SPACE RENAISSANCE ACADEMY

Committee: Space Habitats – Topic: Simulated Gravity (SG)

Chair: Jerry Stone

Co-Chair: Werner Grandl, Architect & Civil Engineer (author of this paper)

born 1957 in Vienna, Austria
1984 Technical University Vienna, degree in architecture
1985 military service, Austrian Air Force
1986-1993 working in some engineering offices
since 1994 freelancing architect and consulting engineer
since 1987 various studies on space stations, space colonies, lunar base design and asteroid resource utilization

Artificial Gravity (AG): the simulation of gravity by centrifugal force

Non-rotating Space Stations:

Advantages

Orbital stations like the present ISS or the former Russian MIR have a lot of advantages.

They offer laboratory conditions both in pressurized modules and in externally mounted experiment and observation platforms. Research in weightlessness (microgravity) and vacuum enables scientists to study physical effects, which are normally hidden due to gravity´s dominance on Earth. That opens up new prospects for the production of alloys and composites, large crystals or complex proteins.

In life science various investigations on the response of microgravity on the lungs, brain, nervous system, bones and muscles can be performed. This research is relevant to the understanding of balance disorders, osteoporosis and cardiovascular disease (E. Messerschmid, R. Bertrand, Space Stations-Systems and Utilization, Springer 1999).

Harmfulness

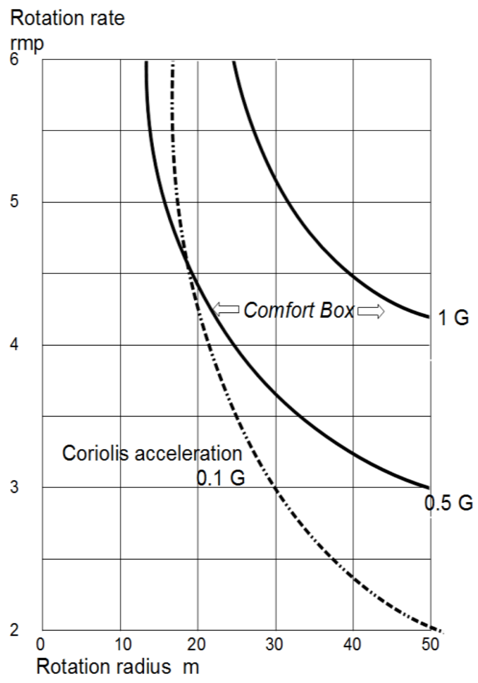
During long duration space missions there are a number of harmful effects of microgravity on the human body, such as loss of bone and muscle mass, loss of red blood cells, fluid shifts, cardiovascular and sensory-motor deconditioning and changes in the immune system (A. Bukley et al., Acta Astronautica 60, 2007, 472-478).

Zero and low gravity may be a show stop condition for long time residence in space, therefore a serious impediment for space settlement and industrialization.

Coriolis acceleration: a physical phenomenon, which occurs on the surface of rotating bodies and causes traverse motion of objects; on Earth the Coriolis acceleration causes traverse winds and oceanic currents near the equator.

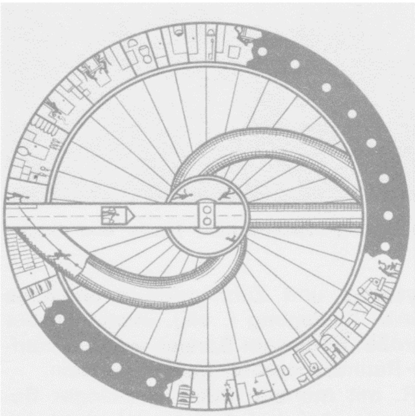
Rotating Space Stations: The simulation of gravity by the use of centrifugal forces will provide a more comfortable habitat for humans in space than a zero-gravity environment. The bigger the radius the better the conditions. At large radii and low rotation rates the Coriolis acceleration can be neglected. At short radius and high rotation rate the Coriolis acceleration can disturb the vestibular sense of humans. In 1987 NASA engineer Jesco von Puttkamer published the so called „comfort box“, which indicates acceptable living conditions in a rotating space station:

According to the „comfort box“ a rotating space station should have a minimum radius of 30 meters and a rotation rate of approx. 4.5 rounds per minute. Shorter radius centrifugation generates AG levels that are different throughout the human body; i.e., smaller at the head and larger at the feet.

