Cheap, Small Electric Space Propulsion

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Abstract

In this research, the author proposes a fundamentally different way to launch spacecraft. The method is characterized in that the spacecraft is accelerated by an electric accelerator that ionizes the air and throws it at a high speed regardless of the speed of the accelerator itself. The accelerator returns to the launch site after the launch and returns the energy spent on accelerating the accelerator body. That is, the electric ground (from the power plant) energy is spent only on the acceleration of the spacecraft itself. As a result, we have the lowest possible launch cost (about $1 / kg) and are not limited in the number of launches. This will allow us to really engage in space exploration. In addition, in wartime, it allows an unlimited number of military vehicles to launch and organize anti-missile defense (electric gun). The proposed invention also allows to solve the problem of the engine for hypersonic aircraft.

Key words: space launch, electric launch, cheapest launch, military launch, anti-rocket defense.

Introduction.

Rocket science and space launches have been developing for more than half a century. However, it is very expensive. Hundreds of billions of dollars have been spent on space launches and flights. Even greater costs for defense, for missile research, for the creation, maintenance and maintenance of thousands of sophisticated combat missiles. Currently, launching 1 kg of cargo into near Earth orbit costs about $30,000 – 150,000. Launch is possible only on large missiles. Scientists, researchers wait sometimes for months to launch a small satellite, because it makes sense to launch a large rocket only when a sufficient number of orders have accumulated.

In liquid and solid-fuel rockets, only minor improvements are possible, such as the first-stage rescue (Falcon 9, Falcon-Heavy), which can reduce the cost of launching by 2-5 times. This does not solve the problem. Large-scale space exploration will begin only when the cost of the launch will decrease thousands of times. Unfortunately, scientists and high-ranking officials are fixated on the world's first German V-2 rocket and persistently go only in this direction, although it is very expensive and has already exhausted all its possibilities.

This is surprising, but the author shows that a simple and cheap (to clarify: the cheapest at present) start is possible on the old, tested, easily calculated knowledge, known for about a hundred years, when there was industrial electricity. But this method was invented, investigated, calculated and described by the author a few years ago [1]-[6]. The method has one drawback-large accelerations. But more than 90% of space cargo can be delivered by this method. The method was invented as a propulsion system for hypersonic aircraft. In the creation of aircraft at hypersonic speeds, the aircraft manufacturers are faced with the problem of overheating and the decrease in the efficiency of conventional heat engines. By compressing the air entering the engine from the high-speed head, the air is heated so much that when it is heated further in order to recycle the heat cycle, no materials can withstand. The proposed method accelerates the air without heating (due to the electric field), the engine can operate at any speed and in any atmosphere. In addition, the method can be used to decelerate in the atmosphere of returning spacecraft, if light stores of electrical energy are invented.

Description and work the offered engine

Diagram of an electric air jet engine for space launches is shown in Fig. 1. This is an ordinary pipe 1 of insulator of round or rectangular cross-section. The pipe has adjustable inlet and outlet nozzles 7-8. The figure shows a square-section engine. It is more convenient to adjust. On top of the pipe there are two ring electrodes 2, 3, to which a high voltage source 4 (several million volts) is attached. It creates a powerful electric field between the electrodes 2-3. Near electrode 2 is located injectors 5 charged particles. Usually it's electrons. Injectors can be cold (needles) or hot. The electrons ionize the air molecules (in particular, creating negative ions of nitrogen). A powerful electric field between the electrodes quickly accelerates the ions. Ions, colliding with air atoms, transmit their momentum to them, i.e. accelerate the flow, give it an additional velocity *v*. This means that they create thrust without heating the flow and without using air oxygen, i.e. such an engine can work in any atmosphere.

Ions in contact with the internal conductive film 6 (grid, lattice), located inside the ring electrode 3, where the field strength of the ring electrode 3 is zero, give the film 6 their extra electrons. These electrons are then transferred to electrode 3, reducing its voltage. Source 4 restores the voltage, i.e. consumes energy to accelerate the flow. Ions that do not have time to give an extra electron to the film 6 are neutralized by the injector 9, producing charges of the opposite sign. Note that the mass consumption of the neutralizer is very small (see Project). A diagram of an electric air jet engine for space launches is shown in Fig. 1. This is an ordinary pipe 1 of insulator of round or rectangular cross-section. The pipe has adjustable inlet and outlet nozzles 7-8. The figure shows a square-section engine. It is more convenient to adjust. On top of the pipe there are two ring electrodes 2, 3, to which a high voltage source 4 (several million volts) is attached. It creates a powerful electric field between the electrodes 2-3. Near electrode 2 is located injectors 5 charged particles. Usually it's electrons. Injectors can be cold (needles) or hot. The electrons ionize the air molecules (in particular, creating negative ions of nitrogen). A powerful electric field between the electrodes quickly accelerates the ions. Ions, colliding with air atoms, transmit their momentum to them, i.e. accelerate the flow, give it an additional velocity *v*. this means that they create thrust without heating the flow and without using air oxygen. That means an engine can work in any atmosphere.

