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BREAKTHROUGH PROPULSION II: A MASS CHANGE EXPERIMENT

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Thrusters that *allegedly* work by pushing off the zero point vacuum electron-positron (e-p) pairs, currently produce thrusts in the range of 2 to 50 μN. If momentum conservation is to be observed, an equal and opposite thrust must be exerted, on the hypothetical, e-p pairs. For the effective lifetime of the electrons and positrons they must be 'real' in a sense of having a non-vanishing rest mass. This paper considers a possible mechanism for producing e-p pairs in a device and gives an estimate of the mass increase involved in their production. During the e-p lifetime they are allegedly acted upon by some externally supplied electromagnetic (EM) field thus producing thrust. We conclude that this mechanism is not realistic and is not responsible for the production of a force in these devices.

Keywords: Vacuum energy density, vacuum plasma, densification of vacuum, EM-drive.

1. INTRODUCTION

A Mach effect gravity assist (MEGA) device consists of a stack of piezoelectric lead-zirconate-titanate (PZT) disks affixed to a brass reaction mass, as shown in Fig. 1. The MEGA device is a space drive, in a sense it requires no fuel as propellant, and uses known physics, Einstein's General Relativity theory and standard classical electrodynamics in the theory of its operation. There is no momentum violation since the energy of the device is shared with the gravitational field. The PZT stack is found to change mass by a very tiny amount, by pushing heavy and pulling back light, we obtain a small net forward thrust. The MEGA theory is well documented both in a book by JFW [1], and in many peer reviewed papers, for example [2-4], we shall not dwell on the theory here.

Here, we consider a possible mechanism for "*densifying*" the vacuum in order to push off, from it. The idea is to use this hypothesis and then prove experimentally that it does not work. This is in the spirit of the "*White*" plasma wake argument mentioned in our previous paper [5]. We have already pointed, in our previous paper [5], that the highly nonlinear nature of the quantum vacuum does not allow spontaneous breakdown into e-p pairs below the Schwinger limit, which defines a needed electric field of about 10^{18} V/m. The EM drives tested to date, have no where near this electromagnetic field strength inside them. However, we will use the *White plasma hypothesis* and see where it leads us.

During operation, we assume that electron-positron (e-p) pairs will materialize inside the MEGA PZT stack (Fig. 2), rather than the plastic disk (or cavity wall) in the EM drive [5]. These pairs will be accelerated by the applied electric field and cause thrust by the reaction through the field on the device. Since the pairs are coupled to the device via the field, their mass will contribute to the mass of the device. This mass increase is what we hope to detect in an experiment. We note that White has not taken the mass increase into account, and does not mention any mass increase in his work. We do not have at our disposal, a vacuum chamber large enough to test an EM drive,

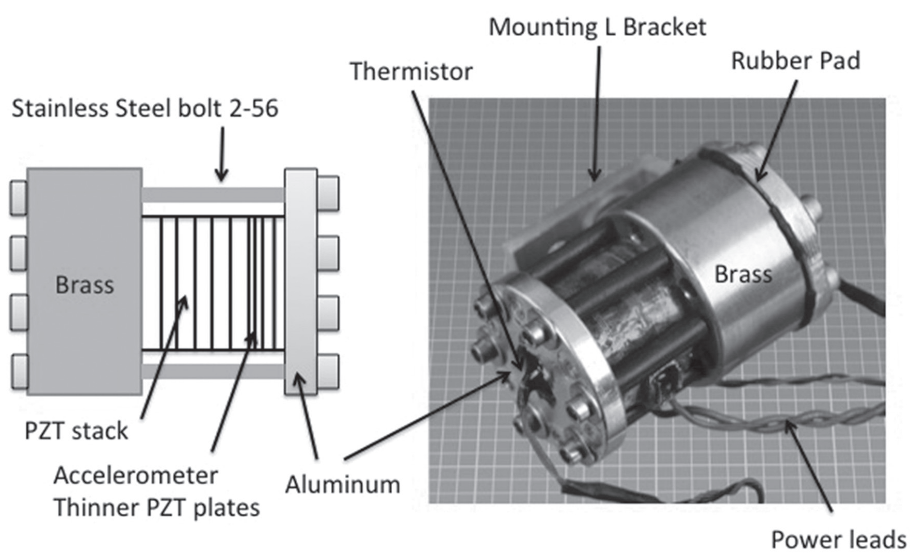

Fig. 1 A Mach Effect Gravity Assist device. There is a large brass end mass, smaller aluminum end mass, and PZT (Lead Zirconate Titanate) stack of 8 disks (plates) each 2mm thick. Two thinner disks, not powered, are used as an accelerometer.

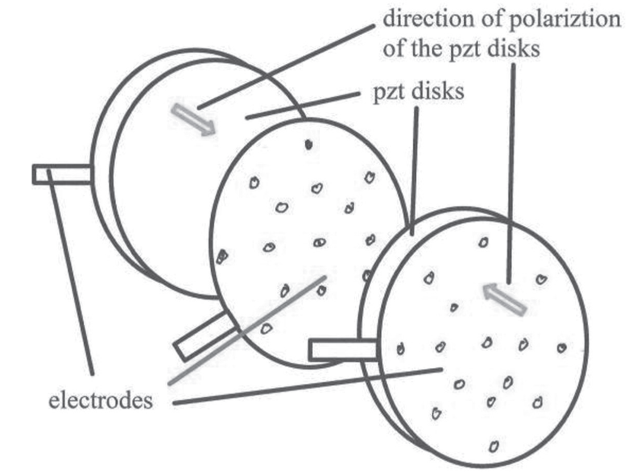

Fig. 2 Configuration of the electrodes in the MEGA device. Adjacent disks have their polarization opposite each other.

of the type used by Eagleworks Laboratory. In our lab, we use a much smaller device, the MEGA device, which is basically a stack of PZT capacitors, able to deform in shape bolted to a passive reaction mass.

We have shown that these MEGA devices can produce a small amount of thrust, between 2-5 μN in the laboratory.

