vegetables or other ancient food sources – it is like abstract art to figurative art. Sometimes traditional shapes or tastes recur, but the possible range of modern space food is so big that it is rare.

Figure 6 (Foster + partner)

Spacers are not necessarily agoraphobic, but few feel like they *live* in space or have any desire to see it raw. Most are happily ensconced within their habitats. The segment of the population working "outside" nearly completely use telepresence. Using easily harmed humans as astronauts is old-fashioned, inefficient, risky and too expensive. Instead space workers control their "bodies" in their shirtsleeves from inside their habitats.

Security is tight in habitats, and everybody is trained from a young age to know exactly what to do if a pressure alert, radiation alert or infection alert occurs.

Many people do not use money in everyday life. Things like food, clothing and buildings can easily be manufactured using biotech, automation or nanotech. Local transport, nanodefenses, energy and information feeds are provided by the habitat. What costs money are things that are scarce – places to build on, exclusive services, travel to other habitats, large amounts of matter etc.

Habitats are legally counted as ships on international water: they tend to be registered with a widely recognized nation, at least on paper following its laws. In practice this is increasingly a formality, although some nations have found a lucrative business as registrars and official representatives for powerful habitats in OTA.

Most habitats are run as a co-op system for the inhabitants, insulating individual members from having to deal with the nitty-gritty. Some habitats are owned by the inhabitant co-op. Other habitats are run by corporations: the habitat is owned by a habitat corporation and staffed by employees who maintain it, billing the customers who inhabit it.

In the pure co-op design the habitats tend to be extreme welfare states: the inhabitants are provided a high material standard of living, but also expected to contribute according to ability to the maintenance of the habitat. In the corporation system inhabitants are expected to contribute enough income to the co-op that it can pay the rents and fees.

A few habitats are total markets: *everything*, including the air and ground costs money based on the current prices.

Figure 7 (Foster + Partners)

Inside habitats public transport is often widespread and built into the structure. In large habitats subway grids connect not just major stations but even individual buildings. Other habitats have wirebuses running on suspended cables. Some habitats have gantry systems near their rotational axis (or the roof), allowing transports, cargo or entire modular buildings to be lifted and moved around.

Figure 8 (Vincent Callebaut Architectures)

