Hypersonic Ground Electric AB Engine

by **Alexander Bolonkin**

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Abstract

At the present time, rocket launch systems, flight passenger-transport and ground passenger systems have reached their peak of development. In the last 30 years there has been no increase in speed or reductions in trip costs and space launch. The space launch and air and ground transportation industry needs revolutionary ideas, which allow a jump in speed and delivery capability, and a dramatic drop in space launch and trip price. This idea (kinetic aviation and space launch) was offered and developed in a series of the author researches [1]-[7], but an important facet of this method – the ground electric hypersonic engine - was insufficiently developed. Rail Gun idea was unfit for low acceleration and long rails. All energy is spent into creating a powerful magnetic field produces a strong flash when the apparatus is disconnected from rails. When the rail length is increased, the efficiency of low speed railgun engine approaches zero.

The main idea of the offered ground hypersonic electric engine is segmentation of the acceleration track on small special closed-loop sections (12.5 – 100 m) and a system of special switches which allow return of the magnetic energy to the system transferring it to apparatus movement. This increases the efficiency of hypersonic engine up 0.9, avoids the burning of rails and using the engine for long periods of time. The same idea may be used in a conventional Rail Gun.

Author designed and computed the feasibility and practability of this invention which he designed for the purpose of using it as a space launcher for astronauts and space load, as method for hypersonic long distance aviation and as method for supersonic passenger ground rail transportation. The offered system will be significantly cheaper than the currently used MagLev (Magnetic Levitation) systems, because the vehicle employs conventional wings for levitation and the hypersonic engine is very simple. The offered system may be also used for mass launch of projectiles in war.

Key word: hypersonic ground engine, space launcher, air catapult transport, kinetic aviation, air kinetic system, new high speed ground system.

1. Introduction

Kinetic aviation. Current takeoff mass of a long distance aircraft is made up of approximately 1/3 aircraft body, 1/3 fuel, and 1/3 payload. The aircraft engine needs expensive aviation fuel. The passenger-transport aircraft cannot exceed the speed of sound. The history of "Concorde" shows that the conventional passenger supersonic aircraft is unprofitable [1]. The hypersonic aircraft, which is under development by the USA, will be more unprofitable still as a passenger long distance aircraft because it will use very expensive hydrogen fuel, it is very complex and it has a high production cost. The hypersonic engine problems have not been solved in spite of spending large multiples of millions of dollars in research and testing. Space launch by the current rocket space system is very expensive. The current high speed (record is up to 580 km/h) MagLev (Magnetic Levitation) transport systems are also very expensive.

Transport, space launch systems and aviation all need new ideas that increase speed, and load capability, and reduce delivery cost. Some of these ideas have been published by the current author [1–16]. The initial author's idea is the acceleration (catapulting) of a cargo glider (vehicle), winged cargo box (non-engine aircraft), or space ship to high speed by using a cable engine. It was offered in 2001 [2] - [7], in particularly, it was presented in [1] and published in [1 -20]. The current research is different because it uses a linear electric engine located on the ground. The vehicle will then use its kinetic energy for flight. The computation shows that a catapulted/kinetic aircraft accelerated to subsonic speed of 270-300 m/s can fly up to 60-80 km until its speed decreases to a landing speed of 50-60 m/s. This is far enough for suburban transport or for air bridges across the Straits of Gibraltar, English Channel, Bering Straits (Russia–America), Sakhalin–Asia, Russia–Japan, etc. For acceleration to this speed at a rate that is acceptable to passengers (overload of 3g) the runway length must be 1.5 km (current runways for large aircraft are 1.5 - 3 km long). For the middle range (200 - 1600 km) the runway must have a length of 4 - 67 km. For the long-distance flight (6000–8000 km), the air vehicle must be accelerated to a speed of 4-6 km/s. For acceleration of no more than 3g the required runway length would then be 270 - 400 km. This runway can be also used for a space launch. One author method and design are described in References [5, 8]. Rather than being a conventional runway, it is an air cable acceleration system [6] – [9] for the acceleration of space vehicles and it is located in atmosphere.

The offered method is different from conventional MagLev because for levitation of the vehicle we employ the conventional wing (no magnetic levitation!). That is significantly cheaper. The offered system has also smaller financial risk because it is uses conventional technologies and in any case one may be used in the place of a conventional ground high-speed transport system between big cities, opening a large market transport, new passenger and cargo transport, catapult aviation, new space launch

Fig.2. Catapult for aircraft. Credit NASA**.**

Brief history. In the World Space Congress-2002, Houston, USA, and series of other works [1]-[20] the author offered and researched many new non-rocket space launchers and space flights apparatus, aviation and high speed ground systems. At that conference, the author of this paper offered and researched the total combined transportation system which can be used as a high speed aviation and space launcher. [6] In one paper [16] he offered and researched the electrostatic high speed engine for a space elevator and space accelerator. The new very simple magnetic engine for acceleration and moving vehicles proposed in that paper is analyzed by computation in this paper. This engine is similar to the rail gun as all magnetic engines uses the magnetic field but there is one significant difference to conventional railguns. Conventional rail guns are long; acceleration is low (more 25 – 50 m, a << 10g); has very low efficiency; and generates a very high plasma flash (fig. 1). Please notice in fig. 1 the gigantic cloud of plasma behind the projectile which is the result of an electric arc between the contacts. About 70 – 80% of electric energy is lost uselessly.