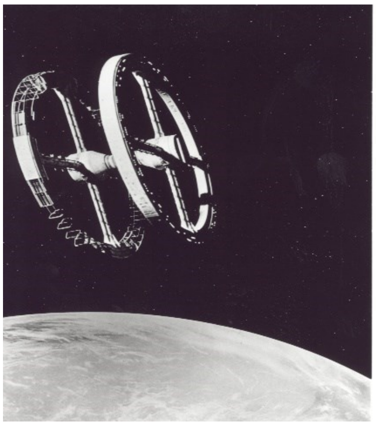


Designs of rotating space stations and colonies: Early concepts of rotating space stations have been made in the 1920ies. In 1926 Konstantin Tsiolkovski first discussed rotating colonies around the Earth. In 1928 Hermann Potocnic (pen name: Hermann Noordung) published a wheel-shaped orbital station, called „Weltraumrad", which became a prototype design for many succeeding toroidal concepts. In the early 1950ies Wernher von Braun proposed a pneumatic torus, which was the first concept to use inflatable structures in space. In 1968 the famous movie 2001- A Space Odyssey showed a wheel-shaped space station to the public.

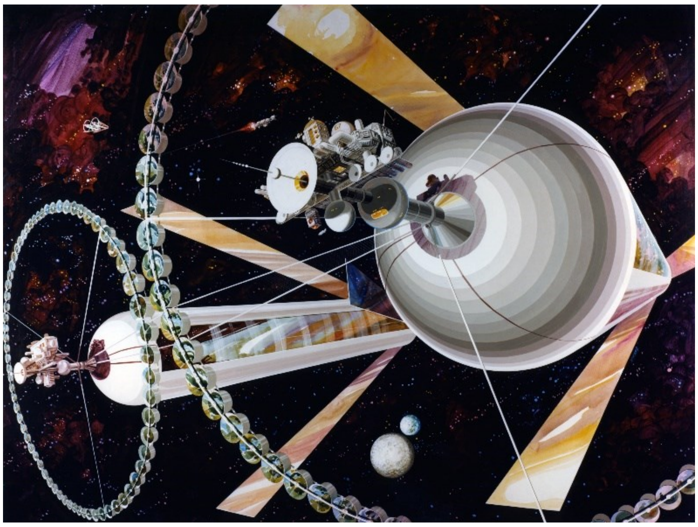
The Stanford Torus of 1975 was a toroidal habitat largely made of lunar material. It should have a diameter of 1.6 kilometers and a population of 10,000 people. The most amazing design for future space colonies were made by Gerard K. O´Neill in 1975. Giant rotating cylinders entirely made of extra-terrestrial material should be located in the Lagrange Points L4 and L5 of the Earth-Moon system. The biggest cylinder was considered to be 36 kilometers long and 6.5 kilometers in diameter, with a population of several hundred thousand inhabitants.



H. Noordung, „Weltraumrad", 1928



2001- A Space Odyssey, 1968

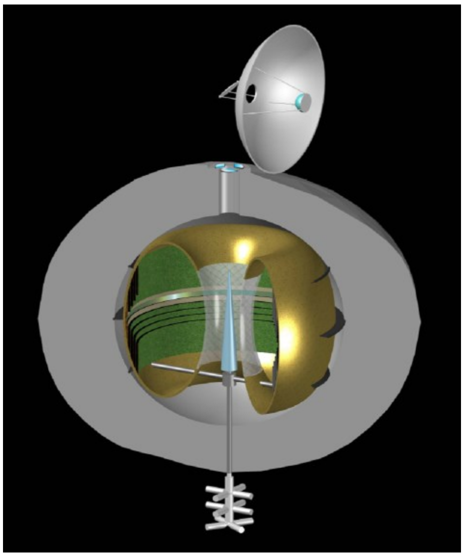


In 1993 Antonio Germano and Werner Grandl published a detailed design of a big space colony, considering feasability and safety and emphasizing structural engine-ering (proceedings of the 11th SSI Princeton Conference, called the High Frontier Conference in honour of Dr. Gerard K. O´Neill, pages 252-268). The colony was considered to be made of lunar and asteroid material, processed by industrial plants in space. The proposed colony , the „Solar Arc", should have a length of 8.2 kilometers and a diameter of 3.2 kilometers, having a population of about 260,000. Natural sunlight should be beamed into the cylinder and be distributed by a central diffusing cone, simulating day and night cycles and a self-sufficient climate.

In 2013 Werner Grandl and Akos Bazso published the design of a prototype Asteroid Colony. The stony Near Earth Asteroid 2008EV5, with a diameter of approx. 400 meters should be forced into an Earth orbit beyond the Moon. After the mining of 50 % of the asteroids volume, we proposed a rotating toroidal colony inside the remaining cave. The shell of the hollow asteroid would provide shelter against meteorites and cosmic rays. The radius of the rotating torus should be 100 meters to minimize the Coriolis acceleration.

