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NEW AIRCRAFT

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Abstract: *Speaking about a new ionic engine means to speak about a new aircraft. The paper presents shortly the actual ionic engines (called ion thrusters) and the new ionic (pulse) engines proposed by the author. Ionic engine (ion thruster, which accelerates the positive ions through a potential difference) is about 10 times more effective than classic system based on combustion. We can still improve the efficiency of 10-50 times if one uses pulses of positive ions accelerated in a cyclotron mounted on the ship; the efficiency can easily grow for 1000 times if the positive ions will be accelerated in a high energy synchrotron, synchrocyclotron or isochronous cyclotron (1-100 GeV). In this, the big classic synchrotron is reduced to a ring surface (magnetic core). Future (ionic) engine will have mandatory a circular particle accelerator (high or very high energy). We can thus increase the speed and autonomy of the ship using a less quantity of fuel and power. One can use synchrotron radiation (synchrotron light, high intensity beams), like high intensity (X-ray or Gamma ray) radiation, as well. In this case will be a beam engine (not an ionic engine), it'll use only the power (energy, which can be solar energy, nuclear energy, or both) and so we will remove the fuel. It proposes using a powerful LINAC at the exit of synchrotron (especially when one accelerates electrons) to not lose energy by photons premature emission. With a new ionic engine one builds a new aircraft, which can travel through water and. This new aircraft will can accelerate directly, without an additional combustion engine and without gravity assists from other planets.*
Keywords: *high energy synchrotron, synchrocyclotron or isochronous cyclotron, circular particle accelerator, new aircraft, new ionic engine*

1. ION THRUSTER [1]

1.1. About the ion thruster

An *ion thruster* is a form of electric propulsion used for spacecraft propulsion that creates thrust by accelerating ions. Ion thrusters are characterized by how they accelerate the ions, using either electrostatic or electromagnetic force. Electrostatic ion thrusters use the Coulomb Force and accelerate the ions in the direction of the electric field. Electromagnetic ion thrusters use the Lorentz Force to accelerate the ions. Note that the term "ion thruster" frequently denotes the electrostatic or gridded ion thrusters, only.

The thrust created in ion thrusters is very small compared to conventional chemical rockets, but a very high specific impulse, or propellant efficiency, is obtained.

Due to their relatively high power needs, given the specific power of power supplies, and the requirement of an environment void of other ionized particles, ion thrust propulsion currently is only practicable in outer space.

The first experiments with ion thrusters were carried out by Robert Goddard at Clark College from 1916-1917. The technique was recommended for near-vacuum conditions at high altitude, but thrust was demonstrated with ionized air streams at atmospheric pressure. The idea appeared again in Hermann Oberth's "Wege zur Raumschiffahrt" (Ways to Spaceflight), published in 1923.

A working ion thruster was built by Harold R. Kaufman in 1959 at the NASA Glenn facilities. It was similar to the general design of a gridded electrostatic ion thruster with mercury as its fuel. Suborbital tests of the engine followed during the 1960s and in 1964 the engine was sent into a suborbital flight aboard the Space Electric Rocket Test 1 (SERT 1). It successfully operated for the planned 31 minutes before falling back to Earth.

1.2. Hall effect thruster

The Hall effect thruster was studied independently in the U.S. and the USSR in the 1950s and 60s. However, the concept of a Hall thruster was only developed into an efficient propulsion device in the former Soviet Union, whereas in the U.S., scientists focused instead on developing gridded ion thrusters. Hall effect thrusters were operated on Soviet satellites since 1972. Until the 1990s they were mainly used for satellite stabilization in North-South and in East-West directions. Some 100-200 engines completed their mission on Soviet and Russian satellites until the late 1990s. Soviet thruster design was introduced to the West in 1992 after a team of electric propulsion specialists, under the support of the Ballistic Missile Defense Organization, visited Soviet laboratories.

Ion thrusters utilize beams of ions (electrically charged atoms or molecules) to create thrust in accordance with Newton's third law. The method of accelerating the ions varies, but all designs take advantage of the charge/mass ratio of the ions. This ratio means that relatively small potential differences can create very high exhaust velocities. This reduces the amount of reaction mass or fuel required, but increases the amount of specific power required compared to chemical rockets. Ion thrusters are therefore able to achieve extremely high specific impulses. The drawback of the low thrust is low spacecraft acceleration because the mass of current electric power units is directly correlated with the amount of power given. This low thrust makes ion thrusters unsuited for launching spacecraft into orbit, but they are ideal for in-space propulsion applications.

