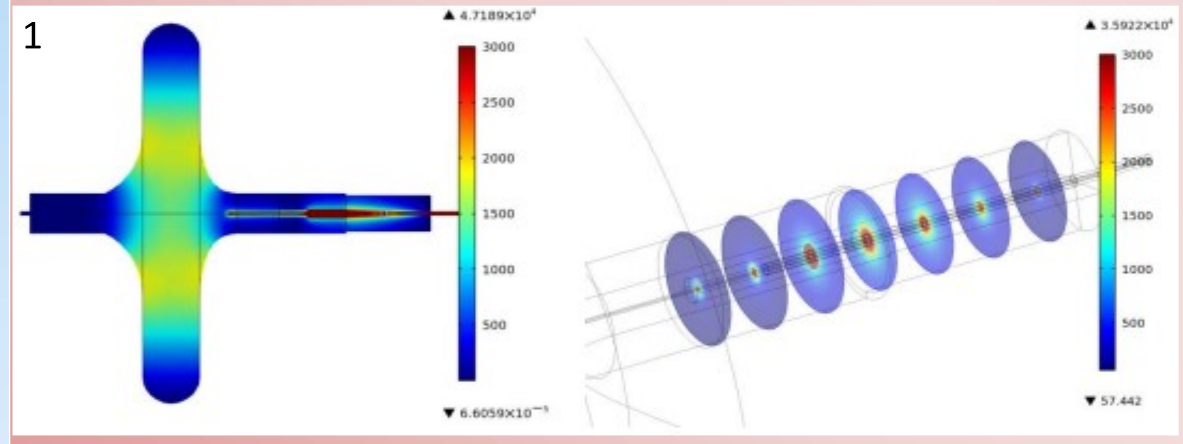
Radiofrequency Resonant Cavity Thruster Research Project

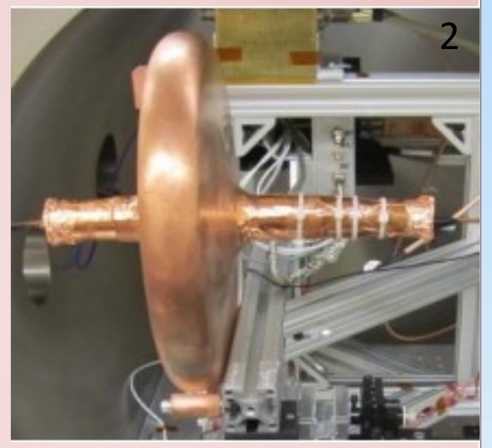
Previous Research

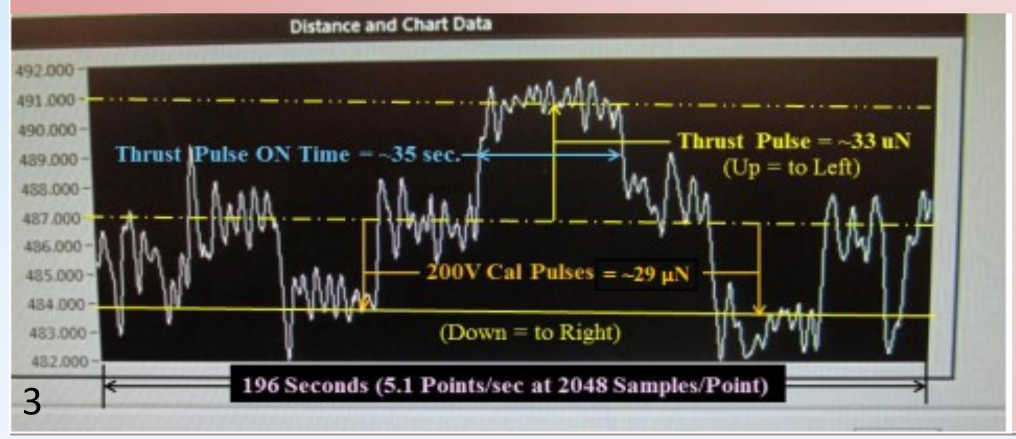
Research has been conducted in this field of propulsion for nearly a decade. The first example of this method propulsion being tested can be traced to Roger Shawyer and his development of the *Emdrive*. Three years later, the Chinese Academy of Sciences at the Northwestern Polytechnical University in Xi'an conducted experiments to determine if the device produces thrust. In 2011, a similar thruster was developed by Guido Fetta known as the *Cannae Drive*, which is comparable in design and methodology to the *Emdrive*. This thruster was then tested by NASA in 2013 at the Johnson Space Center by Eagleworks. The Chinese Academy of Sciences' and NASA's findings and conclusions are detailed below:

