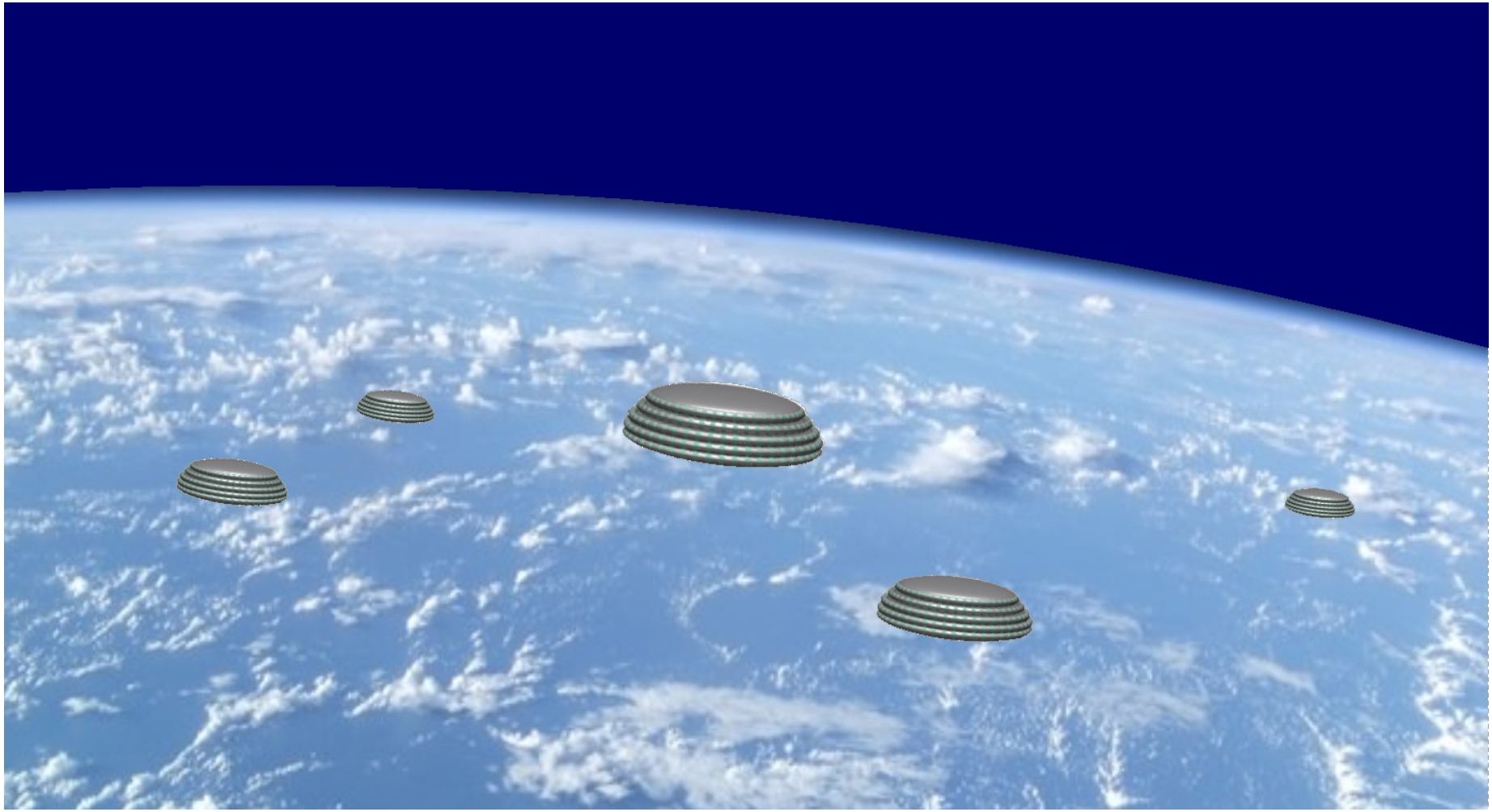
Aerial Habitats

How to Expand Human Habitable Areas and Restore the Environment

Transition to Living in Space

Marek Rozkowski - High Park Architects, Manitoba Airship Research Task Force, Toronto 2024



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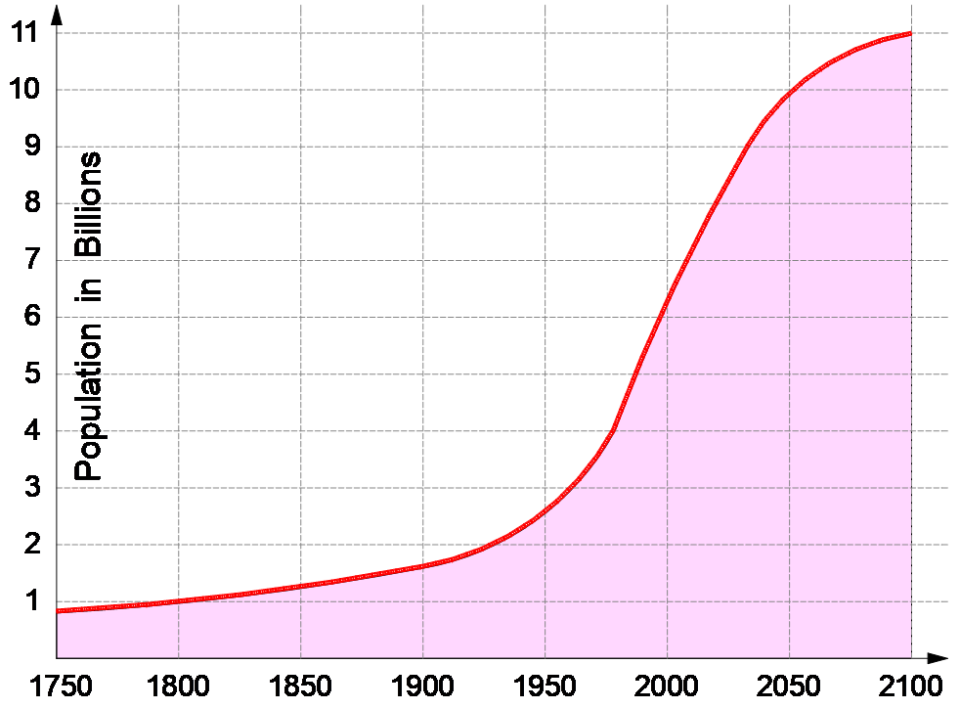
Environmental Crisis

Endless suburban sprawl is encroaching on the natural environment, causing its fragmentation and extinction. Humans occupy most of the Earth's prime lands where life can develop and flourish. To restore the planet's biodiversity and prevent mass extinction we need to revive species on the brink of extinction, de-extinct wiped out species, and re-wild large land areas.