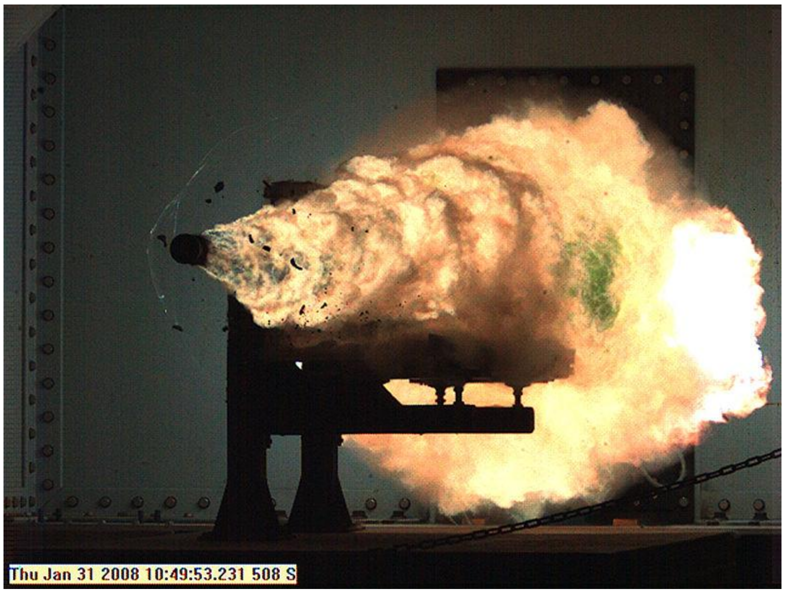

Fig. 1. Railgun. Credit NAVY. Naval Surface Warfare Center test firing in January 2008, leaving a plume of plasma behind the projectile**.** The Gun has a small shell and gigantic plasma flash. The 70 - 80% of energy lost in this flash overheats the rails and does not allow immediately making the next shot.

The offered Hypersonic Engine (HABE) is different from rail gun. It is segmented in special small sections and has a special system of the switches which allows using the magnetic energy stored into rails for moving of apparatus. That significantly (up to 90%) increases the system efficiently, saves the rails from burning, and allows using the rails for a long time.

Description and Innovations

The offered engine is presented in fig.3. One has two rails 1, 2, sliding jumper 3 and an electric current source 11. That part is same as conventional railguns. But unlike the railgun the path is divided into small sections which are only activated when the apparatus moves along in that section. In this design, the rails contain two special motionless jumpers 14, 15 and special three-position electric switches 8. Every part of the railway contains two sections 17 and 16. In the first section 17 the apparatus is accelerated by the outer electric source 11. And in the second section 16 the apparatus is accelerated by the internal inductive electric energy of that part. This operation significantly increases the efficiency coefficient, saves energy and saves the rails from thermal distraction which allows acceleration over any length which can therefore reach a very high speed. Another cost saving feature is that in this design, the railway can be conventional iron rails (not from expensive copper) and small cross-section area which allows using the conventional high voltage electric line for delivering electric energy along the long acceleration distance.

The suggested system works the following way. When the apparatus (jumper 3) located at point “a”, the switch 8 turn on to contact 10 and connect the circuit “abcde” to the electric source 11 (transformer of the high voltage electric line 12). The electric current runs into circuit “abcde”. As the result the moving force appears in jumper 3 and move the jumper and apparatus 5 in direction 6. Simultaneously the circuit “abcd” accumulates the electric energy into Magnetic field. The accumulated energy is large because the current is strong.

When the apparatus reaches point 13 the switch is disconnected from the contact 10 (from outer electric source 11) and one is connected to contact 9 and completes the electric circuit “abcd”. The electric current will decrease, but an inductive magnetic field of “abcd” hinder it and at the same time produces the electric current into circuit “abcd” in the same direction.

In the next part the process is repeated.

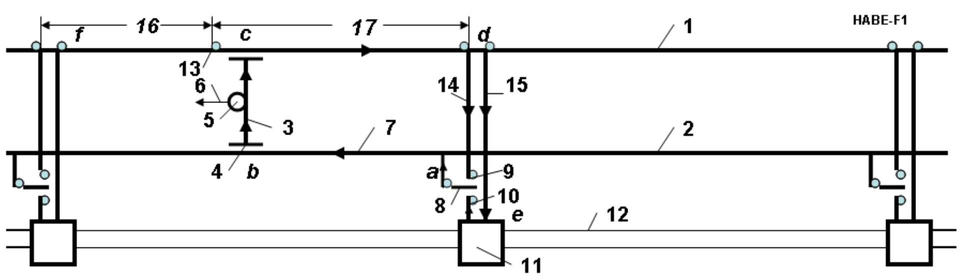

Fig.3. Hypersonic AB Engine (HABE) for super high speed train, launcher for hypersonic aviation and space apparatus/ship. *Notations:* 1 – 2 - rails; 3 – (HABE) mobile jumper; 4 – sliding contact; 5 – train, or hypersonic aircraft, or space ship; 6 – direction of moving apparatus; 7 – electric current; 8 – three-position switch of electric current; 9 – contact for closed loop electric circuit; 10 – contact to outer electric circuit; 11 – electric transformer; 12 – high voltage outer line; 13 – moment of connection of switch 8 to contact 9; 14 – fixed jumper two; 15 – fixed jumper three; *16* – way “*cf”* of engine using internal inductive electric energy; *17* – way “*dc”* of engine using external electric energy; *abcd* – internal electric circuit.

