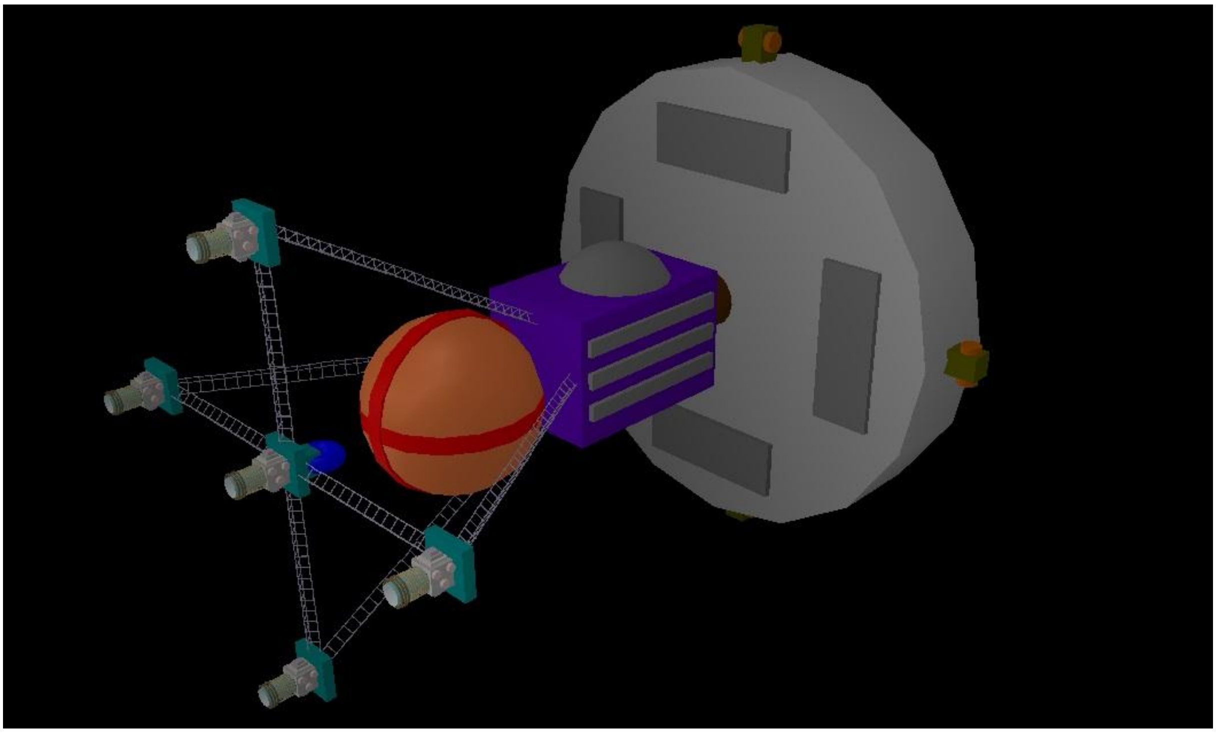
A conceptual design of an interplanetary exploration spaceship with electric high-thrust plasma-propulsion of “Helios”-type

D. Kirmse
danny.kirmse05@gmail.com

Abstract: Nowadays and in the near future the spaceflight to the planets and moons of our solar system is one of the great challenges of space-technology.
Whether robotic and manned to the Mars or on a large-scale exploration mission to the moons of Jupiter, a new kind of payload demands a next step in development of spaceflight technology. Not satellites but spacious ships have to bring extensive exploration equipment, landing vehicles, ground facilities or even human passengers to their interplanetary targets. Such space-vehicles need new kind of space-propulsion too; more than this, the development of adequate new propulsion is crucial for the realization of this kind of missions.



1 Concept of a spaceship for interplanetary exploration with "Helios" thruster as main propulsion unit

Introduction

The voluminous and heavy space-ships that are demanded for the next step of interplanetary exploration need a new kind of propulsion. Propulsion that has to fulfill specific requirements regarding the type of mission. Most important is the ability to bring a space-ship with large inertial mass to its interplanetary target as fast as possible. Especially with human passengers onboard this is crucial.