We grew from one billion in 1,800 and 8 billion at present to 11 billion by the end of this century. Population control policies were ineffective and resulted in massive human rights violations. Even if our number somehow stabilizes in the future, this biosphere is not designed to sustain the 8 billion most eco-friendly people.

Endless suburban sprawl



UN Future Forecast of the World Population

Land Shortage

Land shortages in urban centers and ecological degradation seriously limit and endanger our civilization's development. We need to find additional livable areas to accommodate our rising number, separate ourselves from the Earth's surface, and restore the biodiversity of its ecosystems. A lot of vacant land is required for effective ecological restoration.

Where else can we live to avert ecological disaster? Reaching for a safe alternative to the planet's surface by people under threat is not a new idea; starting from archetypal Noah's Ark to ancient Athenians and Polynesian seafarers. We have often turned to the sea in times of great crises such as war, volcanic eruption, resource depletion, and overpopulation.

Ecological Restoratio

Polynesian Seafarers

Alternatives to Earth's Surface

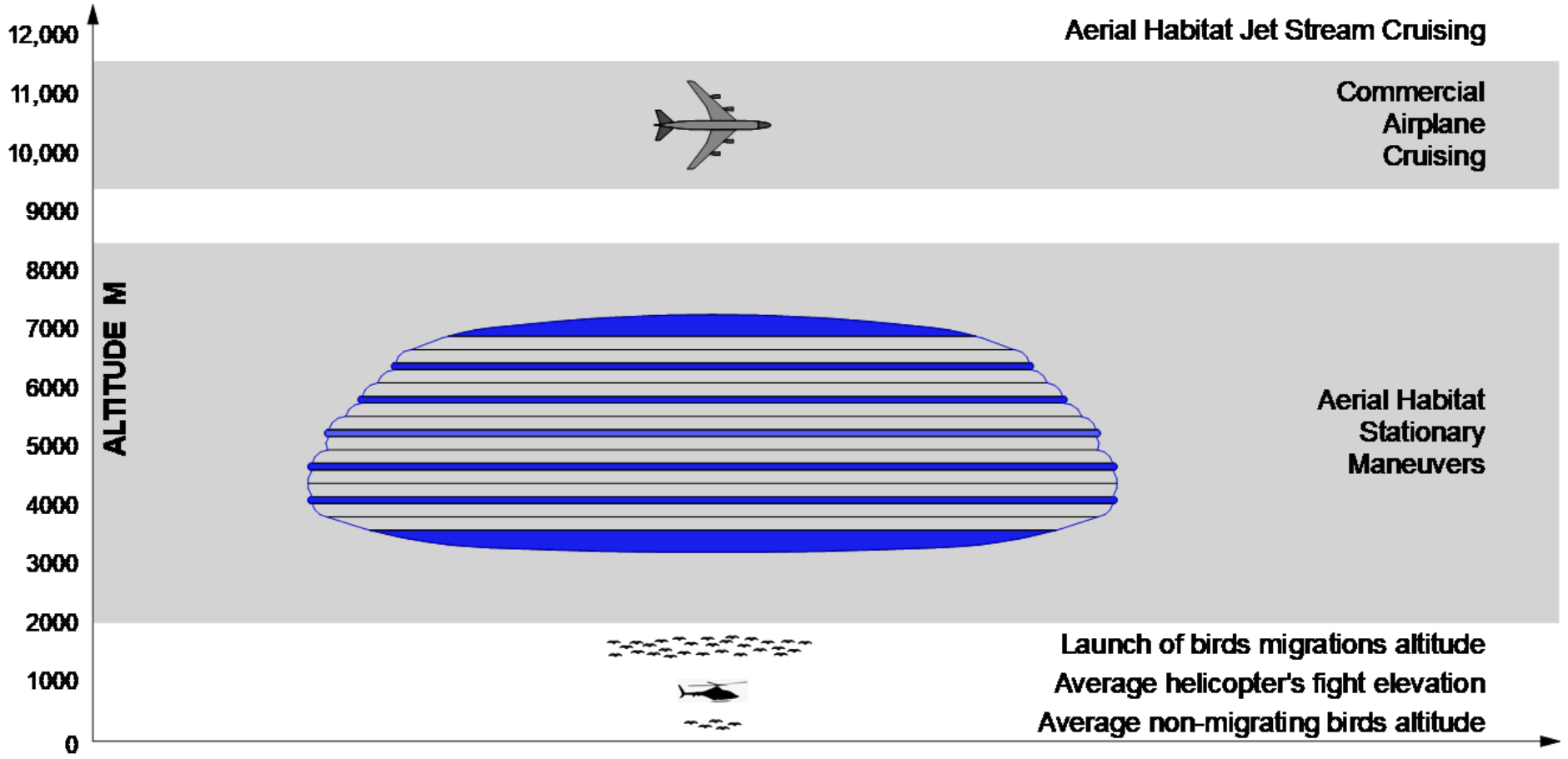
The scarcity of habitable land and the shrinking of critical resources are contributing to global political chaos and military conflicts that no one can effectively control. At the same time, failure to avert environmental catastrophe will lead to humanity's stagnation and decline. Mass migration to outer space will not be feasible, technologically and economically, in the foreseeable future. Are there any viable alternative areas where we can relocate?

There are four terrestrial habitats, beside the planet's surface, that might potentially receive billions of people; ocean surface, underwater, underground, and the atmosphere. The selection criteria between them must include; addressing the land shortage, restoring the environment, residents' health and safety, and ground access ease.

