Preparations for Tomographic Background-Oriented Schlieren at the 31-Inch Mach 10 Wind Tunnel

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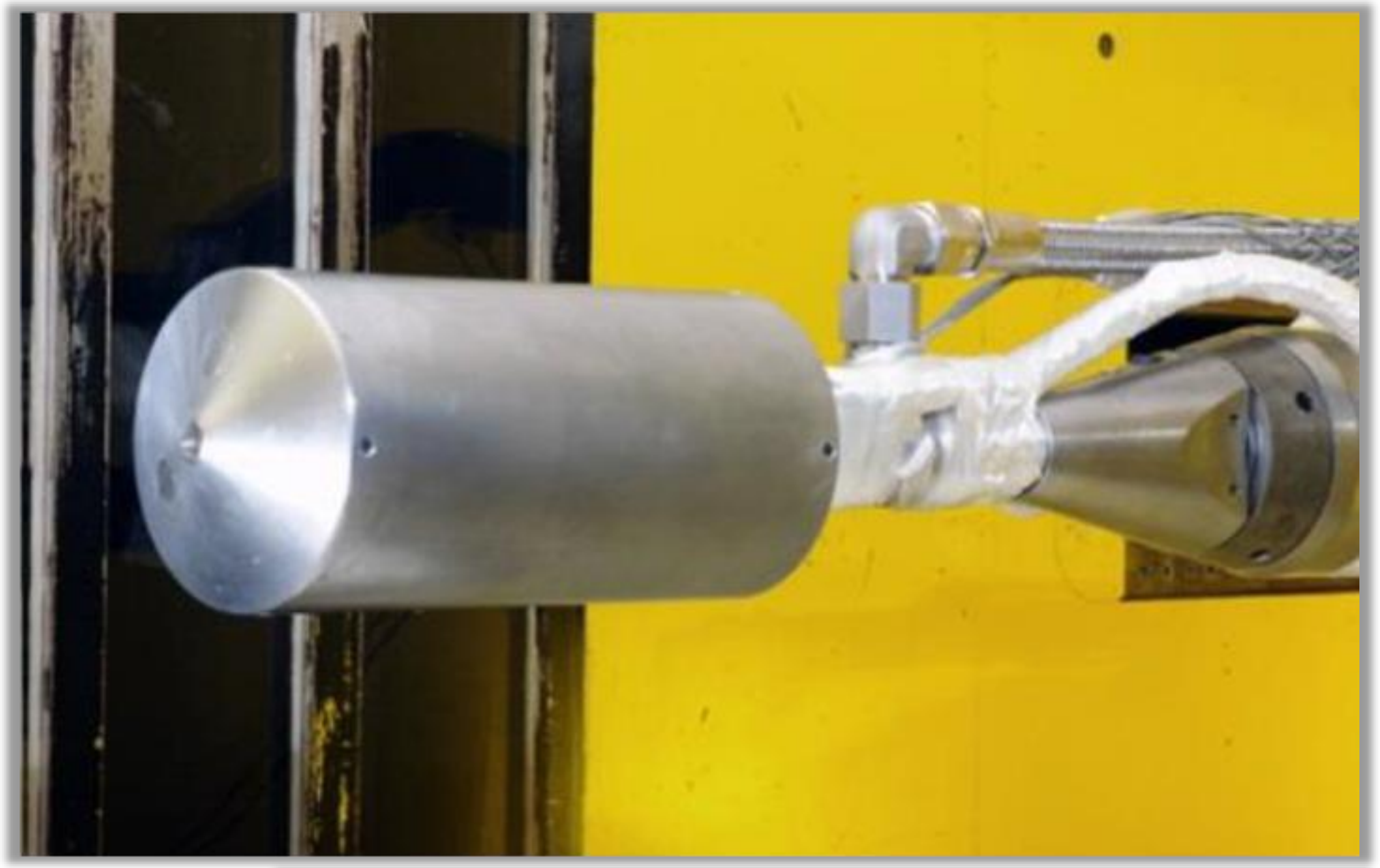
Motivation

- Single- and multi-nozzle supersonic retropropulsion (SRP) test
  - NASA Langley Research Center's 31-Inch Mach 10 wind tunnel
  - Compare off-body flow visualization measurements with on-body high-speed pressure transducer measurements
  - Previous test performed with conventional schlieren
  - Demonstrate high-speed tomographic background-oriented schlieren (tomo BOS)



- Background-oriented schlieren
  - Camera images patterned background
  - Refractive index (density) variations result in distortion of pattern
  - Algebraic reconstruction technique uses 2D BOS image data from multiple perspectives to compute density field reconstruction

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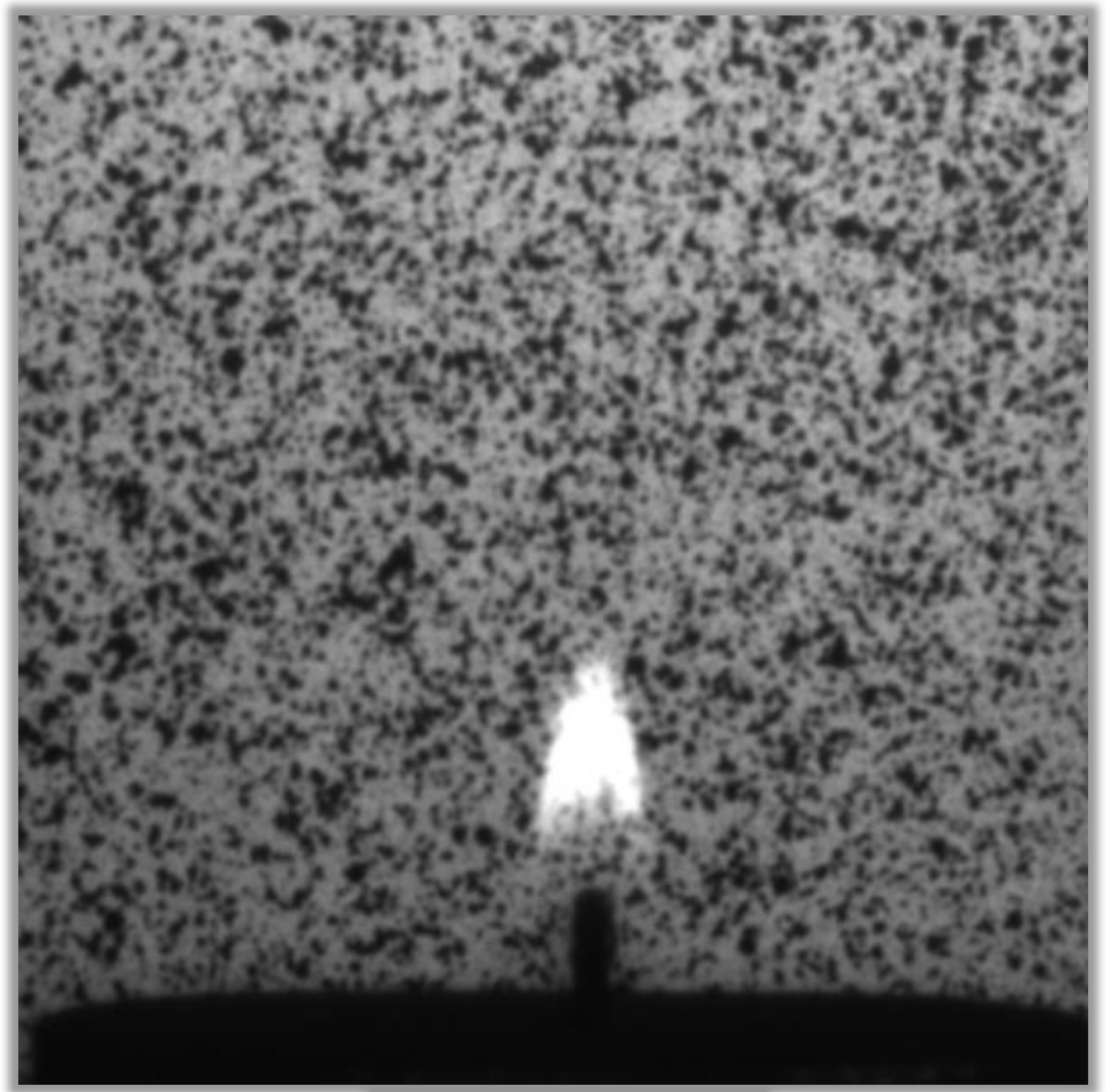

