The Expedition to Jupiter

Dr. Alexander Rubinraut
Freischützstr.110, 81927 Munich, Germany

Abstract - For the first time a project of the expedition to planet Jupiter is proposed, which provides for the implementation of the high-speed flight lasting 68 days from the Earth orbit into orbits of Jupiter and Europa – Jupiter's satellite, at the total amount of expense about 2 billion $ with preliminary launching onto the Europa orbit “the space refueller”, which after landing on the Europa surface, covered by a layer of the water ice, making use a water ice melter, water-to water nuclear reactor, electrolyzer and liquefier produces the working substance being used for return flight from the Europa orbit onto the Earth orbit by cruise electrorocket engine of the space train, consisting of space locomotive, tanks-containers with working substance and takeoff-landing capsule, being launched earlier by means of carrier rocket "Arian 5".

Keywords – Jupiter, Europa, Io, space refueller, ice melter, electrolyzer, liquefier, space train, the system of the electro propulsion of the space train, carrier rocket "Arian 5".

The mastering of the interplanetary space - the main dream of astronautics pioneers Ciolkowsky, Obert and Hogart, can start in 21 century. The rapid development of the astronautics in 20 century has resulted in the mastering of the circumterrestrial space and the expeditions to Moon. But in the last decade of the twentieth century after the end of the cold war and the disintegration of the USSR, the rates of astronautics’ development have in some extent decreased. The space industry had been placed on the commercial basis.

The main achievement of the recent time is the creation of the international space station (ISS), which may become the port, from which the space ship can depart to planets of the solar system. Already the various projects of the expeditions to Mars[1] are developed, which can be considered as the first step towards the human visit of another planet.

A specific feature of expedition to Mars [2] is the usage of the rocket "Ariane-5" to put into Earth orbit the separate modules: the space locomotive, tanks with the working substance and the takeoff-landing capsule.

Making use the docking, at the Earth’s orbit, a space train is formed, which then begins to move towards the Mars orbit. The other feature of the project [2] is the usage of the sustainer electromotor, invented by the author [3], and providing high efficiency and long service life.

The design results have proved that the high-speed flight to Mars can become a reality in the most near future. This allows to move on and take the next step in the mastering of interplanetary space.

In this article, a project of an expedition to planet Jupiter is proposed. The data referring to Jupiter, which are now in the possession of the modern science, as is known, has been derived from astronomical observations and flights of unmanned spacecraft [4]. Thanks to flights the spacecrafts "Pioneer 10" (1973), "Pioneer 11" (1974), the "Voyager 1".

"Voyager 2 "(1979), and the observations made by means of telescope Hubble (beginning from 1990), some remarkable discoveries were made. Especially impressive were the results of researches of the Jupiter atmosphere structure made in 1995 by the probe, which was got down on the parachute from the space craft "Galileo". In 2000 the spacecraft “Cassini”, which was going to Saturn, flew past Jupiter after covering the distance between the orbits of the Earth and the Jupiter for 16 months.

The spacecraft “Cassini” had transmitted the photos of Jupiter surface and the spectrum of its atmosphere.

The time had come to prepare for an expedition to Jupiter.

The purpose of the proposed project is the carrying out the scientific observations during the flight to Jupiter, the flying around Jupiter in immediate vicinity to its surface, the visits the Jupiter' satellites Europa and Io, followed by the closing stage of the expedition - the return to the Earth orbit.

For carrying out the expedition is used the rocket technique, which was developed earlier for carrying out the Martian expedition and is described in details in [2].

Thus the block diagram of the space train, which is assembled on the Earth orbit out of separate elements by means of consecutive docking, remains.

The separate elements: the space locomotive, tanks-containers with working substance and the takeoff-landing capsule with a cabin for astronauts are placed into the Earth orbit with the help of carrier rocket «Arian-5». The scheme of an interorbital rocket train for flight to Jupiter is shown at the Fig. 1.
The movement of the carrier rocket is provided by means of the locomotive 1, which has electric rocket engines 5. For feeding of the electric rocket engines 5, the power supply - the nuclear reactor with MGD generator and turbogenerator, is installed aboard of the locomotive. The working substance for electric rocket engines 5 (liquid hydrogen) is stored in the tanks-containers 2,3, which are docked the locomotive 1 along the horizontal axis.

