Mars Torus Centrifuge Building

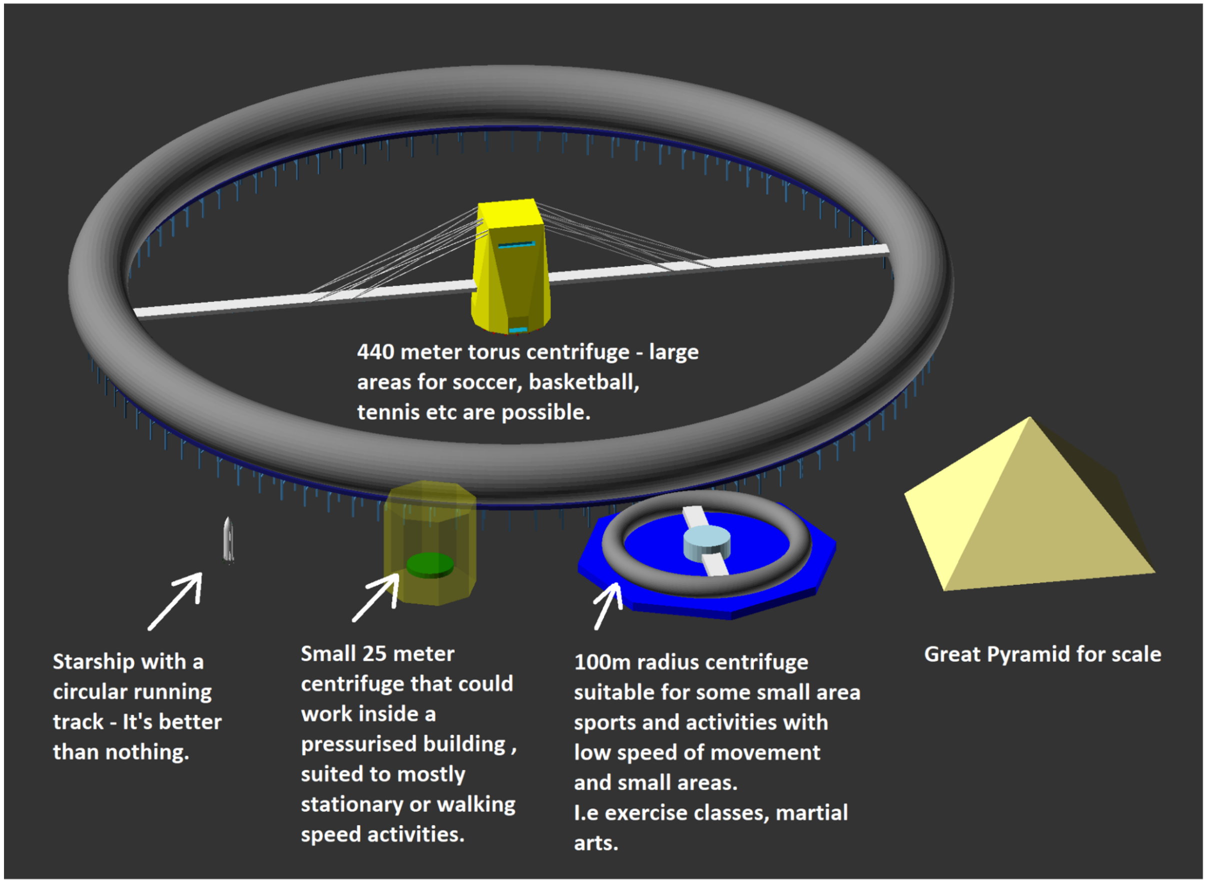
Concept by stephen Humble for a city sized centrifuge providing earth like gravity on mars.

Example centrifuges – size matters.

Centrifuge designs - size comparison.

The free option is to run about the inner circumference of the starship you arrived in.!

But larger more elaborate centrifuges allow more capabilities.



Why would martians want such a large centrifuge

Many activities on earth require large playing areas like basketball, tennis, football etc this torus is large enough to play those sports.

Under mars gravity of 3.71m/ss it is not possible to move as you would on earth.

For mars to be an attractive place for people considering long stays they would want to remain well adapted to earth like gravity.

A Martian population would certainly have children and ensuring they develop normal strength would be an important consideration - a large torus facility would enable people to comfortably spend as much of their time in earth like gravity as they wanted as it could have apartments, sport facilities, offices, businesses, retail, restaurants, schools, hospitals, pools etc.

During Space travel and many other activities which involve high acceleration being well adapted to 1G force is a good starting point to reduce risk of injury.