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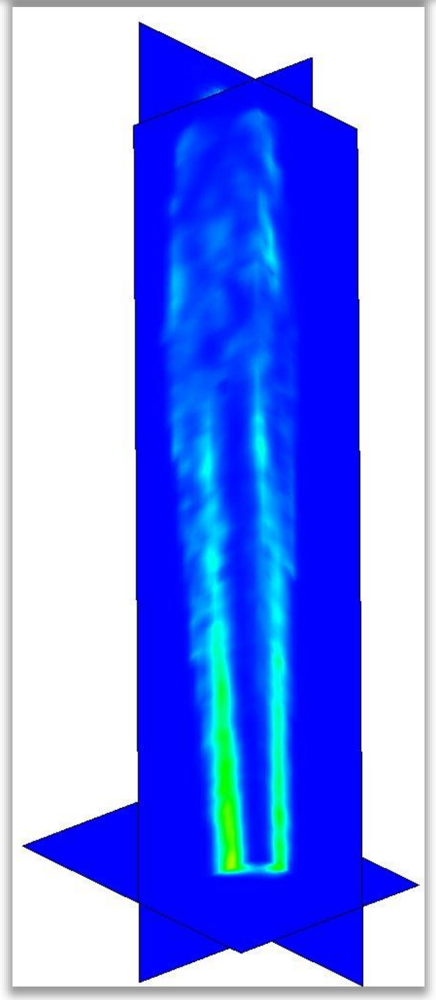
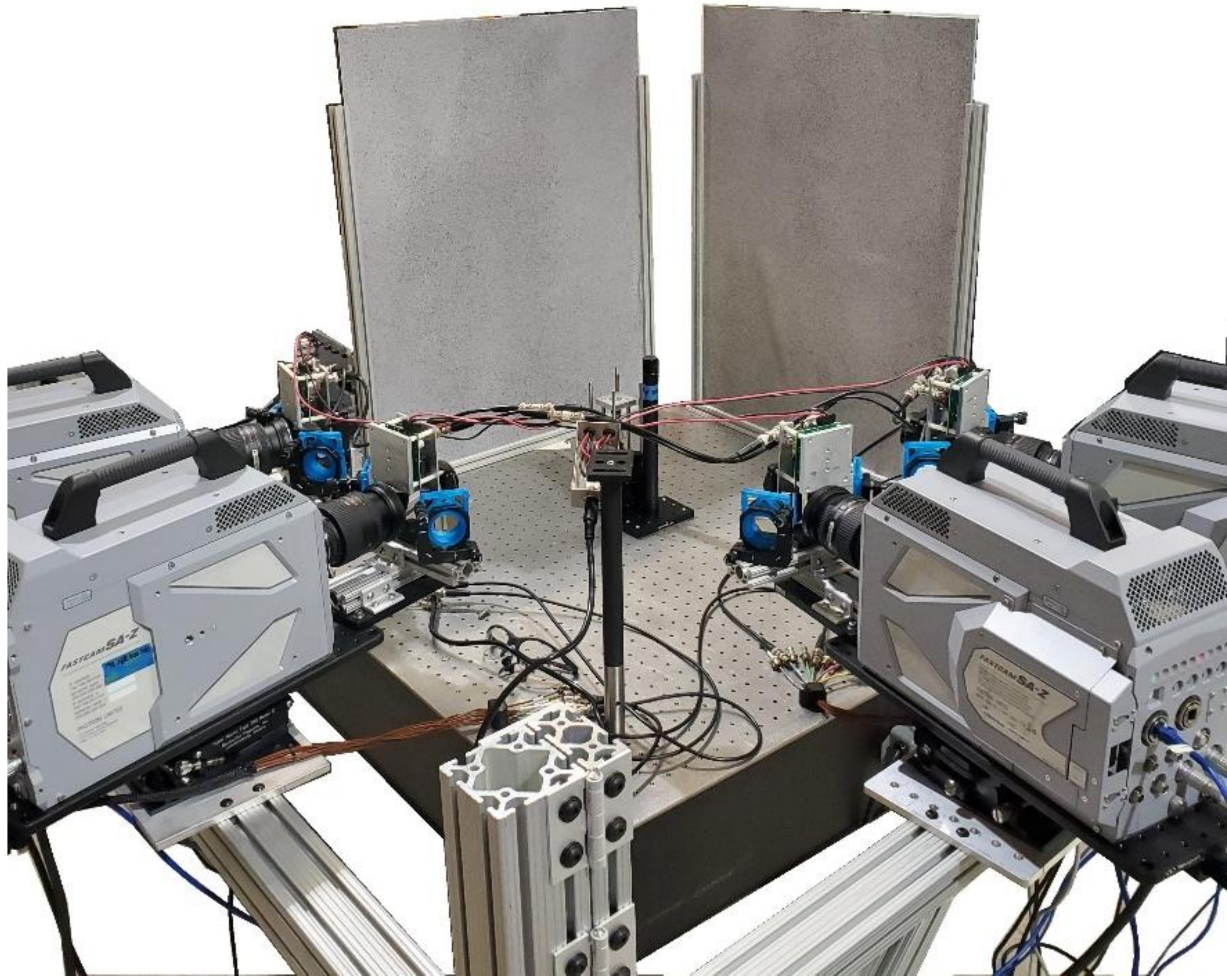
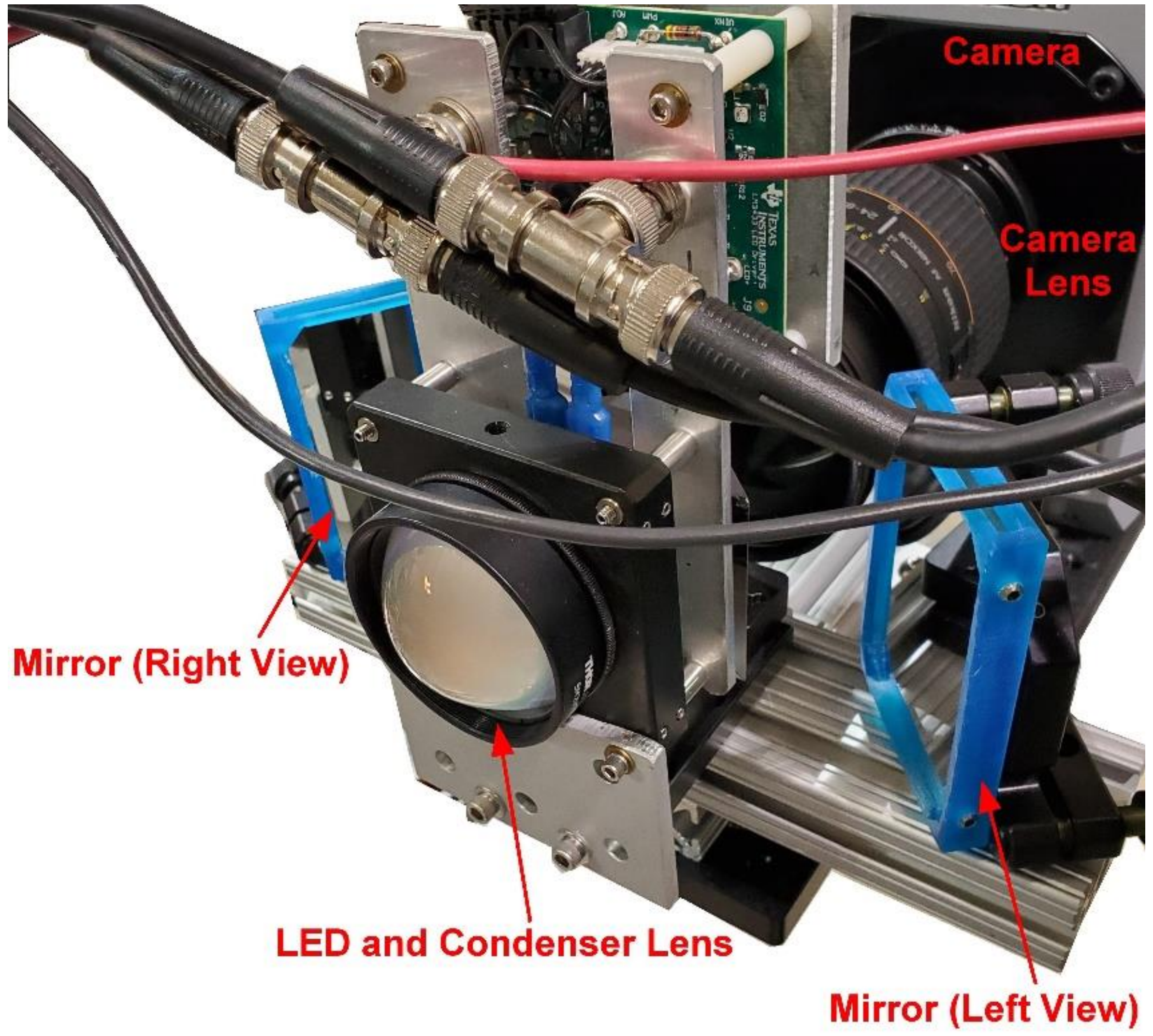