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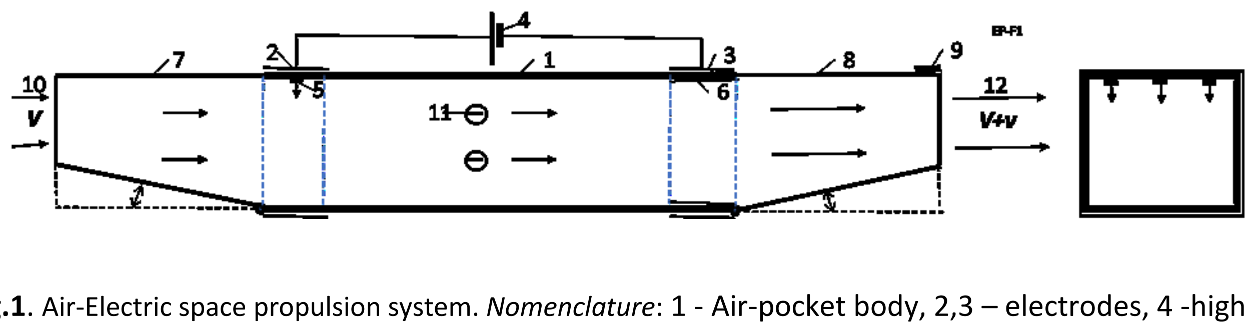

Fig.1. Air-Electric space propulsion system. *Nomenclature*: 1 - Air-pocket body, 2,3 – electrodes, 4 -high voltage issue of electricity, 5 – injector of charges particles (electrons, ions), 6 – collector of charges particles, 7 – controlled inlet nozzle, 8 – controlled outlet nozzle, 9 – additional injector of charged particles, 10 - inlet flow having speed *V*, 11 – ions, 12 – outlet flow having the speed *V+v.*

Launch

The simplest device for a space launch using said electric motor is shown in Fig.2. It is an inclined mast, having a length of about 2 km. (see Project). The mast only supports sliding electrical contacts. One kilometer of its length is used to accelerate the proposed engine 2 (accelerator) with a spacecraft attached to it. The second kilometer is used to brake and return the accelerator to its original position. Since the duration of the shot weighing 1 kg at a speed of 8 km/s about 0.5 seconds (see Project), then theoretically the rate of fire can reach 1 shot per second. That means 86 thousand shots or 86 tons of cargo launched into near earth orbit in day.

The mast is supported by 3 braces with 4 winches, can be rotated in horizontal and vertical planes and has 5 energy storage. The repository can issue and receive energy pulses in a fraction of a second.

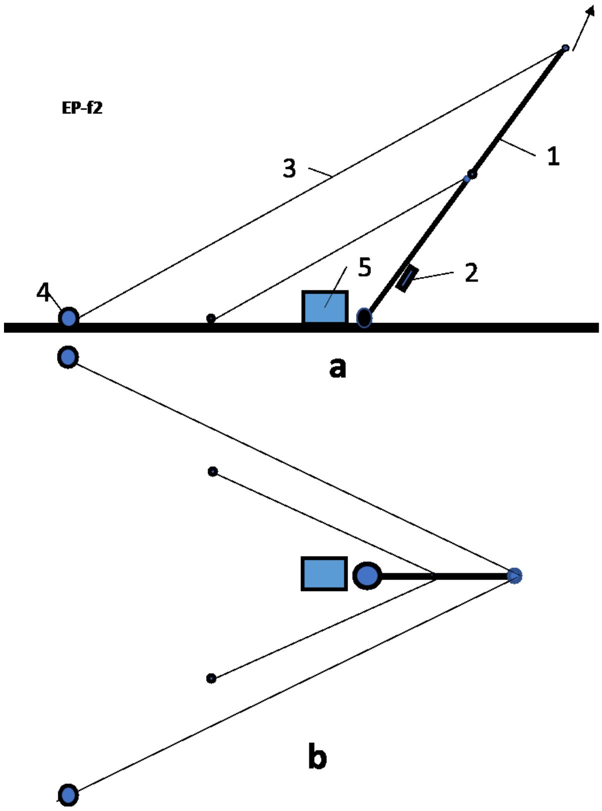

Fig.2. Guide current mast with sliding contacts. The mast allows you to change the angle and direction of fire**. a –** side view, **b** – top view. *Nomenclature*: 1 – mast, 2 – space launcher with satellite, 3 – mast divergence, 4 – control mast, 5 – impulse storage of energy.