Hall effect thrusters accelerate ions with the use of an electric potential maintained between a cylindrical anode and a negatively charged plasma which forms the cathode. The bulk of the propellant (typically xenon or bismuth gas) is introduced near the anode, where it becomes ionised, and the ions are attracted towards the cathode, they accelerate towards and through it, picking up electrons as they leave to neutralize the beam and leave the thruster at high velocity.

The anode is at one end of a cylindrical tube, and in the center is a spike which is wound to produce a radial magnetic field between it and the surrounding tube. The ions are largely unaffected by the magnetic field, since they are too massive. However, the electrons produced near the end of the spike to create the cathode are far more affected and are trapped by the magnetic field, and held in place by their attraction to the anode. Some of the electrons spiral down towards the anode, circulating around the spike in a Hall current. When they reach the anode they impact the uncharged propellant and cause it to be ionised, before finally reaching the anode and closing the circuit.

1.3. Gridded electrostatic ion thrusters

Gridded electrostatic ion thrusters commonly utilize xenon gas. This gas has no charge and is ionized by bombarding it with energetic electrons. These electrons can be provided from a hot cathode filament and accelerated in the electrical field of the cathode fall to the anode (Kaufman type ion thruster). Alternatively, the electrons can be accelerated by the oscillating electric field induced by an alternating magnetic field of a coil, which results in a self-sustaining discharge and omits any cathode (radiofrequency ion thruster).

The positively charged ions are extracted by an extraction system consisting of 2 or 3 multi-aperture grids. After entering the grid system via the plasma sheath the ions are accelerated due to the potential difference between the first and second grid (named screen and accelerator grid) to the final ion energy of typically 1-2 keV, thereby generating the thrust.

Ion thrusters emit a beam of positive charged xenon ions only. In order to avoid the charging-up of the spacecraft another cathode, placed near the engine, emits additional electrons (basically the electron current is the same as the ion current) into the ion beam. This also prevents the beam of ions from returning to the spacecraft and thereby cancelling the thrust.

Gridded electrostatic ion thruster research (past/present):

NASA Solar electric propulsion Technology Application Readiness (NSTAR)
NASA’s Evolutionary Xenon Thruster (NEXT)
Nuclear Electric Xenon Ion System (NEXIS)
High Power Electric Propulsion (HiPEP)
EADS Radio-Frequency Ion Thruster (RIT)
Dual-Stage 4-Grid (DS4G)

1.4. Field Emission Electric Propulsion

Field Emission Electric Propulsion (FEEP) thrusters use a very simple system of accelerating liquid metal ions to create thrust. Most designs use either caesium or indium as the propellant. The design consists of a small propellant reservoir that stores the liquid metal, a very small slit that the liquid flows through, and then the accelerator ring. Caesium and indium are used due to their high atomic weights, low ionization potentials, and low melting points. Once the liquid metal reaches the inside of the slit in the emitter, an electric field applied between the emitter and the accelerator ring causes the liquid metal to become unstable and ionize. This creates a positive ion, which can then be accelerated in the electric field created by the emitter and the accelerator ring. These positively charged ions are then neutralized by an external source of electrons in order to prevent charging of the spacecraft hull.

1.5. Pulsed Inductive Thrusters

Pulsed Inductive Thrusters (PIT) use pulses of thrust instead of one continuous thrust, and have the ability to run on power levels in the order of Megawatts (MW). PITs consist of a large coil encircling a cone shaped tube that emits the propellant gas. Ammonia is the gas commonly used in PIT engines. For each pulse of thrust the PIT gives, a large charge first builds up in a group of capacitors behind the coil and is then released. This creates a current that moves circularly. The current then creates a magnetic field in the outward radial direction (Br), which then creates a current in the ammonia gas that has just been released in the opposite direction of the original current. This opposite current ionizes the ammonia and these positively charged ions are accelerated away from the PIT engine due to the electric field crossing with the magnetic field Br, which is due to the Lorentz Force.

