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Means of geocosmic freight traffic optimization Pilot project based on patents RU2398717 and RU2385275

Innovative aspect.

The more profitable cosmic space becomes for investments the more attention is growing to rising of geocosmic transport efficiency. Rocket is a transport means with very low efficiency characteristics. It was clear already 50 years ago, that's why rockets technology progress has been accompanied by important theoretical searching to find if not an alternative to rocket than at least a serious help to it as well as by reconsideration of bases of geocosmic freight traffic arrangement.

Important achievements in this sphere have been done by Demetriades and Marwick with their projects of space accumulators of substance.

Demetriades proposed method of atmospheric gases accumulation by means of low-orbit satellite. Moving around the orbit Demetriades ' satellite takes discharged air from the boarder of dense layers of atmosphere, compresses it by means of gas-dynamic compression in diffuser and compressors, cools it off and extracts liquid oxygen. The remaining nitrogen is used in nuclear electrorocket engine for compensation of losses caused by aerodynamic resistance. This has solved the problem of reduction in price of rocket fuel delivery to orbital fuel depositories due to the fact that oxygen accumulated from atmosphere by it's mass is the main component of typical rocket fuel and electric rocket engine (ERE) have got high operating resource and low cost as compared with thermochemical ones.

In general Marwick has solved the second part of the problem to deliver rocket fuel to orbital fuel depositories: he proposed the way of delivery from Earth to orbit of any kinds of substances necessary for both production of rocket fuel (like hydrogen), as well as for reaching purposes of space industrialization (like aluminium and silicon for production of mirrors and solar batteries for orbital electric power stations). At the same time Marwick introduced the way of cargoes delivery for industrialization purposes not only from the Earth but from Moon surface as well.

Still both projects have remained unimplemented. The main reason for that was incompatibility of basic points of the projects to modern safety requirements and level of astronautics development.

The project of Demetriades famous as PROFAC Project is based on application of powerful energy source on board an accumulating space device (ASD). Demetriades proposed to use nuclear reactor as such a source of energy supply. Other sources are hard to be used on board a satellite in conditions of it's flight on heights from 105 to 120 km when high resistance of atmosphere demands persistent support of flight by engines draft. Rising of orbit height for reduction of aerodynamic resistance to use solar batteries which have got high windage is making no sense in case with PROFAC Project so far as ASD is capable of efficient absorbing and accumulating air being on its way in front of it only on low heights. For neutralization of braking forces when air is absorbed ASD should use around a half of the absorbed air (but already refined from valuable oxygen) as a working substance for electric rocket engine. Jet stream has to flow out with a speed of 16000 m/s that defines high energy intensity of air accumulation process – 256 MJ/kg with 50% ERE performance. The accumulated gas mix contains 46% of oxygen (by its mass). That's why for accumulation of 300 tons of oxygen in course of one year of operation ERE needs energy supply source with 5,6 MW power capacity, that in an obvious way demands application of nuclear electric generator. However, prohibition imposed by International Agreements on usage of satellites with nuclear reactors on orbits lower than 800 km height has actually closed the perspective project of Demetriades forever.

Later on there appeared proposals to use laser system of energy supply to ASD both from space and from the Earth instead of nuclear source, but by now the achieved level of required technologies development doesn't make it possible to revive PROFAC Project.

Marwick project fixed by two USA patents (US4775120 and US5199671) is based on application of powerful heavy and bulky electromagnetic mass accelerator constructed on the Moon. Second condition of the project implementation is creation of hypermassive satellites on circumlunar orbit in one of libration points and on low circumterrestrial orbit. Marwick system works in following way. Portions of moon regolith processed in corresponding way in order to give them required solidity are ejected from Moon surface by electromagnetic mass accelerator. This substance flow is redirected towards the circumterrestrial hypermassive ASD with a help of circumlunar ASD by uncomplicated means. Simultaneously cargoes from the Earth are directed to the same satellite. Basing on satellite by means of blows momentum (motion impulse) is transferred from high-speed lunar cargoes to low-speed terrestrial ones. That's why instead of directing a rocket to the height of low-orbit base and speeding it up to complete leveling of speeds, the rockets used for cargoes delivery in the described way start up strictly in vertical direction, discharge cargo and fall down to the Earth where they pass technical maintenance and used iteratively. The discharged cargo is directed in such a way that it enters into an opening of a large chamber used for cargoes reception and then inside of the chamber it collides with a big mass of buffer substance by the center of the chamber in such a way that the cargo remains inside the chamber and the chamber walls remain undamaged. Cargoes from the Earth enter the chamber through its front opening at the speed of around 8 km/s and lunar substance cargoes enter the chamber through its back opening at the speed of around 11 km/s (with a speed of 3 km/s relative to the chamber). So far as vector sum of substances' moments directed from the Earth and directed from the Moon is approximately equal to zero due to the right matching of masses, the height and the speed of satellite used for cargoes reception remains practically constant. Insignificantly bigger moment when getting cargoes of lunar substances can compensate atmospheric resistance of environment.

The chamber used for cargoes reception is being located on a very low circumterrestrial orbit (200 km height) due to application of vertical halyard of around 100 km length from the centre of masses of satellite system (which has also got upper block of mass) on 100 km height from masses centre. In such a vertical satellite system with two large blocks of masses the best place for location of large reception chamber is the lower block so far as it is easier (cheaper from the point of fuel consumption … etc.) to transport cargoes from the Earth on lower height.

