AM Machine Gas Flow Characterization & Improvement - Phase 3
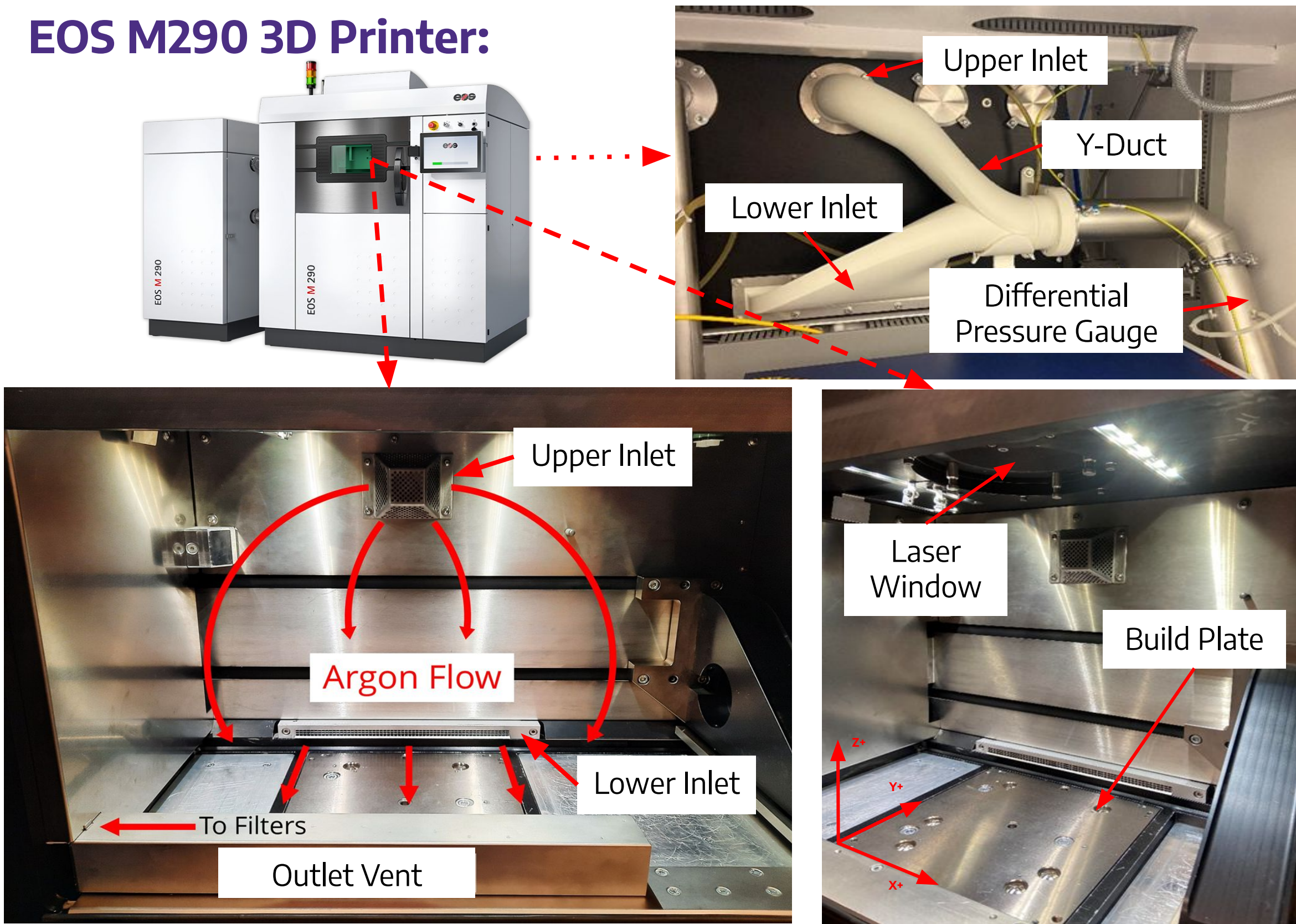
[1]Mechanical Engineering
