IAC-02-S.P.14

NON-ROCKET MISSILE ROPE LAUNCHER

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53rd International Astronautical Congress
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File: WCS Missile Rope Launcher 6-21-02

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Abstract

The method, installation, and estimation for delivering payload and missiles into outer space are presented. This method uses, in general, the engines and straight or closed-loop cables disposed on a planet surface. The installation consists of a space apparatus, power drive stations located along trajectory of the apparatus, the cables connected to the apparatus and to the power stations, a system for suspending the cable, and disconnected device. The drive stations accelerate the apparatus up to hypersonic speed.

The estimations and computations show the possibility of making these projects a reality in a short period of time (see attached project: launcher for missiles and loads). The launch will be very cheap $1-$2 per LB. We need only light strong cable, which can be made from artificial fibers, whiskers, nanotubes, which exist in industry and scientific laboratories.

Introduction

At present, rockets are used to carry people, payloads into space, or to deliver bombs over long distances. This method is very expensive, and requires a well-developed industry, high technology, expensive fuel, and complex devices [1].

Other then rockets, methods to reach the space speed: space elevator [2], the tube rocket [3] and the electromagnetic system (Patent #4,795,113 USA, M. Minovich, "Electromagnetic Transportation system for manned Space travel").

The space elevator requires in very strong nanotubes, as well as, rocket and high technology for initial development. The tube rocket [3] requires in more detailed research.

The electromagnetic transport system, which is suggested by Minovich, is not realistic at the present time. It requires a vacuum underground tunnel 1530 kilometers long located a depth of 40 kilometers. Project requires a power cooling system (because the temperature is very high at this deep), a complex power electromagnetic system, and a huge impulse of energy which is greater than the energy of all the electric stations on Earth.

The author is suggesting a very simple and inexpensive method and installation for launching into space named the Bolonkin Cable Launcher (BCL).

This is a new revolutionary method and transport system for delivering payloads and people into space. This method uses the cable launcher (straight or closed-loop cables), intermediate power stations, any conventional engines (mechanical, electrical, gas turbines), flywheels located on the ground, and specific pass and connection-disconnection devices. After completing an exhaustive literature and patent search, the author cannot find same space method or similar facilities.

The other author non-rockets methods of space flight presented in [11]-[18].

Description of Installation

Brief Description. Fig.1 shows a short slope maintain launcher for an unmanned apparatus (probe, projectile, space loads).

The installation includes the closed-loop cables, which are connected in series one to another to create the cable chain. Every closed-loop cable is moved by the power station. The apparatus is connected by the connection device to the cable. The power stations have the engine. That can be any engine, for example, gas turbine, electrical or mechanical motors. The power drive station has also an energy storage (accumulator of energy, for example, flywheel), a type transmission and a clutcher.

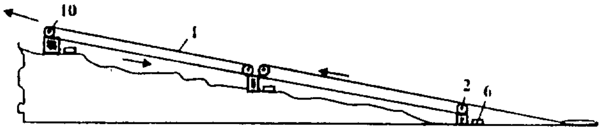

Fig.1. Installation for a space launch by cable chain. Notation are: **1** - closed-loop cable (main cable, apparatus cable); **2** -

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power drive stations; 6 - engine; **10** - terminal power drive station.

The installation works in following way: The power drive station pulls the cable. The cable tows (pulls) the apparatus. The (wing) apparatus (for example, missile, a space load) is accelerated, moves along the chain. In end of the chain the apparatus has a hypersonic speed and it is disconnected from cable.

Advantages. The suggested launch cable system has big advances by comparison to the current rocket systems:

1. The cable launcher is cheaper by some hundred times than the modern rocket launch system. No expensive rockets.
2. The cable launcher decreases the delivery cost by some thousand times (up to $1-$2 per LB).
3. The cable launcher can be made in a few months. The modern rocket launch system requires some years for development, design, and building.
4. The cable launcher does not require high technology and can be made by any non-industrial country.
5. The rocket fuel is expensive. The cable launcher can use the cheapest sources of energy such as wind, water, nuclear or the cheapest fuels such as gaseous gas, coal, peat, etc., because the engine is located on the Earth's surface. The flywheels may be used as an accumulator of energy.
6. It is not necessary to have highly qualified personnel such as rocket specialists with high salaries.
7. No pollution of the atmosphere from toxic rocket gas.
8. We can launch thousands of tons of useful loads annually.

