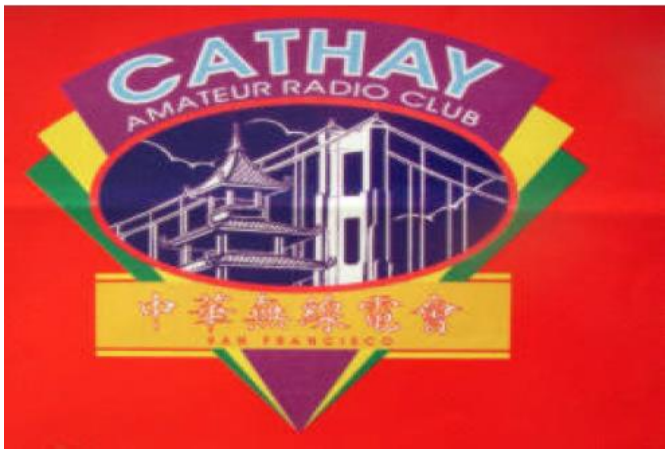


Cathay Oct 2020

www.cathayradio.org

President: George Chong, W6BUR **email:** *W6BUR@comcast.net*
Vice President North: Leonard Tom, *NX6E* **email:** nx6e@hotmail.com
Vice President South: Bill Fong, *W6BBA* - **email:** w6bba@arrl.net
Secretary/Membership: Rodney Yee, *KJ6DZI* - **email:** rodyee2000@yahoo.com
Editor: Rodney Yee, *KJ6DZI* - **email:** rodyee2000@yahoo.com
Treasurer: Vince Chinn aka Mingie, *W6EE* - **email:** vince@vincechinncpa.com
Web Master: Edison Fong – *WB6IQN* - **email:** edison_fong@hotmail.com
Mission: The Cathay Amateur Radio Club is basically an active social club of Ham Radio Operators and their spouses. We support local community requests for HAM emergency communications. Several of us are trained in CPR/ First Aid and are involved with community disaster preparedness.

Monday Night Net Time: 9 PM Local Time/PST, Repeater: WB6TCS - RX 147.210, TX 147.810, Offset +0.6 MHz, CTCSS/Tone PL100 Hz

Please note: Repeater: N6MNV UHF 442.700 Mhz, Offset +5MHz, CTCSS/Tone PL 173.8 Hz in South San Francisco is cross linked every Monday Night Net at 9 p.m. to WB6TCS 2-meter repeater.

The CARC Monday night net is the best way to find out the latest club news. All check-ins are welcome.

Message from the President: George Chong, *W6BUR*

Hello CARC Members and Friends;

Many thanks to Mr. Denis L. Moore – WB6TCS for the use of his repeater for our CARC Monday Night Net.

I wish to thank our CARC members that set aside their valuable time to participate in our Monday night's nets.

I know many of us are having a difficult time dealing with this COVID-19 pandemic.

I wish to say to all of you, “Stay Strong” and we will get through this together.

I hope that you folks have a Happy Chinese Moon Festival (October 1, 2020) and a Happy Columbus Day Holiday this October 12, 2020.

Special QST from CARC member Howard Louie- N6MNV

The original Cathay Amateur Radio Club was started by Chinese American service men returning from overseas service in WW2.

Our current CARC President George Chong – W6BUR is a WWII veteran having been trained as a B-17 belly turret gunner.

Recently George participated in an event that was made into an oral documentary of Chinese Americans that proudly severed in WWII. George’s appearance in the documentary interview begins at 46:33. This video that has been uploaded youtube:

- V75! The World War II Chinese American Honor Event
- https://youtu.be/JHTZI0mFeFc

- Introduction by: Montgomery Hom on the documentary tribute to honor Chinese-American serving in the US Military during WWII.
- https://www.youtube.com/watch?v=3cB4kZ5bAyQ

- WWII veterans from Hawaii
- https://www.youtube.com/watch?v=XWoDJPztL0A

- U.S Department of Veteran Affairs | Chinese-American WWII Veterans Receive Congressional Gold Medal
  https://scvtv.com/2019/02/01/chinese-american-wwii-veterans-receive-congressional-gold-medal/

Special QST from CARC member Wesley Wong - KF6WDX

From: Department of Human Resources Notification Service <CCSFjobs@sfgov.org>
Sent: Monday, September 28, 2020 10:01 PM
To: Wong, Wesley (DPH) <wesley.wong@sfdph.org>
Subject: City and County of San Francisco Job Match

Department of Human Resources Notification Service

THIS IS AN AUTOMATED NOTICE. REPLIES TO THIS EMAIL WILL NOT RECEIVE A RESPONSE.

The City and County of San Francisco is accepting applications for the following job. If you are still interested in this job, please click on the link below and read the announcement. Follow the instructions on how to apply. Please submit your application by the final filing date. Thank you!

REPLIES SENT BACK TO THIS E-MAIL ADDRESS WILL NOT RECEIVE A RESPONSE. If you have any questions about this specific recruitment, please contact the analyst indicated on the announcement. The contact information for the analyst can typically be found in the "How to Apply" section of the announcement.