[2]Material Science & Engineering
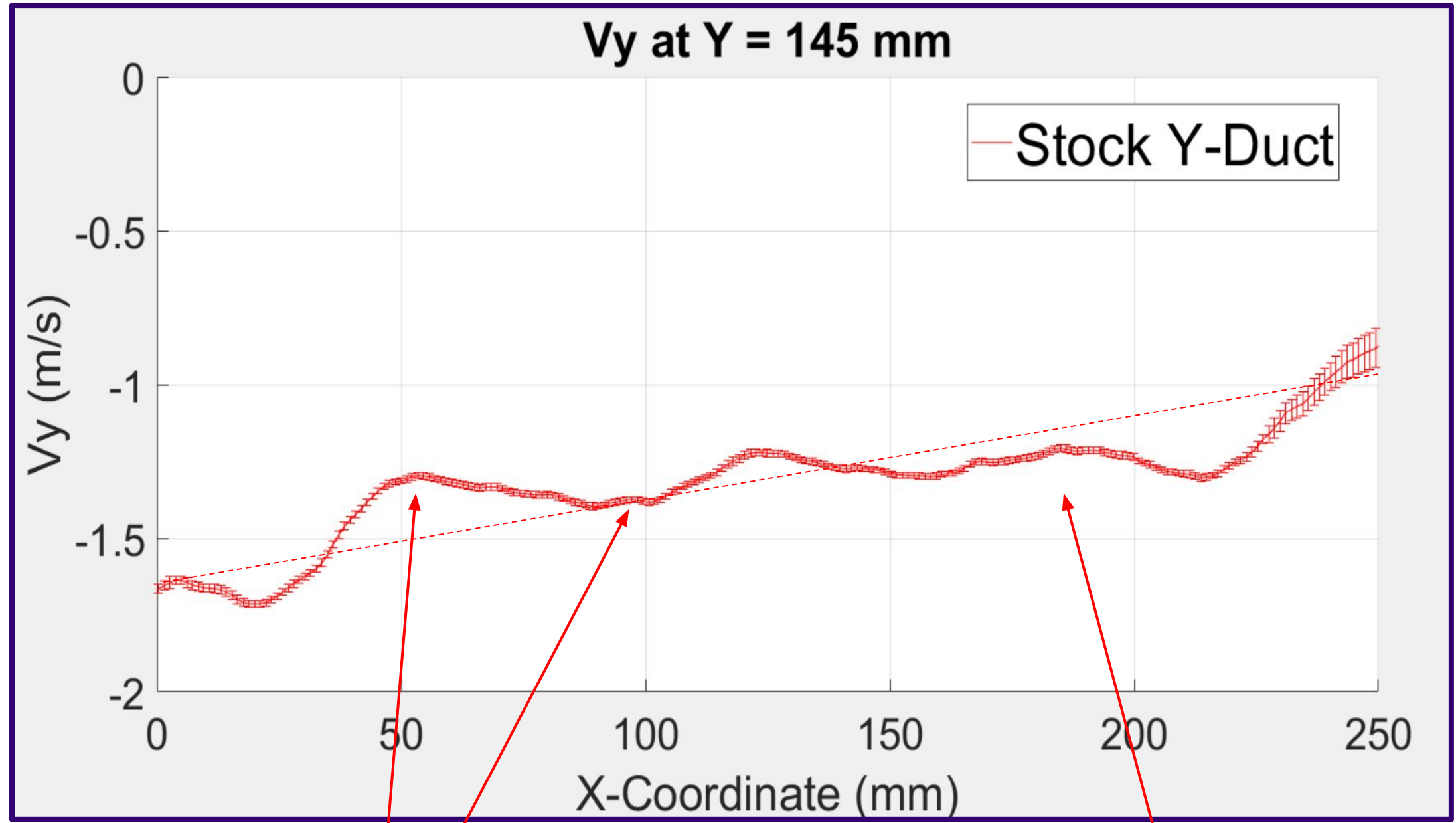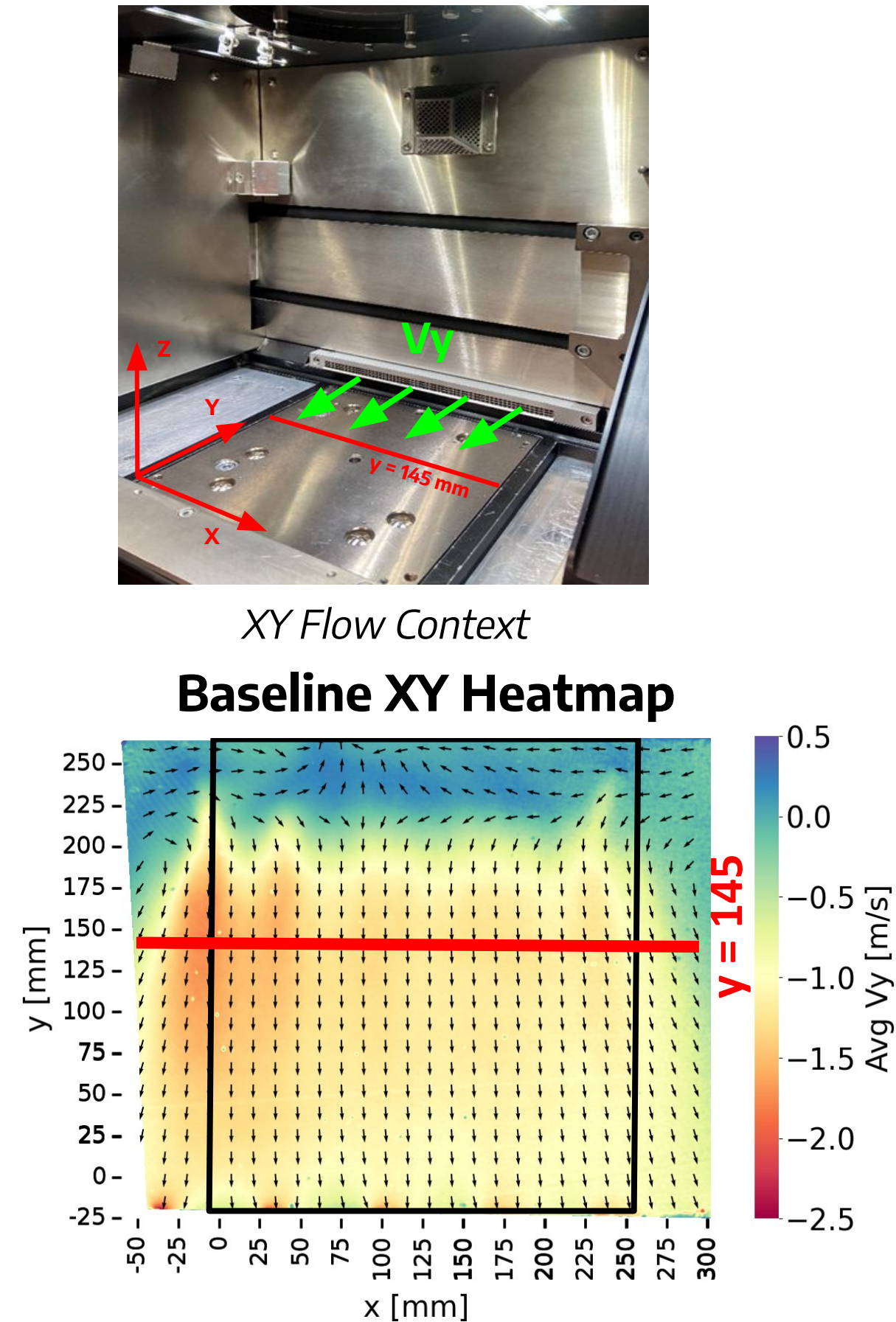
INTRODUCTION/MOTIVATION