A “Helios” thruster for instance, with its large number of particles extracted with high velocity, is able to generate sufficient thrust for such kind of exploration missions. Since thrust is the change of impulse per time, “Helios” influences the resulting impulse even of a mass-rich space-ship in a comparable short time-frame. Direct steerable exploration-ships with a powerful high-thrust engine are the must-have for the future of investigating the space; particularly for the manned journey into the solar system.

Compared with other propulsion types electric propulsion shows general characteristics, that makes it very suitable for interplanetary exploration. The major benefit is the ability to couple into the thrust-generating fuel external electric energy. Hence, it is possible to enhance the thrust-efficiency per extracted particle above the energy-content of the fuel itself. The fuel can be used much more efficient than e.g. with chemical propulsion; especially for long-term journeys into the deep space of the solar system this benefit saves fuel and therewith weight. It is also possible to adjust the thrust-level and to switch off and on again the thruster on demand. These characteristic options of electric thrusters deliver maneuverability in space that simplifies the planning of missions to other planets. And further, space-ships with electric propulsion have therefore a much higher flexibility to react to sudden disturbances within the flight-path. In the light of these features electric propulsion is doubtless an ideal fundament for development of new high-thrust propulsion for interplanetary exploration.

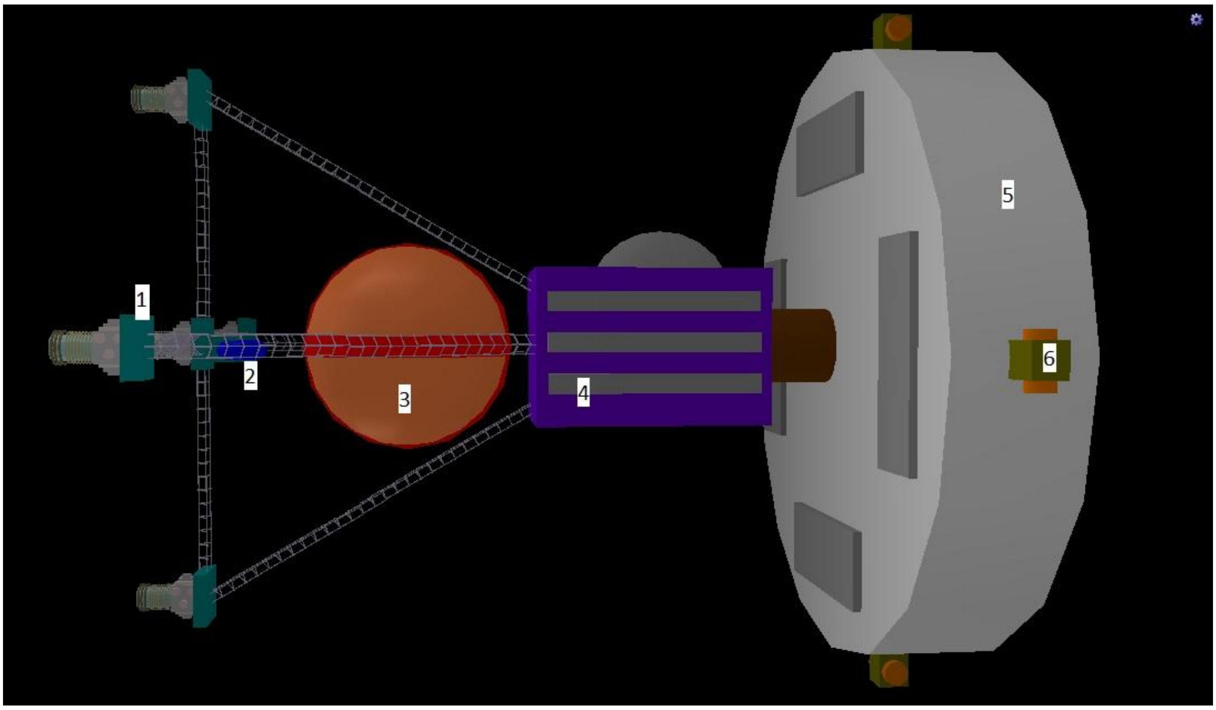
The basic work-principle of every thruster is to generate an impulse that is overlayed with the initial impulse of the space-vehicle. And the sum of initial impulse plus thruster impulse determines the movement of the vehicle. To achieve a significant influence of the thruster onto the absolute movement of the space-vehicle, the impulse of the thruster has to be in the order of magnitude of the vehicle’s initial impulse. An impulse equals velocity times mass. The impulse of the thruster is equivalent to the impulse of the ejected fuel-particles; the velocity times the mass of these particles. As mentioned above, the velocity of extracted particles can be raised to a maximum with electric propulsion. Unfortunately, the number and therefore the mass of extracted particles is extremely low here. This means, the path from present electric propulsion towards high-thrust propulsion leads via the enlargement of ejected fuel-mass.

