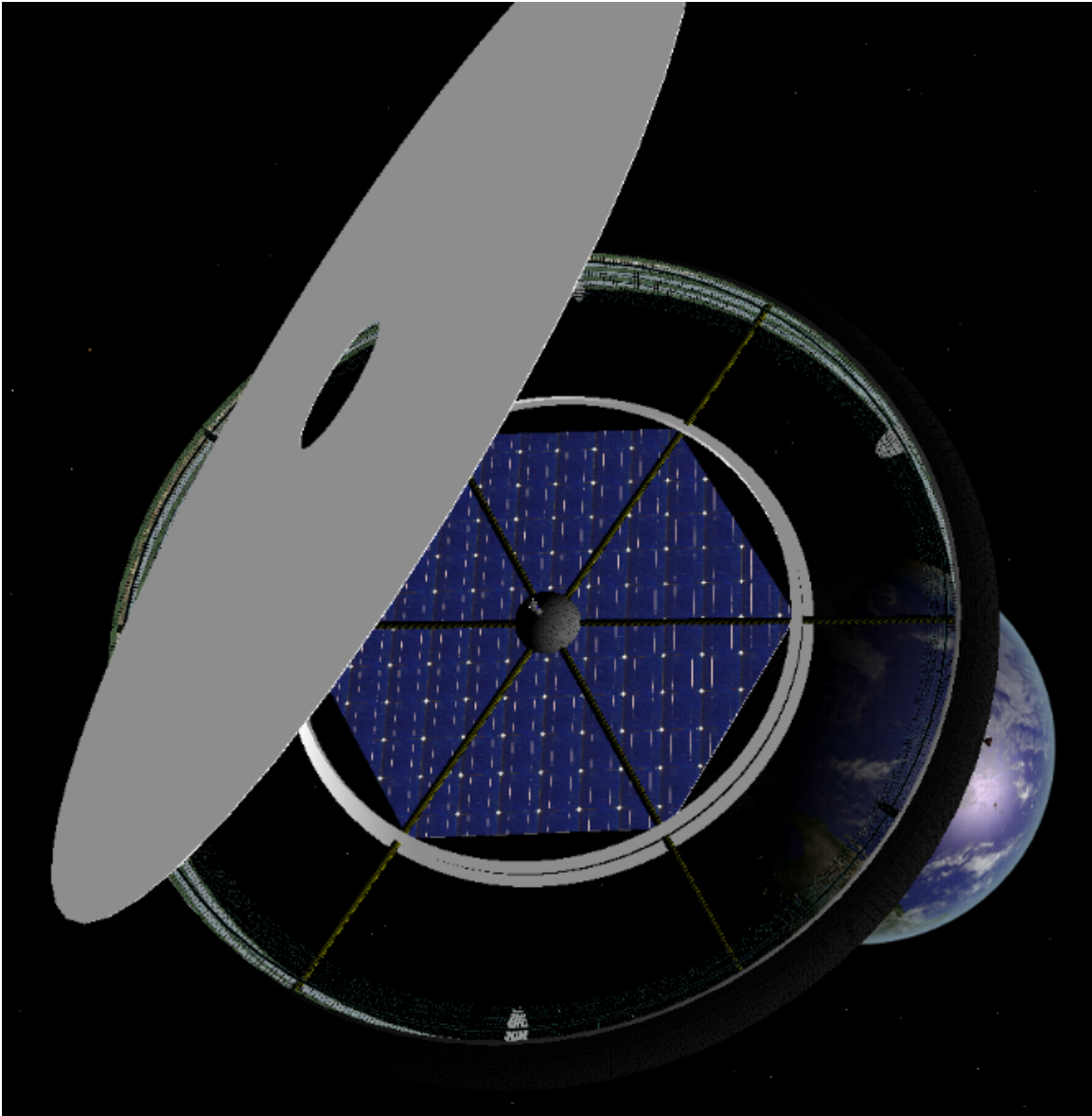


# **The Stanford Torus 1.5**

## **Mankind's First Space Colony**



Model and Documentation by  
Steven "Drake" Ouellette

Text and Model can be modified and redistributed for non-commercial  
applications with attribution  
Textures used in this release are available for non-commercial distribution (see  
acknowledgements for sources)

## Background

The Stanford Torus is based on a design created during a 10 week program in 1975 held at NASA's Ames Research Center and Stanford University. The project participants considered how to create a practicable permanent colony in space using existing technology at minimum cost. To do this, they would also need to:

1. Design a habitat to meet all the physiological requirements of a permanent population and to foster a viable social community.
2. Obtain an adequate supply of raw materials and provide the capability to process them.
3. Provide an adequate transport system to carry people, raw materials, and items of trade.
4. Develop commercial activity sufficient to attract capital and to produce goods and services for trade with Earth.