Preparations for Test Campaign at 31-Inch Mach 10 Wind Tunnel

- <u>Previous high-speed tomo BOS laboratory testing</u>
  - Obtained tomo BOS data with four high-speed Photron SA-Z cameras
  - Frame splitters in front of each camera provided two unique perspective views of the helium jet
  - Illumination provided by single off-axis pulsed LED
  - Camera placement mimicked optical restrictions of top and side wind tunnel windows

- <u>Wind tunnel test requires more extensive preparation</u>
  - Camera placement and alignment
  - Illumination method
  - Pattern placement and survivability
  - Calibration procedure





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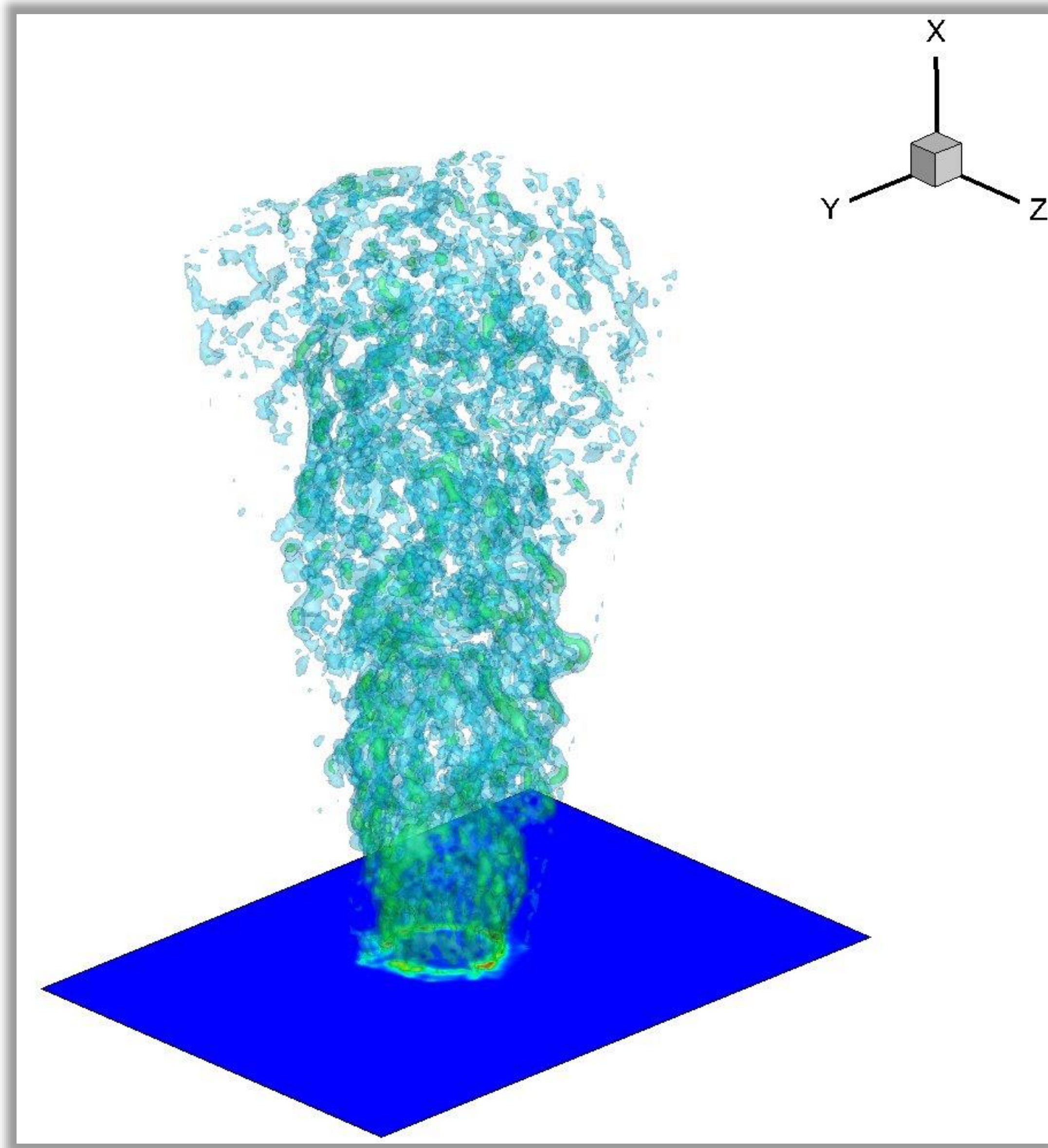