PROBLEM STATEMENT:
Boeing Additive Manufacturing needs a way to improve flow characteristics of the cyclic gas flow system within their EOS M290 Laser Powder Bed Fusion printers. Our team has been tasked with designing nozzles & other flow devices to improve the uniformity of flow within the build chamber and reduce dead zones and recirculation points.
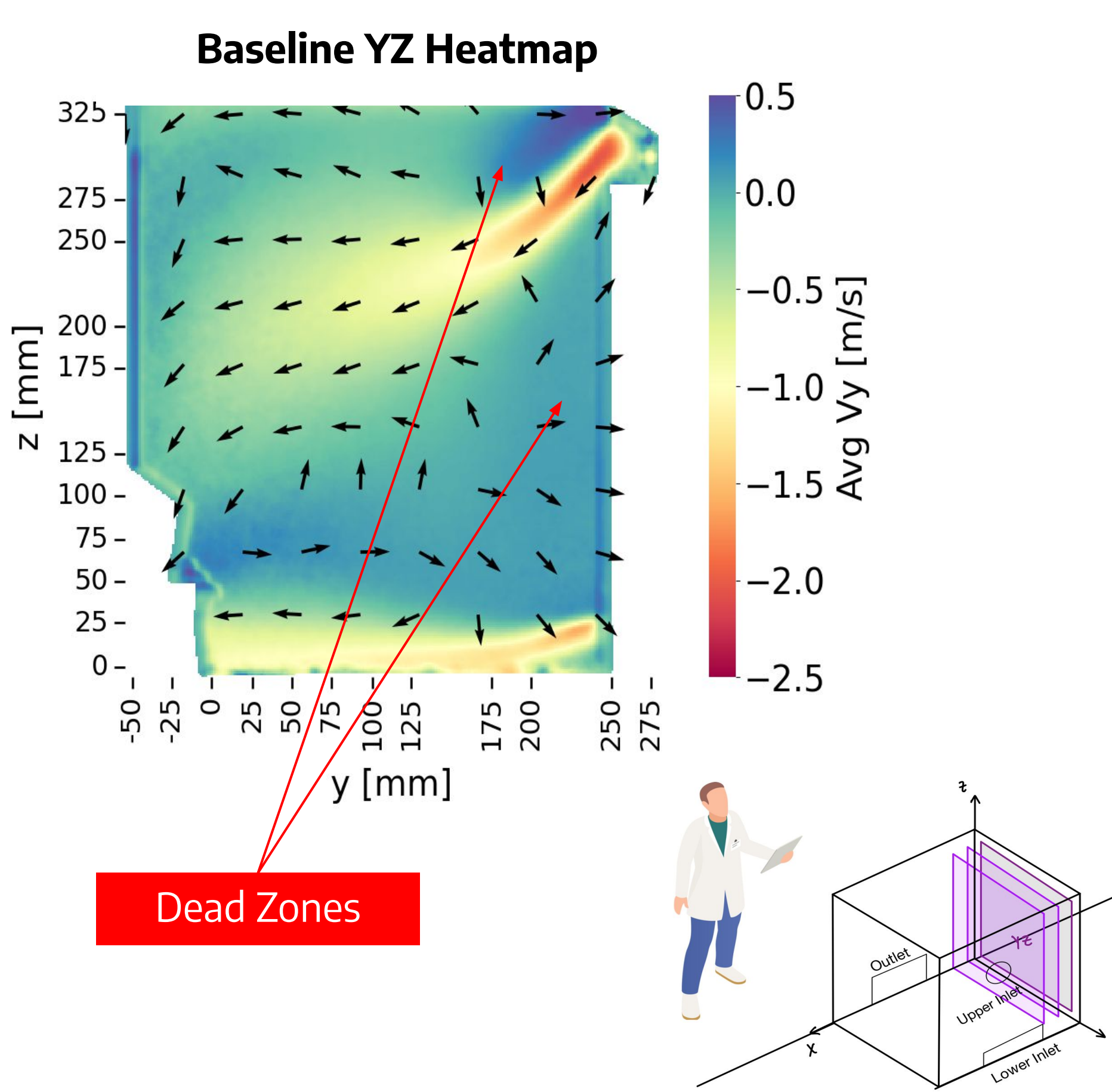
EOS M290 3D Printer:

Upper Inlet
Y-Duct
Lower Inlet
Differential Pressure Gauge
Upper Inlet
Argon Flow
Lower Inlet
To Filters
Outlet Vent
Laser Window
Build Plate

XY Plane Baseline Flow

XY Flow Context

Baseline XY Heatmap

Y = 145

Vy at Y = 145 mm

Stock Y-Duct

Flow Profile at Y = 145mm

Velocity Gradient

Sinusoidal Behavior

YZ Plane Baseline Flow

Baseline YZ Heatmap

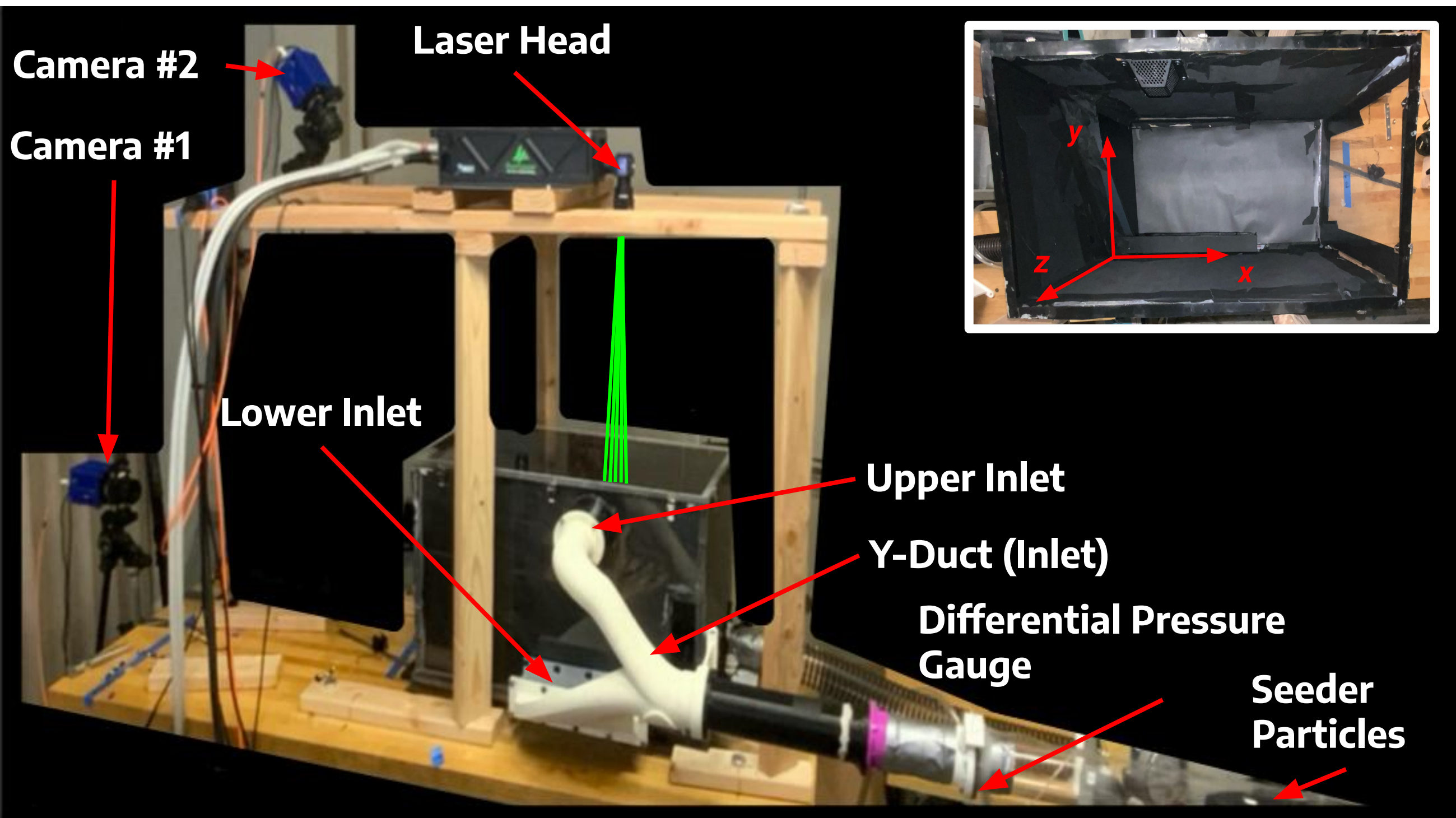Dead Zones

TEST SETUP & PROTOTYPE EVALUATION

PIV Data Collection:
- The method we used to analyze the gas flow was particle image velocimetry (PIV).
- Using low-response time cameras in conjunction with laser-illuminated particles, PIV allowed us to map and evaluate the velocity distribution of the gas flow.
- Key parameters recorded were the velocity in x/y directions and vorticity.