The capsule 4 is the useful load of the carrier rocket and is intended for landing at the solid surface of the Jupiter satellites Europa and Io after their orbiting, as well for taking off the surfaces of the satellites and for orbiting them after the end of the stay. These operations are performed by means of the chemical rocket engine 9. Inside of the capsule 4 the crew cabin is located. In order to provide at the process of the expedition the artificial gravitation in the cabin, the capsule rotates relative to its transverse axis.

The main conceptual special feature of the high-speed flight to Mars [2] was the following: before the main flight of the carrier rocket, a preliminary flight is performed, which purpose is the delivery into the Mars orbit the tank-container with the working substance. This make it possible completely to use the working substance, which is located in the tanks-containers 2 and 3, during the main flight from the Earth orbit to the Mars orbit and to use for the return the working substance, which was sent into the Mars orbit in advance and being stored in two tanks-containers.

As a result, the fuel consumption during the main flight increases in twice, the speed of the carrier rocket increases accordingly and the duration of interorbital flight decreases in twice.

But the realization of the preliminary flight resulting in the delivery of the working substance into the orbit of a planet or its satellite takes too much time.

In order to prove it, let us consider the preliminary flight into the orbit of the Jupiter satellite Europe, which is fulfilled in accordance with the diagram shown at Fig.2.

The space train, being driven by the locomotive 1, has three tanks-containers. Two of them (4 and 5) are delivered, as the useful load, into the Europa orbit. After Europa orbit attainment, the separation of space train takes place (by means of the docking assembly 6). The tanks-containers 4 and 5 remain in the Europa orbit, and the locomotive with the tank-container 3 returns out the Europa orbit into the Earth orbit by scheme shown at Fig.3.

Fig.2 and Fig.3 show that for carrying out the preliminary flight out of the Earth orbit into the Europe orbit it is necessary to spend a half of the working substance, which is there in the tank-container 3.
The second half of the working substance, remaining in the tank-container 3, will be spent to provide the return of the locomotive 1 with the tank-container 3 into the Earth orbit.

After return of the locomotive 1 into the Earth orbit, the train for the main flight into the Europa orbit (Fig. 1) is formed. During the main flight, the working substance, which is in two tanks-containers 2 and 3, will be spent.

The last stage of the main flight: the flight from the Europe orbit into the Earth orbit is also performed in accordance with the scheme 1, using two tanks-containers, which were at the Europe orbit. Thus the mass of the working substance, which is used for the preliminary flight, makes about ¼ of the working substance mass, used for carrying out the main flight. This results in substantial time increase for fulfillment of the total complex of operations providing delivery of cargos and expeditions to planets of the solar system.

The calculations show: if the mass of each component of the space train, shown at Figs 1, 2, 3, is about 20 T, the preliminary flight to the Europe orbit and back can last almost 2 years.

In the search process of the new concept for realization the flight to Jupiter, the attention was paid to the geological structure of the Europe. According to the data of the newest researches, the surface of the Europe is covered with the layer of the water ice. If this ice to convert in the liquid water and out of the liquid water to obtain gaseous hydrogen, it is quite possible to convert the gaseous hydrogen to the liquid state and to deliver it from the Europe surface into its orbit. In this case the necessity for the preliminary delivery of the working substance from the Earth orbit, falls away.

Now into the Europe orbit shall be delivered a stand-alone apparatus, which is able to perform all the necessary operations for filling of the carrier rocket with the working substance.

The scheme of the preliminary flight of the carrier rocket with such a refueller is shown at Fig. 4.

For the purpose of the refueller delivery into the Europe orbit, a space train is formed at the Earth orbit. The space train (Fig. 4) consists of the locomotive 1, having the electrorocket engine 2, two tanks-containers 3 and 4 with the working substance, connected by means of the docking assembly 5 and the stand-alone space refueller.

The refueller 6 is launched out of the Earth surface and is put into its orbit. Then by means of the docking assembly 7, the space refueller is connected with the tank-container 4. By means of the locomotive 1 the space train (Fig. 4) reaches the Europa orbit and during this flight the working substance, which is found in the tanks-containers 3 and 4, is consumed completely.

