Guns…that save lives!? Fluid dynamics of vaccine Gene Guns

Treyson Gleich

Williams Lab

Department of Aeronautics & Astronautics

University of Washington

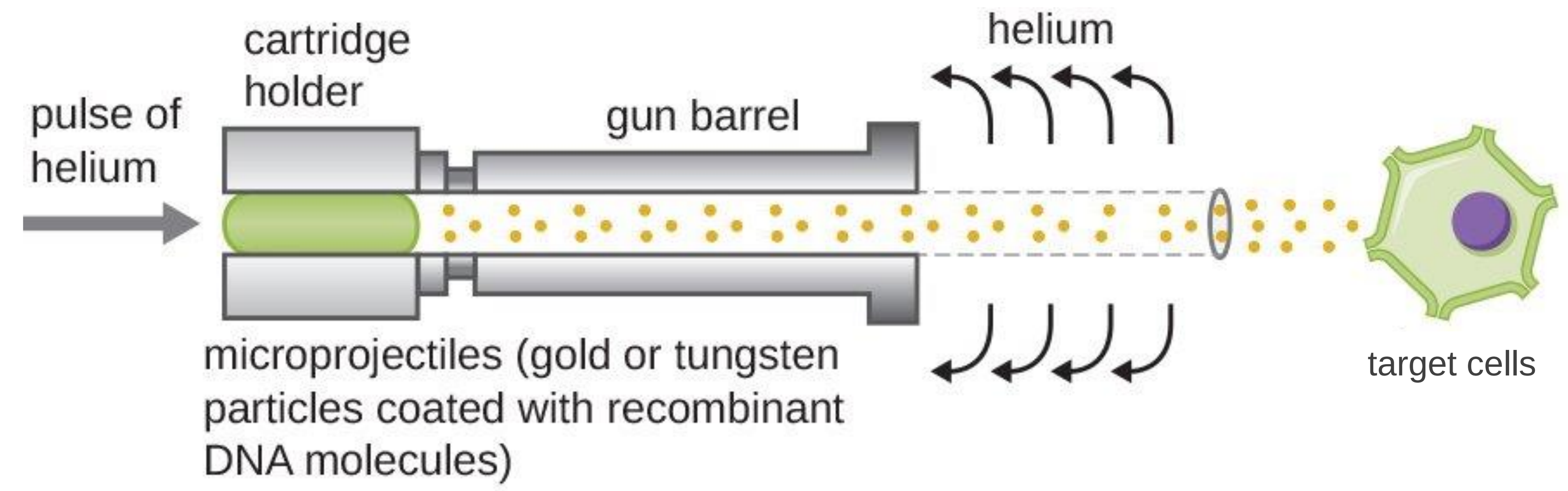
Abstract:

For over 30 years, gene guns have been studied as an alternative way for administering vaccines and other medicines. As opposed to traditional needles, a gene gun delivers vaccines by using a blast of air or helium to propel microscopic, DNA-coated beads into the skin where the body absorbs the genetic material. This method has several advantages over needle injections, including a less painful delivery, fewer disposable parts, and the ability to deliver multiple vaccines or drugs at once without reducing efficacy, an impossibility with traditional injection.

My summer research was focused on improving the gas dynamic properties of gene guns, specifically how using air instead of helium could be advantageous, as well as how different nozzle designs could improve our ability to target the flow speed and tailor it to deliver vaccines. To test these goals, two Mach 3 nozzles were designed using compressible flow calculations, one for air and one for helium. These nozzles were then studied using schlieren imaging, which visualizes flow density, to compare the properties of the waves leaving the two nozzles. At the time of writing, no video analysis has been completed, but theoretical calculations suggest the air nozzle should achieve target gas speeds with less noise and impact on the skin than the helium nozzle. Critically, the air flow should also have higher density and viscosity, allowing particles to accelerate to match the gas speed more easily, an issue facing helium gene guns. This summer, my work has centered on preparing for these experiments: creating a testing enclosure, wiring a new gene gun, reading on contoured shock tubes, setting up schlieren imaging, and 3D printing prototype nozzles. The next steps for these experiments are analyzing the nozzle flows, refining their designs, and moving on to tests with beads in the gun.

Project Goals:

1. Compare the operation of gene guns operated with air instead of Helium
2. Create testing enclosure and procedure



Solenoid opens, pulse of gas flows → Gas carries particles from cartridge → Particles accelerate down barrel → Beads embed in skin, delivering DNA

Project Outline:

- Researched the aerodynamics of gene guns, which are found to operate like Contoured Shock Tubes (CST) or wind tunnels
- Used schlieren imaging to film shock waves exiting the nozzle, allowing for velocity & pressure estimation
- Developed equipment and procedures to rapidly test prototype nozzles
- Compare qualities of air and Helium operated guns that both aim for Mach 3 shock waves

