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The Expedition towards Neptune. Creation A System of Interplanetary Communications.

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Abstract - A project of the expedition towards planet Neptune, which is based on new conception of high-speed flight with usage of stand-alone refueller for refueling with working substance, which is delivered beforehand onto surface of Neptune satellite – Triton, has been considered. A new modification of space locomotive, being equipped with electrorocket engines and onboard power installation of 40 megawatt power is developed. Duration the expedition – 192 days, the expedition cost – 4 billion dollars. The cycle of calculations and engineering works for designing of expeditions towards all the planets of the solar system is summarized. A table of the research results is given, which indicates of the possibility to create a system of interplanetary communications in twenty first century.

Keywords - Neptune, Triton, space train, electrorocket engine, onboard power installation, takeoff- landing capsule, carrier rocket "Falcon Heavy, solar system planets: Mars, Jupiter, Saturn, Uranium, Neptune.

The attainment of the planet- dwarf Pluto by space craft «New Horizonts» in year 2015 has become the outstanding achievement in the history of cosmonautics. And this event has happened on 17 July 2015 exactly in the day which was predicted by NASA scientists [1].

It shall be reminded that the start of «New Horizonts» has taken place on 19 January 2006. While moving from the Earth orbit and crossing orbits of Mars, Jupiter, Saturn, Uranium and Neptune the space craft «New Horizonts» had approached to Pluto on the distance on $12{,}5 \cdot 10^3$ km.

The received information about Pluto is so large that its processing will take several months. One can congratulate the «New Horizons» team with very great success.

While carrying out the flight to Pluto in year 2014 the space craft «New Horizonts» have crossed the solar system border, which goes conventionally along orbit of Neptune - the last gaseous planet and is located on the distance of 30 AU from the Sun.

In this paper the possibility of flight realization to planet Neptune is being considered. It shall be noted that the New Horizonts mission in many relations reminds the flight of the space craft "Voyager 2".

"Voyager 2", which was launched by NASA on 20 August 1977, was the first space craft, which have reached the planet Neptune in August 1989 and has approached to it on distance of 4800 km. After this event the real "scientific storm" of Neptune and its satellite Triton has begun.

As it is known , the discovery of Neptune itself was a triumph of astronomy, as a science. *Le Verrier* and Adams have mathematically determined the position and sizes of a unknown planet and then Galle and D'Arrest were first ones, who have seen planet Neptune on the indicated place of stellar sky by means of a telescope on Berlin observatory. It had happened in year 1856.

Supervisions over the eighth planet of solar system are carried out by all observatories of the world already within 160 years. But the first and the last flight of a space craft for investigation of Neptune had taken place only 27 years ago.

Now one can put a question: whether the modern level of space technology will allow to send an expedition to Neptune?

In the present work the project of such an expedition being executed on the basis of new conceptual and constructive decisions, which have been developed by the author during the latest years, is offered.

In year 2006 an electrical rocket engine of magnetoplasma type with outer superconducting exiting coil, having the maximal efficiency, had been developed [2].

In year 2011 the design of an universal interorbital carrier rocket, consisting of an locomotive and tank-containers with working substance, has been developed.

In the locomotive electrical rocket engines and onboard power installation with gas-phase nuclear reactor and MHD AC generator [3] are installed.

In 2014 a project of a high-speed rocket train has been developed for expedition to Mars providing for minimal expenses for its realization [4].

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In the martian project [4] the design of space electrotrain, consisting of locomotive, tank-containers with working substance and takeoff-landing capsule with a cabin for astronauts, having the strengthened protection against space radiation was presented.

In year 2015 the new conception of space expeditions towards gaseous planets of solar system with usage of "space refueller" has been developed [5].

The design of the space refueller ,which is delivered on the surface of a satellite of the gaseous planet, which is covered by layer of water ice [5], is developed.

Such a satellite for Jupiter is Europa[6], for Saturn – Titan [7], for Uranium – Oberon [8].

The technological schema of the refuelling [5] provides for ice melting and production out of liquid water by means of electrolyze the initial components – hydrogen and oxygen in gaseous state. Then liquation of hydrogen is made for refuelling by it (as working substance) the tanks-containers .

In this connection it shall be noted that the gaseous planet Neptune has a satellite – Triton, which surface on 35% is covered by water ice too. And the conditions for space refueller operation on the Triton's surface are more favorable than on surface of Europe [6], as gravity on Europa's surface is by 7,7 times lower than on Earth surface and on Triton's surface – is by 13 times lower.

The analysis, which was carried out in this project, shows that the space refueller, which was developed for flight to Jupiter and which design is described in details in [6], is perfectly suitable for flight implementation to Neptune.