Advantages and disadvantages of the proposed method.

Advantages:

1) Extreme cheapness. The cost of the launch is reduced thousands of times and can reach $1 / kg (output to Earth orbit). This will allow to start a wide exploration of space, the moon and the planets of the solar system. This is achieved through the rejection of expensive complex and dangerous (cryogenic or poisonous) fuel. The accelerator is used the terrestrial electricity, simple launch technology. None of the existing or the proposed method cannot compete with this method.
2) Extremely simple technique and production and start-up technology available to any developing country.
3) Only Earth electricity is used as energy.
4) Launch is possible in any atmosphere.

Disadvantages:

1) Large accelerations do not allow to start living organisms (except bacteria). If we want small accelerations, we need a different design (use this idea for hypersonic aircraft).
2) High voltages (millions of volts) are Used. Offer method compare with the rail electromagnetic gun is a great advantage, because the current is relatively small and do not burn contacts. From high voltage can be protected by a few millimeters of good insulator.

Project (Estimation of Space Electric Launcher).

This is not optimal project. This example shows possibility to rich the high data of the electric space launcher.
Let us to take the following data: mass of satellite is 1 kg, the mass of accelerator body is 9 kg, the total mass (accelerator plus satellite) is m = 10 kg, final speed after acceleration is V = 8000 m/s. Cross-section of accelerator body is 2x2 meter, length of acceleration camera (distance between main electrodes) is 3 m. Length of acceleration is L = 1000 m, length of braking is 1000 m. Total length of mast is 2000 m. Electric intensity is E_e = 1 MV/m. Electric voltage is U = 3 MV.

Total (for m = 10kg) energy is requested for acceleration is

$$E_t = \frac{mV^2}{2} = \frac{10 \cdot 64 \cdot 10^6}{2} = 320\ MJ\ . \qquad (1)$$

Energy for satellite acceleration (m_1 = 1kg) is

$$E_t = \frac{m_1 V^2}{2} = \frac{1 \cdot 64 \cdot 10^6}{2} = 32\ MJ\ . \qquad (2)$$

Here V = 8000 m/s is final speed of accelerator, m/s.

Value acceleration and acceleration time are

$$L = \frac{a\,t^2}{2}, \quad V = at, \quad L = \frac{V^2}{2a}, \quad a = \frac{V^2}{2L}, \quad T = m\,a, \quad E = TL, \quad P = \frac{E}{t}.$$

$$a = \frac{V^2}{2L} = \frac{64 \cdot 10^6}{2 \cdot 10^3} = 32 \cdot 10^3\ m/s^2 \approx 3200\,g, \quad T = ma = 10 \cdot 32 \cdot 10^3 = 320\,kN = 32\ tons. \qquad (3)$$

$$t = \frac{V}{a} = \frac{8000}{32 \cdot 10^3} = 0.25\,\text{sec}. \quad E = TL = 32 \cdot 10^4 \cdot 10^3 = 320\ MJ, \quad P = \frac{E}{t} = \frac{320 \cdot 10^6}{0.25} = 1280\ MW.$$

Here: L - distance acceleration, m; a – acceleration, m/s^2; V – final speed of accelerator, m/s; t – time, sec., T – trust, N; E – energy, J; P - power, W.

Electric values:

$$\boldsymbol{v_1 = bE_1 = 1.82 \cdot 10^{-4} \cdot 10^6 = 182\ m/s, \quad v = bU = 1.82 \cdot 10^{-4} \cdot 3 \cdot 10^6 = 546\ m/s.} \qquad (4)$$

Where: v_1 – additional speed of flow at the first electrode, m/s; b – mobility of the azote negative ion for atmospheric pressure in area 1 m^2, m^2/sV; v – additional flow speed after the last electrode, m/s.

Let us inject the charge Q_s = 0.6 C/m^3 in 1 sec to the area 1 m^2 in area near at the first electrode.