Flow with tracer particles
Lens
Light-sheet optics
Camera
Laser beam
Double-pulse laser
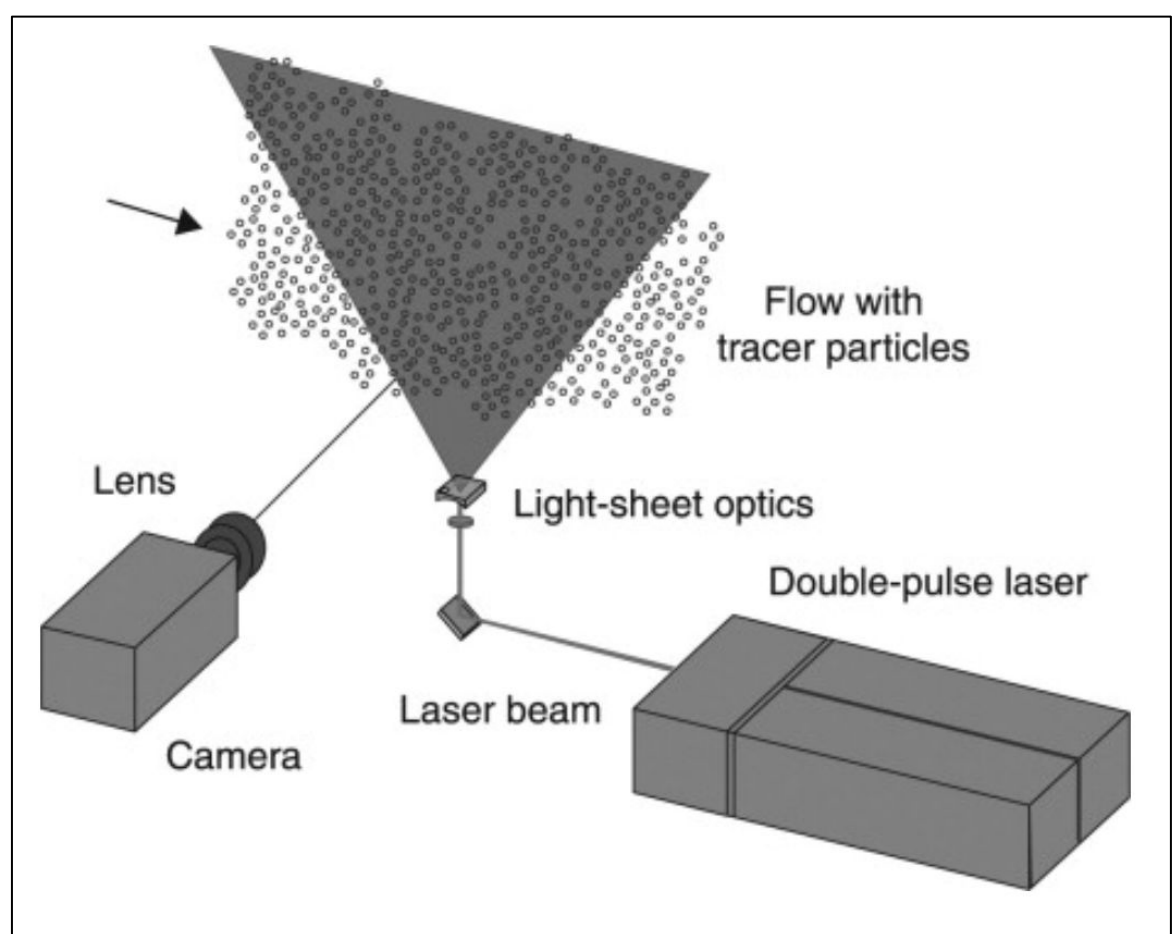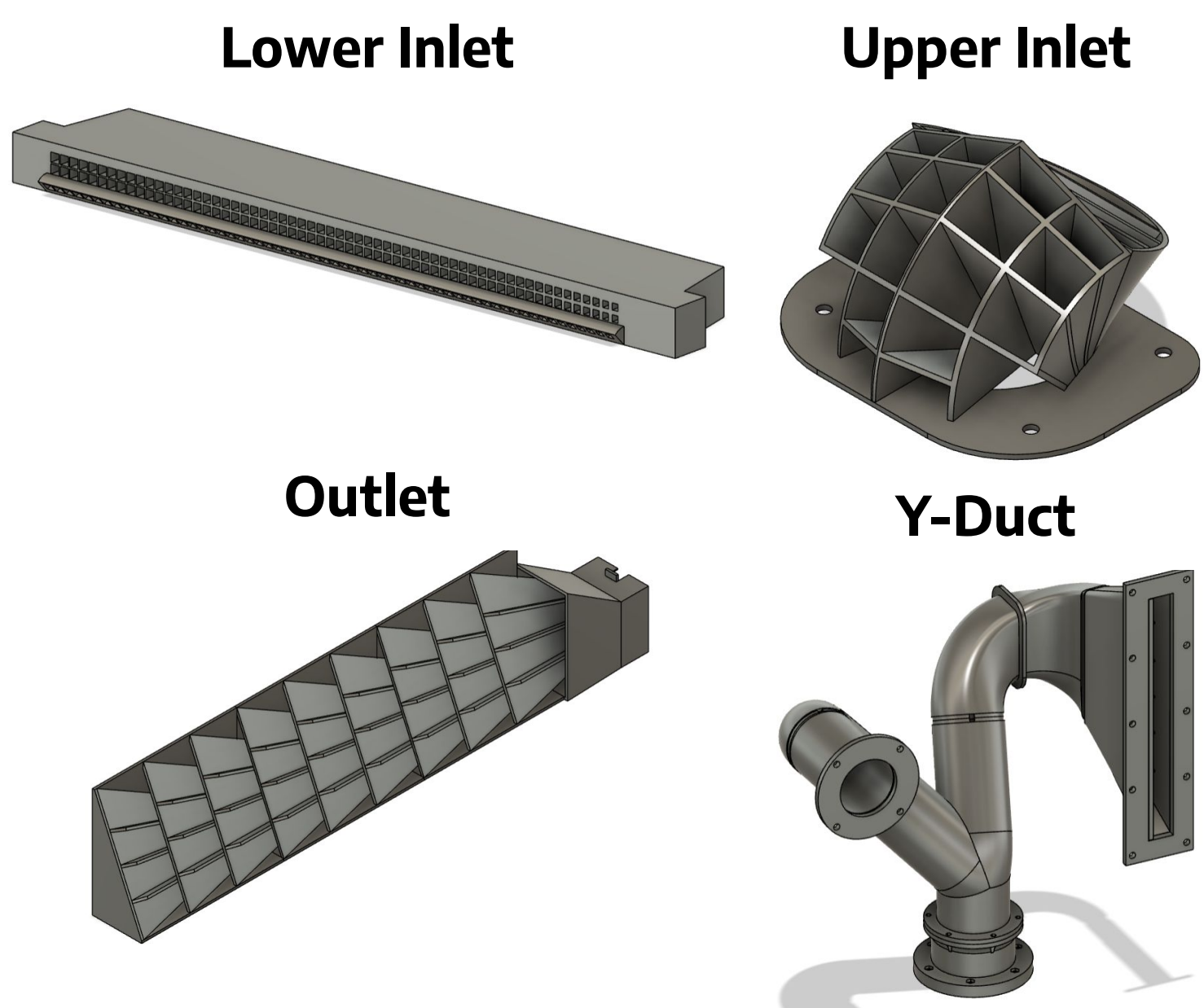
Mock Build Chamber:
- To emulate the EOS M290 machine, we used two test set-ups to analyze gas flow in the XY and YZ planes within the build chamber.
- Analyzing each plane provided unique insight pertinent to different components of the system (lower/upper inlet, outlet), that was used to iterate on the existing stock designs.

