Microwave Energy powered Thruster: a new era of Rockets?

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***Abstract*: Study of microwave rockets involving importance, development of spaceflight using beam energy, how this technology is far better over conventional rockets, its feasibility study and performance. The traditional or chemical rockets should evolve as it is too expensive and explosive. Traditional rockets are powered by chemical propellants and despite years of work, the cost of launch has remained the same. In microwave-powered rockets, the technology that uses to propel hydrogen is something that we use in our kitchen to heat our food that is microwave energy. The main contribution of this work is the comparative study of upcoming new microwave-powered rockets and traditional chemical rockets. This work shall help to notify that microwave rockets is the technology by which the efficiency of the rocket would more than double and the expenses less than halved**

Index Terms: Microwave Rockets (MR), Microwave Thermal Rockets (MTR), Beamed energy propulsion, Solid rocket boosters, Multipulse operation.

I. INTRODUCTION

Evolution is the secret for the next step, Change is the Law of Nature and in this Evolving Era where everything is coming out of its bags: Then why would Rockets stay the same.

In 2002, Kevin Parkin and DD Murakami introduced a MICROWAVE ENERGY POWERED THRUSTER, whose premise is to accelerate onboard propellant heated through a Heat Exchanger irradiated by a millimeter-wave beam from the ground (1). The concept of Microwave Rocket proposes a microwave breakdown mechanism that is based on a Monotonous - pulse microwave-based propulsion system. A blast wave is driven by pulsed plasma generated by a high-power microwave pulse (2). The shock wave is exhausted by a thruster, which then obtains impulsive thrust force. The spaceplane will not be propelled by chemical combustion, it will propel by ejecting hydrogen that has been heated by microwave energy and then expelled via the nozzle to generate thrust. After reaching orbit and deploying payloads, a spaceplane will drive down to the launch area, refuel, and prepare for the next mission. The power grid was used to generate energy, which was then converted to microwave energy with the help of GYROTRON. Energy Continues to beamed from an Antenna to a thruster, guided by a series of beam-shaping mirrors. A thermal thruster with a microwave-absorbing heat exchanger converts microwave energy into thrust. (3).

Three characteristics distinguish Microwave Rocket: First, as the vehicle does not need to carry fuel or an oxidizer, it can attain an outrageous payload ratio. Instead, while flying in a dense environment, it is propelled by atmospheric air. Second, once a ground-based electromagnetic-wave generator facility, such as gyrotrons, is developed, it can be reused for repeated launches. Third, a millimeter wave-supported detonation produces high-pressure gas for thrusting. As a result, there is no need for a turbo-pump system. For these reasons, Microwave Rocket is expected to achieve drastic launch cost reduction and a prominent increase in Efficiency.

The physics of MSD and its application to thrust performance improvement, Complex and huge Gyrotrons system setup, long-distance beam power conveyance, and anomalous ignition are just a few of the issues that are challenge(3).

II. DEVELOPMENT OF SPACEFLIGHT USING BEAMED ENERGY PROPULTION

This concept was invented over a century ago, but it was not publicized or tested.

In the year 2000, Professor L. Myrabo exhibits the launch of a 50-gram thruster model powered by a laser-assisted explosion support detonation (LSD)(1). In 2003, the first launch experiment employed a single pulse operation with a 930-kW millimeter-wave beam. A 10 gram model of a miniature rocket was launched to a height of 2 meters and In 2009, an optimized beam expander is constructed in repeating pulse mode then a 126-grams model was fired to 1.2-meter height.(4)

However, it is only effective at a specific altitude, and increasing the altitude requires a big LSD, which is very costly to set up. This inhibition led to the concept of Microwave Energy.

The GYROTRON includes a high-voltage IGBT (Insulated-gate bipolar transistor) switch with a faster switching speed than previous models, making Microwave powered Thruster a mini-Rocket conceivable in 2011. A Millimeter Wave-class Gyrotron can fire a 1kg-class spacecraft and the time-averaged thrust achieved was high. As a result, the next stage is to launch a 1kg thruster model (5).

