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Human life in the Solar System

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ABSTRACT

The goal of this paper is to provide an overview of ideas and proposals for space stations and space colonies since the last hundred years, starting with the Russian space pioneer Tsiolkovsky and focusing on some recent projects of the author. A permanent lunar base will be the first step, but Moon and Mars have much less gravity than Earth. For this reason engineers and architects were searching for space habitat design using artificial gravity. Rotating space stations – modular, toroidal, spherical and cylindrical – may provide a comfortable environment for astronauts and space settlers of the future. Within the so called "habitable zone" between Earth and Mars natural sunlight can be used for the illumination of space stations and space colonies. In the long run asteroids and the Moon will be mined and may provide the building material for large self-sustaining space colonies. Water can be taken from icy Near Earth Asteroids. We discuss methods of meteorite and radiation shielding as well as thermal protection. Hollow asteroids can be used as a natural shelter for space stations after the end of the mining process.

Contents

1. Introduction

If we accept the survival of Homo sapiens as a final purpose, we have to stretch the concept of nature beyond the biosphere and have it comprehend also the cosmic evolution with all its dangers to survival. Global and cosmic deviations and incidents, be they on a smaller or larger scale, belong to the most terminal menaces to the survival of most or all species on Earth. To build self-sustaining space stations and colonies by the use of lunar and asteroid resources will be a crucial step of human evolution, it will definitely establish human civilization in space. To be independent from Earth is a "life insurance" for the human species in case of

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global disasters caused by nature itself, like super volcanoes, ice ages, asteroid impacts, novae and other cataclysmic events that we may expect in the far future.

First of all we give a compact history of space architecture focusing on rotating orbital stations from the 1920ies up to utopian space colonies of the 1970ies. Then we discuss the simulation of artificial gravity, the use of extraterrestrial material for radiation and meteorite shielding and mention the in situ resource utilization (ISRU) of lunar regolith as an essential material for lunar structures. Besides a successor for the ISS a permanent lunar base will be the first step within the next decades. We describe the author's recent projects to build an initial lunar base including the design of a multipurpose machine for various lunar operations. We show the possibility to use recently detected big holes and lava tubes below the lunar surface for permanent human habitats.

We describe Near Earth Asteroids as possible locations for human colonies with artificial gravity. Probes to Near Earth Asteroids (NEAs) and the development of methods to deflect hazardous asteroids will be some of the next milestones in space technology. NEAs contain important elements such as iron, aluminum, uranium and gold. Some asteroids consist of carbon and water ice, some contain even rare-earth elements [1]. Future mining of asteroids will yield the raw material for an increasing space industry in Earth orbit as well as in the Lagrange points of the Earth-Moon system. Space mining and space industry will enable us to build advanced space stations and at last large rotating space colonies. Finally we present a design for giant space colonies of the far future, called Solar Arks, derived from utopian concepts of the 1970ies, including a model of an artificial climate.

2. A short history of space architecture

In 1926 the Russian space pioneer Konstantin Tsiolkovsky was the first one who discussed the establishment of large colonies around the Earth [2]. He designed a spinning conical habitat in which trees and plants could be grown. His proposal prefigured later and even current space colony concepts and pointed out the possibility of creating artificial gravity. In 1928 Hermann Potočnic (pen name: Hermann Noordung), a Slovenian engineer and former officer of the Austro-Hungarian army, published an accurate design of a wheel-shaped orbital station called "Weltraumrad" (Fig. 1).

The rotating "Weltraumrad" was equipped with parabolic mirrors to use solar light for illumination and a small power station. It can be called the prototype design for many succeeding toroidal concepts.

In 1948 the ideas of Tsiolkovsky and Noordung were recognized by H. Ross and R.A. Smith of the British Interplanetary Society. They envisaged a space station embodying wheel-shaped living quarters (30.5 m in diameter) supporting a big parabolic mirror to collect solar energy for a turbo-generator [2].

