[TYPE THESIS TITLE]

An Undergraduate Research Scholars Thesis

by

James Leaverton

Submitted to the LAUNCH: Undergraduate Research office at

Texas A&M University

in partial fulfillment of requirements for the designation as an

UNDERGRADUATE RESEARCH SCHOLAR

Approved by

Faculty Research [Choose an item: Advisor/s]: Dr. Thomas E. Lacy

May 2021

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# Abstract

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[To our friends, families, instructors, and peers who supported us throughout the research process.]

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Contributors

I would like to thank my faculty advisor, Dr. [XXXX], and my [XXXX], [XXXX], for their guidance and support throughout the course of this research.

Thanks also go to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience.

Finally, thanks to my [XXXX] for their encouragement and to my [XXXX] for her/his/their patience and love.

The [DATA/MATERIALS/etc.] analyzed/used for [MANUSCRIPT TITLE] were provided by [NAME – can be the names of other faculty, graduate students, lab, lab members, teammates, etc. who contributed to specific aspects of the project]. The analyses depicted in [MANUSCRIPT TITLE] were conducted in part by [NAME – can be the name of a department, lab, research group, etc.] and were published in [YEAR] [OR and these data are unpublished].

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[MODIFY SAMPLE wording below]

[B/CS Bryan/College Station

HSUS Humane Society of the United States

P Pressure

T Time

TVA Tennessee Valley Authority

TxDOT Texas Department of Transportation]

## Introduction

[PAGE INSTRUCTIONS AND SAMPLE WORDING] [see comment]

Section 1 should can range from a few paragraphs to a few pages and can contain in-text citations if you wish. If in-text citations are used in the Introduction section, you must include a References first-order subheading at the end of the section. Do not change the title of the section. In this section, be sure to tie your manuscripts together in a cohesive manner and demonstrate the overarching theme of your thesis.

[MODIFY SAMPLE WORDING BELOW]

Recent developments in hypersonic capabilities by the United States’ foreign adversaries, along with the increasing amount of man-made orbital debris (MMOD) are creating a demand in the scientific community for hypervelocity impact (HVI) investigations. Hypervelocity impact occurs when a projectile with a relative velocity greatly exceeding the standard temperature and pressure speed of sound (commonly defined as greater than Mach 5 or ~2000 m/s). Defending against these HVIs is crucial as even microscopic projectiles traveling at hypervelocity pose a serious threat. Due to these threats, developing structural materials to protect against HVIs is a vital to the security of our nation.

The Hypervelocity Impact Laboratory (HVIL) at Texas A&M University conducts research to enable unique high strain-rate materials characterization along with multiscale numerical model development and implementation. The HVIL features a robust testbed for the development and testing of materials to mitigate HVIs. Experiments are conducted using a state-of-the-art 2-stage light gas gun (2SLGG) capable of launching 2-10 mm diameter projectiles at velocities in the range of 2-8 km/s. The 2SLGG is equipped with a high-speed camera capable of filming up to 10 million frames per second, as well as other diagnostic equipment such as a flash X-Ray system, a high speed thermal imaging camera, an AMOtronics Transient Recorder system, and a photon Doppler velocimetry system. This highly capable in-situ diagnostic setup allows for the comprehensive study of hypervelocity impact phenomena.

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Figure 1: A 3D-render of the HVIL 2SLGG. The render features the downrange portion of the gun on the left, and the uprange on the right.

Achieving hypervelocity with an increasing projectile mass is a considerable feat. The 2SLGG, shown in Figure 1, accelerates projectiles in two stages: first, a firing system ignites a primary charge in the firing breech, located at the most uprange point. This charge in turn lights the secondary charge, whose mass serves as the 2SLGG’s primary performance variable. The resulting expanding gas forces a polymer piston downrange through the pump tube. This piston compresses a light gas, typically hydrogen. The gas is compressed into the central breech, which hydraulically separates the high-pressure pump tube (first stage) from the evacuated launch tube, blast tank, and target tank (second stage) via a petal valve (i.e. pressure disk). Upon reaching a critical pressure, the petal valve ruptures, freeing the high-pressure working gas into the launch tube, rapidly accelerating the projectile package downrange towards the blast tank.

The 2SLGG features a smooth-bore launch tube, allowing for multiple size projectiles to be launched using a projectile package, commonly referred to as a sabot. The sabot is usually formed with four ‘petals’ that surround the projectile while fitting flush inside the launch tube.

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[1] S. M. Misemer, “Bridging the gaps in cultural memory: Carlos Gorostiza’s El puente, and Gabriel Peveroni’s Sarajevo esquina Montevideo (El puente),” *Latin American Theatre Review*. 2005, doi: 10.1353/ltr.2005.0015.

[2] S. H. Russell, M. P. Hancock, and J. McCullough, “Benefits of undergraduate research experiences,” *Science*. 2007, doi: 10.1126/science.1140384.