There are two cardinal ways for amplifying this mass: heavier particles or more particles have to be extracted. Heavier particles (like e.g. charged Teflon-flakes) lead to a granularity and therewith to a principle roughness of the produced thrust. Hence, the ejection of more instead of heavier particles seems to be the more progressive way towards high-thrust.

Within this context, the “Helios” plasma-propulsion concepts are examples for the achievement of high-thrust through increasing the number of extracted particles. The “Helios” thruster-type is designed to ionize a fuel-gas under high-pressure condition with the intention to produce a huge number of charged particles that are able to generate thrust by electrical extraction. “Helios” is a system in two stages. The first pre-ionizing stage is responsible to improve the conditions for ionizing. And with this improved conditions the main-stage is able to ionize a gas under high pressure.

Spacecraft setup

Figure 2 shows the structure of the entire spaceship. (1) The propulsion system consists of five thrusters of “Helios”-type. (2) Behind the center thruster the electric energy producing converter is located. (3) As storage for the fuel-gas that is accelerated in the thruster system serves a sphere-shaped tank. (4) The segment for payload contains all equipment that is necessary to fulfill the exploration mission. (5) The workstations and the private quarters for the passengers of the spaceflight are integrated inside the passenger cabin. (6) On the periphery of the passenger cabin secondary thrusters are placed with the task to rotate the cabin around the middle-axis.