The amount of thrust any particular e-p pair can contribute to the total thrust is limited by the lifetime of the pair. That lifetime is dictated by the Heisenberg Uncertainty Principle which specifies the allowable duration of energy conservation violations given some specified energy that is to be promoted to 'real' status from the vacuum. In the case of e-p pairs created at rest, the energy is twice the rest mass-energy of an electron ($\varepsilon = 2m_e c^2$). The Heisenberg Uncertainty principle gives,

$$\Delta\varepsilon\Delta t \geq \hbar/2 \qquad (1)$$

So

$$\Delta t \leq \frac{\hbar}{2\Delta\varepsilon} = \frac{\hbar}{4m_e c^2} \qquad (2)$$

Substituting in known values, $\hbar = 1.05\times10^{-34}$ Js , $m_e = 9.1\times10^{-31}$ Kg and $c = 3\times10^8$ ms^{-1} we obtain, a lifetime of $\Delta t \leq 3.2\times10^{-22}$ sec. Armed with the e-p lifetime we ask how much thrust can be generated by acting on the pair with an external EM field? The electric field is oscillating A.C. so we take $E = E_0 \sin(\omega t)$. We take the thrust to be produced by the Lorentz Force;

$$\vec{F} = e\vec{E} + e\vec{v}\times\vec{B} \qquad (3)$$

where $\vec{v}$ is the velocity of either member of the e-p pair; a quantity that must be calculated as a term including $\vec{v}$ is the one that produces thrust. The velocity is calculated using the Einstein-Hopf approximation: determining $\vec{v}$ produced by the electric force (eE) term, without consideration of the magnetic term ($e\vec{v}\times\vec{B}$) , and then substituting $\vec{v}$ back into the magnetic term. To calculate $\vec{v}$ from the e-p pair lifetime Δt ;

$$\vec{F} = m_e\vec{a} = e\vec{E} \qquad (4)$$

$$m_e\frac{d\vec{v}}{dt} = e\vec{E} \qquad (5)$$

$$d\vec{v} = \frac{e}{m_e}\vec{E}dt \qquad (6)$$

On integrating this equation (6) from 0 to Δt we find

$$\vec{v} = \frac{e}{m_e}\frac{\vec{E}_0}{\omega}(1-\cos(\omega\Delta t)) \sim \frac{e}{m_e}\vec{E}_0\sin(\omega t)\Delta t \qquad (7)$$

The velocity would be very close to zero. If we do not do the integral and rather leave as an approximation, this is the biggest value the velocity can have. Since

$$|B(t)| \propto \mu_0\varepsilon_0\kappa\frac{\partial E}{\partial t}L = \omega\kappa E_0\frac{L}{c^2}\cos(\omega t)$$

where L is a length and c is the speed of light in a vacuum and we have used $\mu_0\varepsilon_0 = 1/c^2$. The current leads the voltage inside a capacitor by $\pi/2$. We will use the B-field inside a capacitor to get the magnitude of the B-field, here we comment only on the time dependence and the phase shift with respect to the external E-field which gives the voltage across the capacitor.

The expression for velocity $\vec{v}$ is substituted back into the magnetic term;

$$\vec{F}_{mag} = e\vec{v}\times\vec{B} = \frac{e^2}{m_e}\vec{E}\times\vec{B}\Delta t = \frac{e^2E_0^2}{mc}\sin(\omega t)\cos(\omega t)\Delta t \qquad (8)$$

where we have used $B_0 = E_0/c$ to give a maximum possible force. Note that this magnetic force depends on e^2 so is in the same direction for electrons and positrons. This is the maximum magnetic force you can expect. It would average to zero over one cycle.

Next we ask about values for both E and B fields for our specific MEGA device. The fields will be perpendicular. The peak voltage across the disks is on the order of 100 Volts. The disks are 2mm in thickness. Naively, this suggests an electric field strength of E_0=5 x10^4 Vm^{-1} in vacuum. However, we have a dielectric present so the answer is not so straight forward. The dielectric constant for ferroelectrics is typically a few thousand, so we shall take a dielectric constant $\kappa = 1000$. This is equivalent to a relative permittivity $\varepsilon/\varepsilon_0$. The dielectric is polarized and near the boundary the surface polarization can partially cancel the external electric field, so in this region you can have a reduced E-field of the size E_0/κ = 50 Vm^{-1}.

The electric field inside a medium is defined by Panofsky and Phillips [6] and also Kittel [7]. You can find your own derivation of the E-field inside a medium. The local field which acts at the site of an atom is different from the macroscopic field inside the medium [7].

There are various approximations with spherical cavities hollowed out or rectangular cavities in different orientations, then the external field adds to the polarization on the surface of the cavity and the atoms/dipoles inside the cavity contribute individually. That way several fields add up to give you the field at the center. The quickest approach is to note we have no real cavity, therefore the only contributions we need consider are the external field and the polarization field, as Kittel [7] puts it on page 384, Eq (7). The disks are essentially thin slabs so the depolarization factor given by Kittel is unity in S.I. units.

$E = E_{0x} + E_{1x}$ where E_{0x} is the external applied field and $E_{1x} = -P/\varepsilon_0$ which is called the depolarization field. The dipole moment is defined from negative to positive so that the dipole moment per unit volume, or polarization, is parallel to the electric field. Using the electric displacement for vacuum is $D = \varepsilon_0 E_0$, or for a medium is $D = \varepsilon E$. Inside the medium the electric field E becomes $E_2 = D/\varepsilon = \varepsilon_0 E_0/\varepsilon = E_0/\kappa$. Some people would argue the value of the electric field inside the dielectric is $E_1 = E_0$, we will consider both. It is true that the charge will accumulate until the voltage across the plates is what you want it to be. However, if you consider a conductor between the plates, but not touching the plates so there is an air gap, then it is clear the E-field inside the conductor (which is a dielectric with infinite dielectric constant) is exactly zero since the induced surface polarization creates a field which exactly cancels the external field inside the conductor… so clearly we must use the internal E-field as $E_2 = E_0/\kappa$, where κ tends to infinity for a conductor.

The two electric fields E_1 and E_2, will lead to two different results. The magnitude of the B field can be set at a maximum with E_0/c for a wave in a vacuum. However, we can calculate the transient B field inside a capacitor exactly. The magnetic field inside a capacitor is circulating parallel to the plates in the same direction as the right hand rule would give for the displacement current.