(Source:<http://lifesci3.arc.nasa.gov/SpaceSettlement/75SummerStudy/Chapt.1.html#Design>)

If you are interested in the results, I encourage you to visit [http://lifesci3.arc.nasa.gov/SpaceSettlement/75SummerStudy/Table\\_of\\_Contents1.html](http://lifesci3.arc.nasa.gov/SpaceSettlement/75SummerStudy/Table_of_Contents1.html) and browse the study. This report is the basis of this add-on with my own interpretations and modifications. Any errors are my own.

Please let me know if you have improvements you would like to see by e-mailing me at [grngnflcn@aol.com](mailto:grngnflcn@aol.com). I hope you enjoy.

## Installation

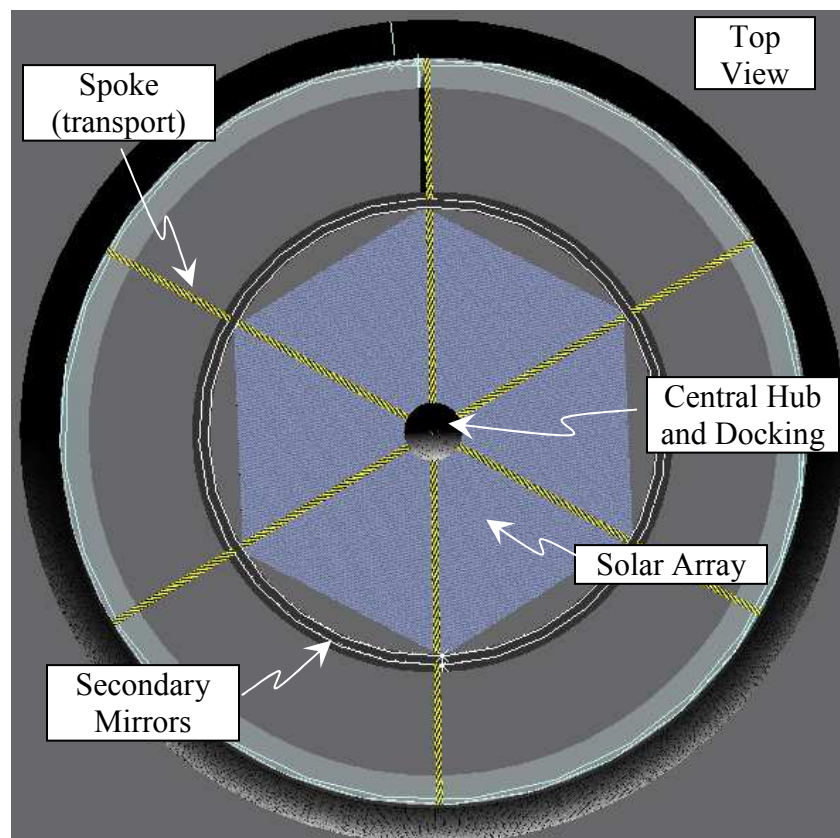
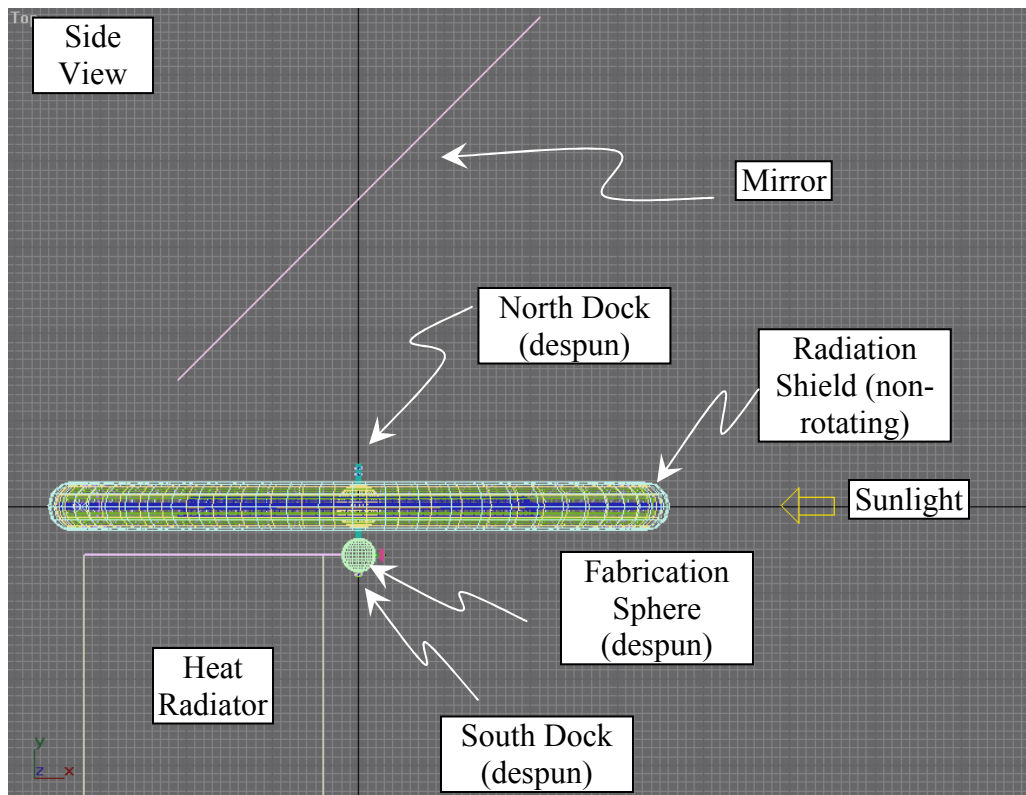
You will need Vinka's spacecraft.dll to use this add-on. It is available here: [http://users.swing.be/vinka/spacecraft030115\\_021217.zip](http://users.swing.be/vinka/spacecraft030115_021217.zip).