Camera #2
Camera #1
Laser Head
Lower Inlet
Upper Inlet
Y-Duct (Inlet)
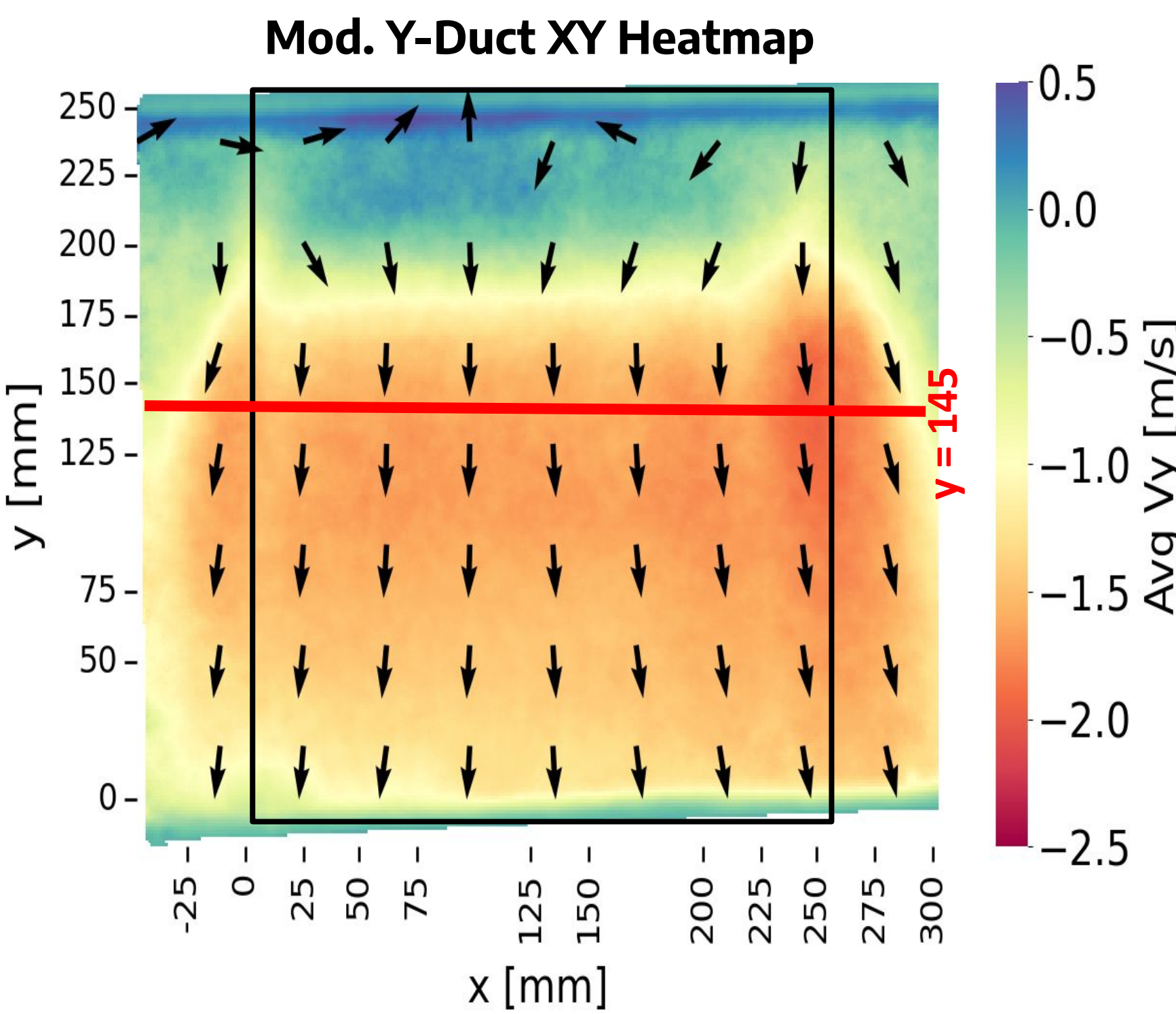