Quality of artificial gravity

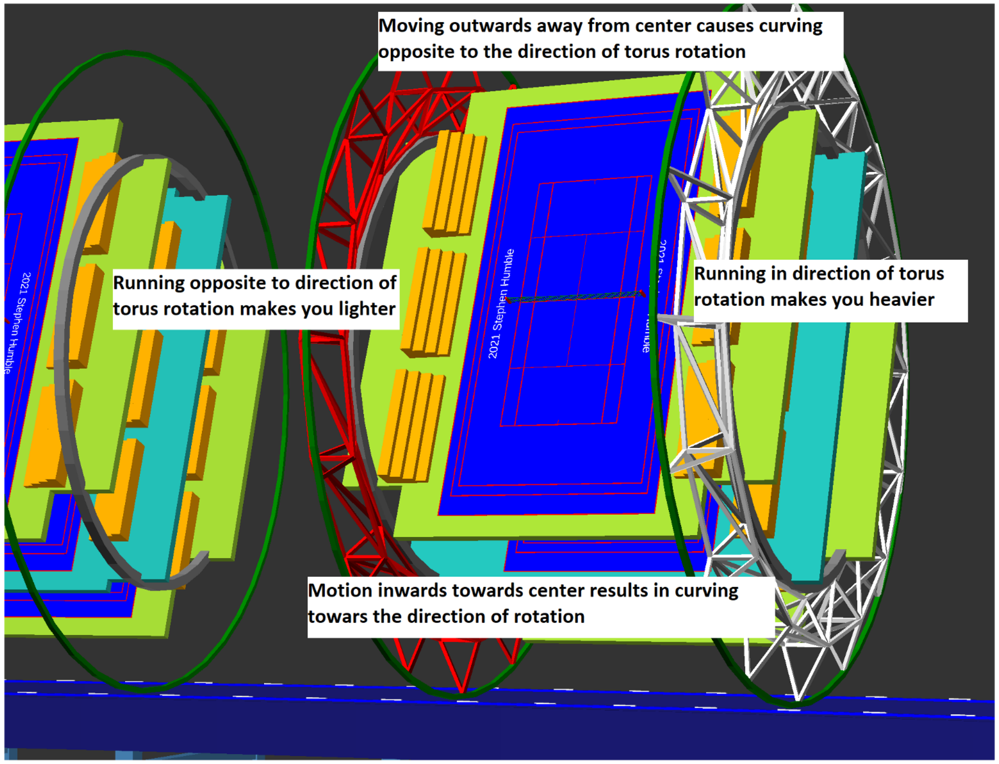
The larger the size and speed of a centrifuge the less noticeable the coriolis and eotvis effects are.

These effects can't be entirely eliminated – the idea is to just make a centrifuge large enough that they have a minimal effect.

A person running around will probably notice differences in their weight and lean angle as they moved about.

The decks in the Torus would need to curve slightly for the floor to be level. Across the width of a tennis court this would be about 1.5 degrees - players would have to adapt to the conditions.

The size suggested is in the range of large ships, bridges, buildings and other structures built on earth – At this size it is feasible for a martian town or city to build one or several of these enormous structures.



Use cases for different radius.centrifuges.

I would expect a variety of different sized facilities as mars population and manufacture capability grows starting with smaller ones and progressively martians will want larger and better.

With a starship radius running track a person sprinting would reach earth like gravity - comes free with every starship that lands.

A rotating building of radius 25 meters would allow people to walk about and do any other mostly stationary activities like eat sleep office work etc – can operate inside a pressurized habitat due to the low speed not causing much drag force and can start and stop quickly.

A 100 meter radius makes jogging speed possible – but trying to run in certain directions would cause a person to lean so much they would fall over or loose traction as their weight can change +-30%. Floor surface is still noticeably curved every 2 steps the floor angle changes 1 degree. The rotational speed is over 100kmph.

At over 300 meters radius motion effects become small enough to easily deal with it's very similar to earth. The curvature of the floor is small so large near flat areas are possible and playing sports like tennis or soccer is possible. The speed is so high it would have to operate in low density mars atmosphere to minimise drag.

A ~400 meters radius centrifuge could have every facility and enable people to live in earth like gravity as long as they wanted or just to visit for sport, recreation and so on all options are possible - the interior volume can contain equivalent population and facilities to a large town with many thousands of people.

A torus shaped centrifuge.

The example design in is shown with buildings the size of the great Egyptian pyramid, the One world trade center and the NASA vertical assembly building to give sense of the scale required. Going much smaller than this would – detract from the quality of the gravity for many activities.

