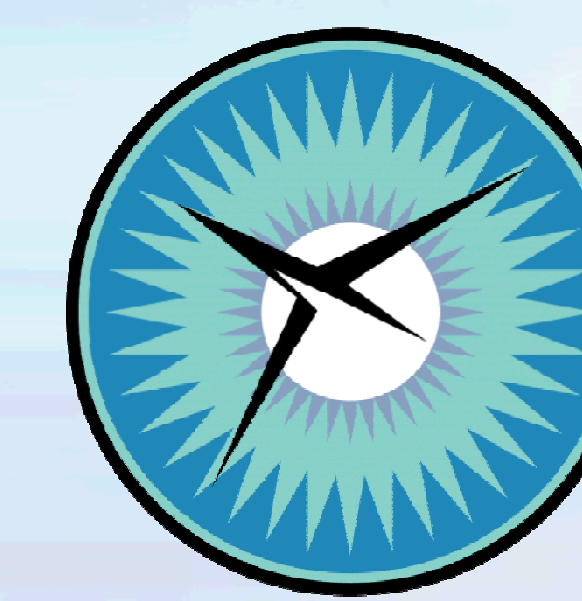


Comparison of the performance of unseeded Molecular Tagging Velocimetry (MTV) methods in a Transonic Cryogenic Windtunnel: FLEET, PLEET and STARFLEET



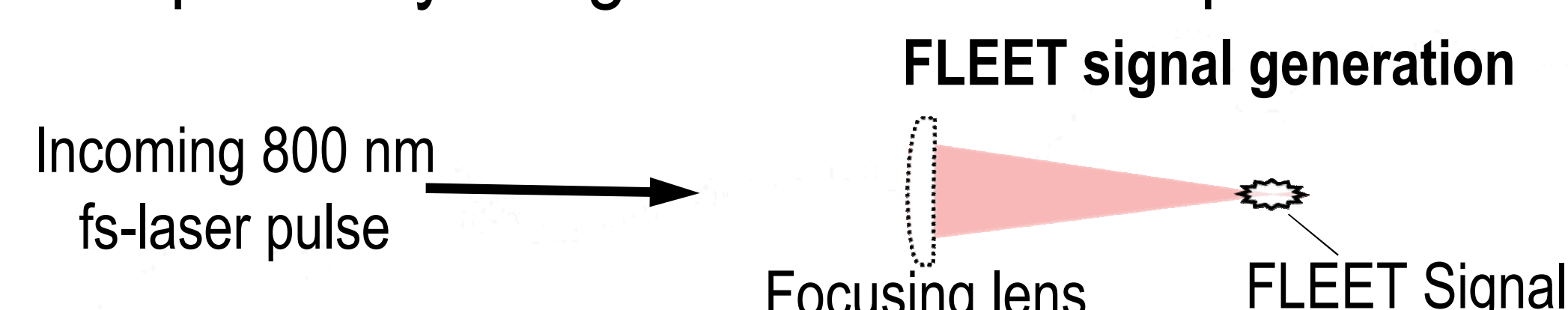
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Overview:

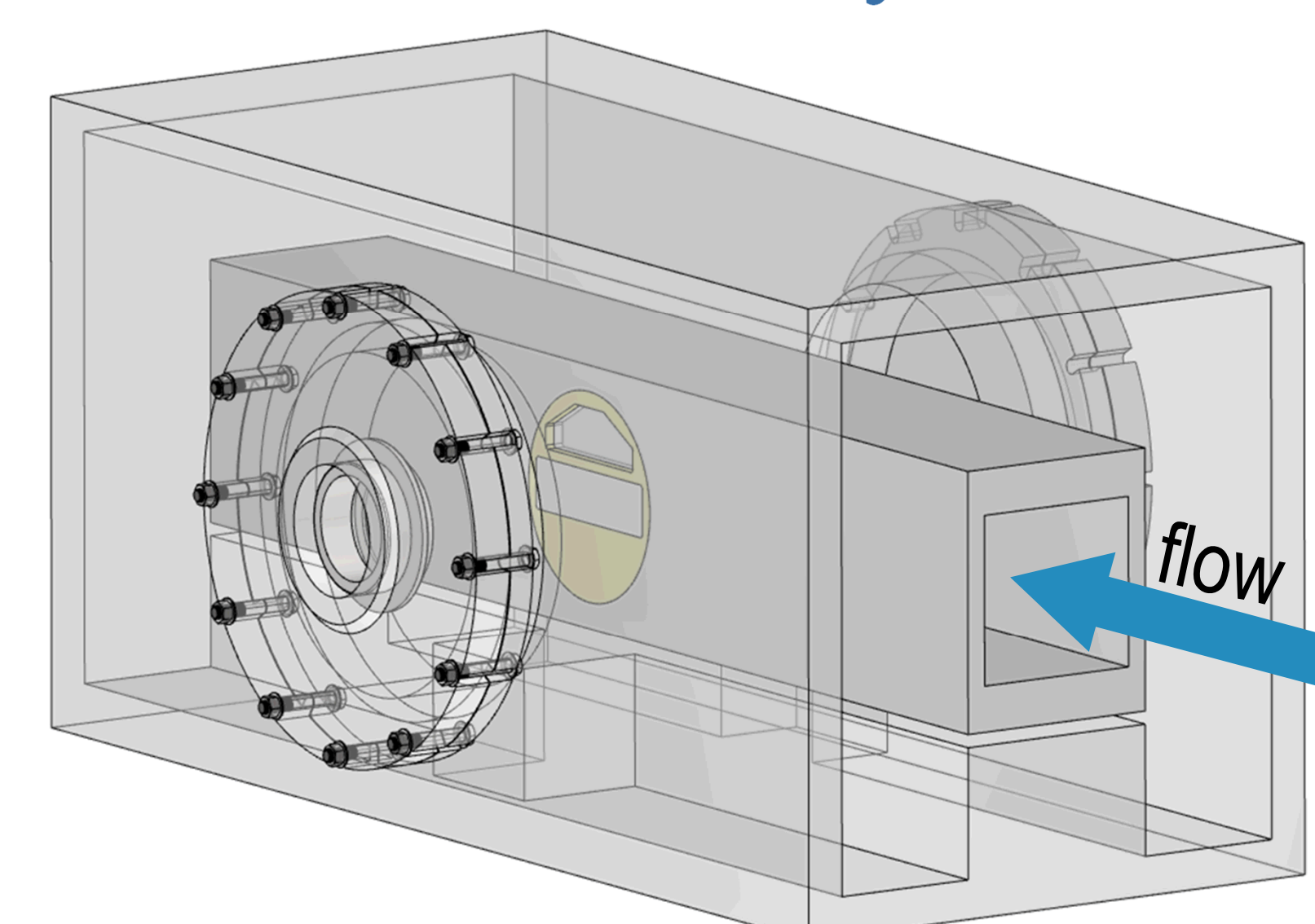
Transonic Cryogenic Tunnels (TCTs) use high pressure, low temperature gaseous N_2 to generate very high Reynolds number transonic flows for aerodynamics studies. The performance of three different unseeded molecular tagging velocimetry (MTV) techniques are demonstrated and compared in NASA Langley's 0.3-meter TCT.

What are FLEET, PLEET and STARFLEET?

- F**emtosecond **L**aser **E**lectronic **E**xcitation and **T**agging uses a focused 100-femtosecond duration laser pulse to dissociate molecular nitrogen
- Recombination of atomic nitrogen results in a long-lived fluorescence (10s of μs), which is sequentially imaged to measure displacements and velocities
- P**icosecond **L**aser **E**lectronic **E**xcitation and **T**agging uses a focused 100 picosecond 1064 nm YAG laser pulse to dissociate molecular nitrogen – 25x faster.
- S**elective **T**wo-photon **A**bsorptive **R**esonance **F**LEET utilizes a focused quadrupled femtosecond-duration laser pulse at 202.5 nm to resonantly dissociate molecular nitrogen – 30-100x lower energy than FLEET: much lower perturbation