Check any college level physics book [8] to find the magnetic field circulating inside a capacitor,

$$\oint B\cdot\, ds = \mu_0 \iint \varepsilon_0 \kappa \frac{\partial E}{\partial t}\cdot \hat{n} da = \mu_0 I_{loop}$$
$$I_{loop} = I_0 \frac{\pi r^2}{\pi R_0^2} \tag{9}$$
$$B = \frac{\mu_0 I_{loop}}{2\pi r} = \frac{\mu_0 r}{2\pi R_0^2} I_0(t)$$

where $I_0(t) = I_0$ time dependent.

Taking the maximum of the current and a small 100 Ohm resistance so that I_0=1 Amp maximum. Here r is the radius of the e-p pair creation above the axis of the capacitor, R_0 is the radius of the disk capacitor. Taking the radius $R_0 = 9.5 \times 10^{-3}$m, $r = 6.3 \times 10^{-3}$m, which is 2/3 the radius of the disk, the permeability $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{Hm}^{-1}$ and I_0 =1 Amp we get $B = 1.40 \times 10^{-5}$ T. Using the maximum possible value $B = E_0/c = 1.67 \times 10^{-4}$ T. We see that the calculated value circulating inside the capacitor is roughly 1/10 the maximum value which seems reasonable. It should be recalled that we are using an AC signal of around 35KHz. During one cycle the capacitor charges up with the left plate positive then discharges and charges again with the left plate negative. Knowing the magnitude of the E and B fields inside the material we can find the magnetic force,

$$|\vec{F}_{mag}| = \frac{e^2}{m_e} \Delta t E B \tag{10}$$

for $E_1 = 5 \times 10^4$ V/m we get $|\vec{F}_{mag1}| = 6.32 \times 10^{-30}$ N, for E_2= 50 V/m we get $|\vec{F}_{mag2}| = 6.32 \times 10^{-33}$ N.

This is the force produced by a single electron (or positron) in an e-p pair. Knowing the measured value of the force produced by our device, we can then estimate how many e-p pairs must be present to produce the measured force if we are to believe the measured force is due to the quantum plasma and not some other effect.

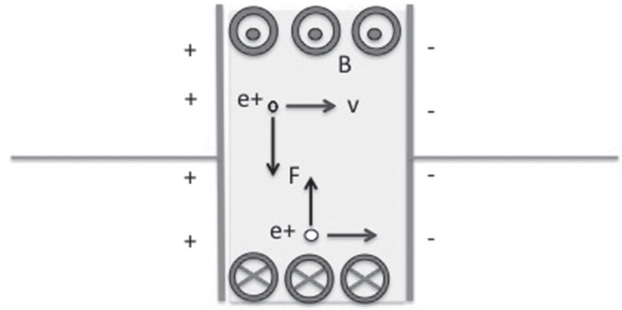

Fig. 3 Magnetic field, shown as circles with dots or crosses, circulates inside the capacitor. A positron e^+ moving with velocity v to the right would experience a downward force in the top half of the dielectric and an upward force in the bottom half of the dielectric. Electrons and positrons experience the same force in the same direction. All these forces cancel out in the top and bottom portion of the dielectric giving a net zero force. Note these forces are radial and would not have contributed to a thrust in any case. Since the capacitor is powered with an AC voltage, of 35KHz, in the second half of the cycle the plates reverse sign and transient B field changes direction leaving the forces on the ep pairs in the same direction as above.

The equivalent accelerations on an electron are $a_1 = 6.95\ \mathrm{ms}^{-2}$ and $a_2 = 6.95 \times 10^{-3}\ \mathrm{ms}^{-2}$. Of the two accelerations the second seems far more reasonable for acceleration acquired in 10^{-22} seconds. Now it should be pointed out that since the magnetic field is circulating one can think of a B field coming out of the page at the top of the capacitor plate and going into the page at the bottom. See figure 3. Positrons in the electric field move to the right. The magnetic force direction is $\vec{v}\times\vec{B}$. It will be downwards for positron in the top half of the capacitor and upwards for positrons in the lower half of the capacitor the net force will be zero since these cancel perfectly. Both electrons and positrons are forced to move in the same direction in the top half and bottom half of the dielectric. So in fact the "densification" of the vacuum actually predicts no thrust for the MEGA device.

Not to worry, we have a different theory which predicts thrust and no need for e-p pairs. Let us calculate regardless and find out what the vacuum densification predicts the mass change of the MEGA device would be.

The MEGA device we will use in our experiment has shown a maximum thrust of 2μN (conservative value). If we divide the known, experimentally measured, force by the force exerted by 1 electron (or positron) we can calculate how many electrons (or positrons) would need to be present to create that thrust (force). So using the number of electrons (or positrons) N_j we find,

$$N_j = \frac{F_{MEGA}}{|F_{mag-j}|} \tag{11}$$

where $F_{MEGA} = 2 \times 10^{-6}$ N. We have two values of the magnetic Lorentz force to consider, for two values of the electric field calculated, with j = 1,2. The results are, $N_1 = 3.16 \times 10^{23}$ and $N_2 = 3.16 \times 10^{26}$, for electric field E_1 and E_2 respectively. Now the increased mass will be $dM_j = N_j m_e$, where m_e is the electron mass (same as the positron mass). Giving both of our results we find,

$$dM_1 = 2.88\,x\,10^{-7}\,Kg \;\approx\; 0.3\,mg$$
and (12)
$$dM_2 = 2.88\,x\,10^{-4}\,Kg \;\approx\; 0.3\,g$$

The first may be tricky to observe, however the second is well within experimental capabilities.

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The dM_1 value is also possible with a lot of signal averaging and a few sleepless nights taking data. A set of values for slightly different parameters is given in Table 1.

The missing values are easily obtained from those in the table, for example N_1=N_2 x10^{-3},

$$F_{mag1} = F_{mag2}\ x\ 10^{-3}\ ,\ a_1 = a_2\ x10^{-3}\ \text{and}\ dM_1 = dM_2\ x\ 10^{-3}$$

The resistance, in the circuit for the device, involves long extended coaxial cables with BNC connectors and extensions. The current through the wires on the device is less than or equal to 1A. The tabulated values above are all sensible values and the experimental situation is I_0 = 400mA. This gives a mass change of approximately 1mg or 1g for dM_1 and dM_2 respectively. The apparatus has the needed milligram accuracy.

