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Accommodating Burgeoning Populations

Population, when unchecked, increases in a geometrical ratio.
Subsistence only increases in an arithmetical ratio.

Thomas Robert Malthus, 1766-1834

With populations inexorably increasing at the same time as land surface is reducing with rising sea levels, the way in which humans normally live may have to change. Large proportions of populations around the globe tend to live near, or on the shores or banks of, oceans, seas, lakes, estuaries and rivers. Much of this low-lying land is threatened by rising sea levels and will no longer be available for agriculture, causing major upheavals and refugees from flooding and inundations.

Where will the displaced people go? The only land that is likely to be available will be inland desert or mountainous regions, neither noted for their hospitality or fertility. And this displacement of people will be happening on all continents and to all island nations. Essentially, the situation will be one of more and more people, needing more and more land for food production, but facing a progressive, concomitant diminution of land for living, energy and food.

There may be a number of potential solutions to this thorny issue, some more realistic and attractive than others…

Littoral Enclaves/Towns

Upper picture: Littoral Enclave, on undersea foundations, with people living above and below the surface level. Lower picture: offshore man-made 'towns' built on rocky islands; designed to combat severe weather and be built progressively upwards as tides rise

With low-lying, productive land area being prejudiced by rising sea levels, an obvious approach to accommodate burgeoning populations is to house them on the land that has been inundated and lost to agriculture. In practice this would mean the creation of towns and cities off shore, partly submerged, or submerged under shallow waters. The figure above. Littoral Enclaves/Towns, shows two approaches to accommodating rising tides and incoming waters. The upper graphic shows buildings, probably built along the shoreline before rising tides overtook them, constructed to be weather and wave resistant, and able to be built outwards and upwards as the tides continue to rise… So, still connected directly to the shore, and to land-based facilities, food supplies, etc.; always supposing them to be available.

The lower picture suggests a slightly different approach, building on rocky islands and outcrops as secure foundations, and raising the small towns within a succession of embankments and ramparts, rather like some medieval castle. Such a cluster of towns would probably be built near a shore-based city-centre, built and rebuilt above the high tide line, to which these off-shore towns would act as 'suburbs.' The suburbs would be designed, from the outset, to be built upwards to keep abreast of rising tides, and they would expect to be more self-sufficient than the littoral enclaves, which would still be heavily dependent on shore based facilities.

So, each suburb would need sources of potable water and power, possibly from rainwater and desalination plants, and from wind, wave, solar, and lunar power (tidal energy generators). Food supplies would come largely from fish and crustaceans, plus seaweed, kelp, etc., and hydroponics for protein and green-stuffs. Fruit could be grown in sheltered, sunny rooftops. The 'suburb' on the left might be designed to accommodate fishing boats, in particular, with an inner harbor protected by lock gates, so that boats may leave and return when tidal levels permit. Each suburb might have its own nurseries and early schools,

while secondary and tertiary education might take place ashore in the city centre, which would be equipped with stores, theaters, arenas, markets, and colleges/university. Similarly, each suburb would have its own market, theaters, assembly rooms, etc., and would provide employment for a myriad of different tradesmen, builders, etc. needed to maintain the functional integrity of the exposed structures, for their continual renewal and expansion with increasing population.