Job title: 0923 Manager II - Radio Communications
Opening date: Sep 28 2020 9:00AM
Final filing date: Oct 19 2020 5:00PM
Recruitment number: TEX-0923-106578
Lley Web link:
http://www.jobapscloud.com/SF/sup/Bulpreview.asp?R1=TEX&R2=0923&R3=106578

You can also watch instructional videos on our website for further assistance with our online application system:

http://sfdhr.org/how-apply-position

Press REPLY to send a message to Department of Human Resources if you have any questions regarding this email.

-Department of Human Resources Notification Service

Tech Article Introduction:

Last month's article about the Wireless Transmission of Commercial Electrical Energy has raised a storm in the scientific community and within our CARC membership. Well that just goes to prove some of folks are reading the CARC newsletter!

Several CARC members and have reached out to me and informed that such endeavors will more than likely fail because of attenuation of transmitted energy though the atmosphere. When you think about it, solar farms are kind of doing a form of energy transmission and storage right now.

Yes, the odds of success are indeed very long on the successful demonstration of wireless transmission of electrical energy on a commercial scale. It may like many other thought provoking and interesting scientific ideas crash and burn and yet is by that very same nature of revisiting and questioning long established scientific principles that our scientific knowledge expands.

In a similar cautionary tone, this month's article is about the "Impossible" EM Drive. The EM Drive is the proposal of creating a rocket engine that runs off of radio waves!

Many physicists and other scientist from around the world have rejected the EM Drive out of hand due to the fact it completely violates Newton's third law of motion: "For every action there is an equal and opposing reaction.

Supporter of the EM Drive state the reason it works is due the **Unruh Effect** that occurs on the quantum level.

To settle the issue for once and all the US Defense Advance Research Project Agency (DARPA) in this year of 2020, it has issued a grant of $1.3 million dollars to the Nascent Light-Matter Interactions (NLM) project.

The NLM project (https://www.darpa.mil/program/nascent-light-matter-interactions) goal is:

Recent advances in our understanding of light-matter interactions, often with patterned and resonant structures, reveal nascent concepts for new interactions that may impact many applications.

Examples of these novel phenomena include interactions involving active media, symmetry, non-reciprocity, and linear/nonlinear resonant coupling effects.

Insights regarding the origins of these interactions have the potential to transform our understanding of how to control electromagnetic waves and design for new light-matter interactions.

The goal of NLM is to bring together and integrate these emerging phenomena with fundamental models that can describe and predict new functionality.

These models will provide design tools and delineate the performance limits of new engineered light-matter interactions. Important applications to be addressed in the program include synthesizing new material structures for sources, non-reciprocal behavior, parametric phenomena, limiters, electromagnetic drives, and energy harvesting.

If by some miracle that the EM Drive really works and is practical (weight vs performance), among the first application of it would for use it in earth orbiting satellites. Currently earth orbiting satellites carry a limited amount of propellant to maintain its orientation to the earth to remain useful. Once the satellite's propellant is used up, it will quickly join the ranks of orbiting space junk.

Now that I have peaked your interest, please read the full details in the Tech Article Section.

Chat sub s'em to all you CARC members! - George W6BUR.

Public Service Announcements

HAM CRAM / HAM Licensing

For upcoming HAM Licensing locations please refer to:
http://www.arrl.org/find-an-amateur-radio-license-exam-session

Auxiliary Communications Service (ACS)

The Auxiliary Communications Service (ACS) was organized by the San Francisco Office of Emergency Services (OES) following the 1989 Loma Prieta Earthquake to support the communications needs of the City and County of San Francisco when responding to emergencies and special events.

The Auxiliary Communications Service holds General Meetings on the third Tuesday of each month at the San Francisco Emergency Operations Center, 1011 Turk Street (between Gough Street and Laguna Street), from 1900 hours to 2100 hours local time. All interested persons are welcome to attend.

The ACS Net begins at 1930 hours (7:30 p.m.) local time each Thursday evening, on the WA6GG repeater at 442.050 MHz, positive offset, tone 127.3 Hz. The purpose of this net is to practice Net Control skills, practice checking in with deployment status in a formal net, and to share information regarding upcoming ACS events. Guests are welcome to check in. ACS Members should perform Net Control duty on a regular

basis. On the second Thursday of each month, the net will be conducted on the output frequency of the WA6GG repeater, 442.050 MHz no offset, tone 127.3 Hz, simplex.

For more information, please attend an ACS meeting or check in on a net, or call 415-558-2717.

Upcoming meetings: TBD

Gilbert Gin (KJ6HKD)

Free Disaster Preparedness Classes In Oakland:
http://www.oaklandnet.com/fire/core/index2.html

CORE is a free training program for individuals, neighborhood groups and community-based organizations in Oakland. The underlying premise is that a major disaster will overwhelm first responders, leaving many citizens on their own for the first 72 hours or longer after the emergency.

If you have questions about the recertification process, you may contact the CORE Coordinator at 510-238-6351 or core@oaklandnet.com.

Free Disaster Preparedness Classes In San Francisco – NERT Taught by San Francisco Fire Department (SFFD).

http://sf-fire.org/calendar-special-events

Upcoming events TBD

***SFFD DOT** is the Fire Department Division of Training. All participants walking, biking or driving **enter through the driveway gate on 19th St.** between Folsom and Shotwell. Parking is allowed along the back toward the cinderblock wall.