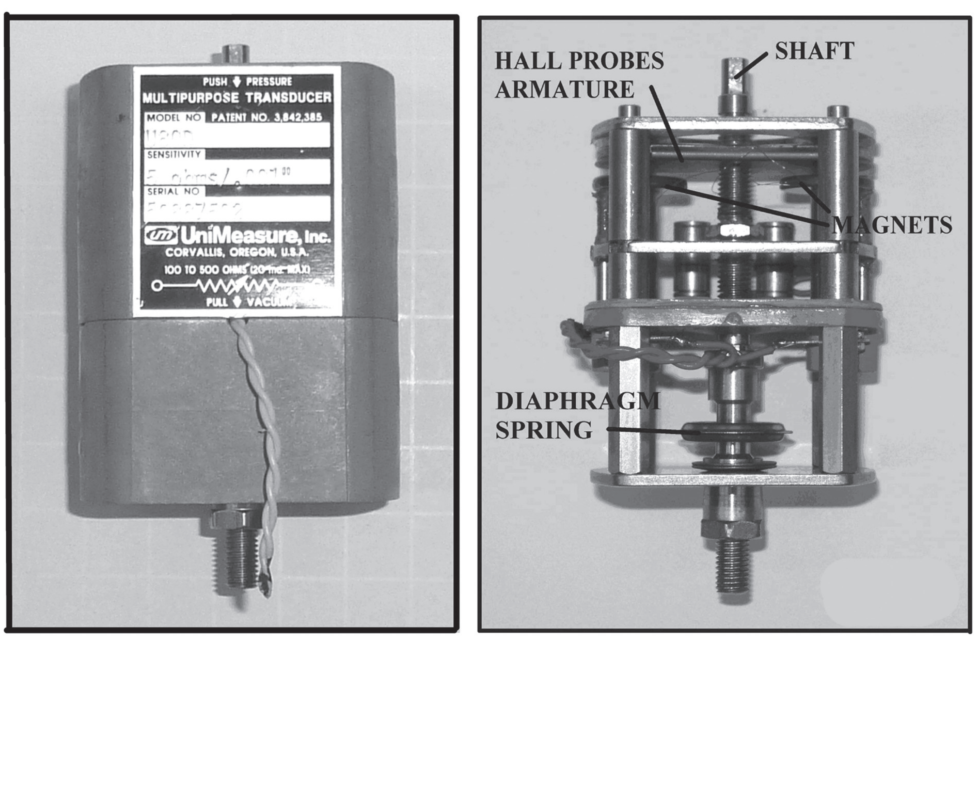
2. TESTING THE VACUUM PLASMA CONJECTURE

The exceedingly short lifetime of electron-positron pairs dictated by the Heisenberg Uncertainty Principle forces one to accept the induction of a very large number of such pairs if acting on them with electromagnetic fields is to produce a measureable thrust. In principle at least, the measurement should not be insuperably difficult. Measuring a milligram is not a great challenge. With a passive object and long integration (signal averaging) time anyway. An object to which 100 plus watts of power is delivered is another matter. Precautions must be taken to insure that the simple power transfer does not introduce spurious disturbances that might be mistaken for the effect being tested. Most very sensitive weigh systems are not well adapted to measurements with this sort of device. The system, described in chapter four of *Making Starships and Stargates* [1] ,based on the Unimeasure U – 80 position sensor, is well suited to this task. The U – 80 is shown in Fig. 4 (Fig. 4.1 in *MSAS*). Since the response speed was not critical in this application, the diaphragm spring in earlier use was replaced by a softer spring. This made it possible to reduce the amplification of the Wheatstone bridge circuit (and its attendant noise) used to sense the small changes

TABLE 1: *Mass Changes for Different Input Values of Current Using 100 Volts*.

Volts=100	I_0=200mA	I_0=500mA	I_0=1 A
B	2.8×10^{-6} T	7.0×10^{-6} T	1.4×10^{-5} T
$\mathbf{F_{mag2}}$	1.26×10^{-33} N	3.15×10^{-33} N	6.32×10^{-33} N
$\mathbf{a_2}$	1.38×10^{-3} ms^{-1}	3.46×10^{-3} ms^{-1}	6.95×10^{-3} ms^{-1}
$\mathbf{N_2}$	1.59×10^{27}	6.35×10^{26}	3.16×10^{26}
$\mathbf{dM_2}$	1.44g	0.6g	0.3g

Fig. 4 A Unimeasure U-80 Position sensor, (left) with and (right) without its plastic case. It has a diaphragm spring to make it a force or weight sensor. The Hall probes in the armature attached to the shaft move in the field of the magnets as the position of the shaft changes causing the conduction path in the probes to change, changing the resistance of the sensor.



in the resistance of the Hall probes in the U – 80 when their position in the field of the fixed magnets changed without changing the sensitivity of the system. The U – 80 is still encased in a 1 cm thick steel case with the upper part of the shaft centered by fine steel wires as shown in Fig. 5. Since the system was to be used as a weigh apparatus, always in vertical orientation, the centering harness that positioned the U – 80 for horizontal operation was removed. The centering harness and magnetic eddy current damper at the top of the weigh stage assembly, however, were left in place. The issue of possible spurious signals arising from significant power transfer to the MET on the weigh stage was dealt with by making the connection to the power circuit with galinstan (liquid metal) contacts.

The voltage that records the differential weight change of the device during the powered part of the runs was found to be 0.3 volts per 0.1 gram when the U-80 was carefully calibrated. See Fig. 6. (The sensitivity of the U-80 sensor is not linear for very small forces/weights. Accordingly, it must be calibrated at the expected level of forces to return a reasonably accurate reading.)