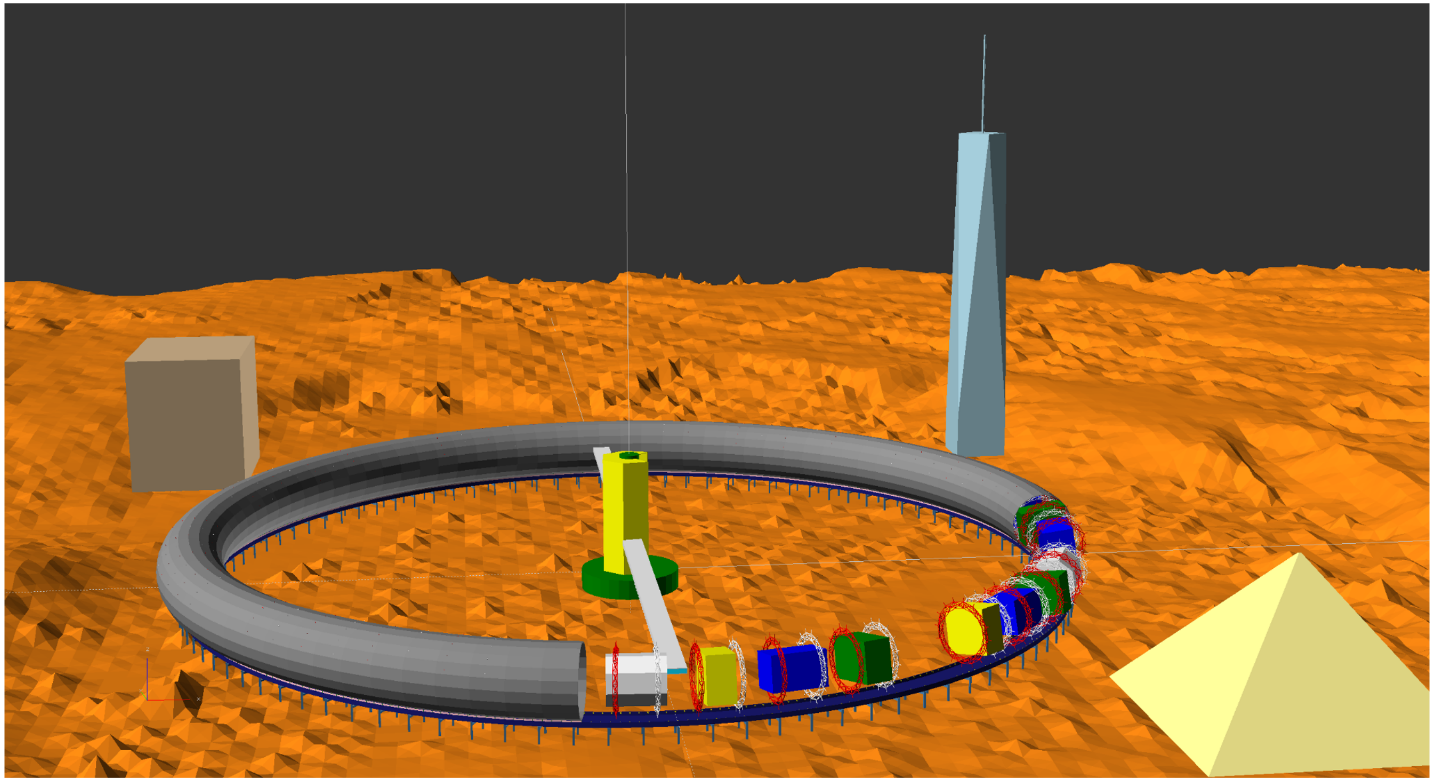
The torus has a 880 meters major diameter and would spin at 230 kmph and reach earth like gravity.

The torus minor diameter is 62 meters, allowing structures up to about 15 stories tall inside.

There are around 40 sectors inside the torus they can rotate on pivot mounting from horizontal up to at least 70 degrees to remain balanced as centrifuge speed increases.