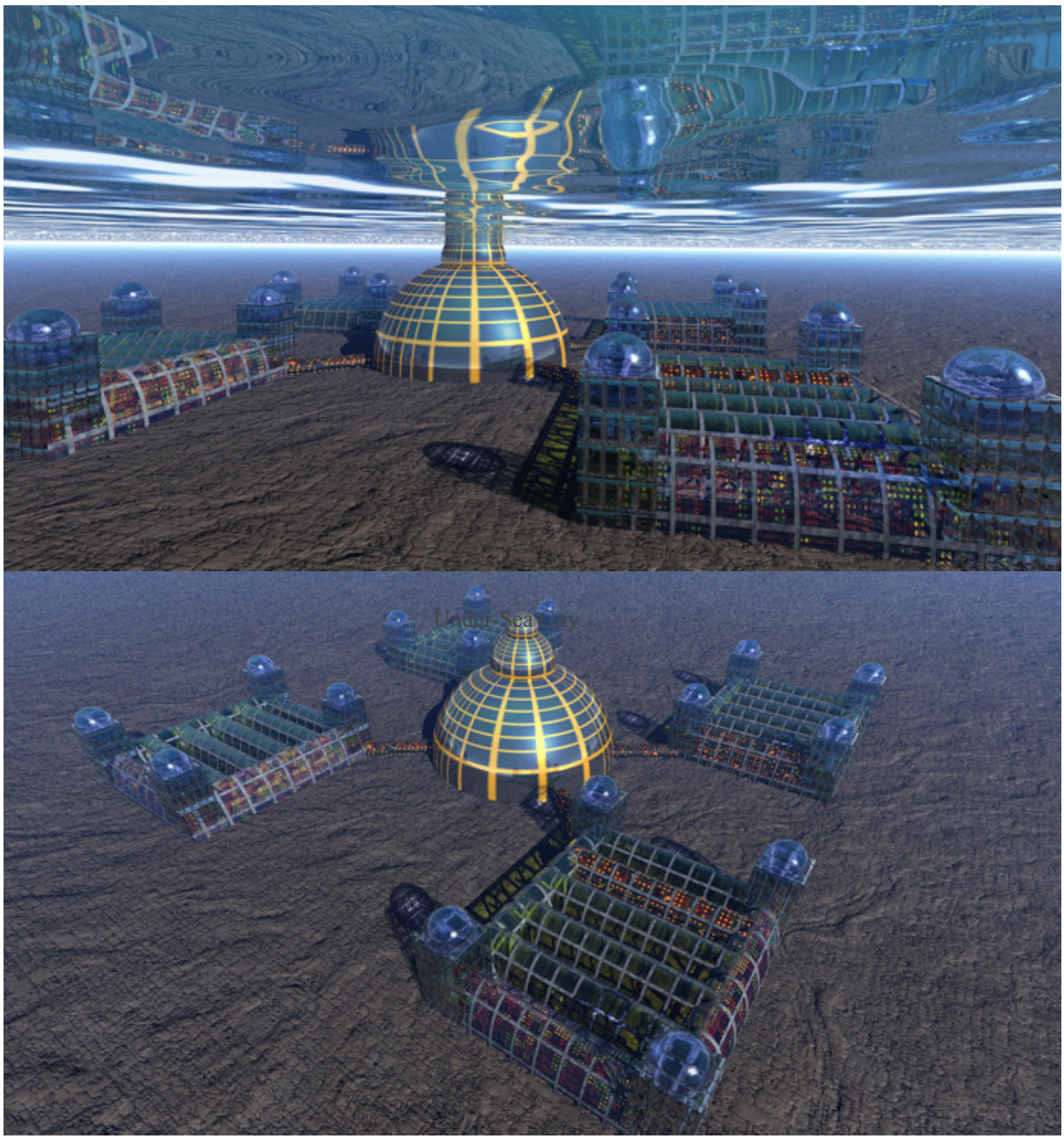
Mykonos Harbor, showing the existing layered embankments.

The photograph of Mykonos Harbor shows a comparable scene from the Greek Islands of the Mediterranean. The town is already built on a series of ‘ledges’ or embankments. Were the Mediterranean to rise by up to, say, 5m, then much of what we see today would be submerged, but the town could move further up the hill on further embankments, and with reducing space for housing and growing.

A conceptual submerged community is presented below as the Undersea City which shows two views, both seen through the clear shallow waters. In this concept there is a large central dome, with secure corridors to four ‘suburbs,’ each set in a square, with a tower at each of the four corners.

The central dome houses a shielded nuclear energy system driving a desalination plant that provides potable water for the whole community. Also in

Undersea City



the central dome are central administration, a central police-, fire-, ambulance- and security-service, a central library, a university, research laboratories, shops, plazas, theaters, a general hospital and an artificially lit sports arena. As the upper graphic shows, the central dome projects above the sea surface: the (telescopic) projection serves as a worldwide communications hub, ventilation shaft and a dock for ships and helicopters.

Each of the self-sufficient suburbs comprises some eight habitats, each able to house, entertain, exercise and employ some 5,000 people, mostly living in family groups. Each habitat may be likened to the inverted hull of a modern cruise liner, reinforced but largely transparent. Like a modern luxury liner, families live in cabins, but tend to eat communally in various food halls, and each habitat has it own gymnasium, swimming pools, play areas, theatre, nurseries, etc. And, also like modern cruise liners, cabin walls may be live screens presenting video images of some external environment, so situating occupants within a virtual reality/environment, both for entertainment and to mitigate any sense of claustrophobia.

One of the two end habitats is dedicated to food production; the other houses schools and colleges, with research laboratories, a suburban police station, and a local hospital. The four towers at each corner are topped with energy focusing lenses that generate power from the light percolating through the water. However, each lens is mounted on a telescopic projection that can take the lens above the sea-surface to collect direct energy from the Sun, should the water be obscuring it. The collected energy is used to power the suburb, to provide general lighting and heating, for food growth, processing and production. The towers also serve as ventilation shafts, continually recirculating air through each of the suburbs.

Taking all four suburbs into account, this community might accommodate up to some 100,000 people. While ostensibly self sufficient, such under sea cities would export and import foodstuffs, clothing, entertainment, and many