Portion of the Introduction and Abstract Found In NASA Report[1]:

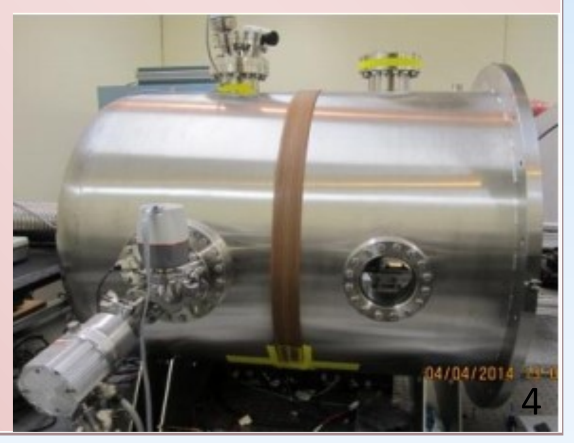
During 2013, Eagleworks Laboratories shifted from investigating previous QVPT designs to investigations involving RF resonant cavities. The first portion of the resonant cavity campaign (Cannae) was conducted during the summer of 2013 and was followed by a subsequent campaign (tapered cavity) that commenced in early 2014. Both resonant cavity designs were evaluated using a low-thrust torsion pendulum that is capable of detecting force at a single-digit micronewton level. During the first (Cannae) portion of the campaign, approximately 40 micronewtons of thrust were observed in an RF resonant cavity test article excited at approximately 935 megahertz and 28 watts. During the subsequent (tapered cavity) portion of the campaign, approximately 91 micronewtons of thrust were observed in an RF resonant cavity test article excited at approximately 1933 megahertz and 17 watts. Test campaign results indicate that the RF resonant cavity thruster design, which is unique as an electric propulsion device, is producing a force that is not attributable to any classical electromagnetic phenomenon and therefore is potentially demonstrating an interaction with the quantum vacuum virtual plasma.


1


2



3


4

Portion of the Introduction Found in the Chinese Academy of Sciences Report[2]:

Roger Shawyer of British Satellite Propulsion Research Co., Ltd. (SPR Ltd.) conducted important research into propellantless microwave thrusters. Roger Shawyer called the propellantless microwave propulsion devices the "electromagnetic drive" (emdrive). In 2003, he developed the first emdrive. Its diameter is 160mm, and its microwave power consumption is 850W. Using a balance beam method, the obtained actual thrust value was measured at 16mN. In 2006, Roger Shawyer developed a second emdrive. Its diameter is 280mm, and its power consumption is 1200W. Using horizontal and hanging measurement programs to measure the thrust, the obtained actual thrust value was 250mN. In 2007, Roger Shawyer carried out dynamic testing in a low-resistance suspended rotating platform. The results of the experiment were that when the second emdrive consumed microwave power of 1000W, thrust reached 287mN and the 100kg air suspension platform was accelerated to 2cm / s.