Torus Overview

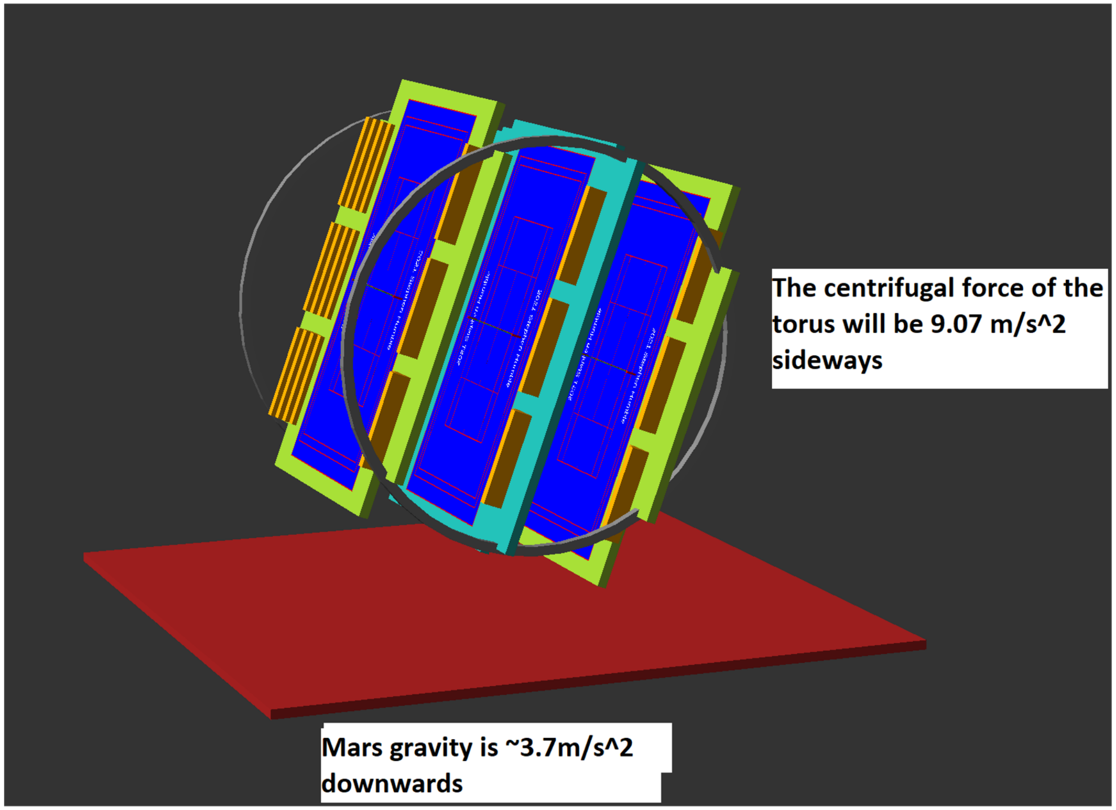
The outer hull is show cut away to see the inner layout – the segments are like large buildings mounted on mechanised rotating pivot brackets.



Summation of acceleration forces at full speed.

Combining the vector sum of mars gravity 3.7m/s^2 downwards and the centrifuge force 9.07m/s^2 sideways we get 9.8m/s^2 or earth like acceleration at an angle of about 69.3 degrees.

This angle is the same for any centrifuge on mars to produce earth like acceleration - no matter the size – even a small running track inside a starship.



Structural forces on the torus.

Inner air pressure of 1 earth atmosphere causes around 32 Kilo tones of tension force around the main circumference.

Centrifuge force from the mass of the torus and it’s contents as they rotate at 230kmph causes ~44 Kilo Tons of tension force

Both these forces are combined to create a large hoop stress around the circumference of ~76 Kilo tones of force- equivalent to the weight of 50000 motor cars.

These combined forces will cause an elastic deformation of the torus main radius of around 20cm – if not accounted for this would cause the torus to de-raila creating a big problem.

To withstand the forces with a safety factor of 2X before reaching the non-elastic deformation limit. The nickle alloy steel hull would need to be around 35mm thick.

Similar sized non moving structures could be about half as thick.

The extra thickness of the torus hull does have the secondary benefit of increasing radiation attenuation so the extra weight does not add much overhead compared to static non moving buildings of similar size which would probably employ similar steel pressure hull designs.

Suspension and drive system

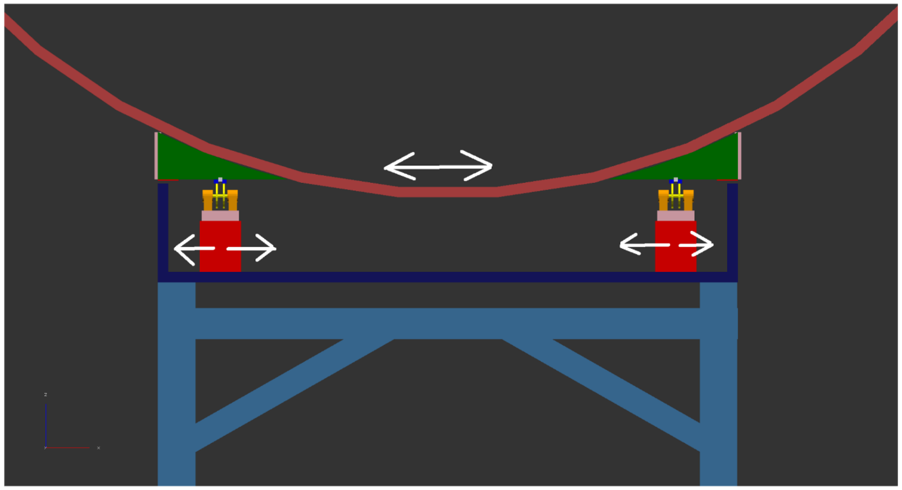
The torus hull would have a set of steel tracks on the bottom and the foundation would have wheel motor drive units that rotate the torus around.