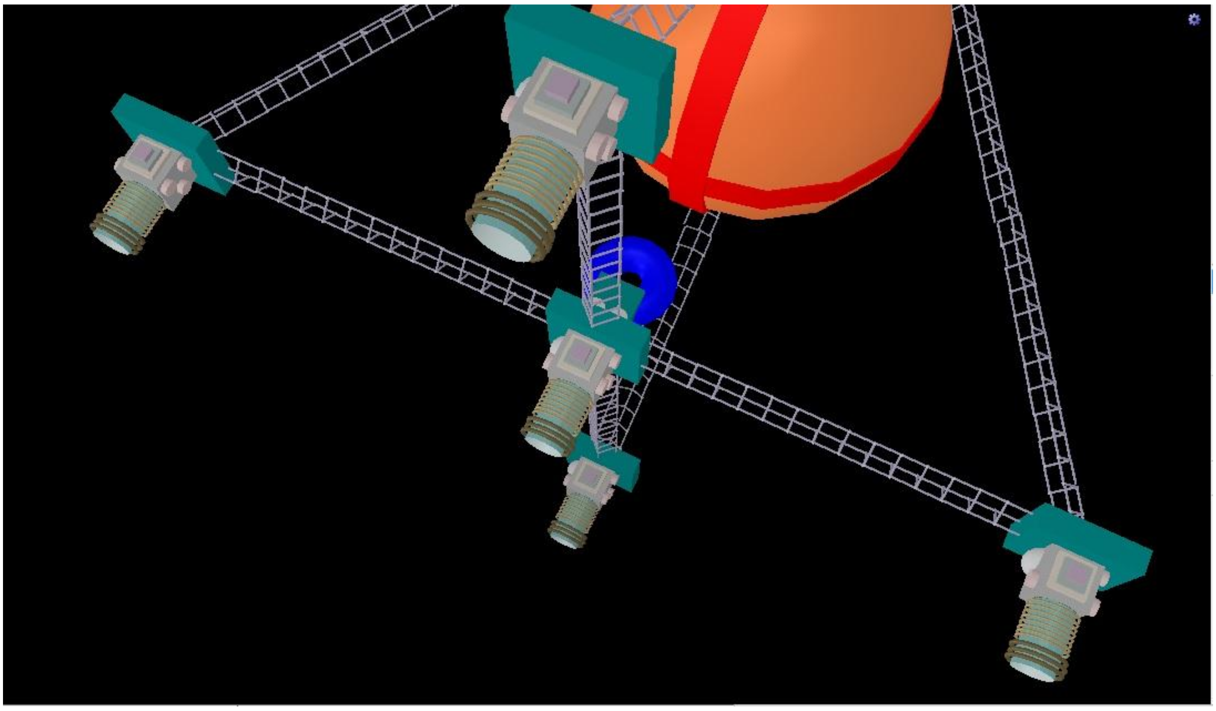


2 Setup of the spacecraft: 1-Propulsion unit, 2-Energy converter, 3-Fuel tank, 4-Payload segment, 5-Passenger segment, 6-Secondary thruster for passenger cabin rotation

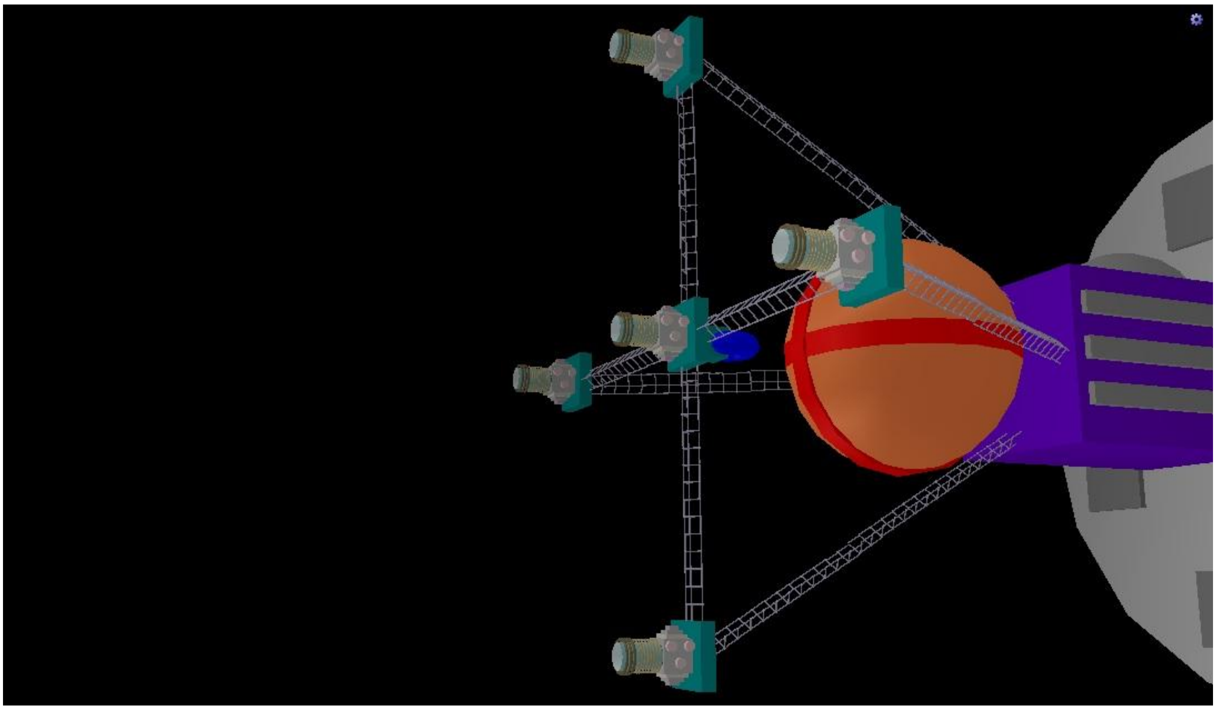
Propulsion system

There are two major requirements for the propulsion system of a manned exploration ship: High thrust and very flexible steering. Since the travel-time for astronauts has to be as short as possible the generation of high thrust-levels is required. The “Helios” high-thrust plasma-propulsion concepts are able to fulfill these requirements [1], [2]. Each of these “Helios” thrusters has the ability to eject a large number of fuel particles with a high velocity and to generate high thrust in this way.