Ocean Surface	Underwater and Underground
Floating ocean colonies in large artificial structures will disrupt a delicate, interconnected marine habitat. Global heating and its impact on the environment originates and manifests itself most acutely in aquatic ecosystems. Settlements will be vulnerable to disasters such as tsunamis, rogue waves, hurricanes, seismic and volcanic activities. Many administrative areas and landlocked countries do not have access to oceans. The farther from the shore, the more difficult it becomes to provide security, prevent human rights violations, and enforce taxation. Long distances to the land will contribute to feelings of discomfort and isolation.	Underwater and underground settlements can not accommodate comfortably and safely the increasing human population to revive the Earth's biosphere. Those locations have serious issues; seismic activities, limited land access, social isolation, claustrophobia, decompression sickness, and lack of natural sunlight. We need vitamin D and serotonin, produced when the skin is exposed to sunlight, and without it, people become depressed. Subterranean living has drawbacks the mining industry knows all too well: a tragic loss of life caused by flooding, fire, poisonous gasses, explosions, and collapse.

Atmosphere: The Next Frontier

The atmosphere can accommodate more people than the four other domains combined; Earth's surface, ocean surface, underwater and underground. Aerial habitats' cumulative density per land area can easily surpass the world's most densely populated cities. Deployment altitude and location will minimize collision risk with airplanes, helicopters, drones, and birds.



Deployment Altitude

Step to the Solar System

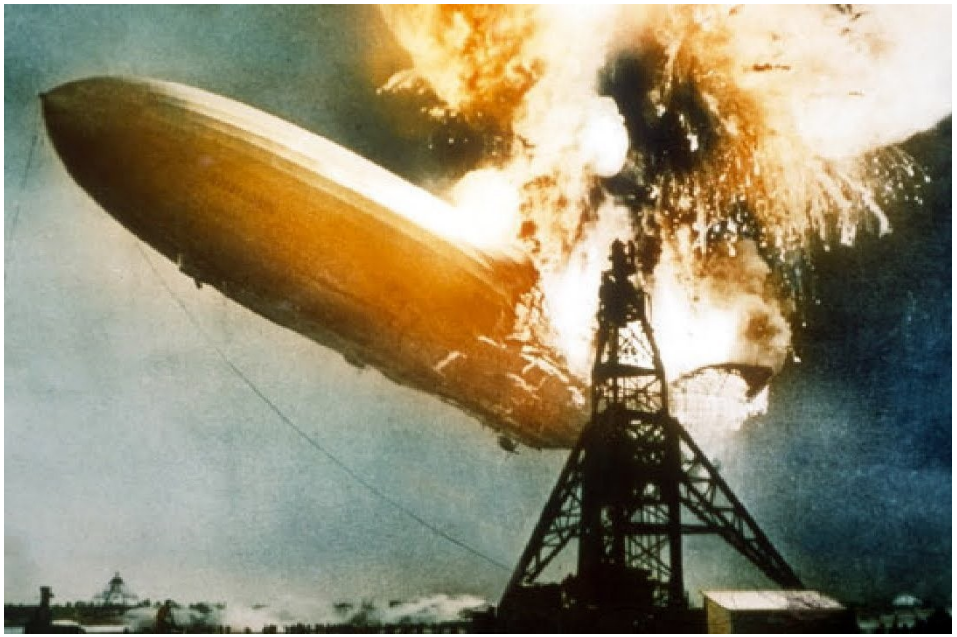
The Aerial Habitat project is proposing residential dwellings in the atmosphere. The technology to build and operate aerial habitat networks is already available. It is a hybrid between lighter-than-air and non-buoyant systems used by airships. Part of its buoyancy is generated, just like in an airplane, from a wind-dependent aerodynamic lift.

Virtually all of our history, except for the last few thousand years, we were nomads. Resuming this natural lifestyle will bring back many typical nomadic features; the use of mobile circular dwellings, seasonal rhythms of movement, preserving available resources, deep connection with the environment, a strong sense of community, and diverse local cultures. The aerial habitats will be organically synchronized with solar cycles and weather events, taking advantage of wind and insolation, minimizing risks of atmospheric turbulences, solar eruptions, etc. Their movement will be reminiscent of ocean marine life; fish, algae, or muscles. Some groups will follow wind currents from one part of the atmosphere to another, horizontally across vast stretches of air and vertically between the Earth's surface and upper stratosphere. Others will harbor in quiet wind bays, maintaining equipment, energy, and water reservoirs. The typical flotilla would include units of various shapes and sizes, from small and medium units to truly massive motherships containing football stadiums, community gardens, and farms. As the number of people moving permanently to aerial habitats grows, urban areas will be reduced. 20th-century infrastructure such as roads, rail networks, parking lots, shopping malls, and airports will be gradually dismantled and returned to nature.

We need to prepare ourselves for an airborne way of life. Space travel became possible after mastering atmospheric flight, and space settlements would become possible when we master atmospheric habitation. Aerial dwellings will play a critical role in our space migration strategy as the necessary intermediate step on the road to space that goes through the atmosphere. The air-floating structure, with Mother Earth within hand reach, has a clear advantage over a space station. It has breathable air inside and outside, standard 1G gravity, a generous residential area, easy access to the land, and no harmful radiation. In a planetary-wide emergency, it is impossible to evacuate millions of people on short notice to space, but in a few decades, we could relocate them safely to the atmosphere. In the following years, the automated production of aerial habitats will be moved to space, including material sourcing, preassembly, and testing. This will allow us to take advantage of the weightlessness and flexibility of orbital plants. After re-entry, the preassembled habitat will be lowered to a designated altitude and the descent slowed by parachutes and inflation. Outfitted, and tested craft is ready to receive residents.

Airships are Paving the Way

The Hindenburg disaster has put a chill on the whole airship concept for decades. However, other similar airships of the time were very successful, with a perfect safety record. In the 21 century, airships make a slow but steady comeback. They are relatively cheap, provide a greater payload lift than the largest planes, are much faster than ocean cargo ships, emit no greenhouse gases, are less noisy, and can land anywhere with no landing strips required.



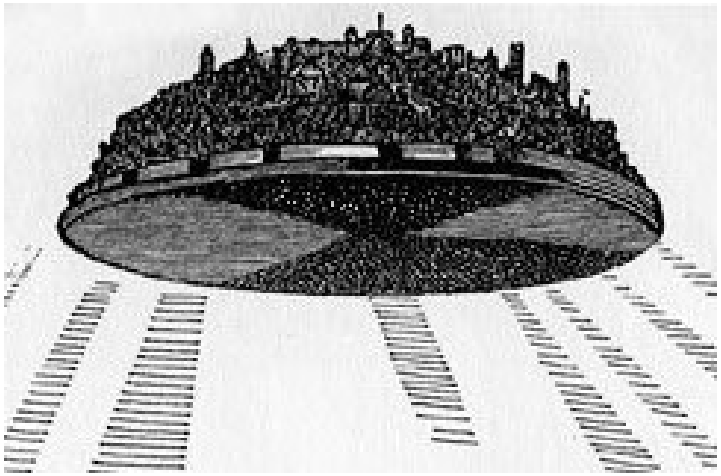
The Hindenburg, the largest passenger-flying airship, was designed, built, and operated by the Zeppelin Company. The fatal 1937 accident occurred in New Jersey during landing maneuvers. The craft caught fire and was destroyed, killing 35 people on board and many more on the ground.