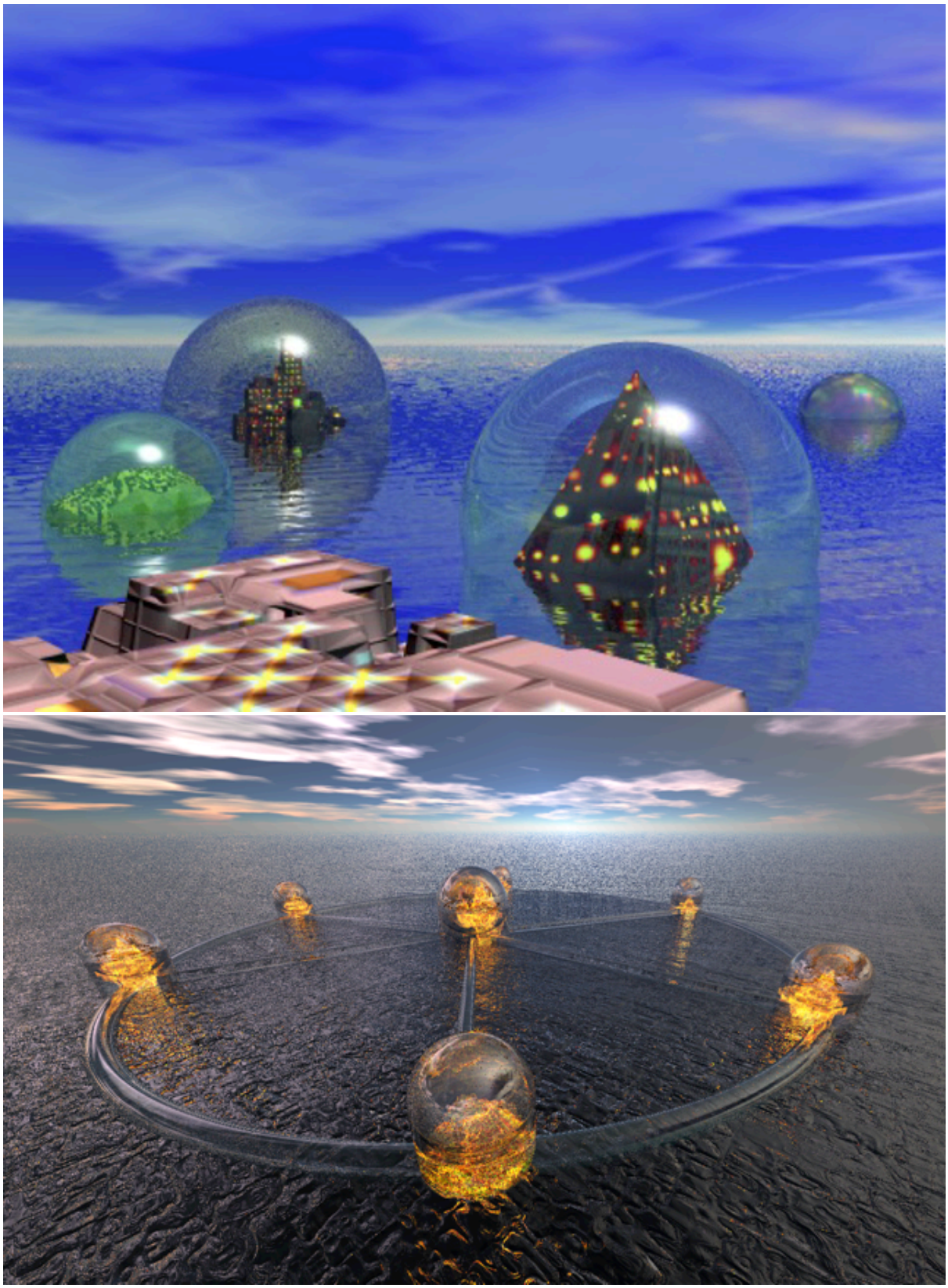
other everyday commodities. Each would, most probably, be viewed as a dormitory city, and associated with some nearby, aboveground centers of population. Indeed, people might be less inclined to reside in the under-sea city permanently, but rather move around between such communities, both above and below water, so living a rather more dynamic lifestyle than might at first appear…

Each suburb, and each under-sea city, will develop its own culture, with those who occupy first considering themselves in some degree 'superior.' Inevitably, a class structure will establish itself, with workers, managers and executives: this is to be expected, and will strengthen societies, rather than weaken them. Each community will produce its own executives, managers, doctors, nurses, engineers, technicians, tradesmen, academics, etc., but may exchange them with other communities to maintain standards, enhance practices and preserve confidentiality.

Of course, the oceans and the seas can potentially accommodate many more people, not only on the surface, or on the bottom, but also in between, submerged to avoid adverse weather. Dwelling on the bottom would be fraught except in shallow waters, because of the pressure, which increases rapidly with depth. While people could no doubt adapt to living under greater pressure, it would restrict their ability to move freely between land and sea habitats…so, atmospheric pressure in the submerged city would probably be maintained at surface levels, typically 1014 millibars/101.4kPa.

In "Floating Cities," below, the upper graphic shows a cluster of floating 'towns,' or suburbs, protected by transparent bubbles against inclement weather. There would be typically five to eight such floating towns in a cluster, each dedicated to different functions. On the left is an island, covered with grass and trees, which would be used for raising cattle, sheep and goats. On the right is a technology sphere, which extracts minerals from

Floating Cities



Floating Cities. Above: a community of floating habitats, each with a different role in the survival of the whole. Below: a larger floating city with a central authority and six peripheral suburbs, all interconnected to form a singular whole.

seawater and uses the minerals to make parts to repair existing facilities within the various towns and, potentially, to create new floating towns as the need arises.