Another thing to keep in mind is that the quantum vacuum plasma thruster scheme doesn't actually predict any thrust generation in PZT stacks in the first place since the magnetic part of the Lorentz force is radial around the symmetry axis of the PZT stack. The only way thrust can arise is if the geometry of the stack assemblies is a bit imperfect so that some small fraction of the thrust generated is oriented in the direction of the symmetry axis. This sort of imperfection likely doesn't exceed a few percent, and that means that instead of being 1 x 10^{-5} Newtons, the MEGA thrust should be > 5 x 10^{-4} Newtons. This increases the e-p pair masses given above by a factor of 50 or so. And the mass range is from tens of milligrams to hundreds of kilograms. Need we say that the masses computed here are ludicrously large?

3. DATA ACQUISITION PROTOCOL

The data acquisition protocol was determined by the fact that the weight sensor signal was contaminated with significant noise. The source of the noise was predominantly seismic,

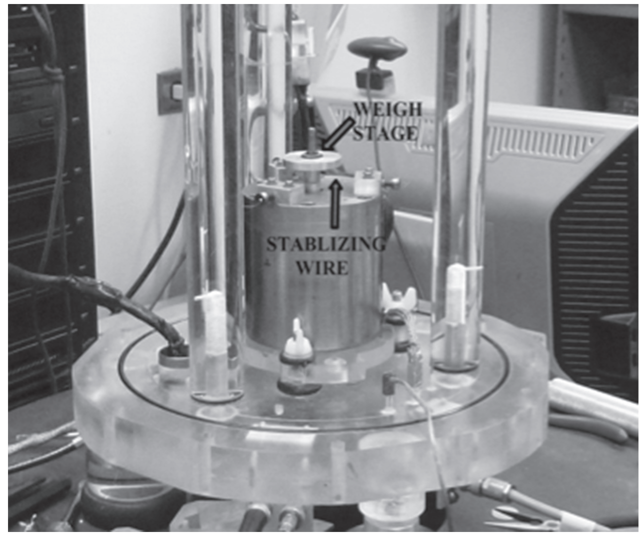


Fig. 5 The U-80 mounted in its 1cm thick steel case resting on the bottom plate of its vacuum chamber. Note the fine steel guy wires that stabilize the weigh stage attached to the shaft of the U-80.

notwithstanding that the vacuum chamber rested on a vibration isolated table equipped with pneumatic isolators, as shown in Fig. 7. This dictated the use of signal averaging to suppress the random noise in the signals of individual runs. Data was also acquired for the applied voltage to the device, the signal of the accelerometer embedded in the PZT stack and the temperature of the stack (monitored with a thermistor embedded in the aluminum retaining cap for the stack). Data was collected with a four channel Picoscope with 12 bit resolution at a ~ 350 Hz rate. Data for each run was stored in comma separated variable format and processed using Mathematica.

As recounted in [1], careful tests of the U-80 system were carried out to insure that it was highly resistant to spurious effects. (The small signal non-linear response, though, was not detected until serious discrepancies with thrust balance results appeared.) The obvious source of spurious effects in this case is electromagnetic pick-up by the weigh system electronics from the applied power signal (and electromechanical effects in the

Fig. 6 Calibration data for the U-80 sensor. One or two steel washers of 0.1g mass each were dropped onto the top of the device while it was not powered on. A very basic electromagnet was set up to do this. The voltage to the electromagnet allowed us to drop initially two washers then pick one up and drop it again. The electromagnet was inside the vacuum chamber and the chamber pumped down to 5mTorr. The calibration was 0.3 Volts per 0.1 gram.

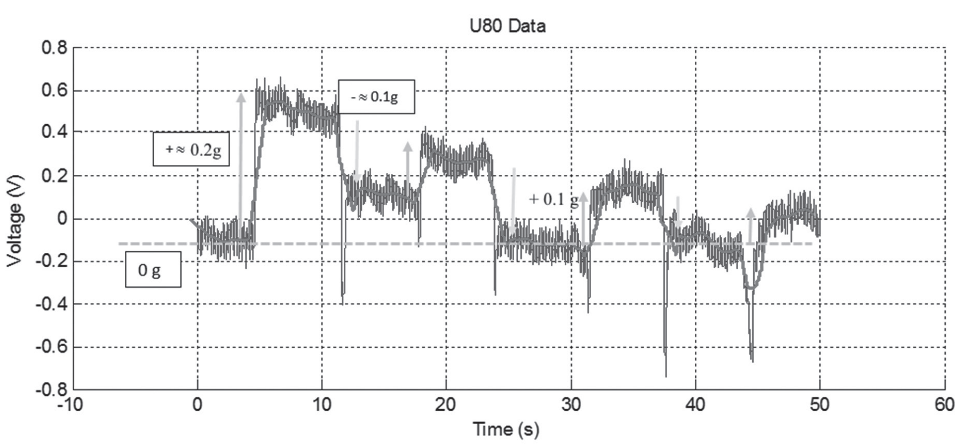


Fig. 7 Vacuum chamber with rubber isolation feet on top of a platform with 3 pneumatic vibration isolation stabilizers. A long copper pipe ran from the vacuum pump to the chamber in order to reduce vibrational noise from the pump.

power leads suppressed by the galinstan contacts). To correct for any spurious signals of this sort, plastic blocks that could be put under the weigh stage to mechanically lock the sensor were machined and mounted as shown in Fig. 8.

The MEGA device used for this experiment, displayed resonant behavior for several frequencies in the range of 34.0 through 37.0 KHz. Four frequencies in this range were selected for testing: 34.0, 34.5, 35.0 and 37.0 KHz. About 50 runs, each with identical timing for power on and off, and the same overall duration so the runs could be simply added in the averaging process, were taken at each frequency. The device was powered on for a 6 second duration. The runs for each frequency were averaged separately; and the average, of the individual frequency averages, was computed as a mean frequency response. The accelerometer and thermal data are suppressed as they do not illuminate the data of interest: the weight and voltage traces. The graphs are drift corrected due to a slight thermal rise in the data. The data acquisition protocol was then repeated to generate "null" run averages that correspond to the averages obtained in "free" operation. The data for drift correction blocked data are plotted for each frequency, and average frequency in Fig. 9. Blocked data refers to when the plastic blocks were used to prevent motion.