The problems, which take place by implementation of a space expedition to far distanced planets of solar system, have been considered at development of expedition project to Uranium[8]. The major circumstance , which defines the possibility of expeditions implementation to far distanced planets is the long-term influence on astronauts of galactic space radiation (GSR), originating from black holes and supernovas.

In order to solve this problem in expedition project to Uranium[8] the new constructive schema of astronauts protection from the space radiation has been developed.

In the takeoff-landing capsule of new design the cabin for astronauts is located in an internal cylinder of tank with liquid oxygen.

And this tank with liquid oxygen is placed in a cylindrical cavity of tank with liquid hydrogen. Thus the cabin is protected by double layer of liquid components.

The other important circumstance is connected with increasing of the flight distance to Neptune. It shell be reminded, that the distance from Earth orbit up to Uranium orbit is 20AU and up to Neptune orbit – already 30 AU.

For this issue consideration let us refer to Fig.1, on which the diagram of space train velocity change during the flight from Earth orbit onto Uranium orbit, is shown.

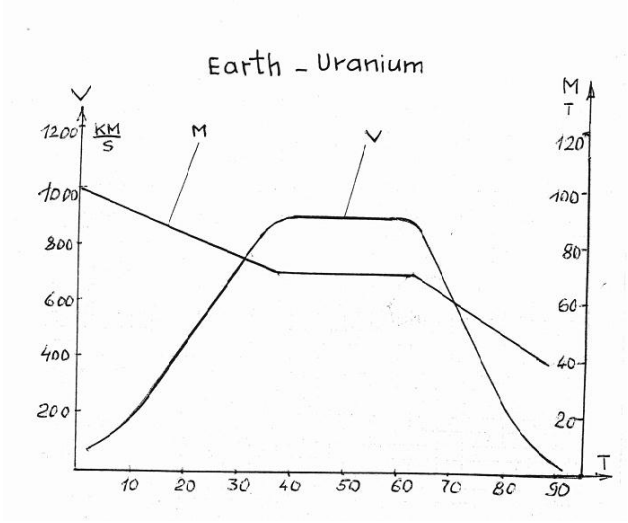

Fig.1

As one can see from Fig.1 the flight of the train towards planet Uranium takes 90 days. This period is the maximal temporal safety border for protection of expedition team from GSR. The movement process of the space train begins from acceleration up to speed of 900 km/s, which lasts during 40 days. During acceleration the electrical rocket engines, which are installed in space locomotive , are working at full capacity. At the second stage, which lasts 24 days, the free flight of the train under its own inertia with the maximum speed at disconnected electrorocket engines, takes place. At the last stage, which lasts 26 days, the braking of the rocket train takes place. Electrorocket engines are working at full capacity while thrust vector is changed on 180º.

The diagram on fig.1 shows that flight with maximal speed takes only. $\frac{1}{4}$ *time* of flight and . $\frac{3}{4}$ time of flight is spent on acceleration and braking.

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It is obvious, that decreasing of acceleration time and braking time will allow to increase range of the fligh,t while preserving its time. Calculations, which were performed on a mathematical model of space train movement has shown, that for decreasing of acceleration time and braking time , while preserving invariable the quantity of working substance, it is necessary to increase the train acceleration during stages of accelerating and braking by means of increasing of driving force of electrorocket engines. In its turn the increasing of driving force of electrorocket engines results in capacity increasing of onboard power installation.

The capacity increasing will demand the corresponding increase in mass of the space locomotive. In this project of an expedition towards Neptune a new development of the space locomotive has been performed, which characteristics are given below.

But such a question rises: if the necessity of space locomotive mass increase can result in a necessity of creation of new heavy carrier rockets for launching the locomotive into circumterrestrial orbit ? The presence of such a demand can be an obstacle for realization of the main idea of composite space train being formed on Earth orbit for expeditions towards distant planets, while using the existing carrier rockets, which cost is minimal.

Fortunately nowadays this problem can be overcome owing to creation of carrier rocket „Falcone Heavy“ by the company “Space X”.

“Falcone Heavy” belongs to the new generation of carrier rockets, in which developments some technical decision of the nineteenth century are used. For instance, chemical rocket engines, in which kerosene is used as fuel substance and liquid oxygen is used as oxidizer. But the advanced technology and the original constructive solutions make it possible to considerably decrease the cost of launchings.

“Falcone Heavy” consists out of a central block and two side accelerators, which are performed on basis of the first stage of carrier rocket „Falcone -9“and makes it possible to deliver onto Earth orbit the payload of 53 T [9].

But the main novelty in design of „Falcone Heavy“ is the system of multiuse. By means of activation of rocket engines and aerodynamic wing flaps, the soft landing on Earth surface of the central block and side accelerators is performed. It makes possible to decrease cost of launching up to 90 million dollars.

It is especially rational to use the new carrier rocket for building a “ long distant “ rocket train. Exactly in such a train, which design is set forward in this project , the astronauts head towards the boundaries of solar system.