With all it's possibilities to reduce in dozens of times the specific cost of cargoes delivery into space with rockets Marwick project still can't be implemented in the nearest future due to far too big masses of applied devices. The mass of lunar mass accelerator is evaluated at 2000 tons. The ASD masses – 10 thousand tons each. Besides, the project doesn't solve the problem of orbital parking of standard spacecrafts so far as there can only be delivered just simple cargoes capable of standing hyperaccelerations and high-temperature heating.

There is also known an invention application by Marwick not legalized by a patent. It proposes a project on satellites acceleration and barking for their transfer to different orbits with a help of series of inelastic collisions of moon substance cargoes directed either to stern part of a satellite for its acceleration or to the frontal part for its barking. In this project cargoes were absorbed and accumulated in the same way as it was proposed in abovementioned Marwick patents. In one of his patents Marwick has proposed to support movement of PROFAC-type device in a similar way. This valuable concept still can't be embodied into life by the same reason of excessive mass of devices implementing the considered methods. Besides, it didn't contain any decision on spacecrafts parking from Earth due to kinetic energy of lunar cargoes – this proposal was limited by satellites.

In Russian patents of Mayboroda (RU2398717 and RU2385275) and analogous applications for foreign patents (WO/2010/082869 and WO/2010/095977) there is a solution of problems impeding embodiment of progressive ASD concept up till now.

The first patent applies to development of Demetriades PROFAC concept and Marwick ASD concept reflected in his patents. The second patent develops Marwick concept reflected in his application for a discovery on using of mechanical energy of extraterrestrial substance for space aircrafts acceleration.

Patent RU2398717 solves the problem of usage of non-nuclear energy supply source for ASD equipped by propulsion device and the problem of excessive mass for ASD accepting not gaseous substances but high solidity cargoes.

Patent RU2385275 solves the problem of launching of cargoes from Earth into space basing on passing them mechanical energy from extraterrestrial substances or, what is more important, from terrestrial substances preliminary accumulated on circumterrestrial orbit.

Solving of problem of non-nuclear source of energy supply for ASD of PROFAC type consists in PROFAC modernization – changing of it's functioning mode – transferring it from atmospheric air collection to collection of substances delivered from Earth by sub-orbital rockets on the scheme similar to that patented by Marwick. In this variant ASD orbit can pass higher than it's usual height where aerodynamic resistance is substantially less. This allows to use large solar converters instead of nuclear reactor, especially in vertical satellite system scheme where solar batteries are located in the upper block (on 200-250 km height) and cargoes reception chamber is in the lower block. Part of cargoes entered from the Earth are utilized as working substance in ERE instead of atmospheric nitrogen.

At the same time with enough lowering-in (till 120-130 km height) of cargoes reception chamber hanging up on a cable and with relatively low (in percentage relation) cable aerodynamic resistance, same as in previous schemes it is possible to accumulate air together with simultaneous reception of cargoes picked up by suborbital rockets. Such a hybrid way of substances accumulation could be useful for creation of orbital stocks of high-boiling (non-cryogenic) rocket fuel in a form of nitrogen combinations with hydrogen (hydrazine) and of nitrogen with oxygen (nitric tetraoxide), so far as in this case rockets would have to deliver only hydrogen which share makes up only 12.5% in hydrazine composition. In actual fact the share of combustible fuel component delivered by rockets will be higher because of necessity to produce also some quantity of asymmetrical dimethylhydrazine which together with hydrogen contains also carbon. At the same time a number of explosive combinations produced only on bases of nitrogen and oxygen combinations makes it possible in production of rocket fuel on orbit to do without delivery of hydrocarbon raw materials by suborbital rockets. This becomes possible in the schemes of getting draught due to application of the known pulse detonation engines.

For the purpose of solving the problem of energy supply to ASD propulsion device the patent proposes to use electrodynamic tether engine instead of ERE. This solution goes well with the considered hybrid scheme of accumulation of both rocket cargoes and atmospheric oxygen and nitrogen basing on the described vertical cable satellite system. Electrodynamic tether engine doesn’t need working substance, has got up to 90% efficiency and draught value which is 4 times less than that of ERE.

The problem of excessive mass for ASD accepting high solidity cargoes is solved by rejection of the scheme proposed by Marwick on reception of cargo in one single portion into one large chamber with big stock of buffer substances protecting it from shock waves: one portion is replaced by a flow of small portions also delivered by one suborbital rocket. The mass of chamber with buffer substance should at least be in 10000 times bigger than the mass of cargo received with the speed of around 8000 m/s. Accordingly partitioning of entire cargo into 10-100 thou. portions (that is its transformation into a substance flow which parts are entering the chamber and brake in it step-by-step) such partitioning reduces the necessary mass of reception chamber with buffer substance in 10-100 thou times as well. In result of this patented solution mass of ASD reception chamber turns out to be reduced from 10000 tons in Marwick project to 1 ton in Mayboroda project. From technological point reception chamber for cargo delivered in a form of substance flow is an analogue to rocket engine but functioning in an opposite way approximately same like for example refrigerating units operating on Brighton reversible cycle and internal combustion engines operating on Brighton direct cycle, or like electric current generator and electric motor.

In practice proposed method of cargoes delivery into ASD chamber represents itself lifting of suborbital rocket on ASD orbit height and emission by this rocket of liquid flow or unwinding of halyard in the upper part of its trajectory along the line parallel to ASD orbit, that is perpendicularly to vector of radial component of rocket speed. Emission of cargo flow from rocket starts 30-60 seconds before reaching the maximal height for the purpose of ASD to pass this zone with substance dispersed along it and for discharged substance to be maximally widely spread along the accumulation zone of ASD trajectory simultaneously not having time to leave the grip zone at the moment of gripping by intaking device. Gripping of substance is best of all to be done at it's minimal speed of movement on vertical line – in 5 meters height zone of movement changing from lifting to descending where cargo spread along ASD flight line is located there for almost 2 seconds that makes it possible considering ASD speed at low orbit to create tracks of around 15 km length, although for the solved problems its enough to create 1 km-length tracks as well as to use corteges of lift-rockets to create tracks of unlimited length.