Visit ***www.sfgov.org/sffdnert*** to learn more about the training, other locations, and register on line. Upcoming Special NERT Events.

San Francisco Police Department: Auxiliary Law Enforcement Response Team (ALERT)

The Auxiliary Law Enforcement Response Team (ALERT) is a citizen disaster preparedness program designed. The ALERT program is for volunteers 16 years of age or older, who live, work, or attend high school in San Francisco.

Graduates of the San Francisco Police Activities League (P.A.L) Law Enforcement Cadet Academy are also eligible to join.

ALERT volunteers will no longer need to complete the Fire Department's Neighborhood Emergency Response Team (NERT) (www.sfgov.org/sfnert) training and then graduate into two 8 hour Police Department course specifically designed for ALERT team members.

ALERT members will work closely with full-time and/or Reserve Police Officers in the event they are deployed after a disaster. The Basic ALERT volunteer will have no law enforcement powers other than those available to all citizens.

SFPD ALERT Training (New Members)

The next SFPD ALERT training class has been scheduled for **TBD**. The class will be held at the San Francisco Police Academy, in the parking lot bungalow, from 8am-5pm (one hour lunch break) on Saturday.

* Class date indicated are only for new members

IMPORTANT- All participants must complete the background interview process in order to be eligible to attend the ALERT training class.

Eligible ALERT participants may register for a training class by contacting the ALERT Program Coordinator, Marina at sfpdalert@sfgov.org, or by telephone at 415-401-4615.

SFPD ALERT Practice/Training Drill

All active/trained ALERT members are asked to join us for our next training drill, scheduled for on **TBD** from 9 AM – 1pm. Details will be emailed to active ALERT members, prior to the date of the exercise. Participation is not required, but strongly encouraged.

For more information on the San Francisco Police Department ALERT Program, email us at sfpdalert@sfgov.org, or call Lt. Marina Chacon (SFPD Ret.), SFPD ALERT Program Coordinator, at (415) 401-4615.

For additional information on the web please refer to:
https://sfgov.org/policecommission/alert

Technical Article – The Impossible EmDrive

EmDrive

From Wikipedia, the free encyclopedia https://en.wikipedia.org/wiki/EmDrive

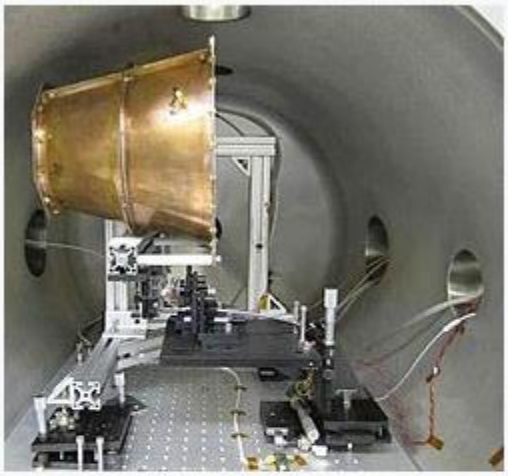
A **radio frequency** (**RF**) **resonant cavity thruster** is a device concept that is claimed to be a spacecraft thruster.[1][2] It is purported to generate thrust by reflecting microwaves internally in the device, in violation of the law of conservation of momentum and other laws of physics.[3][4][5][6][7][8][9][10]

The device is also known as an **EmDrive** and has been often referred to by the media as the **Impossible Drive**.[11][12][13][7]

It was introduced in 2001 by Roger Shawyer.[14][15] There exists no official design for this device, and neither of the people who claim to have invented it have committed to an explanation for how it could operate as a thruster or what elements define it, making it difficult to tell whether a given object is an example of such a device.

However, several prototypes based on its public descriptions have been constructed and tested. In 2016, the Advanced Propulsion Physics Laboratory at NASA reported observing a small apparent thrust from one such test,[16] a result not since replicated. No other published experiment has measured apparent thrust greater than the experiment's margin of error.[17]

EmDrive



EmDrive built by NASA Eagleworks laboratory during their 2013–2014 experiments

Country of origin	United States
Date	2001
Application	Spacecraft thruster
Status	Device concept
Performance	
Thrust (SL)	0.02 N (0.072 ozf) (disputed)

History and debunking

Rocket engines operate by expelling propellant, which acts as a reaction mass and which produces thrust per Newton's third law of motion. In the 1960s, extensive research was conducted on two designs which emit high-velocity ionized gases in similar ways: ion thrusters that convert propellant to ions and accelerate and eject them via electric potentials, and plasma thrusters that convert propellant to plasma ions and accelerate and eject them via plasma currents. All designs for electromagnetic propulsion operate on the principle of reaction mass.

A drive which does not expel propellant in order to produce a reaction force, providing thrust while being a closed system with no external interaction, would be a reactionless drive. Such a drive would violate the conservation of momentum and Newton's third law,[18] leading many physicists to consider the idea pseudoscience.[16] Such drives are a popular concept in science fiction, and their implausibility contributes to enthusiasm for exploring such designs.

