MoJet Tunnel Ventilation – Full-Scale Testing and CFD Analysis

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Motivation

- Would it be possible to significantly increase the thrust from jetfans in a tunnel, while reducing the power consumption?

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Contents

- MoJet Design
- Montgomery Tunnel
- 3D CFD Computations
- Experimental Measurements
- Conclusions

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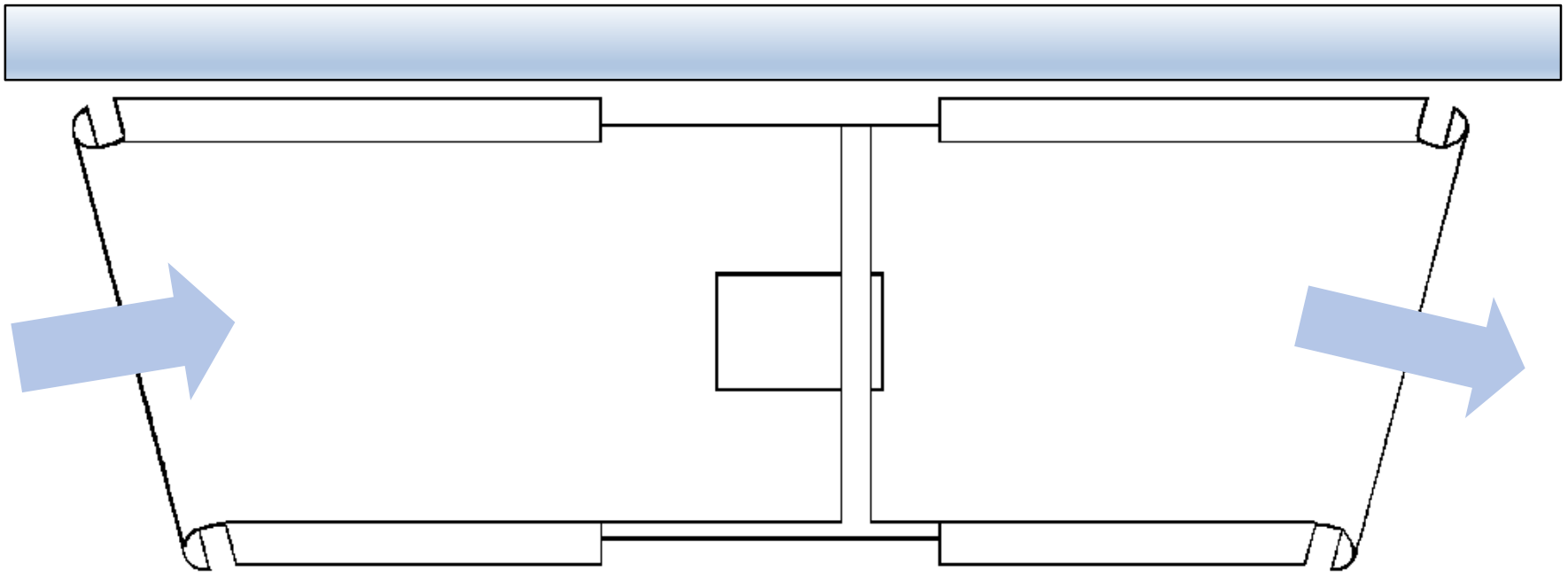
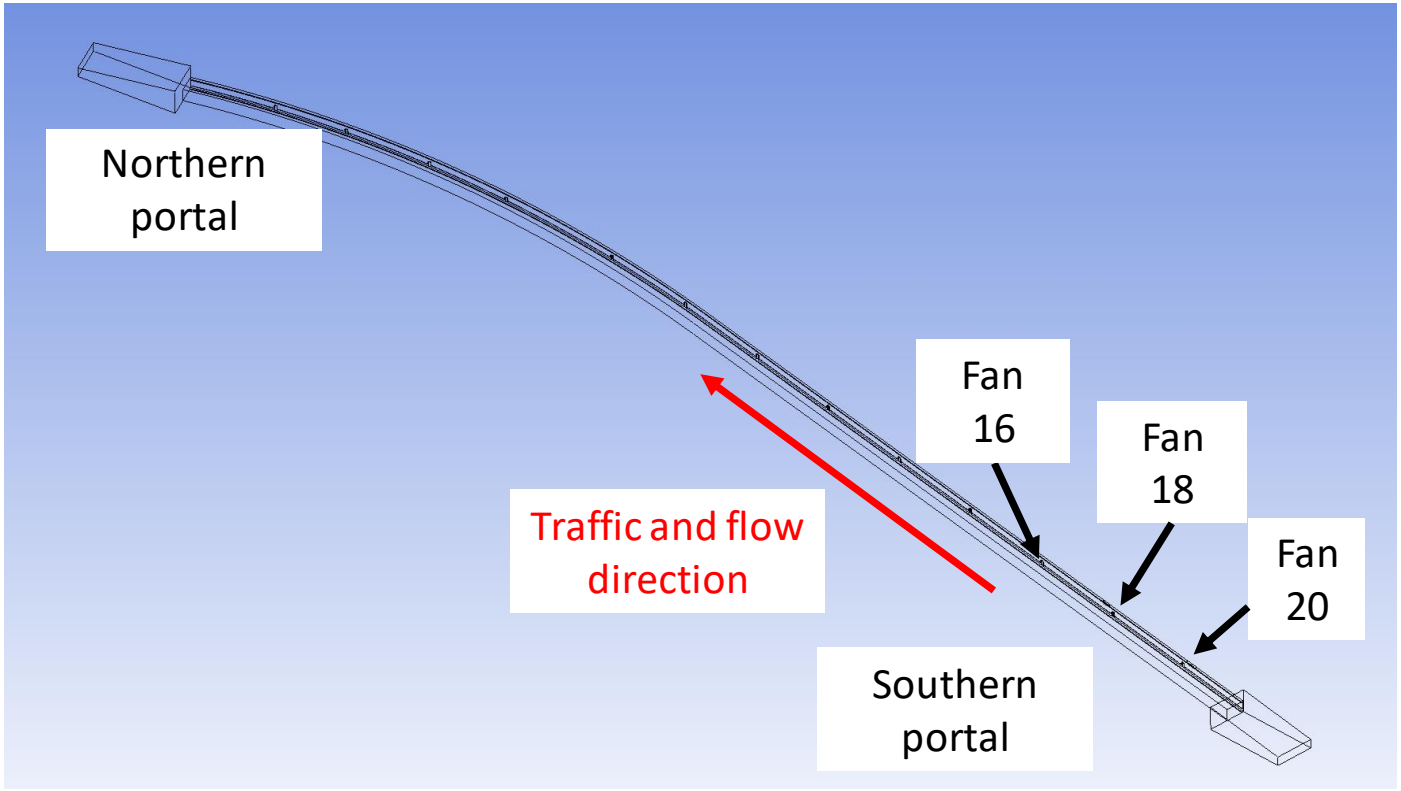
Reversible MoJet