Graf Zeppelin flew from 1928 to 1937 making 590 flights. For five years offered the first transatlantic, passenger service between Germany and Brazil. It made the first airship circumnavigation of the globe, the first non-stop crossing of the Pacific by air, and trip to the Arctic with landing on the Arctic Ocean ice.

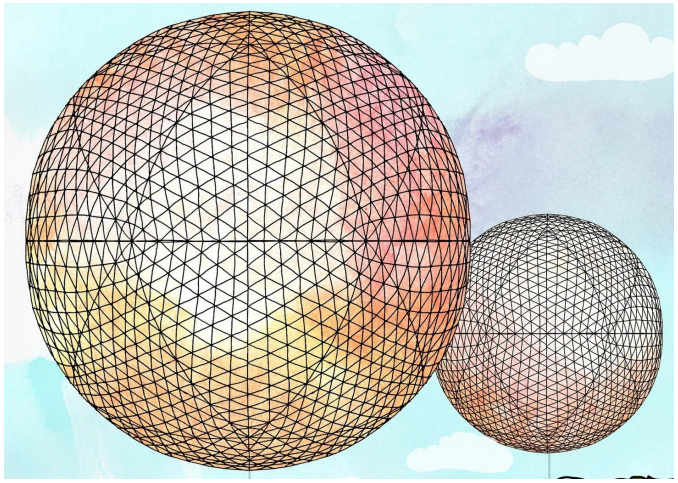
Historical Perspective

In literature, movies, and science, there were many descriptions of populated cities floating in the clouds.

Bishop Agobard in his 815 treatise On Hail and Thunder, describes Cloud of Magonia, with sailors that can magically change weather.



Jonathan Swift, in his 1726 Gulliver's Travels, writes about the City of Laputa floating in the sky, through the use of magnetism.

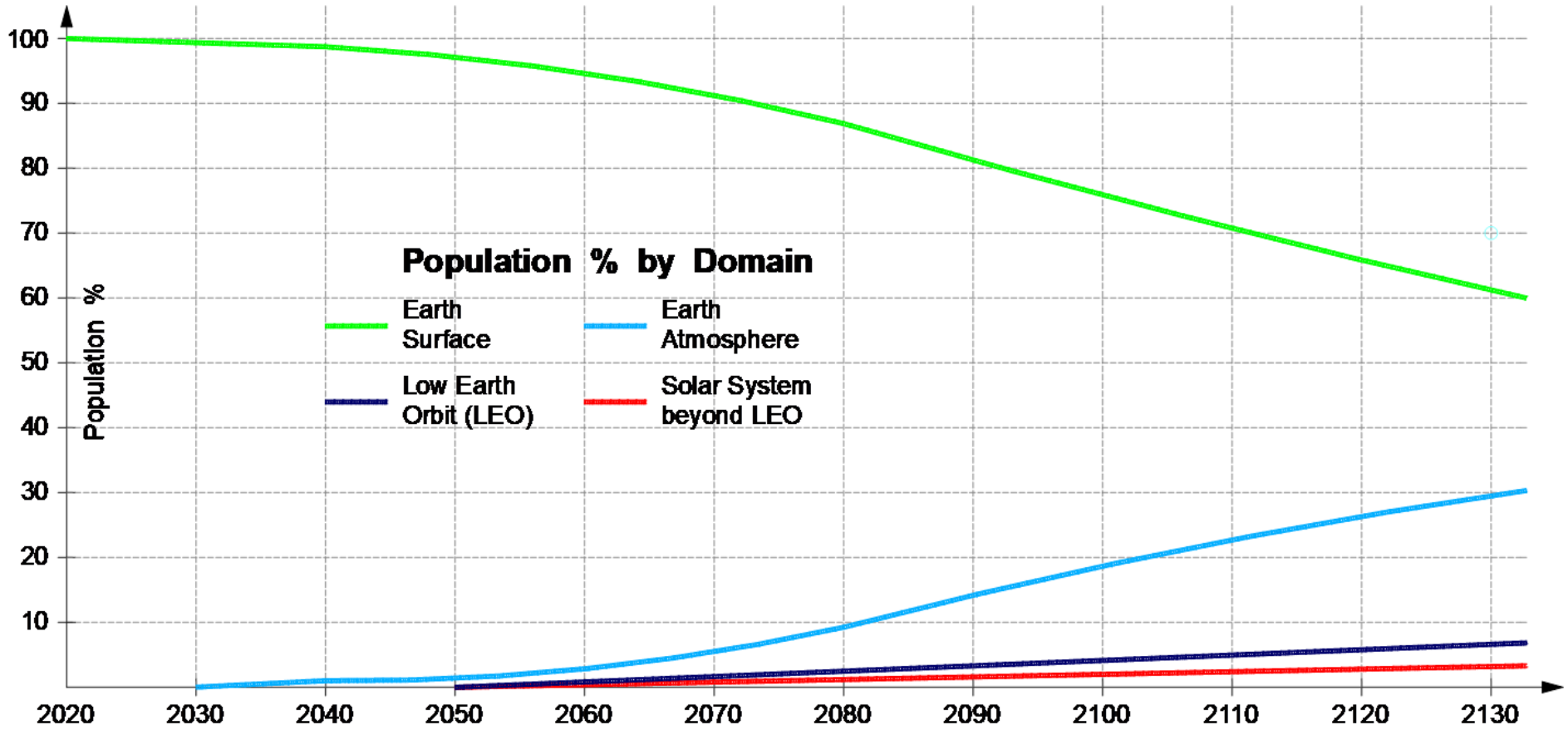


In 1960, Bucky Fuller proposed a 1-mile diameter maneuverable airship city Cloud Nine, that becomes airborne, heated by sunlight.