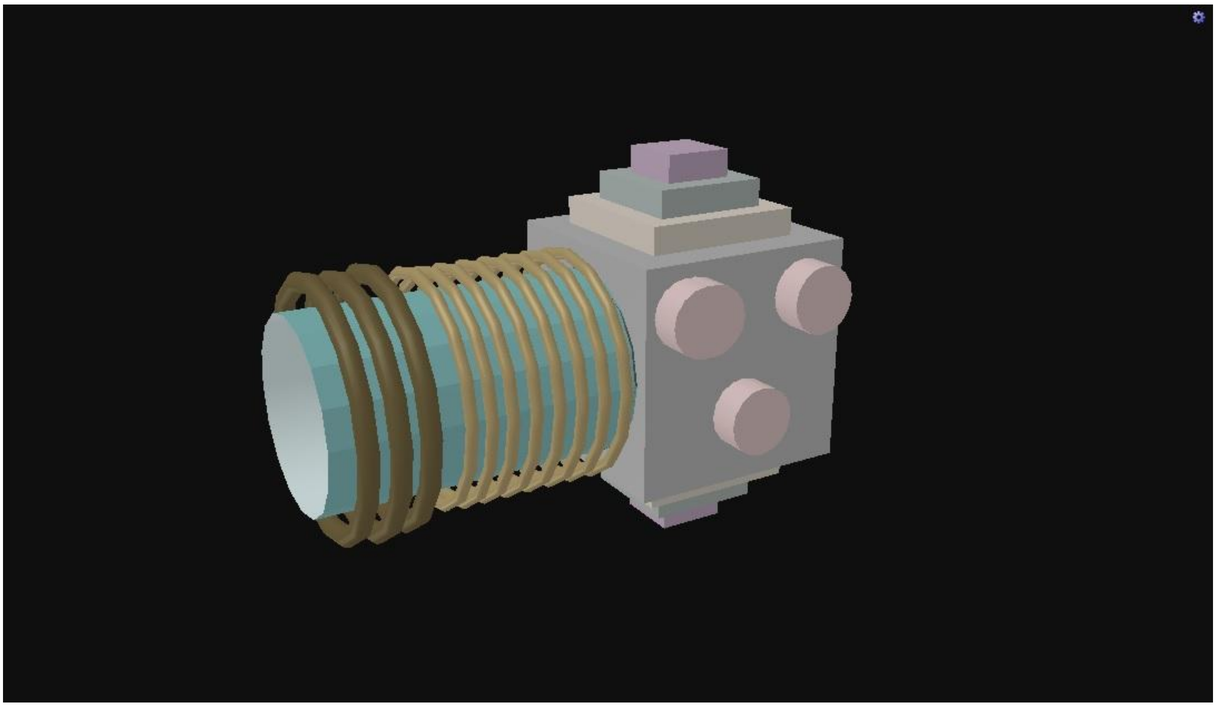
The whole propulsion unit consists of five “Helios” thrusters. One is in the center and four arranged quadratic around the center one. If all thrusters are working at equal level the propulsion unit is a powerful thrust-generator towards the targeted direction. But via the opportunity of switching off single thrusters or adjust the thrust-level of each thruster the entire spaceship can be turned in every requested new direction. This skill of the propulsion system gives the spaceship a very efficient and quick-responding flexibility in steering and piloting.