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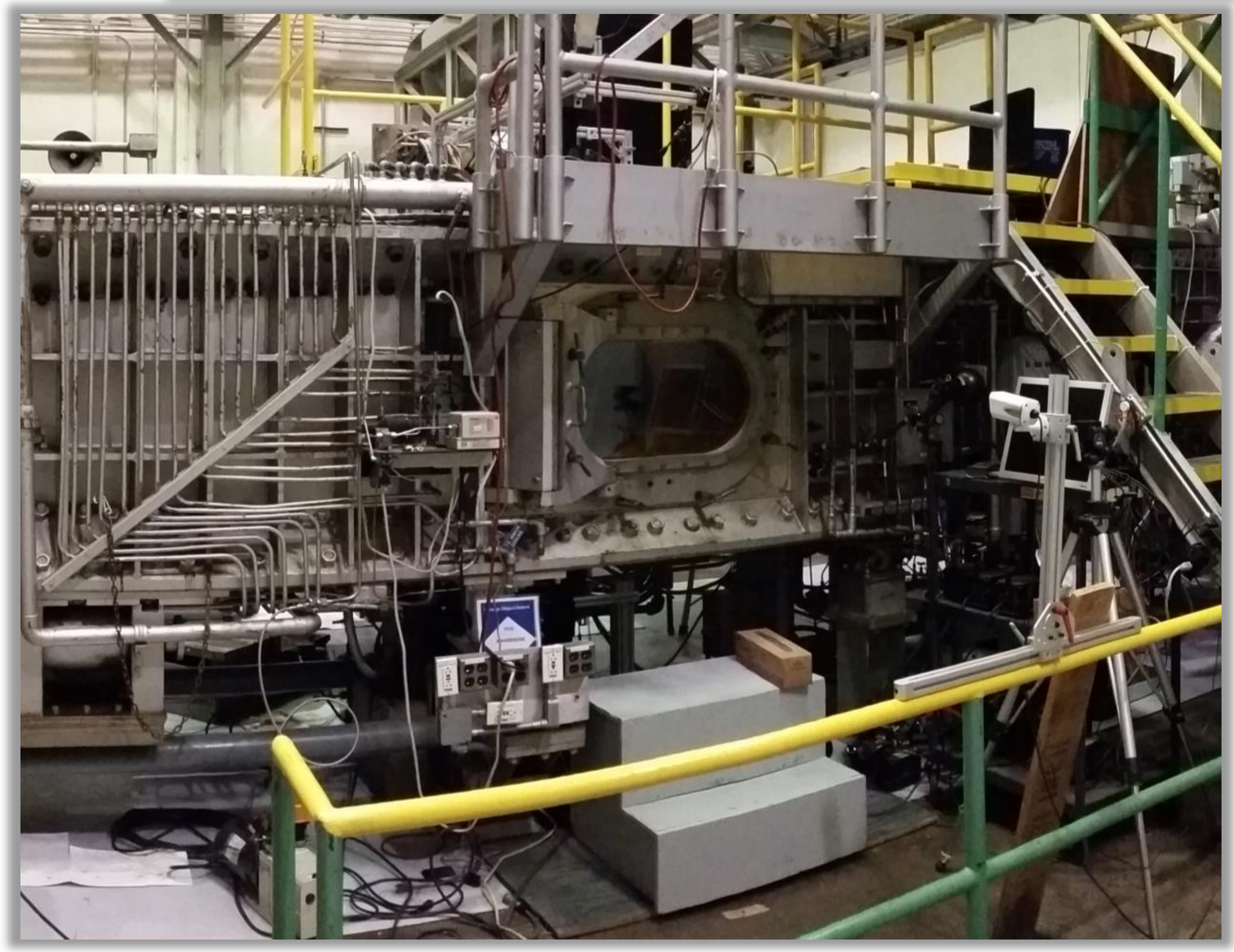
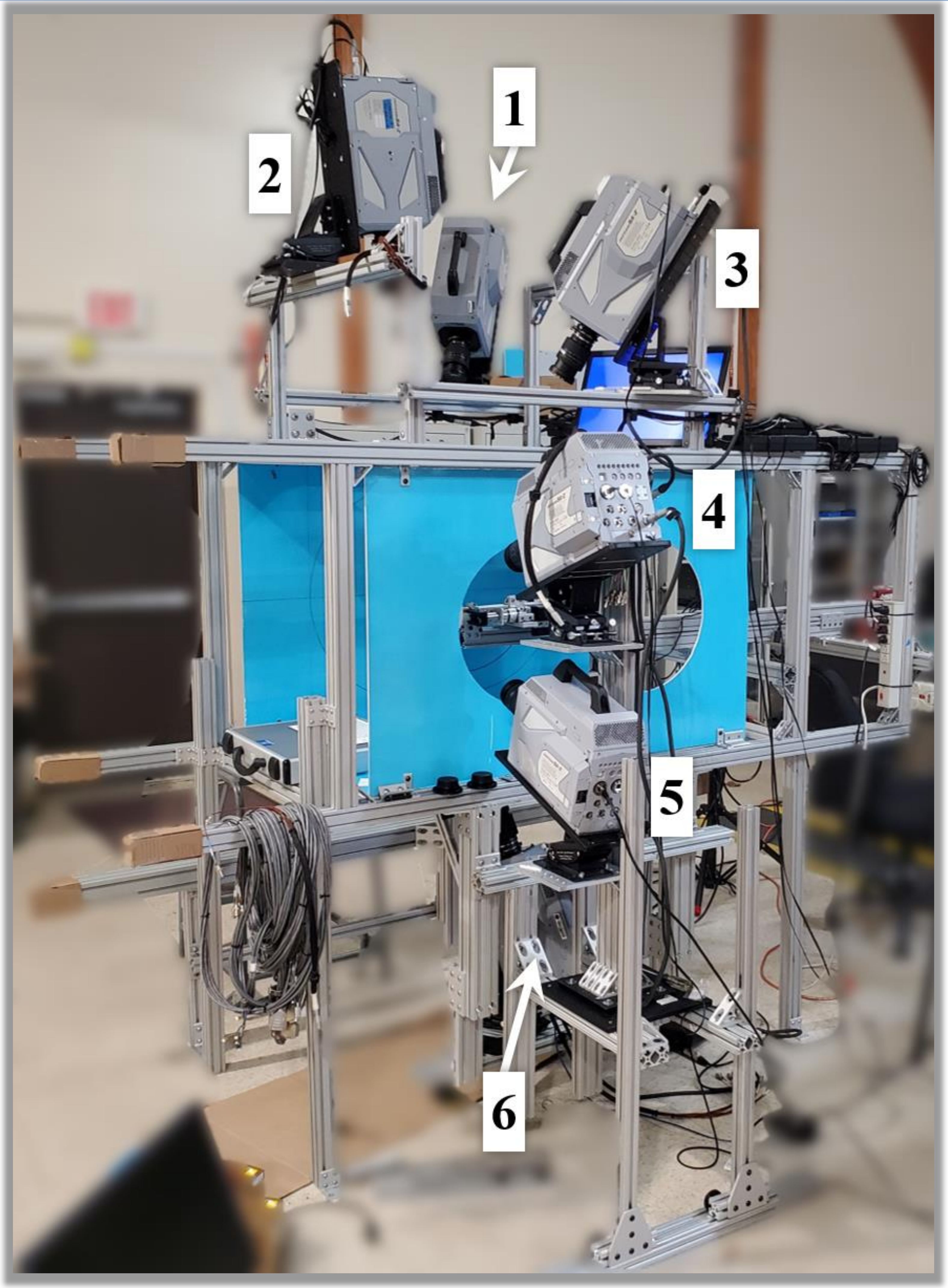


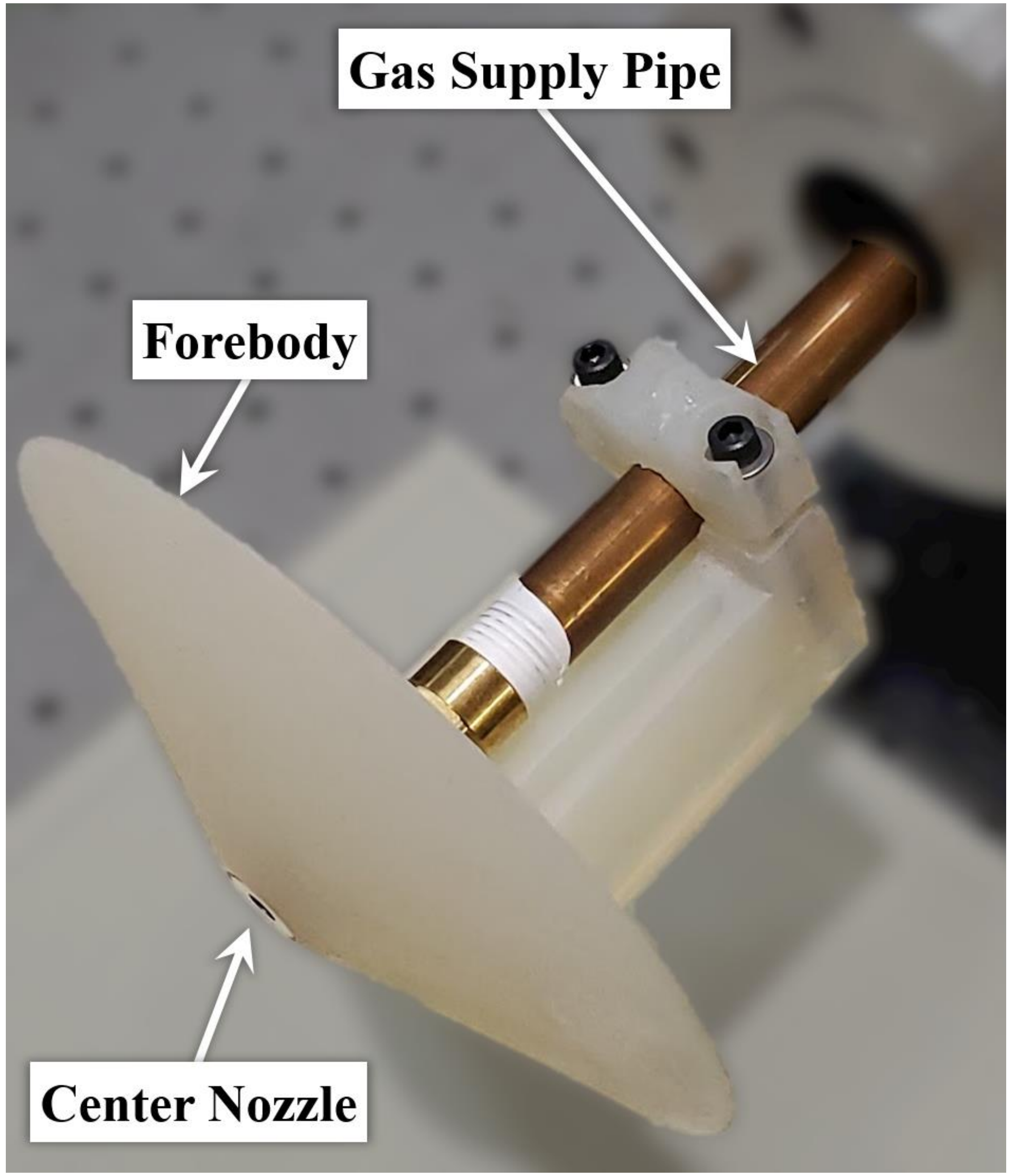
31-Inch Mach 10 Wind Tunnel Full-Scale Mock-Up