1.6. Magnetoplasmadynamic

Magnetoplasmadynamic (MPD) thrusters and Lithium Lorentz Force Accelerator (LiLFA) thrusters use roughly the same idea with the LiLFA thruster building off of the MPD thruster. Hydrogen, argon, ammonia, and nitrogen gas can be used as propellant. The gas first enters the main chamber where it is ionized into plasma by the electric field between the anode and the cathode. This plasma then conducts electricity between the anode and the cathode. This new current creates a magnetic field around the cathode which crosses with the electric field, thereby accelerating the plasma due to the Lorentz Force. The LiLFA thruster uses the same general idea as the MPD thruster, except for two main differences. The first difference is that the LiLFA uses lithium vapor, which has the advantage of being able to be stored as a solid. The other difference is that the cathode is replaced by multiple smaller cathode rods packed into a hollow cathode tube. The cathode in the MPD thruster is easily corroded due to constant contact with the plasma. In the LiLFA thruster the lithium vapor is injected into the hollow cathode and is not ionized to its plasma form/corrode the cathode rods until it exits the tube. The plasma is then accelerated using the same Lorentz Force.

1.7. Electrodeless Plasma Thrusters

Electrodeless Plasma Thrusters have two unique features, the removal of the anode and cathode electrodes and the ability to throttle the engine. The removal of the electrodes takes away the factor of erosion which limits lifetime on other ion engines. Neutral gas is first ionized by electromagnetic waves and then transferred to another chamber where it is accelerated by an oscillating electric and magnetic field, also known as the ponderomotive force. This separation of the ionization and acceleration stage give at the engine the ability to throttle the speed of propellant flow, which then changes the thrust magnitude and specific impulse values [1].

1.8. Plasma Micro Thruster

In the picture number 1 one presents „A Plasma Micro Thruster" Schematic and Prototype (see the figure 1, and [2]).

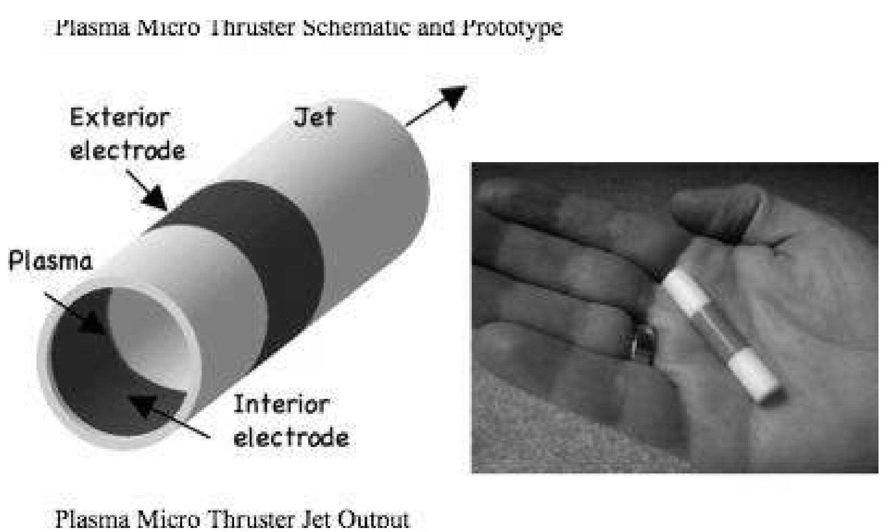

Fig. 1: *Plasma Micro Thruster, Schematic and Prototype*

2. THE HiPEP ENGINE

2.1. Powerful ion engine relies on microwaves

A powerful new ion propulsion system has been successfully ground-tested by NASA. The High Power Electric Propulsion ion engine trial marks the "first measurable milestone" for the ambitious $3 billion Project Prometheus, says director Alan Newhouse.

The HiPEP engine is the first tested propulsion technology with the potential power and longevity to thrust spacecraft as far as Jupiter without gravity assists from other planets.

These assists involve slingshot manoeuvres around planets and can boost the speed of craft significantly. But they require specific planetary alignments, meaning suitable launch dates are rare.