To install the Stanford Torus, merely unzip the contents of the Stanford zipfile into your Orbiter directory. Make sure that your unzipping program preserves the directory structure (this is usually the default setting). Otherwise, you will have to manually place the files in the correct folders as indicated in the folder structure (tedious...). Note that the textures are placed in a unique subdirectory to prevent clutter and assure compatibility and easy update and deletion.

## How to Use This Document

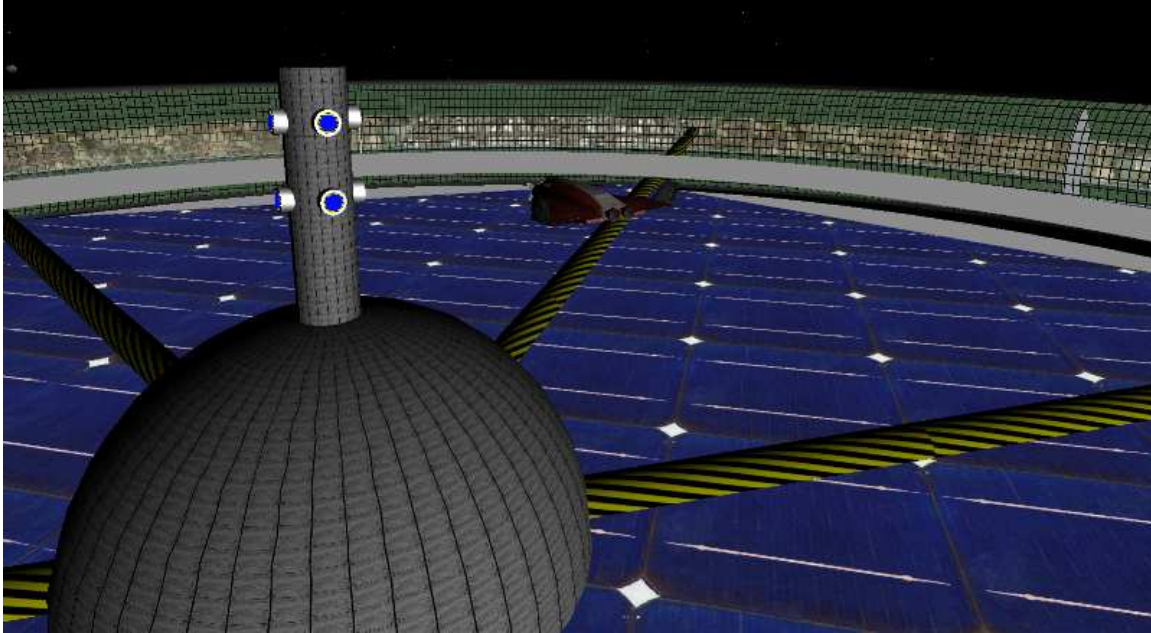
I have highlighted things in **red** if they are important only for maintaining the illusion of reality. If it is highlighted in **blue** you will find it useful to know in Orbiter.