The problem of launching of cargoes from Earth into space basing on passing them impulse from cargoes already located on circumterrestrial orbit is solved similarly to the considered previous problem. Marwick devices which increase their speed only under the influence of moon cargoes incoming from stern should have mass exceeding the mass of single cargo in several degrees. In case of usage of substance flow (liquid or solid) with mass equal to that of single cargo, the mass of cargo reception chamber is reduced in thousands times. However it would still stay big enough if substance flow entering the chamber stayed in the device and accumulated there same as in ASD. That's why in second Mayboroda patent for spacecraft acceleration with kinetic energy of orbital cargoes accumulation of cargoes doesn't take place - elastic collision is applied (in its physical-theoretical meaning). The flow entering the chamber is reflected in opposite direction that reduces chamber mass to values very close to those of the existing rockets engines. In this way the spacecraft mass in its absolute and specific value is brought to the values making it possible to launch such spacecrafts from Earth in the beginning (on the first stage) in usual rocket way up to 100-150 km height and then applying the patented way which consists in fact that the substance track of many kilometers moving at speed of 8000 – 11000 m/s and formed up by special devices is colliding with the aerorspacecraft and accelerates it up to orbital speed in several minutes by uninterrupted pushing it into stern. The mass of such an accelerating track is approximately equal to that of the launched spacecraft. If for example the mass of an spacecraft launched into space is 10 tons and it is launched into elliptical orbit with apogee at 400 km height while orbital track has got speed of 10000 m/s in perigee at 100 km height in the point of contact, then the track mass will also be around 10 tones. Frozen nitrogen can be the substance of the track (as well as its low-volatile liquid and solid combinations with oxygen or such a non-cryogenic product as hydrazine hydrate), reinforced by aramid or polyethylene fibers in quantity of 1% from nitrogen mass. From the night side of the Earth such an accelerating track can be used without any harm to its safety due to absence of solar radiation. Then the required mass of nitrogen could be accumulated PROFAC-type ASD for one month of operation with its engines' draught of 30 N only. If ASD draught is created by electrodynamic tether engine the electric power of solar batteries feeding the engine will be not higher than 0.3 MW (considering calling into shady side of the orbit). In course of one year of operation such system is parking

12 devices with total mass of 120 tones into orbit. As opposed to Marwick projects, cargo of such devices can be both people and different equipment. With next parking at geostationary orbit (if it was the purpose of launching) each such transportation device will be delivering communication satellite of two-three tones. And with 0.9 MW solar batteries power capacity the proposed system will provide devices parked at low orbit with rocket fuel stocks of 240 tones mass.
In general there are no principal limitations on volumes of fuel refueling into low-flying satellites – the volumes of delivery can be as large as necessary basing on calculation of production of 33 tones of fuel per month for each 1 MW of ASD solar batteries' electric power supply.

An important aspect of usage of kinetic energy of orbital stocks of nitrogen and other easily accumulated substances is application of this technology not only for geocosmic trips but for intercontinental transatmospheric flights as well. Well-known models of passengers aircrafts with turbo-jet and rocket engines, like Space Plane by EADS Astrium, worked out for touristic flights beyond the atmosphere with fuel stocks enough only for a simple jump at the height of 100-110 km, could perform intercontinental flights on Sanger scheme on distances up to 20 thou km with getting acceleration from Mayboroda orbital systems. Such aircrafts also equipped with Mayboroda kinetic engines start up in an airplane way from a usual airfield and on 110-120 km height with the help of orbital accelerators turning above the planet surface in different directions and forming stable transportation net could reach sub-orbital speed and after transmission on undulatory Sanger trajectory would make a landing on a usual airfield.

With such way of flight energy supply there is no necessity in obligatory acceleration of such aircrafts to high subcosmic speeds for distant flights – there is always a possibility to accelerate aircraft in space by small impulses from orbital streams corresponding to the route as to compensate aerodynamical losses of energy on lower passes of undulatory trajectory and in this way to keep the aircraft in aerospace as long as its necessary, (for example with average speed of 11 thou km/hour dramatically rising it in case of necessity up to 20-25 thou km/hour).

Economic Aspect

Implementation of the described in Mayboroda patents ways of geocosmic freight traffic in a form of the considered geocosmic transportation system (GCTS) will lead to substantial changes of prices in the sphere of space transportation services and correspondingly in economical spheres which are implementing these services. Lets consider first and second sides of changes one by one.

Economical data on modern space technique make it possible to do an adequate analysis of GCTS and to give proof of availability of its implementation instead of classical rockets.