The blocked data (seismic noise) was then subtracted from the data collected when the shaft of the U-80 was free to move. The plots of drift corrected mass change (voltage from U-80) and blocked data subtracted off are plotted in Fig. 10 for all individual frequencies and the average frequency.

The frequency plot 34.5KHz and the last plot, representing the average frequency data in figure 10, shows an initial dip (jagged curve) then a slight rise in the mass (voltage recorded). From our calibration of the U-80 device 0.03 volts corresponds to 10mg mass change. This is likely a transient effect of the

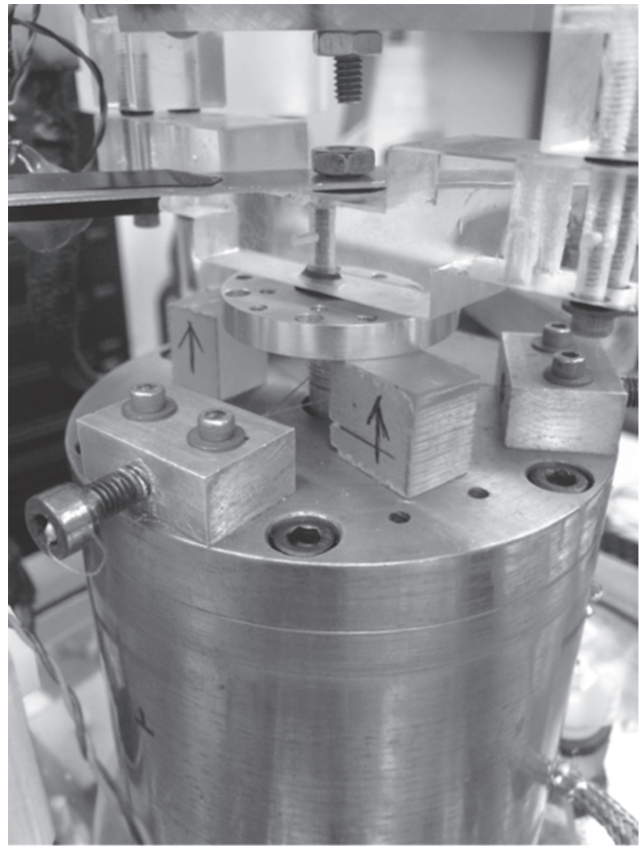


Fig. 8 Plastic blocks were machined to fit perfectly under the cross plate for the U-80 shaft. This prevented the shaft from moving up and down.

MEGA device, which shows larger thrust signals with switch on/off of the device. The thrust also switches direction with on/off. This is not what we are looking for. We do not see any increase in mass, which would indicate no formation of e-p pair "plasma" in our device.

CONCLUSIONS

We have set up an experiment using our Mach Effect Gravity Assist (MEGA) device, to see if the thrust can be caused by a densification of the vacuum by e-p pair creation within the dielectric material. The MEGA device was positioned to show thrust horizontally, whereas we were weighing the device vertically on a U-80 measurement device. We attempted to measure a weight change, by a predicted amount, which would suggest e-p pair production could be responsible for the thrust. We saw no change in weight during the normal operation of the device. There was perhaps evidence of a switching transient, in the all frequency plot minus drift and blocked data, (on the order of 0.01 volt or 3mg change) but this was inconclusive This indicates that e-p pair production does not take place and so cannot be responsible for the thrust in the MEGA device. It is important to note also, that the direction of the force on the e-p pairs, inside the MEGA device, would be radial inside the capacitors. The radial forces cancel, at the top and bottom end of the capacitor, and therefore cannot be responsible for the thrust seen.

ACKNOWLEDGEMENTS

We thank Nolan Van Rossum for the calibration diagram Figure 6, which he put together from data supplied by H. Fearn.

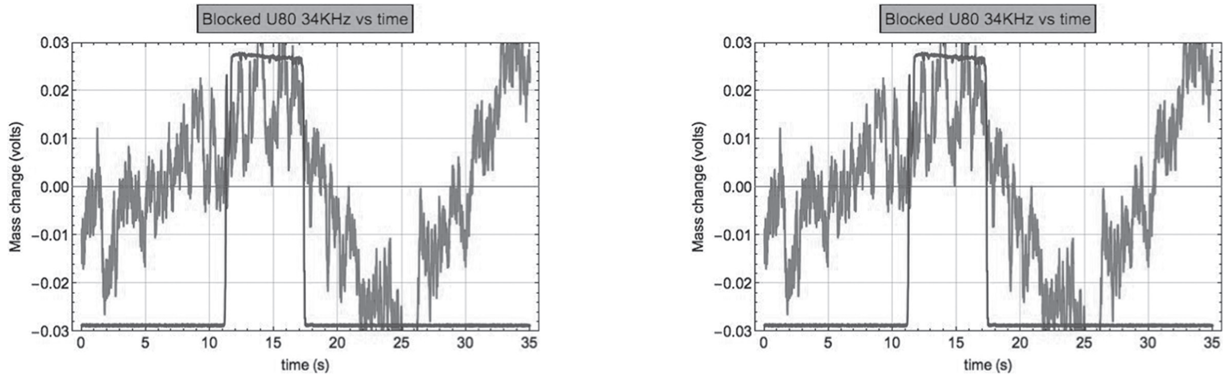


Fig. 9A Drift corrected and blocked data sets for frequency 34KHz. The square pulse line represents the voltage applied to the device. The device was powered with a pulse lasting for 6 seconds. The applied voltage (square pulse) was scaled for a range between -0.03 and 0.03 volts in order to plot on the same scale as the voltage from the U-80. The jagged line represents the voltage from the weighing device (U-80). From our calibration 0.03 Volts corresponds to 0.01 gram.