Two other ‘towns’ are for general accommodation while the one on which the observer stands is the central administrative ‘town.’ Each of the transparent hemispheres caps a cylinder that descends into the sea, giving stability to each structure against storms and wave motion, and each has its own desalination plant, using the pressure at depth of the seawater to power reverse-osmosis processors. Differences between temperature at surface and at depth also power electricity generators, along with solar, lunar and wind power. There are sub-surface entrance and egress points, too, for submarine vessels used for farming the seabed, for exploration, and for recreation. Each “floating city” might accommodate anywhere between 50-100,00 people of all ages and persuasions, and the potential numbers of such floating cities would appear to be limitless…

The floating city in the lower graphic is larger, although – like most things at sea – it is difficult to gauge size and distance. This floating city, however, shows six ‘suburbs’ each housing up to some 25,000 people, together with a central city housing 75,000 people, making some 225,000 in all. As the figure shows, the suburbs are arranged in a ring and are star-connected to the central city, reminiscent of the classic Garden City model. The ring serves, not only as a communication avenue, but also as a breakwater. Together with the star-avenues, this creates six internal ‘lakes’ that can be used as farms for growing kelp, for fish farming, and for recreation. In the figure, the lights in houses, apartments and streets have been left on to attract fish at night. The whole may be potentially able to submerge in the event of storms, storm surges, tsunamis, etc., and may anchor itself to the bottom to prevent drifting, but also to generate electrical energy as the whole city moves up and down with the tides (i.e., lunar power).

Desert Cathedrals

The Cathedral: Aboveground evidence of Subterranean Desert Settlement.

Deserts are generally perceived as barren, relatively lifeless and arid zones. However, some deserts may conceal rivers and ancient lakes of fresh water, deep underground and untapped perhaps for millions of years, which offer the potential for a different style of living. Termites have found ways to live in large numbers, colonies, within so-called termite cathedrals, even without such sources of water. The shapes of their so-called termite cathedrals evolved to provide surprisingly excellent ventilation for their complex arrangements of many interconnected, underground chambers that can extend considerable distances from the visible 'cathedral,' both downwards and sideways. The projections are also watertight at ground level, to avoid desert flash floods pouring down the shafts. The design of these termite cathedral ventilation projections inspired the "ingenious ape" equivalent, which could be as high as a gothic cathedral, some 100-150m.

In The Cathedral can be seen a central pinnacle surrounded by five supporting pinnacles, the whole making one "cathedral," supporting some six underground communities. Shafts lead down from the pinnacles to some deeply submerged lake, from which water is provided to each community, and pumped

to the surface for agriculture and viniculture. The shafts also provide ventilation, and transport for people and goods. (In the event, there might be several 'cathedral spires,' to permit a continuous circulation of air from the surface, through the underground communities and back to the surface; this circulation might be powered by surface winds, by convection from the subterranean communities' heat generation, by pumping, or by all three, and the air would necessarily be filtered to exclude dust, sand, airborne pathogens, etc.)

The 'Cathedral' is surrounded by a torus or toroid, within which are grown fresh greens, fruit, grapes, flowers, etc., using water from the submerged lake. Enclosed corridors lead from the central toroid to other toroids, which also grow fruit and vegetables. These toroids encircle areas given over to open-air cultivation in orchards and fields, the environment being made bearable by the walls of each surrounding toroid that serve as windbreaks and to retain atmospheric moisture…so, latter-day oases, of a kind.

Each of the six subterranean communities would be notionally separate, forming five suburbs around a central core city; this to encourage different cultures to arise, for robust social development. How and where these suburbs may be located will be largely influenced by the underground geology, with space for large numbers of humans being carved out by the natural flow of waters over millions of years, or more recently by people with machines…

Such caverns, naturally occurring or manmade, could potentially become locations for underground suburbs, or "cavern cities." Caverns may be lit by light-pipes from the surface, delivering sunlight, moonlight and even starlight. So, underground lakes, even farms, hamlets and villages may be envisaged. In Cavern City, just one of many possible representations, four different square 'islands,' are evident, each surrounded by water-filled channels from the underground river or lake. The four islands together form one of the five suburbs surrounding some central complex, not shown.

Cavern City

"Cavern City." One of several ‘suburbs’ surrounding an administrative centre. Comprises four islands: a technological complex at front; a residential complex at rear; and two natural islands growing vegetation and lit by solar light pipes from the surface…

Each island performs different functions. The nearest island is a modular technological complex, housing industries, schools, hospitals, colleges, etc. The farthest island is residential, with extensive facilities for entertainment and sport. The island to the left, lit by solar light-pipes from the surface, consists of moss-covered rocky hills and rock pools, while that to the right, also lit from the surface, is similar in appearance to Mediterranean coastal terrain – richly covered with vegetation… Other islands may grow cereal or root/tuber crops according to need and availability of water.