3 Thruster arrangement of the main propulsion unit



4 The tank for the fuel-gas is realized sphere-shaped between the propulsion system and the payload segment.



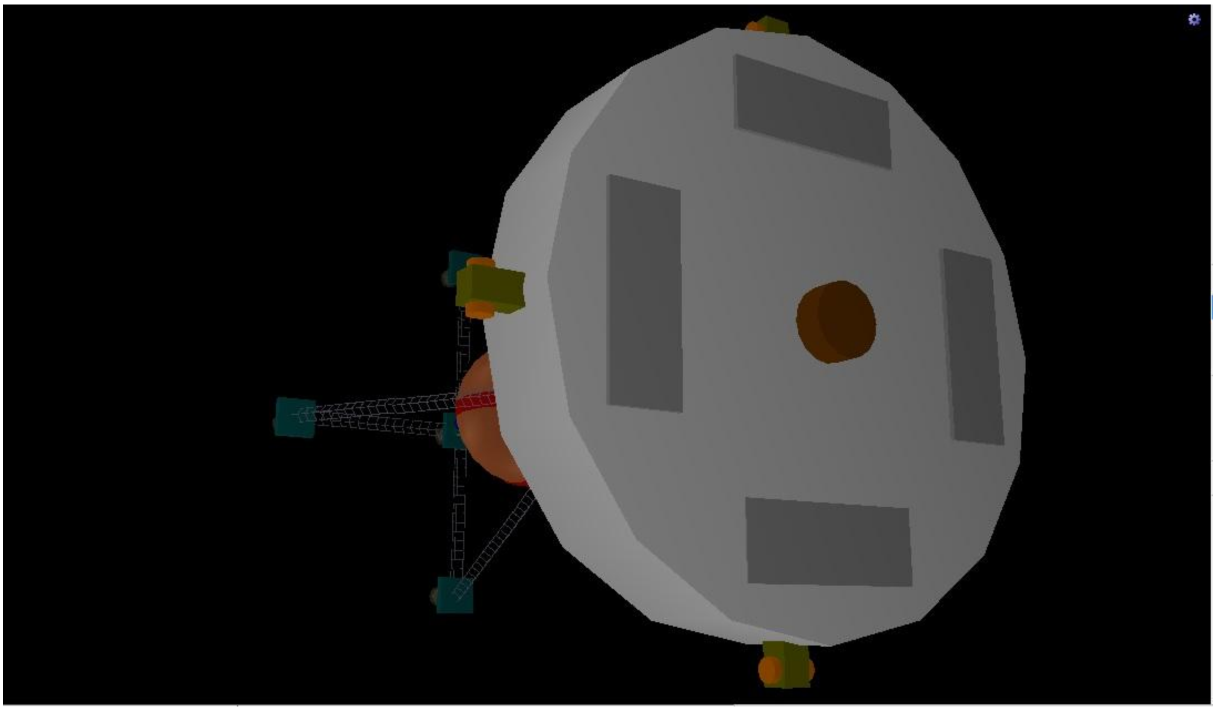
5 "Helios" high-thrust plasma-thruster

Passenger cabin and payload segment

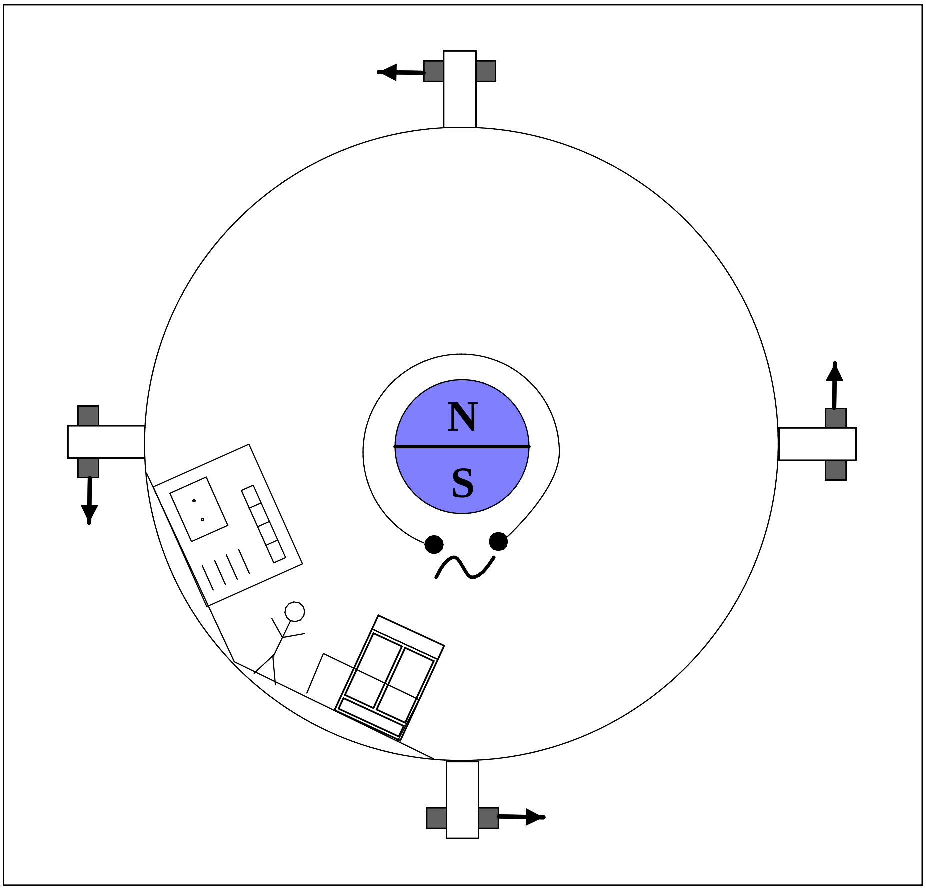
The utilizable infrastructure of the spacecraft consists of a payload segment and a passenger cabin. The equipment that is needed for exploration at the mission target is stored inside the payload segment. This includes satellite probes for orbital scanning, landing vehicles and the equipment for living on the planetary surface and exploring it.