The original proposal for an RF resonant cavity thruster came from Roger Shawyer in 2001. He proposed a design with a conical cavity, which he called "EmDrive". He claimed that it produced thrust in the direction of the base of the cavity. Guido Fetta later built the Cannae Drive based on Shawyer's concept[19][18] as a resonant thruster with a pillbox-shaped cavity. Since 2008, a few physicists have tested their own models, trying to reproduce the results claimed by Shawyer and Fetta. Juan Yang at Xi'an's Northwestern Polytechnical University (NWPU) was unable to reproducibly measure thrust from their models, over the course of 4 years.[20][21][22] In 2016, Harold White's group at NASA's Advanced Propulsion Physics Laboratory reported in the Journal of Propulsion and Power that a test of their own model had observed a small thrust.[23] In December 2016, Yue Chen of the communication satellite division of the China Academy of Space Technology (CAST), said his team had tested several prototypes, observed thrust, and was carrying out in-orbit verification.[24][25][26][27] In September 2017, Chen talked about this CAST project again in an interview on CCTV.[28]

Media coverage of experiments using these designs has been controversial and polarized. The EmDrive first drew attention, both credulous and dismissive, when *New Scientist* wrote about it as an "impossible" drive in 2006.[29] Media outlets were later criticised for misleading claims that a resonant cavity thruster had been "validated by NASA"[30] following White's first tentative test reports in 2014.[31] Scientists have continued to note the lack of unbiased coverage, from both polarized sides.[32]

In 2006, responding to the *New Scientist* piece, mathematical physicist John C. Baez at the University of California, Riverside, and Australian science-fiction writer Greg Egan, said the positive results reported by Shawyer were likely misinterpretations of experimental errors.[33]

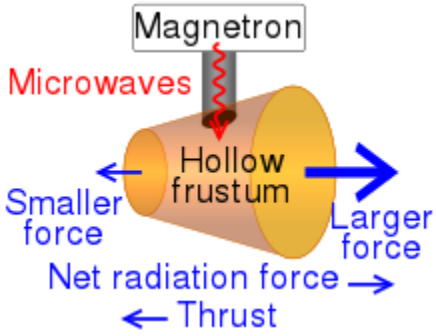
In 2014, White's conference paper suggested that resonant cavity thrusters could work by transferring momentum to the "quantum vacuum virtual plasma."[3] Baez and Carroll criticized this explanation, because in the standard description of vacuum fluctuations, virtual particles do not behave as a plasma; Carroll also noted that the quantum vacuum has no "rest frame", providing nothing to push against, so it can't be used for propulsion.[1][34] In the same way, physicists James F. Woodward and Heidi Fearn published two papers showing that electron-positron virtual pairs of the quantum vacuum, discussed by White as a potential virtual plasma propellant, could not account for thrust in any isolated, closed electromagnetic system such as a quantum vacuum thruster.[2][35]

Physicists Eric W. Davis at the Institute for Advanced Studies in Austin and Sean M. Carroll at the California Institute of Technology said in 2015 that the thrust measurements reported in papers by both Tajmar and White were indicative of thermal effect errors.[36]

In May 2018, researchers from the Institute of Aerospace Engineering at Technische Universität Dresden, Germany, concluded that the dominant effect underlying the apparent thrust could be clearly identified as an artifact caused by Earth's magnetic field interacting with power cables in the chamber, a result that other experts agree with.[37][38][39]

In December 2019, White left the leadership of the Advanced Propulsion Physics Laboratory to lead research and development at Limitless Space Institute. Among other work, he will continue to conduct research on the EmDrive.[40] A U.S. Navy research, Salvatore Cesar Pais, recently applied for a patent similar to the EmDrive.[41] The DARPA project will continue through May 2021.[41] Mike McCulloch, the current DARPA EmDrive project leader, José Luis Perez-Diaz, a physics professor and mechanical engineer at Charles III University of Madrid, and Tajmar have continued to experiment and to develop a theoretical explanation, with papers from Tajmar due in February 2021.[41][42]

Designs and prototypes



Simplified schematic drawing of an EmDrive prototype by Tajmar and Fiedler.

EmDrive

In 2001, Shawyer founded *Satellite Propulsion Research Ltd*, in order to work on the EmDrive, a drive that he said used a resonant cavity to produce thrust without propellant. The company was backed by SMART award grants from the UK Department of Trade and Industry.[18][43] In December 2002, he described a working prototype with an alleged total thrust of about 0.02 newtons (0.072 ozf) powered by an 850 W cavity magnetron. The device could operate for only a few dozen seconds before the magnetron failed, due to overheating.[44]

Second device and New Scientist article

In October 2006, Shawyer conducted tests on a new water-cooled prototype and said that it had increased thrust.[45] He reported plans to have the device ready to use in space by May 2009 and to make the resonant cavity a superconductor,[45] neither of which materialized.