Cable discussing [6]-[9]. Most of the engineers and scientists think it is impossible to develop a strong long cable system. Twenty years ago, the mass of the required cable would not allow this proposal to be possible. However, today's industry widely produces artificial fibers, which have tensile strength 3-5 times more than steel and density 4-5 times less then steel. There are experimental fibers (whiskers) which have tensile strength 30-100 times more than a steel and density 2 to 5 times less than steel. For example, in the book [6] *"Advanced Fibers and Composites"*, by Francis S. Galasso, Gordon and Branch Science Publisher, 1989, p.158, there is a whisker C_D, which has the tensile strength H=8000 kg/mm^2 and density (specific gravity) D=3.5 g/cm^3. If we take an admitted strength of 7000 kg/mm^2 (H=7x10^{10} n/m^2, D=3500 kg/m^3) then the ratio, D/H=0.05x10^{-6} or $k=H/D$=20x10^6, $K=k/10^7$=2. If after 12 years, the ratio, $k=H/D$, has decreased by a factor of two (up to H/D=40x10^6), the load capability in projects increases or the cable mass decreases. Although the graphite fibers are strong (H/D=10x10^6) (1976) , they are at best still ten times weaker than theory predicts. The steel fiber has the tensile strength of 5000 MPA (500 kg/mm^2), the theoretic value is 22,000 MPA (1987). The polyethylene fiber has a tensile strength of 20,000 MPA and the theoretical value is 35,000 MPA (1987).

The mechanical behavior of nanotubes also has provided excitement because nanotubes are seen as the ultimate carbon fiber, which can be used as reinforcements in advanced composite technology. Early theoretical work and recent experiments on individual nanotubes (mostly MWNT's) have conformed that nanotubes are one of the stiffest material ever made. Whereas carbon-carbon covalent bonds are one of the strongest in nature, a structure based on a perfect arrangement of these bonds oriented along the axis of nanotubes would produce an exceedingly strong material. Traditional carbon fibers show high strength and stiffness, but fall far short of the theoretical in-plane strength of graphite layers (an order of magnitude lower). Nanotubes come close to being the best fiber that can be made from graphite structure.

For example, whiskers from Carbon nanotubes (CNT) have a tensile strength of 200 Giga-Pascals and Young's modulus over 1 Tera Pascals (1999). The theory predicts 1 Tera Pascals and Young modules 1-5 Tera Pascals. The hollow structure of nanotubes makes them very light (a specific density varies from 0.8 g/cc for SWNT's up to 1.8 g/cc for MWNT's, compared to 2.26 g/cc for graphite or 7.8 g/cc for steel).

Specific strength (strength/density) $K=k/10^7$ (in million meters) is important in the design of our transportation systems and space circle and elevator; nanotubes have this value at least 2 orders of magnitude greater than steel. Traditional carbon fibers have specific strength 40 times more then of steel. Whereas nanotubes are made of graphite carbon, they have good resistance to chemical attack and have high terminal stability. Oxidation studies have shown that the onset of oxidation shifts by about 100^0 C to higher temperatures in nanotubes compared to high modulus graphite fibers. In vacuum or reducing atmospheres, nanotubes structures will be stable to any practical service temperature. Some American firms promise to produce the nanotubes in 2-3 years.

The price of the whiskers SiC produced Carborundun Co. with σ=20,690 MPa, γ=3.22 g/cc were 440 $/kg in 1989.

Below the author provides a brief overview of the annually research information regarding the proposed experimental (tested) fibers. In addition, the author has also solved additional problems, which appear in these projects and which can look as difficult as the proposed ground or space transportation technology. The author is prepared to discuss the problems with serious organizations, which want to research and develop their projects.