On the Europe orbit, the separation of the space train takes place. The locomotive 1 with the empty tanks-containers remains on the Europe orbit, while the refueller 6 with the help of the chemical rocket engines 8, working in the braking mode, leaves the Europe orbit and carries out the landing on its surface. With the help of the equipment for liquid hydrogen production out of the water ice, which is installed in the refueller, the working substance, which was produced by the refueller equipment itself, is pumped in the hydrogen tank of the refueller.

With the help of the chemical rocket engines, the refueller starts from the Europe surface and orbits it. After approaching the space locomotive 1, the refueller docks to the tank-container 4, making use the docking assembly 7.

Then the pump for pumping the working substance is switched on and the liquid hydrogen, which is found in the refueller, pours into the tank-container 4. After emptying of the refueller tank, the refueller is detached off the tank-container 4.

Then the refueling cycle is repeated: the refueller leaves the Europe orbit and carries out the landing on the Europe surface, produces the working substance out of ice and again orbits the Europa, docks to the tank-container 4.

After fueling the second tank-container, the refueller 6, with the help of the docking assembly 7, detaches off the tank-container. The rocket engines 8 are switched on and the refueller carries out the landing on the Europa surface.

Thereby, the permanent readiness is maintained to fill again the working substance into the carrier rocket and falls away the necessity in carrying out the preliminary flights under fulfillment of the repeated expeditions. The final stage of the preliminary flight is carried out in accordance with the scheme, which is shown at Fig. 5.
The space locomotive with the help of the electrorocket engine 2, using the working substance in the tanks-containers 3 and 4, is going to Earth. After orbiting the Earth, the locomotive 1 is ready to form the carrier rocket, which is shown at Fig. 1, and must carry out the main flight to the Europe – the satellite of Jupiter.

First of all for the flight it is necessary to form the space train, which is shown at Fig. 1. To this purpose, three launchings are carried out with the help of the carrier rocket “Arian-5”. With the help of the first launching into the Earth orbit the tank-container 2, filled with the working substance, is put. The train formation begins: with the help of the electrorocket engines 5 the space locomotive approaches and docks the tank-container 2. Then with the help of the second launching into the Earth orbit the tank-container 3 is put, which with the help of the docking assembly 6 docks the tank-container 2.

With the help of the last launching, the takeoff-landing capsule 4 is put into the Earth orbit. The takeoff-landing capsule 4 is put into the Earth orbit (without astronauts) by means of the carrier rocket “Arian-5” and with the help of chemical rocket engine 9 begins to approach to the international space station ISS. Then in an automatic mode, the taxing and docking to one of the ISS docking assemblies are carried out. After the docking the crew of the expedition, which was delivered beforehand at the ISS, moves into the cabin, located inside the capsule 4. By means of the chemical rocket engine 9, the capsule 4 “pushes off” the ISS and goes into orbit of the space train being formed.

After the docking of the capsule 4 with the tank-container 3 (by means of the docking assembly 7), the space train, consisting of four elements connected, as it is shown at Fig. 1 is ready for the flight to Europa.

Now, the fourth stage of the expedition to Jupiter begins: the attainment the Europe and the landing on its surface. After switching on of the electric rocket engines, the space train speeds up and at attainment of the second space velocity comes into the calculated flight trajectory.

With the help of computerized calculation programs, a search of the optimal calculated trajectory of the flight to Jupiter was carried out. This trajectory has proved to be similar to the trajectory along which the spacecraft “Cassini” had successfully flown in 2000.

The arrangement of the planetary orbits and the calculated flight trajectory are shown at Fig. 6.

At the movement of the space train along the calculated trajectory, the expenditure of the working substance and the decrease of the general mass take place.

The variation process of the movement speed and the mass of the space train in the course of time is shown at Fig. 7.
Fig. 7

The process begins at the motion of the train in the Earth orbit around the Sun from the point “O”.

At this moment Jupiter is also in its orbit on the position “O” and moves 12 times more slowly than Earth. At the first part of the flight, the space train accelerates. The movement is accompanied by an increase in speed and the decrease of the general mass. In 27 days the flight speed of the space train reaches 400 km/s.