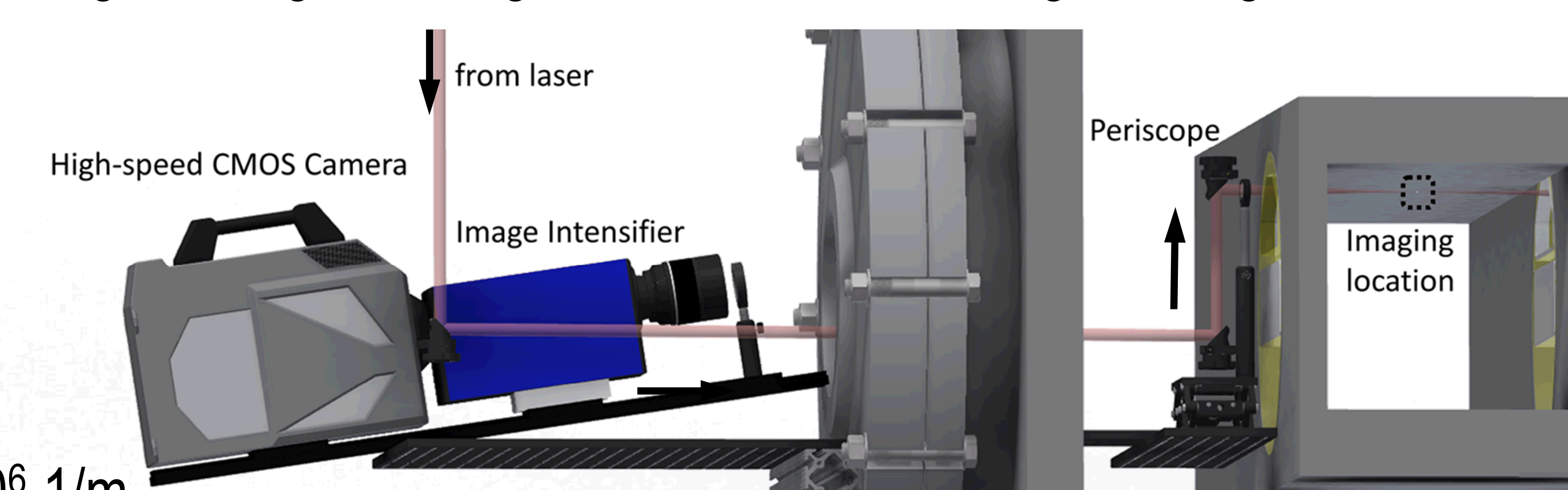
Flow Facility and Measurement systems:



- 0.3-m Transonic Cryogenic Tunnel
- Operating gases: Air, N_2 , SF_6
 - Temperature: 100 K to 300 K
 - Mach number: 0.2 to 0.9
 - Reynolds number: 4×10^6 to 300×10^6 1/m

- FLEET/STARFLEET systems used a Ti:Sapphire laser (1 kHz)
- PLEET used Spectral Energies Quasimodo YAG laser (25 kHz)
- High-speed CMOS camera (200 kHz)
- High-speed image intensifier