The expedition goals are: carrying out scientific observations s during the flight towards Neptune, visit of Neptune’s satellite Triton, flying around Neptune in immediate proximity to boundary of its atmosphere and scientific observations at return onto Earth orbit.

The space locomotive of electric train for flight towards Neptune.

In the expedition project of a flight towards Neptune the new version of space locomotive was developed.

The main constructive schema, which has been offered by the author in 2010 [3], remains the same as in the space locomotive for flight to Mars [4] The developed design is shown on fig. 2

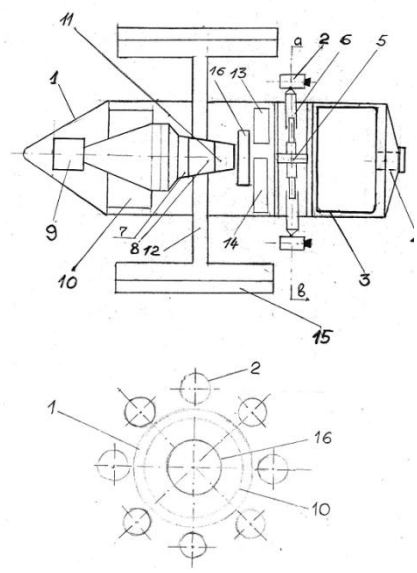

Fig. 2

The calculations, which were performed on a mathematical model, have shown, that in order to achieve Neptune one needs to have driving force of 4000 N.

In order to create the necessary driving force. in tail end of the locomotive 8 rocket electro engines are installed, which are located over an circle.

The electro rocket engine of magnetoplasma type with external superconducting exiting coil has been invented by the author in year 2006 and in year 2015 onto it the Germany patent [2] has been given.

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In this project a decision have been made to install the electrorocket engines, which were intended for the flight towards Saturn [7], because to the moment of beginning of the expedition towards Neptune will be accumulated the experience of multiple usage of this engine.

Characteristics of electrorocket engine are given in Table 1

Table 1

Driving force	500 N
Power	5000 kW
Current	3150 A
Efficiency	94%
Specific momentum	25500 S
Working substance consumption	2 G/s
Exhaust velocity of working substance	10^4 m/s
Magnetic induction	2,3 T
Anode diameter	170 mm
Cathode diameter	40 mm
Anode length	350 mm
Cathode length	170 mm
External cylinder diameter	900 mm
External cylinder length	700 mm

Electrical rocket engines 2 (fig.2) are moved forward out of locomotive body 1 after launching onto Earth orbit. To this purpose a special electromotor is developed , in which a hollow cylinder 6, made out of aluminium alloy, is being moved along transverse axis by means of traveling magnetic field. On the end of the cylinder 6 the rocket electrical engine 2 is fastened.

Working substance of electrorocket engine is hydrogen , which in liquid state is kept in cryogenic tank 3. It allows the locomotive to carry out independently short flights in space. For fulfilment of long –term flights, when the locomotive moves the space train, it is connected by means of a docking assembly and a cryogenic pipeline 4 with a tank-container - the basic carrier of a working substance.

In fore and middle part of the space locomotive along its horizontal axis the onboard power installation is located, which arrangement is shown on fig.2.

For providing power supply of rocket electric engines 2 the capacity of the onboard power installation increases to 40 MW. On fig. 2 the main components of thermal and electrical parts the power installation: gas-phase nuclear reactor 9, MHD AC generator 10, cryoturbogenerator 8, gas turbine 7 and compressor 11 , which are fixed on the same shaft as the generator, are being shown.

The detailed description of these components is given in [4]. A part of thermal schema is radiator 15, which provides heat return in space by means of heat radiation.

A part of the electrical schema is frequency converter 16, which connects turbogenerator 8 with MHD AC generator 10. In the central section a storage battery 14 is being located, which is intended for startup and guarantee supply of the power installation. Onboard computer center 13 performs all the operations during the power installation operation and provides its protection at emergency condition.

The detailed description of the complex, which provides electrical movement of the space train, is given in [6].

In this project calculations of all components of onboard power installation, results of which are given in the tables below, have been performed.