## Station Orientation Views



# Torus Summary

## *Flight Approach*



The Stanford torus is the home of 10,000 people, their businesses, irreplaceable industry, and the future of mankind. As such, there are rules for all vehicles approaching the station. **All incoming traffic must monitor Stanford Approach Control on freq XXX.XX and clear all flight plans at least 24 hours prior to arrival.** The station transponder freq is 170.00. Stanford is equipped with 12 universal docking rings, all with IDS freqs for easy docking. By convention, the docking facility nearest the large primary mirror is the “north” and these eight docking locations are for all passenger arrivals. The four docks on the “south” docking facility are limited to cargo shipments only. Docking alignment for the north dock facility is to the north, while those on the south are aligned to the south. The IDS frequencies start at 136.85 for dock 1 and decrease by 0.05 for each dock until reaching 137.4 in the south.

Again by convention, the docks are numbered 1 through 12, starting with the northernmost sunward dock as 1 and continuing clockwise around the docking facility and then down. Docking rings 3, 7, and 11 are usually used only for local maintenance transports, since an approach directly to these docks would take incoming vessels too close to either the primary mirror or the colony radiator. Exceptions can be made during the rare high-traffic times, but Stanford Approach Control will route these approaches via one of the other three directions, then indicate translation to the final docking ring once well inside the habitat torus.

**Main drives and non-RCS retros or hover jets are prohibited within a sphere of 5km of the center of the colony.** Only RCS can be used within this sphere. This is both for habitat and vessel safety as well as to prevent high-thrust by-product deposition on

any of the optical surfaces (main, secondary, and chevron mirrors and habitat windows). Approach vector speed in this volume is therefore restricted:

- **From 5-4 km less than 100m/s**
- **From 4-3 km less than 50m/s**
- **From 3-2 km less than 25m/s**
- **From 2-1 km less than 10m/s**
- **From 1-0.5 km less than 5m/s**

**During approach, incoming vessels must stay at least 500 meters from any structure excepting of course docking facilities, and no vessel is ever allowed within the spoke rotation area.** In the future, Stanford may well implement tug services for the final approach as space travel becomes more open to private orbinauts, but for the present, we trust the professionalism of our vetted pilots.