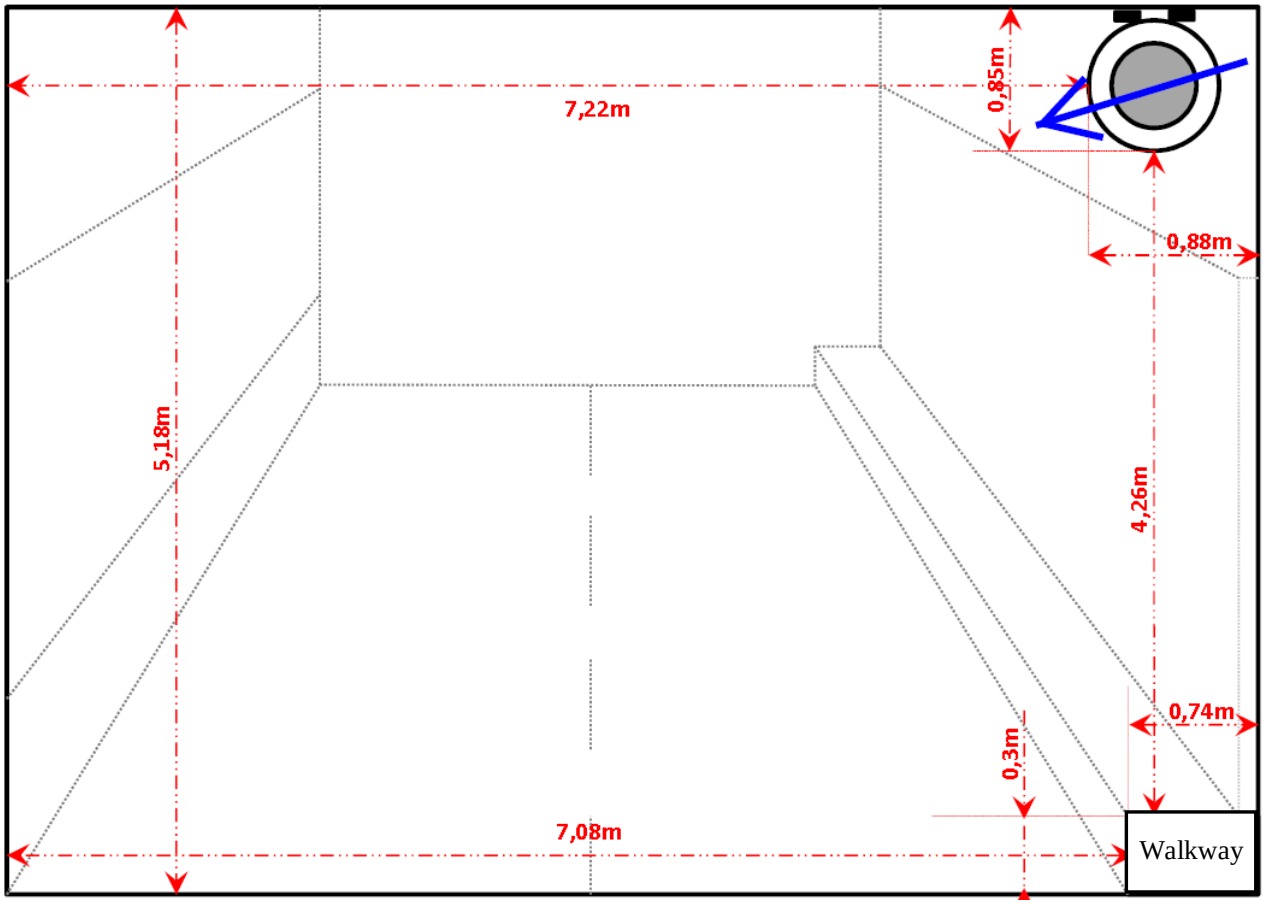


Montgomery Tunnel, Brussels (North Portal)

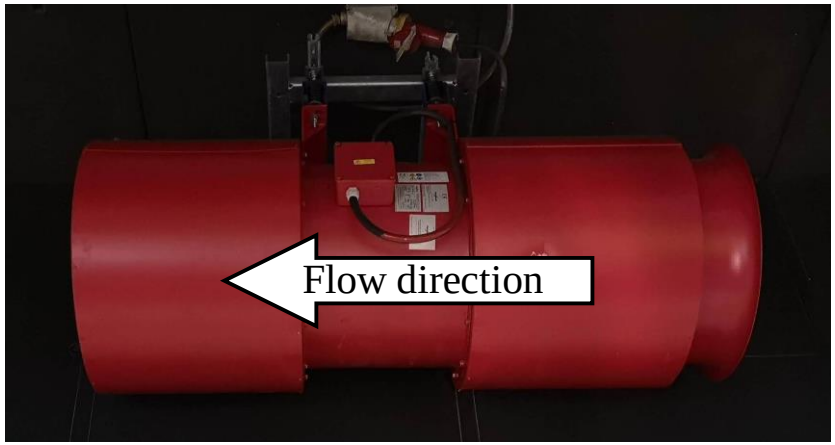
Montgomery Tunnel

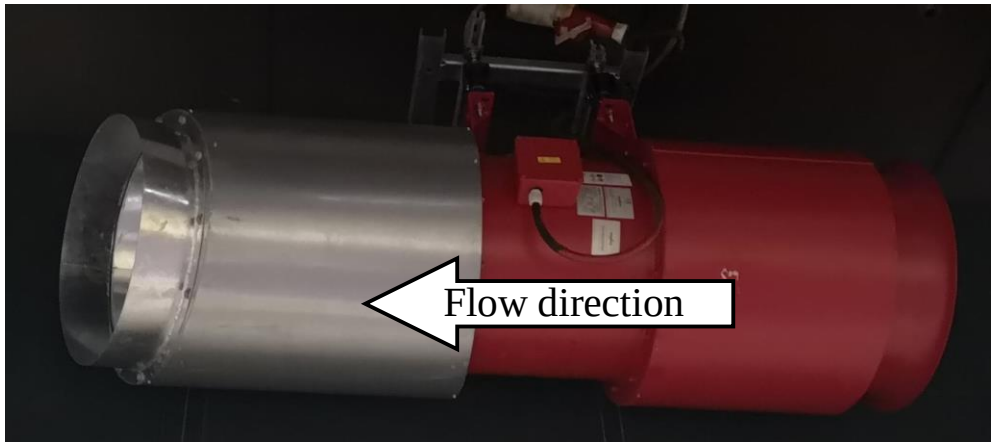


Tunnel Cross-Section



Jetfan Installations





3D CFD Analysis

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Case Set-Up

- The conventional jetfan and MoJet (exhaust silencer only) were compared in the following CFD simulations:
  - Bench thrust (jetfans in isolation)
  - Three fans running in the Southernmost locations (16, 18, 20) of the northbound tunnel (flow direction going from South to North).

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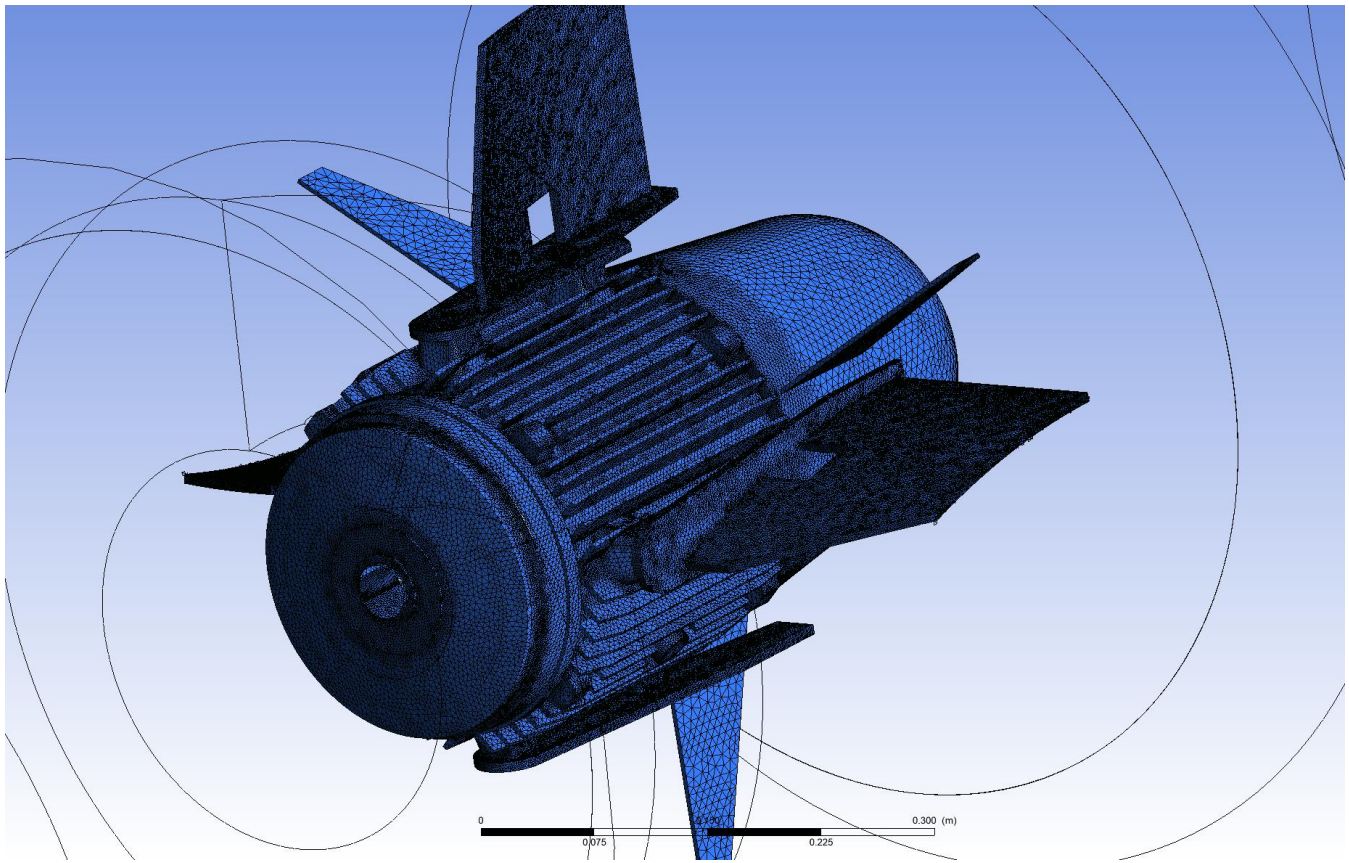
Case configuration