In the early 1950ies Wernher von Braun proposed a pneumatic torus as an initial orbital station. The wheel-shaped station was the first concept to use inflated structures in space. Based on von Braun's idea NASA built experimental models in the 1960ies but did not carry on the concept later. But in 1968 the famous movie *2001 – A Space Odyssey*, based on a novel of British scientist Arthur C. Clarke, showed a wheel-shaped orbital station to the public.

During the 1960ies NASA engineers developed various concepts of modular space stations based on the payload capacity of the Saturn V launcher, both zero-gravity and rotating low-gravity stations. Due to the decreasing NASA budget in the 1970ies all these projects were canceled and only the small SKYLAB mission was completed successfully. Meanwhile Russia (the former USSR) established the MIR orbital station, built of cylindrical modules and nodes, not unlike the former NASA concepts and somehow a precursor of the present ISS.

Despite low space budgets all over the world during the 1970ies some ambitious designs for advanced space colonies emerged from academia. In 1975 the so called *Stanford Torus* evolved by a group of engineers and students during the Ames-Stanford summer study. The essence of the design was a wheel-shaped habitat of largely metal construction spinning in an outer, non-rotating casing to which a shield of lunar rock has been applied for protection against radiation and meteorites. The design emphasized the use of extra-terrestrial materials preferably from the Moon. "Mooncrete" – or lunar concrete – should be produced by processing lunar rocks in a factory. The torus should have a diameter of 1.6 km and was considered to have a population of 10,000 people. The *Stanford-Torus w*ould have been sited in the stable Lagrange points L4 or L5 of the Earth-Moon System [2].

The most amazing proposals for future space colonies were made by Gerard K. O'Neill, Space Studies Institute, Princeton, in 1975. Giant rotating cylinders entirely made of extra-terrestrial material, the biggest one called *Island 3*, should have been 36 km long and have a diameter of 6.5 km [4]. Several hundred thousand inhabitants were proposed to live in an artificial bucolic landscape (Fig. 2).

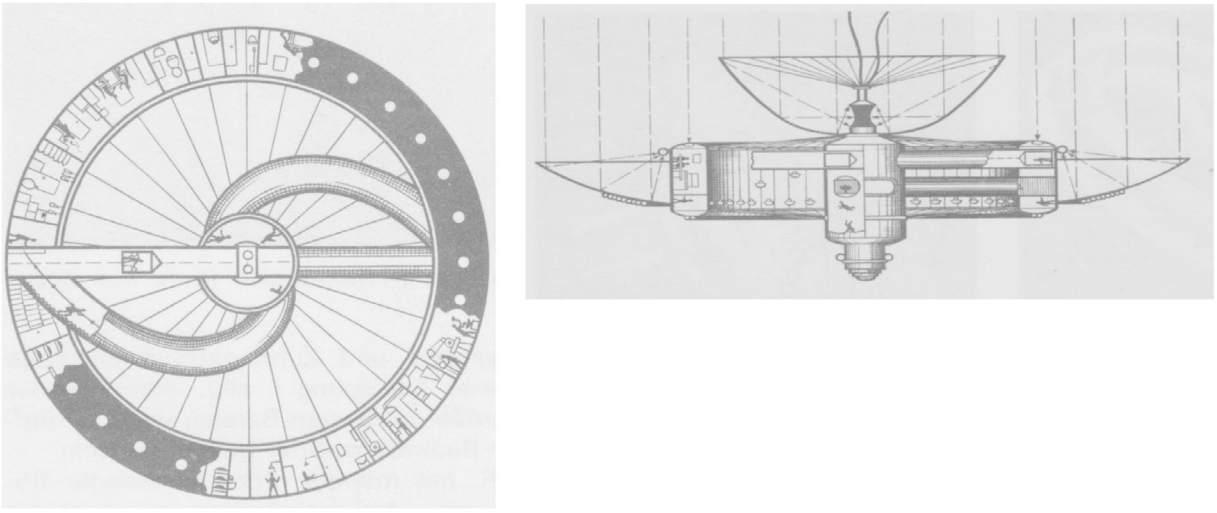

Fig. 1. The "Weltraumrad" (space wheel) of Hermann Noordung (1928) with a diameter of approx. 50 m and a maximum crew of 50 persons [3].