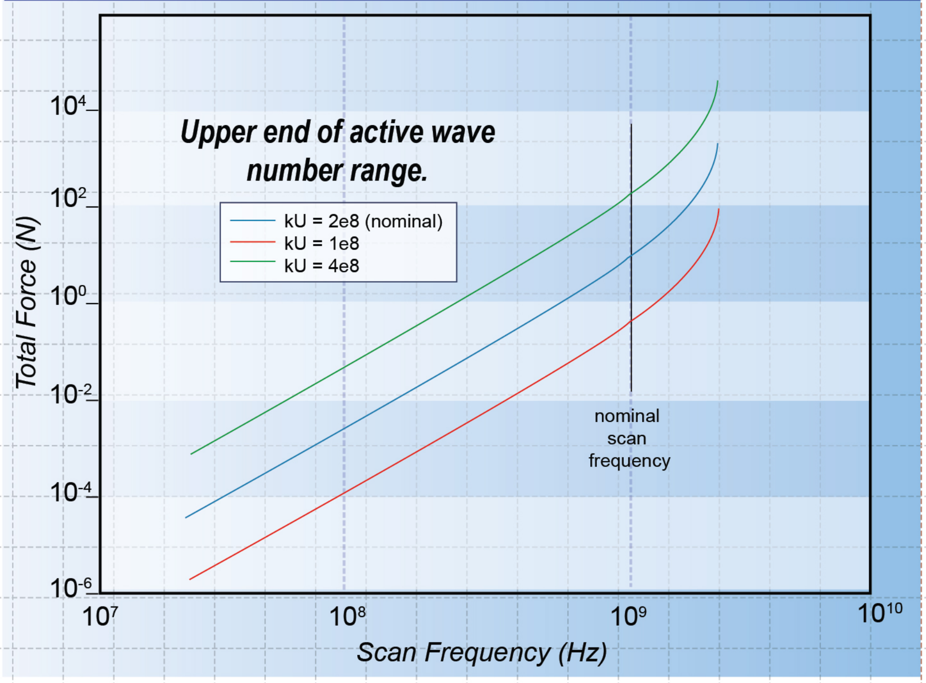
PHYSICS/MATH MODEL CALCULATED PERFORMANCE

INVENTOR - DR. D.C. HYLAND, USA & Foreign - Patents Pending

ASSUMPTIONS

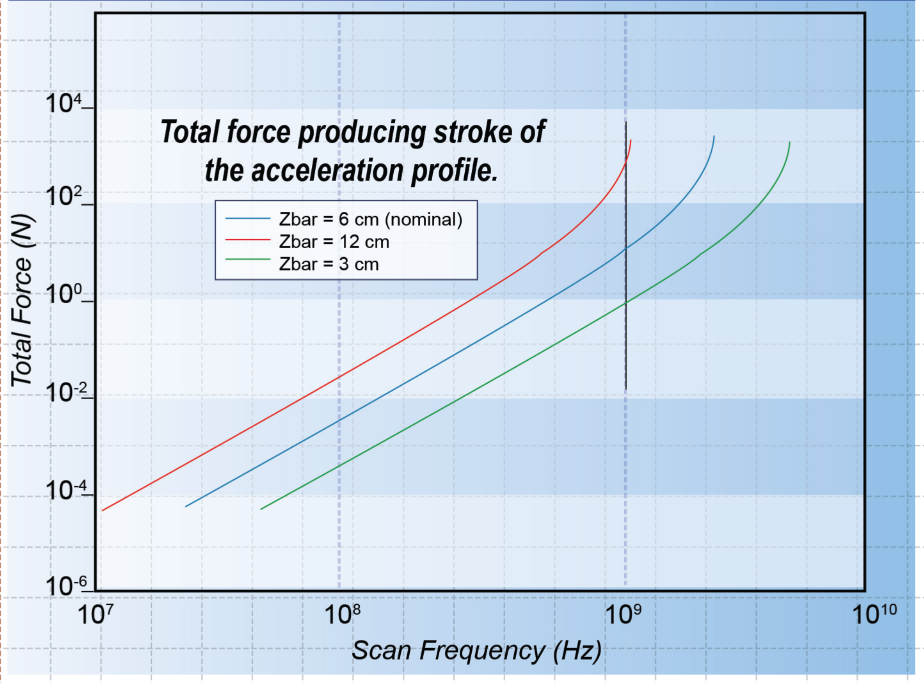
The general objective of the study is the determination of specifications for an experimental device consisting of an epitaxial stack of modest dimensions (< 0.3m), capable of producing forces that are significantly above the threshold of detectability (between 1 and 10 N). It is assumed that within certain wavelength bands, the reflectivity of each lamina can be set within a continuous range from completely reflective to completely transparent. The laminae are also characterized by a finite response time. These features can be combined so that when the laminae are sufficiently closely spaced, and their energizing processes are properly phased, a multi-lamina propagating wave of reflectivity can be created that sustains the properties of a continuously moving mirror.