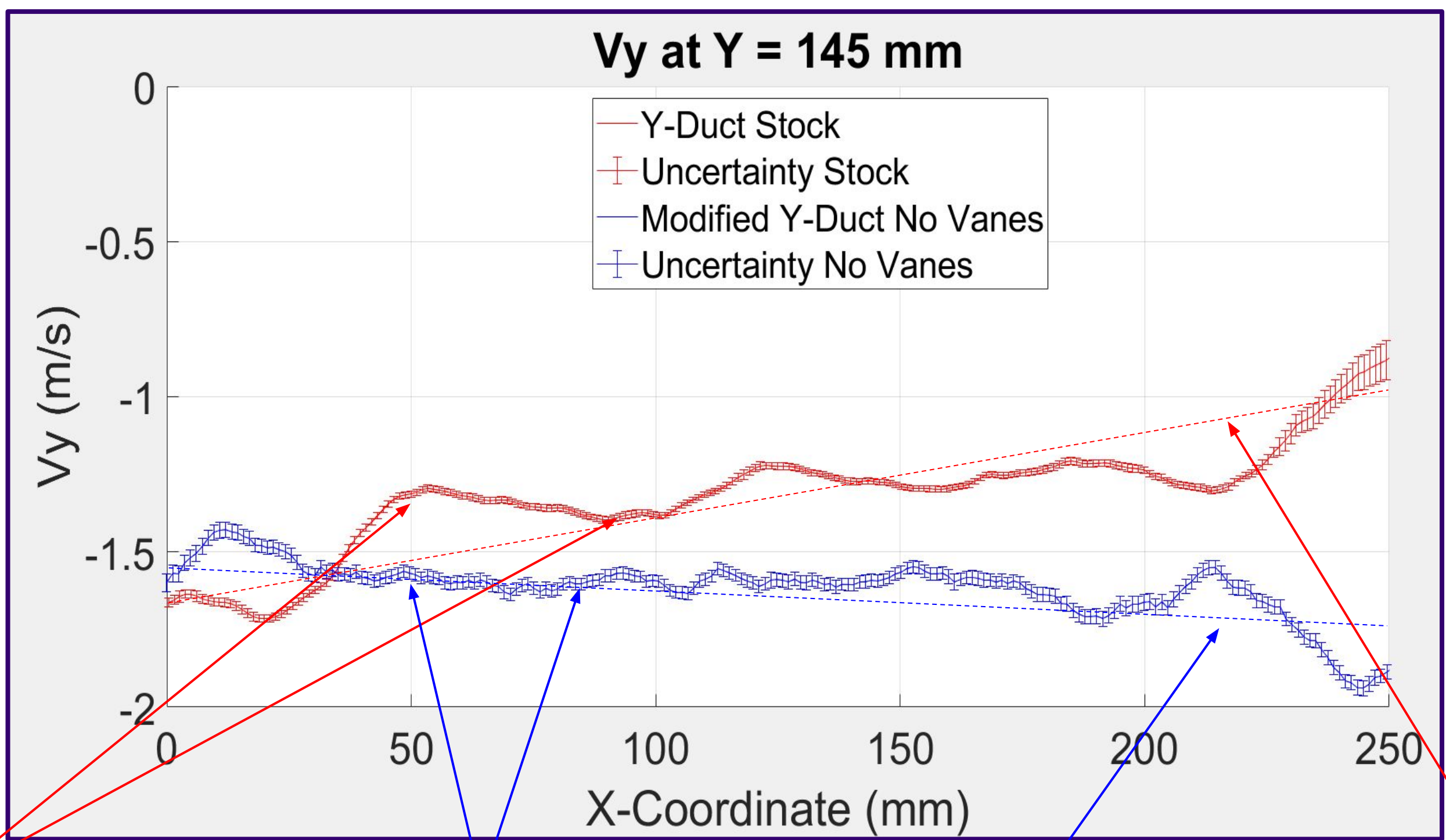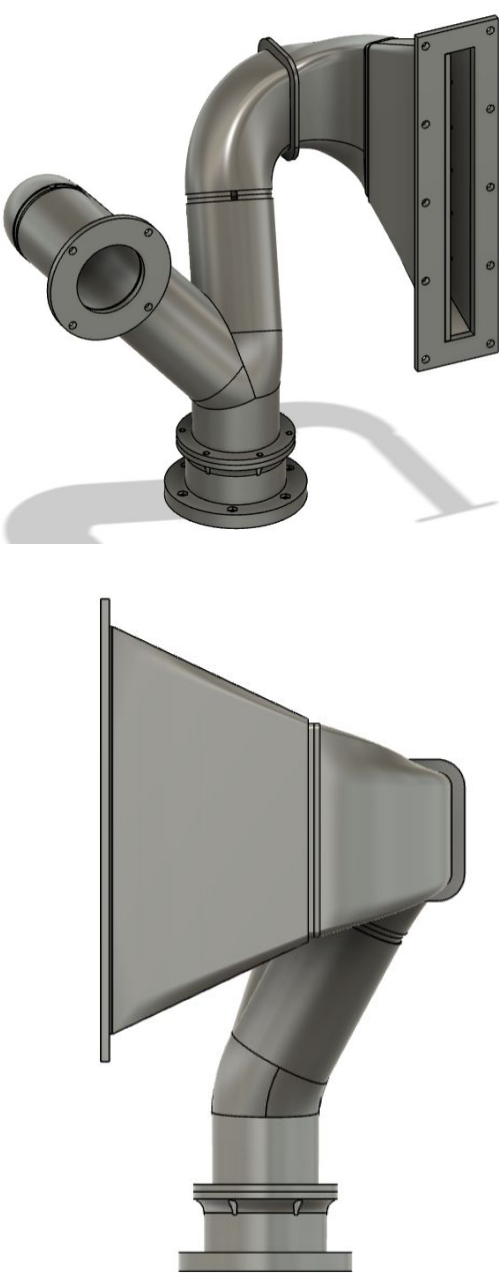Differential Pressure Gauge
Seeder Particles