Problems

Debris

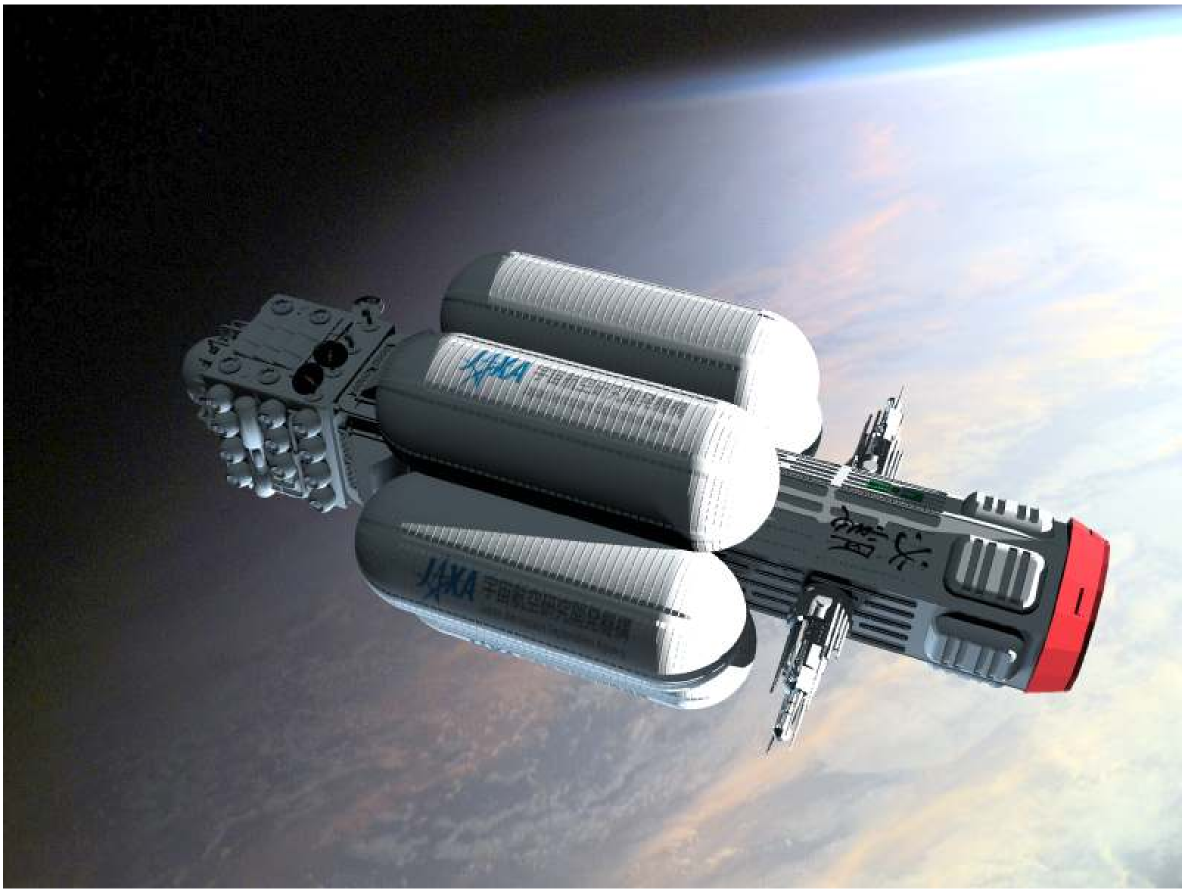


Figure 9: the *Hissho Maru* (Sure Victory), a Sparrow-class rapid tugship used by JAXA and their clients for course correction and debris cleaning.

Space debris is a major problem. Since relative speeds can differ by many kilometres per second even a tiny fragment can cause big damage, and the risk of collision grows with the square of the number of objects in orbit. After the disaster in 2049 when an Orion-style rocket detonated on ascent into LEO and triggered a cascade of wreckage collisions Earth has been surrounded by a dangerous debris cloud in LEO, reaching the mid latitudes. Habitat construction work at L4 and L5 has released large numbers of small objects, and accidents in cislunar space have produced numerous hazards. Seriously polluted or crowded orbits suffer from the "Kessler syndrome" (or an orbital ablation cascade, OAC) where debris hits other object, producing more and more small debris.

OTA policy (and hence insurance company policy) is generally "polluter pays": the originator of debris must make satisfactory attempts to clean it up, or remain liable for damage caused by it or the costs of independent cleanup. Various independent debris management firms are eager to pounce on unclaimed debris to get the insurers of the originator to pay out. The methods vary, from "laser brooms" (using lasers to deflect or evaporate debris) over sending out "aerogel sponges" to catch it to manned teams. The problem is that much debris is unidentifiable, and hence will only give a basic OTA cleanup fee (based on its size, velocity and whether the trajectory was dangerous), possibly supplemented by habitat insurance if the debris was getting close to a habitat.

OTA, most habitats and a few independent organisations such as the LEO, GEO and CILU SIGs maintain radar surveys of debris. These surveys are generally published freely, and various cleanup companies bid or directly compete to clean up profitable objects.

Many habitats are equipped with defensive lasers or reflectors to deal with debris and smaller attacks – a typical *Kore*-habitat has a decent chance to detonate an approaching missile or shuttle if it can detect it.

Conflict

So far no large use of arms has taken place in space. Partially this is because there are so many more peaceful ways of resolving disputes and resources are relatively plentiful, but it is also due to the danger posed by damage to habitats. If a habitat were blown up the amount of debris would be enormous, and seriously threaten numerous other habitats. The break-up of a *Kore*-habitat would likely create a nearly insurmountable debris field. This mutually assured destruction situation deters most habitats from even considering a large attack.

A few habitats can put up defensive debris fields, clouds of small sharp objects that would make any too rapid approach dangerous. Smart dust within the field can detect macroscopic objects passing through, and nanoimmune systems are ready to deal with microscale invaders. Whether they would actually work well in a sharp situation is another matter.

One of the main worries is a deliberately or accidentally misaimed launch laser. Most habitats have a collection of mirrorbags in their Halo: small devices that can very rapidly inflate a large aluminium mirror that reflects laser energy in all directions. While mirrorbags cannot withstand heavy laser fire long, they are cheap enough to be rapidly replaced and give at least a brief time to set up counter-fire.