The Microwave Rocket is a BEP launcher that uses a millimeter-wave oscillator Gyrotron of megawatt class. The high-power, long-pulse, and high-efficiency Gyrotron can now be used for nuclear fusion plasma heating. (6)

How Rocket works and why we are moving towards Microwave Energy-based Rockets.

Rocket is based on the 3rd Law of motion:

"Every action has its equal and opposite Reaction", and here

ACTION is the propellant being ejected from the Rocket's nozzle.
REACTION is the rocket's acceleration.

So, the way to enhance the efficiency is to increase the speed due to which propellant can exceed its capacity, known as specific impulse or ISP. ISP is directly proportional to Exhaust gas velocity. It works like the mpg of a rocket. Ways to increase the efficiency of Rocket: Making a rocket bigger and lighter is prohibitively expensive and explosive: We can understand this by comparing the space shuttle holds 800 tons of a tremendously dangerous combination of liquid oxygen and liquid hydrogen hold this over gravity acceleration from the surface of the earth, The mass fraction of the Space Shuttle Tank is less than that of a can of a soda can, which is prohibitively expensive. So, if we alter the entire concept and boost the ISP to a moderate value, say 800sec, the payload increases considerably by ten folds.

How can we get isp higher and why

The ISP determines how much weight you may send into space. The structure and mechanical support make up 5% of the total mass of the rocket, while the payload and fuel make up 95%. Chemical rocket propellant is overly heavy and takes up too much space, leaving only a few spots for payload. It is mandatory to send as much payload to space as possible. However, if a given Impulse is below roughly 300 seconds won't be able to send any payload to space even the rocket will not travel to space. As a result, a higher ISP is necessary to carry a large payload. (7)

The Technology that uses to propel hydrogen is that we use to heat meals and beverages at home i.e., MICROWAVE ENERGY. We can efficiently launch a rocket to space by broadcasting microwave energy from the ground to the spacecraft to heat the hydrogen.

Chemical Rocket Engines work by combusting hydrogen and oxygen bonds as a propellant at 3600°C (very hot), and the ignited that comes out is largely steam molecules, which aren't traveling quickly enough to offer an ISP of 500 seconds on average. Using a Microwave Rocket Thruster Engine, on the other hand, we can employ a less-weight exhaust molecule to make the exhaust hotter. When heated to 1800°C, hydrogen is an extremely light molecule that moves so quickly that it equates to an ISP of (850-1000) sec. As a result, the Rocket's efficiency increase drastically.(8)

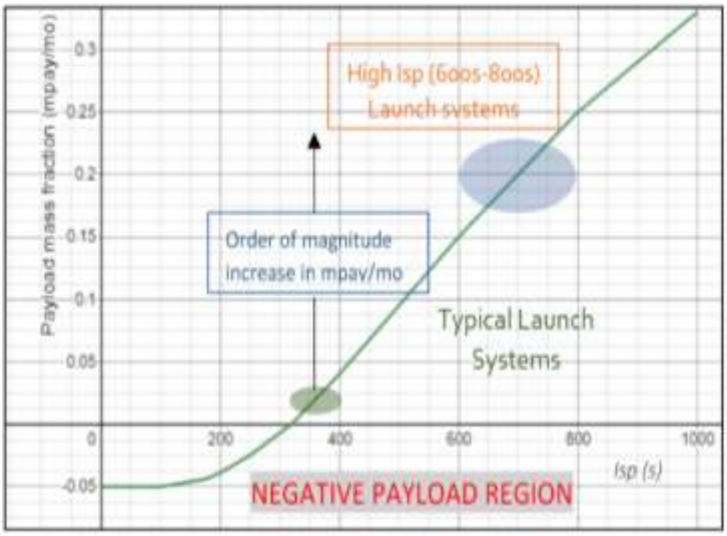

Figure 1. plot between Isp and Payload mass fraction.