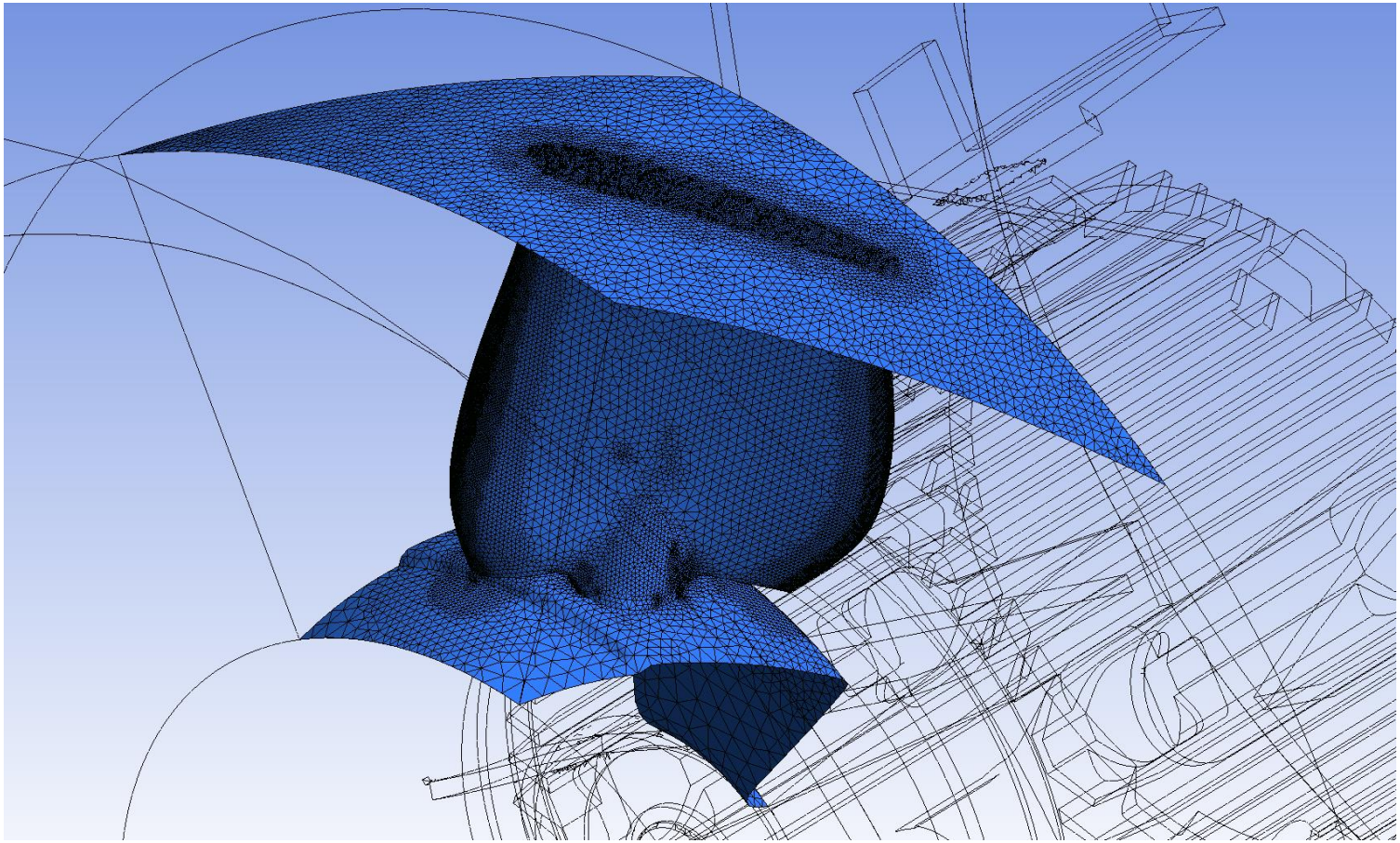
- The simulations were run in CFX 19.2 with the following conditions:
  - Fan rotational speed of 2900rpm
  - Non-buoyant model
  - 1 atm Reference Pressure
  - Total Energy with Viscous Work Term
  - Turbulence Model k-ω SST

