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Lunar Industry on New Physical Principles

Nuclear explosive technologies are a powerful accelerator of the industrialization of the planets of the solar system

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Beyond the orbit of Mars and the asteroid belt, nuclear energy is currently the only way to rapidly and inexpensively industrialize most of the solar system.

In "NG-science" dated October 25, 2023, a sharply polemical article by Andrei Vaganov was published, “Why is humanity being so stubbornly pushed into space. Cosmonautics, and the lunar race in particular, have not yet been able to solve any global problems . ” Among other things, in it the author writes about the almost insurmountable technical and technological problems of exploring the Moon and, especially, deep space. However, conceptual solutions for the economic and industrial development of the Moon already exist. Moreover, the principles of creating industry using nuclear energy on the Moon are also applicable to the industrialization of Mars, dwarf planets and satellites of the giant planets. And, oddly enough, the recent withdrawal by the Russian parliament of ratification of the *Comprehensive Nuclear-Test-Ban Treaty* (CTBT) may help the Russian Federation become a leader in this process.

Dead celestial body

In 1963, the USA, USSR and Great Britain signed a treaty banning nuclear explosions in three environments: space, atmosphere and on Earth. Tension in the world from the expectation of a nuclear apocalypse subsided, but the agreement caused deep disappointment among specialists working on the peaceful use of nuclear weapons in space. Work on the Orion project, which represented the development of a nuclear pulse engine (NPE) using low-power nuclear charges, was stopped, and the development of a project to use industrial “underground” nuclear explosions on the Moon for large-scale production of oxygen and metals from lunar rocks was frozen. Thus, the CTBT stalled space expansion and locked humanity on Earth.

Meanwhile, many pioneers of astronautics, in particular Krafft Ehricke (who is also quoted by Andrei Vaganov), believed that it was nuclear pulse rockets that would ensure the conquest of the Solar System. Freeman Dyson, a key developer of the Orion project, defined the possible results of the project as follows: “To Mars in 1965, to Saturn in 1970!” In our time, research bases and colonies should have appeared on the Moon, Mars, on the satellites of Jupiter and Saturn and large asteroids. The cessation of the use of nuclear weapons in space made all this impossible.

Krafft Ehricke's detailed concept for the industrial development of the Moon remained a pure idea. His concept was based on the most efficient technologies, such as transport rockets with pulsed nuclear engines and thermonuclear charges detonated to thermolyze lunar rocks to produce oxygen and metals. Oxygen is needed to fuel chemical rockets, metals are needed for the lunar industry.

Krafft Ehricke dreamed that appropriate amendments would be made to the treaty, allowing the development of systems with pulsed nuclear propulsion engines and the use of nuclear explosions for industrial purposes. But politicians went even further in

their prohibitionist activities and in 1996 created the Comprehensive Nuclear Test Ban Treaty, the CTBT. Most states have signed and ratified the treaty. And so Russia withdrew its signature on the ratification of this treaty.
Now the cost of delivering cargo to the Moon, at best, is about 100 thousand dollars per 1 kg. It is normal for a delivery price of more than $1 million per 1 kg.
The smaller the rocket, the higher the unit delivery cost. It is clear that against the backdrop of such prices there is constant talk about the impracticality of exploring the Moon and other celestial bodies. However, calls to curtail manned space exploration under the pretext of exorbitant costs are only partially justified - it is only reasonable to talk about the impracticality of space exploration based on chemical rockets. It is precisely this technical basis in the form of ineffective chemical rockets that must be dismantled and, in return, the astronautics must be revived on the basis of pulsed nuclear rocket engines and industrial camouflage nuclear explosions on the Moon, Mars and other celestial bodies.
At the same time, chemical rockets can find a second wind if rocket fuel, primarily the oxygen component, is produced on the Moon and Mars. As the same Ehricke showed, solar energy is ineffective for the large-scale production of fuel and structural materials from lunar raw materials. Industrial scale means production volumes of over a million tons per year, which is not yet possible for solar energy. It is possible to quickly create a rocket and fuel industry on the Moon, as Ehricke showed, only with the help of industrial camouflage nuclear explosions.
The Moon is a dead celestial body with a deadly background radiation from the solar wind and galactic rays, constantly bombarded by asteroids and space rocks. The power of asteroid impacts sometimes exceeds the power of nuclear charges. Ehricke reasonably noted that if explosions of thermonuclear or nuclear charges are carried out at a sufficient depth, in the thickness of the lunar rocks, the surface natural environment of the Moon will not suffer in the least.
Camouflage nuclear explosions that prevent radiation from reaching the lunar surface do not pose a threat to the lunar ecosystem, even if it existed. But the ecosystem as such is simply absent on the Moon. Paradoxically, an artificial ecosystem on the Moon in the form of separate centers of life - colonies - can be quickly and inexpensively created and maintained only with the help of industrial nuclear explosions. In a dead lunar world, hostile to life from Earth, nuclear energy helps create life - a radioactive atom becomes “green”.