The offered hypersonic liner electric engine (HABE) has the following advantages over the RailGun:

1) The railgun is acceptable only for small projectile (some kg) because one cannot have a long barrel (the efficiency became the very small). That means that the railgun must have a very large acceleration not acceptable for manned vehicles. The manned vehicles can have a maximum acceleration 3 – 7 g. The HABE does not have it limitation.

2) The railgun has low efficiency in using electric energy (it losses the inductive energy). The HABE does not have this limitation because it utilizes the internal inductive energy.
3) The inductive energy of railgun in the moment of projectile leaving of barrel is released as a gigantic plasma flash shown in Fig.1 and creates the thermal distraction of rails. The HABE does not have this limitation.
4) The unit length of HABE is cheaper because allows design of the path from conventional iron rails (not from expensive copper) and rail has a small (conventional) cross-section area.
5) HABE allows using the conventional high voltage electric line for delivering electric energy along the large acceleration distance.
6) HABE is able to accelerate large mass (train, hypersonic aircraft, space ship [1]).
7) HABE may be used as engine for super high speed ground transport.

Theory of Hypersonic Engine.

The parameters of HABE may be computed/estimated by following equations:

1. Computation of uniformly accelerated motion:

$$V = at\,,\quad L = \frac{at^2}{2} = \frac{V^2}{2a},\quad F = ma\,,\quad P = FV,\quad E = FS\,, \qquad (1)$$

where a = constant acceleration, m/s; V is speed, m/s; t is time, sec; S is way, m; F is force, N; P is power, W; E is energy, J.

2. Computation of force and voltage when the conductor is moving perpendicular in a magnetic field:

$$F = iBd\,,\quad U = BVd\,, \qquad (2)$$

where i is electric current, A; U is electric intensity in ends of conductor, V; B is intensity of magnetic field, T; d is length of the conductor, m; V is conductor speed, m/s.

3. Trust and current of HABE

$$b = \frac{\mu_o}{\pi}\ln\left|\frac{d-a}{a}\right|,\quad F = bi^2,\quad i = \sqrt{F/b}\,, \qquad (3)$$

where b is coefficient of given design HABE, $\mu_o = 4\pi 10^{-7}$ is magnetic constant, H/m; a is average radius of rail, m;

4. Required voltage, power and energy by HABE:

$$U_m = biV,\quad r \approx \rho\frac{l}{s}\,,\quad U_r = ir\,,\quad U = U_m + U_r\,,\quad P \approx Ui\,,\quad E \approx P\tau \approx Fl\,, \qquad (4)$$

where U_m is requested voltage for overcoming the magnetic field, V; U_r is requested voltage for overcoming the ohmic resistance, V; r is electric ohmic resistance, Ώ; ρ - specific electric resistance for given material, Ώm,

$$\rho = 9.8\cdot 10^{-8}\ \Omega m \quad \text{for iron and} \quad \rho = 1.75\cdot 10^{-8}\ \Omega m \quad \text{for copper.}$$

l is length of conductor ; *s* is cross-section area of the conductor, m² ; τ is a outer current time, s ; *P* is average power, W; *E* is average energy, J .

5. Inductance of two-wire lines (HABE rails):

$$b_1 = \frac{\mu_o}{\pi}\left(\frac{1}{2} + \ln\frac{d}{a}\right); \quad b_1 \approx b\,, \quad L = \frac{\Phi}{i} = b_1 l\,, \qquad (5)$$

b_1 is design coefficient; *L* is inductance, Henry; Φ is magnetic flow, Weber;

6. Energy expended in the creation of a magnetic field

$$E_m = 0.5Li^2 = 0.5b_1 li^2, \qquad (6)$$

7. Self-induced voltage:

$$U_S = -\left(L\frac{di}{dt} + i\frac{dL}{dt}\right) \qquad (7)$$

8. Change electric current in turn on and turn off the electric voltage in a circuit line having the inductance:

$$Turn\ on\ \ i = (U/r)[1 - \exp(-t/T)], \quad turn\ off \quad i = i_o \exp(-t/T), \quad where \quad T = L/r\,. \qquad (8)$$

T is constant, sec, when current changed in *e* = 2.71 times. This change is presented in fig.4. The current reaches the finish approximately in *T* seconds. *T* ≈ 0.1 sec for HABE. The capacitance of HABE is small and we neglect it.

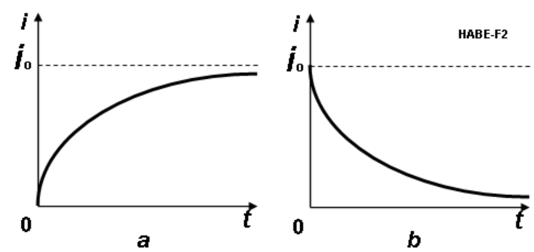

Fig.4. Change electric current via time in turn on and turn off the electric voltage in a circuit line having the inductance.

9. Efficiency of conventional RailGun and HABE may be computed by equations:

$$RailGun \quad \eta = \frac{E_u}{E_k + E_m + E_r}\,, \quad HABE \quad \eta = \frac{E_u + kE_m}{E_k + E_m + E_r}\,, \qquad (9)$$

$$where \quad E_u = Fl = b_1 li^2\,, \quad E_m = 0.5bli^2, \quad E_r = \rho li^2\tau/s\,, \quad b \approx b_1$$

Here E_u is the useful energy, which accelerates the apparatus, J; *k* is coefficient of transferring (returning) the inductive energy in the useful energy, $k \approx 0.5 - 0.95$.