Cable performance. Let us to consider the following experimental and industrial fibers, whiskers, and nanotubes:

1. Experimental nanotubes CNT (Carbon nanotubes) have tensile strength 200 Giga-Pascals (20000 kg./mm^2), Young's modules is over 1 Tera-Pascal, specific density $\gamma=1800$ kg/m^3 (1.8 g/cc)(2000 year). For safety factor $n=2.4$, $\sigma=8300$ kg/mm^2=8.3×10^{10} n/m^2, $\gamma=1800$ kg/m^3, $(\sigma/\gamma)=46\times10^6$. The nanotubes SWNT's have density 0.8 g/cc, the nanotubes MWNT's have the density 1.8 g/cc. About 300 kg nanotubes will be produced at the USA in 2002.
2. Whiskers C_D has $\sigma=8000$ kg/mm^2, $\gamma=3500$ kg/m^3 (1989). We take for computation $\sigma=7000$kg/mm^2, $\gamma=3500$kg/m^3, $\sigma/\gamma=20\times10^6$.
3. Industrial fibers have $\sigma=500$-620 kg/mm^2, $\gamma=1800$ kg/m^3, $\sigma/\gamma=2{,}78\times10^6$.
   Issues [6]-[9].

Theory of the suggested Launcher

Formulas for Estimation and Computation developed or used by A. Bolonkin
(in metric system)

Below is a well-known formula of physics and formulas developed by the author. These formulas allow you to calculate different variants.

1. Cross-section area and the weight of a cable of a **constant** cross-section area can be found from equality (balance, equilibrium) an inertia force to cable stress

$$S=mng/(\delta-ng\gamma L),\qquad W=SL\gamma, \qquad (1)$$

where: S - cross-section cable area [m^2]; m - mass of apparatus [kg]; n - overload; δ - tensile stress [n/m^2]; γ - specific density [kg/m^3]; L - distance between power stations [m]; W - cable weight [kg]; $g=9.81$ m/s^2.

2. Cross-section area and weight of a cable of an **equal (constant) stress** can be found as a solution of the difference equation of local balance of inertia force and cable stress

$$S=S_o\,exp(ng\gamma L/\delta),\qquad S_o=ngm/\delta,$$
$$W=m[exp(ng\gamma L/\delta)-1)],\ K=10^{-7}\sigma/\gamma, \qquad (2)$$

where S_o - cross-section area of cable near the ship [m^2], K - stress coefficient.

Results of computation in fig.2-3.

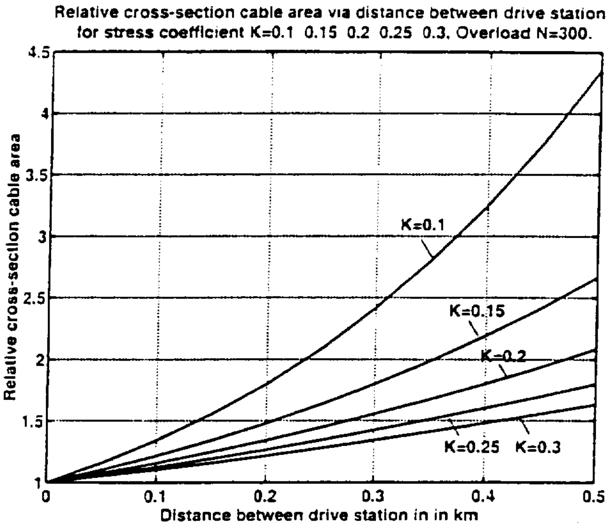

Fig.2. Relative cross-section cable area via the distance between drive station for stress coefficient K=0.1 – 0.3 ($K=10^{-7}\sigma/\gamma$) and overload 300.

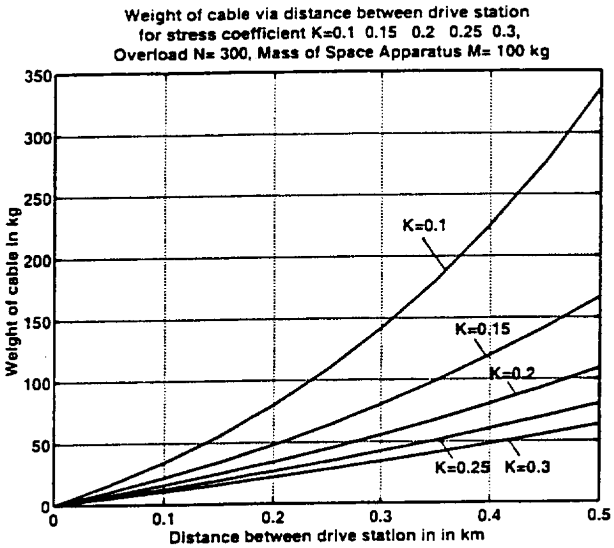

Fig.3. Weight of cable via distance between drive station for K=0.1 - 0.3, overload 300, and apparatus mass 100 kg.