Ecocrashes

Spacers are natural environmentalists - especially after the experience of the first generation spacers when their habitat ecologies often crashed. The first ecosystem designs were either very simple or highly unstable. Whether they worked depended largely on luck and hard work from not just the ecotects but much dirty hands-on weeding from the inhabitants. Many early habitats still have very messy ecosystems where different unwanted species seem to crop up everywhere. People joke to this day about the ants of *Gagaringrad* or the perennial mushroom invasions in *New Kansas*.

Kore had the first major ecocrash in space 2056. At the time, it was PSDs largest habitat and home to nearly 100,000 people. Almost overnight the sol ecosystem was taken over by an aggressive mold that killed of most plant-roots. As the ecologists tried to contain it, the dying plants both started to release significant carbon dioxide and methane, as well as dry out. Due to the danger of fires the climate had to be made moist, producing even more molds and decay. By 2058 *Kore* was widely nicknamed "Halloween" for its creepy environment; people were leaving in droves, further adding to the air of decay. When the problem was eventually fixed it took a decade (and expensive rebranding as *Solange*) for the habitat to recover population-wise. Many people still swear that the original, scary *Kore* drifts out there, filled with horrific and deadly mold growths.

Plants are especially susceptible to pathogens in microgravity. PSD made use of then-modern biotechnology to create the first space-adapted varieties, and since then low- or microgravity strains have been developed for nearly any organism used in space. Still, plant pathogens seem to thrive in space ecosystems and may produce sudden bursts of infections. While it is easy to limit spread to within a habitat, it is often hard to prevent the infection from spreading inside.

The most common problem is the spread of pests. Most habitats have elaborate bioscanning of visitors to ensure they do not bring with them anything invasive. The worst offenders tend to be mold spores: molds appear to love space environments, and often grow in the strangest places. Sometimes they can just suddenly erupt, attacking some material or environment. It is also common that soil bacteria have sudden die-offs, perhaps as a result of mutated bacteriophages. Most habitats have soil repair robots ready to deal with any bare patch. In wet environments biofilm sludge can rapidly build up if left unchecked, jamming the hydrological cycle and fouling the air with yeasty smells.

A more subtle problem is nutrient lock-in, where a key nutrient such as phosphorous starts to disappear from the ecosystem. Finding and patching such "leaks" is a common job for ecologists. Often the cause is proliferation of some resource-hogging species in an out-of-the way part of the ecosystem. A worse problem is toxin buildup: toxic by products from the ecosystem or human activity that are not cleaned out fast enough. Today most habitats track air, soil and water chemistry meticulously to see if anything untoward is happening, and then release bioengineered organisms to deal with the toxin.

The truly complex issues are trophic slide and bioregenerative blockage: fundamental errors in the ecosystem itself. In trophic slide biomass starts to accumulate at lower trophic levels: large plants and animals give way to weeds and smaller pests, which in turn give way to fungi, algae and insects if the slide is not stopped. Bioregenerative blockage involves a stiffness of the ecosystem that makes it unable to respond flexibly to disturbances, increasing the risk of some other problem.

Modern habitats have ecological resiliency, often handled by elaborate biostructures. In Earthside habitats they are often almost mini dragon castles, able to send out and receive reprogramming plasmids. Lunaside nanosystems, robot warrens and recently artilife are used instead.

Maintenance

The early habitats have not aged well. While built to be robust and failsafe, they were designed and constructed in the early days of space colonization. Many flaws have been discovered, ranging from minor nuisances like AX-5 doors jamming after a few years to serious threats like the breakdown of 2040's fullerene cables due to ion accumulation. Many of the earliest habitats have been renovated at great expense, or replaced with newer habitats.

In a few cases the flaws have caused accidents and disasters. Thermal expansion and contraction can set up material fatigue, old nanostructured composites sometimes develop flaws and disappearing polymorphs have caused significant damage. Especially the old Innana and Juno habitats are today regarded as unsafe and frankly ugly.

A decaying habitat is a danger not just to its inhabitants but to the surrounding habitats. A single outgassing accident can release hundreds of dangerous debris fragments. Badly maintained equipment or parts can come loose and drift away. Habitats in economic crisis are also less able and willing to clean up after themselves; a big accident could cost more than they could pay. This has led to a few instances of abandoned installations where the owners have simply slunk away to avoid paying the potentially exorbiant fees, insurance premiums and penalties associated with them.