The electric currency is

$$I = Q_s v_1 S = 0.6 \cdot 182 \cdot 4 = 437\ A. \qquad (5)$$

Where S = 4 m^2 is cross-section of accelerator.

Power of electricity is

$$P = IU = 437 \times 3 \cdot 10^6 = 1310\ \text{MW}. \qquad (6)$$

Consumption electric energy in acceleration of launcher is

$$E = Pt = 1310 \cdot 0.25 = 327\ \text{MJ}. \qquad (7)$$

The mass of accelerator body is 90% of full mass. This means 90% the full energy may return. The energy will only be spent in acceleration the satellite.

Let us estimate the consumption of energy in ions, ionization of air, loss energy (drag) in atmosphere.

Number n of ions inserted in flow in 1 second is

$$n = \frac{Q_s}{q} = \frac{0.6}{1.6 \cdot 10^{-19}} = 3.75 \cdot 10^{18}\ \ 1/m^3\ . \qquad (8)$$

Where $q = 1.6 \cdot 10^{-19}$ is charge of one electron, C.

Consumption the ion mass for

$$M = \mu\, n\, m_p = 10 \cdot 3.75 \cdot 10^{18} \cdot 1.67 \cdot 10^{-27} = 6.26 \cdot 10^{-8}\ kg/m^3 \qquad (9)$$

Here μ is number of nucleus in nuclear; $m_p = 1.67 \cdot 10^{-27}$ kg is mass of one nucleus.

Consumption energy for ionization 2 eV

$$\boldsymbol{E_i = 2enS = 2 \cdot 1.6 \cdot 10^{-19} \cdot 3.75 \cdot 10^{18} \cdot 4 = 4.8\ \ J/s} \qquad (10)$$

As you see all the computations is small and we can neglect them.

Let us estimate the drag energy of atmosphere. This loss be significant. It is known, the 100 km rarefied atmosphere may be replaced 8 km the atmosphere having density at Earth surface.
Therefore, we will position the mast on a mountain or mountain plate about 4500 m. Than decries the air density in two times and thickness the atmosphere (trajectory) in two times. We take the angle of the top shell equals θ = 30°. The drag efficiency equals $C_d \approx 2 \cdot \theta^2 = 0.125$ (here θ is top angle of shell in radians). The gross-section of shell (satellite 1 kg) is s = 0.0625 m². The air drags D and drag energy E_d are

$$D = C_d \frac{\rho V a}{2} s = 0.125 \frac{0.65 \cdot 8 \cdot 10^3 \cdot 330}{2} 0.0625 = 10^3 N \approx 100\, kg. \quad E_d = D \Delta H = 10^3 \cdot 4 \cdot 10^3 = 4\ MJ \quad (11)$$

Here $\Delta H = 4 \cdot 10^4$ m is thickness of the density atmosphere, m; a =330 is the sound speed, m/s.

This (4 MJ) is about 10% full energy. The rest of spacecraft speed is

$$\Delta V = \sqrt{\frac{2E_d}{m}} = \sqrt{\frac{2 \cdot 28 \cdot 10^6}{1}} = 7.5 \cdot 10^3\ m/s \quad (12)$$

That means the loss of satellite speed about 500 m/s. The speed of circle Earth orbit at height 200 km is 7700 m/s. The satellite needs a small additional impulse for reaching the circulate orbit.

Thrush *at* H=1km (ρ = 1.08 kg/m³) is

T = ms.

Data

Some useful data is in Tables below.

1. Mobility of ions and electrons.

Table 1. Ions mobility of different gases for pressure 700 mm Hg and for T = 18 °C.

Gas	Ion mobility 10^{-4} m²/sV, b_+, b_-		Gas	Ion mobility 10^{-4} m²/sV, b_+, b_-		Gas	Ion mobility 10^{-4} m²/sV, b_+, b_-	
Hydrogen	5.91	8.26	Nitrogen	1.27	1.82	Chloride	0.65	0.51
Oxygen	1.29	1.81	CO_2	1.10	1.14			

Source [10] p.357. For air b = 1.9 ÷ 2.

In diapason of pressure from 13 to 6×10⁶ Pa the mobility follows the Law bp = const, where p is air pressure. When air density decreases, the charge mobility increases. The mobility strength depends upon the purity of gas. The ion gas mobility may be recalculated in other gas pressure p and temperature T by equation:

$$b = b_0 \frac{T p_0}{T_0 p}, \quad (12)$$

where lower index "o" mean the initial (known) point. At the Earth surface H = 0 km, T_0 = 288 K, p = 1 atm.