Nominal Values, except k_U varied by a factor of 2



Calculation of the force produced by the nominal design, compared with results produced by varying k_U

Nominal Values, except Zbar varied by a factor of 2



Calculation of the force produced by the nominal design, compared with results produced by varying $\bar{Z}$

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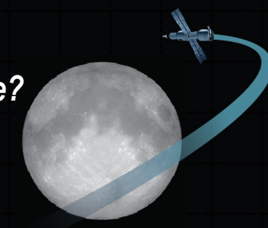
CONCLUSION

An in-depth investigation of the lamina switching algorithm was performed. From the performance analysis, details of the switching algorithm were refined, and the greatly improved "one-sided continuous array" design was developed. The updated design significantly reduces the device complexity and fabrication precision required while permitting much higher peak accelerations of the motion profile (hence, higher force outputs). Integrating these refinements with the design, we performed trade-off analyses considering the more than dozen significant design parameters. A nominal design was developed meeting our goal of 1N to 10N force produced by a test device with size scale about 10cm. The sensitivities of this design to variations in the design parameters was explored. Within the state of our present knowledge, the nominal design can attain performance well above the edge of detectability, and there is considerable latitude in selecting design parameters to sustain this capability.

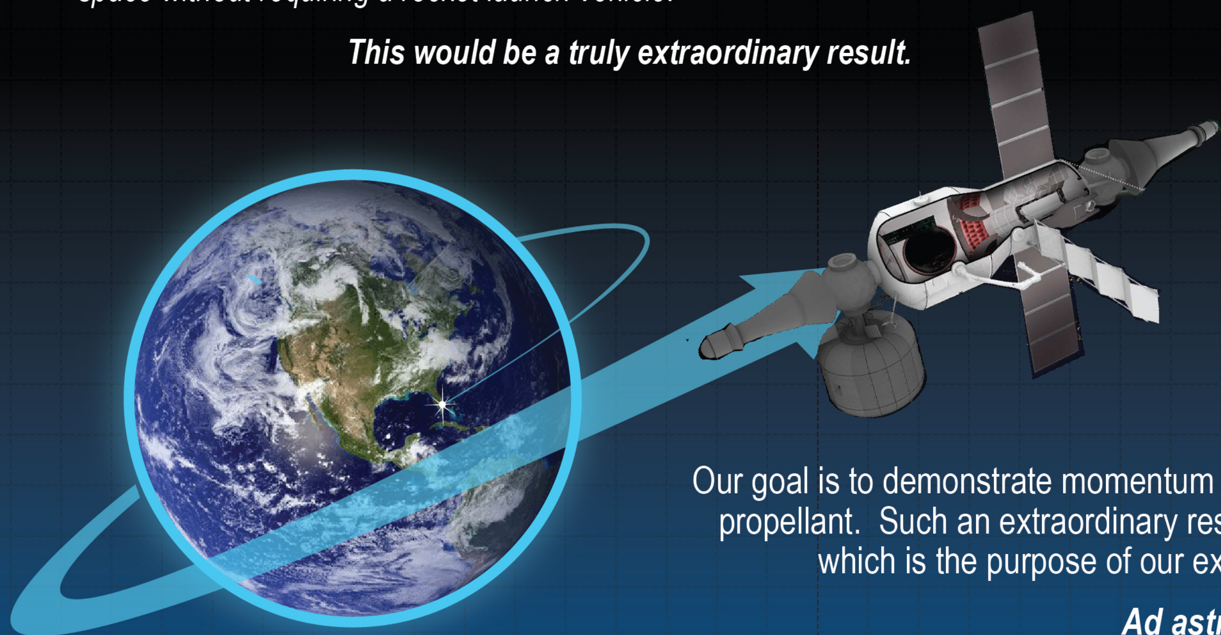
THE FUTURE

Will Excalibur's proposed 'proof of concept' device produce a measurable force? If it does, how much force?