III. COMPARATIVE STUDY BETWEEN CHEMICAL ROCKETS & MICROWAVE POWERED ROCKETS

In Traditional Chemical Rockets, Efficiency Limitations are there as they require multiple stages and are generally non-reusable. Solid-fuel rockets have a lower specific impulse than liquid-fuel rockets, which is a measure of propellant efficiency. Only a few % of the Rocket contains Payload as more than 95% is taken by heavy propellant the payload that is finally released into orbit is a tiny fraction of the rocket that lifts off from the ground, While the microwave rocket engine is much simpler than a chemical combustion rocket engine, it still requires a tank to hold the hydrogen and a heat exchanger below it to absorb the microwave energy as the hydrogen flows through it and heat it up to the temperature required so that it can be converted efficiently to thrust when it passes through the nozzle. By omitting the fundamental energy density limit of chemical propellants Microwave and laser thermal rockets may carry more payload to space. To accomplish this, energy is channeled from the ground to a heat-exchange layer on the rocket's base. The heat-exchange layer then heats and expels inert fluid, propelling the rocket forward. Rockets can be made safer and frigid by substituting inert monopropellants for standard propellants and combustion chambers for heat exchangers, allowing them to take payloads into orbit in a single stage. Because they can lift so much more weight, the cost per kilogram delivered to low Earth orbit drops from $10,000 to less than $1,000. Payload prices for reusable rockets drop from $3,000 to less than $300. History of spaceflight been Perilous, Chemical propellent are spectacularly energetic and immensely dangerous on other hand In Microwave Rockets Eliminating stage separation, which occurs when one booster comes off a rocket and the next takes its place, simplifies the vehicle and reduces its risk of failure. The explosive concerns of storing oxidizers near fuel are eliminated by eliminating combustion. Reusability may be easier to achieve because a spaceplane glides back to Earth rather than the difficult-to-control freefall of a rocket stage. Whatever the future cost of conventional rockets turns out to be, thermal rockets are the next-level upgrade to greater economy, safety, and performance.(9)

Assaying nothing is perfect or Ideal, Technology has numerous constraints, such as eliminating interference of leakage magnetic fields from superconducting magnets requires caution of the adjacent distance between gyrotron. One launch takes roughly 200 seconds to operate the gyrotron. Even if 10 launches are made per day, the total operating hours are only 200/year, which is far less than the 5000 hours projected lifetime of a standard gyrotron system. Although the building cost of That large and complex Gyrotron Setup is the most significant of all Expenses, the expenses can be balanced by multiple launches (1).

IV. FEASIBILITY OF MICROWAVE ROCKETS :

Microwave Rockets are projected to have a momentum coupling coefficient of around 300 N/MW. The Microwave Rocket achieves the time average thrust of 60 N by assuming a beam energy power of 1 M W and a duty cycle of 0.2 for the millimeter-wave beam pulse (3).

Launch Cost estimation

The first stage of the H-IIB launch vehicle is replaced by a microwave rocket. The launch cost of the H-IIB heavy, which is capable of orbiting a 19-ton payload to LEO, will be reduced by 77 percent by replacing its first stage with four Solid Rocket Boosters with the Microwave Rocket, according to subsonic to supersonic flight analyses, feasibility studies of transportation to low earth orbit, and launch cost analyses for the Microwave Rocket. In a dense environment, the vehicle accelerates significantly and is cut off at a height of 20.7 kilometres at a velocity of 2 kilometres per second. The payload ratio is increased to 0.155 when the traditional second stage is used, which is approx. 4 times higher than the payload ratio achieved by the H-IIB heavy lift rocket. The replaced stage manufacturing cost is estimated to be under 3 million dollars, which is significantly less than the standard H-IIB first stage, which costs over 85 million dollars. To create 188 GW of output power, approximately 94,000 gyrotrons are required for this journey(1).