New Scientist magazine[14] featured the EmDrive on the cover of 8 September 2006 issue. The article portrayed the device as plausible and emphasized the arguments of those who held that point of view. Science fiction author Greg Egan distributed a public letter stating that "a sensationalist bent and a lack of basic knowledge by its writers" made the magazine's coverage unreliable, sufficient "to constitute a real threat to the public understanding of science". Especially, Egan said he was "gobsmacked by the level of scientific illiteracy" in the magazine's coverage, alleging that it used "meaningless double-talk" to obfuscate the problem of conservation of momentum. The letter was endorsed by mathematical physicist John C. Baez and posted on his blog.[33][1] *New Scientist* editor Jeremy Webb responded to critics:

It is a fair criticism that *New Scientist* did not make clear enough how controversial Roger Shawyer's engine is. We should have made more explicit where it apparently contravenes the laws of nature and reported that several physicists declined to comment on the device because they thought it too contentious ... The great thing is that Shawyer's ideas are testable. If he succeeds in getting his machine flown in space, we will know soon enough if it is ground-breaking device or a mere flight of fancy.[29]

New Scientist also published a letter from the former technical director of EADS Astrium:

I reviewed Roger's work and concluded that both theory and experiment were fatally flawed. Roger was advised that the company had no interest in the device, did not wish to seek patent coverage and in fact did not wish to be associated with it in any way.[46]

A letter from physicist Paul Friedlander:

As I read it, I, like the thousands of other physicists who will have read it, immediately realised that this was impossible as described. Physicists are trained to use certain fundamental principles to analyse a problem and this claim clearly flouted one of them ... The Shawyer drive is as impossible as perpetual motion. Relativistic conservation of momentum has been understood for a century and dictates that if nothing emerges from Shawyer's device then its centre of mass will not accelerate. It is likely that Shawyer has used an approximation somewhere in his calculations that would have been reasonable if he hadn't then multiplied the result by 50,000. The reason physicists value principles such as conservation of momentum is that they act as a reality check against errors of this kind.[47]

Later work

In 2007, the UK Department of Trade and Industry granted SPR an export licence to Boeing in the US.[48] According to Shawyer, in December 2008 he was invited to The Pentagon to present on the EmDrive, and in 2009 Boeing expressed interest in it,[49] at which point he stated that SPR built a thruster which produced 18 grams of thrust, and sent it to Boeing. Boeing did not, however, license the technology and communication stopped.[50] In 2012, a Boeing representative confirmed that Boeing Phantom Works used to explore exotic forms of space propulsion, including Shawyer's drive, but such work later ceased. They confirmed that "Phantom Works is not working with Mr. Shawyer," nor pursuing those explorations.[19]

In 2013 and 2014, Shawyer presented ideas for 'second-generation' EmDrive designs and applications at the annual International Astronautical Congress. A paper based on his 2014 presentation was published in *Acta Astronautica* in 2015.[51] It describes a model for a superconducting resonant cavity and three models for thrusters with multiple cavities, with hypothetical applications for launching space probes.

In 2016, Shawyer filed further patents[52][53] and launched a new company, *Universal Propulsion Ltd.*, as a joint venture with *Gilo Industries Group*, a small UK aerospace company.[50]

Cannae and other drives

The Cannae Drive (formerly Q-drive),[54] another engine designed to generate propulsion from a resonant cavity without propellant, is another implementation of this idea. Its cavity is also asymmetric, but relatively flat rather than a truncated cone. It was designed by Fetta in 2006 and has been promoted within the US through his company, Cannae LLC, since 2011.[54][55][56][57][58] In 2016, Fetta announced plans to eventually launch a CubeSat satellite containing a version of the Cannae Drive, which they would run for 6 months to observe how it functions in space.[59]

In China, researchers working under Yang at NWPU developed their own prototype resonant cavity thruster in 2008, publishing a report in their university's journal on the theory behind such devices. In 2012 they measured thrust from their prototype, however, in 2014 they found this had been an experimental error. A second, improved prototype did not produce any measured thrust.[19][60][61]

At the China Academy of Space Technology, Yue Chen filed several patent applications in 2016 describing various RF resonant cavity thruster designs. These included a method for stacking several short resonant cavities to improve thrust,[62] and a design with a cavity that was a semicylinder instead of a frustum.[63] That December, Chen announced that CAST was conducting tests on a resonant cavity thruster in orbit,[64] without specifying what design was used. In an interview on CCTV in September 2017, Chen Yue showed some testing of a flat cylindrical device corresponding to the patent describing stacked short cavities with internal diaphragms.[65][62]

Theoretical inconsistencies

The proposed theory for how the EmDrive works violates the conservation of momentum, which states any interaction cannot have a net force; a consequence of the conservation of momentum is Newton's third law, where for every action there is an equal and opposite reaction.[16] The conservation of momentum is a symmetry of nature.[66]

An often cited example of apparent nonconservation of momentum is the Casimir effect;[67] in the standard case where two parallel plates are attracted to each other. However the plates move in opposite directions, so no net momentum is extracted from the vacuum and, moreover, energy must be put into the system to take the plates apart again.[68]

Assuming homogeneous electric and magnetic fields, it is impossible for the EmDrive, or any other device, to extract a net momentum transfer from either a classical or quantum vacuum.[68] Extraction of a net momentum "from nothing"[69][70] has been postulated in an inhomogeneous vacuum, but this remains highly controversial as it will violate Lorentz invariance.[68]

Both Harold White's[71][72][73][67] and Mike McCulloch's[74] theories of how the EmDrive could work rely on these asymmetric or dynamical Casimir effects. However, if these vacuum forces are present, they are expected to be exceptionally tiny based on our current understanding, too small to explain the level of observed thrust.[68][75][76] In the event that observed thrust is not due to experimental error, a positive result could indicate new physics.[77][78]