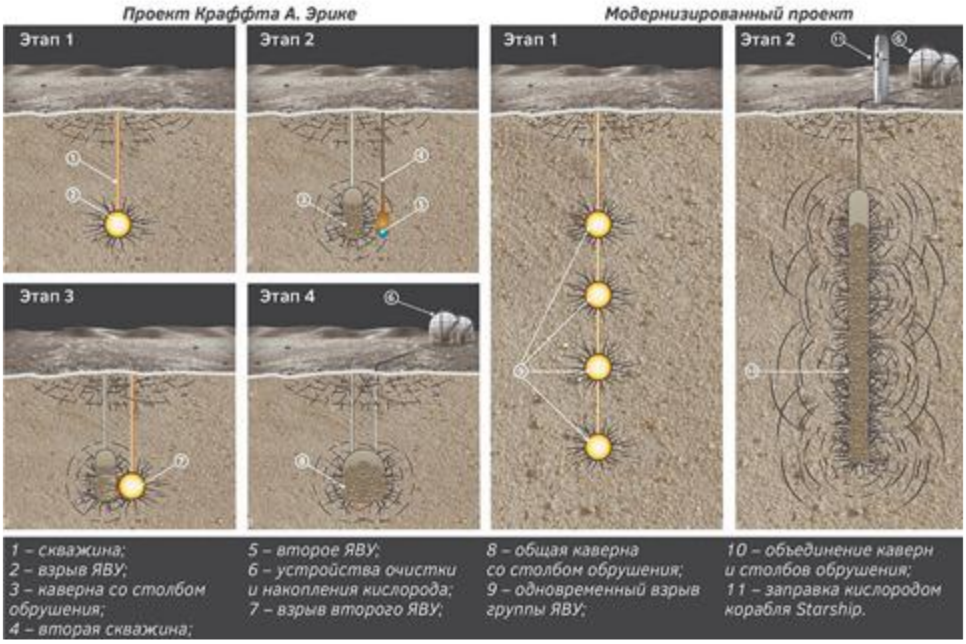

Fig. 1. Explosive technology for extracting oxygen from lunar rocks.

Lunar oxygen

The sublunar explosion will release a large amount of oxygen: its content in lunar rocks reaches 40%. If oxygen is removed from the blast cavity quickly enough, rich metal ores will form in the natural lunar rocks surrounding the cavity. Under Earth conditions, such technology cannot be used due to the danger of causing damage to nature. The moon seems to be specially created for the development of explosive technology on it. Unlike living earthly nature, dead lunar nature is insensitive to the “polluting” effects of industry. Thus, thanks to a fundamentally new technological factor, the energy sector of the lunar industry is closely linked with its raw materials sector.
An assessment of oxygen production using the Krafft Ehricke technology gives the following figures. To obtain oxygen, it is advantageous to use charges of medium and high power, about 1 Mt. This reduces radioactive contamination of products due to the minimized use of fissile nuclear materials - most of the energy is released through nuclear fusion. Such thermonuclear explosions are considered “clean”.
With an explosion of such power at great depths in basalt, the radius of the evaporation zone is 20 m, in which the mass of evaporated basalt is 90,600 tons. The oxygen content in the evaporated stone and thermal decomposition of oxides is 36,000 tons. Taking into account the release of oxygen in the melting zone, the surrounding zone evaporation, an additional 12,200 to 56,600 tons of oxygen can be released.
Behind the melting zone there is a hot solid-phase zone of crushing and crushing. It can also release oxygen during the decomposition of iron oxide FeO. The decomposition of FeO can produce a minimum of 50,000 tons of additional oxygen from the evaporation and melting zones. Total allocation: from 98,000 tons to 143,000 tons per 1 Mt. On average - 120,000 tons of oxygen, O2.
Thus, with an annual consumption of thermonuclear charges with a total capacity of 8 Mt, the volume of oxygen production by the lunar industry will reach 1 million tons. The scale of production can increase quite quickly as the demand for rocket fuel for refueling spacecraft outside the Earth grows. Large consumers of lunar oxygen will be companies implementing plans for the