“Although this initial cost could be as much as 3350 M$ including an energy storage facility, it will be amortized with launch counts and the cost per launch is decreased to the same level of conventional launch cost with about 42 launches, and finally 77% cost reduction is expected as shown in Figure.2”. (1)

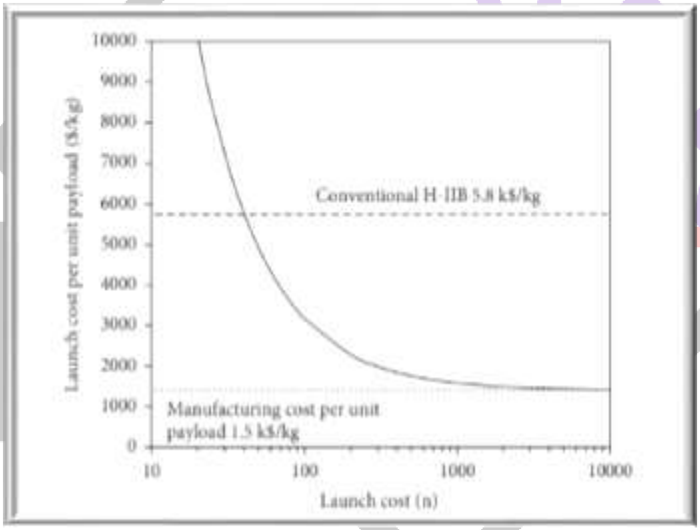

Figure 2. “Estimated launch cost to LEO per unit payload as a function of launch counts.
Dashed line: cost for H-IIB heavy; Dotted line: manufacturing cost for Microwave Rocket and H-IIB second stage” (1)

Trajectory analysis : MTR v/s UAV

The first stage of the TSTO launch system is MR instead of UAV, while the second stage is MTR. The first stage, with a power output of 50 MW and a beam range of 34 km, has capacity equivalent to the second stage, which has a beam range of 105 km. After the 2nd stage thrust comes to a halt at the edge of the 1st beam director's beam range, it takes a sub-orbital flight until it enters the 2nd beam director's beam range, where it drives itself back into the beam range to achieve rest of change in velocity. Figure 2 depicts a trajectory, This trajectory design maximise the potential of MR while also improving the overall performance of the launch system. The payload fraction of this trajectory was optimised while the beam parameters of the second beam source were fixed. The payload-fraction is around 3 times that of a UAV depicted in table1. (10).

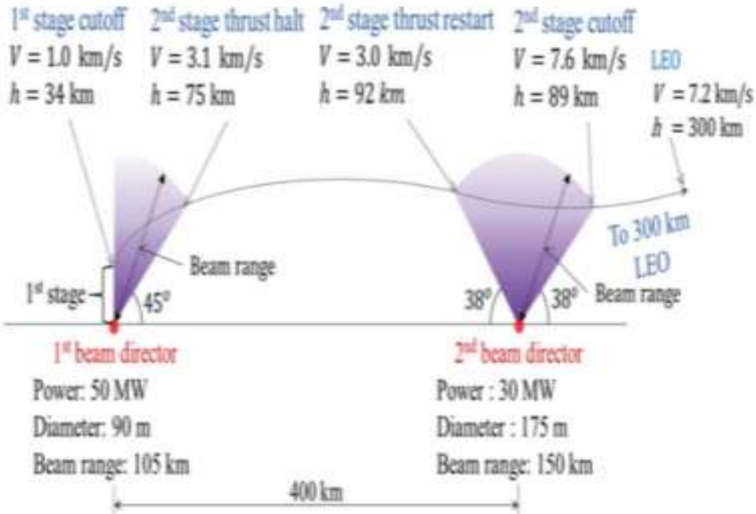

Figure 3. "Trajectory using MR and MTR"(10)

1st stage	**Unmanned aerial vehicle (kg)**	**Microwave Rocket (kg)**
Propellant-mass	37	37
Payload-mass	2	4
Payload-fraction	**4%**	**13%**

Table- 1 [1]

Thruster performance with multipulse operation:

The shock wave propagation velocity at the first pulse in multipulse operation with a forced-breathing system was equal to the result in single-pulse operation. When the air supply was insufficient for refuelling, the propagation velocity was increased at the second pulse. At the third and subsequent pulses, the velocity became stable. Similarly, with the second pulse, the impulse supplied by each pulse diminished, and at later pulses, a constant impulse was obtained. As a result, in multipulse operation with a forced breathing system, stable repeating impulses were successfully created(2).

