Virtual Research Presentation Conference

Exploring Gas-phase Dynamics in a High-Speed Particle-Laden Jet Using Particle Image Velocimetry

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Program: Spontaneous Concept

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Tutorial Introduction

Abstract

The objective of this study is to simultaneously measure the ejecta and surrounding high speed gas flows in a condition that is relevant to plume surface interactions during the powered descent of a spacecraft. Such experimental datasets are currently unavailable, but they are crucial for validating numerical simulations that will be used in guiding future missions. To overcome the technical challenges, this project funded a feasibility study using a high-speed particle-laden jet facility at Johns Hopkins University. The current setup at the JHU Jet facility uses compressed air to create sonic to supersonic flows. Inertial particles were injected along the centerline of the jet far upstream of the nozzle. To achieve the goal of simultaneous two-phase measurements, the particle image velocimetry (PIV) and Lagrangian particle tracking (LPT) method were used together to understand the interaction between two phases. Example of a basic optical setup is shown in Figure 1, as sub-micron sized tracer particles are illuminated by a laser sheet.

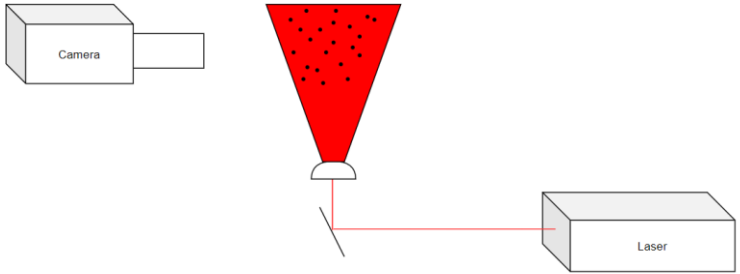

Figure 1: Basic PIV setup

Problem Description

a) Context

- As Nasa embarks on its journey to the moon, understanding the underlying physics of both take-off and landing is crucial in ensuring a successful mission.
- A high-speed particle-laden jet is used to understand multiphase flows within this context to better understand the dynamics of inertial particle motion in the compressible regime

b) SOA

- Current JHU Jet facility is a cold-air system with a 2 mm diameter nozzle to accelerate air to sonic speeds at the exit.
- Previously, only inertial particles speeds could be accurately tracked. Our objective is to also provide gas-phase velocities by upgrading the facility to utilize Particle Image Velocimetry (PIV)

c) Relevance to NASA and JPL (Impact on current or future programs)

- This will provide a better understanding of particle flow in the compressible regime which lead to design practices to take concerns over liberated Lunar ejecta into consideration.

Methodology: Tracer particles

- To enable gas-phase measurements, a common and widely accepted technique is using the Particle Image Velocimetry (PIV).
- Small particles are injected into the flow, called tracer particles, that follow the flow. When the velocities of these particles are measured, the gas phase velocity is obtained.
- Tracer particles are generated using LaVision's Aerosol Generator with modal size of 0.25 μm (Figure 2)
- For safety, a Nitrogen tank is used throughout the system in case DEHS mineral oil combusts due to high laser energy output