Tests and experiments

Tests by inventors

In 2004, Shawyer claimed to have received seven independent positive reviews from experts at BAE Systems, EADS Astrium, Siemens and the IEE.[79] However no independent expert has published a positive review, and at least one directly disputed Shawyer's claim. In a letter to *New Scientist*, the then-technical director of EADS Astrium (Shawyer's former employer) denied this, stating:

I reviewed Roger's work and concluded that both theory and experiment were fatally flawed. Roger was advised that the company had no interest in the device, did not wish to seek patent coverage and in fact did not wish to be associated with it in any way.[46]

In 2011, Fetta tested a superconducting version of the Cannae drive. The RF resonant cavity was suspended inside a liquid helium-filled dewar. The weight of the cavity was monitored by load cells. Fetta theorized that when the device was activated and produced upward thrust, the load cells would detect the thrust as a change in weight. According to Fetta, when pulses of RF power were sent into the resonant cavity, there was a reduction in compressive force on the load cells that could indicate thrust.

None of these results were published in the scientific literature, replicated by independent researchers, or replicated consistently by the inventors. In a few cases details were posted for a time on the inventors' websites, but no such documents remain online as of 2019.[80]

In 2015, Shawyer published an article in *Acta Astronautica*, summarising existing tests on the EmDrive. Of seven tests, four produced a measured force in the intended direction and three produced thrust in the opposite direction. Furthermore, in one test, thrust could be produced in either direction by varying the spring constants in the measuring apparatus.[81]

Northwestern Polytechnical University

In 2008, a team of Chinese researchers led by Juan Yang (杨涓), professor of propulsion theory and engineering of aeronautics and astronautics at Northwestern Polytechnical University (NWPU) in Xi'an, China, said that they had developed a valid electro-magnetic theory behind a microwave resonant cavity thruster.[20][82] A demonstration version of the drive was built and tested with different cavity shapes and at higher power levels in 2010. Using an aerospace engine test stand usually used to precisely test spacecraft engines like ion drives,[18][60][61] they reported a maximum thrust of 720 mN at 2,500 W of input power.[61] Yang noted that her results were tentative, and said she "[was] not able to discuss her work until more results are published".[18] This positive result was over 100x more thrust per input power than any other experiment.

In a 2014 follow-up experiment (published in 2016), Yang could not reproduce the 2010 observation and suggested it was due to experimental error.[21] In that experiment they refined their experimental setup, using a three-wire torsion pendulum to measure thrust, and tested two different power setups. In one trial, the power system was outside the cavity, and they observed a "thrust" of 8–10 mN. In a second trial, the power system was within the cavity, and they measured no such thrust. Instead they observed an insignificant thrust below their noise threshold of 3 mN, fluctuating between ±0.7 mN with a measurement uncertainty of 80%, with 230 W of input power. They concluded that they were unable to measure significant thrust; that "thrust" measured when using external power sources (as in their 2010 experiment) could be noise; and that it was important to use self-contained power systems for these experiments, and more sensitive pendulums with lower torsional stiffness.[21]

NASA Eagleworks

Since 2011, White has had a team at NASA known as the Advanced Propulsion Physics Laboratory, or Eagleworks Laboratories, which is devoted to studying exotic propulsion concepts.[83] The group has investigated ideas for a wide range of untested and fringe proposals, including Alcubierre drives, drives that interact with the quantum vacuum, and RF resonant cavity thrusters.

In 2014, the group began testing resonant cavity thrusters of their own design and sharing some of their results. In November 2016, they published their first peer-reviewed paper on this work, in the *Journal of Propulsion and Power*.[23][84][85]

EmDrive and tapered cavities

In July 2014, White reported tentative positive results for evaluating a tapered RF resonant cavity.[3] Testing was performed using a low-thrust torsion pendulum able to detect force at the micronewton level within a sealed but unevacuated vacuum chamber (the RF power amplifier used an electrolytic capacitor unable to operate in a hard vacuum).[3] The experimenters recorded directional thrust immediately upon application of power.

Their first tests of this tapered cavity were conducted at very low power (2% of Shawyer's 2002 experiment). A net mean thrust over five runs was measured at

91.2 μN at 17 W of input power.[3] The experiment was criticized for its small data set and for not having been conducted in vacuum, to eliminate thermal air currents.

The group announced a plan to upgrade their equipment to higher power levels, to use vacuum-capable RF amplifiers with power ranges of up to 125 W, and to design a new tapered cavity that could be in the 0.1 N/kW range. The test article was to be subject to independent verification and validation at Glenn Research Center, the Jet Propulsion Laboratory and the Johns Hopkins University Applied Physics Laboratory.[3][86] As of 2016, this validation has not happened.[87]

In 2015, Paul March from Eagleworks made new results public, measured with a torsional pendulum in a hard vacuum: about 50 μN with 50 W of input power at 5.0×10^{-6} torr.[86] The new RF power amplifiers were said to be made for hard vacuum, but failed rapidly due to internal corona discharges. Without funding to replace or upgrade them, measurements were scarce for a time.[88]