- Outer structure made of 80/20 t-slotted profiles
- Walls made of Alumalite paneling
- Window cutouts sized and placed exactly as in the facility test section
- Six cameras mounted on Huber Type D 300 pitch/roll/yaw stages for fine alignment
- Mock-up of wind tunnel model mounted to an 80/20 sting assembly that allowed adjustment in streamwise and spanwise directions using linear bearings



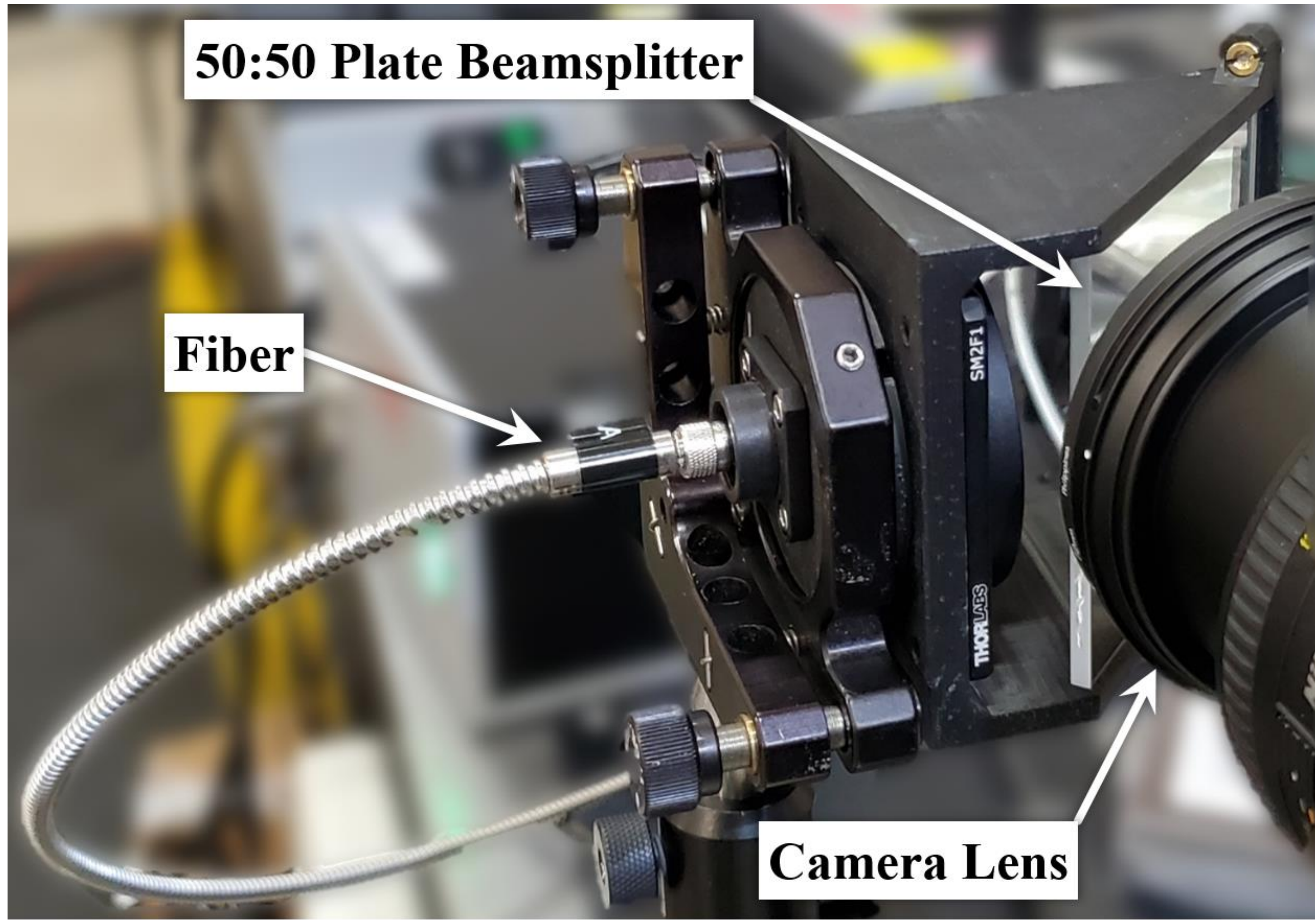
3D-Printed Model of SRP Forebody

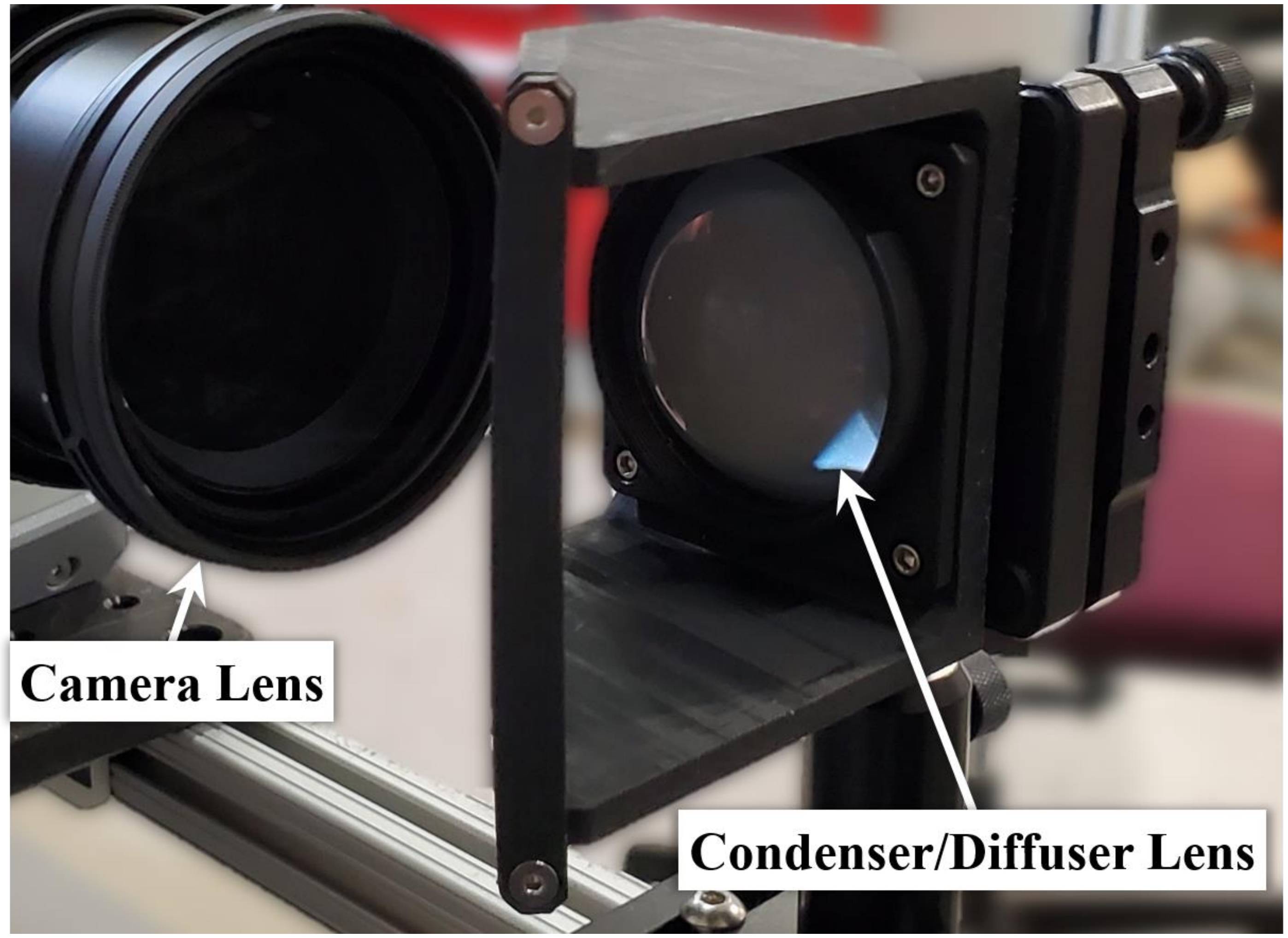
- Aid in alignment of cameras and provide high-speed jet for testing tomo BOS system performance
- Did not want to damage the actual model, which has been instrumented with a significant number of high-speed pressure transducers
- 70° sphere-cone forebody with same dimensions as full wind tunnel model
- Needed to replicate the exact dimensions of the model forebody, which would be in the field-of-view of each camera
- Embedded 60° cone spray center nozzle that allowed for high-pressure gas supply (helium, compressed air) to be connected for BOS imaging purposes