For normal air density the electric intensity must be less than 3 MV (E < 3 MV/m) and depends from pressure.

Electron mobility. The ratio $E/p \approx$ constant. Conductivity σ of gas depends upon density of charges particles n and their mobility b, for example:

$$\sigma = neb, \quad \lambda = 1/n\sigma, \quad (13)$$

where b is mobility of the electron, λ is a free path of electron.

Electron mobility depends from ratio E/n . This ratio is given in Table 2.

Table 2. Electron mobility b_e in gas vs E/n

Gas	***E/n*** ×10⁻¹⁷ 0.03 V·cm²	***E/n*** ×10⁻¹⁷ 1 V·cm²	***E/n*** ×10⁻¹⁷ 100 V·cm²	Gas	***E/n*** ×10⁻¹⁷ 0.03 V·cm²	***E/n*** ×10⁻¹⁷ 1 V·cm²	***E/n*** ×10⁻¹⁷ 100 V·cm²
N_2	13600	670	370	He	8700	930	1030
O_2	32000	1150	590	Ne	16000	1400	960
CO_2	670	780	480	Ar	14800	410	270
H_2	5700	700	470	Xe	1980	-	240

Source: Physics Encyclopedia http://www.femto.com.ua/articles/part_2/2926.html

The electrons may connect to the neutral molecules and produce the negative ions (for example, affinity of electron to O_2 equals 0.3 - 0.87 eV, to H_2O equals 0.9 eV [9] p.424). That way the computation of the mobility of a gas containing electrons and ions is a complex problem. Usually the computations are made for all electrons converted to ions.

The maximal electric intensity in air at the Earth surface is E_m = 3 MV/m. If atmospheric pressure changes the E_m also changes by law E_m/p = constant.

Example. If $E = 10^5$ V/m, then v = 20 m/s in Earth surface conditions.

2. Electron injectors.

There are some methods for getting the electron emissions: hot cathode emission, cold field electron emission (edge cold emission, edge cathode). The photo emission, radiation emission, radioisotope emission and so on usually produce the positive and negative ions together. We consider only the hot emission and the cold field electron emission (edge cathodes), which produces only electrons.

Hot electron emission.

Current *i* of diode from potential (voltage) *U* is

$$i = CU^{3/2} \tag{14}$$

where *C* is constant which depends from form and size cathode. For plate diode

$$C = \frac{4}{9}\varepsilon_0 \frac{S}{d^2}\sqrt{\frac{2e}{m_e}} \approx 2.33\cdot10^{-6}\frac{S}{d^2}, \tag{15}$$

where $\varepsilon_o = 8.85\cdot10^{-12}$ F/m; *S* is area of cathode (equals area of anode), cm^2; *d* is distance between cathode and anode, cm; e/m_e is the ratio of the electron charge to electron mass, C/kg;

Result of computation equation (14) is in fig. 3.

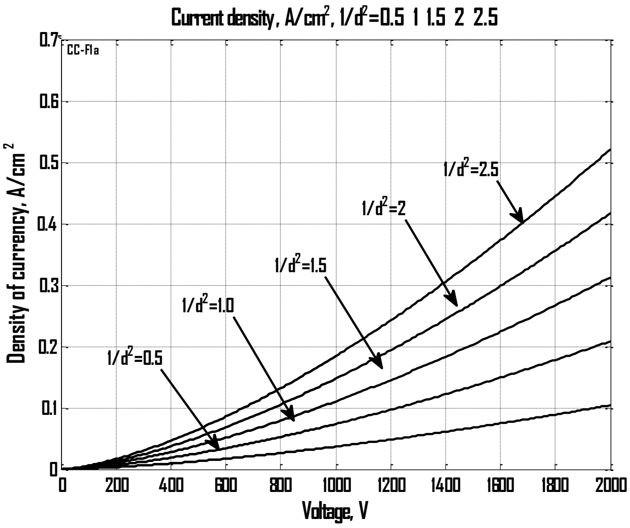

Fig.3. Electric current via voltage the plain cathodes for different ratio of the distance.