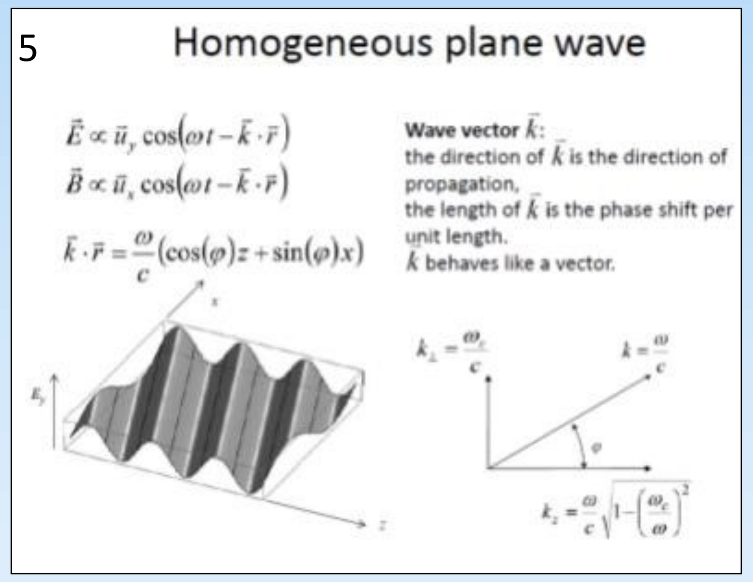
Abstract

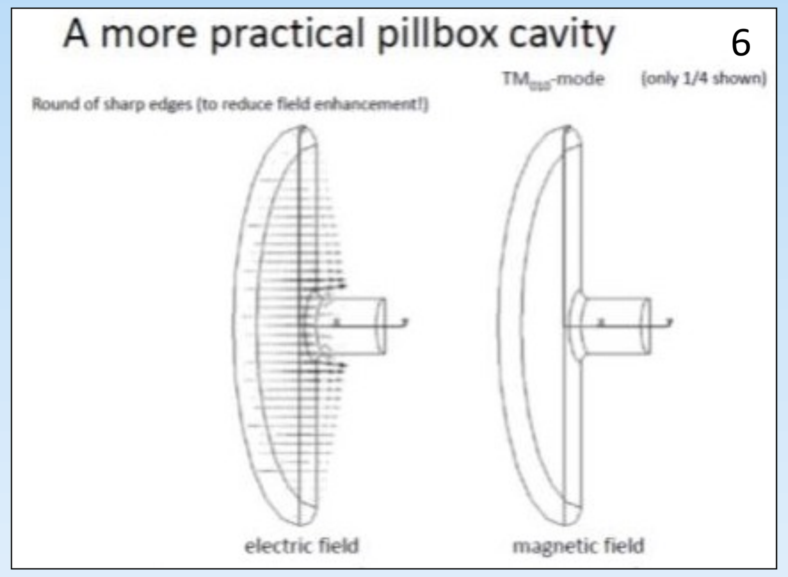
In order to meet the needs of new and more ambitious space missions, a new form of space propulsion must develop. The method of propulsion with the greatest potential to influence the space industry is the RF Resonant Cavity Thruster. This thruster is a new type of technology that was developed by Roger Shawyer and Guido Fetta as a way of producing small amounts of thrust without any onboard reaction mass. This project focuses on learning from the experiments conducted by NASA and the Chinese on this form of propulsion to design and build a new version of the thruster. These previous results and conclusions, combined with other equations and design methodologies for building a resonant cavity/waveguide will be used to design a different variation of thruster. The research is primarily focused towards a conceptual design projected over the next year, but there is potential to build and test the device. The research is based on topics such as resonant cavity/waveguide particle accelerator design, quantum mechanics, and superconductivity.

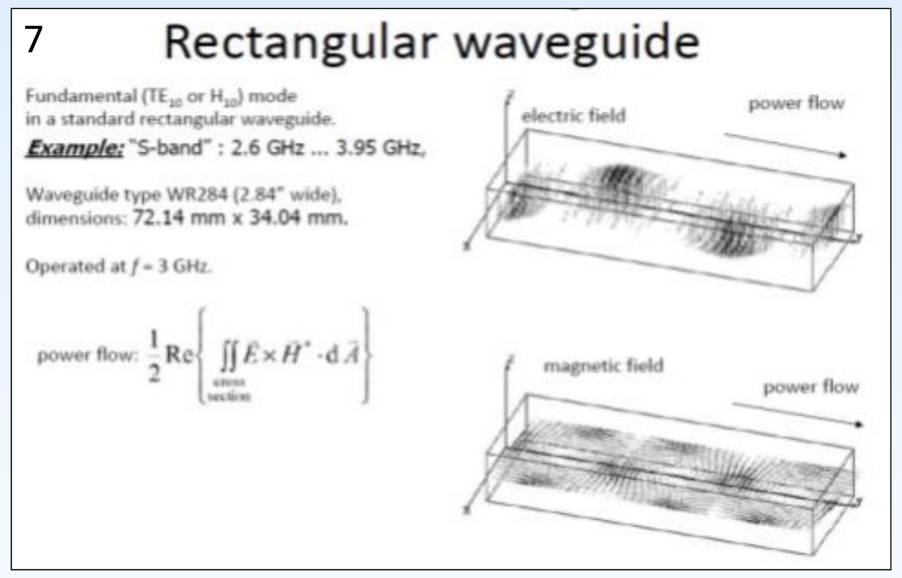
Are RF Resonant Cavity Thrusters a feasible method of propulsion? If so, is there a better way to produce more thrust than has already been seen in previous experiments?