Drawing your attention to the coefficient of HABE efficiency has in numerator additional member kE_m which increases the efficiency of HABE.

Substituting the second line in equation (9) to the first line of (9) we get

$$RailGun \quad \eta = \frac{1}{1.5 + p\tau / bs}; \quad HABE \quad \eta = \frac{1 + 0.5k}{1{,}5 + \rho\tau / bs} \quad . \qquad (10)$$

As you see the HABE has more efficiency then RailGun in any case approximately in 25 – 30% plus less damage from flash.

The computation for different $S = \rho / 2s$ are presented in Fig. 5.

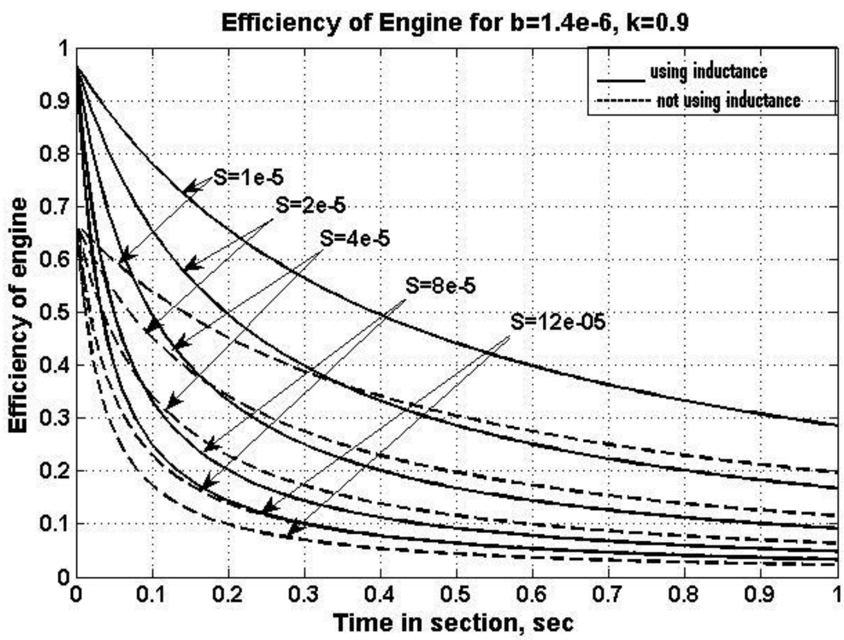

Fig.5. Comparison of efficiency the RailGan (dash line) and HABE (full line) via outer current time τ for different Ohm resistance $S = \rho / 2s$.

As you see for high efficiency the Ohm resistance and stay time in every section 17 (fig.3) must be small.

10. The repellant force of rails may be computed by equation:

$$F_R = \frac{\mu_o}{2\pi d} i^2 . \qquad (11)$$

11. Safety heating of rails is

$$\frac{i}{s} = \left(\frac{c_p \gamma}{\rho} \frac{\Delta T}{t} \right)^{0.5}, \quad b_3 = \sqrt{\frac{c_p \gamma}{\rho}}, \quad \frac{i}{s} = b_3 \sqrt{\frac{\Delta T}{t}}, \qquad (12)$$

where *i/s* is safety density of current, A/m²; ΔT is change temperature of rail, C or K; *t* is time of heating, sec., γ is specific gravity of rail, kg/m³. For iron γ = 7900 kg/m³. C_p is heat capacity of rail, J/kg.K (for iron C_p = 0.45 kJ/kg.K, for copper C_p = 0.39 kJ/kg.K). Computation by equation (12) is presented in fig. 6.

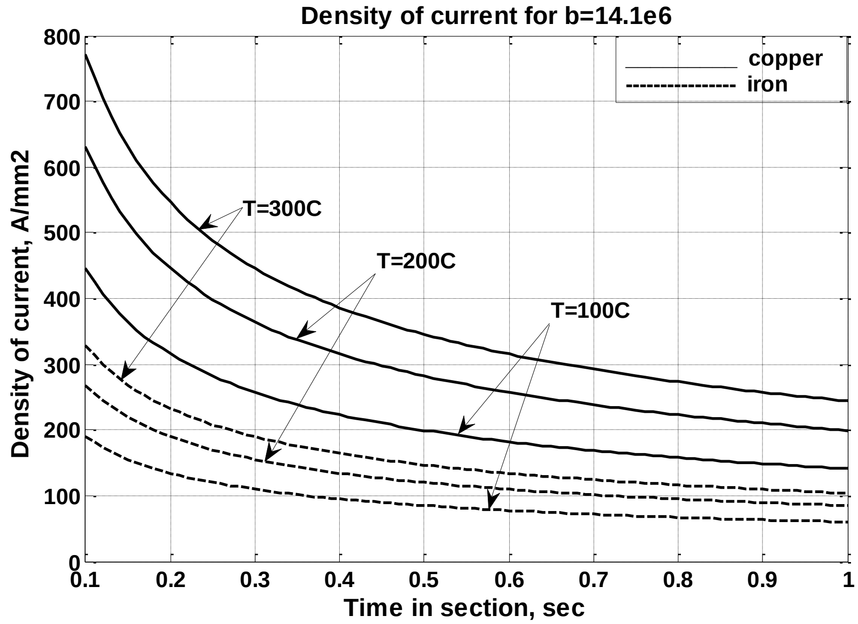

Fig.6. Safety current density versus time of iron (dish line) and copper (full line) and for different safety rail temperature.