The maximal **hot cathode** emission computed by equation:

$$j_s = BT^2 exp(-A/kT)\,, \tag{16}$$

where *B* is coefficient, A/cm^{2}K^2; *T* is cathode temperature, K; $k = 1.38\times10^{-23}$ [J/K] is Bolzmann constant; $A = e\varphi$ is thermo-electron exit work, J ; φ is the exit work (output energy of electron) in eV, $e = 1.6\cdot10^{-19}$. Both values *A, B* depend from material of cathode and its cover. The "*A*" changes from 1.3 to 5 eV, the "*B*" changes from 0.5 to120 A/cm^{2}K^2. Boron thermo-cathode produces electric current up 200 A/cm^2. For temperature 1400 -1500K the cathode can produce current up 1000 A/cm^2. The life of cathode can reach some years.

Exit energy from metal are (eV):

W 4.5, Mo 4.3, Fe 4.3, Na 2.2 eV, (17)

From cathode covered by optimal layer(s) the exit work is in Table 3.

Table 3**.** Exit work (eV) from cathode is covered by the optimal layer(s):

Cr – Cs	Ti – Cs	Ni – Cs	Mo – Cs	W – Ba	Pt - Cs	W - O – K	Steel- Cs	Mo_2C-Cs	WSi_2-Cs
1.71	1.32	1.37	1.54	1.75	1.38	1.76	1.52	1.45	1.47

Source [8]: Kikoin, Table of physic values, 1976, p. 445 (in Russian).

Results of computation the maximal electric current (in vacuum) via cathode temperature for the different exit work of electrons *f* are presented in fig.4.

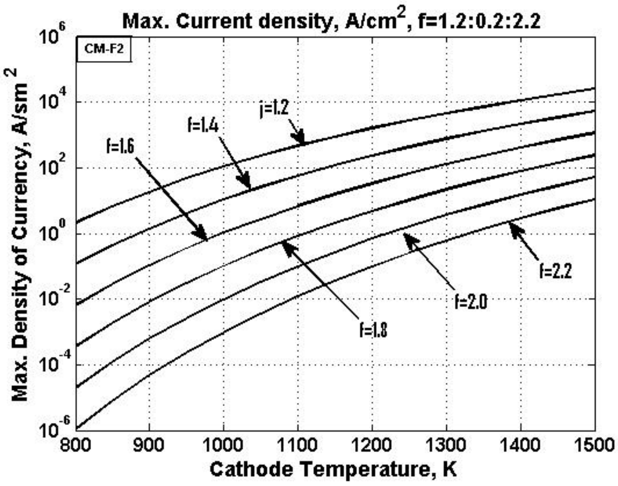

Fig.4. The maximal electric current via cathode temperature for the different exit work of electrons *f*.

Method of producing electrons and positive ions is well developed in the ionic thrusters for space apparatus.

3. The field electron emission. (The edge cold emission).

The cold field electron emission uses the edge cathodes. It is known that the electric intensity E_e in the edge (needle) is

$$E_e = U/a \, . \qquad (18)$$

Here a is radios of the edge. If voltage between the edge and nears net (anode) is U = 1000 V, the radius of edge a = 10^{-5} m, electric intensity at edge is the $E_e = 10^8$ V/m. That is enough for the cold electron emission. The density of electric current may reach up 10^4 A/cm^2. For getting the required current we make the need number of edges.

The density of electric current approximately is computed by equation:

$$j \approx 1.4 \cdot 10^{-6} \frac{E^2}{\varphi} 10^{(4.39\varphi^{-1/2} - 2.82 \cdot 10^7 \varphi^{3/2}/E)}, \qquad (19)$$

where j is density of electric current, A/cm^2; E is electric intensity near edge, V/cm; φ is exit work (output energy of electron, field electron emission), eV.

The density of current is computed by equation (19) in Table 4 below.

Table 4.

φ = 2,0 eV		φ = 4,5 eV		φ = 6,3 eV	
$E\times10^{-7}$	lg j	$E\times10^{-7}$	lg j	$E\times10^{-7}$	lg j
1,0	2,98	2,0	-3,33	2,0	-12,9
1,2	4,45	3,0	1,57	4,0	-0,88
1,4	5, 49	4,0	4,06	6,0	3,25
1,6	6,27	5,0	5,59	8,0	5,34
1,8	6,89	6,0	6,62	10,0	6,66
2,0	7,40	7,0	7,36	12,0	7,52
2,2	7,82	8,0	7,94	14,0	8,16
2,4	8,16	9,0	8,39	16,0	8,65
2,6	8,45	10.0	8,76	18,0	9,04
		12,0	9,32	20,0	9,36

