**WAVE ASSISTED ELECTRONIC PROPULSION SYSTEMS: A NOVEL APPROACH TO INCREASING THRUST EFFICIENCY USING SOUND**

**PART 2, OF A CONTINUING SERIES**

*Simulating Electronic Propulsion: Using Sound to Accelerate Particle Velocity*

**Undergraduate Research 294**

Winter 2018 Quarter Research Proposal (ENGINEERING REVISION 1)

Team Name: “CGSCC”

Authored By: Cory Andrew Hofstad

1. **Introduction:**

Increasing thruster performance while reducing dependency on chemical fuel is essential to future spaceflight applications. (1) Research projects goals for Spring 2018 consist of investigations using harmonic oscillation resonance of a 9”, dual-coil wave driver to create kinetic energy in *Lycopodium* (a substance used to simulate gas). Spring quarter will be dedicated to increasing particle velocity in our *Lycopodium* while attaining a stable geometric pattern in our oscillation chamber using sound waves generated by software interface on a laptop computer.

**NEW RESEARCH**

Currently, increasing thrust velocity during the pre-exhaust stage is done through the use of thermal and electromagnetic energy. Current methods for increasing thruster performance include manipulation of cathode shape(2), wall materials(3), anode geometry(4), channel length(5), magnetic field strength(6), and column configuration(7).

Methods of increasing electronic propulsion velocity using sound add to the body of scientific knowledge associated with aerospace engineering, space travel, and electronic propulsion. These investigations provide scientists and engineers with new and alternative methods for increasing efficiency in propulsion systems, which are used in satellites, space stations, deep space expeditions, and manned spaceflight. If successful, this project will extend the range of chemical fuel restricted missions by creating additional thrust from electrical energy which is converted to exhaust velocity through sound wave. Successful results have the potential to cut down travel time associated with spaceflight using electronic propulsion systems and can also decrease dependency on chemical fuel which is used to attain velocity.

**II. Research Question:**

**“Can an embedded wave driver be used to increase kinetic energy in electronic propulsion devices?”**

**ADRESSING BIG PICTURE**

Research in sound wave assisted electronic propulsion is being done to address the issue of both space transportation efficiency and thruster performance for future spaceflight missions.

The hypothesis of this experiment is as follows:

1. Sound can be used as a method to transfer stored electrical energy into usable exhaust velocity.
2. Energy transfer through sound wave is a novel method of reducing overall dependence on chemical fuel and its associated mass during spaceflight.
3. Through the use of sound, greater overall inertia can be maintained during long voyages by increasing kinetic energy of propellant gases during pre-ejection stages, allowing for higher velocities per mol of chemical fuel.

Harmonic oscillation of propellant gases using an embedded wave driver is a novel method for increasing thrust efficiency during spaceflight. This experiment looks for qualitative and quantitative results during oscillation of *Lycopodium* (8); a gas like particle used in physics, in an effort to produce spherical vortex formations which can be guided down the exhaust column using standard electronic propulsion methods to create increased exhaust velocity. Size and shape of vortex formations can be increased and decreased through tuning of amplitude and frequency during calibration. During early testing and experimentation during spring break, geometric formations and an increase in velocity from rest and a visible structure was found at 47 Hz when using various amplitudes. This suggests that our hypothesis may be correct and brings this project closer attaining proof of concept, which will hopefully assist in attaining expert analysis and additional funding for further experimentation.

**III. Methods:**

**Investigation of *Lycopodium* oscillated by sound wave**

**in a cylindric column with 9” diameter and adjustable length**

During Spring quarter 2018, we will use a 9” dual channel wave driver to observe geometric patterns in sound waves created using a software synthesizer.

Qualitative observations will be used to determine at which frequencies sound in a column will create geometric patterns in *Lycopodium*. These observational methods will be used to calibrate frequencies, which can be used to find which combinations of (frequency, amplitude, and wave type) allow for the best transformation of energy into the *Lycopodium* powder.

While observing *Lycopodium* during oscillation, frequencies which produce repeating patterns and geometric formations will be recorded. Recorded frequencies will then be observed under varying amplitudes to determine amplitudes which offer the best structural stability under high amplitude vibration. Higher amplitudes of oscillation within our vortex pattern will give us a higher transfer of energy into particle velocity from our wave driver.

Acceleration of *Lycopodium* powder will be used as a proof of concept for acceleration of other reagents via sound. The method of accelerating particle velocity via sound will be used in future research involving gases such as SF6 and xenon. Acceleration of chemical fuel in can be used during pre-exhaust stages to allow for higher exhaust velocities in experimental electronic propulsion devices.

**Safety Protocols**

The group has been aware of a specific safety concern involving this experiment, related to the reagent “Lycopodium Powder” which the project has chosen for oscillation.

1. Lycopodium is classified as a category 1 combustible dust.

During oscillation of Lycopodium powder, the experiment will follow the following GHS precautionary statements which are assigned to lycopodium, outlined in attached Lycopodium Safety Data Sheet “S25396.pdf” from Fisher Scientific.

**IV. Equipment, Reagents, Supplies and Other Needs:**

For equipment list used in this experiment, please see attached excel spreadsheet “ Hardware.xlsx”.