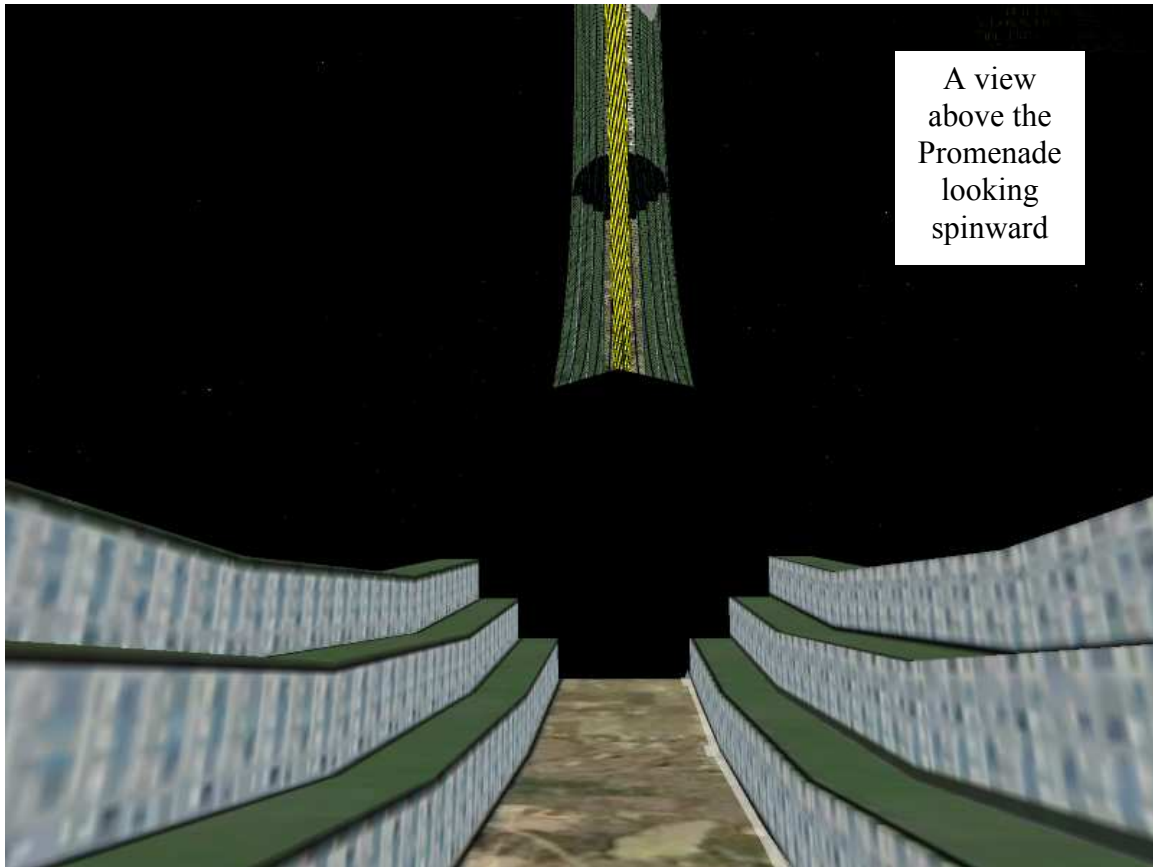
### ***Passenger Arrival***

After passenger disembarkation, comfortable zero-gee waiting areas are present for those awaiting customs clearance and, for immigrants, permanent assignment. In the unfortunate and completely preventable event of quarantine, small but serviceable Class III bio-hazard quarters will be provided until clearance, deportation, or other resolution. Transients can also find a helpful interactive display to familiarize them with the layout of the colony as well as specific locations within the habitat. Please support those businesses whose advertising fees provide this valuable service.

Once cleared for admission, you will proceed via the drop shaft to the Central Hub, or just “The Hub”. It is here you will find mass transport via the spokes to the habitat surface or subsurface, as well as the famed zero-gee sports and recreation area. Private rooms can be rented by the hour.



## ***Directions in the Torus***



A view  
above the  
Promenade  
looking  
spinward

Directions in the habitation area follow these conventions: **spinward** and **anti-spin** are longitudinal directions corresponding to moving in the direction of spin (faster than the torus) or against the direction of spin (slower than the torus). [Note that high-speed mass transport in the spin direction will increase the pseudo-gravity of passengers, while going anti-spin will lessen it.] **Rimward** and **hubward** indicate apparent vertical direction where rimward is “down” and hubward “up.” North and south indicate transverse locations with north being the direction of the primary mirror and south the direction of the fabrication sphere. **Promenade** or **hab level** both refer to the center strip of parks and commercial areas that are on the surface of the habitat. **Terraces** refer to the residential areas on either side of the hab level. **Garden 1, 2, and 3** will sometimes be used to describe the communal garden and play areas on top of each terrace. Garden references obviously must include either north or south, and 1 indicating the areas closest to the hab level. **Bulkhead** or **angle** refers to the location around the ring in degrees, with spoke 1 being the location of bulkhead 0. Spokes are numbered incrementally clockwise.

## ***Habitat Orbital Placement***

A quick note on the placement of the Stanford torus: the original paper recommended the Earth-Moon libration point L5. L5 is located 60° ahead of the Moon on the Moon’s orbit. Theoretically, this would be ideal, since both L4 and L5 are stable, meaning that if something is placed at this point, it will stay there with no station-keeping needed, and it

would have nearly uninterrupted solar power. In reality, however, the Earth-Moon L4 and L5 points are not stable due to the eccentricity of the Moon's orbit. Something placed there will shortly either crash into the Earth or Moon, or be ejected from Earth orbit completely. You are encouraged to try placing the habitat at L5 in a scenario and to see what happens. It is easiest to do this using the ELEMENTS syntax.