Source: http://www.femto.com.ua/articles/part_1/0034.html

Example: Assume we have needle with edge $S_1 = 10^{-4}$ cm^2, φ = 2 eV and net $S_2 = 10\times10 = 10^2$ cm^2 located at distance L = 10 cm. The local voltage between the needle and net is $U = 10^2$ volts. Then electric intensity at edge of needle, current density and the electric current is:

$$E = \frac{S_2 U}{S_1 L} = \frac{10^2 10^2}{10^{-4} 10^1} = 10^7 \text{ V/cm}, \quad j = 10^3 \text{ A/cm}^2, \quad i = jS_1 = 10^3 10^{-4} = 0.1 \text{ A}, \qquad (20)$$

Here j is taken from Table 4 or computed by equation (19). If we need in the electric current 10 A, we must locate 100 needles.

Computation of equation (19) is presented in fig. 5.

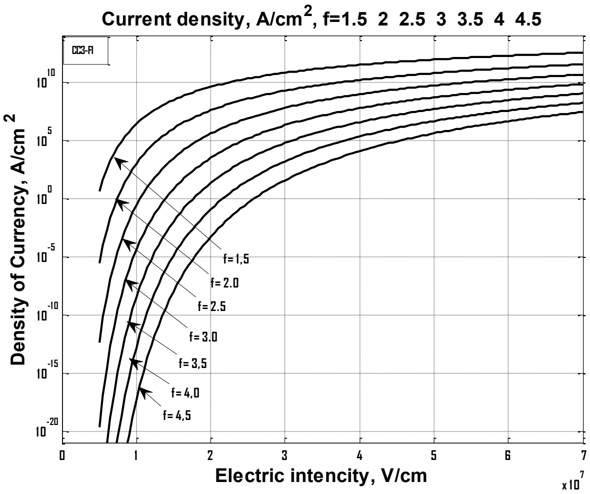

Fig.5. Density of electric current the noodle injector via the electric intensity for different the field electron emissions *f*.

Important note (Compensation of flow charge). Any contact collector cannot collect ALL charges. Part of them will fly away. That means the generator (apparatus) will be charged positive (if fly away electrons or negative ions) or negative (if fly away the positive ions). It is easy to delete the negative charges by edge. The large positive charge we may delete by a small ion accelerator. The art of ion engines for vacuum is well developed (space ion engines). They may be used as injectors and dischargers in the first design.

The charges may be deleted also by grounding.

Below is spark gap in air.

Table 5. Electric spark in air (in mm. For normal atmospheric pressure).

Voltage, kV	Two edges,	Two spheres, d = 5 sm	Two plates
20	15.5	5.8	6.1
40	45.5	13	13.7
100	200	15	36.7
		Two spheres, d = 2 sm	
200	410	262	75.3
300	600	530	114

Source [8], p124.

Table 6. Properties of various good insulators (recalculated in metric system)

Insulator	Resistivity Ohm-m.	Dielectric strength MV/m.. E_i	Dielectric constant, ε	Tensile strength kg/mm^2, $\sigma\times10^7$ N/m^2
Lexan	10^{17}–10^{19}	320–640	3	5.5
Kapton H	10^{19}–10^{20}	120–320	3	15.2
Kel-F	10^{17}–10^{19}	80–240	2–3	3.45
Mylar	10^{15}–10^{16}	160–640	3	13.8
Parylene	10^{17}–10^{20}	240–400	2–3	6.9
Polyethylene	10^{18}–5×10^{18}	40–680*	2	2.8–4.1
Poly (tetra-fluoraethylene	10^{15}–5×10^{19}	40–280**	2	2.8–3.5
Air (1 atm, 1 mm gap)	-	4	1	0
Vacuum (1.3×10^{-3} Pa, 1 mm gap)	-	80–120	1	0

*For room temperature 500–700 MV/m.

** 400–500 MV/m.

Source: Encyclopedia of Science & Technology[9] (Vol. 6, p. 104, p. 229, p. 231).
Note: Dielectric constant ε can reach 4.5 – 7.5 for mica (E is up 200 MV/m); 6 – 10 for glasses (E = 40 MV/m) and 900 – 3000 for special ceramics (marks are CM-1, T-900) (E = 13 – 28 MV/m). Dielectric strength appreciable depends from surface roughness, thickness, purity, temperature and other conditions of material. It is necessary to find good insulating materials and reach conditions which increase the dielectric strength.