Fiber-Based Illumination Modules

- Original LED-based illumination modules used did not provide on-axis illumination, which gives maximum gain from retroreflective background material
- This required longer pulse width to sufficiently illuminate background, limiting the framing rate to 10-20 kHz
- Intensity of LED was also limited
- Constructed 3D-printed module that allowed us to couple high-intensity pulsed laser light onto the camera’s optical axis using a 50:50 plate beamsplitter
- Used a custom 7-fiber bundle that coupled to a Cavitar Cavilux HF pulsed laser light source operating at 640 nm
- Demonstrated sufficient illumination intensity and uniformity using this approach





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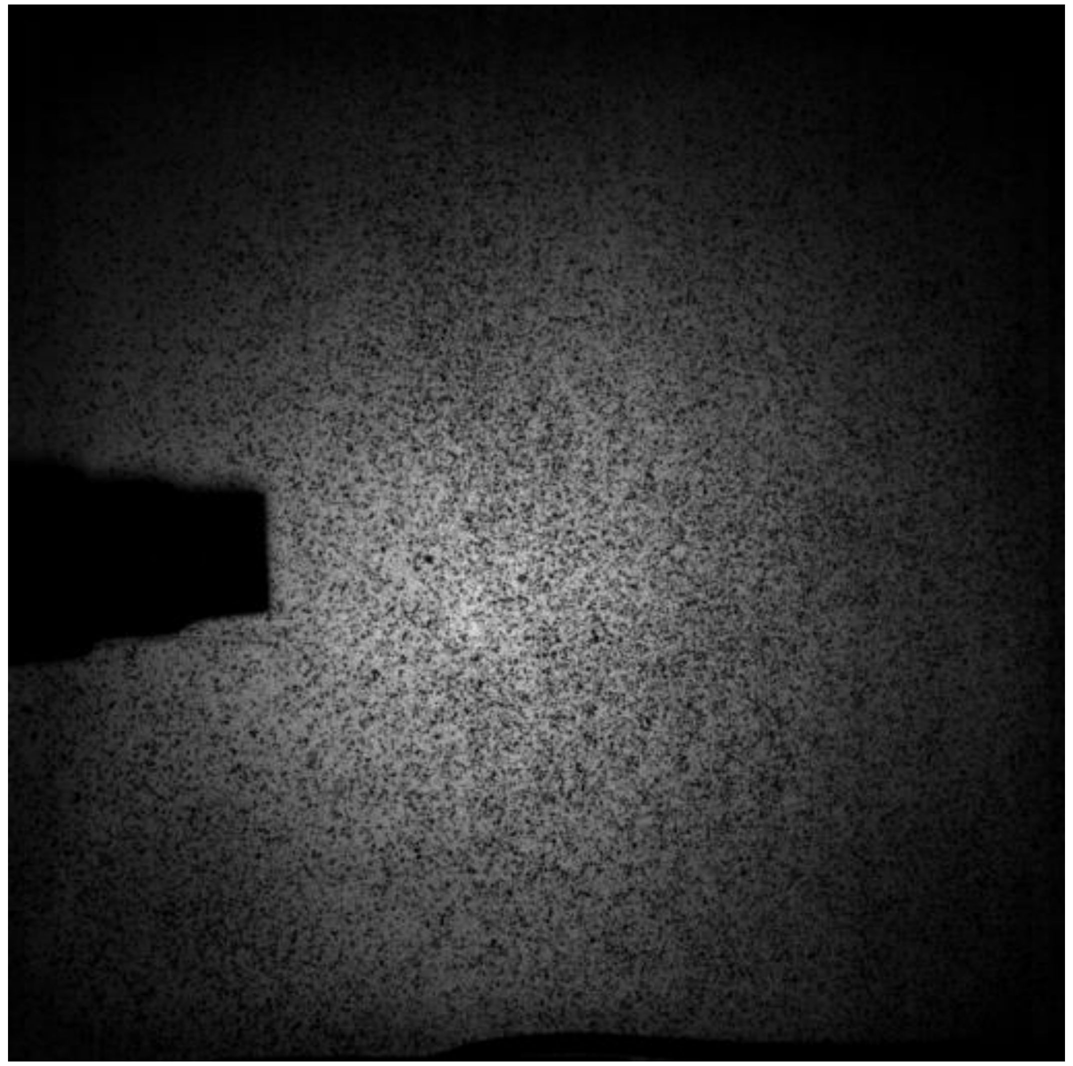
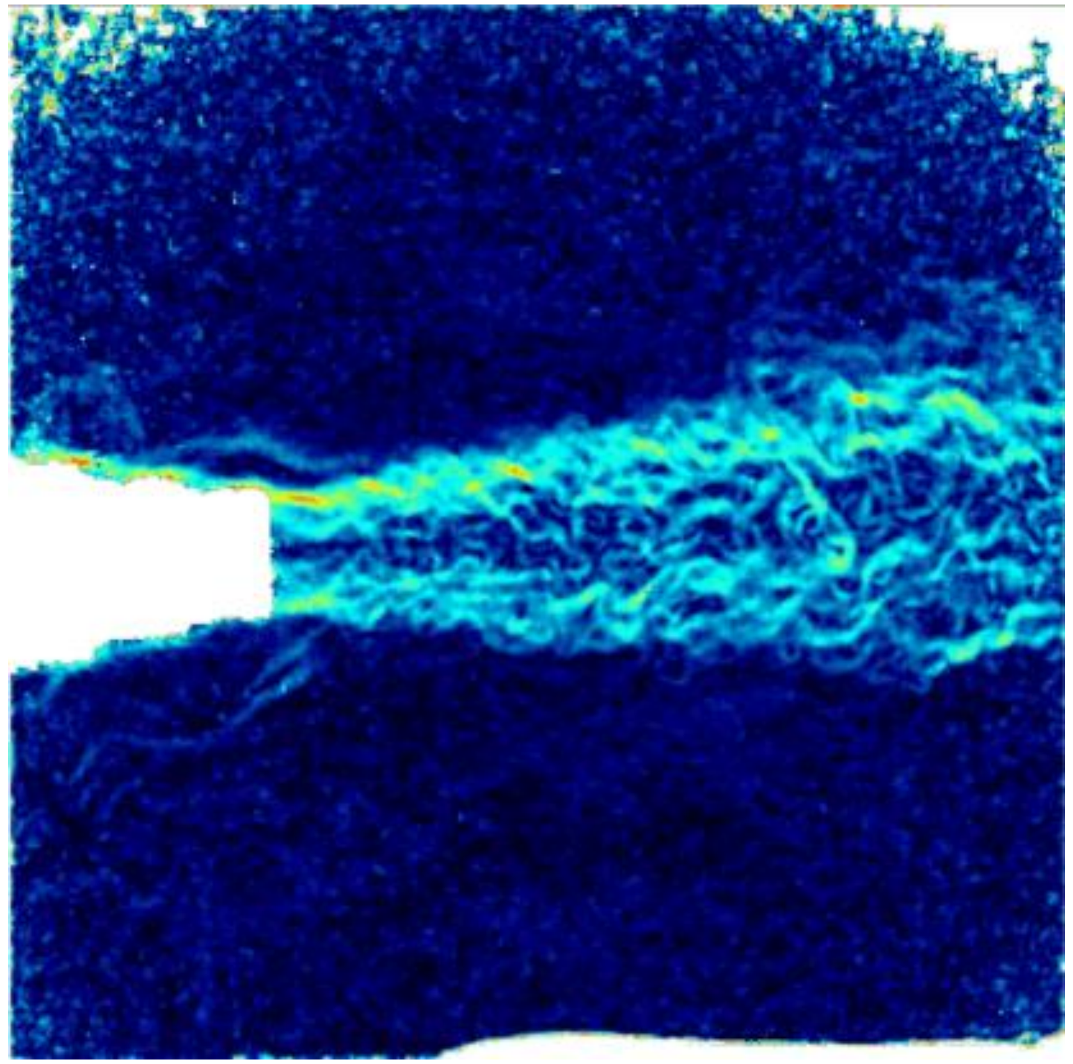
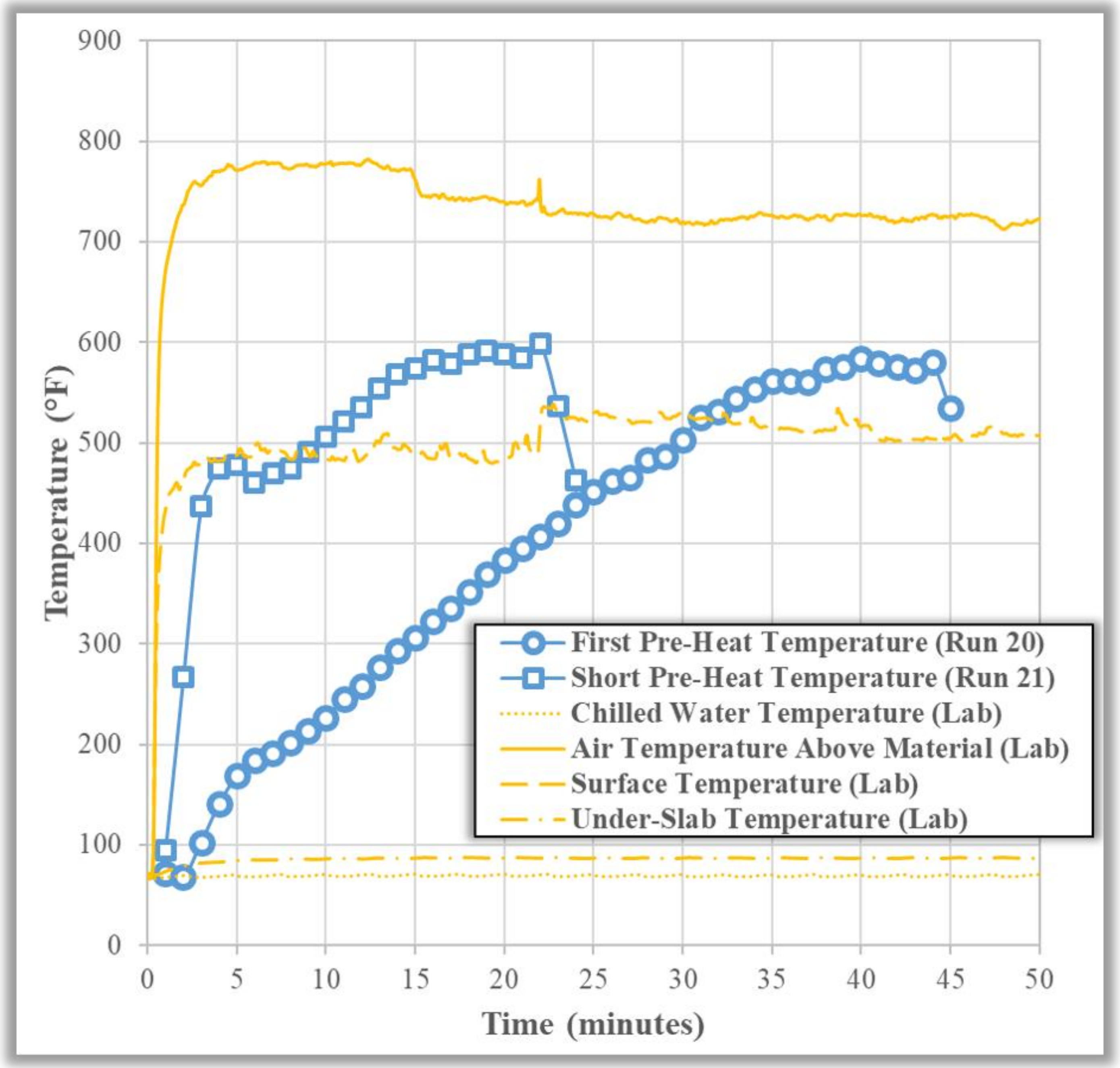
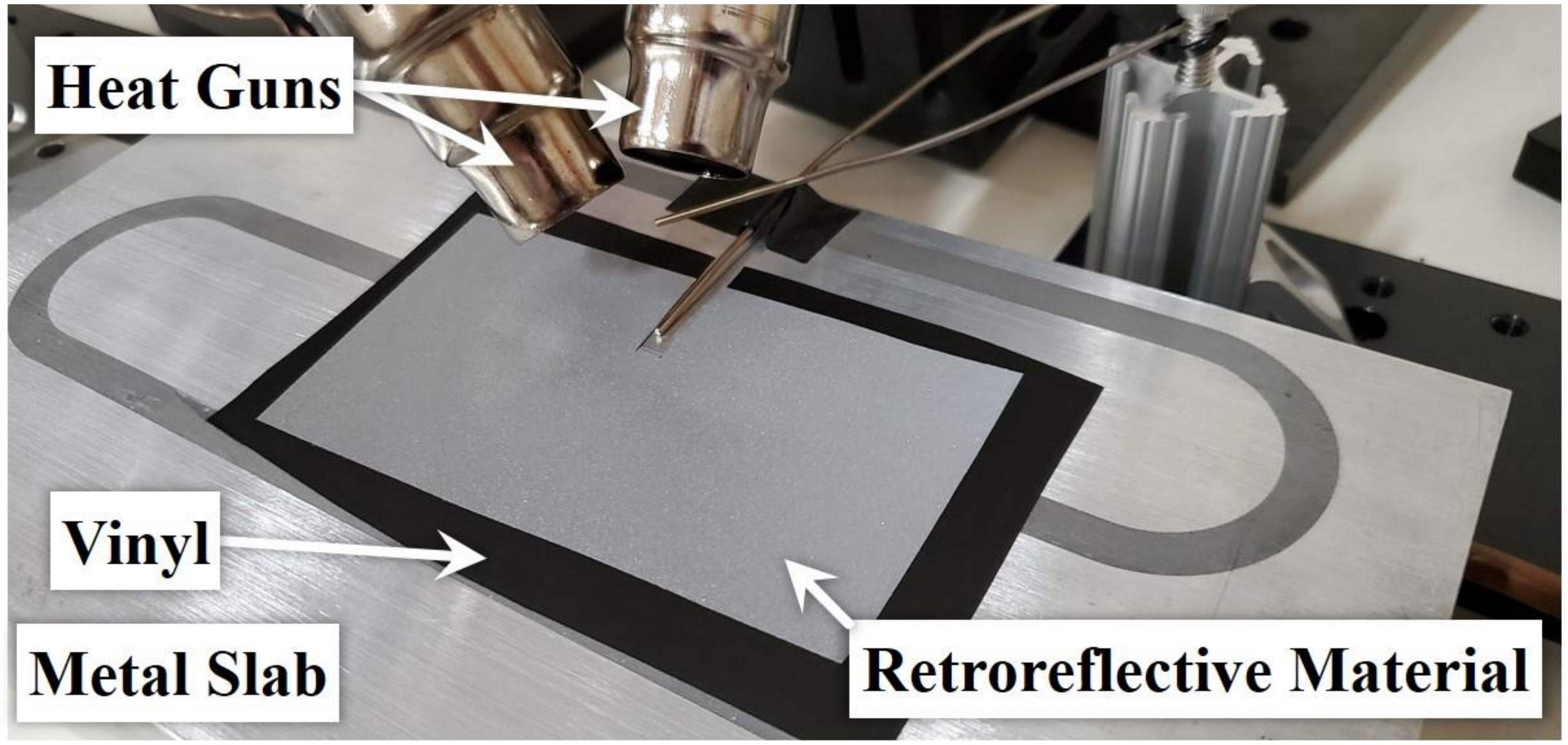