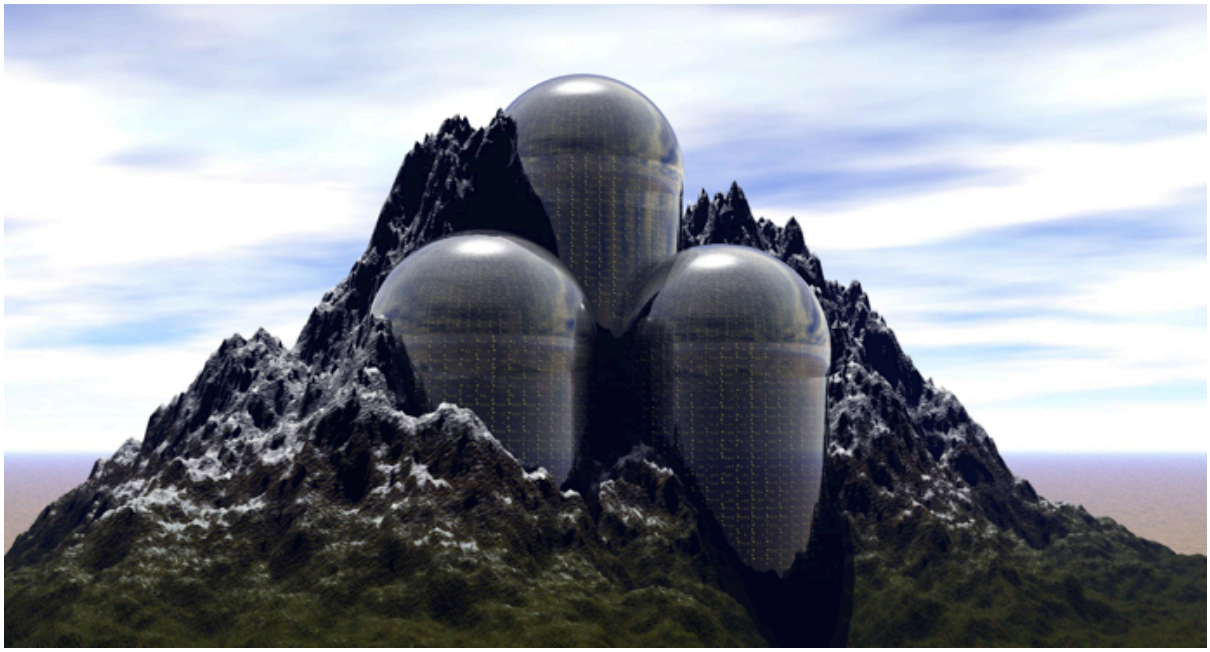
The solar light would be moved across the “sky” to represent the movement of the Sun, and of course the solar light would shine only by day, in synchronism with the surface environment to encourage vegetation growth. Fish farming might be a major industry to provide food for the population, plus farming of crustaceans, seaweeds, etc. The surrounding water would, no doubt, be used for water sports of all kinds, always bearing in mind the dangers of water pollution that could prove disastrous in such an enclosed water cycle.

Both of these islands would be designed to address a potential problem: maintaining the oxygen balance in the cavern atmosphere once hundreds and thousands of humans start breathing the cavern air. The cavern atmosphere will have to be continually refreshed from the surface, always presuming the surface atmosphere remains benign; pumping in fresh air would also create a wind, a convection current, helpful to robust plant growth and for removing airborne dust and bacteria. It would be prudent to grow vegetation, and encourage suitable bacteria, to absorb the increase in CO_2 from the human population, and provide additional oxygen. Both unoccupied islands may be used, given suitable air quality, for outdoor activities: rock climbing; walking; cycling, etc.

The numbers of people living in such a potentially vast underground habitat could be huge, millions in principle, but may be limited in practice, not so much by shortage of water, but by the need to maintain water purity, together with a balanced atmosphere, food supplies and, most importantly, by waste management, including industrial and human waste.

Whether large numbers of people would be content to live in such confined, potentially-claustrophobic circumstances is a moot point; and the potential for disease to spread cannot be overlooked. However, with continuing increases in population, rising sea levels, reducing land for agriculture, increasing shortages of potable water, etc., there may be little choice, and the ingenious ape will perforce find ways of addressing these negative aspects.

Few humans live on the top of mountains, for obvious reasons: the cold, the lack of vegetation and food, and the thin atmosphere. Mountains generally have one thing going for them, however: water, in the form of ice and snow. Global warming is unlikely to change that: as the air warms at lower altitudes, it will also hold more moisture which will then be deposited on mountains as winds drive up the mountains, cooling the air



Mountain Habitat, above the snow line...

which will then deposit its surplus water as snow and ice. So, higher mountains may be expected to retain more water, rather than less, with global warming…

Living at altitude would be problematic, however: Sherpa may have evolved genetic adaptations for surviving and operating in the reduced atmospheric pressures of high altitudes, but for the bulk of humanity, the altitude would prove debilitating. The solution to the dilemma, then, would be to provide a sealed environment at or near the top of suitable mountains, with a contained atmospheric, suitably pressurized.

The conceptual Mountain Habitat exists above the snow line, where water as ice, snow and glacier would hopefully be plentiful. Three very large "canisters" are shown – there could be more. Each "canister" is the projection from a largely-hidden community into the visible world; the remainder of each community is carved out of the mountain interior, either in the form of caverns, or in the form of houses, buildings, offices, schools, hospitals, theaters, etc., carved out of the solid rock after the manner of *Al Khazneh* (The Treasury) at Petra. Using this approach of carving from the rock, it would be possible to create an extensive, multi-level, multi-story, multi-suburb community inside the

mountain, with sports arenas, parks, shopping plazas, etc., so creating an attractive, if enclosed, habitat for human city dwellers.

