SLATT UNDERGRADUATE RESEARCH FELLOWSHIP
FINAL REPORT

SCHOLAR NAME:	Evan Bursch
FACULTY ADVISOR:	Professor Ryan McClarren
PROJECT PERIOD:	Fall and Spring 2023
PROJECT TITLE:	Formulating a spherical model of radiation hydrodynamics from the planar Hammer and Rosen model
CONNECTION TO ONE OR MORE ENERGY-RELATED RESEARCH AREAS (CHECK ALL THAT APPLY):	**( ) Energy Conversion and Efficiency** **(X) Sustainable and Secure Nuclear** **( ) Smart Storage and Distribution** **( ) Transformation Solar** **( ) Sustainable Bio/Fossil Fuels** **( ) Transformative Wind**

MAJOR GOALS AND ACCOMPLISHMENTS

Summarize your research goals and provide a brief statement of your accomplishments (no more than 1-2 sentences). Indicate whether you were able to accomplish your goals by estimating the percentage completed for each one. Use the next page for your written report.

RESEARCH GOALS	ACTUAL PERFORMANCE AND ACCOMPLISHMENTS	% OF GOAL COMPLETED
Produce theory and simulation on 1 dimensional radiation hydrodynamics based on the Hammer and Rosen model	Accomplished to the level needed to carry out goal 2.	100%
Produce a spherical variation of the 1-dimensional planar case of the Hammer and Rosen model of radiation hydrodynamics	Considerable progress has been made. We remain in the final stages of validation on our initial progress in development.	80 %

RESEARCH OUTPUT

Please provide any output that may have resulted from your research project. You may leave any and all categories blank or check with your faculty advisor if you are unsure how to respond.

CATEGORY	INFORMATION
EXTERNAL PROPOSALS SUBMITTED	(Sponsor, Project Title, PIs, Submission Date, Proposal Amount)
EXTERNAL AWARDS RECEIVED	(Sponsor, Project Title, PIs, Award Date, Award Amount)
JOURNAL ARTICLES IN PROCESS OR PUBLISHED	(Journal Name, Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
BOOKS AND CHAPTERS RELATED TO YOUR RESEARCH	(Book Title, Chapter Title, Authors, Submission Date, Publication Date, Volume #, Page #s)
PUBLIC PRESENTATIONS YOU MADE ABOUT YOUR RESEARCH	(Event, Presentation Title, Presentation Date, Location)
AWARDS OR RECOGNITIONS YOU RECEIVED FOR YOUR RESEARCH PROJECT	(Purpose, Title, Date Received)
INTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions) Work with Ethan Smith, a graduate student in the Engineer department. Weekly meetings.
EXTERNAL COLLABORATIONS FOSTERED	(Name, Organization, Purpose of Affiliation, and Frequency of Interactions)
WEBSITE(S) FEATURING RESEARCH PROJECT	(URL)
OTHER PRODUCTS AND SERVICES (e.g., media reports, databases, software, models,	(Please describe each item in detail)

curricula, instruments, education programs, outreach for ND Energy and other groups)	

RESEARCH EXPERIENCE
Please let us know what you thought of your research experience: Did this experience meet your expectations? Were lab personnel helpful and responsive to your needs? What else could have been done to improve your experience or achieve additional results?
This experience exceeded my expectations. Working with Professor McClarren and Ethan Smith has been highly formative for me as a student and a researcher. It also directly led to my acceptance to a summer program at the DIII-D National Nuclear Fusion Facility in the Summer of 2023. Recently, it has contributed to my acceptance to the Columbia University Ph.D. program in Applied Physics to study plasma physics and nuclear fusion energy production.

FINAL WRITTEN REPORT

(Please use the space below to describe your research project and objectives, any findings and results you can share, and graphs, charts, and other visuals to help us understand what you achieved as a result of this research experience.)

Formulating a spherical model of radiation hydrodynamics from the planar Hammer and Rosen model

Evan M. Bursch, Ethan Smith, Ryan McClarren

Introduction

The field of nuclear fusion research represents a bright future for clean and sustainable energy production. Fusion produces more energy per amount of fuel than any other method of energy production (including coal, oil, natural gas, nuclear fission, etc.), and is an inherently safer method than nuclear fission power plants. Fusion produces no long-term radioactive waste and is unable to cause safety issues with runaway chain reactions, since it requires a continuous source of fuel in order to continue producing energy. One method for nuclear fusion energy production which thus far has produced the greatest output of power to energy input is the method of inertial confinement nuclear fusion. The flagship United States institution working on this is the Lawrence Livermore National Laboratory's National Ignition Facility. There they first produced a net gain of 'lab frame' energy from a nucelar fusion reaction. This has been continually developed there and other places around the world including many labs and universities. This research contributes to this area of fusion energy, because the reactions at the National Ignition Facility are of sufficient energy and density that it is governed by the laws of high energy density physics known as radiation hydrodynamics. Specifically, we seek to develop a spherical formulation of one of the traditionally used models of radiation hydrodynamical systems known as the Hammer and Rosen model. The spherical formulation will allow for increased computational accuracy and efficiency when compared to current methodologies being used in national laboratories as well as private companies.