Prototypes:
- Created prototype nozzles and flow devices to "tune out" existing issues
- Focused on 4 primary areas: Upper/Lower inlets, outlets, and Y-duct
- Ran trials on multiple early phase prototypes in various PIV configurations to observe flow
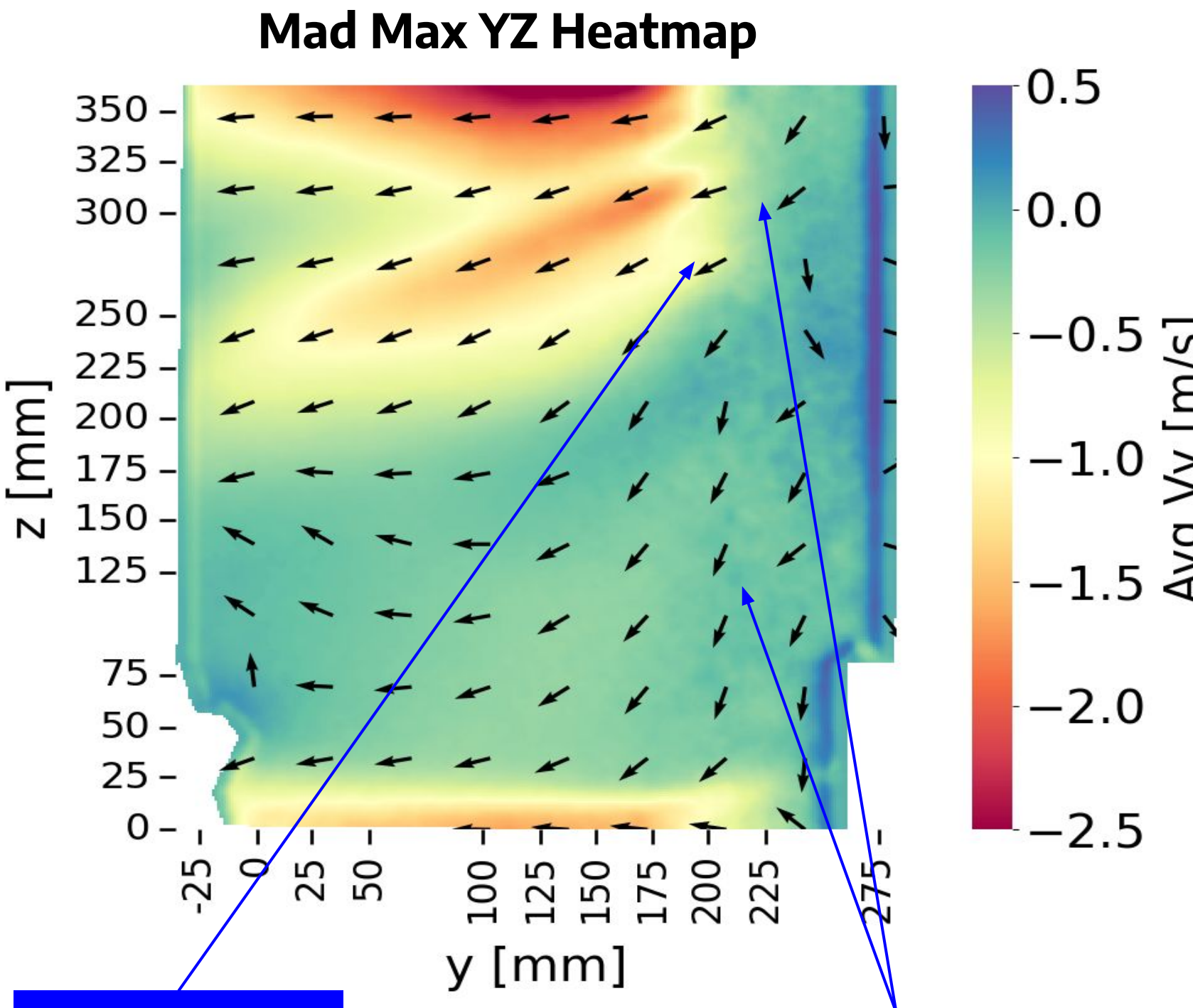- Iterated upon the most promising concepts

Prototype Examples:

Lower Inlet
Upper Inlet
Outlet
Y-Duct

RESULTS & FUTURE WORK

XY Plane Improvements - Modified Y-Duct

Vy at Y = 145 mm

- Y-Duct Stock
- Uncertainty Stock
- Modified Y-Duct No Vanes
- Uncertainty No Vanes

Y = 145

Sinusoidal Behavior
Sinusoidal Behavior Reduced
Velocity Gradient Reduced
Velocity Gradient

Mod. Y-Duct XY Heatmap

Y = 145

YZ Plane Improvements - Mad Max Upper Inlet

Mad Max YZ Heatmap

Radial Flow
Deadzone Reduction

Future Work:
- Y-duct design expansion
  - Further exploration into Y-duct geometry changes
- Upper inlet / Outlet design iterations
  - Continuation of promising results seen this year
- Full scale machine implementation
  - Design modification to fit onto EOS M290
  - Material property testing of builds using baseline and modified flow systems

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