Hypothesis

Although the previous tests of radio frequency resonant chambers have produced minimal thrust, this is primarily because the chambers have been designed and built only as proof of concept. The purpose of this research project will be to take the this concept and optimize it to prove the viability of the technology. The optimization will focus on the equations behind the design, which stem from waveguides and pillbox cavities, and the material with which the chamber is made. Different techniques will also be utilizes to power the device compared to conventional methodologies.







Investigators

Dr. Charles Lee- Faculty Mentor, Embry-Riddle Aeronautical University- Assistant Professor of Engineering Physics

Andres Artze- Embry-Riddle Aeronautical University- Aerospace Engineering- Sophomore

John Lobdell- Embry-Riddle Aeronautical University- Aerospace Engineering- Sophomore

Jonathan Rach- Embry-Riddle Aeronautical University- Software Engineering- Freshman

Kari Slotten- Embry-Riddle Aeronautical University- Engineering Physics- Sophomore

Applications

This new form of propulsion offers to greatly reduce the travel times for missios in deep space. Other applications also include satellite deployment and the possibility of multiple missions and destinations for a single space probe. More detailed applications have also been described by NASA's Report[1]:

Based on test data and theoretical model development, the expected thrust to power for initial flight applications is expected to be in the 0.4 newton per kilowatt electric (N/kWe) range, which is about seven times higher than the current state of the art Hall thruster in use on orbit today. The following figures show the value proposition for this class of electric propulsion. Figure 23 shows a conservative 300 kilowatt solar electric propulsion roundtrip human exploration class mission to Mars/Deimos. Figure 24 shows a 90 metric ton 2 megawatt (MW) nuclear electric propulsion mission to Mars that has considerable reduction in transit times due to having a thrust to mass ratio greater than the gravitational acceleration of the Sun (0.6 milli-g's at 1 AU). Figure 25 shows the same spacecraft mass performing a roundtrip mission to the Saturn system spending over a year around two moons of interest, Titan and Enceladus. Even in this last class of mission which requires only a single heavy lift launch vehicle, the mission has less mission duration than is common with a current conjunction-class Mars mission using chemical propulsion systems and which would require multiple heavy lift launch vehicles.

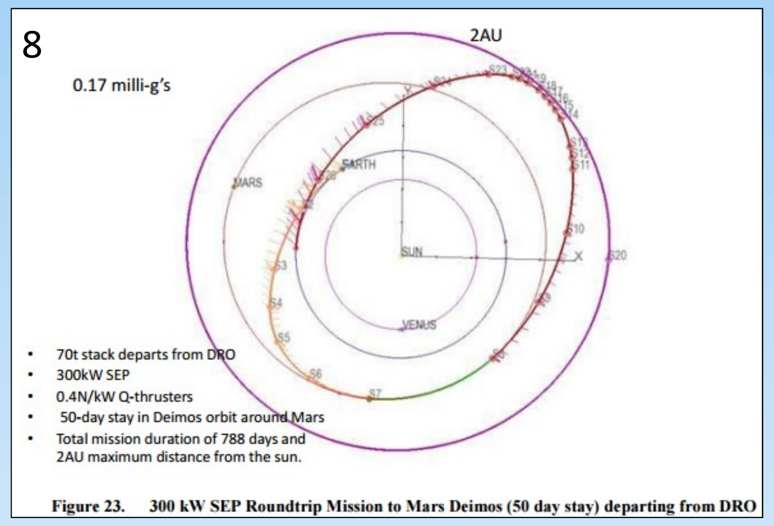


Figure 23. 300 kW SEP Roundtrip Mission to Mars Deimos (50 day stay) departing from DRO

