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Electrodynamic Tether

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ABSTRACT—

Electrodynamic tether is a lengthy conducting wire which is extended from spacecraft. It provides propellent less propulsion to spacecraft in low earth orbit. It works as a thruster, because a magnetic field exerts a force on a current carrying wire. The earth supplies magnetic field.It can be used to pull or push a spacecraft to act as brake or a booster. It works on the principle of Lorenz force.It is completely reusable and environmental friendly clean and provides all these features at low cost.It still has some problems despite, that electrodynamic tether is a promising technology which plays a important role in the future for exploring the other planets.

Keywords: long conducting wire

1. INTRODUCTION

Electrodynamic tethers are long, thin conductive cables stationed in space that can be used too induce power by removing kinetic energy from their orbital stir, or to produce thrust when adding energy from an on- board source. In either case, the frictional or thrust force, is produced electrodynamically, through the commerce between moving charges and glamorous fields. From then, we notice that the operation of electrodynamic tethers is confined to elysian objects that have anon-zero glamorous field and ionospheric tube (e.g., Earth, Jupiter, Saturn, etc, not the moon or Mercury, etc).

Electrodynamic (ED) tether is a lengthy wire prolonged from spacecraft. It has a strong potential for providing propellant less propulsion to spacecraft in low earth orbit. The tether uses the same principle as electric motor in toys, appliances and computer disk drives. It works as a thruster, because a magnetic field exerts a force on a current carrying wire. The earth supplies magnetic field. By properly controlled the forces generated by this “electrodynamic” wire can be put to use pull or push a spacecraft to act as brake or a booster. NASA plans to lasso energy from Earth’s atmosphere with a tether act as one of the family first demonstration of a propellant-free space propulsion system, potentially leads to a revolutionary space transportation system. Working with Earth’s magnetic field would benefit numerous spacecraft including the International Space Station. Tether propulsion requires no fuel. Is completely reusable and environmentally clean and provides all these features at low cost.here is artificial gravity inside spacecrafts.

2. LITERATURE REVIEW

[1] **Gallagheer D. L, Johnnson L, Mooree J, Bageenal F, in this paper” Electrodynamic Tether Propulsion and Power Generation at Jupiter"** The findings of a research conducted to assess the viability and benefits of employing an We describe a tether for a spaceship in the Jovian system that will power and propel it. The Jovian system's atmosphere features elements that are particularly conducive to the use of an electrodynamic tether. The planet in question has a powerful magnetic field, and because of its bulk, it must orbit at high speeds. This, along with the planet's swift rotation, can result in extremely high relative velocities between the magnetic field and the spacecraft. Tether propulsive forces are discovered to be as high as 50 N and power levels as high as 1 MW in a circular orbit that is close to the planet.

[2] **Johnson L, Fujiii H, A Sanmartin JR, in this paper “ Electrodynamic System Tether Experiment (T- REX)**.” Japanese-Propelled A led international team is constructing a suborbital test of orbital-motion-limited (OML) bare wire anode current collectio for use in electrodynamic tether (EDT) propulsion.In the summer of 2010, a mission will launch on an S520 Sounding Rocket. At a pace of roughly 8 m/s during ascent and over 100 km in attitude, the tape tether will be removed.The tape tether will function as an anode once it is in position, grabbing electrons from the ionosphere. A hollow cathode device will discharge the electrons into space, completing the circuit and letting current to flow.To determine the validity of. This essay will describe the objectives of the proposed mission, the technology that will be employed, and how the results will be applied to future space exploration.

[3] The Propel Electrodynamic Tether Demonstration Mission was described in this work by Bilen, Sven G., Johnson, C. Les, Wiegmann, and Leslie Alexander.

The PROPEL ("Propulsion using Electrodynamics") mission will show how an electrodynamic tether propulsion system works in low Earth orbit and increase the technology's degree of readiness for a variety of uses. The PROPEL mission has two main goals: first, to show that electrodynamic tether technology can provide reliable and secure near-propellantless propulsion for orbit-raising, de-orbiting, changing planes, and maintaining station; second, to demonstrate orbital power harvesting and formation flight;Additionally, it is important to properly characterise and evaluate the performance of an integrated electrodynamic tether propulsion system in order to qualify it for minimally modified integration into future multiple satellite platforms and missions. An overview of the PROPEL system, design reference missions, mission objectives, necessary metrics, and ongoing PROPEL mission design activities are given in this document.