In the 1980 film, The Empire Strikes Back, the Cloud City colony is floating in the lower atmosphere of a giant planet.

Preliminary Schedule

By the end of this decade, we could build aerial habitat prototypes and in the 30s, the first trial versions. Aerial habitat technology will continue to mature, spurred by urban land scarcity and skyrocketing prices. By 2050, aerial habitats will become standard fixtures, with developed legal and infrastructure frameworks. In the second half of this century, two additional habitation domains will become available; Low Earth Orbit (LEO) and space beyond LEO. By the end of this century, about 20% of people will live permanently above Earth. In the 30s of the next century, this number will match those that live on the Earth's surface.



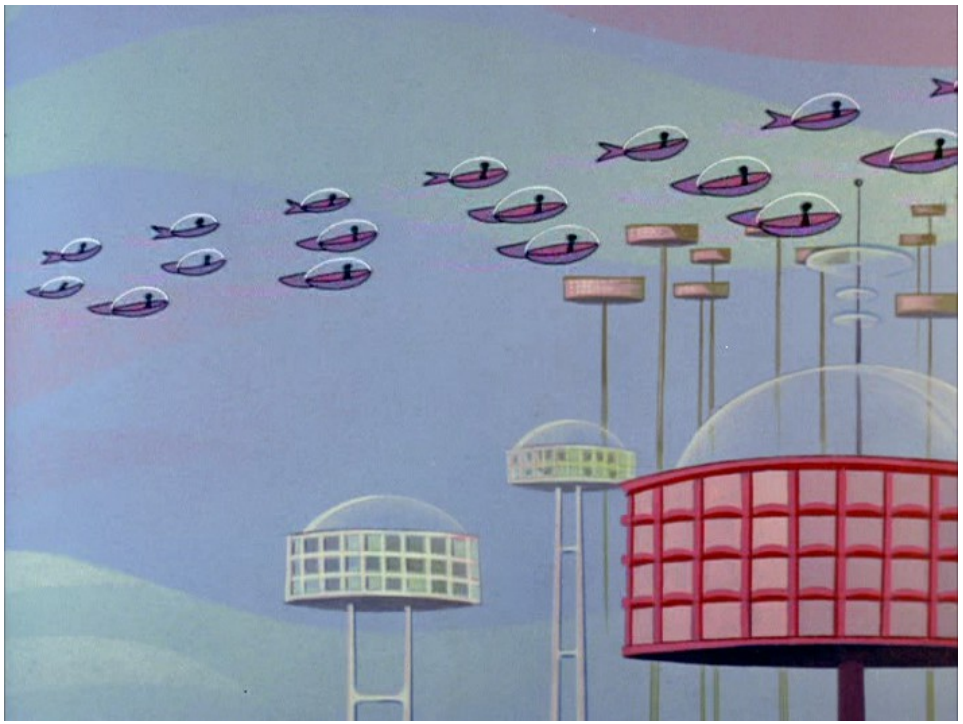
Living in an Aerial Habitat

Occupying a high ground gives us a sense of security and being in control. The penthouse apartments at the top of downtown high-rise buildings are the most expensive real estate properties desired by the rich and famous. Aerial habitats will b e attractive, comfortable, and safe accommodations offering opportunities to work, socialize, relax, and travel, with standard amenities such as high-speed physical and virtual connectivity, accessible sunlight, spectacular views, and stunning night sky. Residents are, on average, 15 minutes away from the land below, which will be gradually restored to a natural state.

Flying Farms - Mcheileh Studio

Airborne farms will serve as an important supply of fresh fruits, vegetables, and recreation community gardens. On Earth's surface, there would be extended opportunities for traditional lifestyles such as hunting-gathering and organic cultivation. Many indigenous tribes that still value and practice a subsistence way of life should see their importance strengthened as custodians of the land.

The Jetsons

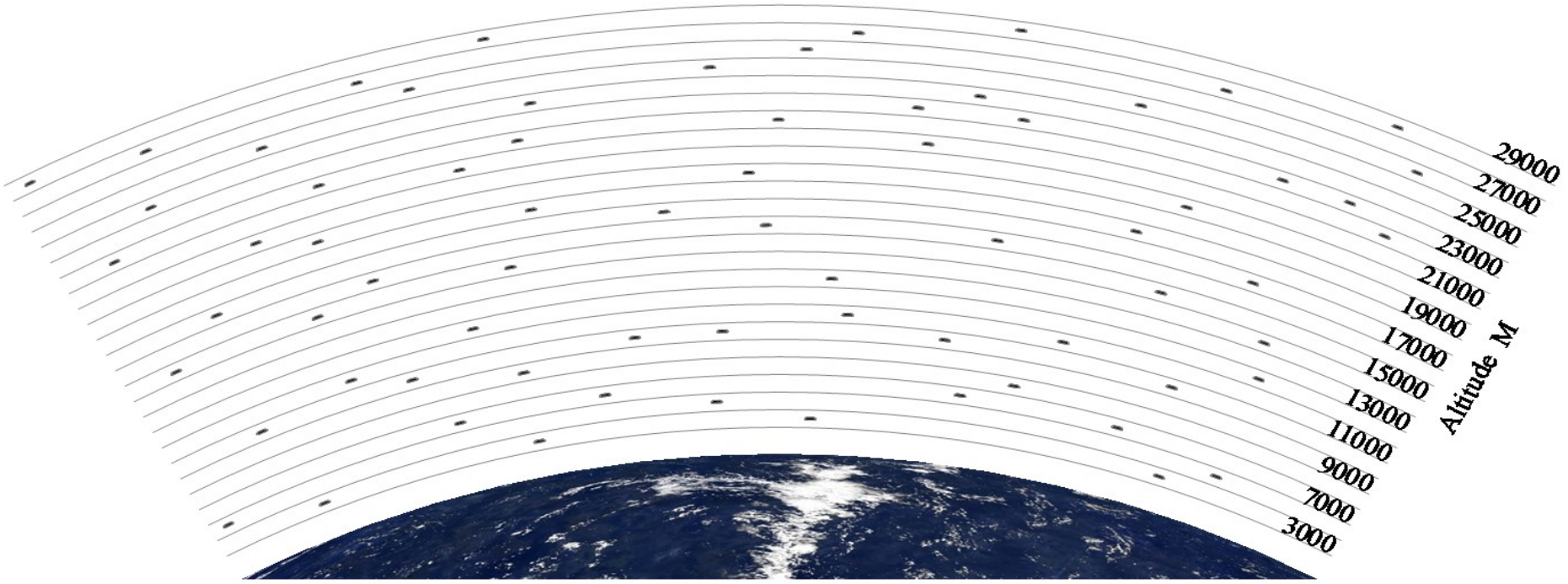


Just like in The Jetsons Orbit City, automated shuttles accessible from internal docks will maintain a connection to the land and to other aerial habitats. A trip will be as routine as an elevator ride. The sub-orbital planes could fly from North American habitats to Europe or China within an hour and orbital planes will transfer passengers to space stations.