If only a few Newtons, it could replace Hall thrusters. If an embodiment of the device could be built that produces a few hundred kilo-Newtons, it could lift our proposed 32mT space station directly from the Earth's surface to space without requiring a rocket launch vehicle.

This would be a truly extraordinary result.



Our goal is to demonstrate momentum transfer to an object without using propellant. Such an extraordinary result requires extraordinary proof, which is the purpose of our experimental investigation.

Ad astra.

Experimental design of a semiconductor propulsion device using the dynamic Casimir effect to transfer momentum to an object by interaction with the electromagnetic field ground state.

BACKGROUND

"One of the most surprising predictions of modern quantum theory is that the vacuum of space is not empty. In fact, quantum theory predicts that it teams with particles flitting in and out of existence." Christopher Wilson, Chalmers University, Sweden, in his paper "Observation of the Dynamical Casimir Effect in a Superconducting Circuit." arxiv.org/abs/1105,471

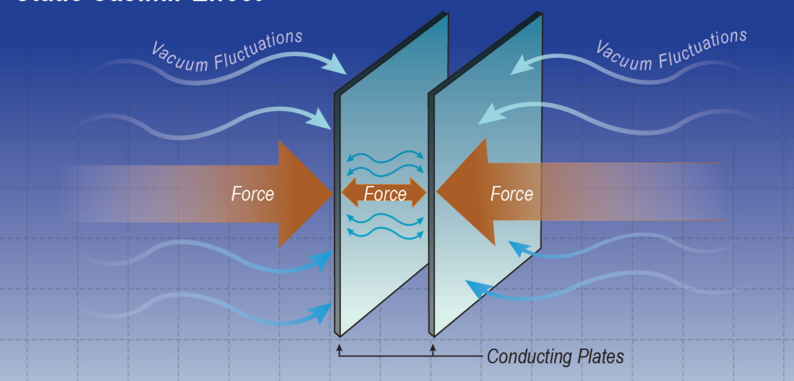
If two conductive plates are held close together and parallel to each other they will be pushed together when the gap between them is smaller than the wavelength of some of the virtual particles. This causes the vacuum pressure inside the gap to be less than the vacuum pressure outside, forcing the plates together.

This force is the ***static Casimir effect.*** It was first measured by two teams in the US in 1998. When the conductors are separated by distance of about 10 atomic diameters, the Casimir force is roughly equal to air pressure at sea level; about 96,000 N per square meter.

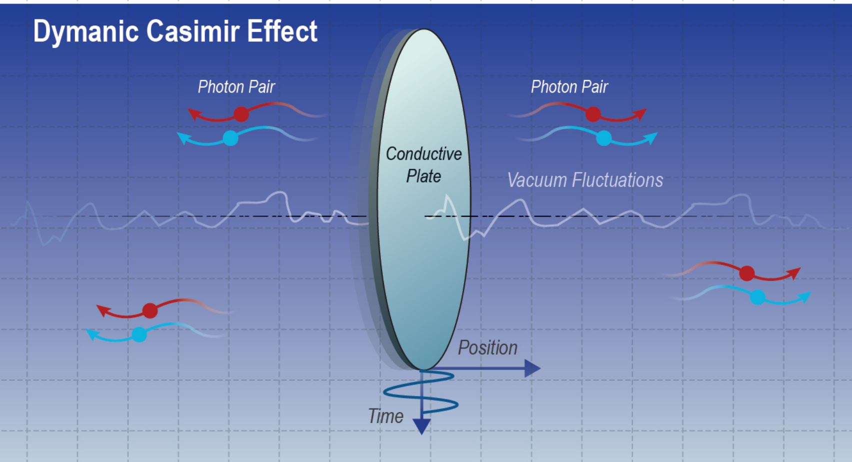
Another force, the ***dynamical Casimir effect***, is produced when a single conductive plate is moved at relativistic speed. At slow speeds, virtual particles can adapt to the conductor's movement and continue to come into existence in pairs and then disappear as they annihilate each other. However when the speed of the conductor approaches the speed of the photons; i.e. at an appreciable fraction of the speed of light, some photons become real causing the moving conductor to transfer momentum from empty space and produce light.