There is a theoretical stable orbit *around* Earth-Moon L4 or L5, which is harmonic with the Earth's orbit around the Sun, such that the tidal forces of the Sun correct the perturbations due to the Moon's eccentricity. While it is very interesting to consider orbiting the habitat around an empty point in space, I do not have access to the stable L5 halo orbit information, so I have chosen to place the station at a geosynchronous orbit (GEO), which might also provide additional income to the colony through satellite relaying services. However, one of the benefits of L5 is that the habitat can exist solely on direct sunlight for power since the Sun is rarely eclipsed there. At GEO the station will experience the usual day-night cycle, and so will need some sort of power storage or additional non-solar generation capacity.

## **Construction**

A number of technologies need to be in place before the construction work on the torus can begin. Much of the work to test pilot plants for metal extraction, refining, and manufacturing, as well as the mass catcher, could be done in low-Earth orbit (LEO). Some manufacture of components may also take place in LEO. This is significantly less expensive than attempting the same things at geosynchronous orbit (GEO) or even farther. For a few special components, manufacture may need to be on Earth's surface, requiring transshipment to LEO and then to the colony site.

Additionally, a lunar mining facility will provide refined metals, glass, and soil for the colony. An important by-product of these mining activities is oxygen, which can be used as a fuel oxidizer or for the habitat's initial atmosphere. (The initial nitrogen will need to be compressed and shipped from Earth.) These lunar raw materials will be launched to the torus construction site by a mass-launcher and retrieved by a mass-catcher. Slag from the lunar mining operations can be sent as well to be incorporated into the non-rotating radiation shield protecting the habitat from solar radiation. It is expected that once on-site refining facilities are functional, some metal manufacture will be performed at the colony, though due to heat dissipation issues, it would likely be small amounts of specialty metals. Lunar mining will easily provide sufficient aluminum for habitation construction. (The stresses due to atmospheric pressure and rotation the station will experience are well within aluminum alloy mechanical strength.)

Actual construction will take place starting with a non-spun section. As the project proceeds, additional sections will be added, capped, and pressurized ("tunneling" in space), to give workers a shirt-sleeve environment in which to build the internal structures.

Dwellings and businesses will be made from light modular construction plans, so that as requirements change, reconstruction will be manageable. Most businesses will be built

under the main habitation level, with living quarters provided in the terraced areas. The habitation ring surface will be divided into six sections with the middle of each section a spoke. These six sections alternate between agricultural/ranching and residential/business use of the hab level and terraces with the ends isolated by bulkhead systems. Most of the time these sections will allow easy cross-transport at locks to prevent major spillage of environment, but in an emergency each section can be completely isolated. The spokes serve not only as transportation and energy conduits, but provide circulation of air from section to hub to section. The agricultural areas will be maintained at higher temperature, humidity, and light flux to provide an optimal growing environment while the habitation areas will be optimized for the human residents. The agricultural areas also provide efficient carbon, phosphorous, nitrogen and water recycling, as well as carbon dioxide to oxygen conversion.

### ***Pseudo-gravity***

Pseudo-gravity is a result of momentum and spin. Stanford rotates at 1 rpm, with the large diameter of the torus minimizes the gravity gradient at the hab level while providing approximately 1g. However, this rotation is not completely analogous to gravity. Dropped items will be affected by an apparent Coriolis force, leading to curved trajectories. Also, the small but noticeable gravity gradient from the top to the bottom of the habitable areas does affect property values, with the higher g areas being least desirable.

### ***Power***

Power is supplied mainly by a large solar panel array in the open part of the torus. A large, non-rotating mirror is used to deflect sunlight down onto the array. A solar furnace is used for additional power generation and heat source at the Fabrication Sphere. A superconducting battery system exists to provide backup power during the night, and an auxiliary nuclear power station can be used in the event of failure in the solar panel system. An emergency system using distributed fuel cells is the third system to prevent power failure for critical systems.

### ***Lighting***

A small portion of the sunlight from the primary mirror is redirected to the habitat by the secondary mirrors to provide illumination. Chevron louvers (not visible on this model) are used to redirect visible light while absorbing higher energy wavelengths. The secondary mirrors can be individually rotated to customize lighting, for example increasing the lighting in farming areas to maximize production, or changing station day lengths in the residential areas to emulate seasonal changes needed by the human circadian system. Light pipes are used in many homes to provide natural spectrum lighting.