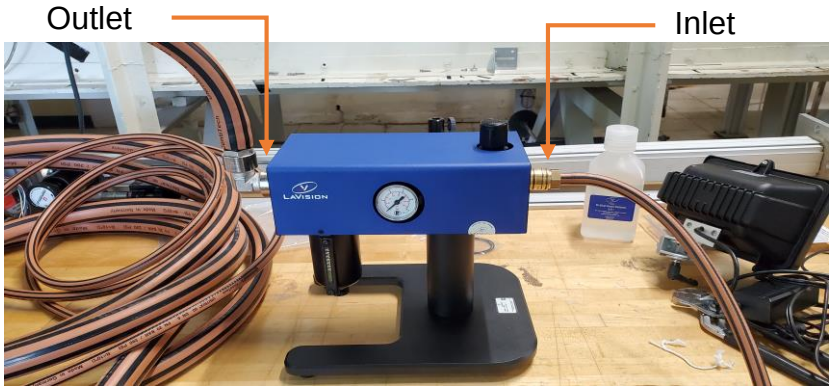

Figure 2: LaVision Aerosol Generator

Methodology: Pulsed Laser for PIV

- A pulsed laser is commonly used for PIV to illuminate tracer particles
- Laser used is a double pulsed Nd:YAG laser from Quantel Big sky Laser ($\lambda = 532$ nm, 200 mJ/pulse)
- System runs at a maximum of 10 Hz
- Is paired with a laser synchronizer and camera system from TSI to synchronizer laser pulses with frames taken by the camera
- This is a class 4 laser, so a laser safety specialist provided consultation and a design for a beam enclosure

Figure 3: Quantel Big Sky Laser

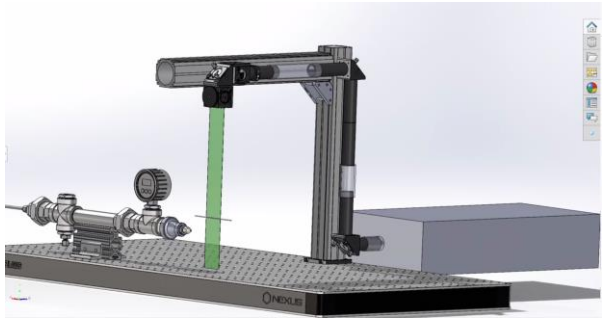

Figure 4: CAD for Beam Enclosure

Methodology: Schematic for PIV Setup

- Particle chamber is used to inject inertial particles into flow
- Particles are introduced into the flow through a pressure differential and a valve
- Nitrogen tanks used for aerosol generator and jet
- Camera is placed perpendicular to laser sheet to capture particle dynamics

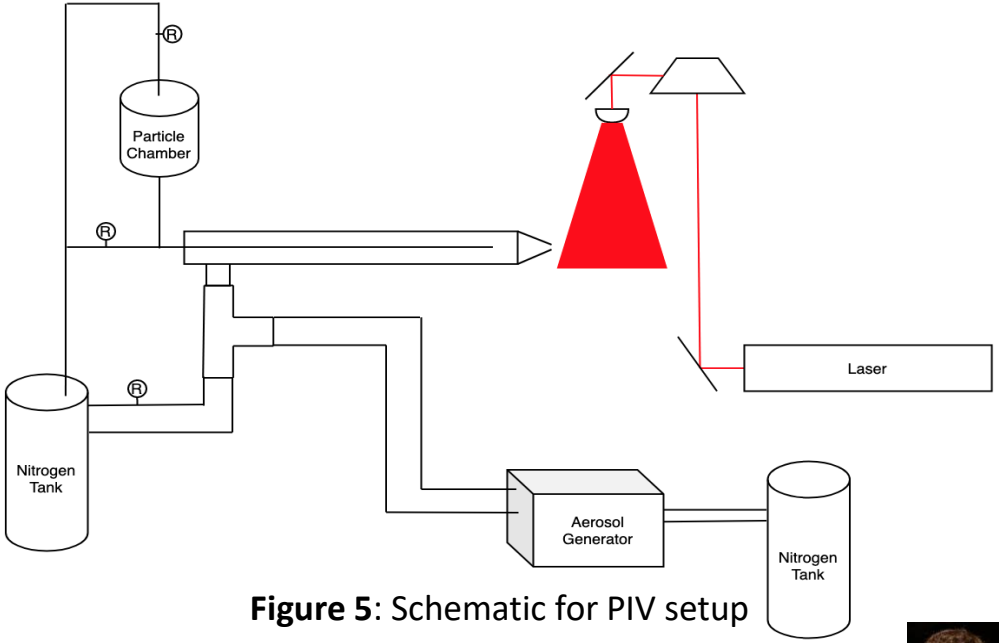

Figure 5: Schematic for PIV setup

Results: Progress on Final Assembly

- The final design is still being assembled and will be completed shortly.