At the point 2 the train leaves the circular orbit and proceeds with the movement along the calculated trajectory, which has the form of parabola. The cruise rocket engines are switched off and the movement continues. The space train accelerates, the movement is accompanied by an increase in speed and the decrease of the general mass. In 47 days of the flight, the train approaches the planet Jupiter. By means of the thrust vector change on 180°, the braking of the space train, using the working substance, which is there in the tank-container, is carried out. Decreasing the movement speed, the space train goes into the Jupiter orbit in 66 days of the flight. At this time Jupiter, moving along its orbit, reaches the point 3, where already the space train is.

The space train, maneuvering by means of electrorocket engines, crosses the orbits of Jupiter satellites Calisto and Ganymede. Then it makes one more maneuver and orbits Europe. After speed decrease up to 2 km/s, the space train carries out the orbital flight around Europe. Then the space train divides.

The takeoff-landing capsule 4 comes off with the help of the docking assembly 7. The astronauts, which are in the capsule, carry out the landing on the Europe surface. For this purpose, they switch on the chemical rocket engine 9 and move the capsule 4 into the braking mode.

When the speed decrease lower than 2 km/s, the capsule loses weightlessness and is directed to the Europe surface.

With the help of the rocket engine 9, the soft landing in the chosen area on the Europe surface is carried out. (It shall be kept in mind, that the gravity on the surface of Europe by 7.7 times less than on the surface of Earth) After the landing, the astronauts begin to carry out the research program, which is intended for 7 days.

For movement over the Europe surface, the astronauts use a delivered vehicle - “rocket sledge”.

At the same time the space train, shown at the Fig. 5, moves along the Europe orbit with empty tank-container 3 and 4. The space refueller, which was delivered on the Europe surface, gets a starting signal.

All the elements, intended for working substance production on the Europe surface, sequentially join in the work.

After completion of the working substance production cycle, the stand-alone refueller takes off the Europa surface and orbits it.

Being on the Europe orbit, the refueller approaches the space train and docks to it, as it shown at Fig. 4. The cryogenic pump is switched on and the working substance is pumped over from tanks of the refueller into tank-containers 4 and 3. After the completion of the refueling, the refueller 6 comes off from the train, leaves the Europe orbits and carries out the landing on its surface.

The space train continues the movement along the Europe orbit already with completely filled tank-containers 3 and 4.

After completion of intended research program of stay on Europe, the astronauts take the places in the crew cabin and switch on the chemical rocket engine. The takeoff-landing capsule begins to move straight up and at achievement of the orbital velocity it goes into the Europe orbit, along which the locomotive 1 (Fig. 1), docked to tank-containers 3 and 4, moves.
After docking the capsule 4 to the tank-container 3, the electrorocket engines 5 of the locomotive 1 are being switched on and the second stage of the expedition, during which the astronauts carry out the researches at the Jupiter satellite — Io, begins.

After switching on the electrorocket engines 5, the space train moves from the Europe orbits into the Io orbit, which is at the distance of 250000 km.

Moving along the Io orbit, the space train divides and the capsule 4, with the help of the docking assembly 7, moves away the tank-container 3. With the help of the chemical rocket engine 9, the astronauts move the capsule 4 in brake mode and carry out the soft landing at a chosen area on the Io surface. During the time of stay on the Io surface (7 days) the astronauts carry out the research program, moving through the Io surface with the help of the backpack rocket accelerators, taking into consideration the specific features of the Io relief (mountains and volcanoes).

After completion of the researches, the astronauts switch on the chemical rocket engine and the capsule goes into the Io orbit.

After docking to the space train (by means of the docking assembly 7), the electrorocket engines 5 are being switched on and at achievement of the second space velocity the train leaves the Io orbit.

The third stage of the expedition -the flying around the planet Jupiter, which external envelope is at the distance of 421000 km from the Io orbit, begins.

The electrorocket engines are being switched on the total power and in three days the space train, at achievement of the first space velocity for Jupiter, goes into its orbit, which diameter is 144000 km. Moving around Jupiter, the astronauts carry out the intended program of the Jupiter probing.

After completion of these explorations, the last stage of the expedition – the return into the Earth orbit, begins.