12. Computation of space ship/apparatus (SS) trajectory launched by offered Hypersonic Engine.

Equations for computation of the apparatus trajectory are:

$$\begin{aligned}
&\dot{r} = \frac{R_0}{R} V\cos\theta, \\
&\dot{H} = V\sin\theta, \\
&\dot{V} = -\frac{D}{m} - g\sin\theta, \\
&\dot{\theta} = \frac{L}{mV} - \frac{g}{V}\cos\theta + \frac{V\cos\theta}{R} + 2\omega_E\cos\varphi_E,
\end{aligned} \tag{13}$$

where r is range of ship flight, m; R_0 = 6,378,000 is radius of the Earth, m; R is radius of ship flight from Earth's center, m; V is ship speed, m/s; H is ship altitude over Earth, m; θ is trajectory angle, radians; D is apparatus drag, N; m is apparatus mass, kg; g is gravity at altitude H, m/s^2; L is apparatus lift force, N; ω_E is angle Earth speed; φ_E is lesser angle between perpendicular to flight plate and Earth polar axis; t is flight time, sec. (We take $\varphi_E = 0$).

The magnitudes in equations (13) compute as:

$$\begin{aligned}
&g = g_0\left(\frac{R_0}{R_0+H}\right)^2, \quad \rho = 1.225e^{-H/6833}, \\
&D = 0.5C_D\rho aVS, \quad L = 2\alpha\rho aVS, \quad K = L/D, \\
&C_D = C_{D,0} + C_i, \quad C_{D,0} = C_{D,F} + C_{D_0,W}, \\
&C_{D,F} = 2\beta^2 S_F/S, \quad C_i = B(M)\alpha^2,
\end{aligned} \tag{14}$$

where $g_0 = 9.81$ m/s^2 is gravity at the Earth surface; ρ is air density, kg/m^3, $\rho = 1.225$ at $H = 0$; C_D is apparatus drag coefficient; $C_{D,0}$ is apparatus drag coefficient when $L = 0$; C_i is coefficient of the inductive drag; $C_{D,F}$ is fuselage drag coefficient; $C_{D_0,W}$ is wing drag coefficient for $\alpha = 0$; α is wing attack angle, rad; β is wedge angle of fuselage, rad; S_F is fuselage cross-section area, sq.m; S is wing area; *B(M)* is induces coefficient; a is sound speed, at zero altitude. One is $a = 330$ m/s at $H = 0$.

13. The loss of energy for air drag in acceleration area (tube), in climb trajectory (flight with vertical overload n) and lifting of apparatus at altitude H ($H \approx 100$ km) can be estimated the equations below:

$$\begin{aligned}
&E_0 \approx 0.5DL_0\,,\quad E_1 = mV\sqrt{0.5ngH_1}/K\,,\\
&\sin\theta = \sqrt{2ngH_1}/V,\quad t_1 = \sqrt{2H_1/ng}\,,\quad E_2 = D_2L_2\,, \qquad (15)\\
&E_3 = mgH\,,\quad E = mV^2/2\,,\quad V_f = \sqrt{2(E - E_1 - E_2 - E_3)/m} + V_E\,,
\end{aligned}$$

where E_0 is a loss of energy in acceleration area, J; E_1 is a loss of energy in climbing trajectory, J; E_2 is loss of energy from air drag D_2 in distance L_2 - lifting trajectory without vertical acceleration; E_3 is a loss of energy for lifting the apparatus at altitude H; L_1 is length of acceleration distance (tube) m; n is overload in "g"; K is ration L/D ($K \approx 4 - 5$ for hypersonic aircraft); $H_1 = 8440$ m is thickness of the Earth atmosphere if one has constant air density, m; V_f is the final speed at altitude H, V_E is additional speed from Earth rotation ($V_E = 463$ m/s at equator); E is energy in end of acceleration distance.

14. Heating of apparatus in re-entry protected by conventional method.

$$\begin{aligned}
&Q = \frac{5.52\cdot 10^7}{R_n^{0.5}}\left(\frac{\rho}{\rho_{SL}}\right)^{0.5}\left(\frac{V}{V_{CO}}\right)^{3.15},\quad R_n = \sqrt{\frac{S_n}{\pi}}, \qquad (16)\\
&T_1 = 100\left(\frac{Q}{\varepsilon C_S} + \left(\frac{T_2}{100}\right)^4\right)^{1/4},\quad T = T_1 - 273,
\end{aligned}$$

where: Q is heat flow in 1 m^2/s of apparatus, J/s·m^2; R_n is vehicle equivalent radius, m; S_n is cross-section fuselage area, $\rho_{SL} = 1.225$ kg/m^3 is air density at sea level; $V_{CO} = 7950$ m/s is circle orbit speed; T_1 is temperature of apparatus in Kelvin, ^{o}K; T is temperature of apparatus in centigrade, ^{o}C; T_2 is temperature of the standard atmosphere at given altitude, ^{o}K ($T_2 = 288\,^o$K at $H = 0$ km) ; $C_S = 5.67$ W/(m^2·K^4) is coefficient radiation of black body; ε is coefficient of a black ($\varepsilon \approx 0.03 \div 0.99$): K is ration *L/D*.