Specific value of cargoes launching into orbit in GCTS is formed by two main value characteristics. The first one is the specific value of vertical lifting of cargoes by sub-orbital carrier rockets (CR). The second one is the specific value of operation on gripping and acceleration of cargoes on board an ASD. Second economical characteristic is based on very favorable technical parameters of ASD – its main systems have got more than three years operation resource and capable of operation in the limit case up to 15-20 years and that's why the part of specific value defined by ASD price will be unsubstantial in price structure because of long terms of amortization. Its not hard to define maximal specific value of vertical lifting of cargoes by carrier rockets (CR) on ASD orbit height. Lifting of useful cargo (UC) on 200 km height without considerable acceleration in cross direction to radial speed vector (horizontally) is performed by modern CR at the account of first step operation. The mass of CR first step makes up about 2/3 of starting mass. For example the share of the first step for CR "Proton" makes up 65%. In connection with the fact that in those variants of GCTS project where there is no need in considerable CR acceleration in cross direction (horizontally), the mass of UC delivered to ASD by one-step analogue of "Proton" can make up 35% of the starting mass. This is 10.86 times more than the mass of UC of 3-steps version of CR "Proton". In prices of the considered period specific value of cargoes launching into orbit of 200 km height is equal to $3250/kg for a Russian CR "Proton" and $4731/kg for an Ukrainian CR "Zenith" (according to the data of 2007 the cost of launching of both CR corresponds to $65 million with UC mass of 20 tons and 13.740 tons correspondingly). Accordingly almost 11-times increase of UC share in one-step version of CR "Proton" gives specific value reduction down to $299/kg with constant launching cost. At the same time ASD reception device can from time to time get down on a cable from 150-200 km height to 110-130 km height and due to it UC mass delivered to cargo withdrawal ASD device with the help of one-step "Proton" analogue can make up around 44 and more percents of the starting mass. In this case the received value of $299/kg should be reduced in 1.25 times that gives $239/kg for a one-step CR of "Proton" type.

The received value doesn't yet consider the fact that the cost of one-step rocket is at least two times less than the cost of it's multistep analogue – the first step costs less than 50% of whole multistep CR cost. To define the influence of one-step factor it is necessary to use data on structure of launching services price. Thus, in Ukrainian investigations on pricing of launching services following data on commercial structure of costs are given:

- CR production and transportation – 43%
- Space launching site services – 17%
- Launching insurance – 17%
- Development works (DW) – 9%
- Contingencies – 9%
- Contract management – 3%
- Contract maintenance – 2%

Basing on these data specific value of CR in considered variant makes up $103/kg and other expenses – $136/kg, but considering double reduction of expenses on one-step CR ($51.5/kg reduction) the result will be equal to $187/kg.

In other expenses conditionally constant part is the share consisting of space launching site services (17% from $239/kg or $41/kg) and all the resting expenses

($136 minus $41 or $95/kg) – are the conditionally variable part, that means it depends on multiplicity of CR usage. In the examined case CR is a single-mission one and the received value of $**187**/kg should be considered as the upper limit of price of cargoes lifting to ASD reception device in the variant when launching is performed from terrestrial (sea) space launching site by a single-mission carrier. In the variant of air-start scheme implementation price will be less.

At the same time along with air-start projects there are the projects of partially reusable and multistage CR like "RN-35" where preservation of the first step is supplied with usage of wings. The saved steps are also the versions of "A block" of CR "Energy" with folding wings. These versions are the modifications of presently exploited CR "Zenith". There is also known a project of rocket accelerator "Baikal" – the winged version of rocket step of CR "Angara" with multiplicity of usage up to 25 times, as well as pilot project of similar step for CR Ariane-5. It is supposed that multiplicity of usage of the first step of "RN-35" will be equal to 100. In this case in respect to the examined one-step variant of reusable CR there can be expected reduction of specific value in 4 times and reaching of $45/kg price, while for completely reusable two-steps "RN-35" prognosed price will be $500/kg -$1000/kg.

To get an idea of the lowest limit of cargoes delivery to orbit we can consider projects of reusable rockets. Then in respect to $187/kg price for modified one-step CR "Proton" where the share of space launching site services on launching provision will make up around $41/kg in the price of the fixed part, the shares of variable expenses depending first of all on quantity of CR re-employments – will make up $51/kg for one-time usage CR and $95/kg for other expenses or $146/kg for all variable expenses in total. With reusable CR number of launches equal to 100 variable part will be reduced to $1.46/kg, of course provided that the cost of reusable CR will be same as that of one-time usage CR. For the first steps of CR (with low load capacity) it is almost like this, quite often their rescue is provided by usage of parachutes and alighting on water. In this case the price is increased but not substantially. If to consider that the price for reusable suborbital (low-speed) CR grows substantially, for example in 2 or 3 times, then the variable part of price will take values of $2.92/kg and $4.40/kg. Considering the fixed part of $41/kg the lowest limit of launching specific value will be in the range from $**44**/kg to $**45.4**/kg.

Here it should be noted that in practice conditionally-constant expenses on services rendered on space launching site are also reduced with launches frequency increase (for this reason they are "conditional" in their constancy) and that's why minimal limit of drop in specific price on suborbital CR implementation is defined by the cost of combustible, oxidant and consumables used for launch. As is generally known, *cost of any product in mass production tends to raw materials cost.* This can also be fully related to space industry as well. That's why as foreseeable future forecast probable price of UC delivery to ASD reception device should be accepted as cost of kerosene ($700-750 per ton) and of liquid oxygen ($6 per ton) necessary for vertical lifting of 1 kg of UC on 100 km height (without UC cross acceleration) and plus several extra percents to this sum on amortization and overhead expenses of aerospace company. Thus launching services *based on suborbital CR* with growth of launches frequency in reachable perspective will be tending to the level of $0.8/kg, but in present calculation $45/kg is taken as minimum.

The predictable prices for GCTS are calculated basing on CR of high load capacity that will be fair for GCTS of second generation while for GCTS of first generations calculations should be based on CR of low and extremely low load capacity: such postwar one-step rockets as Aerobee Hi (launching mass about 500 kg) and Viking (launching mass about 4500 kg) can be defined as analogues of these low load capacity CRs. The modern prototype of such one-step rocket plane can be multistep CR “Micron” (launching mass 7000 kg) launched from board of plane MiG-31. Application of these means of cargoes delivery by small portions to ASD orbit will most probably not give substantial differences in pricing – so far as experience can show usage of microcarrier “Micron” doesn’t cost more than launches of “Proton”-type CR per one unit of launched cargo.