Table 2
Characteristics of the MHD generator

Active power	20000 kW
Voltage	6100 V
Current	4500 A
Current frequency	200 Hz
Magnetic induction	2,5 T
Power factor	0,44
Efficiency	0,81
Input diameter of cone	1,2 m
Output diameter of cone	1,5 m
Working channel length	2,1 m
Working channel height	0,1 m
Average velocity of working substance	200 m/ s

Table 3
Characteristics of cryoturbogenerator

Power	20000 kW
Voltage	6100 V
Current	4100 A
Power factor	0,5
Current frwquency	200 Hz
Rotation frequency	12000 rev/min
Magnetic induction	2,8 T
Efficiency	0,98

Calculation results of masses of locomotive components (in tons) are given in Table 4

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Table 4

Locomotive	48,0
Nuclear reactor	27,0
MHD generator	4,0
Gas turbine	1,3
Cryoturbogenerator	1,5
Electrorocket engines	1,6
Storage battery	1,5
Frequency converter	1,1
Tank with liquid hydrogen	2,5
Body	3,5
Radiator	4,0

On the basis of the calculations of the component parts, a constructive development of a space locomotive, which has maximal power, has been performed. On fig.3 the arrangement of the locomotive, which during start onto circumterrestrial orbit is installed on the central block of carrier rocket „Falcone Heavy“ is shown.

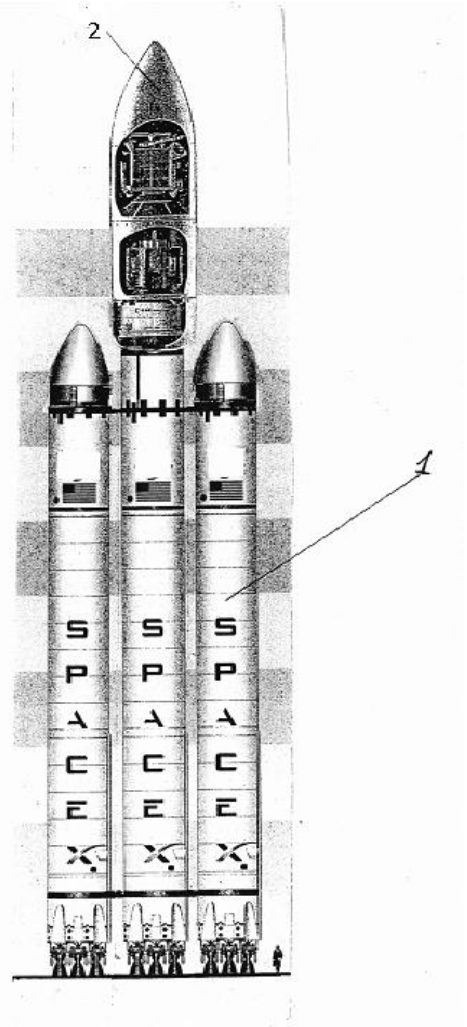

Fig. 3

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One can see how the carrying part of the carrier rocket 1 and the space locomotive are correlated with each other.

Conception of the high speed flight towards Neptune

As a base of the conception the procedure of the expedition implementation, which would be tested at flights to gaseous planets Jupiter, Saturn and Uranium, has been taken.

In accordance with the developed procedure the expeditions towards Neptune is beginning from a preliminary flight of the space train, which purpose is to deliver the space refueller onto circular orbit of Neptune satellite – Triton.

Schema of rocket train for the preliminary flight is shown on fig. 4.

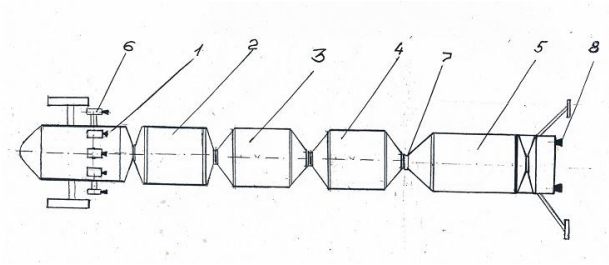

Fig. 4

The train consists out the locomotive 1 with 8 electrorocket engines 6. The train structure includes 4 "cars". The "cars" 2,3 and 4 are tanks-containers with working substance –hydrogen in liquid state.

The last"car"5 is space refueller, which design was described in details in [6].

The space train (fig.4) is being formed on circumterrestrial orbit. At first the space locomotive of new modification 1 is being launched, while using the up-to-date carrier rocket „Falcon Heavy" . Thereafter the tanks- containers 2,3 and 4 are being launched with help of three launches of the carrier rocket "Ariane-5" and are being connected with the locomotive and between each other with the help of docking assemblies. By means of the last launching the space refueller 5 is being put into orbit with the help of carrier rocket "Arian -5".

While maneuvering with the help of chemical rocket engines 8, the space refueller is being connected with the space train, using the docking assemble 7. On command from Earth the cruise electrorocket engines 6 of the locomotive 1 are being switched on and the space train after achievement of the second (escape) space velocity begins its movement towards planet Neptune.