In contrast, a probe powered by a HiPEP engine could launch any time. One goal of Project Prometheus, formerly called the Nuclear Systems Initiative, is to launch a spacecraft towards Jupiter by 2011. The flight would take at least eight years.

The key elements of the HiPEP engine are a high exhaust velocity, a microwave-based method for producing ions that performs for longer than existing technologies and a rectangular design that can more easily be scaled up than circular ones.

Spacecraft are increasingly being built with ion engines rather than engines that burn rocket fuel. This is because ion engines produce more power for a given amount of propellant, and provide a smooth output rather than intermittent spurts.

"Jupiter is such a far away target. Using a chemical system, you just couldn't do it," says John Foster, one of the principal creators of the engine at NASA's Glenn Research Center in Cleveland, Ohio.

The HiPEP engine differs from earlier ion engines, such as that powering NASA's Deep Space One mission, because the xenon ions are produced using a combination of microwaves and spinning magnets. Previously the electrons required were provided by a cathode. Using microwaves significantly reduces the wear and tear on the engine by avoiding any contact between the speeding ions and the electron source.

2.2. Nuclear fission

A Japanese asteroid-chasing spacecraft is already using microwave-based technology to produce ions, but Hayabusa uses a small device that could not produce enough power to fly to Jupiter. The HiPEP engine is currently capable of 12 kilowatts of power but its output will be boosted to at least 50 kW for the Jupiter mission.

The rectangular cross section of the HiPEP engine will make this easier, as it can be expanded along one of its sides. A circular engine would have to be rebuilt, says NASA.

Nonetheless, other researchers at NASA's Jet Propulsion Laboratory in Pasadena, California, are working on a cylindrical high-power ion engine, also for the Prometheus project. But Newhouse notes that building a powerful, long-lasting propulsion system is just "one of the pieces we need to get to Jupiter". The electricity for the ion engine is slated to come from on-board nuclear fission reactor. This part of the Prometheus Project is just beginning, with safety considerations, the miniaturisation of the reactor and the identity of the fuel all needing to be decided.

3. NEW IONIC OR BEAM PULSES ENGINES

By this paper the author propose a new pulse engine which works with beam or ionic (ionic beam) pulses. With a new ionic engine one builds a new aircraft (a new ship). The principal characteristic of this kind of engine is the high power (energy) which accelerates the beam at very high energy, in circular accelerators, in modern linear accelerators (LINAC), or in both. One can use accelerators similar with the static physics accelerators (synchrotron, synchrocyclotron or isochronous cyclotron).

Ionic engine (ion thruster, which accelerates the positive ions through a potential difference) is about 10 times more effective than classic system based on combustion. We can still improve the efficiency of 10-50 times if one uses positive ions accelerated in a cyclotron mounted on the ship; the efficiency can easily grow for 1000 times if the positive ions will be accelerated in a high energy synchrotron, synchrocyclotron or isochronous cyclotron (1-100 GeV). Future (ionic) engine will have mandatory a circular particle accelerator (high or very high energy; see the figure 3) . Sure that the difficulties will arise from design, but they need to be resolved step by step. We can thus increase the speed and autonomy of the ship using a less quantity of fuel. One can use synchrotron radiation (synchrotron light, high intensity beams), like high intensity (X-ray or Gamma ray) radiation, as well. In this case will be a beam engine (not an ionic engine).

A linear particle accelerator (also called a LINAC) is an electrical device for the acceleration of subatomic particles. This sort of particle accelerator has many applications. It used recently as to an injector into a higher energy synchrotron at a dedicated experimental particle physics laboratory. In this, the big classic synchrotron is reduced to a ring surface (magnetic core).

The design of a LINAC depends on the type of particle that is being accelerated: electron, proton or ion.

It proposes using a powerful LINAC at the exit of synchrotron (especially when one accelerates electrons) to not lose energy by photons premature emission (figure 3).

One can use a LINAC in the entry in the Synchrotron and one at out (figure 2). To use a small entrance LINAC, between him and synchrotron, one put an additional speed circuit in a stadium form (fig. 2).