During the stay in the system of the planet Jupiter, the space train have moved along the Jupiter orbit from point 3 to point 4 (Fig.6). The planet Earth, moving along its orbit, during the same period have passed from point 0 to point 1.

Now the space train must move from point 4 into point 2 along the familiar calculated trajectory, but in opposite direction. As the Earth moves towards to the train, the return way will be by 340 millions km shorter. And as it can be seen at Fig. 7, the flight duration from the Jupiter orbit into Earth orbit, decreases from 66 days up to 56 days. The flight between the Jupiter orbit and the Earth orbit along the trajectory : point 4 –point 2, is carried out at the operation of electrorocket engine in acceleration mode, in the free flight mode and in the brake mode at the rated power.

By going into the Earth orbit the space train (Fig.1) is being divided. The takeoff-landing capsule 4 is separated from the tank-container 3. The astronauts, which are in the cabin of the capsule, switch on the chemical rocket engine 9 and carry out a maneuver, resulting in the capsule going into the orbit of the international space station ISS. The capsule 4 “moors” to the ISS and docks it. The astronauts leave the capsule 4 and pass to the ISS. After unloading the specimens, being delivered from the Europa and Io surfaces the speed flight, which has lasted 136 days, is over.

According to [5] the cost of the carrier rocket “Arian 5” launching is 150 million dollars. Therefore, in order to carry out the five launchings, being planned in this project, it is necessary to spend 750 million dollars.

The costs of development and manufacturing of the space refueller will be within 1,25 milliard dollars.

Thus, one may expect, that the costs of implementation of the expedition to Jupiter, not exceeds 2 milliard dollars.

Now let us consider more in details the design of the space refueller, which is the “heart” of this project, as well the operation of electric motion system of the space train, being proposed in the project.

The refueller for the working substance refueling in space

The stand-alone refueller, when it is located on the external surface of Europe, is shown at Fig. 8
The refueller has an external housing 3, having the form of cylinder, which passes into the cone in head part of the rocket. In its tail part the chemical oxyhydrogen rocket engines 16 are installed, which provide the braking of the refueller at leaving the Europa orbit and the soft landing on Europa surface. The chemical rocket engines 16 are intended also for the refueller takeoff out the Europa surface and the going into Europa orbit. The fuel for the chemical rocket engines – the liquid hydrogen – is supplied by means of cryogen pipeline out the tank 6, which has the cryogenic isolation. The oxidizer – oxygen, is located in liquid condition in the tank 15, which has the form of hollow cylinder.

For carrying out the technological process, resulting in liquid hydrogen production out the water ice, the refueller has all the necessary devices.

The ice melter 8 is located in the bottom part of the rocket along its axis. The ice melter 8, which design is shown below, is intended for creation in the ice strata 1 a pool with the unfrozen water.

By means of the external heating, making use oxydric torches, the water temperature increases up to 274K and the ice melting takes place. In the ice surface 1, the pool 2 with the necessary volume of liquid (unfrozen) water arises.

After formation of the pool 2 with the unfrozen water, the device, which constantly maintains the necessary volume of the liquid water in the unfrozen pool 2 by means of feeding of the hot water by the piping 11, begins to take part in the technological process.

The piping 10 and 11 have a mechanical device with an electric drive, with which help the ends of the piping 10 and 11 are being moved out the bottom of the rocket and are sunk into the pool with unfrozen water.

The piping 10 and 11 are being connected to the condensing loop of the steam turbine generator. The steam turbine generator is a part of the refueller power installation.

The onboard power installation 9 is intended for supplying by heat and electric power all the devices of the refueller. It is arranged in form of cylinder, which is installed along the refueller axis. The onboard power installation consists of a water-moderated reactor, which has the steam turbine with condenser and turbogenerator in the secondary circuit.

For producing the gaseous hydrogen and oxygen out water the electrolyzer 13 is installed. The liquid water out the unfrozen pool enters in the electrolyzer 13 with the help of movable piping 12, which has the same design as the piping 10 and 11. In order to bring hydrogen and oxygen in liquid state, a liquefier 14 is being installed. It is arranged in form of a hollow cylinder, inside which the onboard power installation 9 is being located. The liquid hydrogen out the liquefier 14 enters in tank 4 and the liquid oxygen enters in tank 15.