Survivability of Retroreflective Background

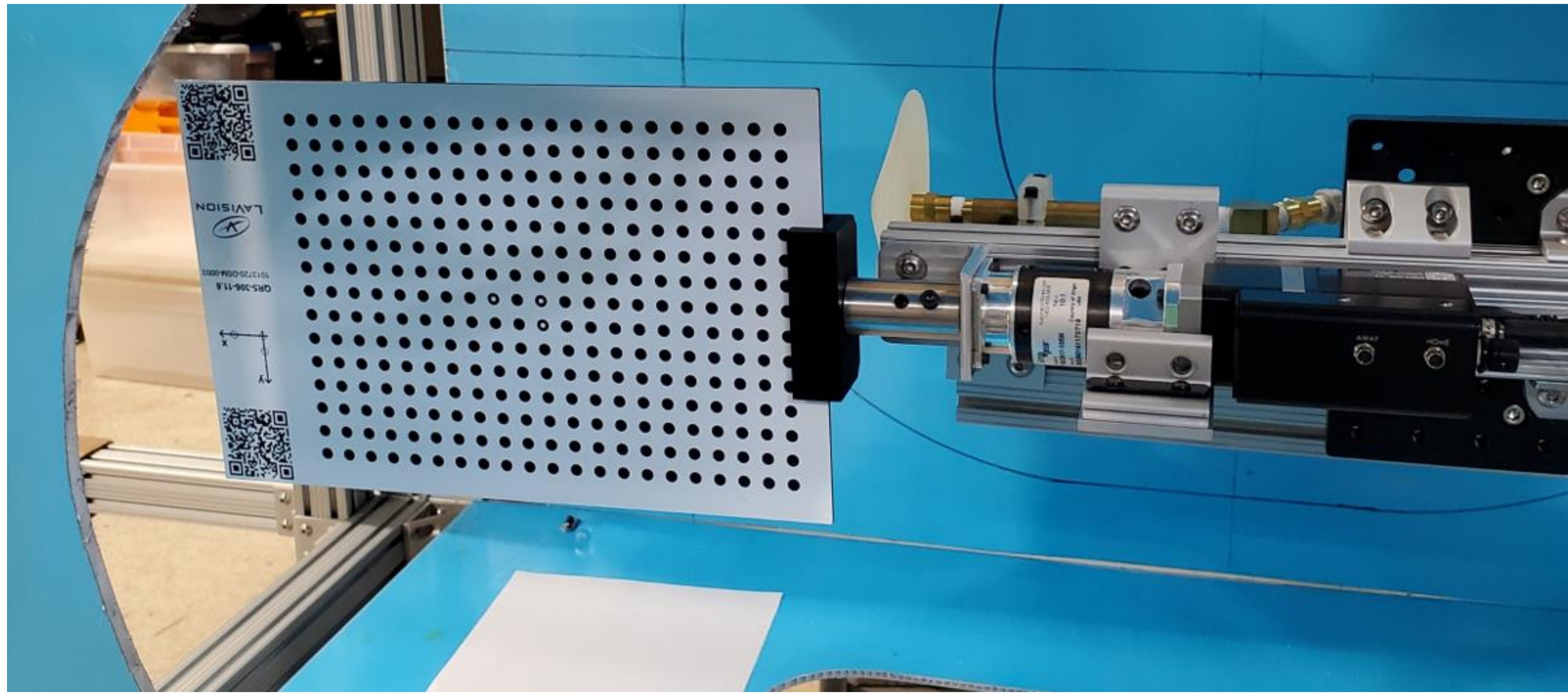
- Camera layout will require patterned retroreflective material to be placed on interior surfaces of wind tunnel
- For ease of application/removal, 3M Scotchlite 7610 is mounted onto 3M 1080 vinyl wrap material, which is then mounted on tunnel wall
- 31-Inch Mach 10 is pre-heated at beginning of day and between each run, but test section temperature during this procedure was unknown
- Performed measurements of static temperature in test section during a pre-heat
- Performed laboratory test with background material mounted to water-cooled metal slab subjected to high temperature air to simulate pre-heat
- Determined that material is highly likely to survive pre-heat

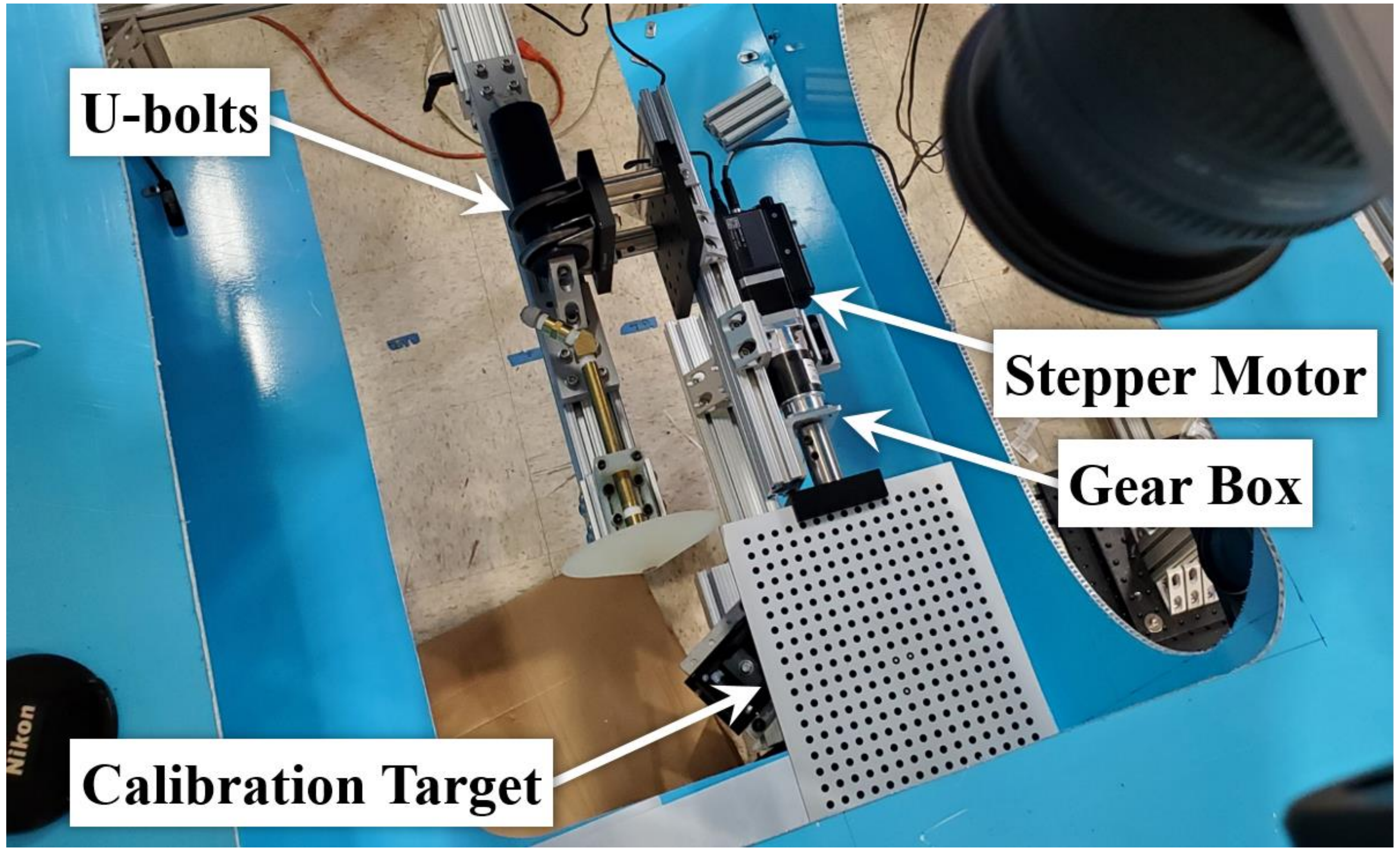




Remotely Controlled Calibration System

- No physical access to test section once cameras have been mounted around tunnel and aligned
- Designed remotely controlled calibration system consisting of a stepper motor, gear box, and calibration target
- System mounts to 2-inch-diameter SRP model sting with two U-bolts
- Model will be injected manually such that rotation axis of calibration system is aligned to tunnel centerline
- Calibration target is rotated through all camera views for volumetric calibration





Conclusions

- Discussed preparations for supersonic retropropulsion (SRP) test that will be conducted in 31-Inch Mach 10 wind tunnel at NASA Langley Research Center
  - Using a six-camera high-speed tomographic background-oriented schlieren (tomo BOS) system to visualize jet flow
  - Constructed full-scale mock-up of wind tunnel facility to optimize camera placement and alignment
  - Fabricated 3D-printed SRP forebody model with center nozzle to aid in alignment and provide high-speed jet for testing out tomo BOS system
  - Split pulsed laser source into seven fibers using 7-fiber bundle and coupled light onto camera axis with a 50:50 plate beamsplitter
  - Performed tests to ensure retroreflective backgrounds would survive test section pre-heat
  - Designed remotely-controlled calibration system

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