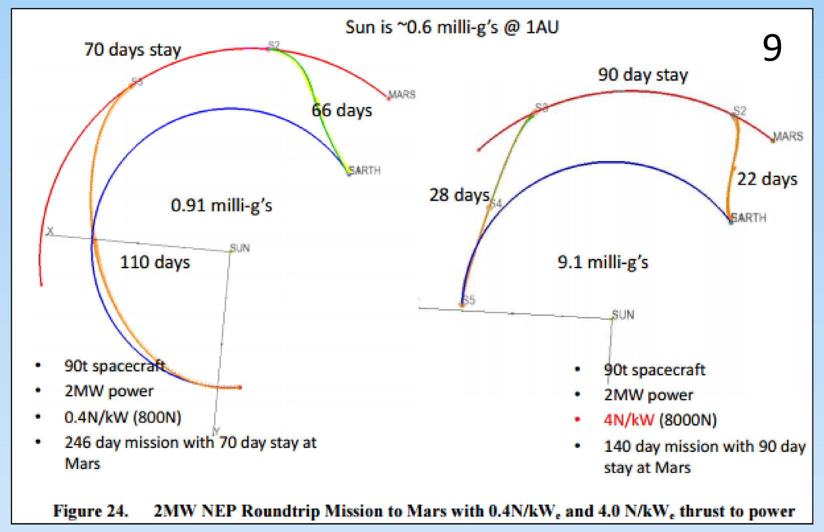


Figure 24. 2MW NEP Roundtrip Mission to Mars with 0.4N/kW, and 4.0 N/kW, thrust to power

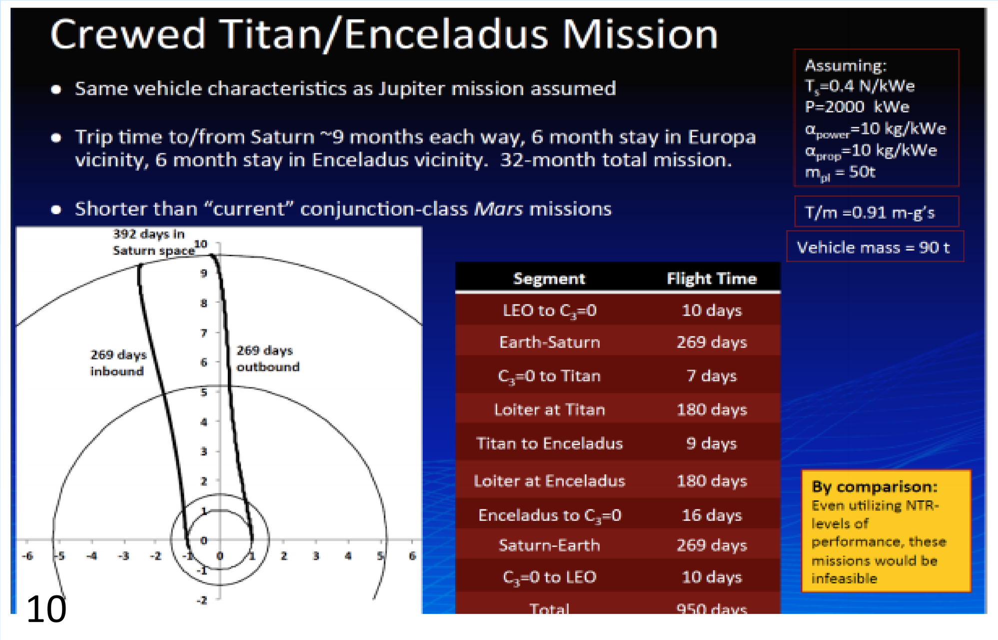


Figure 25. 2MW NEP (90t spacecraft) Crewed Titan/Enceladus Mission with 0.4N/kW, thrust to power

Picture Descriptions

1. COMSOL analysis of the Cannae Drive. [1]
2. Side view of the Cannae drive in the testing chamber. [1]
3. Graph of the results found when measuring thrust. [1]
4. External view of the test chamber. [1]
5. Describes how an electromagnetic wave moves through space [3]
6. Shows alternative geometries when designing a cavity. [3]
7. Graph of the power concentrations within the waveguide. [3]
8. Details a possible flight plan for a mission to Mars using this form of thruster [1].
9. Comparison of flight plans of alternative thrust capable engines. [1]
10. Details a possible flight plan to Enceladus or Titan if this device is used. [1]

Works Cited

[1] Brady, D. A., White, H. G., March, P., Lawrence, J. T., & Davies F. J. (2014, July 28). Anamolous thrust production of an RF test device measured on a low-thrust torsion pendulum. *American Institute of Aeronautics and Astronautics.* doi: 10.2514/6.2014-4029

[2] Emdrive. (2007). In Una McGovern (Ed.), *Chambers dictionary of the unexplained.* Retrieved from http://ezproxy.libproxy.db.erau.edu/login?url=http://search.credoreference.com.ezproxy.libproxy.db.erau.edu/content/entry/chambun/emdrive/0

[3] Jensen. (2011). *RF Cavity Design.* Retrieved March 15, 2015, from CERN Accelerator School: http://cas.web.cern.ch/cas/Greece-2011/Lectures/Jensen.pdf