BENCH THRUST SIMULATIONS

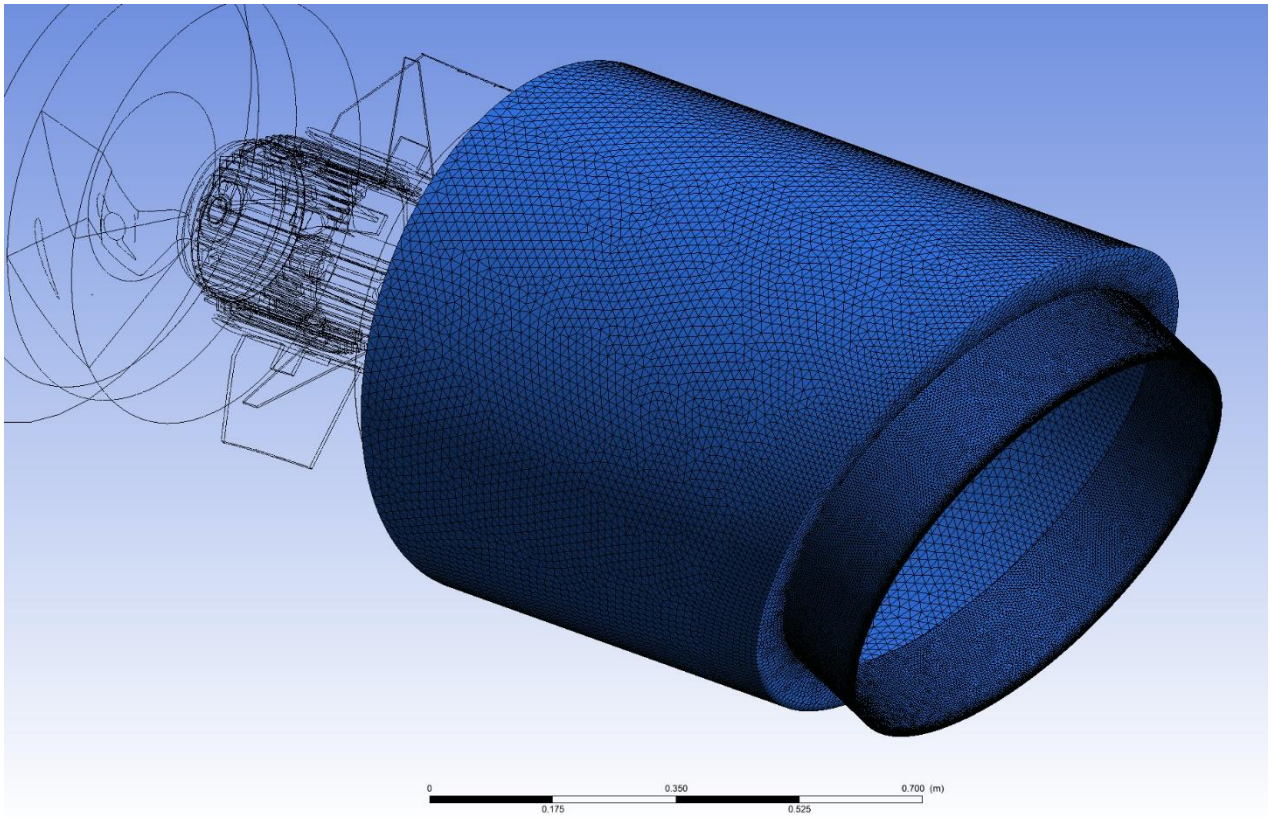
Mesh on Motor



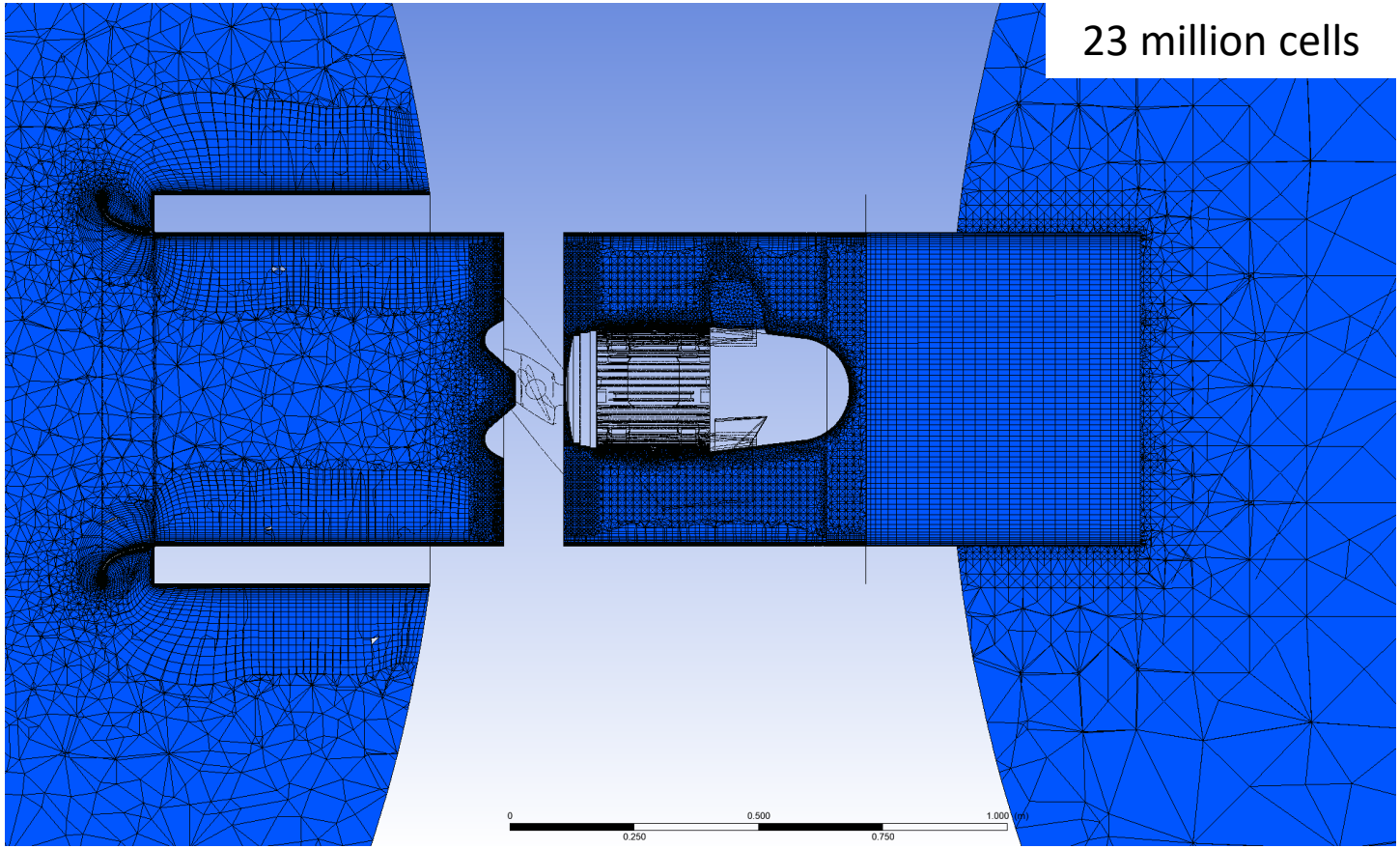
Mesh on Blade



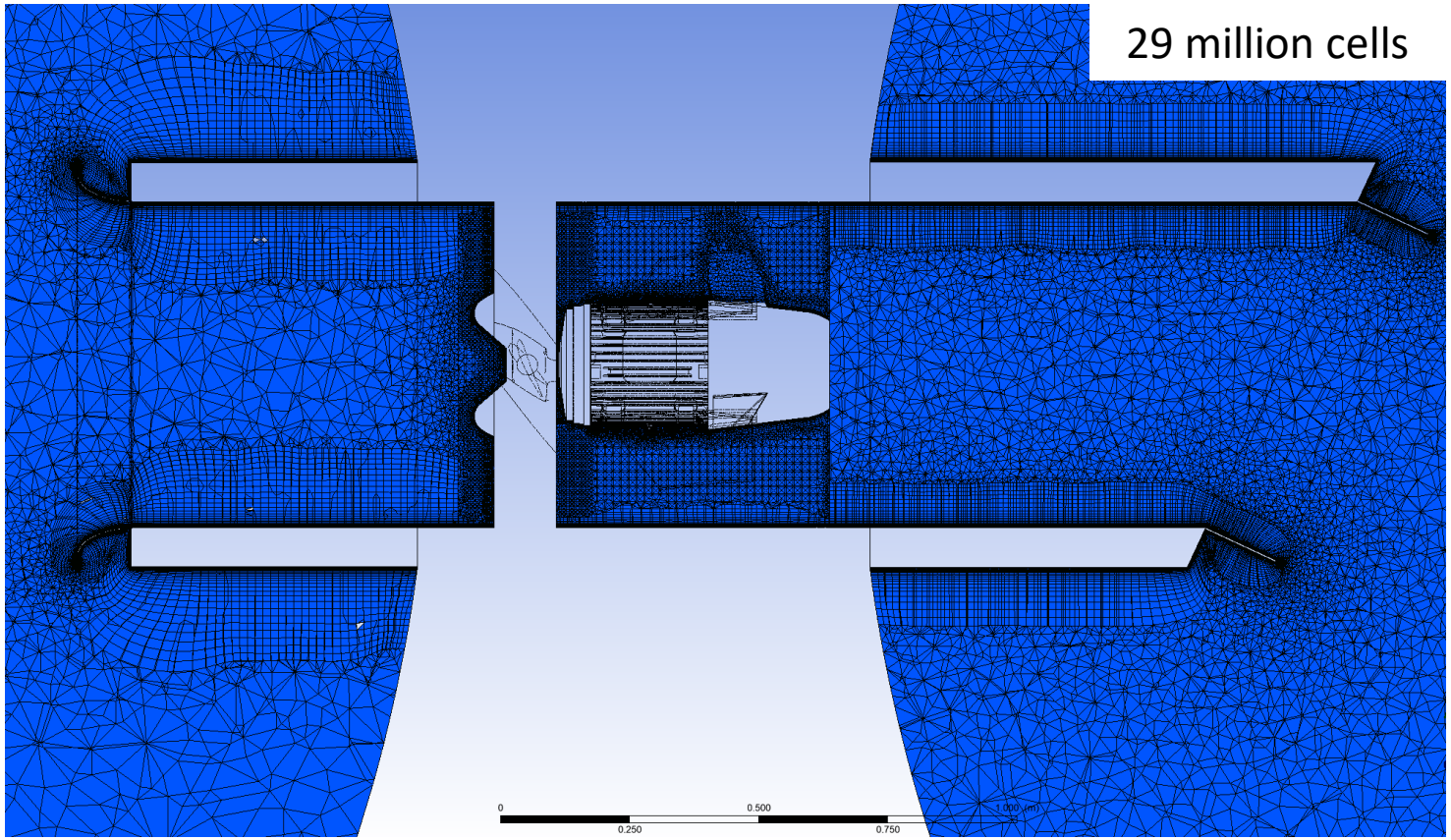
Mesh on Silencer



Conventional jetfan volume mesh



MoJet volume mesh



Case results

- Experimental results:
  - Ux 30.5 m/s (21° pitch angle)
- Conventional jetfan
  - Ux 27.5 m/s (mass flow average)
  - VFR 8.21 m^3/s
- MoJet
  - Ux 30.8 m/s (mass flow average)
  - VFR 8.27 m^3/s