The tank 4, in which the liquid hydrogen is stored, intended for refueling of carrier rocket, has the docking assembly 19, with which help the refueller is being connected to the tank-container of the carrier rocket.

The liquid hydrogen pumping-over at the refueling is carried out with the help of a cryogenic shaftless pump 6, which is installed at the cryogenic piping 5. For landing on the Europe surface, the refueller has telescopic legs 18 with the pointed shoes 17.

The technological scheme of functioning of the devices, being installed in the casing of the refueller, which was shown at Fig.8, is shown at Fig.9.
The onboard power installation has a water-moderated water-cooled reactor 5, which is realized in accordance with the well-known double circuit schema, being used in the industrial power supply systems. In the first circuit, the circulating pump 8 is installed. In the second circuit, the water steam is created with the help of a steam turbine generator and goes to blades of the steam turbine 7. On the shaft of the steam turbine 7, the electric generator 9 is installed, which supplies the energy for all functional components of the refueller. Steam condensation is carried out in the condenser 10, which design differs from the well-known condensers by the presence of two water cooling circuits. The cooling water from the first circuit 12 with the help of the circulating pump 17 goes through the piping into radiator of the electrolyzer 18 and into radiator of the liquefier 19. In such a way the task of the necessary temperature maintenance for components of the refueller with simultaneous cooling of the condenser, is being resolved.

The second cooling circuit of the condenser 11 with the help of the circulating pump 14 is intended for providing the constant volume of the liquid water in the unfrozen pool 2 by way of its warming up by warm water. For this purpose, the circuit of the condenser 11 is connected to the movable pipelines 15 and 16, which sink into the unfrozen pool with the liquid water. The pool with unfrozen water in the ice layer 1 arises originally with the help of ice melter 4, which consists of the gaseous oxyhydrogen torches being connected to tanks with hydrogen 21 and oxygen 23.

In the pool 2 with unfrozen water, the movable pipeline is located, which intended for the water intake in electrolyzer 20 with the help of the pump 26. The electrolyzer, which produces the gaseous hydrogen and oxygen out the liquid water, gets electric current from the turbogenerator 9.

The gaseous hydrogen and oxygen enter through pipelines into a liquefier 21. After liquefaction, the hydrogen enters into the tank 24 and the oxygen into the tank 23.

With the help of the cryogenic pump 25, the refueling of the tank-containers of the carrier rocket in accordance with the schema, shown at Fig. 4, is carried out.

A functional schema, which is shown at Fig. 9, has a computerized control system, as well the stand-alone systems of the guaranteed power supply and the startup of the refueller onboard power installation. The startup of the power installation is carried out with the help of electric generator 27, consisting of a battery of the oxyhydrogen fuel cells.

The structure of the ice melter is shown at Fig. 10.

The ice melter has a cylindrical case 6, in which internal cavity the gas burners 8 are installed.

The burner 8 operates in accordance with the well-known principle of the thermodynamic mixing. As the fuel, the hydrogen is used, which is fed into the combustion chamber 1 with the help of a nozzle 2.
As an oxidizer, the oxygen is used, which is fed under pressure from the chamber 3 into the chamber 1. For torch formation, the burner has an external tube 4 and for the mixing of the heat flow it has internal tube 5. The fuel and oxidizer feeding is carried out with the help of the tubes 10 and 11. For the passage of the water pipelines into condenser and electrolyzer, there are the holes 9 in the ice melter case.

The structure of the moveable pipeline, with which help the water intake from pool 2 with the unfrozen water takes place, is shown at Fig. 11.

In the position „a“ the pipeline is lowered in the pool 2 with the unfrozen water, and in the position „b“ it is put away in the refueller case. The movable pipeline consists of two concentric tubes: the external immovable (fixed) tube 3 and the internal movable tube 4.

The external tube 3 made of nonmetallic material, for instance, of fiberglass plastic and the internal tube 4 made of metal having high electrical conductivity, for instance, of aluminum.

On the external surface of the tube 3 the linear asynchronous electric motor 5 is mounted, which has three-phase winding, generating the traveling magnetic field directed along the axis.