After acceleration up to velocity of 900 km/s the space train moves along a calculated trajectory with constant velocity. At the approach to Neptune the train is being switched over into braking mode. The first task is being solved: to deliver the space refueller onto Triton surface. As it is known, Triton revolves around Neptune (but in opposite direction) with radius of orbit 355 x 10^3 km. The space train decreases its velocity and goes into a circular orbit around Triton. While moving along the orbit the space train is divided. The chemical rocket engines of the refueller 8 are being switched on and it performs soft landing onto Triton surface. It shall be reminded that 35% of Triton surface is covered by a crust of water ice at temperature 38 K°. Atmosphere composition nearby the Triton surface – traces of Nitrogen under pressure of 5 Pa . Gravity - 0,78 m/s^2.

All these characteristics are very favorable for space refueller operation. Immediately after the landing in a chosen region with smooth ice surface the space refueller begins to operate and to produce out of water its components - hydrogen and oxygen. Liquid water out of a pool (unfrozen patch of water) made with the help of ice melter is being pumped inside of the refueller. With the help of an electrolyzer the decomposition of the water into gaseous components is takes place and the liquefier transforms the gaseous hydrogen into liquid state. After filling of a tank with liquid hydrogen, the refueller 5 starts from Triton surface with the help of chemical rocket engines 8 and goes into orbit around Triton. The refueller approaches the space train and with the help of docking assemble 7 is being connected with it, as it is shown on fig. 4.

Liquid hydrogen, which is in tank of refueller 5, is being pumped over with the help of a cryogenic pump into tank-container of the rocket train. After the tank emptying the refueller is being disconnected from the tank-container of the rocket train and with the help of chemical rocket engine 8 moves away from the space train and by way of braking again performs landing onto Triton surface. Thereafter the repetition of the refilling cycle takes place. As a result the tanks-containers 2,3 and 4 are refilled completely and the space train, which is shown on fig.5 , is ready to return onto Earth orbit.

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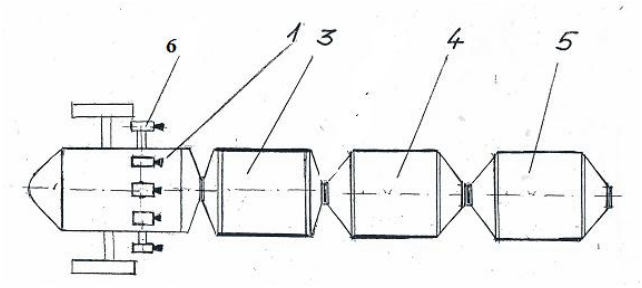

Fig. 5

The space refueller 5 again performs soft landing onto ice surface of Triton and stays there in waiting mode up to arrival of the expedition towards Triton.

The space train (fig.5) is being accelerated with the help of electrorocket engines 6 , reaches the maximal speed 900 km/s while moving along the calculated trajectory between the Neptune orbit and the Earth orbit. At approaching the Earth orbit the electrorocket engines are being switched on, which are working in braking mode.

The preliminary flight is being ended by the returning of the space locomotive onto circumferential orbit. After disconnecting of the empty tanks 3,4 and 5 the forming of the train for the main flight begins.

The schema of forming the space train for the main flight of an expedition towards planet Neptune is shown on fig.6

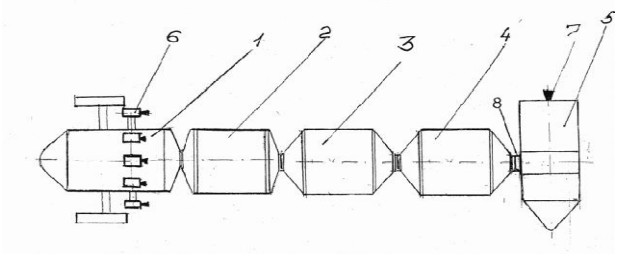

Fig..6

In order to make up the space train for flight on route "Earth orbit – Triton orbit" into Earth orbit with the help of carrier rocket "Arian-5", the tanks-containers 2,3 and 4 with working substance are being launched and are sequentially being connected with the locomotive 1.

For the flight the takeoff-landing capsule, which has been used for flight towards Uranium, is used. The detailed description of this takeoff-landing capsule was given in [8]. It is intended for the remote planets of solar system and has an enhanced protection against galactic space radiations. To the beginning of the main flight the takeoff-landing capsule 5 is located by a moorage of the international space station.

After the last expedition towards Uranium at the takeoff-landing capsule the works has been carried out in order to equip it with the equipment which is necessary for investigation of Neptune and its satellite –Triton.

The crew of the expedition towards Neptune, which consist out of two person, is beforehand delivered on the international orbital station,, where they take part in works for preparation of the capsule to the flight.

The expedition towards the most remote planet of solar system begins. Astronauts take seats in takeoff-landing capsule and perform undocking of the capsule from orbital station. Then they switch on chemical rocket engine 7, cast off the moorage and go into circumterrestrial orbit, where the space train is located. After approaching the space train, the takeoff-landing capsule docks with tank-container 4 with the help of docking assemble 8, which is installed along vertical axis of the capsule. Astronauts switch on the system of creation of artificial gravitation in cabin and the capsule 5 begins to revolve in superconducting bearing 8 relative to transverse axis.