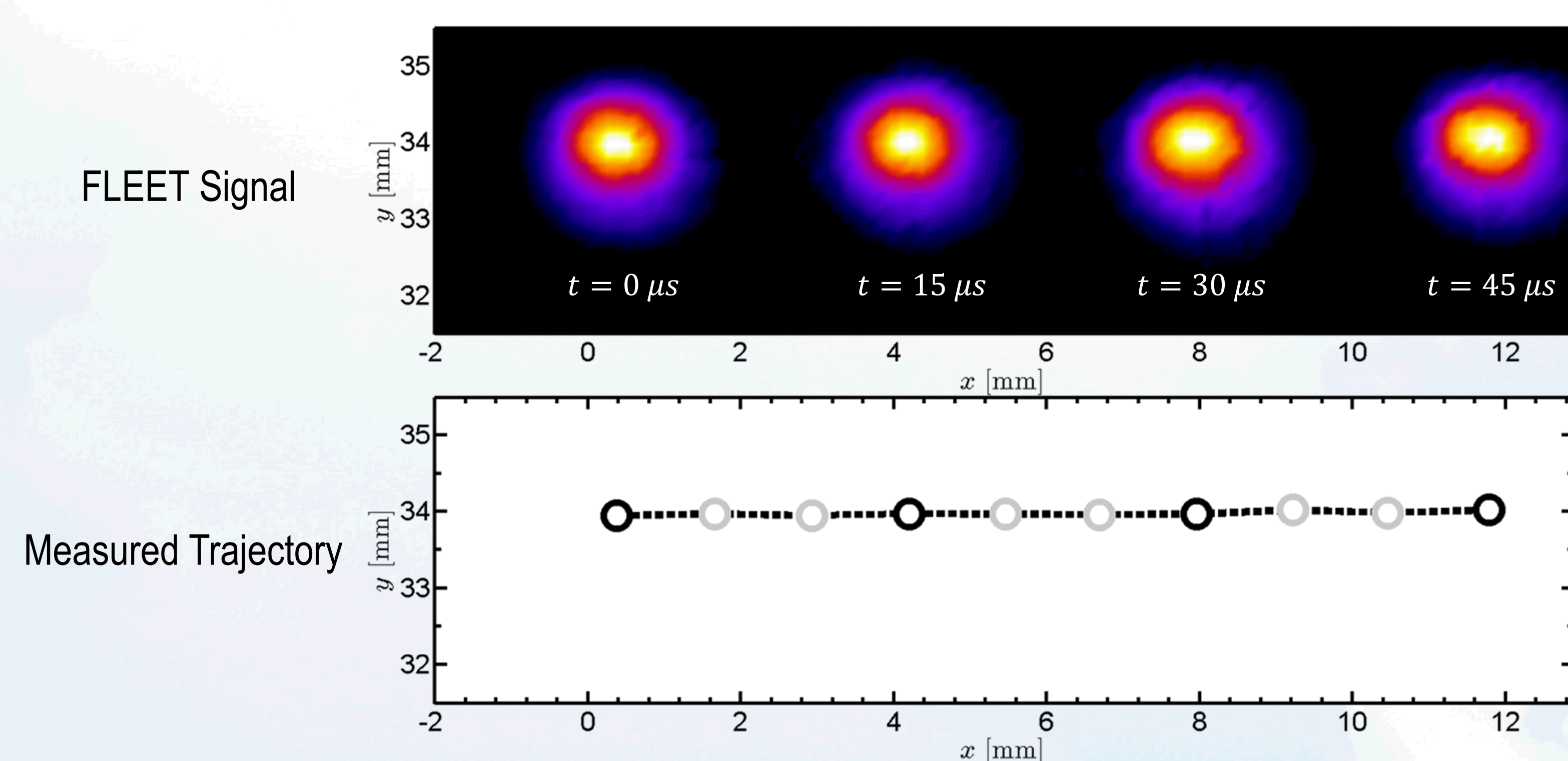
Signal imaged through windows in a bore-sight configuration



Sample Data:

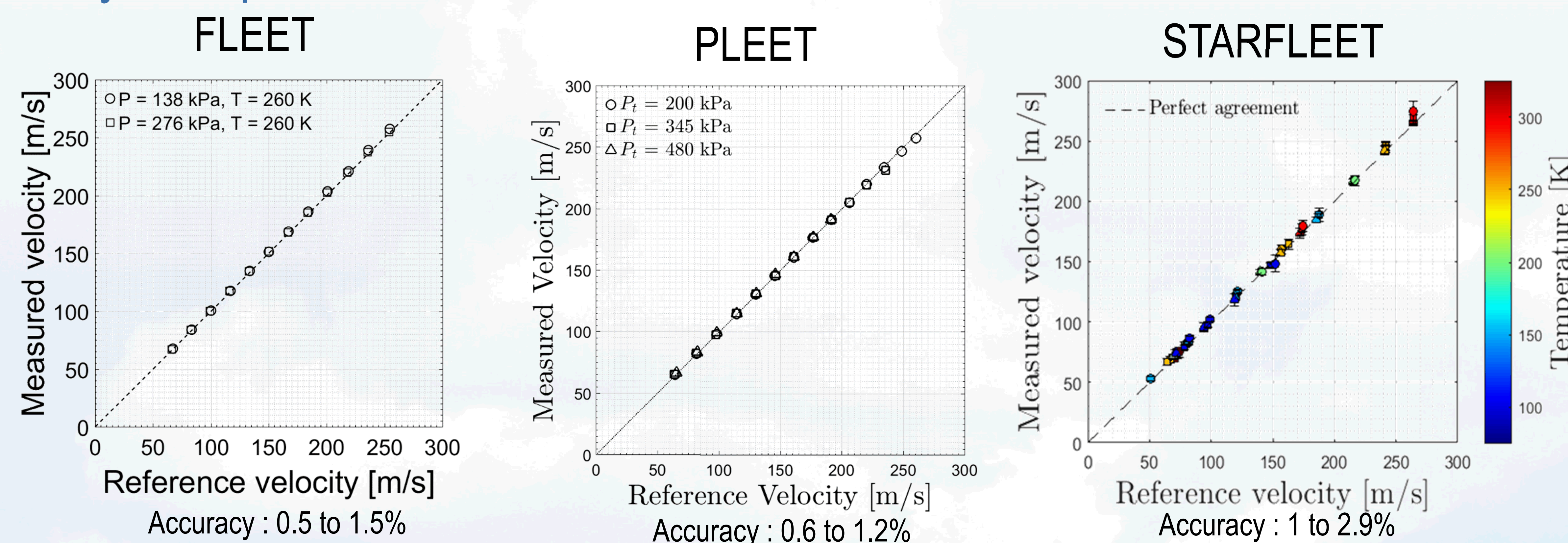
$$u = \Delta x / \Delta t, \quad a = \Delta u / \Delta t$$

Freestream Measurements



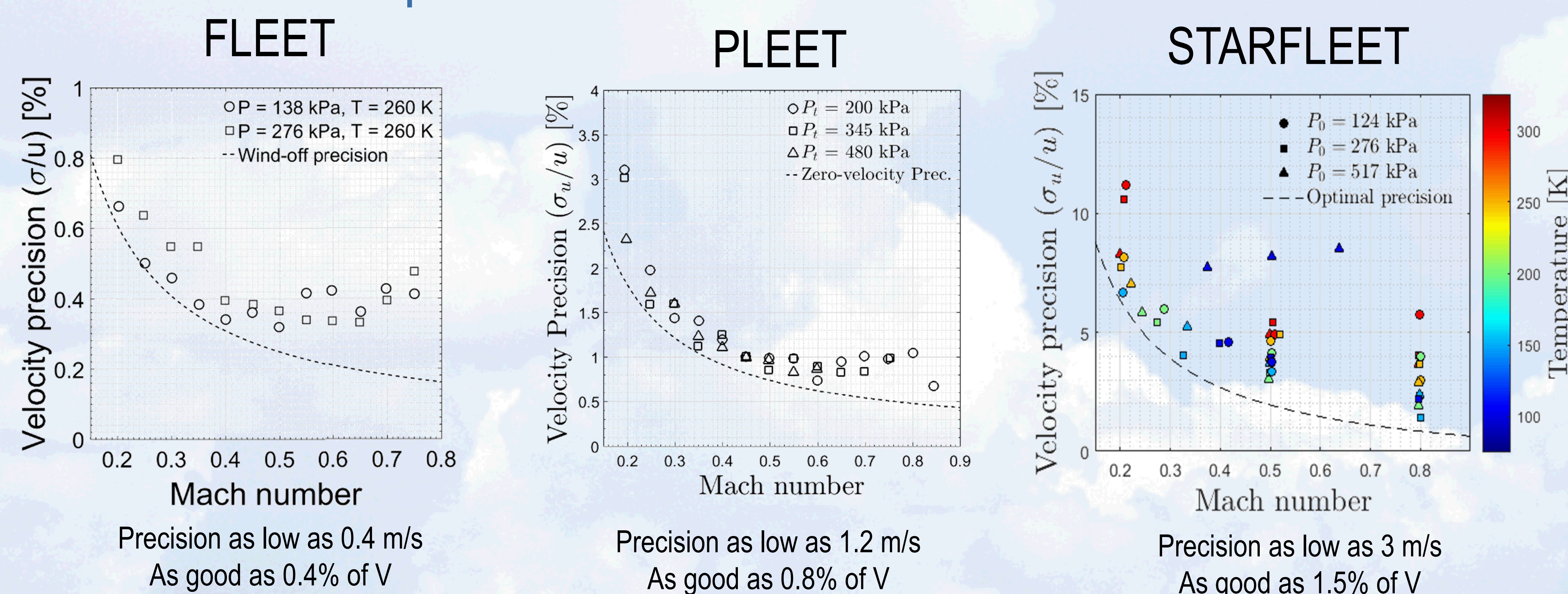
Sample freestream FLEET data ($M = 0.75$, 1 out of 3 images shown for clarity)