Table 7. Standard Earth Atmosphere. ρ_o=1.22 *kg/m*^{3}

H [km]	0	1	2	3	4	5	7	10	20	40	60	100	200	300
$\rho/\rho o$	1	0.887	0.764	0.692	0.609	0.533	0.406	0.261	0.0545	$0.292 \cdot 10^{-2}$	$0.238 \cdot 10^{-3}$	$0.32 \cdot 10^{-5}$	$0.345 \cdot 10^{-9}$	$0.157 \cdot 10^{-9}$
T K	291	281	275	269	262	256	243	223	217	258	253	200	211	1358

Source: [11] p.252.

Discussion

The main obstacle to widespread space exploration at the present time is an emergency high cost of space launches. Launching cargo into space orbit requires a lot of energy. And the cost of the launch cannot be lower than the cost of energy acceleration of space cargo to space speed. This cost is approximately $1 / kg. But the cost of running a 1kg load is currently around $30,000/kg. Elon Musk promises to reduce it by about 2-3 times by reusing rockets. This is the limit for chemical missiles. It will not allow to make a breakthrough in space exploration.

In this paper, the author proposes a fundamentally different way to launch spacecraft. The method is characterized in that the spacecraft is accelerated by an electric accelerator that ionizes the air and throws it at a high speed regardless of the speed of the rocket itself. The accelerator after launch returns to the launch site and returns the energy spent on the acceleration of the accelerator body. That is, the electric ground (from the power plant) energy is spent only on the acceleration of the spacecraft itself. The launcher is very simple. It is a guide mast for sliding electrical contacts. As a result, we have the lowest possible launch cost (about $1 / kg) and are not limited in the number of launches. This will allow us to really engage in space exploration. In addition, in wartime, it allows an unlimited number of military vehicles to launch and organize anti-missile defense (electric gun). The proposed invention also allows to solve the problem of the engine for hypersonic aircraft.

The proposed launcher creates large accelerations unacceptable to living organisms. But 90% of the cargo can withstand them. For example, Elon Mack wants to launch tens of thousands of small satellites for global Internet and communication with any point of the Earth. Electronics is always possible to construct so that it will withstand any acceleration. A person can safely withstand a long-time acceleration 3g. Trained person up to 6g. To reduce acceleration, it is necessary to increase the acceleration distance. This is possible with the help of hypersonic aircraft.

References

1) Bolonkin A.A., **Electric Hypersonic Space Aircraft.** http://vixra.org/abs/1407.0011 , 1 July 2014; http://archive.org/details/ElectricHypersonicaircraft, http://gsjournal.net/Science-Journals-Papers/Author/1481/Alexander,%20Bolonkin .
2) Bolonkin A.A., **Electrostatic Generator and Electric Transformer,** http://Vixra.org/abs/1407.0016**,** http://GSJournal.net, 2 July 2014; http://intellectualarchive.com, #1289;
3) Bolonkin A.A., **Jet generator.** http://Vixra.org/abs/1407.0180 , https://archive.org/details/, http://gsjournal.net/Science-Journals-Papers/Author/1481/Alexander,%20Bolonkin
4) Bolonkin A.A., **Innovation and New Technologies (v.2).** LUL, 2013. Part 1, Chs. 7,8; Part 2, Chs.4,5,10.
5) Bolonkin A.A., **Electrostatic Gunnon**., http://viXra.org/abs/1911.0232 . https://archive.org/details/articleelectrostaticguneng101219 , https://www.gsjournal.net/Science-Journals/Research%20Papers-Engineering%20(Applied)/Download/8000 . sent 11 13 19.
6) Bolonkin A.A., **Thermonuclear Micro-Projectile and Methods for its Use in Defensive Protection from Space Rockets, Peaceful Energy and Transport.** 9 22 19. https://archive.org/details/articleafterrcstrategicdefthermonuclearmicro-projectileandmethodsforitsuseindefe , www.IntellectualArchive.com #2192, http://viXra.org/abs/1909.0475, http://www.gsjournal.net
7) Bolonkin A.A., Patent application "Electric Space Propulsion".
8) Koshkin N.I. and Shirkebich M.G., Directory of Elementary Physics, Nauka, Moscow, 1982 (in Russian).
9) Kikoin I.K., Table of Physics Values. Atomisdat, Moscow, 1976 (in Russian).
10) Kalashnikov S.G., Electricity. Moscow, Nauka, 1985. Калашников С.Г., Электричество. Москва, Наука, 1985. (in Russian).

11) Feodosiev V.I., Basics of rocket flight technique. Moscow, Nauka, 1981, Феодосьев, Основы техники ракетного полета, Москва, Наука, 1981.

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