3. Let us take a small part of the rotary circle and write it balance

$$2SR\alpha\gamma V^2/R=2S\sigma\sin\alpha,$$

where V is rotary cable speed [m/sec], σ is cable tensile stress [n/m^2], γ is cable density [kg/m^3], S is cross-section area [m^2]. If $\alpha\to0$ the relationship between maximum rotary speed V and tensile stress of the closed loop cable is

$$V=(\delta/\gamma)^{1/2}. \qquad (3)$$

Result of computation is presented in fig.4.

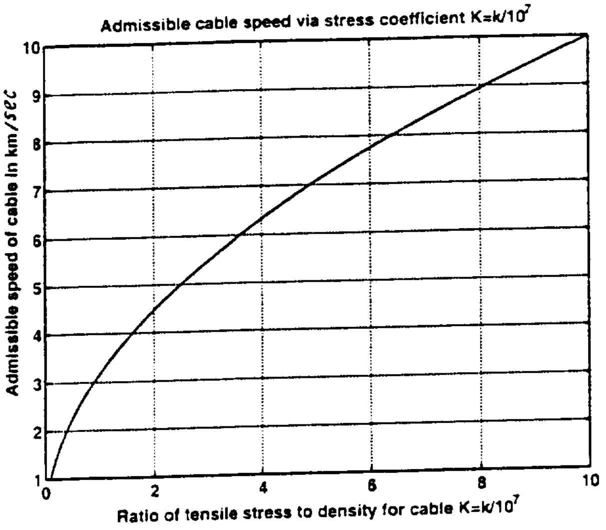

Fig.4. Admissible cable speed via stress coefficient K.

4. Energy, E, storage by rotary flywheel per 1 kg cable [joules/kg] can be found from the known equation of the kinetic energy

$$E = 2\delta/\gamma\ . \qquad (4)$$

Result of computation is presented in fig.5.

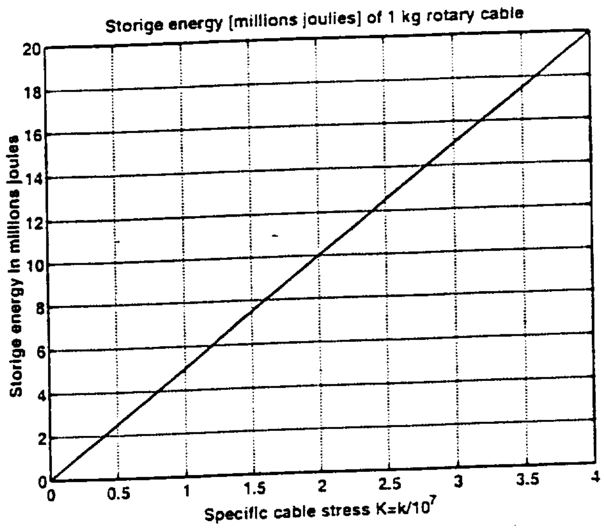

Fig.5. Storage energy of 1kg rotary cable.

5. If we add to Eqs. (2) the stress from the cable support fly vehicles, we get the cross-section area of the cable of equal (constant) stress for wing suspension system

$$S = [g(mn + m_r/k)/\delta]\exp[g\gamma(n-1/k)L/\delta]\ , \qquad (5)$$

where m_r is mass of cable; k is ratio lift to drag of wing. This additional stress is small.

6. We can get an estimation of the loss of speed of an wing apparatus when crossing the atmosphere with k=const from the equation of kinetic energy. This estimation is

$$\Delta V = [2ng(H-H_o)/k\sin\theta]^{1/2}. \qquad (6)$$

where ΔV - loss of speed [m/s]; H=50,000 m - bound of atmosphere; H_o [m] - altitude where apparatus disconnected from cable; θ - angle trajectory to horizon in the moment of disconnection.

7. Maximum distance L [km] between supports of suspension system for $h<<R$, R –radius of Earth, can be found from geometry. That is

$$L = 320\, h^{1/2}\ , \qquad (7)$$

where h [km] - altitude of support.

8. A sag ΔH of the cable (from its weight and curvature of the Earth) can be found from balance weight and stress. That is

$$\Delta H \approx L^2(S\gamma/T - 1/R)/8\ , \qquad (8)$$

where ΔH sag of cable [m]; L - distance between supports [m]; T - tension of cable [kg].