For this experiment, a standard speaker box has been outfitted with a cardboard tube, attached perpendicular to the speaker, for oscillation of *Lycopodium* powder. Signals used for oscillation of *Lycopodium* will be generated using a laptop and computer software. The wave driver for this experiment is a 9” dual coil car audio speaker powered by a 300-watt dual channel car amplifier and +12VDC Power Supply.

The combination of laptop and car audio electrical equipment over EET Department signal generation electrical equipment was chosen from a need for a mobile soundwave research platform which would not rely on expensive lab equipment from the North Seattle Electronics Engineering Department.

The current lab environment consists of a standard midrange-subwoofer in a speaker box with an audio input connected to a laptop running professional audio-acoustical engineering software. The addition of a cardboard column to the speaker allows for controlled oscillation of the *Lycopodium* powder.

**V. Project Timeline:**

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| **Week** | **Goals** |
| 1 (4/2 – 4/6) |  |
| 2 (4/9 – 4/13) | Final Proposal Due  Rocket Club! |
| 3 (4/16 – 4/20) | Poster Intro and Layout Due  Rocket Club! |
| 4 (4/23 – 4/27) | Poster Methods Draft Due  Rocket Club! |
| 5 (4/30 – 5/4) | Poster Results Draft Due  Rocket Club! |
| 6 (5/7 – 5/11) | Complete Poster Draft Due  Rocket Club! |
| 7 (5/14 – 5/18) | PRINT POSTER  5/18 Research Symposium @ UW  Rocket Club! |
| 8 (5/21 – 5/25) | Improve Presentation for NSC Expo  Rocket Club! |
| 9 (5/28 – 6/1) | 5/31 Research Symposium @ NSC  Start Propulsion Research Portfolio  Rocket Club! |
| 10 (6/4 – 6/8) | Complete S18 notebook  Rocket Club! |
| 11 (6/11 – 6/15) | Rocket Club! |

**Conclusion:**

Simplifying research into a clear, step-by-step process is helping this project progress to a point where on campus lab work can be accomplished through shop resources in the North Seattle College Rocketclub Workshop. The NSC rocket club is managed by Engineering and Physics faculty member Tracy Furutani, who is also the lab equipment supervisor for the physics department. Tracy has shown great interest and knowledge of my field and project goals and has provided positive support and acted as an educational resource since this project was first proposed.

This experiment would most likely remain unfeasible for on-campus lab work without the NSC rocket-club, whose members are all involved in some type on engineering, many who are in the field of space propulsion and aerospace. The shop area, students, and faculty involved within the rocket club are also prepared to deal with the dangers and safety precautions involved with working around sawdust and other combustible materials from both wood, glue and plastics and have very supportive of my project’s involvement within the rocket-club workshop.

As the rocket club is also a privately funded school project, it has shown the project’s value as being a privately funded research project. All materials and hardware used for this project are student owned by researchers, which allows for easy transport for outside testing and demonstration.

This quarter will be dedicated to further establishing a research portfolio in Electronic Propulsion research as well as making preparations for the research symposium at University of Washington. Safety concerns and budgeting issues from previous proposals have been addressed through private funding and implementing an step-by-step process. Active research has been started in an exciting field which has gained on campus support and project help from students and faculty involved in the Rocket Club.

**References**:

1. Jahn, R. G., & Choueiri, E. Y. (2003). Electric Propulsion. Encyclopedia of Physical Science and Technology, 125-141. doi:10.1016/b0-12-227410-5/00201-5 URL: <http://alfven.princeton.edu/publications/ep-encyclopedia-2001>
2. Lun, J., & Law, C. (2015). Influence of Cathode Shape on Vacuum Arc Thruster Performance and Operation. IEEE Transactions On Plasma Science, 43(1), 198-208. doi:10.1109/TPS.2014.2361439
3. Poizin, K. A., & Reneau, J. P. (2009). Effect of Conductive Walls on the Performance of a Pulsed Inductive Thruster. IEEE Transactions On Plasma Science, 37(2), 359-364. doi:10.1109/TPS.2008.2009987
4. Uchigashima, A., Baba, T., Ichihara, D., Iwakawa, A., Sasoh, A., Yamazaki, T., & ... Iwasaki, T. (2016). Anode Geometry Effects on Ion Beam Energy Performance in Helicon Electrostatic Thruster. IEEE Transactions On Plasma Science, 44(3), 306-313. doi:10.1109/TPS.2016.2522079
5. Ding, Y., Boyang, J., Sun, H., Wei, L., Peng, W., Li, P., & Yu, D. (2018). Effect of matching between the magnetic field and channel length on the performance of low sputtering Hall thrusters. Advances In Space Research, 61(3), 837-843. doi:10.1016/j.asr.2017.11.003
6. Holak, K., Wonho, C., Youbong, L., Seunghun, L., & Sanghoo, P. (2017). Magnetic field configurations on thruster performance in accordance with ion beam characteristics in cylindrical Hall thruster plasmas. Applied Physics Letters, 110(11), 1-5. doi:10.1063/1.4978532
7. Peng, H., Hui, L., Yuanyuan, G., & Daren, Y. (2016). Effects of magnetic field strength in the discharge channel on the performance of a multi-cusped field thruster. AIP Advances, 6(9), 1-8. doi:10.1063/1.4962548