At electric motor switching on (the position „a“) the traveling magnetic field induces eddy currents in the tube 4. As a result of interaction of the eddy currents and the magnetic field, the force, directed along the electromotor axis, is being created. The tube 4 moves from position „b“ into position „a“ and descends in the pool 2 with unfrozen water, being created by the ice melter. On the end of the movable tube 4 an intake 6 is located, through which water begins to come inside the refueller (as it is shown at Fig. 9): along pipelines 15 and 16 - into condenser cooling circuit 11 and along pipeline 3 - into the water intake chamber of electrolyzer 20.

The condenser design of the turbogenerator installation of refueller is shown at Fig. 12.

The case of the condenser 1 has nontraditional geometrical shape. It is attributed to the fact, that the condenser has two heat exchangers 2,3, two input chambers 4 and 5, and two output chambers 6 and 7. The heat exchanger 3, consisting of a bundle of parallel pipes, which are connected with the help of a pipe plate 10, is included in heating circuit of electrolyzer and liquefier. The heat exchanger 3 is included in the circuit of the constant heating of the pool with unfrozen water. The water vapor after exhausting in turbine enters inside the case 1 through a steam-supplying branch 9. The condensed water enters into a condensate gathering tank 8 and then into the steam-turbine circuit.

The development of refueller design (Fig. 8) requires to provide the optimal arrangement of all its components. Criterion is achievement of maximal volume of the tank with the working substance 4. The traditional design of the cryogenic pump for pumping-over of liquid hydrogen from the refueller tank 4 into the tank-container of the carrier rocket supposes the installation of a circulating pump on cryogenic pipeline at outlet out of the refueller tank. The circulating pump has a working wheel, shaft and a remote motor. The shortcoming of the traditional design is the substantial volume occupied by the pump and the outlet pipe, as well the losses of the working substance because of heat absorption at the shaft.

In order to increase the volume of the tank with the working substance and to decrease the losses of the working substance, it is reasonable to place cryogenic pump 6 inside of the tank with the working substance in close proximity to the docking assembly 19.

The design of the cryogenic pump is shown at Fig. 13.
Fig. 13

The cryogenic pump has no shaft. It consists of the metal rotor 2 of cylindrical shape, on which internal surface the propeller screw vanes are installed. On the outside of the rotor 2, the stator of the driving electromotor 4, which has a laminated magnetic core and three-phase winding 5, is located.

The magnetic field being created by the winding 5, brings into rotation the rotor 2, which for decreasing of the energy losses is made of aluminum. The stator winding 5 is made out of the superconducting wire, for instance, of magnum – boron. The external case of the pump 10 is connected with the pipeline 1, along which the pumping-over of the liquid hydrogen from the refueller tank into tank-container of the carrier rocket is carried out. For rotation of the pump rotor inside the pipeline 1, it has a magnetic suspension, working on Meissner effect. The magnetic interaction is carried out with help of the permanent magnets 6 and 7, being installed on the stator, as well as by end rings 7 and 8, which are made out superconductor and installed on the rotor (Fig. 13).

The calculated data of the main characteristics of the space refueller, shown at Fig. 8, are given in the Table 1, and masses of the particular units and the space capsule in whole by launching on Earth are given in the Table 2.

The main characteristics of the refueller

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mass of the working substance being produced for refueling-up of the carrier rocket .......... 18 T</td>
</tr>
<tr>
<td>2. Maximal tractive force of the chemical rocket engine ............................................. 70 kN</td>
</tr>
<tr>
<td>3. Heating capacity of the onboard nuclear power station ............................................. 1500 kW</td>
</tr>
<tr>
<td>4. Heating capacity of the warming of the pool with unfrozen water .......................... 1000 kW</td>
</tr>
<tr>
<td>5. Electric power of the onboard power installation ...................................................... 500 kW</td>
</tr>
<tr>
<td>6. Electric power of the electrolyzer ................................................................. 400 kW</td>
</tr>
<tr>
<td>7. Electric power of the liquefier ................................................................. 100 kW</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>The refueller mass ......................................................... 18 T</td>
</tr>
<tr>
<td>including:</td>
</tr>
<tr>
<td>Onboard power installation .................. 8.0</td>
</tr>
<tr>
<td>Tank with liquid hydrogen .................. 3.0</td>
</tr>
<tr>
<td>Tank with liquid oxygen .................. 2.0</td>
</tr>
<tr>
<td>Electrolyzer .................. 2.5</td>
</tr>
<tr>
<td>Liquefier .................. 5</td>
</tr>
<tr>
<td>Ice melter .................. 1.0</td>
</tr>
</tbody>
</table>

The system of the electro propulsion of the space train.