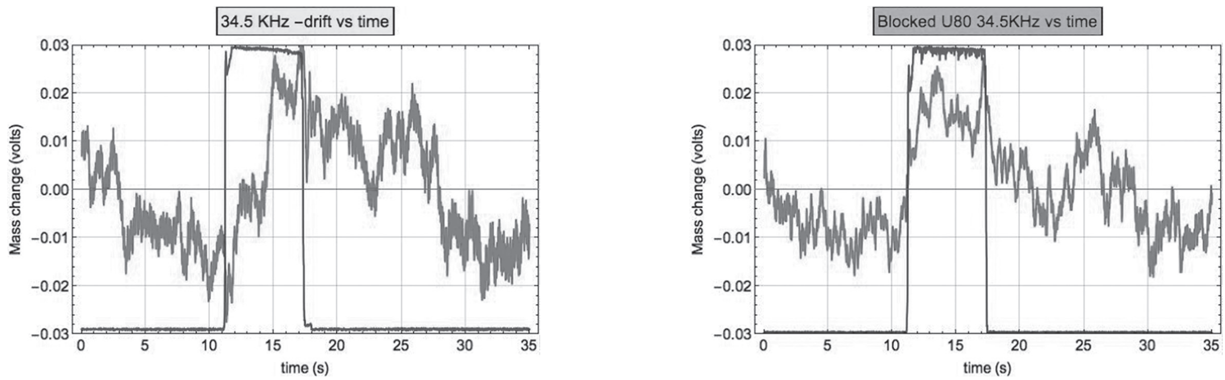


Fig. 9B Drift corrected and blocked data sets for frequency 34.5KHz. The square pulse line represents the voltage applied to the device. The jagged line represents the voltage from the weighing device (U-80).

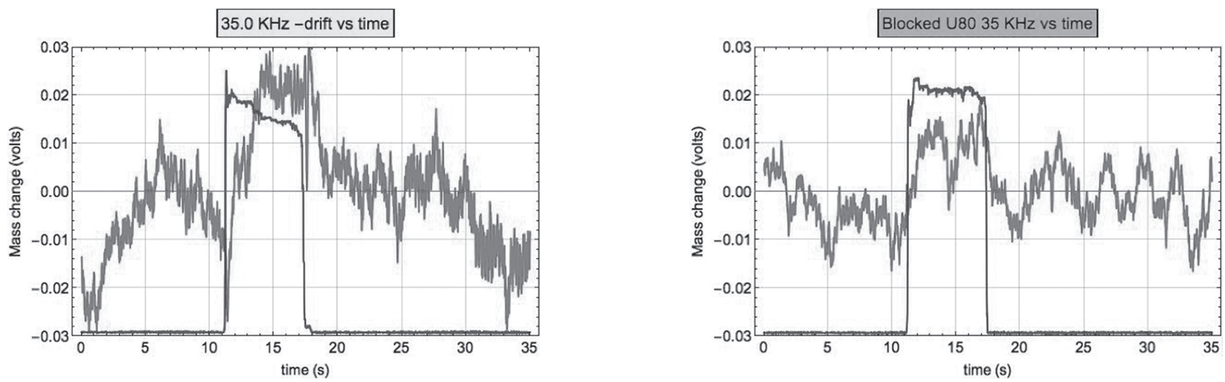


Fig. 9C Drift corrected and blocked data sets for frequency 35KHz. The square pulse line represents the voltage applied to the device. The jagged line represents the voltage from the weighing device (U-80).

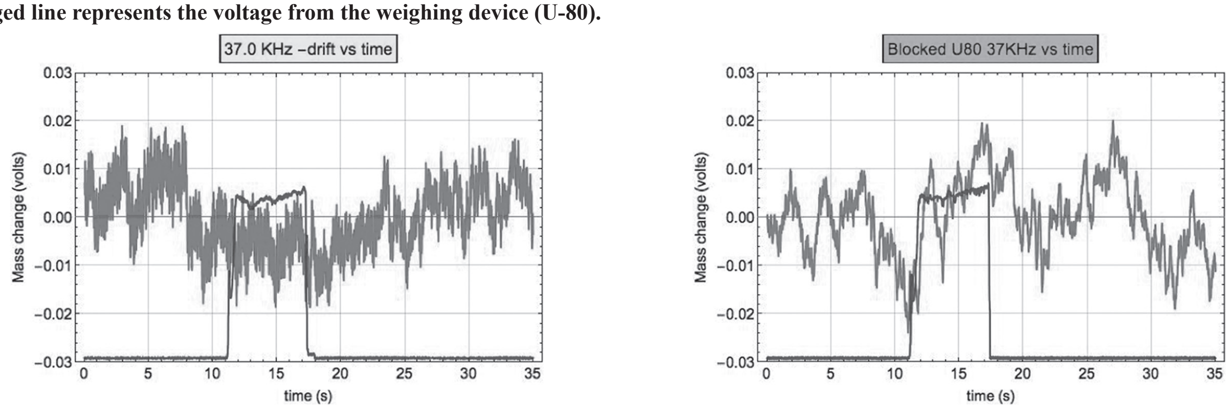


Fig. 9D Drift corrected and blocked data sets for frequency 37KHz. The square pulse line represents the voltage applied to the device. The jagged line represents the voltage from the weighing device (U-80).

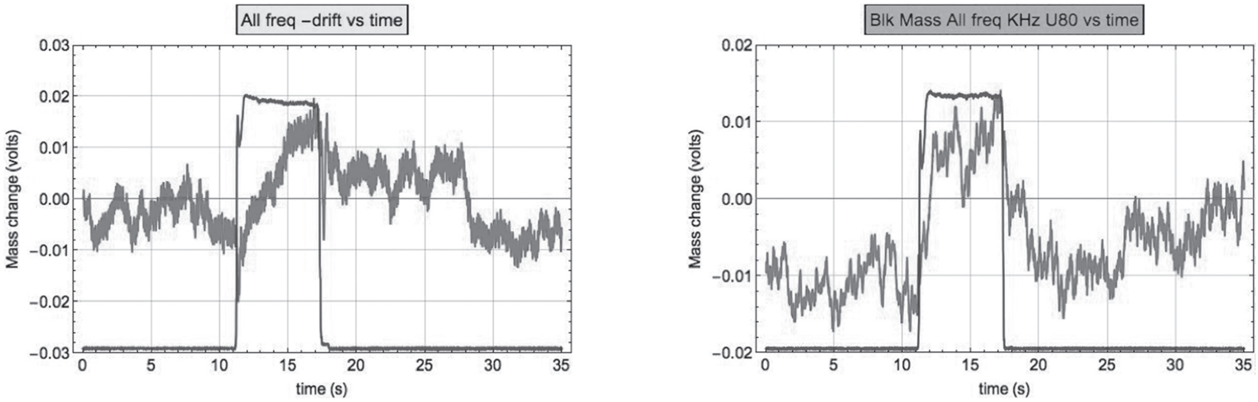


Fig. 9E Drift corrected and blocked data sets for frequency the average frequency, the combination of all of the above results. The square pulse line represents the voltage applied to the device. The jagged line represents the voltage from the weighing device (U-80).