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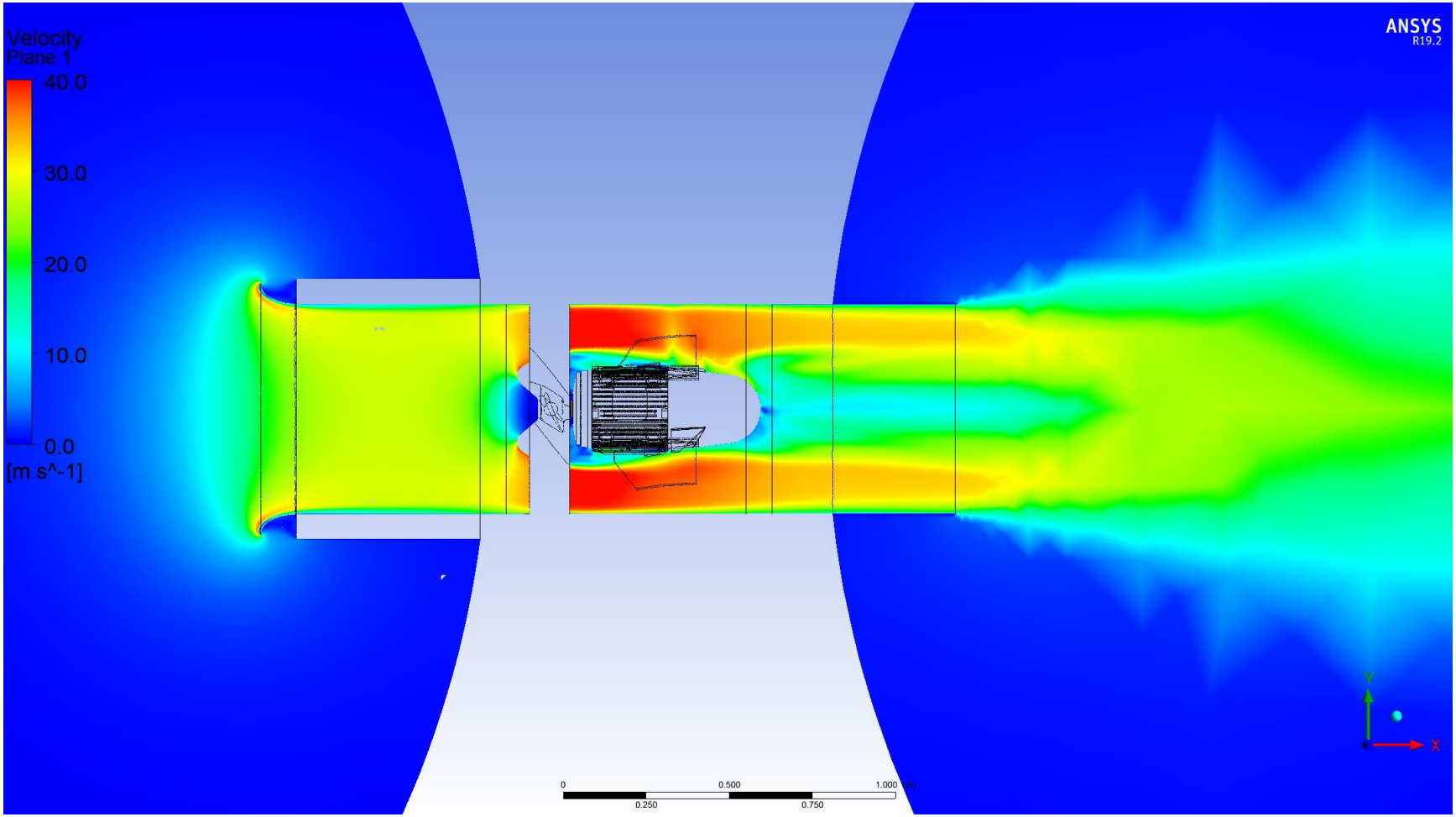
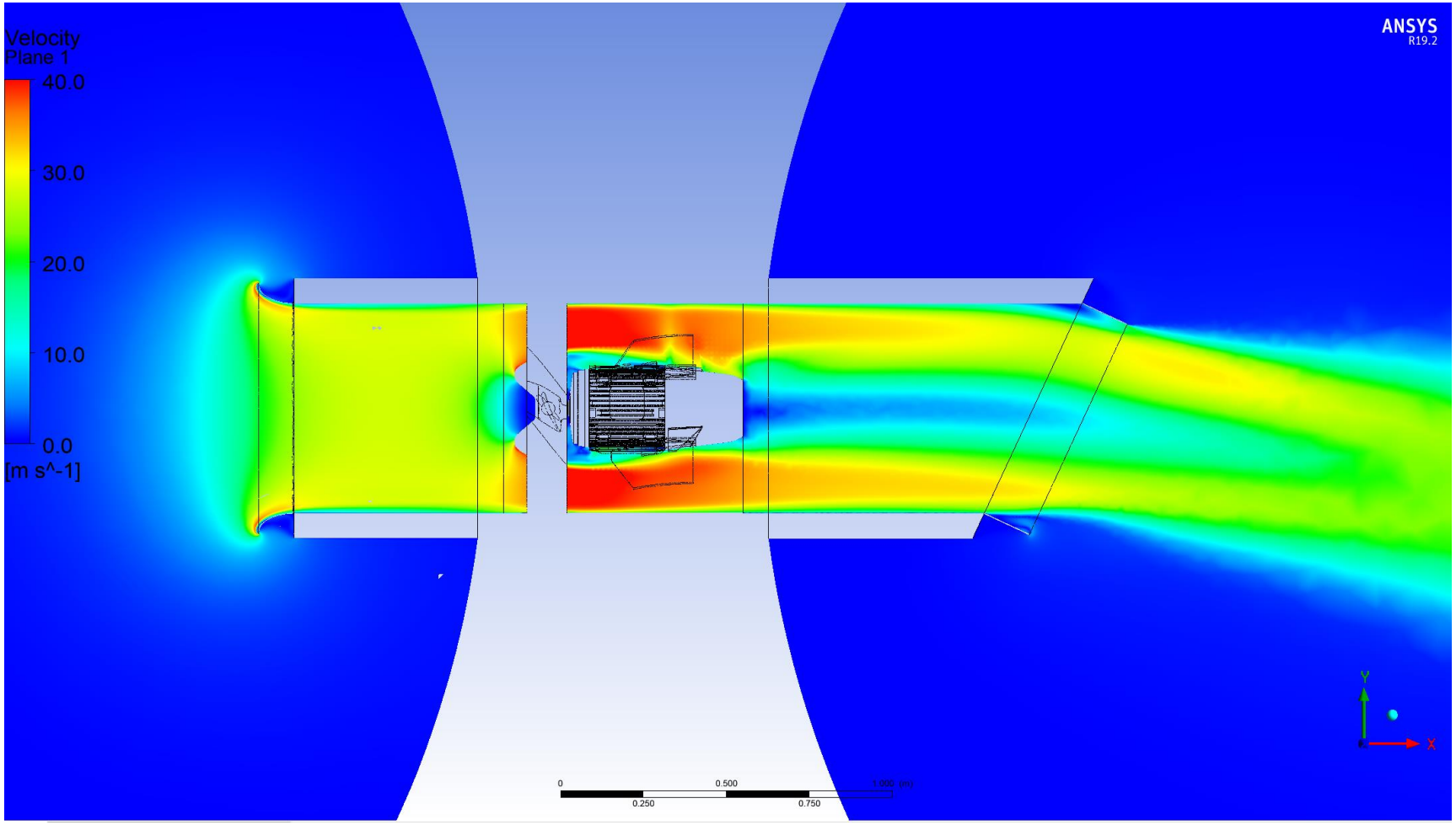
Velocity Contours – Conventional Jetfan