Carving into the mountain rock might encounter fresh-water springs, which would add to the essential water supplies. In any event, such communities would have to recycle waste to conserve their supplies of water and air, and would necessarily create extensive hydroponic farms to feed the population, the size of which would be limited by water, food and air – so, like a spacecraft, but with gravity. Unlike a spacecraft, however, the mountain communities could import goods and services, and could potentially export minerals discovered and mined in the mountain and surrounds. Moreover, the mountaintop habitats need not be isolated: shafts would connect the habitats with lower levels and with other communities in the locale and nearer the base of the mountain.

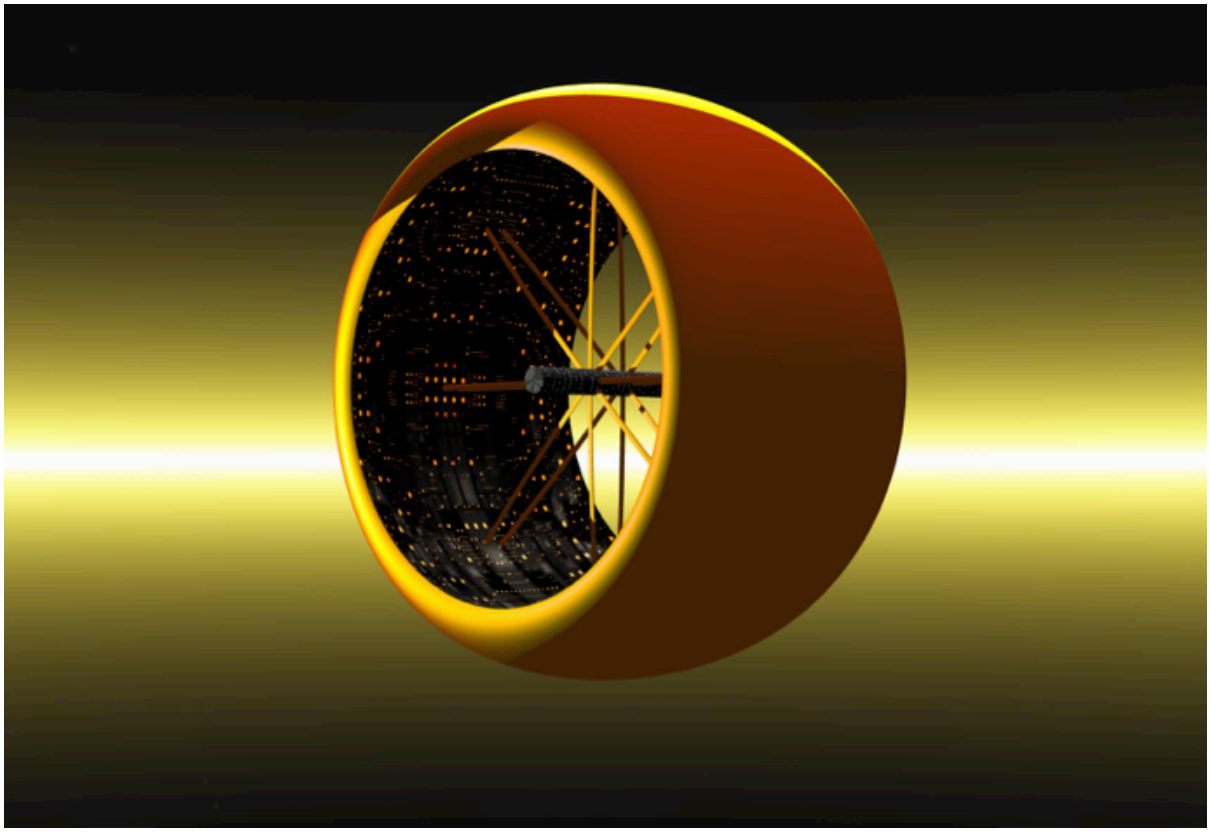
The location of the mountain habitat suggests that it might be ideally located to become a "university city," pursuing astronomy, astrophysics, physiological adaptation, global communication systems, etc. How many people could be accommodated in such a habitat? That would depend on the supplies of food, water, air, etc., on the ability to recycle, to import/export, to manage waste, so an unknown at present. However, a target, self-sufficient population of 30-50,000 does not seem unreasonable, given time to undertake the building works, which would be continual, but essentially "low-tech."

Such a target population seems low in relation to the rate at which populations are expanding and sea levels are rising. To make this concept viable, many mountains would have to be surveyed and scoured; many habitats constructed; many new populations started… These habitats would, however, be on virgin territory, so they would offer the potential to expand without interfering with other communities and without impinging on precious agricultural land, which will be in increasingly short supply.

A different approach, much favored by science fiction writers and filmmakers, is for humanity to migrate into space. One approach to providing habitat, is the rotating Space Wheel, placed in orbit around the Earth after the fashion of a space station, so protected by the Earth's magnetic field against the harsh solar radiation and damaging cosmic particles.