The habitats for the astronauts and any control and exploration infrastructure that is needed during the flight are placed inside the passenger cabin. The cabin is cylinder-shaped and it is possible to rotate it around a center axis. Secondary thrusters that are arranged at the periphery of the passenger cabin produce a tangential thrust to maintain this rotation. This rotation produces a centrifugal force against the outer wall of the passenger cabin. The habitats and the workstations of the astronauts are located on the bottom of this outer wall. This provides the possibility to imitate a gravitational force during the flight that supports the well-being of the astronauts on their journey.

Additionally, there are permanent magnets inside the axis and electric wires in the passenger cabin. Thereby the rotation of the cabin generates additional electric energy by induction.



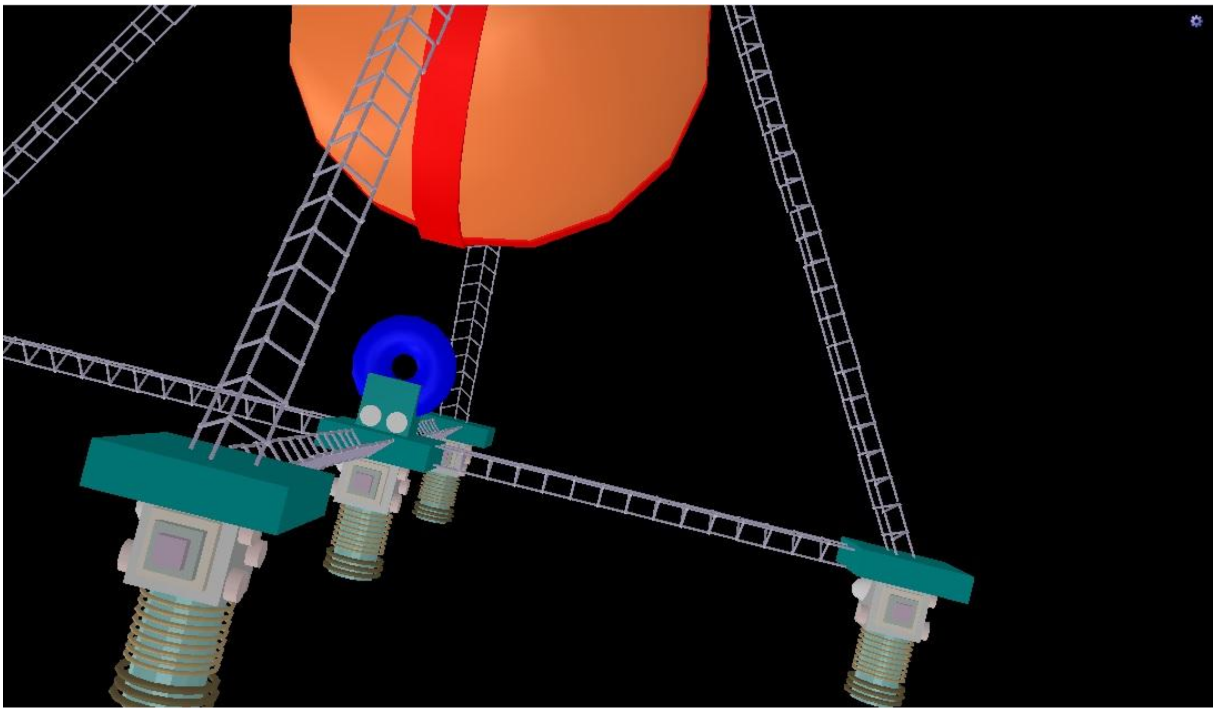
6 Front-view of the spacecraft with passenger cabin in the foreground