Our Work

Over the last year, thanks to the support of The Vincent P. Slatt Fellowship for Undergraduate Research in Energy Systems and Processes, we have built out a more robust version of the planar case of the Hammer and Rosen model. By filling in derivations and working on simulations based off their initial paper, we have been able to successfully reproduce their results and apply it to problems relevant to inertial confinement fusion energy production. Next, we took the robust planar Hammer and Rosen model and worked on a spherical formulation of the model in order to simulate with greater speed and accuracy complex spherical inertial confinement fusion energy experimental conditions. While this work is still in progress, we have made great strides in this development and are close to fully validated spherical formulation of the Hammer and Rosen radiation hydrodynamic model. Some of our initial validations are seen in Figure 1 below. It displays a comparison of the analytical, spherical, Hammer and Rosen model with a Sigmoid Analytical approximation and a numerical method approximation. The figure also shows that the model produces more accurate results for a decreasing value of epsilon, which is a physically derivable quantity equal to beta divided by the quantity four plus alpha. Epsilon is inherent to every material used for the experiment. This knowledge of proportional accuracy to epsilon informs experimental design of the materials used in the inertial confinement fusion energy experiments.

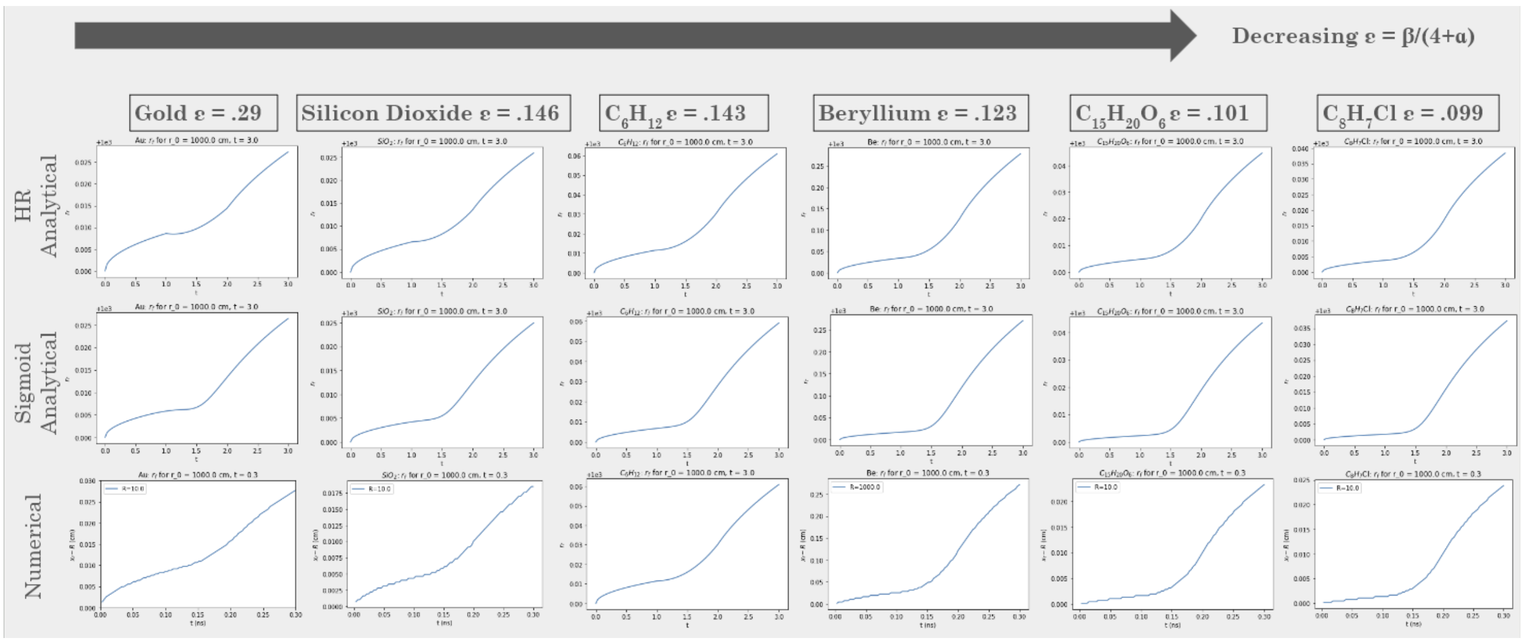

Figure 1: A variety of plots generated of the spherical simulation of the 1-dimensional formulation we derived from the planar Hammer and Rosen radiation hydrodynamics model.

Conclusion

This past year, thanks to the Slatt Family, we have produced a more robust planar Hammer and Rosen radiation hydrodynamics model which is the necessary basis for the formulation of a spherical version. Then, we worked off of the planar case to contrast a novel spherical radiation hydrodynamics model which can be used to model inertial confinement nuclear fusion energy experiments. Going forward, further work will be done to finish validation of the spherical model and we hope to publish the results. Then, experimental work can be done to validate the accuracy of the model and determine the relative strengths and weaknesses that it provides researchers when compared with alternative formulations or methodologies used in the field of radiation hydrodynamics simulations.