colonization of Mars and other celestial bodies. Another consumer will be companies operating in near-Earth space, for example, building satellite solar power plants to supply the Earth with clean energy.
A schematic diagram of the process is shown in Fig. 1 (stages 1, 2, 3 and 4). To prevent intense reoxidation of metals and silicon, oxygen must be removed from the explosion cavity as quickly as possible. For this purpose, Ehricke proposes using a channel drilled in advance, running from the surface of the Moon to an initial cavity located at the required depth, into which a nuclear charge is placed. A bridge of exactly the calculated thickness is left between the initial cavity and the lower end of the channel. During an explosion, this jumper is instantly destroyed, and hot oxygen rushes upward through the channel. Reception and treatment facilities and oxygen storage tanks must be constructed in advance above the upper mouth of the canal. However, this is not the best solution. Moreover, today it is already clear that Krafft Ehricke's technology can be improved. In Fig. 1 (steps 5 and 6) shows the process optimization flowchart.
It should be noted that only a few elements have maximum resistance to induced radioactivity: hydrogen, helium, beryllium, carbon, oxygen, lead. In this regard, oxygen from the nuclear storage cavity (after purification from radioactive dust in cyclones) does not pose such a danger as, for example, air nitrogen, which is very sensitive to induced radiation.

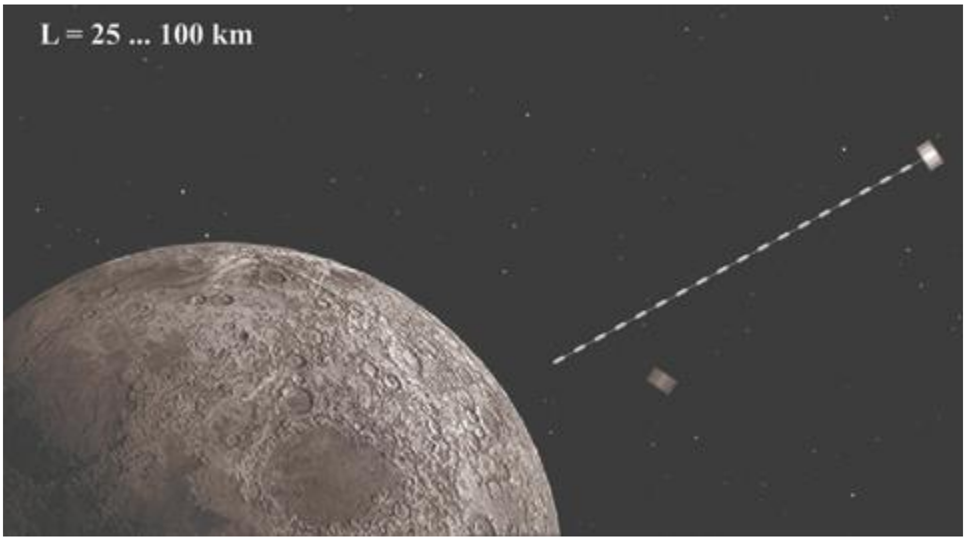

Fig. 2. A chain of strikers deployed as it approaches the Moon.