Similar to the „Solar Ark“ design, natural sunlight should be collected by a free floating array of parabolic mirrors outside the colony, beamed into the cave and distributed by a central cone with parabolic facets. The toroidal structure would rotate 3 rounds per minute on circular electromagnetic bearings (magnetic levitation) to provide 95 % of terrestrial gravity. Coriolis acceleration would be just about 0.05 G, comfortable for humans. The non-rotating spaceport outside the asteroid´s shell provides docking and storage modules and is derived from a former mining facility (published in: Asteroids- Prospective Energy and Material Resources, Ed. V. Badescu, 2013, pages 415-438).

A. Germano, W. Grandl, „Solar Ark“, 1993 250,000 inhabitants, with „natural landscape“, green living areas and broad lakes



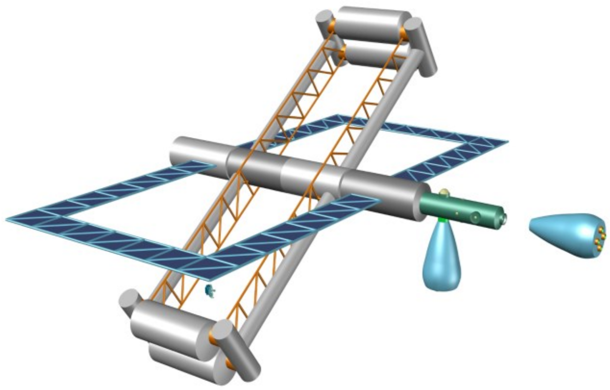
W. Grandl, A. Bazso, prototype Asteroid Colony, 2013, 2000 inhabitants

Current Studies and Objectives: The current ISS in orbit will probably be decommissioned until 2030. Besides the new Chinese orbital station we should develop a successor of ISS. For this reason we should propose a rotating orbital station with AG. New launch vehicles like SpaceX Falcon 9 or Falcon Heavy can carry payloads between 22 and 54 tons to Low Earth Orbit (LEO). Also the European Ariane 5ES or the Russian Proton M can launch about 20 tons to LEO. The SpaceX Falcon rockets now have reusable first stages and may reduce payload costs to approx. $ 2700 per kg.

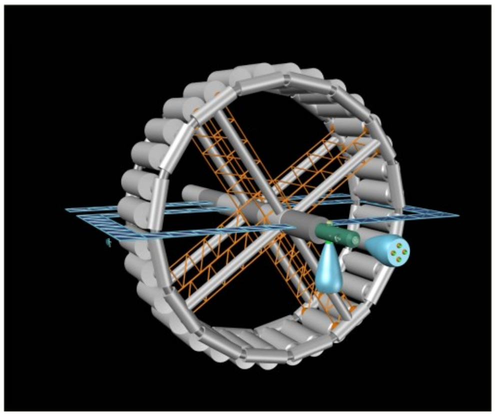
Werner Grandl and Clemens Böck are working since 2017 on the design of a modular orbital station called AGOS (Artificial Gravity Orbital Station). Although there is done much research on inflatable strutures, e.g. by Bigelow Aerospace, we propose hard-shell aluminium structures for the AGOS modules. Metal-frame hard-shell modules can be lifted into LEO with their entire furniture and equipment, air locks, etc., whereas pneumatic structures are emty after inflation. AGOS would be assembled in orbit by astronauts and assisting robots. The remains of ISS could be used as a „site hut“ and storage facility during assembling.

The initial stage 1 of AGOS contains four rotating living modules with 0.9 G, four zero-gravity central modules (two of them rotate), a docking module, connecting tubes and structural framework to stiffen the entire structure. The modules have 7 meter in diameter and 14 -18 meter length. The non-rotating framework carries 1600 m² solar panels. Two joints connect the rotating elements with the non-rotating parts of the station. The entire initial stage will have approx. 270 tons. Including the transport of robots, tools, etc., it will take 15 launches to establish stage 1.

Due to its modular design AGOS can be enlarged by „plug in“ of additional modules and structural framework. The possible final stage will be a closed ring of 32 living quarter modules with a maximum crew of about 180 persons.



AGOS initial stage 1, crew 24
length 78 m, span 102 m,
rotation radius 40 m
rotation rate 4.3 rpm



AGOS final stage, crew 180

Current Efforts & State of the Art (here shall be attached references to existing literature, polices, agreements and formal recommendation made by the specialists)

Coming soon

Current engineering work and development plan:

- Designing the „Roto-Joint“ which connects rotating and non-rotating parts of AGOS
- Light- weight structural design of the cylinders
- Workout of a time schedule
- Estimation of costs (stage 1, 2, 3, final stage)

Partnerships

- Looking for partnerships with technical universities, ESA, space industries

Coming soon

Resources (A list of organizations and offices working on this topic).

Coming soon