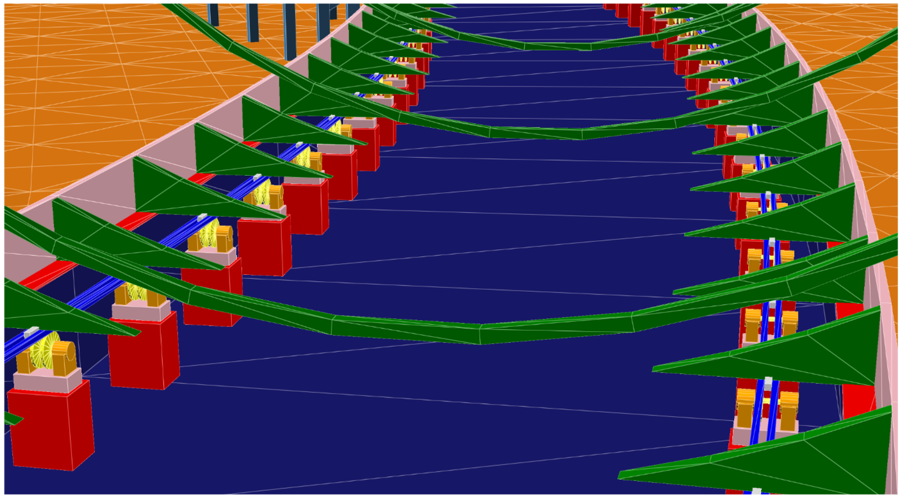
The motor drives would be able to shift sideways with actuators and adjust as the torus is pressurized, changes temperature or changes speed causing it's radius to change.

The wheels and motor guides would also keep the torus rotating about the center of mass.

The foundation channel would also be able to move on it's foundations to deal with temperature expansion during operation.

Mars temperature range from -70 to 20 celcius would cause the main radius to change by 43cm. Mars structures need to be designed to deal with significant thermal expansion and contraction.



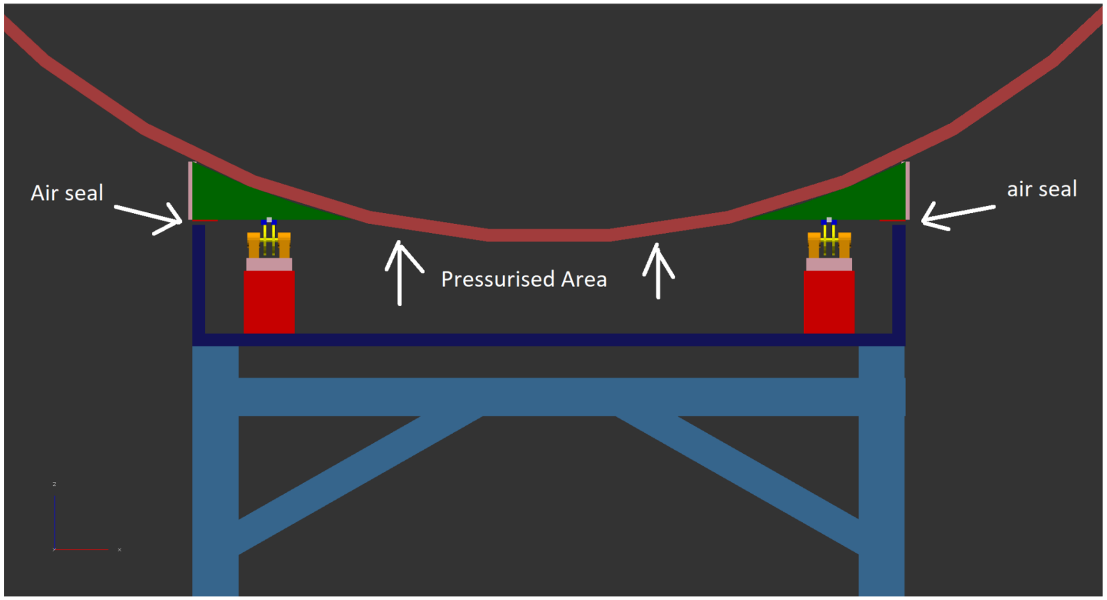


Air hover bed support of the torus.

The torus would also be supported by an air pressure bed using martian atmosphere compressed by fans – this is similar to how a hover craft or hover train works.

With an air bed width of 26 meters and pressure of 15kpa or about 1/6 of earth atmosphere each meter of foundation can carry over 107 Tones of mass under mars gravity.

Supporting most of the weight using air pressure reduces rolling resistance, reduces wear on drive systems and lowers energy usage.