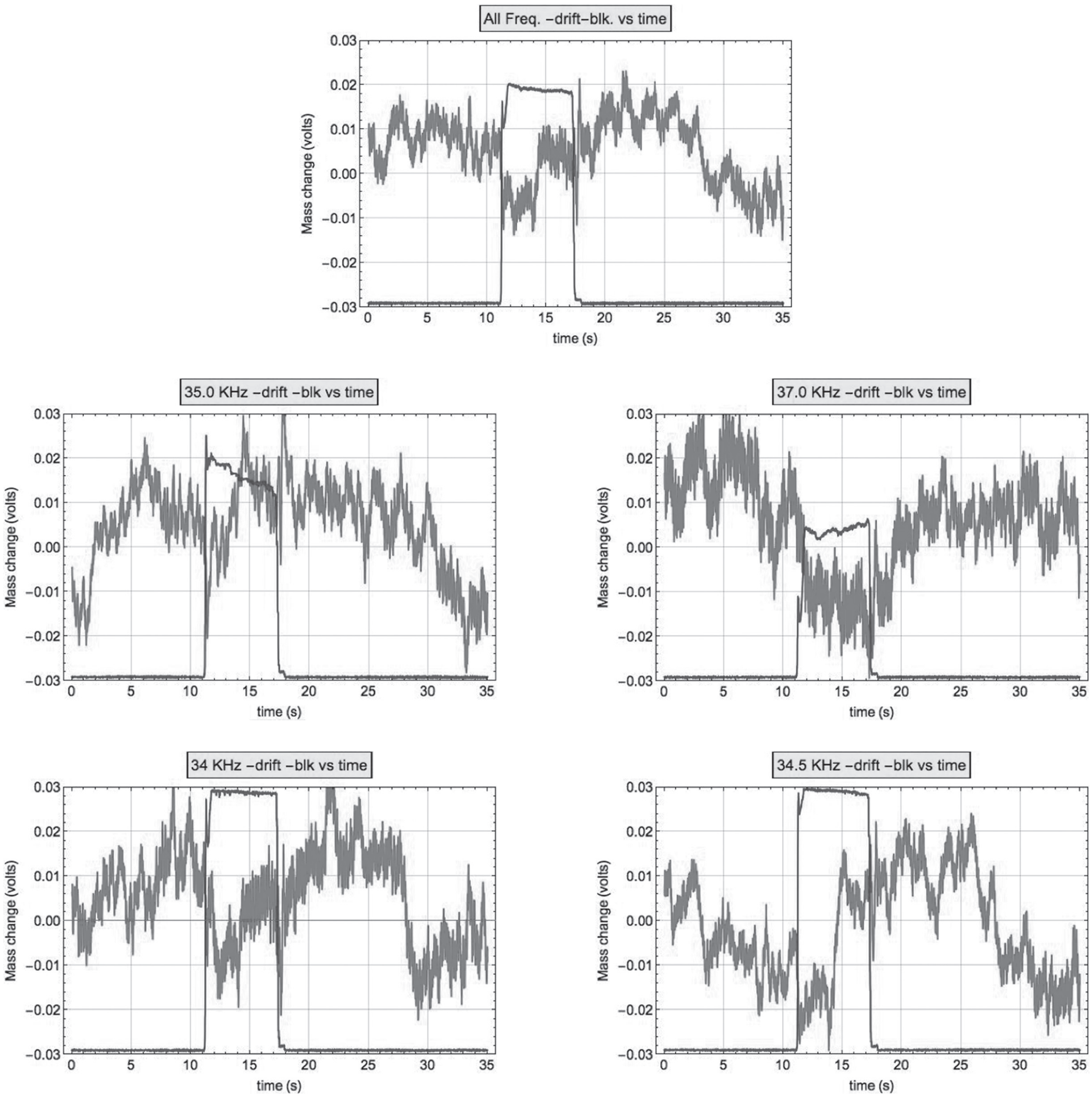


Fig. 10 Drift corrected frequency runs with blocked noise data subtracted. All frequencies and averaged frequency data. The square pulse line is the applied voltage to the MET device. The jagged line is the voltage form the weighing device U-80.

REFERENCES

1. James F. Woodward, "*Making Starships and Stargates; The Science of Interstellar Transport and Absurdly benign wormholes*", Springer Publishing, December 2013.

2. H. Fearn and J. Woodward, "Experimental null test of a Mach Effect Thruster", *J. of Space Exploration*, **2**, pp.98-105, 2013.

3. H. Fearn and K. Wanser "Experimental tests of a Mach Effect Thruster", *J. of Space Exploration*, **3**, pp.197-205, 2014.

4. H. Fearn, N v Rossum, K. Wanser and J. F. Woodward, "Theory of a Mach effect thruster II", J. Mod. Phys., **6**, pp.1868-1880, 2015.

5. H. Fearn and J.F. Woodward, "Breakthrough Propulsion I: The Quantum Vacuum", *JBIS*, **69**, pp.155-162, 2016.

6. W.K.H. Panofsky and M. Phillips, "*Classical Electricity and Magnetism*", 2nd Ed. Addison-Wesley Publishing Co., 1962, see pages 33-38.

7. C. Kittel, "*Introduction to Solid State Physics*", 7th edition, Wiley, NY, 1996, Chapter 13, pp383-387.

8. D. Halliday, R. Resnick and J. Walker, "*Fundamentals of Physics*", extended 9th edition, John Wiley and Sons, Inc., 2011, chapter 31.

9. H. White, P. March, N. Williams and W. O'Neil, "Eagleworks Laboratories: Advanced Propulsion Physics Research", https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110023492.pdf. (Last Accessed 5 April 2017)

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