15. Cooling system and additional thrust.

The cooling system is heating, evaporates of cooling liquid, heating of the vapor up high temperature and emitted with high speed from reactive/rocket nozzle. As result we obtain additional thrust. The estimation can be made by equations for the vertical acceleration distance $H = 0 - 20$ km:

$$D = ngm/K, \quad Q = \eta DVt_1, \quad Q_1 = C_p \cdot \Delta T_1 + r_1 + C_{p,1} \cdot \Delta T_2, \quad m_c = Q/Q_1,$$
$$I = m_c v, \quad F_1 = I/t_1, \quad \Delta V = v \cdot \ln\frac{m}{m_0}, \quad if \;\; m_c << m, \; then \;\; \Delta V \approx v\frac{m_c}{m}, \tag{17}$$

where Q is heat (energy) accepted by space ships, J; η is transfer coefficient, for sharp edge fuselage and wing η ≈ 0,02 – 0.08; $t_1 = V_y / ng$ is flight time in distance H = 0 – 20 km, sec; Q_1 is heat for heating 1 kg of given liquid, J; C_p is heat capacity of cool liquid, J/kg.K (for water C_p = 4.19 kJ/kg.K); $\Delta T_1 = 85\,°$C is change of temperature for boiling, K; r_1 is coefficient of evaporation, KJ/kg (for water r_1 = 2200 kJ/kg);; $C_{p,1}$ is heat capacity of vapor, J/kg.K (for water $C_{p,1}$ = 2.21 kJ/kg.K); $\Delta T_2 \approx 600 - 800\, C$ is temperature of vapor, m_c is mass of cooling liquid, kg; v is speed of gas/vipor from a rocket nuzzle, m/s ($v \approx$ 2000 – 3000 m/s); I impulse, kg.m/s; F_1 is trust of the rocket nozzle, N; τ_1 is work time of rocket nozzle, sec.; ΔV is the additional speed, m/s; m is mass of the space ship, kg.

For the lifting distance ΔH = 20 - 100 km the requested mass of the cooling liquid may be estimated by equation:

$$D_2 = 0.5 \cdot C_D \rho_a a V S_F, \quad where \quad C_D = 2\beta^2, \quad \rho_a = \frac{\rho_0 b_2}{\Delta H}\left(1 - e^{-H/b_3}\right), \quad b_2 = -\frac{\Delta H}{\ln(\rho/\rho_0)},$$
$$if \quad \Delta H >> b_2 \quad then \quad \rho_a \approx \frac{\rho_0}{\ln(\rho/\rho_0)}, \quad L_2 \approx \frac{\Delta H}{\sin\theta}, \quad Q_2 = \eta D_2 L_2 t_2, \quad m_{w,2} = Q_2/Q_1. \tag{18}$$

Where ρ_a is average air density in given diapason of altitude ΔH, kg/m³; ΔH is given region of the atmospheric altitude, m; ρ_0 is air density in beginning (bottom) of the given diapason of the altitude ΔH, kg/m³; ρ is air density in an end (top) diapason of altitude ΔH, kg/m³; L_2 is distance of lifting, m; $m_{w,2}$ is a need mass of cooling liquid, kg (small); Q_2 is heat from air, J; $t_2 \approx L_2/V$ is the flight time in distance ΔH = 20 - 100 km.

16. Estimation of the energy loss and speed of SS in the flight time in the Earth atmosphere and additional speed from head rocket.

$$E_1 = ngmVt_1/K, \quad E_2 = D_2 L_2, \quad E_3 = mgH, \quad \Delta V_L \approx \frac{E_1 + E_2 + E_3}{mV},$$
$$\Delta V = -v\ln\frac{m - m_c}{m}, \quad if \quad m_c << m \quad then \quad \Delta V = v\frac{m_c}{m}. \tag{19}$$

where E_1 is energy for curvature of trajectory; E_2 is energy for air drag in diapason ΔH = 20 - 100 km, E_3 is energy for lifting the SS mass at altitude H = 0 – 100 km; K is ratio C_L/C_D; ΔV_L is summary loss of the SS speed in Earth atmosphere in diapason H = 0 – 100 km; ΔV is the SS additional speed from the rocked cooling system, m/s; v is the gas/vapor nozzle speed of rocket-cooling system, m/s; m_c is the mass of used cooling liquid, kg.

Project

From these computations we can estimate parameters of the operation of the offered hypersonic engine and space launcher. Suppose we want to estimate the system which uses as the supersonic ground transportation (speed up 4 km/s), continental hypersonic kinetic aviation (maximal speed up 5 km/s) and space launcher with speed up 8 km/s.

Space Launcher is most difficult in design, so for the sake of illustration, in this paper we estimate only one. The ground supersonic transport and kinetic air hypersonic transport are more simple in design and, if we get the acceptable space launcher for current technology, the installation may be used also as ground and air transportation system.

1) ***Acceleration track (tube) for space ship:*** Let us take the mass of space ship m = 10 tons = 10,000 kg, overload n = 6 (acceleration $a = ng$ = 60 m/s²) and the final nozzle speed V = 8 km/s = 8000 m/s. The overload n = 6 is acceptable for trained people (astronauts can endure shortly time n up 9). The conventional people can endure n = 3, but in this case the acceleration track must be ~ two time longer.