The rotating wheel concept was highlighted in the 2013 science fiction film *Elysium*, where the wheel appeared to be in geosynchronous orbit, so some 36,000km above, but clearly visible from, the ground. According to the film's storyline, Earth of 2154 had become polluted by industry and overcrowded, with many people in poverty and suffering from illnesses that could potentially be cured. An elite of wealthy and powerful people had taken to living on the

Conceptual Space Wheel.



Conceptual Space Wheel. The wheel resides in geosynchronous orbit, and rotates about its hub to provide artificial gravity to those living on and in the rim cavity, which may also retain a breathable atmosphere if the rate of rotation, and hence the centripetal force, is sufficient. The wheel would be built in sections over time, and could be potentially quite large, although the rotational velocity would put considerable stress on the structure.

orbiting wheel, where all of the advanced medical facilities were retained, for their exclusive use, above and beyond the squalor. This elite ruled the Earth through an administration backed up by a robotic police force on the ground, with the *hoi polloi* forcibly denied access to the advanced medical facilities.

The wheel in the figure shows the general concept. As in the film, the wheel would rotate about its principal axis, so that people and things on the inside rim experience approximately Earth gravity, making continual exchange of people between ground and wheel convenient, i.e. without any need for acclimatization.

For a "space wheel" to be clearly visible from earth's surface, it would be size-able. If we suppose it to be, say, 10km diameter, then the rate of wheel rotation to give "earth gravity equivalent" at the rim would be one revolution every 3 minutes—which might be disconcerting for anyone standing or walking about on the rim experiencing the Coriolis effect and the fast-changing visual scene… Moreover, the forces tending to pull the wheel apart would be very large.

However, humans are the ultimate adapters, so perhaps people could adapt to such an environment, and in principle, given that level of centripetal acceleration, it may be possible to retain a breathable atmosphere within the rim cavity.

On the other hand, it is difficult to see how the wheel's occupants might be self-sufficient. It seems more likely such an occupied wheel would require continual support from Earth for food, oxygen, water, materials, tools, technology, waste disposal… so, perhaps, an expensive and unlikely habitat, and no viable solution to housing an expanding human population.

Also popular with science fiction writers is the idea of the ‘Cylinder in Space,’ a futuristic Noah’s Ark, in which a complete biosphere may be stored and conveyed, put into orbit around a suitable star, including our Sun, or even projected into the galaxy in search of a new planet to ‘seed’ with life from Earth.

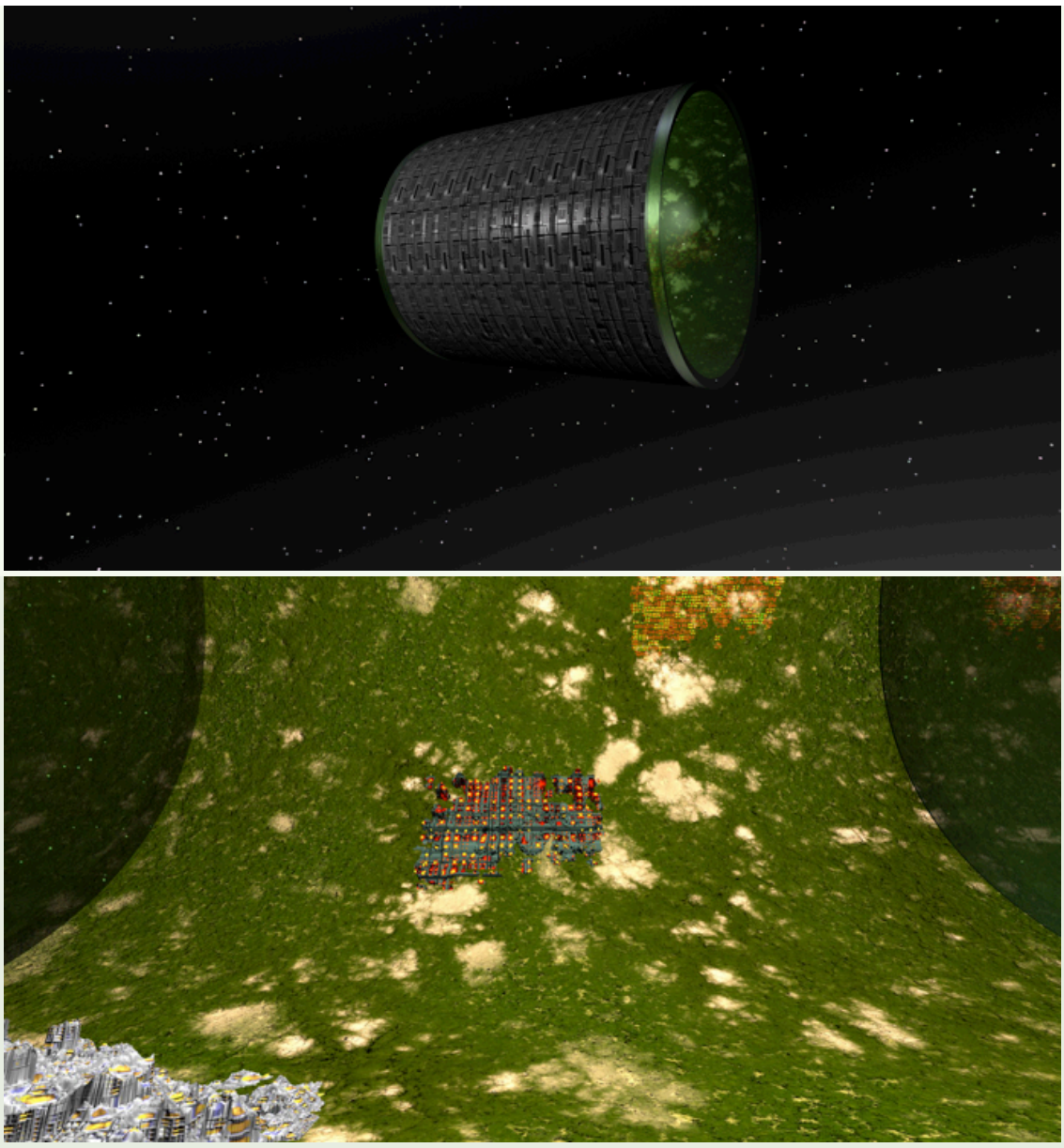
The Cylinder in Space is an interesting concept. A huge, sealed cylinder has a complete biosphere on its inside surface, in contrast with spheroid Earth, with its biosphere on the outside. The cylinder rotates around its major axis to provide some equivalent to gravity, and it is large enough to have its own internal weather system. Internally, the major axis also serves as a cylindrical bar ‘sun,’ providing light and heat to the whole inner surface, ideally driven, perhaps, by a fusion generator that can collect fuel from space as the space cylinder travels…