Now let’s define the range of upper and lowest values of specific cost of operation on cargoes gripping and acceleration on board of ASD.

Here first of all rocket fuel delivery to orbit is interesting. As it has already been explained oxygen is accumulated without participation of suborbital CRs, but only in result of application of PROFAC-type ASD reception chamber tugged on cable with compensation of aerodynamic braking forces by draught of electrodynamic tether engine fed by solar batteries located in upper part of vertical satellite system. In this variant air entering ASD is not consumed in ERE to create draught and in this connection correlation of oxygen and nitrogen stocks on board of satellite turns to be absolutely same as it is in atmosphere – 21% and 78% on volume and 23.1% and 75.5% on mass correspondingly. Then using 21% of oxygen (by volume) in nitric tetraoxide production it is possible to combine 10.5% of nitrogen. The resting nitrogen will make up 67.5%. Part of it can be used in production of rocket combustible fuel like hydrazine. With consideration of already produced oxidant it is necessary to provide suborbital rockets with hydrogen in the amount (by mass) of 1 kg per 8 kg of oxygen contained in nitric tetraoxide, and this is quite favourable for increasing profitability of GCTS operation because of little number of necessary launches of CR. As related to volume it will require 10.5% more of nitrogen from its rest of 67.5% of volume. In this way with delivery of combustible fuel in the form of hydrogen and accounting on complete utilization of oxygen for its oxidation the rest of nitrogen will make up 57% of volume. This rest will partially go for commercial reserve, e.g., for its utilization as material for production of orbital tracks and launching of spacecrafts from Earth to low orbits with their help, or for acceleration of hypersonic intercontinental passenger and/or tourist aircrafts. The other part of unused nitrogen like for example 7% out of 57% will go to create working substance (WS) stocks for ERE of interorbital tugs and ASD own correction motors. Finally it turns out that for the purposes of production and accumulation of commercial stocks of rocket fuel in a form of hydrazine and nitric tetraoxide and ERE working substance as well it is real to use just a half of accumulated air and the second half can be used as substance of orbital accelerating tracks for spacecrafts. At the same time hydrogen deliveries will make up 2.9 kg per 100 kg of accumulated air or 2.8% from total composition of all the created stocks.

The revealed rates of mixture make it possible to calculate economic parameters of ASD operation with different flows of cargoes and current market prices on geocosmic transportation. If to take the existing level of cargo traffic as basic which is varying in different periods rising up to 1000 tons per year and going down to 500-600 tons per year then possible demand on spacecrafts refueling services on low support orbit will make up the minimum of 400 tons of rocket fuel per year plus launching of the orbital devices with total mass up to 400 tons in addition. It has been defined above that this is approximately half a mass of substance which combined "cargo-air" ASD is accumulating in course of one year with the help of rocket deliveries of hydrogen and direct intake of atmospheric air. Out of this volume of working substance equal to 800 tons the share of hydrogen will make up only 22.4 tones. For lifting of such mass to ASD cargo collectors it is necessary to perform 448 launches of meteorological class microrocket of Aerobee Hi type. It is accepted that in one launch 50 kg of liquid hydrogen can be lifted. ASD reception chamber used for gripping of this amount of hydrogen has got the mass of not less than 50 tons with consideration of ballast mass of liquid nitrogen, while its own dry mass is in the range of 13.7-20 tons.

Its not hard to provide multiple use of such class CR with multiplication factor from 100 launches per rocket. In this case to provide yearly stream of hydrogen into ASD just 4-5 multiuse microrockets are enough (with 2 small unmanned aviacarriers CR in case of air-start scheme implementation). Low launching mass of modified variant of Aerobee Hi (500 kg) makes it possible to apply air-start scheme with implementation of unmanned aircrafts, that substantially reduces the share of "space launching site" services expenses.

Launching cost of multiuse variants of Aerobee Hi is diminished in total 800-tons mass of accumulated working substance. With \$45/kg price the cost of delivery of 22400 kg of hydrogen will come to the sum of a bit more than \$1 million. Reckoning on the basis of the whole mass the specific price of rocket expenses will add up just \$1.25/kg to the specific price of accumulated stocks.

From the point of view of ASD production consumers, it would be more interesting for them to purchase not pure hydrazine but its blend with asymmetrical dimethylhydrazine (famous as Aerozine 50) containing not only light hydrogen but also relatively heavy carbon. The blend proportion is 1:1. In this variant the number of hydrogen deliveries to provide production of "Aerozine 50" should be increased in 1.5 times. Plus to this deliveries of carbon (C) are also added in proportion S mole of C per 1 mole of N_2. In concrete figures it will be 33600 kg of hydrogen (H_2) per 67200 kg of carbon (C). Deliveries can be performed in the form of high-boiling hydrocarbons with total mass of 100800 kg per year as rocket makeweight of UC to air stocks with 800000 kg overall accumulation of total mass. In practical aspect this means increase of substance delivery to ASD by rocket means in 4.5 times or increase of launches of suborbital micro-CR up to 2016 annually or 5-6 launches daily. The fleet of multiuse CRs is then growing up to 20 units and the detachment of small unmanned aircrafts for air-start provision will consist of 2-3 aviacarriers.

With \$45/kg price the cost of 100800 kg of hydrocarbons delivery will make up \$4.5 million. Reckoning on the basis of the whole mass of substance accumulated different ways the specific price of transportation expenses will be increased only by

$5.625/kg.