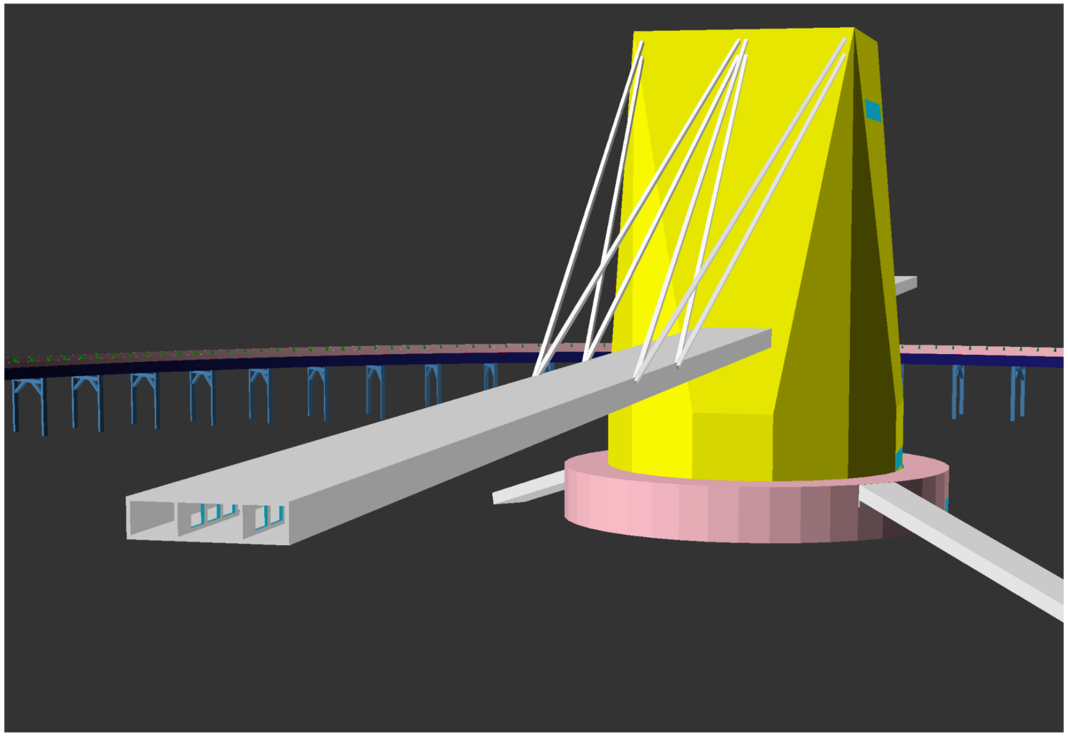
Torus Access arms

The weight of the torus is ~250 thousand tones or similar to 200,000 automobiles so it takes a long time to stop and start – to enter or exit during operation we have access arms. Under mars gravity a mid supported suspension bridge can be made of alloy steel that can span the full ~400 meters from the center hub to the torus.

In the torus arms carriages moving on rack and pinion drives with the ability to tilt to suit the angle of gravity would could carry goods or people.

The arms would need to have an aerodynamic profile as although mars atmosphere is thin it requires several MW of power to overcome the drag of each arm.

The arms connection to the torus needs to allow for expansion and contraction, maintain a pressure seal, support the vertical arm weight without unduly unbalancing the torus, transfer horizontal torque forces yet avoid distorting the torus hull at the connection point.