Velocity Contours - MoJet



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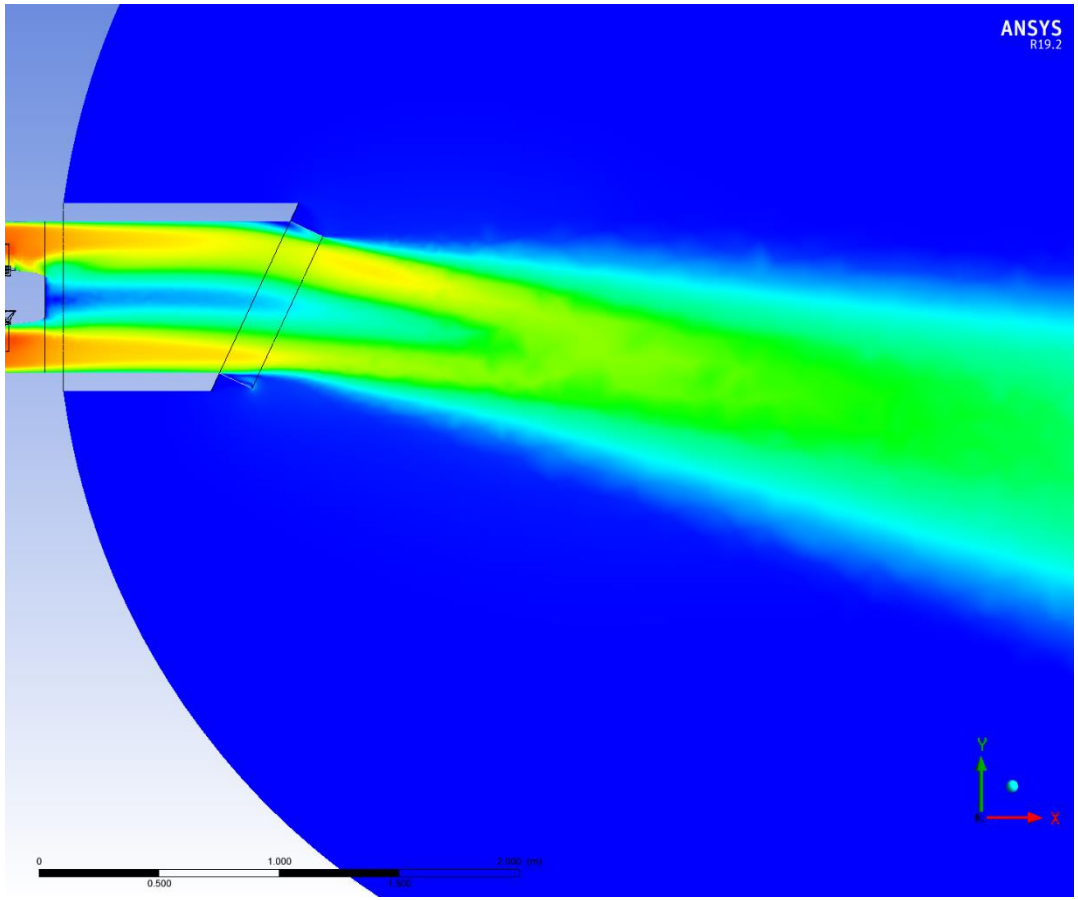
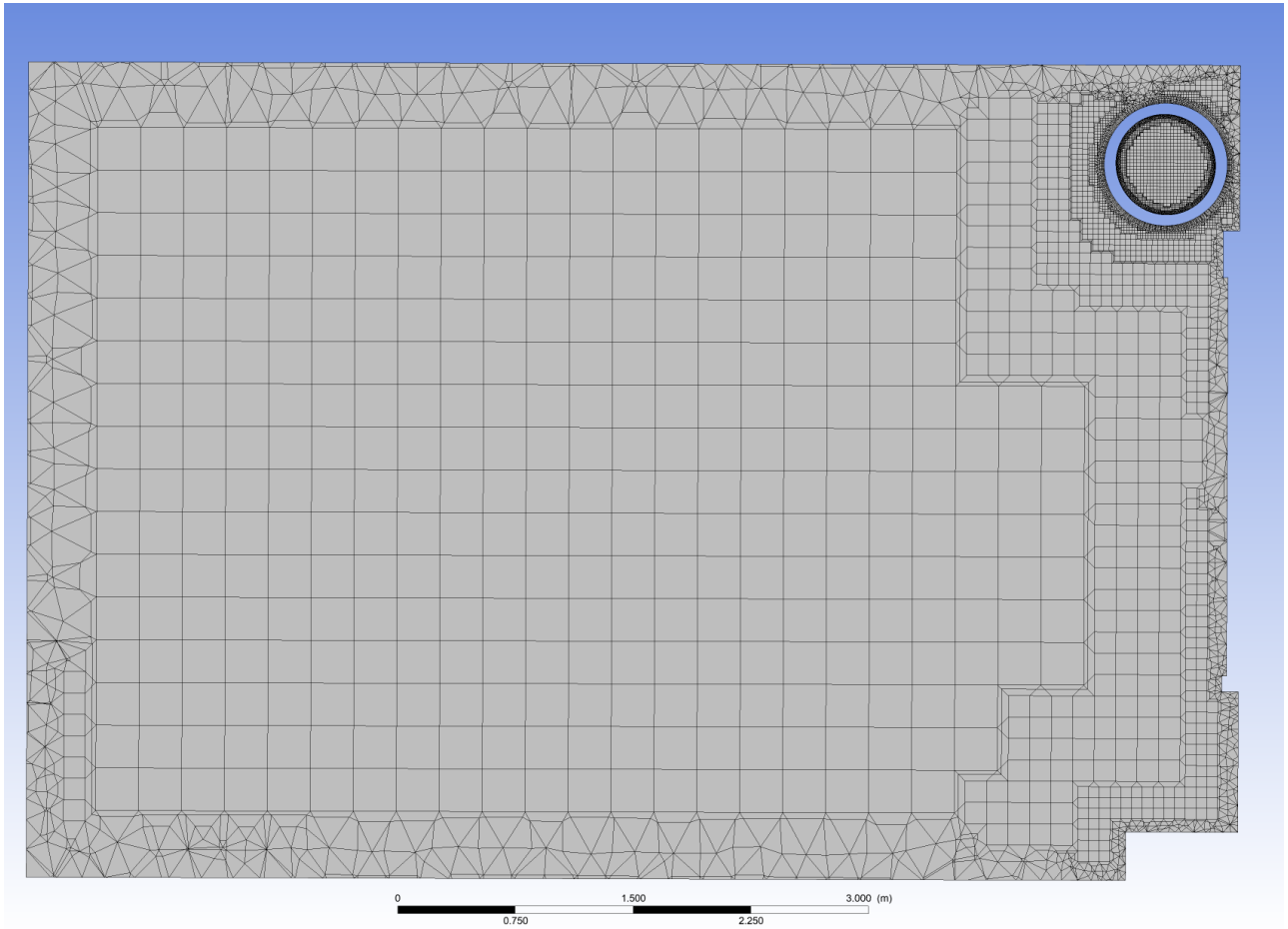
Flow Deflection - MoJet

- The MoJet achieved a deflection angle of 11° from the horizontal axis.