For our data the acceleration track L and acceleration time t must be (all computation are in metric system):

$$L_0 = \frac{V^2}{2a} = \frac{64 \cdot 10^6}{120} = 533\, km, \quad t_0 = \sqrt{\frac{2L_0}{a}} = 133 \sec . \qquad (20)$$

Needed thrust, maximal power and total energy we increase in 10% for tube air drag (from primary computation). The needed force, maximal power and total acceleration energy are

$$F = 1.1 \cdot am = 6.6 \cdot 10^5\ N, \quad P_m = FV = 6.6 \cdot 10^5 8 \cdot 10^3 = 5.3 \cdot 10^9\ W,$$
$$E = 0.5 F L_0 = 1.76 \cdot 10^{11}\ J. \qquad (21)$$

2) ***Estimation of Hypersonic Engine*****.** The railway track in Europe is d = 1.435 m, half of rail head is a_1 = 0.036 m, cross-section area of rail is s =0.00613 m², length of rail l = 12.5 m, iron rail has specific electric resistance $\rho = 9{,}8 \cdot 10^{-8}\ \Omega / m$.

Need electric current, voltage, power, energy are:

$$b = \frac{\mu_0}{\pi} \ln \left| \frac{d - a_1}{a_1} \right| = 1.46 \cdot 10^{-6}, \quad i = \sqrt{\frac{F}{b}} = 6.72 \cdot 10^5\ \ A\,,$$
$$U_m = biV = 7.85 \cdot 10^3\ V, \quad r = \rho \frac{l}{s} = 2 \cdot 10^{-4}\ \ \Omega, \quad U_r = ir = 134\, V. \qquad (22)$$

Inductance L rail track for the rail length l = 12.5 m is:

$$b_1 = \frac{\mu_0}{\pi} \ln \left| \frac{d}{a_1} \right| \approx b = 1.46 \cdot 10^{-6}, \quad L = b_1 l = 1.82 \cdot 10^{-5}\ \ \text{H}. \qquad (23)$$

Maximal energy of magnetic field time constant of inductance are

$$E_m = 0.5 \cdot L i^2 = 3.74 \cdot 10^6\ J, \quad T = L / r = 0.09 \sec. \qquad (24)$$

Average efficiency coefficient η for l = 50 m, V = 4 km/s, k_1 = 0.9, τ = 50/4000 = 0.0125 sec.

$$\eta = \frac{1+0.5k_1}{1.5+\rho\tau/bs} = \frac{1.45}{1.5+9.8\cdot10^{-8}\cdot0.0125/1.46\cdot10^{-6}\cdot6.13\cdot10^{-3}} = 0.886 \qquad (25)$$

Repel force of rail and safety heating time t of for safety iron rail temperature $\Delta T = 400^o C$ are:

$$F_R = \frac{\mu_0}{2\pi d} i^2 = 5.74\cdot10^4 \ \ N/m, \quad t = \frac{C_p\gamma\,\Delta T}{\rho}\left(\frac{i}{s}\right)^{-2} = \frac{4.5\cdot10^2\cdot7.9\cdot10^3\cdot4\cdot10^2}{4.8\cdot10^{-8}\cdot0.8\cdot10^{16}} = 1.34 \text{ sec.} \ (26)$$

Here γ is specific gravity of rail, kg/m³. For iron γ = 7900 kg/m³.

3*) Trajectory into Earth atmosphere:* We take the next trajectory after the acceleration (tube) distance. Curvature of trajectory to up by the lift force of the wing space ship (vertical acceleration with a = 6g = 60 m/s) from altitude H = 0 to H = 20 km and lifting of space ship with constant trajectory angle θ from H = 20 km to H = 100km.

$$V_y \approx \sqrt{2aH} = \sqrt{2\cdot60\cdot20000} = 1550 \ \ m/s, \quad t_1 \approx V/a = 8000/60 = 25 \text{ sec},$$
$$\sin\theta \approx V_y/V = 1550/8000 = 0.194, \quad \theta = 11.2^o, \quad L_1 \approx Vt_1 = 8000/25 = 200 \ km. \qquad (27)$$

where V_y is vertical speed of space ship (SS), m/s; L_1 is horizontal distance, m/s.

The lifting distance from H = 20 km to H = 100 km is approximately:

$$L_2 \approx \Delta H/\sin\theta = 80000/0.194 \approx 412 \ km, \quad t_2 \approx \Delta H/V_y = 80000/1550 \approx 52 \text{ sec}. \qquad (28)$$

The diagram of SS overload and trajectory is presented in fig. 7.

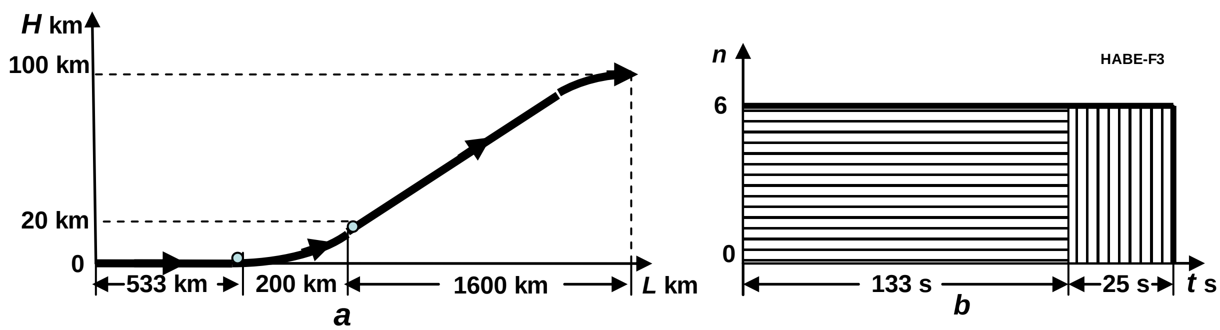

Fig.7. Launch trajectory of space ship (a) and diagram of overload (b).