## First Manuscript Title[[1]](#footnote-1)

[page INSTRUCTIONS] [see comment]

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### Introduction

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### Methods

#### First Manuscript Second-order Subheading

To determine the degree of sabot petal separation in the 2SLGG, visual data was acquired through photography of the sabot stripper plate. After aerodynamic separation, sabot petal impacts result in large indentions in the steel stripper plate. Throughout the stripper plate’s service life, the resulting surface damage compounds to form a cratered surface. To distinguish new impacts, standard operating procedure included painting the face of the sabot stripper with a white primer spray paint. After the hypervelocity test occurred, the stripper plate was inspected and photographed. The photography configuration consisted of an iPhone camera balanced on the baffle in the center of the blast tank focused on the stripper plate. The phone was positioned so that the central vector of the camera’s field of view was coincident with the axis of penetration and normal to the face of the stripper plate (Figure 2a). Post-test photography was performed on successful tests, defined as all four sabot petals impacting the stripper plate.

The raw images were then imported into Adobe Photoshop on a standard canvas size of 2000 by 2000 pixels. The images were scaled to position the outer circumference of the stripper plate concentric with a standard circular outline (diameter of 1836 pixels) centered on the canvas. Three images were not photographed in a configuration coincident with the axis of penetration and were adjusted with Photoshop’s perspective tool to remove any eccentricity, assuring normalcy.

Sabot petal impacts form indentations 0.15 – 0.75 in. deep depending on the grade of steel and impact velocity. These indentions expose new steel not coated in the white paint. The exposed steel contrasts with the white paint, permitting easier identification of the impact location. These impact locations were traced and converted into black entities in Photoshop. As shown in Figure 2b, these entities were exported with a white background to form a black and white vector image.

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Figure 2: (a) An example of a photograph of the sabot stripper plate with impacts. (b) The same photograph converted into a black and white image in Photoshop. (c) An visual representation of the minimum, maximum, and centroid distances from the axis of penetration for a sabot petal impact entity.

To quantify the degree of sabot separation, the radial distance between each impact and the axis of penetration was measured. To convert the visual data into measurable quantities, edge detection software was developed in Python using the Open Source Computer Vision Library (OpenCV). The vector images were imported into the script and converted to greyscale, transforming the RGB channels into a single channel with each pixel being assigned an intensity value ranging from 0 (black) to 255 (white). Each greyscale image was then converted to a binary image using OpenCV’s threshold function, using the 50% grey value of 127. From this binary image data, the sabot petal impact entities were converted into contours using OpenCV.

In OpenCV, contours are identified by a curve joining all the continuous points along the boundary of an entity possessing the same color or intensity. A boundary with edge points was fitted to each impact entity, with X and Y pixel positions assigned to each edge point. For each image, the software iterated through each of the four sabot petal impact contours and found the two-dimensional Euclidian distance in pixels between each edge point and the axis of penetration (1000 px, 1000 px). The distance between the closest and farthest edge points (from axis of penetration) was recorded to characterize the degree of separation in the radial direction. These values are visualized in Figure 2c.

Additionally, the centroid, or geometric center, of each contour was found using OpenCV’s Image Moment function. Image Moment uses a weighted average of pixel intensities to calculate the centroid, but each sabot petal impact entity had a uniform intensity, effectively implementing the arithmetic mean position of all points in a shape:

The Euclidian distance between each contour’s centroid and the axis of penetration was calculated.

For each image, the contours’ centroid distances were averaged. The minimum and maximum distances were also averaged to respective values. All distances were then converted from pixels into inches.

### Results

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#### Another First Manuscript Second-order Subheading

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### Discussion

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## Second Manuscript Title

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### Introduction

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### Methods

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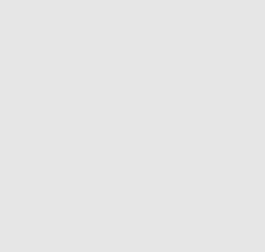


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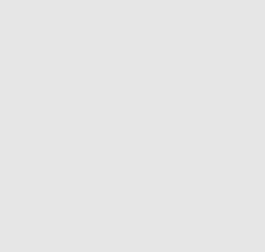


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### Discussion

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### References

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## Third Manuscript Title

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## Conclusion

[PAGE INSTRUCTIONS]

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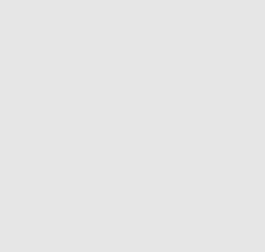


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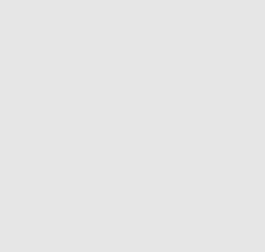


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