[4] Stone, Nobie H in this paper "Electrodynamic Tether

Operations beyond the Ionosphere in the Low-Density Magnetosphere"

This paper will, therefore, present the fundamentals of a concept that would allow electrodynamic tethers to operate almost anywhere within the magnetosphere, the region of space containing the earth's planetary magnetic field. In other words, because operations would be virtually independent of any ambient plasma, the range of electrodynamic operations would be extended into the earth's shadow and out to synchronous orbit--forty times the present operational range. The key to this concept is the active generation of plasma at each pole of the tether so that current generation ,does not depend on the conductivity of the ambient ionosphere. Arguments will be presented, based on ,existing flight data, which shed light on the behavior of charge emissions in space and show the plausibility of the concept.

[5] Vas, Irwin E.; Kelly, Thomas J.; Scarl, Ethan A, in this paper "Space Station Reboost with Electrodynamic Tethers."

The findings of a study on an electrodynamic tether system to restart the International Space Station (ISS) are presented in this publication. One suggestion is to utilise an electron collection tether that is partially bare. There are several locations for the space station where the tether system should be attached. Since the tether system can neutralise aerodrag during quiet periods and, if deployed from a movable boom, can allow laboratory location to be optimised with respect to acceleration contours, its impacts on the microgravity environment may actually be advantageous. The deployment and retrieval of tethers using alternative methods are described. It is shown that a relatively short tether system, 7 km long, operating at a power level of 5 kW could provide cumulative savings or over a billion dollars during a 10-year period ending in 2012. This savings is the direct result of a reduction in the number or nights that would otherwise be required to deliver propellant for reboost, with larger cost savings for higher tether usage. In addition to economic considerations, an electrodynamic tether promises a practical backup system that could ensure ISS survival in the event of an (otherwise) catastrophic delay in propellant delivery.

3.WORKING PRINCIPLE

The basic principle of an electrodynamic tether is Lorentz force. It is the force that a magnetic field exerts on a current carrying wire in a direction perpendicular to both the direction of current flow and the magnetic field vector. The Dutch physicist Hendrik Androon Lorentz showed that a moving electric charge experiences a force in a magnetic field. (if the charge is at rest, there will not be any force on it due to magnetic field) Hence it is clear that the force experienced by a current conductor in a magnetic field is due to the drifting of electrons in it. If a current I flows through a conductor of cross-section A then I = neAv where v is the drift speed of electronics n is number density in the conductor and e the electronic charge.

If a current I flows through a conductor of cross-section A then I = neAv where v is the drift speed of electronics n is number density in the conductor and e the electronic charge. For an element dI of the conductor Id = nAdIev But Adi is the volume of the current element. Therefore, nAdI represents the number (N) of electrons in the element Hence, nAdIe = Ne = q, the total charge in the element. Therefore, IdI = qv.

An electrodynamic tether is a mechanism that uses the magnetic energy of the Earth to power a spaceship or act as its propulsion. A conductive wire or cable that is often several kilometres long and is deployed from a spacecraft while it is in orbit makes up the tether. The tether interacts with the Earth's magnetic field, which causes a voltage to be induced along the length of the tether as a result of their relative velocity.

The spacecraft's electrical systems can be powered by the voltage produced by the tether, or it can be utilised to propel the spacecraft by interacting with Earth's magnetic field.

4. TECHNOLOGY

A long conducting wire, typically constructed of a lightweight material like aluminium or copper, known as an electrodynamic tether is used in space applications for a variety of functions including propulsion, energy production, and attitude control. As the tether moves through the Earth's magnetic field, it interacts with the magnetic field to produce energy. Systems on board a spacecraft may be powered by this electricity, or thrust may be produced.

Electrodynamic tethers are created and run using a variety of technologies, such as:

[1] Tether Materials: The tether's construction material must be robust, light, and electrically conductive. Aluminium, copper, and alloys like Nitinol are often used materials in electrodynamic tethers.

[2] Mechanisms for Deploying Tethers: There are a variety of techniques to deploy a tether in space, including from a spinning spacecraft, from a flying object, or by utilising a tether reel system. Every deployment method has benefits and drawbacks that vary depending on the particular application.

[3] Control and navigation of the tether are essential for maintaining the electrodynamic tether's desired orientation and preventing spacecraft collisions. To monitor the tether's position and modify its course as necessary, sophisticated algorithms and sensors are needed.

[4] Power conditioning is necessary to adapt the electricity produced by the tether to the needs of the spacecraft's systems. To do this, the voltage and current must be adjusted to the proper values while being filtered to remove any noise or interference.

[5]Tether Reeling Mechanisms: To change the length and position of a tether, it can be reeled in and out. This calls for a device that can maintain the tension on the line while withstanding the stresses and strains caused by the movement of the tether.

[6]Tether Insulation: The tether needs to be protected from the environment to avoid short-circuiting or arcing. Various materials, including ceramics and Kevlar, can be used for this.