The electrical rocket engines 6 of locomotive 1 are being switched on and the space train increases its speed . After reaching of the second (escape) space velocity it leaves the orbit around Earth and enters into the calculated trajectory. In the project a calculation of trajectory of space train to planet Neptune is performed. It was carried out with the help of astrodynamical computer program, referring to movement of an artificial body in gravitational field of solar planetary system.

The movement of the train along the calculated trajectory is being attended by change of speed and mass, as it is shown on fig.7

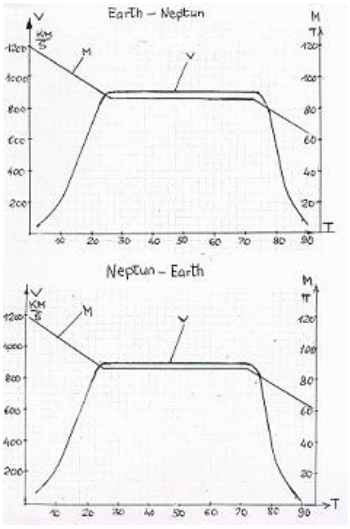

Fig.7

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In 24 days of acceleration the speed reaches its maximal value – 900 km/s and mass of the train is decreased from 120 T up to 90 T. After reaching of the maximal speed the electrical rocket engines of locomotive are being switched off and the train continues to move along the calculated trajectory while being in inertial flight.

With the help of astronomical instruments ,which are being installed in the takeoff-landing capsule, the astronauts perform the scheduled researches of space. The flight at maximal speed continues 50 days. After its completion the train will already overcome the distance from Earth equal to 25 AU. The command for space train braking is being given. The astronauts turn the electrorocket engines on 180º (with the help of electric drive) and switch them on. The speed of the rocket train is being decreased. During this process the working substance is being spent, which is in tanks - containers 3 and 4. In 74 days of the flight the space train decreases its speed and approaches planet Neptune. At this moment a command is given to the space refueller, which had been delivered on surface of Neptune satellite – Triton. The refueller begins to work: it melts ice and produces liquid hydrogen. In 90 days of the flight the space train will already overcome the distance equal to 30AU. While decreasing its speed up to 1,4 km/s with the help of a maneuver the train goes into orbit around Triton, which is located on distance of 355 x10^3 km from Neptune.

While entering into orbit around Triton it shall be taken into account that Triton is moved along its orbit around Neptune in opposite direction (relative to Neptune revolution) and in addition its orbit has the slope to ecliptic equal 130 º. While being on orbit around Triton, the space train (fig.6) is divided. The takeoff-landing capsule 5 is disconnected and moves away from the train while moving around Triton. The command on landing is being given. The astronauts switch on chemical rocket engine 7 in braking mode. The takeoff-landing capsule perform soft landing onto Triton surface.

Astronauts go out into Triton surface, which temperature is -235 Cº. But it shall not be forgotten, that at expeditions on Europe, Titan and Oberon sufficient experience of the work in the conditions of low temperatures while using heated spacesuits was accumulated. Temperature on Oberon surface was - 200 Cº!

To this time the space refueller , which is on Triton surface already has produced liquid hydrogen, which is in a cryogenic tank.

With the help of chemical rocket engines the refueller performs the vertical take-off from Triton surface, goes onto round orbit and docks with tank-container 4 with the help of docking assemble 7.

During stay of astronauts on Triton surface the refuelling of tanks-containers 2,3 and 4 takes place. After train tanks refuelling the refueller 5 with the help of chemical rocket engines returns on Triton surface. It shall be noticed that permanent stay on Triton will give a possibility to use the refueller as a stand-alone relocatable and controllable from Earth research device. To this purpose it can be equipped with instrument complex_, which make it possible to implement researches on Triton surface and to perform observations of Neptune and its satellites. In this sense the refueller becomes a permanent scientific and information beacon on the very boundary of solar system.

During the stay on Triton surface astronauts perform the intended program of researches which is meant to perform during 8 days. They study Triton surface and visit crater "Mazomba", which causes a great interest among scientist. Besides they travel along an area, which has got the name „cantaloupe terrain", as it reminds a melon crust. Astronauts study also the unique cryogenic volcanoes and geysers on Triton surface.