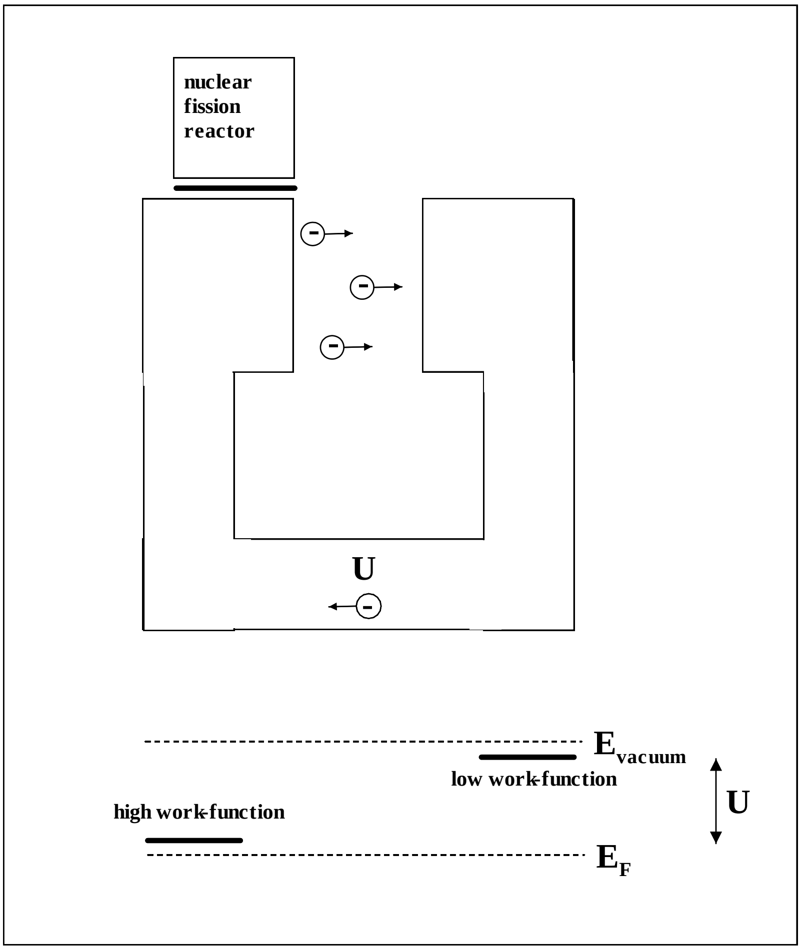
7 Look inside the passenger cabin; cross-section

Energy system

The task of the energy system is to convert thermal energy into electric energy. Here a thermionic converter performs this function. A thermionic converter consists of two different materials; one with a low work-function and one with a high work-function. The difference of these work-functions with respect to the Fermi-level determines the voltage of the power system directed for electrons from the low work-function to the high work-function. To generate the electrons that are accelerated by this voltage the end of the converter with the high work-function has to be heated. Trough heating electrons leave the surface of the material with the high work-function and penetrate the surface of the material with the low work-function. The voltage inside the system accelerates these electrons from low work-function to high work function. This resulting electron current is the source of the needed electric energy. A small nuclear fission-reactor produces the heat that is required for this process.



8 The energy converter for the generation of electric energy is located behind the center plasma thruster



9 Functional scheme of a thermionic converter

References

[1] D. Kirmse: “Two concepts of high-thrust plasma-propulsion engines for use as main-thruster units for interplanetary exploration” 2014; http://vixra.org/abs/1408.0096

[2] D.Kirmse: “An estimation of power-consumption and thrust-generation at a medium-sized thruster of Helios-type” 2015; http://vixra.org/abs/1511.0161