In pricing of rocket fuel produced on board of ASD substantial turn to be not rocket deliveries of subsidiary substance but the cost of ASD itself and it's operation resource. On the stage of project introduction with low cost of device itself ($1-10 thou. per 1 kg of construction with cable ASD upper and bottom blocks dry mass of 13.7-20 tons each block), the most expensive in price structure will be as usual DW (development works) expenses. Considering world experience in creation of new generations of space vehicles and rockets depending on the country of origin DW costs can be evaluated in a very wide range - from $1-5 billion and more. However, the shown demand on stocks of working substance created by ASD provides coverage of DW expenses even with lowest possible prices. If we refer to the known temporal downturn in prices on CR "Proton" launching services when from $70 million there occurred dumping drop to $25 million with UC mass of 20 tons and specific launching price dropped down almost to the level of its prime cost of $1250/kg, even then with working substance sales volume of 400 tons annually in course of 10 years of ASD exploitation the gain will make up $5 billion.

At the same time there also remains same stocks of liquid nitrogen which can be sold at same minimal price by creation of orbital tracks from frozen nitrogen and utilization of these tracks for acceleration of suborbital passenger intercontinental and travelling-entertaining aerospace crafts, as well as for launching of part of UC from Earth to low support orbit. Altogether total sales volume will make up $10 billion for 10 years of system exploitation. Accordingly reserve of DW expenses is rising up to values exceeding $5 billiard and can even be on the level of $7-8 billion. Although it is not ruled out that probably expenses will be limited by minimum amount of $1 billion so far as ASD pilot system may in an obvious way contribute to expenses reduction in course of pilot exploitation in space. Besides, considering the increased level of prices on launch services for standard rocket systems selling of orbital stocks of fuel and rendering of launch services based on acceleration tracks will be competitive with services specific cost of $2500/kg. This will still be the minimal possible price level on global market. With this level 10 years of GCTS exploitation (even with outrageous DW costs) will supply provider company with $20 billion earnings with disbursements and profits guaranteed as 50/50. This is in the most unfavorable variant. And in optimal case when DW expenses don't exceed $1 billion the received profit will be in the range of $9-19 billion.

In reality possible profit should be bigger considering that there are no circumstances interfering with the desirable from economical point of view price reduction on GCTS services down to $1000/kg – the level at which experts consider substantial growth of cargo traffic in space possible – reaching the level of 4000 tons per year. This level corresponds to capacity reserve of GCTS. With rising of electric power capacity of solar converters up to 10MW, ASD is lifting mass of received cargoes and absorbed air up to 4000 tons annually turning into exclusive supplier of geocosmic transportation services due to absence of real competitors. In this scheme earnings will make up $40 billion.

Additional increase of cargo traffic is expected at the account of implementation of plans of a number of countries on construction of a group of solar electric power stations of at least 1GW capacity each on geostationary orbit. These plans implementation are contributed by present success in creation of thin-film solar converters with specific mass of 0.5-1 kg/KW. With a system of electricity converters into a flux of microwave or infrared radiation the mass of such stations will be around 2000 tons per 1 GW. There are known at least 3 national projects of satellite electric power stations that gives us approx 6000 tons of cargoes liable to launching to geostationary orbit by solar interorbital tugs or around 12000 tons of initial mass of these cargoes liable to launching on low support orbit. With $500/kg price for cargoes launching on low support orbit (and this is very profitable for electric power stations constructors) the bulk of order on three stations will make up $60 billion (Japan is planning to spend more than $22 billion on their national project of obtaining energy from space). Part of transported solar batteries can be used not only for energy supply to ERE of interorbital tugs but also what is the most important for provision of process of their own launching from Earth to support orbit.

As much as energy and ecology crisises is rising necessity of electric power supplied to Earth customers from space will be growing continuously. It is supposed that in perspective energy supply from satellite electric power stations will grow up to the existing level of power consumption (only for energy supply of each 1 million private houses deliveries of 3 GW capacity are required), including the level of energy-release from hydrocarbon fuel considering the possibility of its complete substitution in transport and industry. If prices on transportation of raw materials and equipment for construction of space electric power stations drop down to $50-100/kg, the scenario of terrestrial energy sources substitution by space ones is becoming the most progressive direction of space activity in comparison with information direction that is leading today. Then with $50-100/kg prices there become possible orders of cargo traffic of 200-400 thou tons annually with turnover from $100 billion to $400 billion.

At the same time maximum low prices on GCTS services can be reached even with substantially less cargo traffic. The results of analysis considering possible terms of GCTS amortization in 7-15 years with different types of engines, efficiency, types of orbits, show that total specific cost of cargoes delivery by CR into space in form of raw material to low support orbit and their reacceleration on board of ASD in the best GCTS variants is tending to specific value of suborbital delivery of cargoes to ASD and could make up $**50-100**/kg with perspective of further reduction with suborbital carriers improvement.

In this way implementation of even simplest variants of GCTS working as orbital fueling stations with present high prices on delivery of rocket fuel to orbit opens the door to transformation of cosmic space into profitable sphere of capital investment provided DW start in the nearest future.

Implementation of GCTS basing on PROFAC ASD in a form of vertical cable system and kinetic engine in suborbital devices makes it possible to launch substantial quanta of cargoes into space including manned spacecrafts without usage of heavy CR like Saturn V or Space shuttle. For example single-step rocket based on CR "Zenith-2" with its useful utilization block equipped with Mayboroda kinetic engine can launch into orbit from 100 km height cargoes of around 200 tons, single-step variant of CR "Proton" – around 300 tons, one-step variants of CR Space shuttle and CR Saturn V – up to 800 tons and 1200 tons accordingly. Economic benefit from such innovation – economy of budgets on development and commissioning of heavy CR of tens of billion dollars, economic effect from substantial reduction of terms of big cargoes launching start and their exploitation, reduction in launches specific value. As for modern cargoes with not great mass within the limits of 5-10 tons – for their launch it is enough to use single-step CRs with 15-25 tons launching mass.