[7]End-of-Life Tether Disposal: The tether must be properly disposed of when it has served its purpose in order to prevent it from endangering other satellites or spacecraft. This may entail burning the tether up on purpose in the Earth's atmosphere or deorbiting it.

In general, the development and use of electrodynamic tethers necessitate a wide range of technologies and knowledge from numerous fields, including materials science, mechanical engineering, electrical engineering, and space physics.

5. FUTURESCOPE

Electrodynamic tethers have the potential to revolutionise space technology and space exploration in a number of ways in the future. Future uses of EDTs could include the following:

Space trash can be de-orbited using EDTs, as can outdated satellites. A satellite or other spacecraft can launch a space-based EDT, which interacts with the Earth's magnetic field to produce electrical power and drag. The debris's height will be lowered by this drag, reentering the atmosphere where it will burn up.

EDTs are a possible in-space propulsion technology. The EDT reacts with the Earth's magnetic field when a current is run through it, creating a force that can be used for propulsion. This can be used to control spacecraft or even to give interplanetary travel a steady acceleration.

EDTs may be utilised as a component of a space elevator. A potential construction called a "space elevator" would connect the surface of the Earth to geostationary orbit, making it possible to carry people and freight into space on a budget.

Tethered satellites: Tethered satellite systems can be built using EDTs. These systems, which can be used for communication, observation, and other purposes, are made up of two or more satellites connected by an EDT.

6. APPLICATIONS

The following are some possible EDT applications:

Deorbiting space trash: The buildup of space debris is one of the main issues in space. By causing the junk to fall back into Earth's atmosphere and burn up there, EDTs can be employed to deorbit this waste.

EDTs can be utilised as a propulsion mechanism for satellites. The tether can be used to alter the satellite's orbit by creating a force with the Earth's magnetic field; this is especially helpful for maintaining a geostationary orbit.

Electricity generating is another application for EDTs. An electrical current that can be used to power the spacecraft's electrical equipment is induced as the tether travels through the Earth's magnetic field.

EDTs can be used for scientific research, including determining the characteristics of the Earth's magnetic field and examining the ionosphere.

EDTs can be employed to slow down a spacecraft or satellite and hasten the deorbiting process by creating atmospheric drag.

This is helpful for lowering the amount of orbital debris and avoiding collisions.

7. RESULTS

A long, conductive wire is used in the electrodynamic tether (EDT) technology to produce electricity or give propulsion in space. When an EDT system is deployed, it interacts with the magnetic field of the Earth and causes an electric current that can be utilised to propel the craft or power its onboard equipment.

EDTs offer a lot of potential for a range of space applications, including satellite repositioning, debris removal, and potentially power generation for interplanetary missions, according to recent studies. Technical issues including the tether's vulnerability to microvibrations and the possibility of electrostatic discharge, however, still need to be resolved. The usefulness of EDTs has already been shown in a number of missions, such as the European

Space Agency's operation to deorbit a dead satellite and the Japanese Space Agency's experiment on the International Space Station. More EDTs will probably be deployed in space as the technology develops, opening up new possibilities for exploration and enabling new capabilities.

Electrodynamic tether technology may have certain advantages, however there are a number of obstacles that must be solved. The deployment and management of the tether is one of the key difficulties. Tethers can be challenging to deploy and operate in space, and if not correctly maintained, they risk becoming tangled or damaged. Tethers may also be exposed to radiation and extreme temperatures in space, which may compromise their performance and lifespan.

In general, the development of electrodynamic tether technology could revolutionise space propulsion and open up new avenues for space exploration and exploitation.

8. CONCLUSION

A long, conducting wire that can be utilised for both propulsion and electricity in space is known as an electrodynamic tether. The tether can be used to slow down or speed up a spaceship by altering its orbital velocity, or it can create electricity by electromagnetic induction by interacting with the Earth's magnetic field.

Compared to conventional propulsion systems, electrodynamic tethers have a number of benefits, including the capacity to function without propellant, great efficiency, and the potential to drastically lower the cost of space missions. The deployment and use of electrodynamic tethers, however, is fraught with difficulties, such as the requirement for a robust yet lightweight tether material, the control of electrical power and heat, and the possibility of collisions and space debris.

The Tethered Satellite System (TSS-1R) mission, which launched a tethered satellite from the Space Shuttle in 1996, and the Electrodynamic Debris Eliminator (EDDE) mission, which demonstrated the removal of space debris using an electrodynamic tether in 2019, are just two examples of successful electrodynamic tether technology demonstrations in space. In general, electrodynamic tethers have the potential to revolutionise space travel and offer a cheap and environmentally friendly way to generate power and propulsion in space. To fully realise their promise and to overcome the technical and operational constraints related to their utilisation, additional research and development are necessary.

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