They conducted further experiments in vacuum, a set of 18 observations with 40-80W of input power. They published the results in the American Institute of Aeronautics and Astronautics's peer-reviewed *Journal of Propulsion and Power*, under the title *"Measurement of Impulsive Thrust from a Closed Radio-Frequency Cavity in Vacuum"*. This was released online in November 2016, with print publication in December.[23][84][85] The study said that the system was "consistently performing with a thrust-to-power ratio of 1.2±0.1mN/kW", and enumerated many potential sources of error.[23]

The paper suggested that pilot-wave theory (a controversial, non-mainstream deterministic interpretation of quantum mechanics) could explain how the device produces thrust.[23][84][85] Commenters pointed out that just because a study reporting consistent thrust was published with peer-review does not necessarily mean that the drive functions as claimed.[16] Physicist Chris Lee was very critical of the work, saying that the paper had a small data set and a number of missing details he described as 'gaping holes'.[89] Electrical Engineer George Hathaway analyzed and criticized the scientific method described in the paper.[90]

Cannae drive

White's 2014 tests also evaluated two Cannae drive prototypes.[3] One had radial slots engraved along the bottom rim of the resonant cavity interior, as required by Fetta's hypothesis to produce thrust;[55] another "null" test article lacked those radial slots. Both drives were equipped with an internal dielectric.[3] A third test article, the experimental control, had an RF load but no resonant cavity interior. These tests took place at atmospheric pressure.

About the same net thrust was reported for both the device with radial slots and the device without slots. Thrust was not reported for the experimental control. Some considered the positive result for the non-slotted device a possible flaw in the experiment, as the null test device had been expected to produce less or no thrust based upon Fetta's hypothesis of how thrust was produced by the device.[1][91][92] In the

complete paper, however, White concluded that the test results proved that "thrust production was not dependent upon slotting".[3]

Dresden University of Technology

In July 2015, an aerospace research group at the Dresden University of Technology (TUD) under Martin Tajmar reported results for an evaluation of an RF resonant tapered cavity similar to the EmDrive.[93] Testing was performed first on a knife-edge beam balance able to detect force at the micronewton level, atop an antivibration granite table at ambient air pressure; then on a torsion pendulum with a force resolution of 0.1 mN, inside a vacuum chamber at ambient air pressure and in a hard vacuum at 400 μPa (4×10^{-6} mbar).

They used a conventional ISM band 2.45 GHz 700 W oven magnetron, and a small cavity with a low Q factor (20 in vacuum tests). They observed small positive thrusts in the positive direction and negative thrusts in the negative direction, of about 20 μN in a hard vacuum. However, when they rotated the cavity upwards as a "null" configuration, they observed an anomalous thrust of hundreds of micronewtons, significantly larger than the expected result of zero thrust. This indicated a strong source of noise which they could not identify. This led them to conclude that they could not confirm or refute claims about such a thruster. At the time they considered future experiments with better magnetic shielding, other vacuum tests and improved cavities with higher *Q* factors.

In 2018, the TU Dresden research team presented a conference paper summarizing the results from the most recent experiments on their upgraded test rig, which seemed to show that their measured thrust was a result of experimental error from insufficiently shielded components interacting with the earth's magnetic field.[94] In their experiments, they measured thrust values consistent with previous experiments, and the thrust reversed appropriately when the thruster was rotated by 180°. However, the team also measured thrust perpendicular to the expected direction when the thruster was rotated by 90°, and did not measure a reduction in thrust when an attenuator was used to reduce the power that actually entered the resonant cavity by a factor of 10,000, which they said "clearly indicates that the "thrust" is not coming from the EMDrive but from some electromagnetic interaction." They concluded that "magnetic interaction from not sufficiently shielded cables or thrusters are a major factor that needs to be taken into account for proper μN thrust measurements for these type of devices," and they plan on conducting future tests at higher power and at different frequencies, and with improved shielding and cavity geometry.[95][94]

Tests in space

In August 2016, Cannae announced plans to launch its thruster on a 6U cubesat which they would run for 6 months to observe how it functions in space. Cannae has formed a company called Theseus for the venture and partnered with LAI International and SpaceQuest Ltd. to launch the satellite. No launch date has yet been announced.[59]

In November 2016, the *International Business Times* published an unconfirmed report that the U.S. government was testing a version of the EmDrive on the Boeing X-37B and that the Chinese government has made plans to incorporate the EmDrive on its

orbital space laboratory Tiangong-2.[96] The US Air Force has only confirmed that the X-37B mission in question did an electric propulsion system test using a Hall-effect thruster, a type of ion thruster that uses a gaseous propellant.[97][98]

In December 2016, Yue Chen told a reporter at China's *Science and Technology Daily* that his team was testing an EmDrive in orbit, and that they had been funding research in the area for five years. Chen noted that their prototype's thrust was at the "micronewton to millinewton level", which would have to be scaled up to at least 100–1000 millinewtons for a chance of conclusive experimental results. Despite this, he said his goal was to complete validation of the drive, and then to make such technology available in the field of satellite engineering "as quickly as possible".[99][100][101][102][64]

Experimental errors

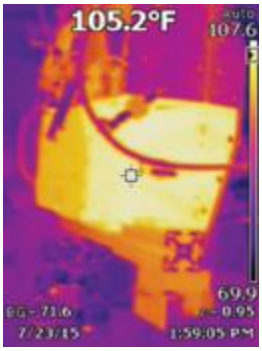
Experimental errors in the testing of the prototypes generally fall into four categories[103]

- Measurement errors. Most theoretical scientists who have looked at the EmDrive believe this to be the likely case.
- Electromagnetic effects.
- Exhaust not being measured or taken into account.
- Speculation that our current understanding of the laws of physics are completely wrong.