Cost of services on such launches realization is mainly defined by GCTS main devices life time and accordingly by amount of depreciation charges. Physical conditions of system operation on air accumulation and further creation of orbital tracks from frozen air are so favourable as opposed to alternative systems that it is possible to give justified prognosis about its 10-20 years operation capacity.

Launch services global market in its full size goes to owners of GCTS technologies because price of launches in described way can always be made cheaper than the price of launching in usual rocket way with whatever level of CR modernization. Competition from the side of classic rocket way could be presented by rockets with pulse nuclear engines using series of plutonium charges explosions behind the spacecraft stern for getting draught. However usage of such devices for Earth-start is absolutely ruled out, at least in commercial purposes because of disastrous consequences of radioactive infection, while in cosmic space there holds a prohibition on nuclear explosions and even cancellation of prohibition of nuclear explosions in circumterrestrial cosmic space won't open the road to such devices – electromagnetic impulses from explosion will collapse electronic devices of operating navigation and communication satellites.

With present prices on launching services realization of many space projects important for global economy turn to be unprofitable. But if we reduce delivery cost to $1000/kg then, as investigations show, a real space boom will start. According to specialists' evaluation in this case 3-4 thou tons of cargoes will be annually "casted" into circumterrestrial space (5-8 times more than at present). It will thoroughly change the world economy. Even more dynamics to global economy GCTS will give in result of reduction of prices to the level lower than $100/kg.

First direction of GCTS commercial exploitation will be creation of orbital depositories of rocket fuel and refueling systems for low-orbit satellites, first of all those which should be launched to geostationary orbit. The share of fuel necessary for satellite transmission from low orbit to geostationary one makes up in average 75% of accelerating block launching mass on low support orbit. Accordingly creation of refueling service for devices delivering geostationary satellites gives fourfold profit in CR commercial payload. Instead of fuel stocks three additional satellites more can be launched into orbit. Besides geostationary satellites themselves have got their own stock of fuel for correction motors meant for 7-15 years of satellite operation. This stock makes up around 80% of mass of satellite already launched into geostationary orbit, in this case the mass of device with fuel is 5 times more than the mass of satellite useful equipment. Considering possibility of refueling of this rocket fuel mass not on the Earth but also in orbit CR's useful load can be finally increased in 20 times.

Second direction of GCTS commercial exploitation will be launching of satellites and interplanetary spacecrafts. Considering the fact that since now CRs have to consume fuel only for vertical climbing with obtaining only radial speed while velocity cross component is provided by contact with orbital flow, CR useful load with climbing on around 100 km height rises up to 50% of launching mass and the cost of single-step CR is reduced twice. With CR construction mass increase on 15-25% for creation of tested CR rescue systems for further multiple reusability, launching specific expenses drop down to $50-100/kg same as in case of valuation of fuel delivery to orbital depositories.

Third direction of GCTS commercial exploitation will be establishment of service of circumterrestrial space cleaning from so-called cosmic garbage. Basing on rocket fuel refueling systems there will be arranged a group of interorbital interceptor-tugs. The number of trips for each interorbital device before its capital repair for operation on heights up to 3000 km can be defined as 1000 – it means 3-10 hours total operation of the cleaning device liquid rocket engine (LRE). Then to fulfill main scope of works on space clearance 100 interorbital handling devices will be enough. On estimation of Russian specialists market of cosmic garbage liquidation services will make up $3 billion.

Fourth direction will be rendering services on evacuation of part of radioactive wastes from Earth. For example, liquid radioactive wastes (RW) treatment technologies require rather high expenses. The cost of RW processing and storage makes up 5-10 thou/m^3. Practice shows that for 1 year of nuclear power station (NPS) operation there generated from 0.5 to 1.5 m^3 of medium-active liquid wastes per 1MW of reactor block's electric capacity. This gives around 1000 tons annually as cargo for GCTS. Solid radioactive substances treatment comes to cost quite expensive. In Western Europe commercial plants on high-activity RW vitrification are processing around 1000 tons per year. Proceeding from possibility of some types of wastes burial in space at $1000/kg -$2500/kg price, the scope of services in this direction will initially make up not less than 1000 tons per year.

Fifth direction of commercial activity – transportation of raw and constructional materials, details of constructions and aggregates to build satellite solar electric power stations on the known plans of Germany, Japan and USA. Low cost of services is the ground of getting the major share of this market. This direction is also perspective due to the fact that electric power stations which can be assembled by parts in orbits can be a part of GCTS system during a certain time-period and in this way can provide for themselves their inexpensive transportation from Earth into space. It would be recalled that 1 MW of GCTS solar batteries electric power provides delivery of 33 tons of cargoes from earth per month or 400 tons per year. This means that with plans of creating gigawatt-capacity electric power station there will appear "free" possibility of launching equipment for the station with total mass of up to 33 thou tons per 1GW of station capacity monthly in case of delivery to low orbit and not less than 10 thou tons per 1GW monthly in case of geostationary orbit.

Sixth direction of commercial activity – space travelling which (with present hyper-high prices) makes up around $1 billion annually according to "Space Adventures" company estimations and $3 billion annually according to EADS

“Astrium” estimations.

Opinion surveys have shown that substantial part of developed countries' population is ready to travel into space. For example in Japan there was held a public inquiry defining how much an average Japanese wishing to make a space trip was ready to pay for that. 70% of those asked have signified such an intention and every second of them has been ready to part with his three-months salary for a trip. Analogous public inquiry held in USA has shown that 42% of Americans want to get into space and average sum made up $11 thou.