After completion of the intended scientific researches astronauts come back in cabin of takeoff-landing capsule. After switching on chemical rocket engines the takeoff-landing capsule goes into orbit around Triton and is connected with the space train (fig.6). Afterv switching on electrical rocket engines 6 of locomotive 1 the space train leaves Triton orbit and heads for "blue" planet Neptune. While moving towards Neptune surface astronauts perform scientific researches connected with study of Neptune satellites. Many of them had been discovered in year 1989 during flight of "Voyager 2". It is quite not excluded, that the expedition succeeds in discovering some new Neptune satellites. In accordance with the scientific program, the space train flies past Proteus. Astronauts photograph Proteus surface, which has irregular geometric shape. Afterwards the space train approaches "Adam ring", where a system consisting of three satellites Egalite, Lieberte, Fraternite is located. While decreasing its speed the space train goes into round orbit around Neptune at the distance of 3000 km from its atmosphere boundary

Investigation of Neptune atmosphere is the last stage of scientific program of the expedition. Neptune atmosphere keeps many items, which are still unsolved by science.

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For instance, why the thermosphere of this planet has abnormally high temperature – 750 Kº? Owing to it the planet has blue color. What is formation mechanism of dark spots in its atmosphere? and so on.

While moving around Neptune the astronauts launch probes with measuring apparatuses into its atmosphere. After investigation completion, which lasts 2 days, astronauts make preparations for return on Earth.

While moving along round orbit around Neptune the astronauts switch on the cruise electrorocket engines 6 of locomotive 1 (fig.7) on maximal capacity. In 1 day the space train reaches the second (escape) space velocity 23,5 km/s and begins its flight towards orbit of planet Earth.

After entering into the calculated trajectory, the space train is being accelerated during 24 days up to the maximal speed 900 km/s, as it is shown on fig. 7. The train mass owing to working substance consumption is being decreased from 120 T up to 90 T. Thereafter the engines 6 are being switched off and the train is in inertia flight during 50 days.

The space train crosses orbits of all the gas planets of solar system –Uranium, Saturn and Jupiter. Astronauts carry out astronomical observations with the help of telescope. It shall be reminded that design of the cabin for crew being located inside of takeoff-landing capsule provides for protection against galactic space radiation with the help of liquid oxygen and hydrogen.

The device for creation of artificial gravity with the help of superconducting bearing unit [8] provides for comfortable conditions for work and recreation of astronauts. In 78 days the last stage of return onto the Earth orbit begins. Astronauts move the train into braking mode by change of vector of driving force of electric motors on 180 º. The braking takes 18 days. In 88 days the flyback is being ended by space train putting into the circumterrestrial orbit. Takeoff-landing capsule detaches from the space train. Astronauts switch on chemical rocket engine 7 and the capsule 5 begins movement towards orbit of international space station. Then braking of the capsule, approaching and taxiing to a moorage of the international space station take place. The takeoff-landing capsule docks to the moorage of the ISS, where doctors and astronauts meet the expedition crew. In this way the expedition towards the most remote planet of solar system, which was proceeding in total 192 days, is being ended.

And now let us try to estimate expenses which are necessary for realization of this expedition.

For implementation of a preliminary flight it was necessary to carry out launching into Earth orbit space locomotive of new modification with the help of carrier rocket «Falcone Heavy", which cost is 90 million dollars [9]. For putting into Earth orbit of three tanks-containers with working substance and space refueller it was necessary to carry out 4 launching of carrier rocket "Arian-5" For implementation of a preliminary flight it was necessary to perform launching of space locomotive of new modification into Earth orbit with the help of carrier rocket «Falcone Heavy", which cost is 90 million dollars [9]. For putting into Earth orbit of three tanks-containers with working substance and space refueller it was necessary to carry out 4 launching of carrier rocket "Arian-5".

For implementation of main flight it will be necessary to carry out launching of three tanks-containers with working substance and takeoff-landing capsule. Thus, for implementation of the expedition it will be necessary to carry out 8 launchings of carrier rocket "Arian-5", which cost will be 1200 million dollars [10].

But the main expenses will be necessary for creating of the extra-high- powerful locomotive, which will make not less than 1,5 billion dollars.

Thus, according to the preliminary estimation, the total expenses for implementation of this expedition will be 3,0 billion dollars

Creation a system of interplanetary communications.

The implementation of the expedition towards Neptune completes the whole cycle of calculated and constructive works, determining the possibilities for space mastering in the twenty first century. While summarizing one can tell that an engineering decision of the global task of interplanetary space mastering has been found, which makes it possible to realize the expeditions towards all the planets of the solar system.

The developed projects [2], [3], [4],[5],[6], [7], [8] have shown that the expeditions shall be performed step-by-step, beginning from Mars and Jupiter. For performing the subsequent expeditions towards Saturn, Uranium and Neptune the new method has been proposed and developed, which consist in the following: for providing of minimal duration of flight from Earth orbit onto orbit of a gas planet the "space refueller" of working substance is used, which preliminary is delivered on the surface of the planet satellite, which is covered by layer of water ice.