### ***Radiation Protection***

Slag, lunar rock, and any other medium- to high-density waste material will be formed into standard bricks and built into a non-rotating radiation shield to protect the habitat from high-energy solar radiation. (Rotating this huge mass is unnecessary and would



exceed the material strengths of cost effective materials.) This radiation shield forms an outer “tread” around the rotating inner habitation torus. The outer torus surface is 5m from the inner shield surface. This distance is maintained by an automatic reaction control system mounted to the shield. A light, low-friction ablative shield protects the rotating hab section in the extremely unlikely event that this system fails.

## ***Industry***

Like any colony, the Stanford torus must generate more economic wealth than it consumes to insure longevity. Stanford has extra power generation which it beams to rectennas on Earth via microwaves. Additionally, its geosynchronous orbit allows it to serve as a communications relay satellite using an external high-bandwidth transceiver facility (not modeled). These are not a major component of the station’s income.

Its primary income is from two sources: power satellite manufacturing, placement, and maintenance, and low-gee manufacturing.

By manufacturing power satellites which are then placed in GEO, the station achieves financial payback in an estimated 28 years. In addition, pollution-free power can be provided at a rate that will replace retiring terrestrial power generators as well as meet growing power demand. Waste heat generation is minimized with microwave transmission from space, as conversion to electricity is up to 85 percent efficient, as compared with the maximum efficiency of 50 percent for terrestrial thermodynamic power generation. By using this low-cost electricity to “crack” water to create hydrogen, highly transportable clean energy will supplant petrochemical sources, and within 70 years the United States would become energy independent. Most other industrialized countries would be completely free of petrochemical dependence long before this. Emerging and non-industrialized countries would reap the benefits of the investment by the industrialized ones and be able to provide very inexpensive power without following in the polluted footsteps of the industrialized ones. As global dependence on petrochemical energy wanes, the rate of change of warming due to climate modification will virtually disappear and then begin to decrease. Some small amount of waste heat due to power consumption will still be present, but this will be negligible compared to the current and predicted states.

Low-gee manufacturing allows for a number of unique industrial products. Large and single crystal growth for example, provides extremely efficient solar panels as well as high temperature fatigue-resistant turbine blades, microchip substrates, and many other products. A number of pharmaceuticals can only be grown and purified in zero-gee. And given the ready availability of vacuum far in excess of anything on Earth, exotic material manufacture becomes easier.

Products destined for Earth are shipped via “dumb cans” for ballistic orbital insertion, parachute, and splashdown at various locations. The cans are made from lunar steel and are recycled on Earth.

## Known Issues

- ~~Textures are not tiling correctly, due no doubt to me not understanding something basic about texturing— fixed! Change the UVW parameters on the Surface Parameters on the loft, not in the material texture dialog!~~
- The rotating sections are animated, not actually rotating, so gyroscopic effects are not present
- ~~Textures are pretty basic— this is due to me not being a texture artist. If anyone wants to texture it, please let me know, as I know what needs to be done, but not how.~~ Fixed thanks to the USGS and learning how to texture. Many thanks to those on the Orbiter boards who were patient with my newbie questions, especially Mr. Batman and Donamy.

## Acknowledgements

Dr. Martin Schweiger – creator of the simulation

“Vinka” for spacecraft.dll

“Mindblast” for max2msh

The Ames-Stanford Project Paper:

[http://lifesci3.arc.nasa.gov/SpaceSettlement/75SummerStudy/Table\\_of\\_Contents1.html](http://lifesci3.arc.nasa.gov/SpaceSettlement/75SummerStudy/Table_of_Contents1.html)

All textures used were presented as free for use and non-commercial distribution.

Solar Cell Photo: [www.eng.mu.edu/crovettj/ses/promotional-media/](http://www.eng.mu.edu/crovettj/ses/promotional-media/)

Metal Plating: <http://www.grsites.com>

Building Face: <http://www.mayang.com>

Rad Shield Bricks: <http://www.grsites.com>

Tiger Stripes: <http://shaders.org>

Hab surface: Courtesy of the USGS. (side note: the buildings you see are the main street of my town Longmont, Colorado. The farms are farms right near my house with one exception that is on the East Coast somewhere, and the park is one I go to all the time with my daughters.)

Transponder help: “MSLV2”

Change Log:

March 17, 2005: Release v1.5 - Figured out texture problem and fixed, minor edits to documents

January 25, 2005: Changed Dock Center material to be blue emissive

January 24, 2005: First Release v1.0