Atmosphere: Population Capacity

Air traffic control requires maintaining a minimum of 300 meters of vertical separation between aircraft, provided they are equipped with collision-avoidance systems and use instrument flight rules (IFR). Atmosphere population capacity calculation assumes a 1,000-meter separation between aerial habitats and flight altitude between 3 km and 28 km. The 25 km high flight zone contains 25 spherical, 1 km high flight strata, with an area of 25 habitable surfaces;
r – average flight radius = 6,370 km (average Earth radius) + (25 + 3) / 2 km (average flight zone height) = 6,384 km
The area of habitable spheres = $4 \pi r^2 \times 25 = 4 \times 3.14 \times 6{,}384^2 \times 25 = 12.56 \times 40{,}755{,}465 \times 25 = 12{,}797{,}216{,}000$ km^2
The current Earth's average world population density, including land and water, is 15.7 people per km^2. Using this density for the atmosphere, it can accommodate over 200 billion people. Using the end of the century 11 billion population number to calculate density, sets us back 10,000 years to the density level at the end of the Neolithic Age.

Flight Altitude Routes



Mobility and Maintenance

Aerial habitats would be a hybrid system between lighter-than-air and non-buoyant technologies. The heavier-than-air craft generates part of its buoyancy from a wind-dependent aerodynamic lift. The automatic pilot would coordinate the craft's azimuth orientation with the wind direction to maximize the lift/drag ratio. The rest of the lift will be delivered by multi-engine, electric rotor propulsion, and stabilizing jet packs assisting with horizontal and vertical maneuvers. Buoyancy mediums such as hydrogen, helium, hot air, and vacuum systems will continue to evolve toward greater safety and efficiency.

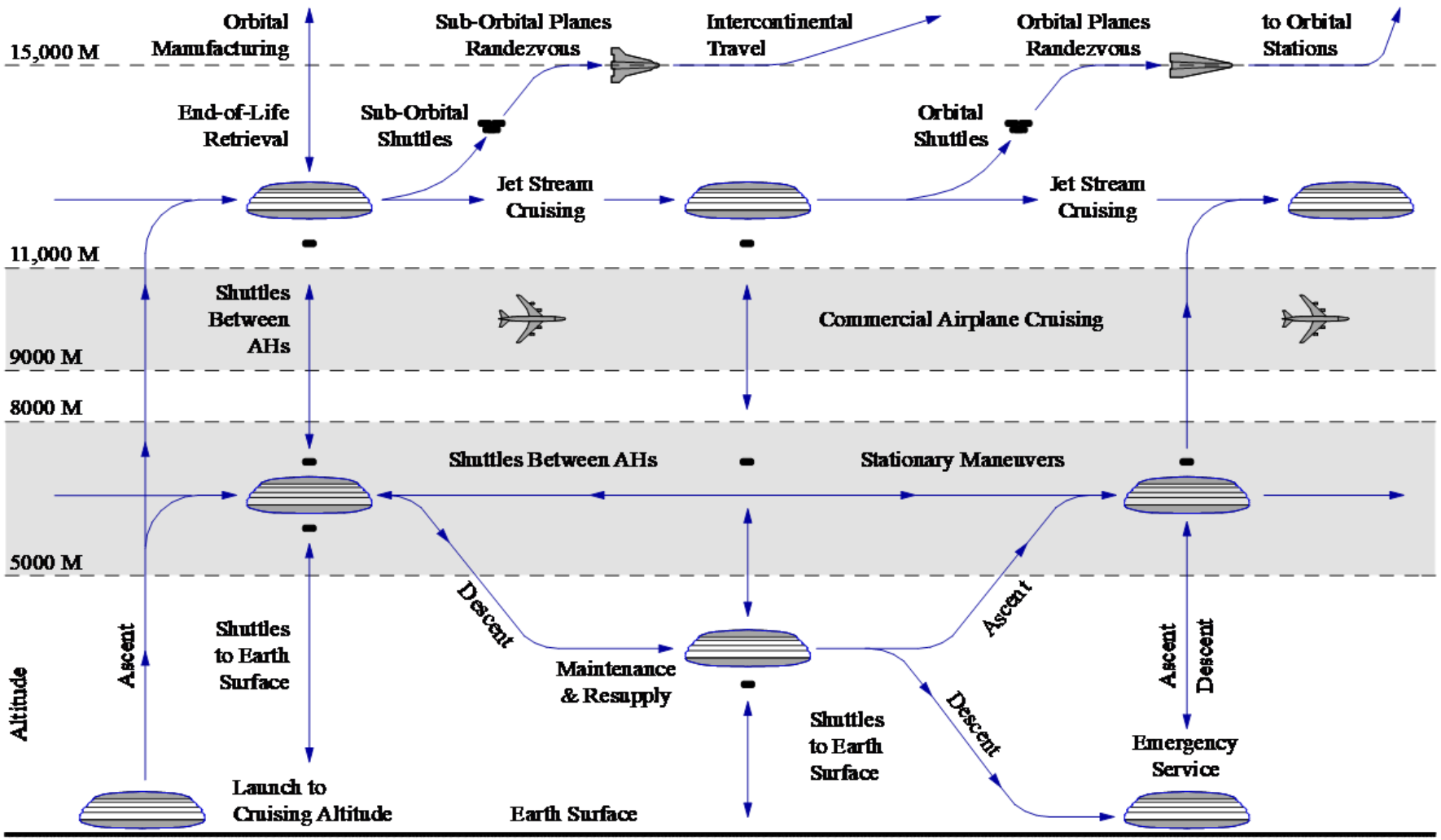
Aerial habitats would fly in formation, connected electronically to each other with adaptive cruise control, synchronizing adjacent habitats' movements. Autonomous systems integrate several types of sensors, including GPS, optical, laser, radar, etc. This will allow for aerial habitats controlled movement and prevent collisions with crafts traveling at different speeds or directions.