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In the projects it is also shown that the most reasonable technical solution for expedition delivery means is a space train, which is driven by a locomotive, equipped by an electrorocket engine. The electrorocket engine of magnetoplasma type with an external superconducting winding, creating transversal magnetic field, is connected to an onboard power installation, consisting out of nuclear reactor, MHD AC generator and cryoturbogenerator. The working substance of the engine – liquid hydrogen is located in tanks-containers , which are being connected with the locomotive by means of docking assembles. The expedition crew is located in the takeoff-landing capsule, which is attached to the tanks-containers

The results of the calculated and constructive researches are shown in Table 5.

Table 5
Characteristics of expeditions towards planets of solar system

Planet	Mercury	Venus	Mars
Distance from Earth (AU)	0,6	0,28	0,64
Place of refueling	Mercury	Venus	Mars
Carrier rocket	Arian-5	Arian-5	Arian-5
Flight duration (days)	27	17	28
Number of tanks with working substance	1	1	1
Driving force of locomotive (kN)	1,0	1,0	1,0
Capacity of onboard power installation (MW)	10	10	10
Max. speed (km/s)	200	200	200
Cost (billion $)	1,5	2,0	1,5

Table 5 (cont.)

Planet	Jupiter	Saturn	Uranium	Neptun
Distance from Earth (AU)	4,4	9	19	29
Place of refueling	Europa	Titan	Oberon	Triton
Carrier rocket	Arian-5	Delta Heavy	Delta Heavy	Falcone Heavy
Flight duration (days)	61	66	88	90
Number of tanks with working substance	2	2	3	3
Driving force of locomotive (kN)	1,0	2,0	2,0	4.0
Capacity of onboard power installation (MW)	10	20	20	40
Max. speed (km/s)	400	700	900	900
Cost (billion $)	2,0	3,0	3,0	4,0

Table 5 fixes a situation, which will be created, if the described in this work the expedition towards Neptune will be successfully implemented.

There are technical facilities, which makes it possible to overcome maximal distance from Earth of 29 AU

The space refuellers, which can be installed on Europe, Titan, Oberon and Triton, will make it possible to implement the repeated expeditions and even regular flights towards all planets of the solar system without any preliminary flights. Thus already at the very beginning of the twenty first century a system of interplanetary communications ,which undoubtedly will be improved in the lapse of time , is actually designed.

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It shall be once more noted, that the space refuellers are capable to fly (at the command from Earth) around satellites, on which surfaces they are located . Thus the refuellers can in addition to perform a function of the permanent research laboratories. Out of Table 5 one can see that maximal duration flight out of the Earth orbit towards the boundary of the solar system does not exceed 90 days ! And this period probably is the safety boundary for human organism from the point of view of the permanent galactic space radiation. Maximal speed of the space train at flight towards far planets reaches 900 km /s, and maximal capacity of onboard power installation reaches 40 MW.

Nowadays it is the limit, which corresponds to the real level of space technology.

The question of cost of the interplanetary communications is the matter of principle. The last line in Table 5 shows that the cost of the most expensive expedition towards the most far plant Neptune does not exceed 4 billion dollars. And the cost of all 7 expeditions is 17 billion dollars.

In conclusion of this research work , in which the consideration subject is the real flight of man towards the boundary of the solar system, it is necessary to remind about the great scientist-discoverer , the founder of new science – cosmonautics K.E. Tsiolkovskiy. As it is known exactly to him belongs the idea of space train creation, which is being realized in this project of the expedition towards Neptune [11]. And his words, that "The mankind does not stay eternally on Earth, but in pursuit of light and space will begin to penetrate beyond the limits of atmosphere, initially timidly, but later will conquer all the circumsolar space" , had proved to be prophetic.

What does it mean the words " will conquer" ? In my opinion it means: While overcoming all hardships of staying in space, human being by way of consecutive expeditions will visit all the planets of the solar system. On Titan a permanent scientific research center will be built.

Scientist-astronauts will carry out the researches, which may be genuine breakthroughs in many fields of science. I do not see the necessity of a mankind resettlement onto another planet. On Earth there is quite enough light and space for worthy life of every human being.

It is high time to learn, at last, to master it without barbarous destruction of the nature and self-destruction of people in holocaustal wars.

Indeed there is an apprehension that an accidental, unpredictable asteroid early or late will come into collision with Earth. It will be the end of the human civilization. But in year 2015 all the world was watching the first landing of space craft "Rosetta" on surface of comet 67p/c-G [12].

This event can be a beginning of development of a rescue technology, which by nuclear explosions can destroy the dangerous asteroid.

In this connection it should be noticed, that the space train, which is developed in the project of expedition towards Neptune, can be successfully used as a "fighter interceptor". Calculations shows that such a fighter of "stray (mad)" asteroids is capable to overcome the distance from Earth orbit up to asteroid belt during 14 days!

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