My Role

Designed & built testing enclosure to prevent injury when test firing

↓

Created wiring system that allows gun to be fired remotely

↓

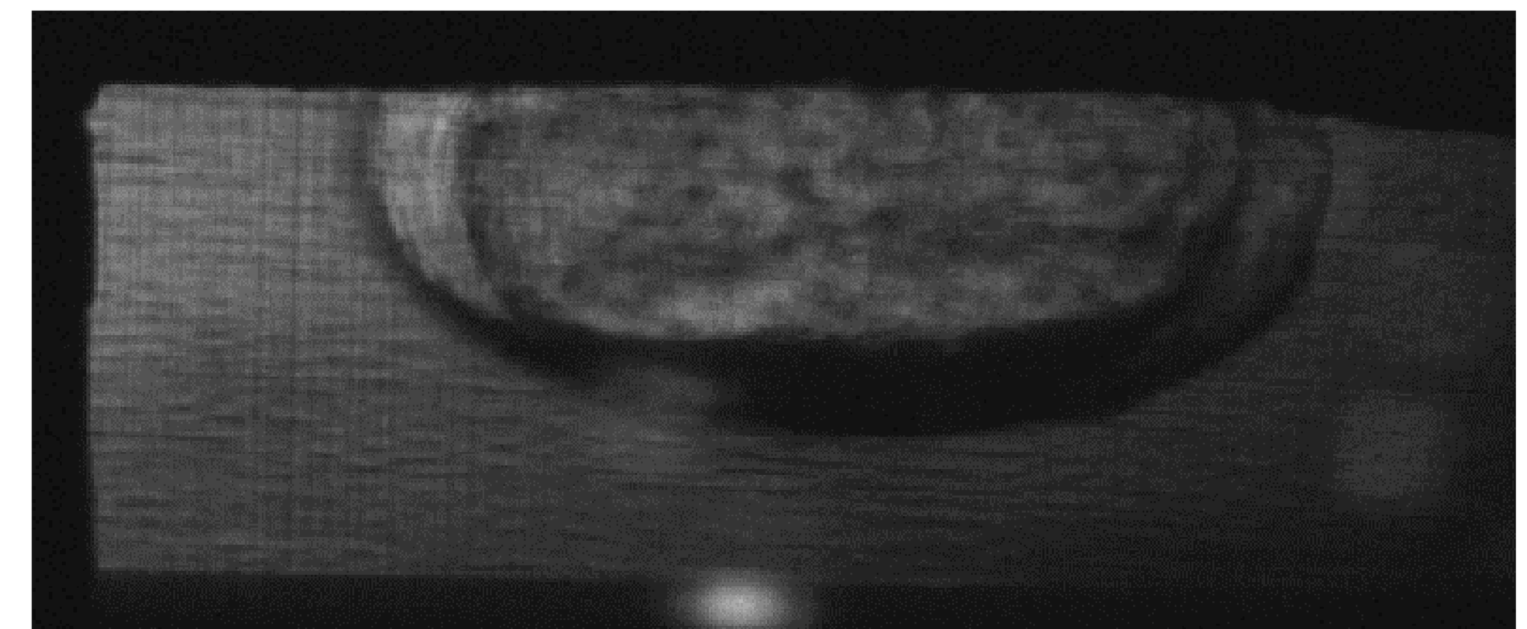
Designed & printed new nozzles to compare how air & helium behave in the gun

Helium Gun

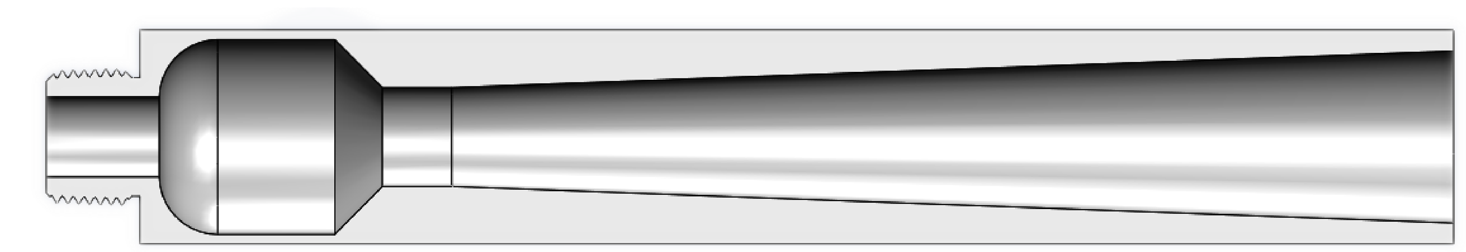
- Traditional method
- Lower gas density
- Higher speed of sound
- Smaller nozzle needed

Air Gun

- Quieter shock wave
- Cheaper gas
- Higher mass flow
- Better particle acceleration



Pressure wave from new Helium nozzle



Preliminary design for Mach 3 Helium nozzle

FINDINGS:

- **Testing still in progress**
- **Calculations show nozzle throat needs to be much larger than original design**
- **Previous experiments found original gene gun could not achieve supersonic shocks**
- **Oxford study predicts air may be better than Helium**

Contact: treysong@uw.edu

(360) 865-1333

Acknowledgements: Owen Williams, Brad Stone, Berit Syltebo, Washington Space Grant, UW Aero & Astro