To forestall this OTA has a fund for emergency repair and cleanup. Truly down-on-their-luck habitats can apply for rescue money, and OTA will provide whatever is necessary. Unfortunately this has led to a few cases where failing habitats are essentially leeching from the OTA budget while OTA has little say in how they are run internally. The interplanetarist movement want to add the possibility of putting bankrupt habitats into receivership.

Infection

Figure 10 (AP)

Habitats have different policies on what kinds of biological activity is allowed. Some allow Hosts to work with just minor oversight; others try to retain a pure and natural pre-biotech environment. Even a brief contact between two habitat biospheres can be enough to infect one (or both) with something nasty. Indigos are downright paranoid about infections, and have serious suspicions against many of the more genetically liberal groups.

The *Maranatha* downgrade 2088 was widely publicized: a plasmid infection forced the Maranatha habitat to downgrade from Indigo status to Yellow, causing great distress among the inhabitants and their fellow Indigos. The cause was found to be a small set of stealth-spores that entered the habitat through a smuggled antiquity.

Something nearly everybody agrees on is that the Dragons should not be allowed in orbit. There is a significant fear of viable dragon spores in orbit. Most experts agree that dragon spores, unless deliberately designed to survive, will be rapidly sterilized in space. That does not calm many people. There have even been suggestions for total quarantine of the Earth, although at present this is unrealistic.

Station-keeping

Habitats, satellites, installations and other objects orbiting in space are not following perfect orbits. They are perturbed by the oblateness of the body they orbit (Earth or the Moon), the gravity of the Sun and other objects, solar radiation pressure and near Earth by magnetic fields and in low orbits some air resistance. The result is a need to perform station keeping, or the objects will slowly drift into new orbits. Usually this is done either with attached thrusters, by hiring tug-ships or occasionally by laser pressure.

Flares and radiation

Space is filled with dangerous radiation. All non-zero habitats tend to have extensive radiation shielding. It is to a degree an either-or decision: having thin shielding is worse than none at all, since spallation from cosmic rays hitting thin shielding do more damage than the rays themselves. Big habitats usually solve the shielding by having plenty of gravel or water around the inhabited parts.

Ships are harder to protect. Heavy radiation shielding works when there is a high thrust engine powering the ship, but is very inconvenient for smaller ships powered from the outside. One popular solution for passenger ships is miniature magnetospheres. Superconducting coils (powered by rectennas in turn powered by beamed energy) unfolded around the ship generate strong magnetic fields to deflect particles outside the ship, just like the Earth's magnetosphere. This is usually enough unless a very strong flare or CME occurs.

Radiation-proofing humans is another approach, which is very widespread among the more upgrade-accepting human groups. Ratcheting up DNA repair, antioxidant production and mutation detection costs metabolic energy and can cause some annoying medical conditions, but it saves on radiation shielding and allows much easier spacelife. Most shuttles carry antioxidant medications that increase radiation resistance, either to take as a prophylaxis or if a radiation storm is imminent.

Radiation Belts

Figure 11: Aurora Jewellery (Yanko Design)

Earth has two radiation belts, consisting of high energy solar wind particles trapped by the magnetic field. The inner belt lies between 700-10000 km above the surface. The outer extends between three and ten Earth radii, with a peak between 4 and 5 radii. It is fairly diffuse and strongly affected by the solar wind. The high energy protons and electrons are a hazard to sensitive electronics and organic life. This is why habitats tend to orbit either in LEO (below the inner belt) or in GEO (outside much of the outer belt).

Recently FluxControl Inc, a Disco Volante based corporation, has begun a somewhat controversial project to discharge the belts. They are orbiting 100 kilometre charged conducting tethers. The tethers are attracting the particles, changing their pitch angle and sending them into the atmosphere. Despite some problems with plasma sheath formation the principle seems sound, but many have protested against the project. LEO habitats worry that they could be hit by an increased flux of radiation, environmentalists worry that it could upset the protective aspects of the earth's magnetic field, and aesthetes complain that it is ruining the auroras. On the other hand, during tests in the inner belts the tethers have caused equatorial auroras instead.