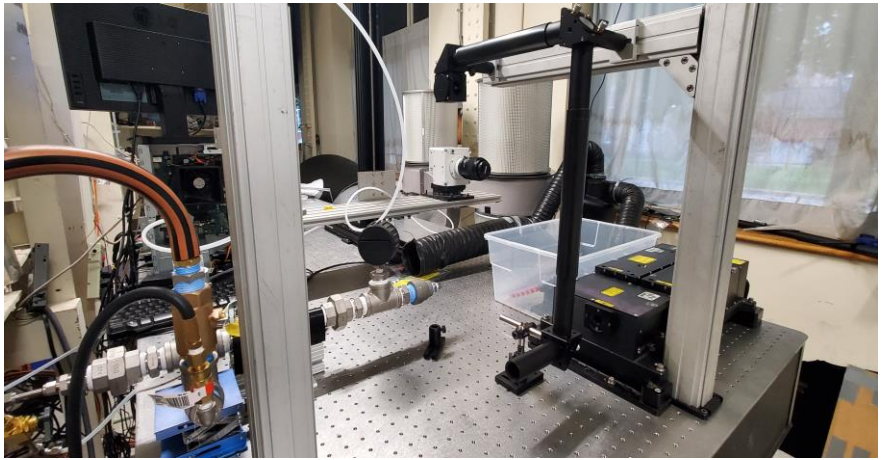

Figure 6: Laser with Beam Enclosure

Figure 7: Jet enclosure with hose for particle separator

Preliminary Results

- A similar setup to this has been used in the past to prove the usefulness of PIV in the JHU jet facility
- Figure 6 is a sample PIV image using this technique
- Figure 7 shows preliminary results for the gas phase velocity field
- PIV setup designed under this grant and discussed is currently in its final stages and will soon be able to provide results as well.

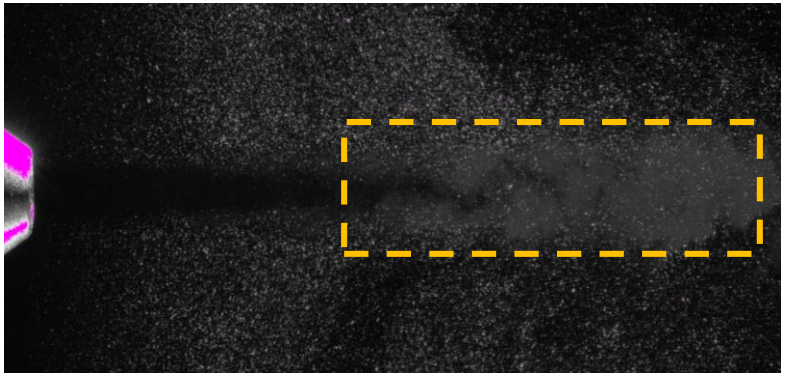

Figure 8: Sample PIV image

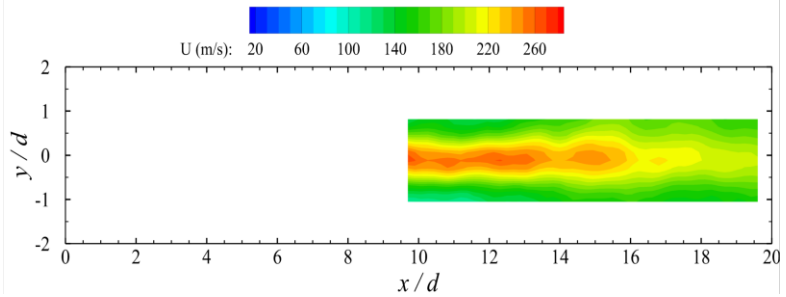

Figure 9: Ensemble averaged velocity field

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