4) *Cooling system:* We take the water-rocket cooling system. The data of this system in the vertical acceleration distance may be estimated by equations (17) for K = 5, η = 0.04:

$$D = am/K = 60\cdot10000/5 = 1.2\cdot10^5 \ \ N, \quad Q = \eta DVt = 0.04\cdot1.2\cdot10^5\cdot8000\cdot25 = 9.6\cdot10^8 \ \ J,$$
$$Q_1 = C_p\cdot\Delta T_1 + r_1 + C_{p,1}\cdot\Delta T_2 = 4.19\cdot85 + 2200 + 2.21\cdot700 = 4.1\cdot10^6 \ \ J/kg,$$
$$m_c = Q/Q_1 = 9.6\cdot10^8/4.1\cdot10^6 = 234 \ kg, \quad I = m_cV_c = 234\cdot2500 = 5.85\cdot10^5 \ kg\cdot m/s, \qquad (29)$$
$$F_1 = I/t_1 = 5.85\cdot10^5/25 = 2.34\cdot10^4 \ \ N = 2.34 \ tons, \quad \Delta V \approx v\frac{m_c}{m} = 2500\frac{234}{10000} = 58.5 \ m/s.$$

Here F_1 is additional thrust from the air heating in distance 0 - 20 km and ΔV is additional speed of SS.

The water-cooling in lifting distance (from H = 20 - 100 km) is small and expended water mass equals 2.8 kg. The total cooling water mass is 237 kg.

5) *Estimation of loss the energy and speed of SS in Earth atmosphere:* Curving of trajectory in distance H = 0 – 20 km

$$E_1 = ngmVt_1 / K = 60\cdot 10^4 \cdot 8000\cdot 25/5 = 2.4\cdot 10^{10}\ J\ . \qquad (30)$$

Air drag in distance H = 20 – 100 km

$$E_2 = D_2 L_2 = 700\cdot 4.12\cdot 10^5 = 2.9\cdot 10^8\ J\ . \qquad (31)$$

Lifting the SS mass in altitude H = 0 – 100 km

$$E_3 = mgH = 10000\cdot 10\cdot 100000 = 10^{10}\ J\ . \qquad (32)$$

Total loss of energy in moving the Earth atmosphere is

$$E = E_1 + E_2 + E_3 \approx 3.4\cdot 10^{10} \quad J\ . \qquad (33)$$

The total speed loss is significantly less than SS speed. So we can use the equation (18)

$$\Delta V \approx E / mV = 425\ m/s, \qquad (34)$$

The total additional speed from the cooling system is about 60 m/s. The maximal additional speed from the rotating Earth at equator is 463 m/s. We take 370 m/s for mid-latitude. In result we receive the final speed on the 100 km satellite orbit about 8 km/s: 8000 – 425 + 60 + 370 = 8005 m/s.

Fig. 8. Magnetic catapult (Credit NASA)

Discussion

The offered project of HABE engine uses conventional iron rails which are not only 28 times cheaper than copper or 7 times cheaper than aluminum rails, but iron rails have in 3 – 6 times more specific electric resistance. The road with these conventional iron rails may be used as a high speed conventional rail track. That means that in the worst case scenario the cost of construction will not be lost. The longest in World Beijing to Guangzhou high-speed line (China) will open Dec. 26, 2012. A

2,298-kilometer (1,428 mile) line links the nation's capital and the southern city will have average speed 300 km/hours. The speed record of rail train is about 580 km/hour.

The offered space launcher will need an initial acceleration up 100 m/s (360 km/hour) by a conventional locomotive because HABE has low efficiency in low speed. After initial acceleration the locomotive will be disconnected from launcher. The other features of the offered road (if one will be used also as a space and long distance aviation accelerator) are following: one must be strictly rectilinear and into a light (better partially transparent) tube. Sound waves from supersonic and hypersonic flight should not disturb the nearest population.

A conventional power electric station can produce sufficient energy to operate the offered HABE but the offered HABE engine needs a set of the electric transformers to produce a high ampere electric current.

For re-entry to the Earth atmosphere the Space Ship may be used the special brake parachute offered in [9] Ch. 8 and others.

Conclusion

In this article the author describes the new idea, theory, computations and design of the new hypersonic ground electric high efficiency engine (HABE) for space launch, hypersonic aviation, supersonic ground railroad transport and RailGun.

Important advantage of the offered engine is its very high inductive efficiency coefficient, close to 0.9 (compared to the efficiency of the current railgun equal to 20 – 40%). The suggested launcher is very simple, uses conventional iron rails, does not generate high heating and may be produced by present technology. The power of strong electric plant is enough for launching the space apparatus of some tens tons.

The offered magnetic space launcher is a thousand times cheaper than the well-known cable space elevator. NASA is spending hundreds of millions of dollars for research of space elevator. A small part of this sum is enough for R&D of the hypersonic launcher and to make a working model.

Small cheap prototypes would be easily tested.

The computed projects are not optimal. That is only illustration of an estimation method. The reader can recalculate the HABE-Launcher for his own scenarios (see also [1]-[23]).

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(The reader may find some of these articles, at the author's web page: http://Bolonkin.narod.ru/p65.htm , in http://www.scribd.org , in the WEB of Cornel University http://arxiv.org , and in http://aiaa.org search term "Bolonkin")

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