Accuracy Comparison: Accuracy $\equiv$ how velocity differs from a known reference (facility data acquisition system)



- Main error source is likely from camera calibration (magnification)

Precision Comparison: Precision $\equiv$ 1 standard deviation of an ensemble of measurements

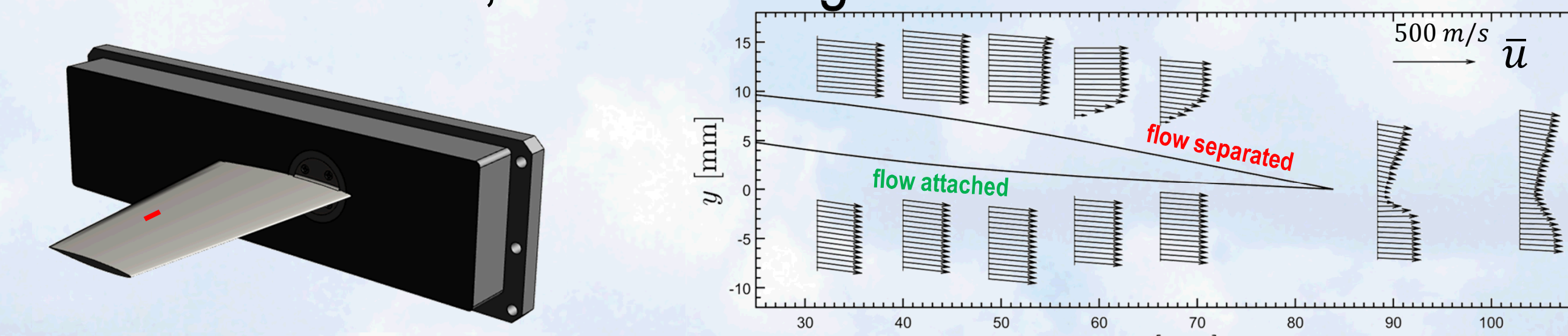


Conclusions:

- FLEET, PLEET, STARFLEET velocimetry successfully applied in a smaller scale TCT facility over full operation envelope of tunnel.
- Accuracy characterized: ~1% for all techniques
- Precision characterized: Best > worse: FLEET > PLEET > STARFLEET
- STARFLEET limited by laser mirrors: 85% reflectivity

Recent / Planned Advancements:

- Have acquired velocity profiles in more applied flowfields (airfoil, cylinders in 0.3 m TCT, wake of wing of commercial aircraft in NTF TCT)



- Fully implement FLEET technique in larger National Transonic Facility

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