The end LINAC can be reduced if one put more end LINACs. See diagram below (fig. 2.) © 2008 Florian Ion TIBERIU-PETRESCU

Fig. 2: *A high energy synchrotron schema*

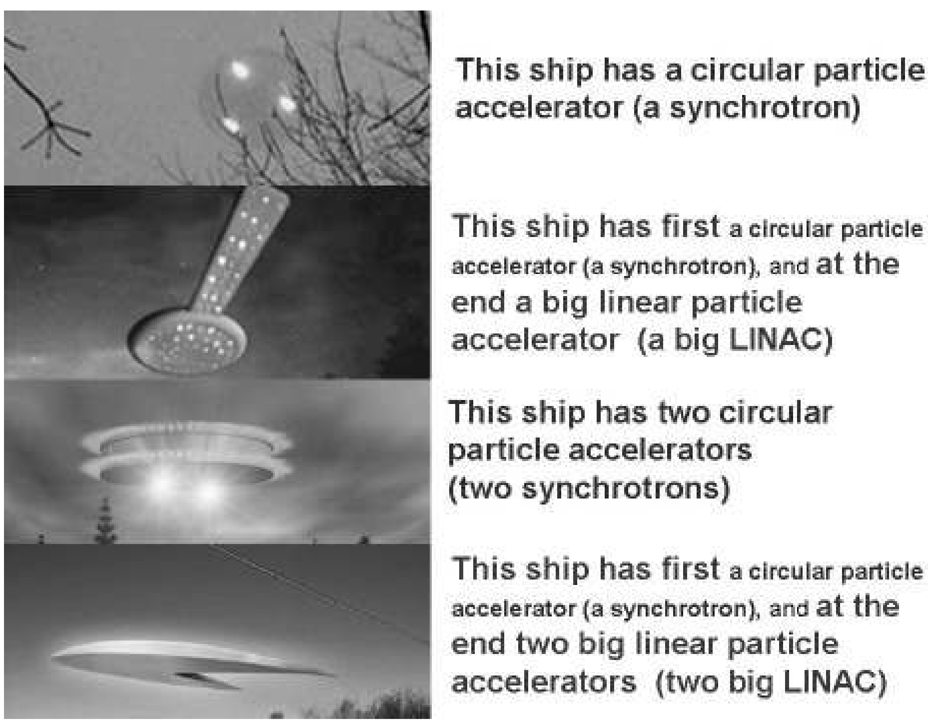

Fig. 3: *Some flying synchrotron prototypes*

4. CONCLUSION

Speaking about a new ionic engine means to speak about a new aircraft.

The paper presents shortly the actual ionic engines (called ion thrusters) and the new ionic (pulse) engines proposed by the author. Ionic engine (ion thruster, which accelerates the positive ions through a potential difference) is about 10 times more effective than classic system based on combustion.

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With a new ionic engine one builds a new aircraft, which can travel through water and. This new aircraft will can accelerate directly, without an additional combustion engine and without gravity assists from other planets

Ionic engine (ion thruster) has 2 major advantages (a) and 2 disadvantages (b) compared with chemical propulsion; (a) the impulse and energy per unit of fuel used are much higher; 1-the increased impulse generates a higher speed (velocity; so we can walk longer distances in a short time), 2-the high energy decreases fuel consumption and increase the autonomy of the ship; (b) generate force and acceleration are very small; we can not defeat any forces of resistance to lodging by atmosphere and we have no chance to exceed gravitational forces - ship will not leave a planet (or fall on it) using the ion thruster (It required an additional motor). Vacuum ship acceleration is possible but only with very small acceleration.

Increasing more the energy (and also the impulse) can reach the necessary forces and acceleration (Growth will need to be very high, 100 PeV-1000 PeV). Particles energy increased can be made with accelerators circular and or modern linear. Particles energy increased will be huge and in addition will need to grow and the flow of accelerated particles (and the tor diameter; if one increases enough the flow, the necessary energy will be 10 GeV-10 TeV).

Immediate consequence of increasing particle energy will be the increasing of speeds and autonomy of the ship. Now we can achieve huge speeds in a very short time. The ship will pass through any atmosphere (including water) with great ease. The ship can take off or land directly.

Initially one can use to ship the old forms (the old design) which adapts and the accelerator(s).

REFERENCES

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[2] Dan Tanna, *Technology today*, edit on 10-6-2008, a net Link.