Percussion-rope drilling

The depth of a camouflage explosion under lunar conditions for a 1 Mt charge should be 3000 m from the surface, which is 2.5 times greater than on Earth. For a charge with a power of 400 kt, the depth will be 2250 m. With a charge power of 9 kt, the depth will be 625 m.
Drilling equipment for laying charges on the Moon has a small mass if you use the long-known percussion-rope drilling method. In ancient China, wells were drilled to a depth of more than 1200 m; bamboo tools and manual labor were used to drill them. This method, in an improved form, is still used today. A tripod with an electric winch and a drilling tool weighing 1200 kg are required. Experts believe that it is more profitable to drill hard rocks using the percussion-rope method, even to depths greater than 1000 m. At the same time, they note that the mechanical speed of impact drilling in very hard rocks is close to the speed of rotary drilling, and sometimes even equal to it; at the same time, the cost of impact drilling under these conditions is 2.5 times less than for rotary drilling. New methods have been developed in which the mechanical drilling speed increases from 2 to 10 times compared to the speed of rotary drilling. For lunar conditions, the shock-rope method is the best.
You can estimate the cost of producing oxygen using the Krafft Ehricke method at current prices. Detonation of a charge with a power of 400 kt will create 50 thousand tons of oxygen, the cost of which will be $ 0.56 per 1 kg. This is 180 thousand times less than the cost of delivering oxygen to the Moon using the traditional method!
It is also necessary to take into account the costs of delivering a thermonuclear charge, drilling equipment and a station for pumping, purifying and storing oxygen. However, these are not fixed values - they decrease as the nuclear industrialization of the Moon progresses.
Today, delivering cargo to the Moon costs, at best, $100 thousand per 1 kg. And tomorrow, with the industrial production of oxygen on the Moon and the supply of lunar oxygen to reusable shuttles, the price will drop by orders of magnitude. When filling the Luna-Earth Orbit-Moon shuttles with lunar oxygen, it costs less than $2 million.
Delivery of drilling equipment will cost more – around $300 million at current prices. However, this equipment can be used repeatedly (at least for 10 more wells). Therefore, the contribution from drilling equipment to the cost of a single explosion will not exceed $30 million.
The contribution to costs from oxygen storage tanks and the purification system will be insignificant, since the resulting oxygen is stored in an "underground" tank, and not in external tanks - it is consumed to refuel the shuttles not at once, but in portions. The cost of delivering the storage and treatment complex is estimated at $300 million.
Thus, taking into account the indicated main cost factors at the first stage, the total costs will be $390 million per single explosion. If the mass of oxygen produced is 50 thousand tons, then the cost of oxygen will be $7.8 per 1 kg.
In the future, thanks to the reduction in the cost of flights to the Moon, when the price of delivering cargo from low-Earth orbit to the Moon is reduced from 100 thousand dollars per 1 kg, for example, to 10 thousand dollars per 1 kg, the total cost of a single explosion will decrease to 64 .2 million dollars. In this case, the cost of oxygen will be 1.3 dollars per 1 kg.
The next round of price reductions for flights to the Moon, to $5 thousand per 1 kg, will bring down the total costs of a single explosion to $46.1 million. This will reduce the cost of oxygen at lunar gas stations to $0.92 per 1 kg.

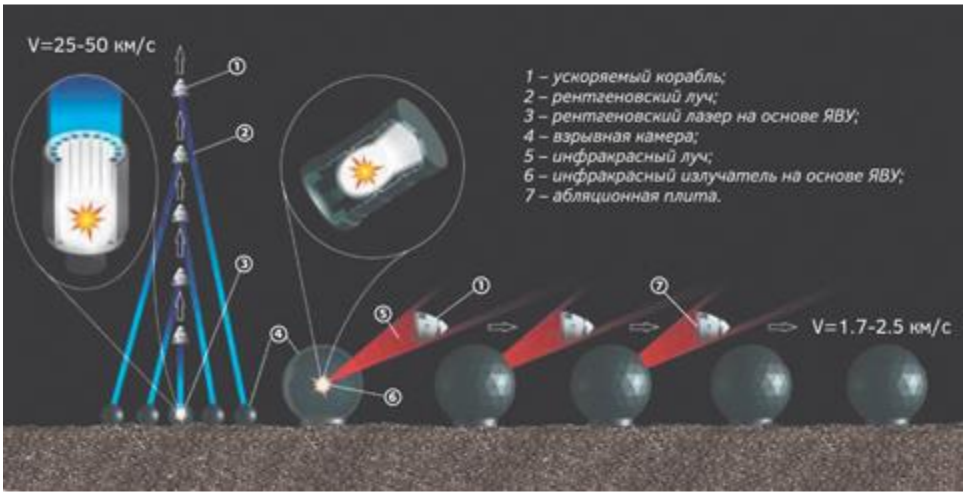

Fig. 3. Launch of Orion-type cargo ships using focused radiation from chamber charges. Author's illustrations

Lunar "oil"

Unfortunately, rockets on the Moon can only be fueled with oxygen, and fuel - hydrogen or methane - will have to be delivered to the Moon. Rockets with an oxygen-hydrogen engine must bring 20 kg of hydrogen from Earth for every 100 kg of lunar oxygen (hydrogen in rocket fuel is taken in excess). Rockets with an oxygen-methane engine should deliver up to 27.9 kg of earthly methane (also in excess) for every 100 kg of oxygen. This somewhat reduces the weight of the delivered cargo, but is still beneficial.