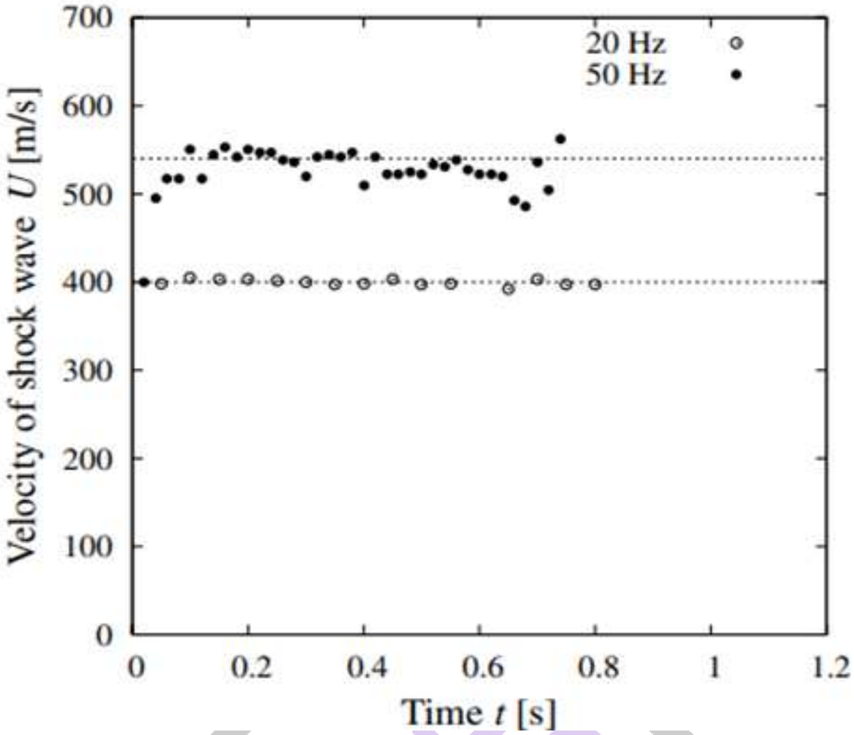

Figure.4 "Estimated velocity of the shock wave at each pulse" (2)

V.CONCLUSION:

The invention of a microwave-powered thruster that uses Beamed Energy Power is paving the way for a new era of rockets. It presents tremendous benefits; high efficiency, economical, multiple times Reusable, high payload ratio, and decrement in the risk of explosion and failure. On the other hand complex and huge Gyrotrons setup cost and its sensitivities are major challenges. The expenses of gyrotron set up could be amortized further by the multiple launches. When hydrogen is used as a propellant, the ISP exceeds 800 sec which is significantly higher than the average (ISP) of 400 seconds for chemical rockets. In comparison to conventional rockets, the predicted launch cost to LEO (low earth orbit) per unit payload that can be represented as function of launch counts is substantially lower in microwave rocket technology. For H-IIB heavy 77 percent cost reduction is expected by substituting its first stage with 4 Solid Rocket Boosters with the Microwave Rocket. Replacing MR for the first stage and MTR for the 2nd stage instead of UAVs, the payload-fraction is around Three times that of UAV depicted in table1 and this trajectory design maximises the potential and capability of the stage. So, provide an overall improvement in the performance of the launch-system. For shockwave propagation velocity using multipulse operation with force-breathing system gives stability to performance of thruster as Impulses were created successfully.
As a result, the efficiency of rockets will be more than doubled, and the launch cost per unit payload will be less than halved if Microwave Powered Thrusters are used.

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