Measurement errors

The simplest and most likely explanation is that any thrust detected is due to experimental error or noise. In all of the experiments set up, a very large amount of energy goes into generating a tiny amount of thrust. When attempting to measure a small signal superimposed on a large signal, the noise from the large signal can obscure the small signal and give incorrect results. The strongest early result, from Yang's group in China, was later reported to be caused by an experimental error.[21]

Shift in center of gravity due to thermal effects



Infrared image showing heating of the heat sink

The largest error source is believed to come from the thermal expansion of the thruster's heat sink; as it expands this would lead to a change in the centre of gravity causing the resonant cavity to move. White's team attempted to model the thermal effect on the overall displacement by using a superposition of the displacements caused by "thermal effects" and "impulsive thrust" with White saying "That was the thing we worked the hardest to understand and put in a box". Despite these efforts, White's team were unable to fully account for the thermal expansion. In an interview with *Aerospace America*, White comments that "although maybe we put a little bit of a pencil mark through [thermal errors]... they are certainly not black-Sharpie-crossed-out."[104]

Their method of accounting for thermal effects has been criticized by Millis and Davies, who highlight that there is a lack of both mathematical and empirical detail to justify the assumptions made about those effects. For example, they do not provide data on temperature measurement over time compared to device displacement. The paper includes a graphical chart, but it is based on *a priori* assumptions about what the shapes of the "impulsive thrust" and "thermal effects" should be, and how those signals will superimpose. The model further assumes all noise to be thermal and does not include other effects such as interaction with the chamber wall, power lead forces, and tilting. Because the Eagleworks paper has no explicit model for thrust to compare with the observations, it is ultimately subjective, and its data can be interpreted in more than one way. The Eagleworks test, therefore, does not conclusively show a thrust effect, but cannot rule it out either.[77]

White suggested future experiments could run on a Cavendish balance. In such a setup, the thruster could rotate out to much larger angular displacements, letting a thrust (if present) dominate any possible thermal effects. Testing a device in space would also eliminate the center-of-gravity issue. [104]

Electromagnetic interaction with the vacuum chamber's wall

Another source of error could have arisen from electromagnetic interaction with the walls of the vacuum chamber.[104] White argued that any wall interaction could only be the result of a well-formed resonance coupling between the device and wall and that the high frequency used imply the chances of this would be highly dependent on the device's geometry. As components get warmer due to thermal expansion, the device's geometry changes, shifting the resonance of the cavity. In order to counter this effect and keep the system in optimal resonance conditions, White used a phase-locked loop system (PLL). Their analysis assumed that using a PLL ruled out significant electromagnetic interaction with the wall.[23]

Lorentz force from power leads

Another potential source of error was a Lorentz force arising from power leads. Many previous experiments used cups with Galinstan metal alloy, which is liquid at room temperature, to supply electrical power to the device in lieu of solid wires. Martin Tajmar and his graduate student Fiedler characterized and attempted to quantify possible sources of error in their experiment at Dresden University of Technology. They ran multiple tests on their experimental setup, including measurements of the force along

different axes with respect to the power supply current. While eliminating or accounting for many other sources of error in previous experiments, such as replacing a magnetic damping mechanism with an oil damper, less efficient but significantly less interacting with electromagnetic field, the study remained inconclusive as to the effects of electromagnetic interaction with the apparatus' power feed, at the same time noting it as possibly the most significant source of noise.[93] White's power setup may have been different, but their paper does not state if the connections are all coaxially aligned with the stand's rotation axis, which would be required to minimize errors from Lorentz forces, and it gives no data from equivalent tests with power into a dummy load so these influences can be compared with those seen in the Tajmar-Fiedler run.[77]

Speculation regarding new physical laws

White's 2016 paper went through about a year of peer review involving five referees.[104][16] Peer review does not mean the results or observations are true, only that the referees looked at the experiment, results and interpretation and found it to be sound and sensible.[16] Brice Cassenti, a professor at the University of Connecticut and an expert in advanced propulsion, spoke to one of the referees, and reported the referee did not believe the results point to any new physics, but that the results were puzzling enough to publish.[78] Cassenti believes there is a mundane explanation for the results, but the probability of the results being valid is slim but not zero.[78]

White's paper was published in the *Journal of Propulsion and Power*. Marc Millis and Eric Davies who ran NASA's previous advanced propulsion project, the Breakthrough Propulsion Physics Program have commented that while White used techniques that would be acceptable for checking the electric propulsion of Hall thrusters, the tests were not sufficient to demonstrate that any new physics effect exists.[77]

See also

- Abraham–Minkowski controversy
- Beam-powered propulsion § Direct impulse
- Casimir effect
- Crookes radiometer
- Dean drive
- Quantum vacuum thruster
- Reactionless drive
- Unruh effect
- White–Juday interferometer experiment
- Woodward effect

Notes

References

(please visit Wikipedia Webpage)
https://en.wikipedia.org/wiki/EmDrive