Back in the last century, engines using aluminum powder as fuel were tested. Oxygen engines with fuel based on powdered magnesium and silicon were also proposed. These three types of fuel are produced on the Moon during camouflage thermonuclear explosions. Deposits of these substances can be developed approximately 10 years after their formation at the site of explosions, which will undoubtedly contribute to reducing the cost of lunar rocket fuel.

The costs of creating wells can also be reduced, using the space method, which is feasible on the Moon, but inaccessible under terrestrial conditions. The initial drilling of wells can be carried out by a flow of high-density bodies, for example, made of iron (Mayboroda A.O. Base on the Moon: technologically advanced and inexpensive // Technology for Youth. No. 14. 2017). In Figure 2 shows a schematic diagram of such a space-based method for drilling wells.

Initially, the chain of impactors can be launched from Earth orbit. Then, at the stage of advanced industrialization, launch can be carried out from the Moon by rockets filled with lunar fuel and impactors made of lunar iron. It is also permissible to use basalt impactors, although this requires an increase in their mass. Impactors may contain portions of highly volatile substances.

At the stage of developing artificial deposits of metals generated by thermonuclear explosions, it is possible to create a system for launching spaceships using the energy of nuclear explosions, as in the Orion project. The project can be modified - nuclear explosions carried out in steel chambers similar to the large Sphere explosion chamber of the Explosion Center of the Joint Institute for High Temperatures of the Russian Academy of Sciences (JIHT RAS) are used as an energy source.

Hermetically sealed explosions with a power of less than 0.1 kt are carried out in explosion chambers, that is, outside the natural environment, without the dispersion of fissile materials and chain reaction products. The chambers are equipped with windows, which are sealed with a gas (plasma) seal at the moment of explosion. Radiation from the explosion is let out, and the fission products and unreacted uranium or plutonium are locked in the chamber. Fissile materials can be reused after purification.

Charges designed during the work on the Orion project are used as nuclear charges. Most of their energy is released in the form of radiation focused in one direction. Orion charges emit infrared radiation. Low-power charges that generate directed X-ray radiation can also be used. The radiation causes ablation (evaporation of matter) of the ship's push plate, which creates jet thrust with a high specific impulse.

Industrialization of the Moon could lead to the creation of a space transportation system based on chamber nuclear explosions that generate infrared focused beams and X-ray laser radiation. The lunar transport system for launching spacecraft will ensure reaching speeds of about 20–30 km/s and higher.

Schematic diagrams of the creation of jet thrust by radiation pulses from explosion chambers on the Moon are shown in Fig. 3. At the same time, launches at speeds of tens of kilometers per second should be rare. Basically, the upgraded Orion system should be operated for launches at speeds of about 2.5–3 km/s. This speed is sufficient to deliver cargo to near-Earth space and to alien colonies.

Conclusions

The principles of creating industry using nuclear energy on the Moon also apply to the industrialization of Mars, dwarf planets and satellites of the giant planets. Outside the orbit of Mars and the asteroid belt, it is almost impossible to harness solar energy. Here, nuclear energy, especially in pulsed-explosive form, is so far the only way to quickly and inexpensively industrialize most of the Solar System. And the atmospheres of the giant planets contain reserves of thermonuclear fuel accessible (to storage devices like PROFAC), which so far can only be used in thermonuclear charges. Thermonuclear reactors, even if they mature to industrial use, will be orders of magnitude more expensive to operate than thermonuclear charges.

The lunar industry on new physical principles for industrially weak countries and outsiders of the space race can become the same Colt revolver, which, according to the well-known saying, equalized people created by nature as physically unequal. The simplicity and low cost of industrialization of the Moon based on the nucleization of industry, subject to equal access to the Moon, will ensure equalization of the level of development, if not on Earth, then in space. Of course, the successes of nations in the industrialization of the Moon will contribute to their development on Earth and the equalization of economic potential.

Movement in this direction can begin today. For example, to begin with, carry out tests on the Moon to pierce a hole with a chain of steel strikers falling at a speed of 2.5–3 km/s. And tomorrow we will carry out a test explosion in the bowels of the Moon.