Photovoltaic surfaces of aerial habitats' exterior cladding and mounted wind turbines will generate electrical energy. Automatic navigation would adjust elevation levels to optimize wind strength and sun insolation. Additional energy could be provided by a small modular reactor.

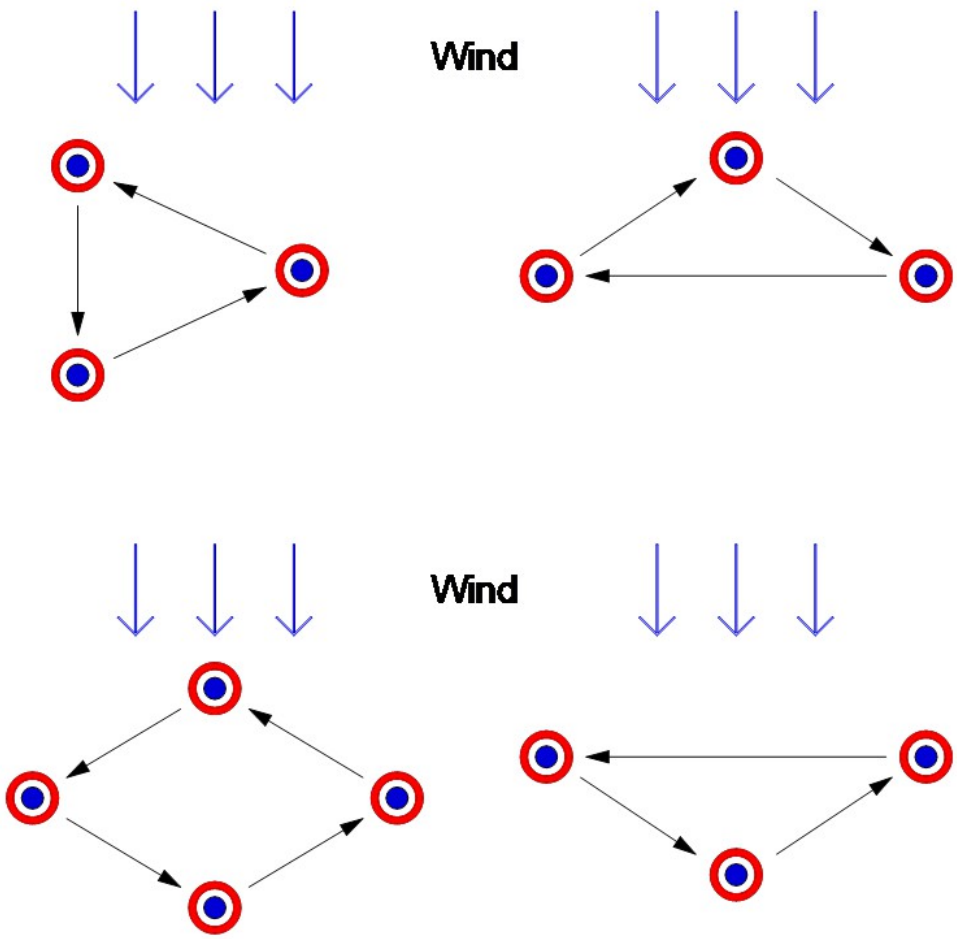
Utility and drinking water are collected from rain and cloud condensation. Airborne farms will serve as an important supply of fresh fruits and vegetables as well as recreation community gardens. Food will be also delivered from the Earth's surface.

Routine day-to-day operations will be run by a computerized system, backed up by a crew responsible for support, monitoring, and emergency response. Commercial aviation infrastructure and procedures would be shared with the aerial habitats' network. High coordination between various airborne systems will be necessary to streamline operations and avoid confusion and accidents.

Operations Diagram



Travel Patterns



Stationary Maneouvers

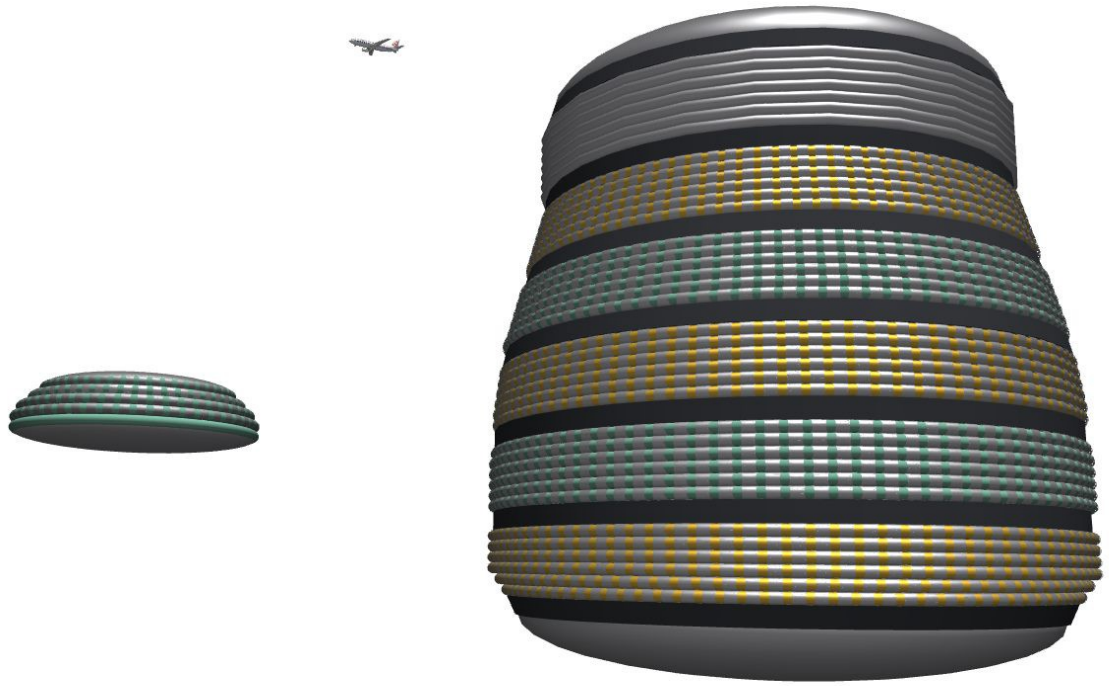
During flight, an aerial habitat will assume one of a few basic travel patterns or their combination;

Nomadic - Default travel pattern, that is organically synchronized with the Earth's weather cycles as well as the solar and cosmic events. It takes place if a craft is not on the route towards a defined destination and the fixed location is also not required. The habitat could drift freely in the stratosphere with less organized wind streams until the next scheduled flight route becomes available.