9. Estimation of range, r, of wing projectile in atmosphere is found from the kinetic energy

$$r = k(V_2^2 - V_1^2)/2g\ , \qquad (9)$$

where: k - is ratio lift/drag (k=3 - 6); V_2 - beginning speed of projectile [m/s]; V_1 - finish speed of projectile [m/s].

10. Equation for estimation a wave drag D of an edge cable for supersonic velocity can be got from aerodynamic

$$D = 0.5c^2Vw\int\rho(H)a(H)\sin\theta(H)dH\ , \qquad (10)$$

where $\int$ - integral from altitude H_o to H; c - ratio a thin to a width (w) of an edge (type) cable; $\rho(H)$ - air density; $a(H)$ - speed of sound; $\theta(H)$ - angle of cable to horizon. After integration it is

$$D = 2b^{-1}(e^{bH} - e^{bH_o})\rho_o aV(S^2/w^3)\sin\theta, \qquad (11)$$

where b = - 1.3115.10^{-4} –coefficient of change of air density with altitude, ρ_o =1.225 is air density at H=0, S is cross section cable area.

11. Loss ΔV [m/s] of speed when a projectile passes through the atmosphere can be found from the energy equation

$$\Delta V = (V^2 - 2A/m)^{1/2}\ , \quad A = 2daVFc^2/\sin\theta,$$
$$d = 2354\text{-}8430[0.22308\text{-}(1\text{-}H/44300)^{5.256}]\rho_o\ , \qquad (12)$$

where: V - initial speed of the projectile [m/s]; m - mass of the projectile [kg]; a=300 m/s - speed of sound; F - horizontal area (plane projection) of projectile [m^2]; c - semi-angle of projectile edge in radian; θ - angle of trajectory to horizon; H - altitude of projectile disconnection from cable [m]; ρ_o =1.225 kg/m^3 - air density on altitude H=0. Result of computation is presented in fig.6.

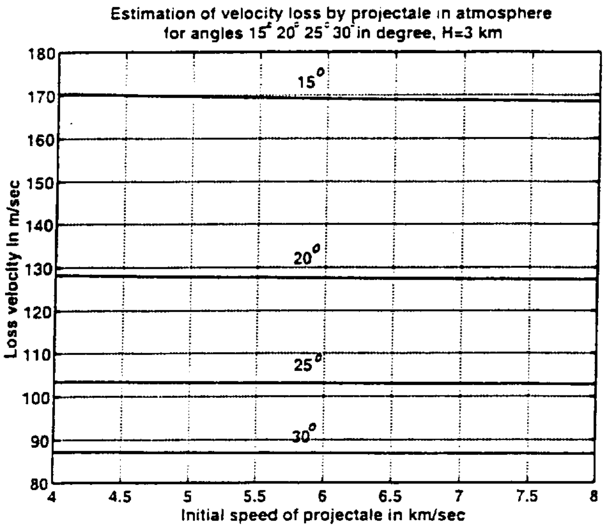

Fig.6. Estimation of velocity loss by projectile in atmosphere.

12. Estimation of cable friction due to the air.

This estimation is very difficult because there is no experimental data for air friction of an infinitely very thin cable (especially at hypersonic speeds). A computational method for plates at hypersonic speed described in the book *"Hypersonic and High Temperature Gas Dynamics"* by J.D. Anderson, p.287, [10] was used. The computation is made for two cases: laminar and turbulent boundary layer.

The results of this comparison are very different. Turbulent flow has maximum friction.

It is postulated that a half of the cable surface will have the laminar boundary layer because a small wind will blow away the turbulent layer and restore the laminar flow. The blowing away of the turbulent boundary layer is studied in aviation and is used to restore laminar flow and decrease air friction. The laminar flow decreases the friction in hypersonic flow by 280 times! If half of the cable surface has a laminar layer it means that we must decrease the air drag calculated for full turbulent layer by a minimum of two times.