For such mass clients short 2-3 hours duration trips into orbit will be suitable in the foreseeable future, including not too complicated planet flyby along undulating suborbital Sanger trajectory with alternation of weightlessness and short space overloads. For the time being in sales market of space trips with 2-4-weeks attendance on orbital station or in space hotel there is a queue of clients ready to pay from $15 million to $35 million for a trip. With price fall to the level lower than $1 million for a trip there should be expected sharp increase in demand. The main clients in this sector are such companies like Bigelow Aerospace, Galactic Suite and Shimizu Corp., interested in substantial decline in prices on passengers delivery to orbital hotels and cut of the hotels construction costs.

As predicted by Japanese specialists with launches specific cost of which is reduced to $200/kg space travelling market will be growing very fast – with several billion dollars per year speed. In several years in orbit there will be a necessity in hotels capable to provide residence for 10000 guests.

Seventh direction of commercial activity – passengers' hypersound air transportation. The share of intercontinental flights in global air traffic makes up 12-16%. That's why it can be forecasted that with prices insignificantly higher than usual ones minimum 1.5% of total number of passengers in the world will be using suborbital intercontinental flights. With prices comparable with those of supersonic airliners flights (approximately in 10 times higher than the usual ones) passenger traffic will be on the analogous level – 110 thou people annually, like in Concorde aircraft system. There should be paid attention to the fact that such a hypersound system will consume combustible fuel only on the stage of takeoff from airfield, jump on more than 100 km height and landing on airfield. While the major part of energy for a flight with several kilometers per second speed (3-6 km/s) will be imparted to plane-rocket aircraft by a stream of frozen air in a form of orbital track created for account of electric power produced by GCTS solar power station.

Eighth direction of commercial activity – transportation of asteroid substance (mostly iron and nickel) to circumterrestrial space to extract iron and nonferrous materials for Earth consumers, as well as transportation of lunar raw materials and water for orbital stations with simultaneous utilization of kinetic energy from extraterrestrial substance flows for launching into orbit of devices sent from Earth to Moon and to outer space. On Earth steel market has exceeded $1 billion per year and nickel market – $1 million per year. Considering the fact that asteroid iron represents itself practically ready-made product (in the form of iron and nickel alloy with 9% nickel content) and its transfer to circumterrestrial orbit pays for itself with launching of new cargoes from Earth at the account of it's free kinetic energy, it is possible to expect initial demand of at least 0.1% of global steel sales market and 50-90% of nickel accompanied by scarce metals of platinum group. With low delivery prices provided by GCTS asteroid metals especially the rare-earth ones can supply demand on nonferrous metals completely.

Ninth direction of commercial activity – usage of asteroid metals and lunar basalt ingots of aerodynamic shape for transferring of their kinetic energy with minimal losses through atmosphere from space to terrestrial surface for explosive works instead of excavation nuclear explosions. In a number of countries there exist thoroughly elaborated plans of African deserts reconstruction and irrigation of other lifeless regions of the planet, building of river and sea dams, creation of new sea bays for port constructions, development and shutting of mines for minerals extraction, cutting of watercourses, destruction of icebergs threatening to navigation. But these projects are intended for application of nuclear explosions and that's why they are frozen for uncertain period. At the same time it was shown in last century investigations that cylindrical-conical shaped objects of certain mass-overall characteristics can pass through atmosphere at a speed of over 10 km/s almost without losses of kinetic energy. And the energy from collision with Earth surface of such ingots in the form of pestles from asteroid iron or basalt with relatively small sizes can be comparable with energy of nuclear charges. Specific power intensity of substance casted from the Moon exceeds power intensity of usual explosives in 12-14 times. On collision pestle of 700 tons mass will discharge energy equivalent to nuclear charge of 10000 tons trinitrotoluene capacity. The length of such a pestle of basalt is 30 metres, its diameter – 3 metres, and the length of an iron pestle is 28 metres with 2 metres diameter (without consideration of tip and aerodynamic stabilizers length).

Tenth direction – hoarding activity. GCTS can realize delivery of different substances to orbital warehouses in volumes exceeding current demands of clients. But with consideration of real value of such stocks like aluminum, silicon, technical carbon, nitric tetraoxide and hydrazine for future space industry, as well as of safety of their preservation (for example in depositories on "eternal" circular orbit of more than 800 km height where braking forces of residual atmosphere are extremely low) exchange resale of space stocks is possible. In a certain sense this is even more attractive than buying up and accumulation of oil, nonferrous metals and food for creation of strategic and other stocks on the Earth.

In future to substances coming into hoarding depositories from the Earth there will be added up asteroid nonferrous metals including rare-earth ones. There will also be increased the number of orbital safes – as long as interplanetary resources will be developed to depositories in circumterrestrial space there will be added accumulating stations on orbits around Moon, Mars and other planets. The main purpose of their creation is to provide regularity of ASD working processes by selling temporally surplus production to hoarders.

Considering chronic global financial crisis, absence of reliable objects for money investments, participation in creation of such space banks should be quite attractive for many states and financial establishments. To a certain extent such banks of strategic resources could become an updated version of gold backing in currency protecting industry and population from abuse of financial monopolies. Besides prevention of basis of financial speculations space banks' securities would contribute to creation of single world currency with real backing.

These are the ten main directions of commercial application of the considered geocosmic transportation system. As eleventh direction there could be defined services on monitoring of asteroid danger from outer space and correction of asteroid orbits threatening the Earth. But its obvious that this direction will be automatically realized in case of implementation of other ten directions of GCTS utilization in modern economy.

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