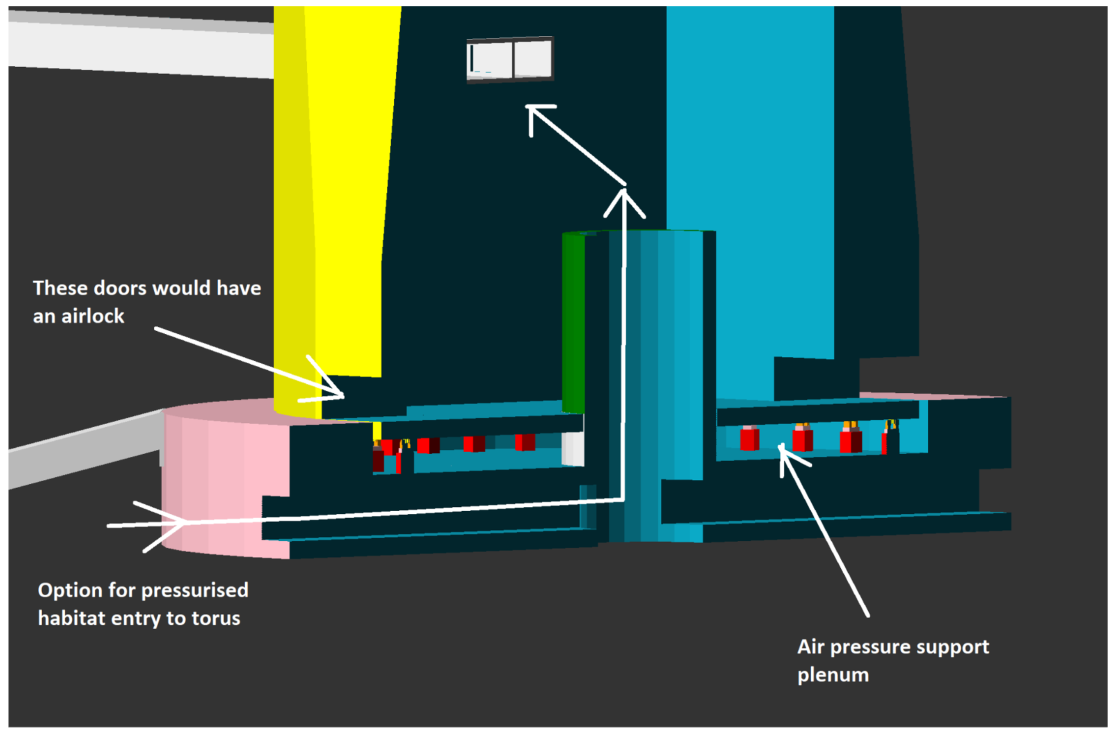
Torus Center hub

The center hub at it's radius of ~38 meters would be moving at 20kmph to enable easy entry – a secondary turntable could be used to reduce this to zero if needed.

The center hub is supported by air pressure as well as a set of tracks and wheels.

The center spindle would have rotary couplings that connect electricity ,water and oxygen,sewage and other ducts to the torus.

A pressurized center shaft can enable people and goods to enter from a pressurized transport tunnel from other connected habitats without needing space suits.



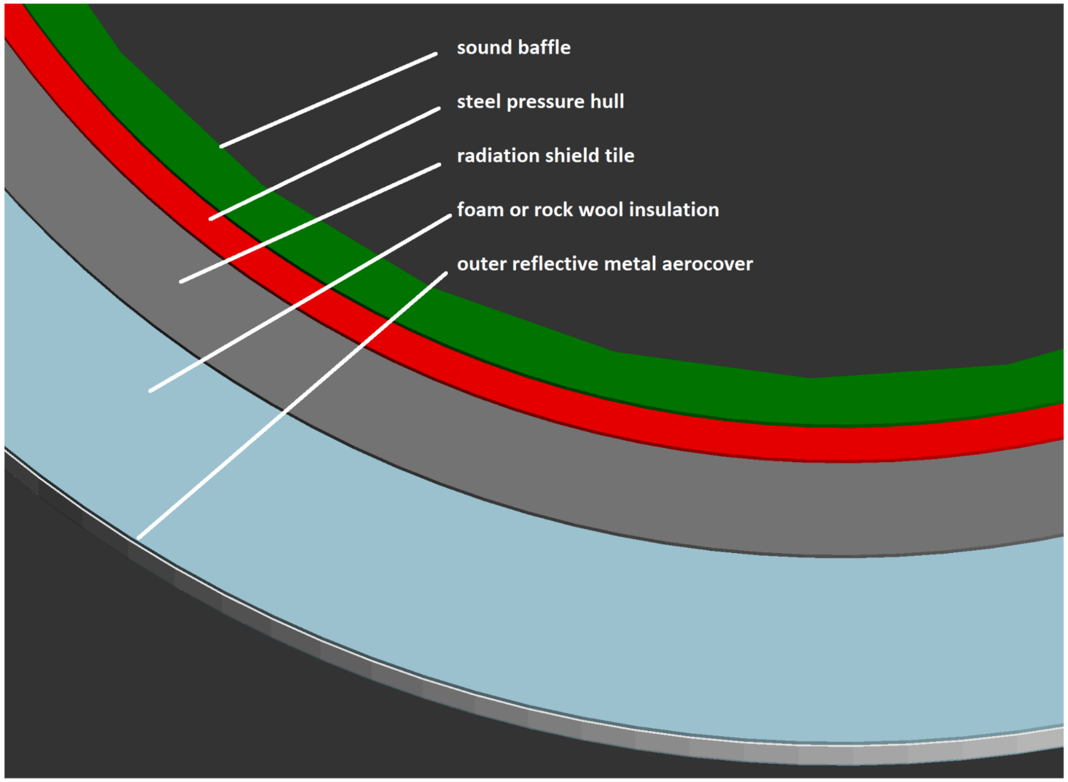
Torus Thermal insulation and considerations.

The thin martian atmosphere is cold however it's low density makes it a poor conductor of heat – insulation materials are around 5X more effective on mars. Insulating buildings well is surprisingly easy.

Keeping the structure at a constant temperature reduces thermal stress and distortion.

Inside the torus large fans would circulate air to equalise the hull temperature.

Similar insulation techniques would be used for many other martian structures, buildings and vehicles.

