Imperial College London

INVESTIGATING PRACTICAL ION PROPULSION ENGINES

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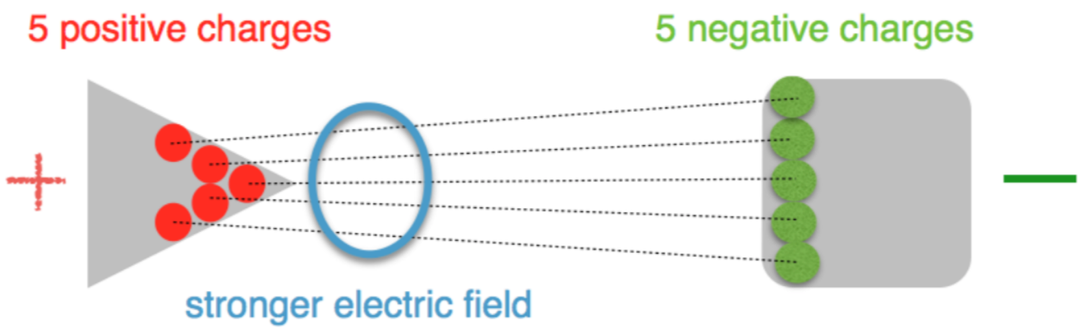
WHAT IS ELECTRIC PROPULSION?

Electric propulsion (EP) technology generates thrust by using electricity to increase the propellant exhaust velocity. Spacecraft powered by typical EP systems may eject propellant at up to 20 times the speed of conventional chemical systems, delivering a much higher specific impulse (Isp), or the amount of thrust obtained for the weight of fuel burned. They also have 10 times the mileage (miles per gallon of propellant) of chemical rockets. For space applications, the reduced propellant mass can enable the use of a smaller aircraft, and thus lower cost, to deliver an object into orbit or deep space.

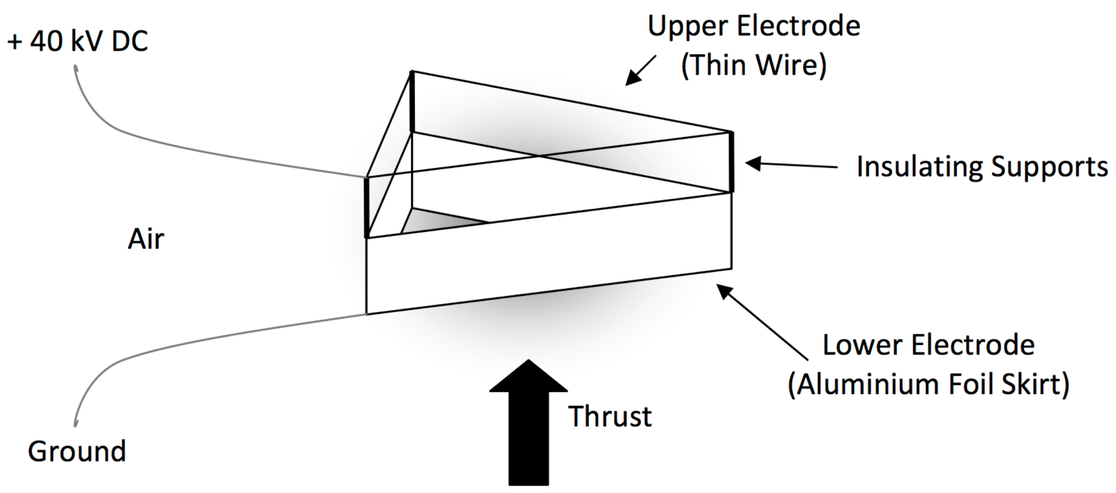
WHAT IS CORONA DISCHARGE?



Corona discharge refers to the phenomenon when the electric field near a conductor is strong enough to ionize the dielectric surrounding it but not strong enough to cause an electrical breakdown or arcing between conductors or other components. The potential at which corona originates is called the corona threshold voltage or corona inception voltage. Above this voltage, there is a limited region within which current increases linearly with voltage.

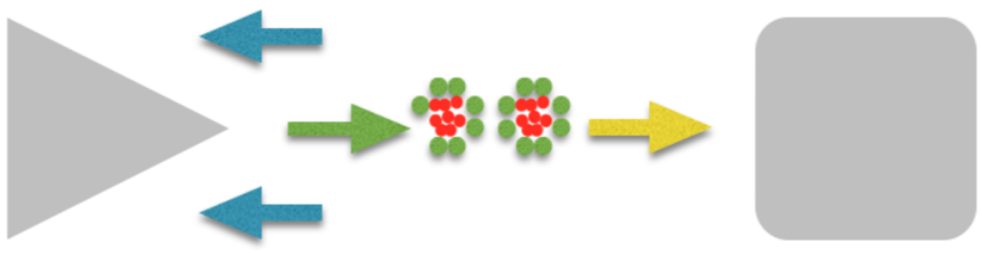
IONOCRAFT: ELECTROHYDRODYNAMIC ION PROPELLED AIRCRAFT

Electrohydrodynamics (EHD), also known as electro-fluid-dynamics or electrokinetics, is the study of the dynamics of electrically charged fluids. It involves analysing the motions of ionized particles or molecules and their interactions with electric fields and the surrounding fluid. A popular application of EHD is the lifter shown in the figure below. It has no moving parts. Instead, the surrounding fluid is ionized and accelerated by a high potential gradient to generate an ionic wind.