It is mechanically impossible to move a large area conductor at relativistic speed over a significant distance. Wilson, cited above, modulated a superconducting quantum interference device to achieve about 5% of the speed of light over the distance of about a nanometer near a transmission line a hundred micrometers long. This movement produced microwave photons. It was the first experimental observation of the force produced by the dynamical Casimir effect.

Static Casimir Effect



Dymanic Casimir Effect



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Experiment Design for Investigation of Momentum Exchange with the Vacuum State

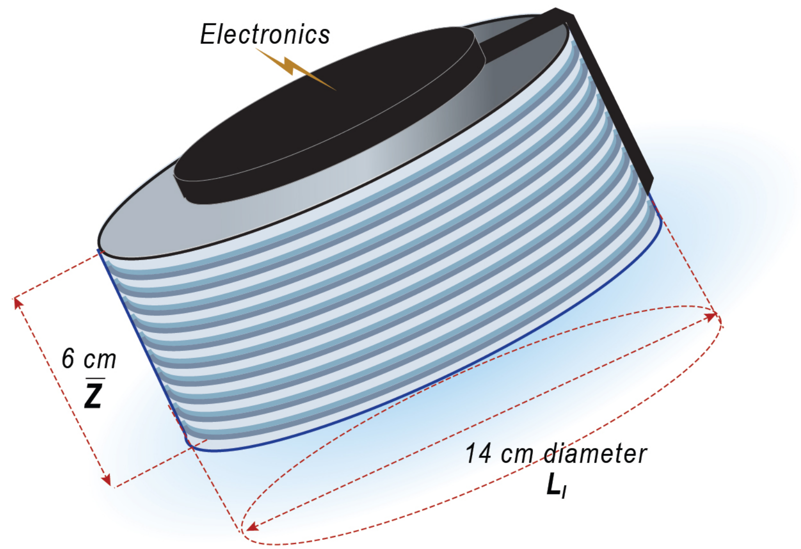
INVENTOR - DR. D.C. HYLAND, USA & Foreign - Patents Pending

SUMMARY

The device operates by changing the position of the conductive region in a large scale (cm to meters) semiconductor structure by successively applying an electric field at different positions in the semiconductor structure without requiring mechanical motion. Movement of a large area conductor through a large distance at relativistic velocity produces a dynamical Casimir force strong enough to be useful for propulsion and for other purposes.

Parameter Estimates - *This table summarizes the nominal values of the design parameters so far estimated.*

Quantity	Definition	Nominal Value
{	Exponent in the power law acceleration profile	2
k_U	Upper end of the active wave number range	$2 \times 10^8\ m^{-1}$
k_L	Lower end of the active wave number range	$0.3 \times 10^8\ m^{-1}$
Ω_{MAX}	Maximum scan frequency	1GHz
t_R	Minimum switching pulse rise time	1 ns
$\overline{V}$	Maximum speed in the acceleration profile	0.95 c
$\overline{Z}$	Total force producing stroke of the acceleration profile	6 cm
N_1	Number of lamiae	>10
∂	Lamina thickness	5 mm
r_l	Maximum lamina reflectivity	>0.2
t_l	Maximum lamina transparency	0.995
L_l	Circular lamina diameter	14 cm



Tasks Completed

1. Thoroughly review and correct, as necessary, the theoretical analysis of the force that can be produced by the device, particularly for the unrestricted (large) amplitude case.
2. Perform design trade-off comparisons, determining force capability, size, dimensions of the laminae, wavelength range, power requirements, etc.
3. Researching the literature to identify semiconductor or liquid crystal devices for which there is a wavelength range where the device can be switched from reflector to transparency, and vice versa. Estimate the achievable active wavelength band, and switching frequency.
4. With a preliminary design, based upon Tasks (2) and (3), formulate the specifications for the manufacturer.

THE ADVANCED PROPULSION WORKSHOP

Access EA Data Details

The theoretical review of the fundamental concepts of the epitaxial device was presented at the Advanced Propulsion Workshop held at the Aerospace Corporation, El Segundo, California, November 1-3, 2017, and submitted as the paper "An Epitaxial Device for Dynamic Interaction with the Vacuum State" to the ***Journal of the British Interplanetary Society.***