Stationary - To stay in one location for an extended period, an aerial habitat will “drop an anchor”. This is an automatic steering mode where the craft, acting as a sail, changes travel direction, mobilizing thrust power up to 35° into the wind direction. Performing 360-degree turnaround in a series of tacking maneuvers, it could remain in the same area for as long as required.

Cruising - An aerial habitat connects and moves with the global jet stream in the upper troposphere, above airplane routes. This mode may be helpful if residential use is combined with cargo freight use.

Economy of Scale



Size Comparison

An aerial high-rise will be a real workhorse of the future residential atmospheric fleet. Just like high-rise buildings in a contemporary city, it will contain a bulk of available, livable space. Each high-rise habitat can provide comfortable accommodation for hundreds of tenants. For economic and operational reasons, the floor-area-to-volume ratio needs to be maximized. The support services will be grouped efficiently together and concentrated in the layout core that includes elevators, staircases, plumbing shafts, sewer lines, electrical cables, HVAC ducts, etc. The buoyancy provided at every few levels by independent chamber hulls keeps the craft aloft, even if half of the hulls are breached or compromised.

Flight Safety

Flight Safety

Atmospheric aerial habitats are less vulnerable to natural disasters than dwellings in the other four domains.

They would be immune to seismic activities and volcanic eruptions. Weather-related threats such as hurricanes or tornadoes could be avoided by raising elevation to above disturbance as meteorological warnings are received. A lightning protection system defends structures from thunder or electric storms.

Lift-providing compartments will be designed in a way that a leak in one or multiple hulls, causes only a limited buoyancy loss. In an emergency, supplemental multi-rotor electric propulsion allows for self-repair time or would bring a structure safely down.

With internal gas pressure maintained at the 1.5% level above the surrounding air, aerial habitat is highly tolerant of damage, and attack by small-arms fire or missiles.

An atomic bomb explosion effect is rapidly decreasing with increasing altitude because there is less air mass to absorb nuclear and thermal radiation energy and convert it into a damaging blast. At 30 km altitude, an explosion shock wave is less than one percent of sea-level strength because of reduced air density. Aerial habitats can operate above this elevation and leave the danger zone quickly if necessary.

All administrative units, have access to the atmosphere above and can use it, therefore aerial dwellings do not create legal and political ambiguities to deal with security, human rights, and taxes.

Age of Expansion

A change from our current lifestyle to airborne habitats will be a volunteer movement just like the present rural-urban or urban-rural mobility. People would enjoy living in aerial habitats, offering affordable housing, connectivity, better amenities, and social interaction, a connection to other habitats, the entire planet, and the lower orbit. It will be a short 15-minute shuttle descent to restored wilderness areas with designated campgrounds and hiking trails. With a large ratio of habitats' floor area per ground surface unit, we can accommodate comfortably all; everyone is important, no need for population control measures.

The upcoming period could be called the Age of Expansion, with unprecedented international cooperation on many levels. The impact on our civilization might be more profound than the Age of Exploration. We are never going back to the previous destructive way of living. Our great-grandchildren would have a hard time imagining that we were once poisoning and denying living areas to plants, animals, and even ourselves. Paradoxically, our connection with Earth will be much stronger after we become more independent from its hospitality. Just as a relationship between parents and their children becomes stronger once they grow up from demanding and defiant teenagers into self-sufficient young adults.

Venus's Atmosphere Habitat

In 2015, NASA proposed the Venus HAVOC mission. It included robotic exploration and human crew in a remotely preassembled airship, floating 50 kilometers above the surface. Later missions would eventually establish a permanent human habitat in the planet's atmosphere. Permanent human habitat is already seriously considered by NASA in Venus's hostile atmosphere; far less complicated aerial habitats in Earth's friendly atmosphere should also be seriously considered.

Project Summary

Livable land shortage and ecological degradation seriously endanger our civilization. We occupy most of the Earth's life-supporting areas. The planet can't sustain 8 billion, even the most eco-friendly people. The scarcity of land for new settlements and the shrinking of resources is contributing to global chaos and conflict that no one can control. At the same time, failure to avert environmental catastrophe will lead to humanity's stagnation and decline.

We need to find additional livable areas separate from the Earth's surface. Aerial Habitat Project proposes Earth's atmosphere as a place for future habitation domain, the best suited to address the land shortage, and environmental crisis, and maintain residents' health and safety with easy access to the ground surface. The atmosphere can accommodate more people than the four other domains combined.

The atmosphere is a hospitable environment with standard gravity and pressure, an abundant supply of solar energy, water, and oxygen, with no harmful cosmic radiation. We already use most of the components required to build and operate aerial habitats. They are relatively cheap, provide a greater payload lift than the largest airplanes, emit no greenhouse gases, are quiet, and can land virtually anywhere. Infrastructure such as roads, rail networks, parking lots, malls, and airports, could be gradually dismantled and returned to nature.

Aerial habitats will be comfortable and safe, offering unique opportunities to, work, relax, socialize, and travel. Many would choose to live in atmospheric habitats because of affordable housing, connectivity, social interaction, connection to other habitats, the entire planet, the lower orbit, and easy access to nature below.

Aerial dwellings are immune to seismic activities, volcanic eruptions, and weather-related threats such as hurricanes, tornadoes, lighting, etc. In an emergency, supplemental propulsion would bring a structure safely down. In the planetary-wide crisis, it will be possible to evacuate millions of people on short notice to the atmosphere.

By the end of this decade, we could build prototypes and in the 30s, aerial habitats trial versions. By 2050, aerial habitats will become a standard residential development. At the end of this century, about 20% of people will live above Earth, and in the 30s of the next century, this number will match those that live on the Earth's surface.

Permanent human habitat is already seriously considered by NASA in Venus's hostile atmosphere; far less complicated aerial habitats in Earth's friendly atmosphere should also be seriously considered.