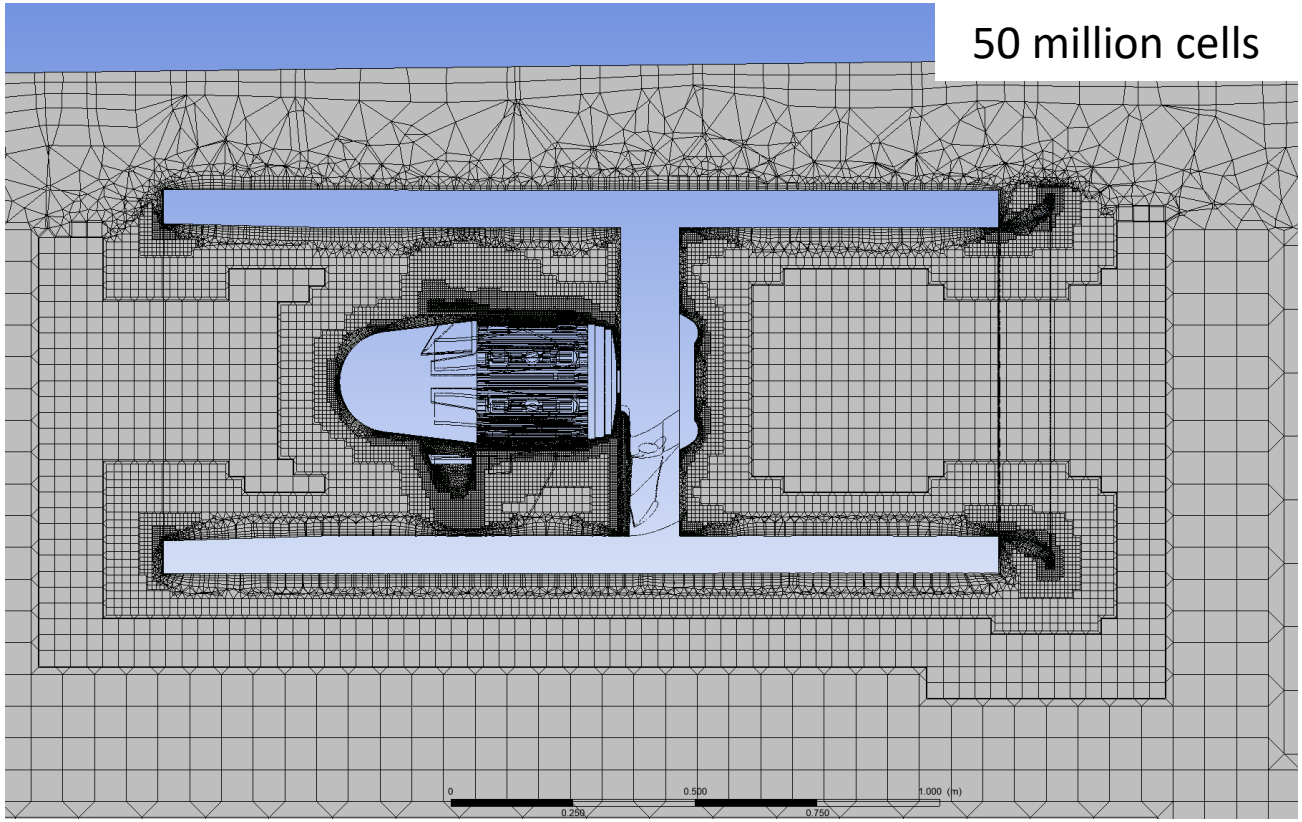


TUNNEL SIMULATIONS

Mesh Across Tunnel Section

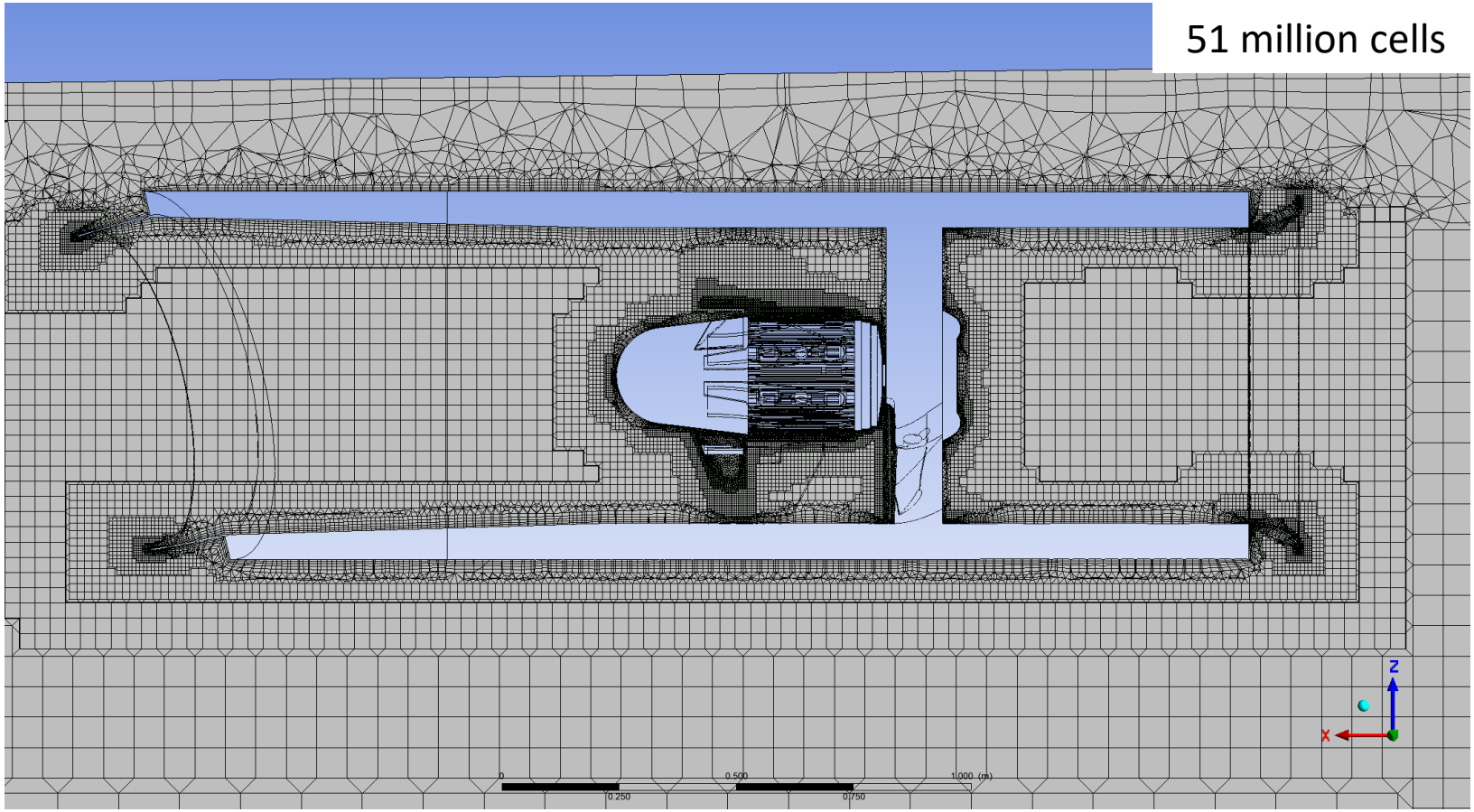


Conventional jetfan volume mesh



MoJet volume mesh

51 million cells



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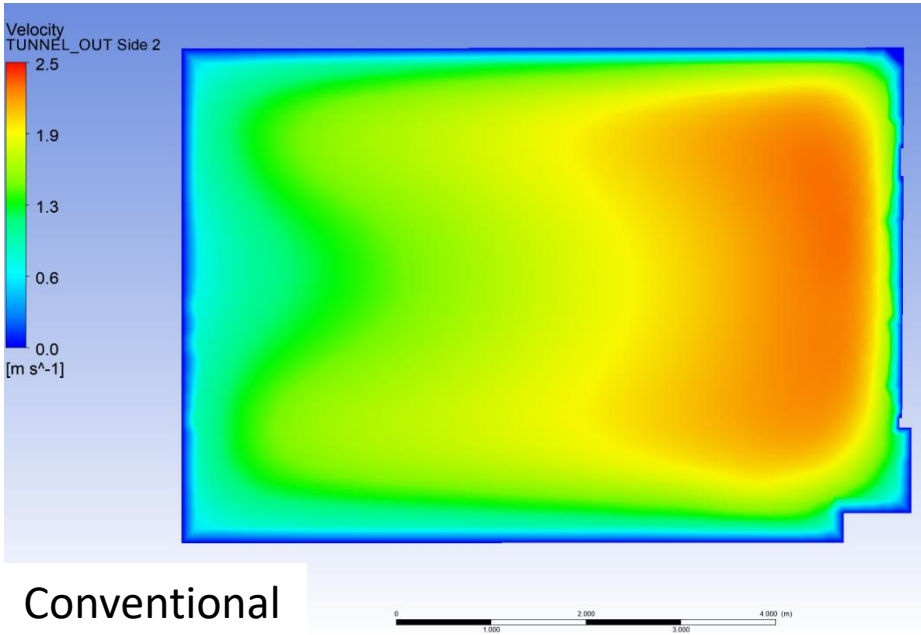
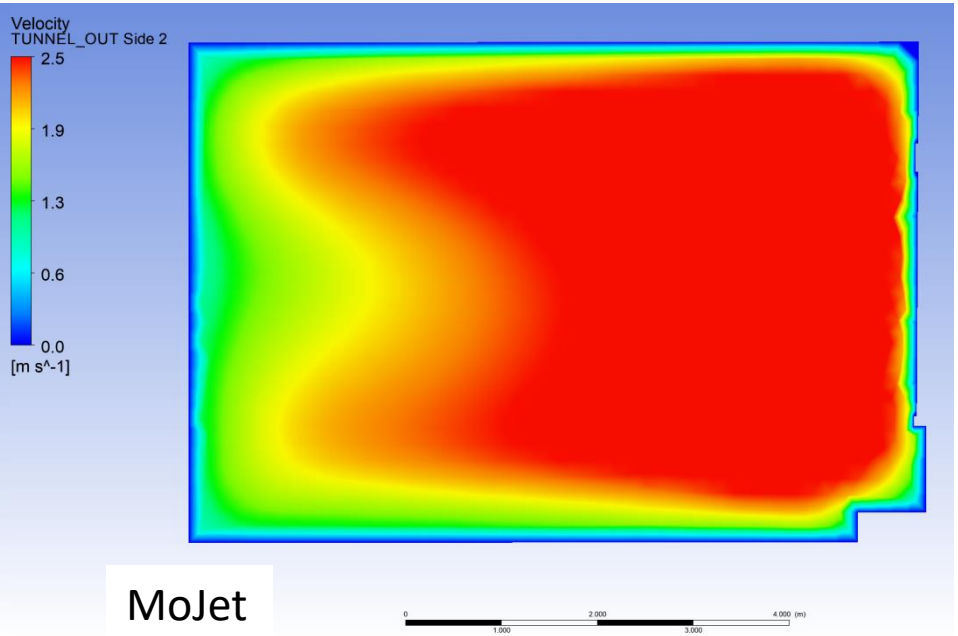
Velocity Contours at North Portal