Below, the equation from Anderson for computation of local air friction for a plate is given.

$$(T^*/T) = 1 + 0.0032M^2 + 0.58(T_w/T - 1)\ ;$$

$$\mu^* = 1.458x10^{-6}T^{*1.5}/(T^* + 110.4);$$

$$\rho^* = \rho T/T^*; \quad Re^* = \rho^* Vx/\mu^*\ ;$$

$$C_{f,l} = 0.664/(Re^*)^{0.5}; \quad C_{f,t} = 0.0592/(Re^*)^{0.2};$$

$$D_L = 0.5C_{f.l}\rho^* V^2 S\ ; \quad D_T = 0.5C_{f.t}\rho^* V^2 S\ . \quad (13)$$

Where: T^*, Re^*, ρ^*, μ^* are reference (evaluated) temperature, Reynolds Number, air density, and air viscosity respectively. M is Max Number, V is speed, x is length of plate (distance from the beginning of the cable), T is flow temperature, T_w is body temperature, $C_{f,l}$ is a local skin friction coefficient for laminar flow, $C_{f,t}$ is a local skin friction coefficient for turbulent flow. S is area of skin [m^2] of both plate sides, it means for the cable we must take $0.5S$; D is air drag (friction) [n]. It may be shown, that the air drag for the cable equals $0.5(D_T+D_L)$, where D_T is turbulent drag and D_L is laminar drag.

From equation (13) we can derive the following equations for turbulent and laminar flows of horizontal cable

a) For hypersonic speed

$$D_t = 0.0573\rho^{*0.8}\mu^{*0.2}\ V^{1.8}L^{0.8}d\ , \qquad (14)$$

$$D_L = 1.04\rho^{*0.5}\mu^{*0.5}\ V^{1.5}L^{0.5}d\ . \qquad (15)$$

Where d is diameter of cable [m].

b) For subsonic speed the formulas (14)-(15) are same, but you must insert conventional ρ and μ

The estimation show that the cable air friction is small, because in the project below the cable length between drive station and common is small: 500 m and 12 km respectively.

Project

The launcher for payload (projectile) with big acceleration (270g) (fig.1)

Assume the weight of the space apparatus is 100 kg (222 lb.); the escape velocity is 8 km/s, the distance of acceleration is 12 km, the height of a mountain is 3 km (a slope is about 15^0), the acceleration stations are locate every 0.5 km.

The acceleration will be

$$a = V^2/2L = 8000^2/2x12000 = 2666\ m/s = 267g.$$

Assume a fiber tensile strength of δ=250 kg/mm^2 for initial closed-loop cables (this fiber is widely produced by current industry and not expensive). The cross-section area of the cable is 120 sq.mm. The total weight of the cables (all sections) is 5184 kg. The needed energy for one launch is 3.2 Gj. If an engine efficiency is η=0.3 then the needed amount of fuel is 248 kg for one launch. If the frequency of the launching is 0.5 hours then the needed power is 1800 Kw. The weight of flywheels is about 100 tons. The loss of velocity is 170-300 m/s when the projectile crosses the atmosphere with angle 15° - 25°.

<u>The economical efficiency [4]-[5]</u>. Assume the cost of installation to be 3 million dollars, with a life time of 10 years, and a maintenance cost of 300,000$ per year, with a frequency of launching every 30 min.

We can launch 4.8 tons per day or 4.8x360=1728 tons per year. The production cost will be 600,000/1,728,000=0.35$/kg plus fuel cost.

We take the fuel consumption 5 kg per 1 kg payload and price 0.25 $/kg. The fuel cost is 1.25 $. The total cost is 0.35+1.25=1.6 $/kg

General discussing

Science laboratories have whiskers, nanotubes that have high tensile strength [6]-[8] . The theory shows that these values are only one tenth of the theoretical level. We must study how to get a thin cable, such as the strings or threads we produce from cotton or wool, from whiskers and nanotubes.

The fiber industry produces fibers, which can be used for some of the author's projects at the present time. These projects are unusual (strange) for specialists and people now, but they have huge advantages, and they have a big future. The government must award scientific laboratories and companies who can get a cable with the given performances for a reasonable price.

Patent applications are 09/974,670; 09/873,985; 09/789,959; 09/978,507 (2001).

The author has developed an innovation, estimation, and computations of the above mentioned problem. Even though these project seem impossible for the current technology, the author is prepared to discuses the project details with serious organizations that have similar research and development goals.

The other author ideas about non-rocket flight in Space shortly discussed in [3],[11]-[18]. Patent Applications are 09/893,060 of 6/28/01; 09/946,497 of 9/6/01.

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