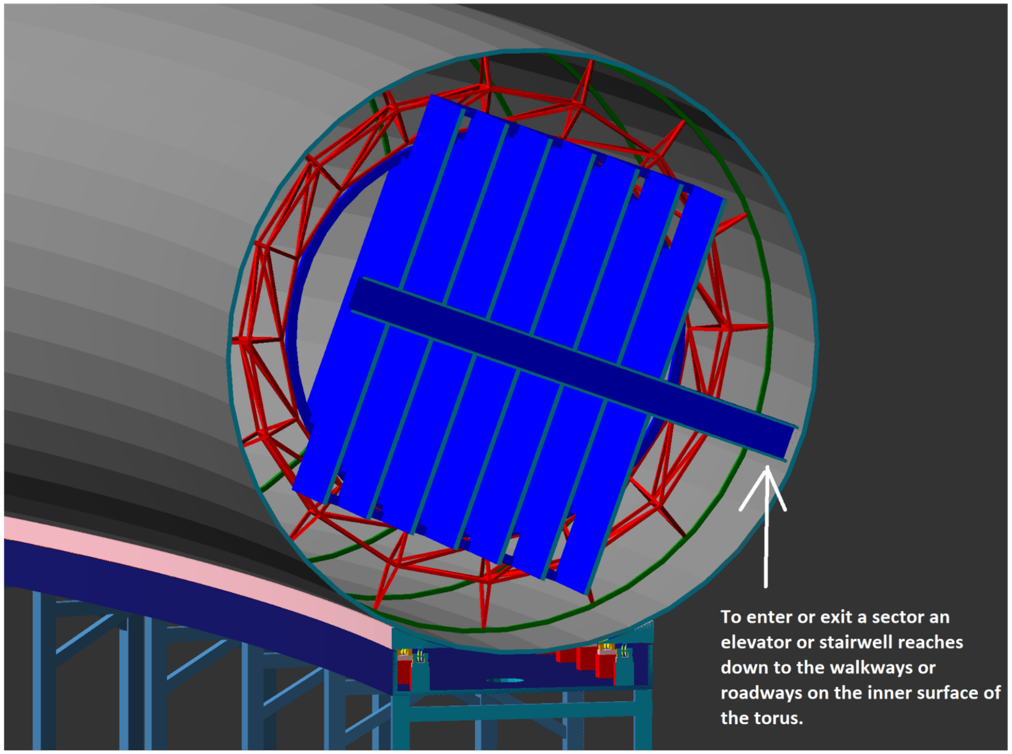


Transport and Travel inside the torus

Inside the torus low speed electric fork lifts and trucks could be used to move containers of goods and materials about. These would travel on roads on the inner surface of the torus – there would be roads at several angles.

The tilting sectors would have steps a ramp or elevator from a lower entry level accessible from the walkway/ roadway level of the torus.

The depicted apartment building cut away view shows levels that are 5 meters high – the elevator shaft is 50 meters high – the building could comfortably house a hundred or more people.



Economic Costs

The torus would be part of a larger city metropolis – it would require a power station air and water and other supplies.

Energy use is expected to be around 20Mw while operating to overcome rolling friction, aerodynamic resistance, run pumps , fans, heating, lighting, air conditioning and support around 10000 people – or about 2000W per person – this is similar to a typical house running air conditioning on earth per person.

Torus could last for many centuries – the martian environment is dry there is no corrosion. The thermal cladding eliminates thermal stress the enclosed track reduces contamination that cause wear.

The cost of the torus relative to other forms of habitat is higher but perhaps only by a factor of two – on mars all habitats will require thermal cladding, a pressure hull, radiation shielding, provision for pressure and temperature related expansion and contraction etc.

Cost of construction

At current power prices the embodied energy content of the steel would cost about 300 million USD.

It would take a 1Gw nuclear reactor about 5 months to produce the energy required to produce all the structural steel required.

The torus would be built in a similar way to large ships with a factory making sub segments that are then transported to the torus build location and joined together (by welding, bolting etc).

As well as steel it would also require large amounts of other materials like copper, aluminium and plastics for electrical power and motors. It would require high precision items like roller bearings, gears etc. Where possible low cost light weight construction materials like cement fibro sheeting, plastics, wood (could that be grown on mars economically ?) would be helpful.

Further Notes.

The mostly steel design is intended to be as economical as possible – nickel steel can easily be produced on mars for over 95% of the mass.

The drive system was determined to be able to use similar bearings to freight trains on earth – the weights and speeds involved are similar to those of existing rail transport systems.

O'Neill Cylinders are far bigger orbital space structures and are significantly more expensive to build. They require huge mass and vast amounts of energy to travel to them and can only exist in microgravity. Such extreme sized centrifuges although relatively simple in design seem an impractical fantasy. The mars torus concept described is realistically achievable and is specifically designed to work on mars surface.

The design is targeted for mars – a similar size lunar torus would probably have to be contained inside a cavern to contain low pressure suspension air or use a maglev suspension system.

Once you overcome the thin unbreathable atmosphere, low gravity and other hazards on mars there seem to be many benefits to the mars environment.