The inner surface would be covered with rocks, soil, flora and fauna, after the fashion of a Wardian case, the whole filled with atmosphere, and sealed, after which it should then continue, develop and evolve as would the equivalent on Earth, providing a pristine environment replete with climate cycles, rainfall, a full range of life forms and food chains, etc., in which potentially to establish human habitats.

It seems reasonable to suppose that a space cylinder – as described, and supposing its construction, energizing, stocking and sealing to be feasible – would provide a unique habitat for some humans; but for how many? The humans would perforce have to live in harmony with the rest of the natural environment, hunting, trapping, fishing, gathering and farming to feed themselves. So, not too many humans, since they would be obliged to live within their means or die out. The human population would probably reach a dynamic equilibrium: increase beyond that level would lead to famine and death, until the population returned to the level at which it could be sustained. In

the process of adjustment, in desperation, the humans might well kill off both floral and faunal species, so prejudicing their future environment by eliminating essential variety.

Cylinder in Space



Cylinder in Space. Upper diagram shows the sealed drum with its translucent end panels travelling through space either freely or in orbit. Lower diagram: an internal view showing the upward curving terrain with horizons on both sides formed by the translucent end-panels. As depicted, the human habitats would necessarily form a small part of the overall terrain and biosphere; continued human existence would depend on maintaining the viability of flora, fauna and environment upon which man, the hunter-gatherer, will depend…

The space cylinder, then, does not seem to offer a viable solution to the problems of population expansion. It could be of interest to a fundamentalist group wishing to escape from Earth, but the cost of such an enterprise would surely be prohibitive…

The Cylinder in Space does, however, provide an object lesson for the rest of us on Earth about the end facing us if we do not maintain our natural environment and curb our population growth. It is relatively straightforward to see the threats and risks of self-destruction facing the human population of a sealed space cylinder. They appear to be largely identical, however, to those on our isolated Earth…

Critique

It must seem questionable, doubtful even, that *homo sapiens* would be able to live in many of the habitats presented above. Surely, they would be too cramped, too confining, too claustrophobic, too insular, too *everything*…to be even *conceptually* acceptable*,* let alone practicable. And yet…

We humans appear to be in the course of "auto-speciation," i.e., we are rapidly turning ourselves—well, most of us—into eusocial animals, living in crowded monocultural 'island cities.' Not sure? Don't agree? Look around you. How many of us 'live, work and have our being' in cities: how few in the country, living self-sufficiently? And, those that live in cities, are housed in monocultural structures, just like termites live in monocultural cathedrals/mounds of their own construction, excluding other life forms. We divide ourselves into 'castes,' not unlike honeybees: builders, carriers, energy distributors, food distributors, water and sanitation purifiers and providers, doctors & nurses, teachers, entertainers, carers, undertakers, etc., etc., and none of us can do all of the many jobs different needed to keep the city operating…just like bees in a hive, or termites in a mound. Like it or not—and most of us seem to—we *already* live in pro-eusocial societies…

The thing about eusocial societies, like honeybees, termites, naked mole-rats,

etc., is that they are incredibly introspective and crowded. They need to be. They cannot exist as individuals.

So, is it the case that we humans, we *homo sapiens,* are morphing into a eusocial form, let is call it *homo gregaria,* at just the *moment critique,* to enable *Homo* to continue on Planet Earth?

Well, no, perhaps not. We may have left it too late. To become *fully* eusocialized is going to take humanity hundreds of years…And it is becoming pretty clear that we may not have that long…