The propulsion system, which was developed in the frames of the project, belongs to the class of electrical systems: generator - engine with stand-alone onboard nuclear energy source.

In this case, the joint operation of the synchronous turbogenerator with MHD AC generator onto MHD DC engine was considered for the first time.

The description of the onboard power installation is given in [2].

The electric circuit of power installation, located in the locomotive, is shown at Fig. 14.
The special feature of the developed scheme consists in usage of the phenomenon of superconductivity for creation magnetic fields in the main components of the installation.

The liquid hydrogen, which is located onboard of the locomotive, is used for cooling of the superconducting components and, simultaneously, as the working substance for the cruise electrorocket engines, which are installed onboard.

The AC winding of the MHD generator 1 is connected to the AC winding of the turbogenerator 2 by means of the frequency converter 7.

The excitation of the turbogenerator is carried out by means of the superconducting winding 3.

The electric power consumer is the electrorocket engine 5, which has an external superconducting excitation coil 6.

For the power installation start-up, the storage battery 4 is placed onboard of the locomotive. The frequency converter 7 is performed on the basis of the controlled power transistors. The control system of the converter ensures the functioning of power installation in all the operating modes.

For power installation start-up, the constant voltage from the storage battery 4 is fed to the input of the frequency converter 7, which is connected to the armature winding of the turbogenerator 2.

The frequency converter produces a current, which frequency gradually increases. After switching on of the excitation coil of the turbogenerator 3, it is accelerated up to nominal speed, working as a synchronous electric motor. Simultaneously the compressor, which is pumping over the gaseous helium in the closed circulation loop of the power installation, which is shown in [2], begins to operate. Then the start of the gas-phase nuclear reactor (by means of control drums) takes place.

When the pressure and gas temperature are being increased, the turbine, which provides the energy for the compressor operation, starts to work. The accumulator battery becomes disconnected from the convertor 7. For start-up of the MHD generator, the frequency converter 7 is connected to the winding 1. Then the current in the excitation coil of the turbogenerator increases and the turbogenerator begins to operate as a synchronous compensator.

Electric current from the winding of the turbogenerator 2 through the frequency converter 7 comes in the winding 1 of the MHD generator. In working channel of the MHD generator the travelling magnetic field is being generated, and it produces an active power.

The electrorocket engine 5 is connected to the power installation through the controlled rectifier 8, with which help the control of the cruise engines 5 is carried out.

By changing current in the electrorocket engine, the tractive force of each of four cruise engine is being changed, providing necessary flight direction of the space locomotive. As an explanation, in the Table 3 the main data of the components, which are shown at Fig.14, are given.

### Table 3
The characteristics of the system of electro propulsion.

<table>
<thead>
<tr>
<th>Component</th>
<th>Power</th>
<th>Voltage</th>
<th>Current</th>
<th>cos ϕ</th>
<th>Tractive Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHD generator</td>
<td>6000 kW</td>
<td>3400 V</td>
<td>2200 A</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>Turbogenerator</td>
<td>5000 kW</td>
<td>3400 V</td>
<td>1700 A</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>MHD engine</td>
<td>2500 kW</td>
<td>1150 V</td>
<td>2250 A</td>
<td></td>
<td>250 N</td>
</tr>
<tr>
<td>Storage battery</td>
<td>12 V</td>
<td></td>
<td>4000 Ah</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In conclusion, it shall be noted, that the calculations and constructive researches, which were carried out in frames of this project, show the possibility to implement the expedition to Jupiter during the next 5 years after the flight to Mars. Even already nowadays the achieved level of the space technology is sufficient. And the necessary is only the financial will!

**REFERENCES**