HOW IS THRUST GENERATED?

The ions are collected at the collector electrode and do not contribute to thrust, but the neutral air molecules that gained energy in the collisions along the way escape the system with net momentum along the direction from the emitter towards the collector. This produces thrust in the opposite (i.e upward) direction.



Blue arrow: overall movement of ionocraft
Yellow arrow: movement of neutral atom after getting bumped by ion
Green arrow: movement of ion

THRUST TO POWER RATIO

The thrust and thrust to power ration generated by a single stage ionocraft (having one emitting electrode) can be derived to be:

$$Thrust = \frac{I \times d}{\mu} \qquad \frac{Thrust}{Power} = \frac{d}{\mu \times v}$$

where *I* is the total current flowing through the emitting electrode, *d* is the electrode separation distance, *v* is the average drift velocity, and μ is the ion mobility.

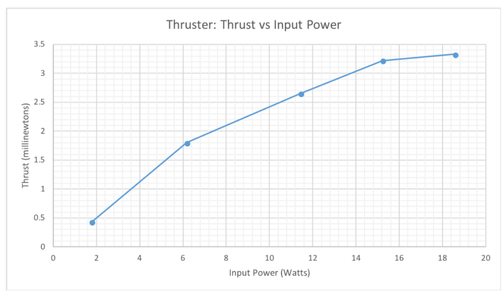
PROTOYPE DESIGN AND CONSTRUCTION

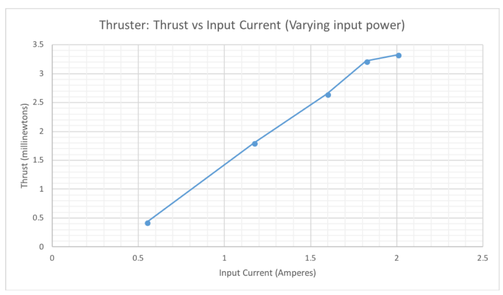
The circuit from a plasma ball has been used to provide the switching and current amplification necessary for the transformer. This voltage is further boosted using a Cockcroft Walton voltage multiplier to produce an HVDC output which is fed to either the thruster (shown below) or the ionocraft. The maximum output of this system was 20 kV at 1.7 A.

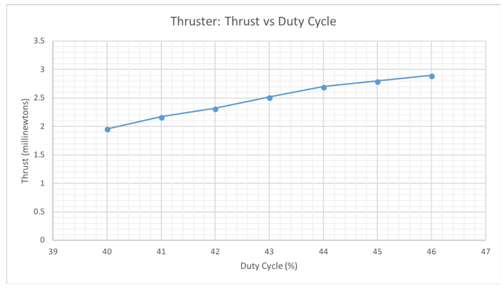
The anode and cathode of the thruster have been fabricated with copper pipes and nails while acrylic slabs provide the supporting structure. The ionocraft needs to maximise the thrust to weight ratio, and is therefore built using plastic straws cut in half for its skeleton, thin aluminium foil for the receiving electrode, and 42 SWG wire for the emitting electrode.

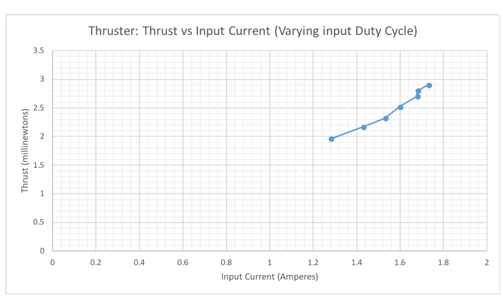
TESTING AND RESULTS

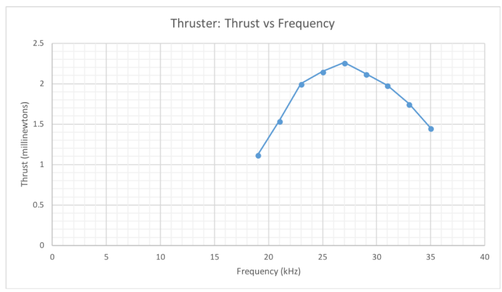
A function generator was inserted instead of the fixed oscillator to vary input power, duty cycle and frequency. The thrust output follows the input current as expected. The ionocraft was able to sustain a tethered elevation of about 4 cm at 29 kV, 0.55 mA using an HVDC supply.

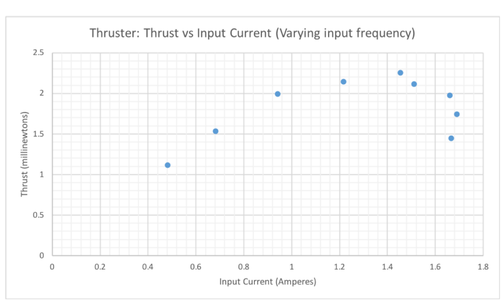












CONCLUSION

Electric propulsion will remain unviable on Earth until mankind invents a power source that is dense enough to produce the required voltages and light enough to lift itself along with any necessary payload.