Conventional

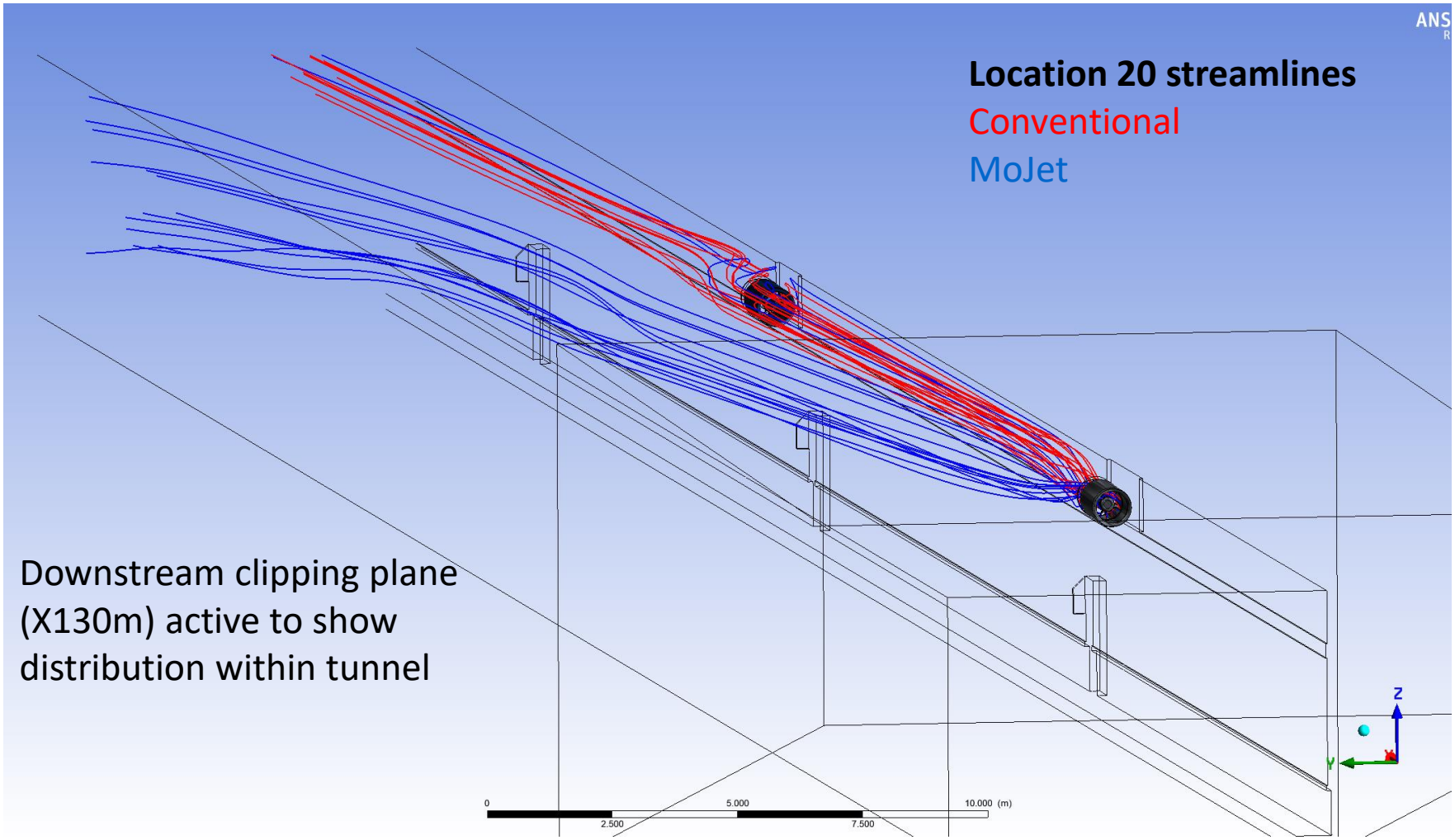


MoJet

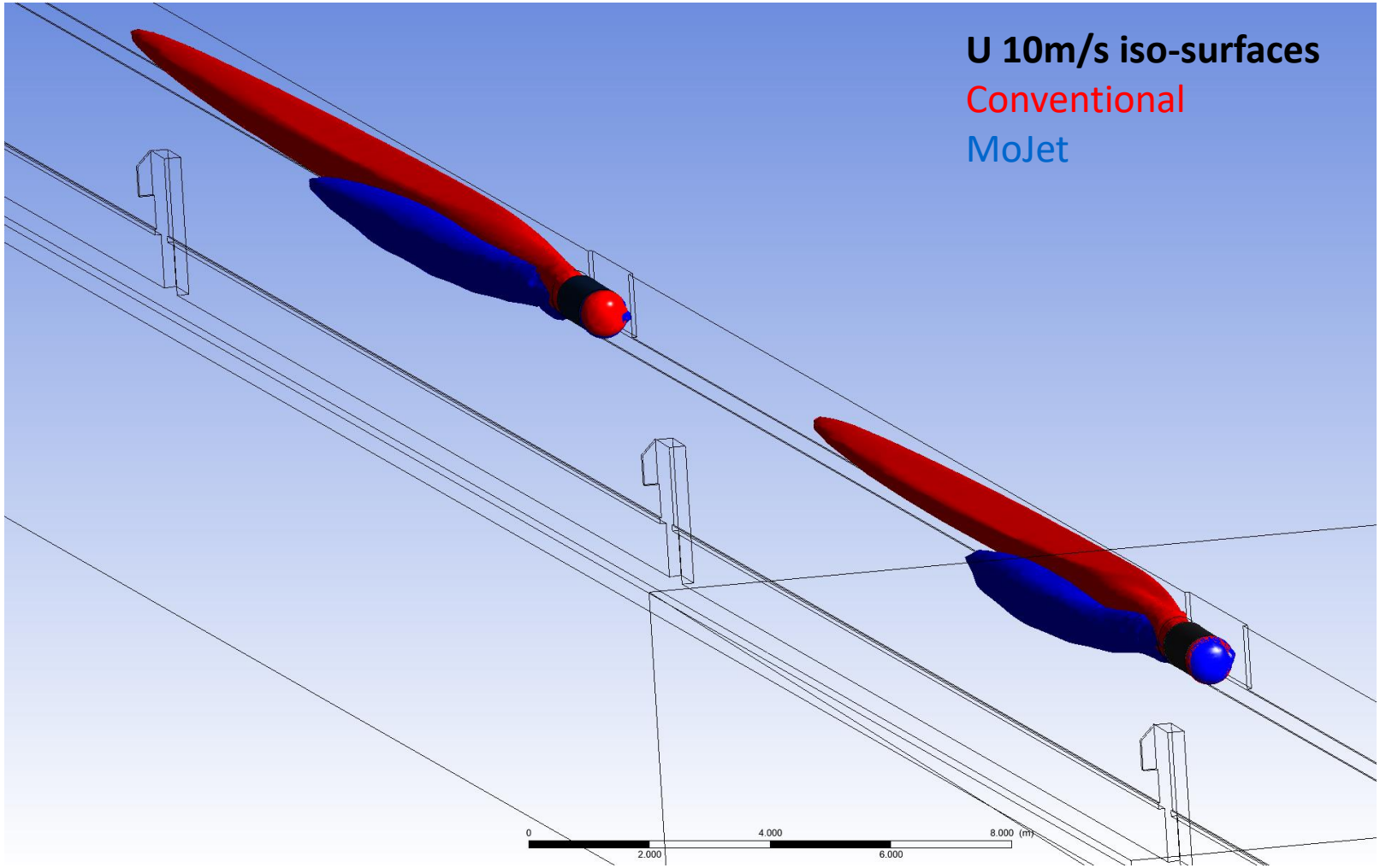
Jetfan Installation Factors

- Applying the volumetric flow rates from the tunnel simulations to 1D CFD (using IDA RTV) produces the following installation factors :
  - Conventional 0.25
  - MoJet 0.53 (+112%)

Streamlines Comparison

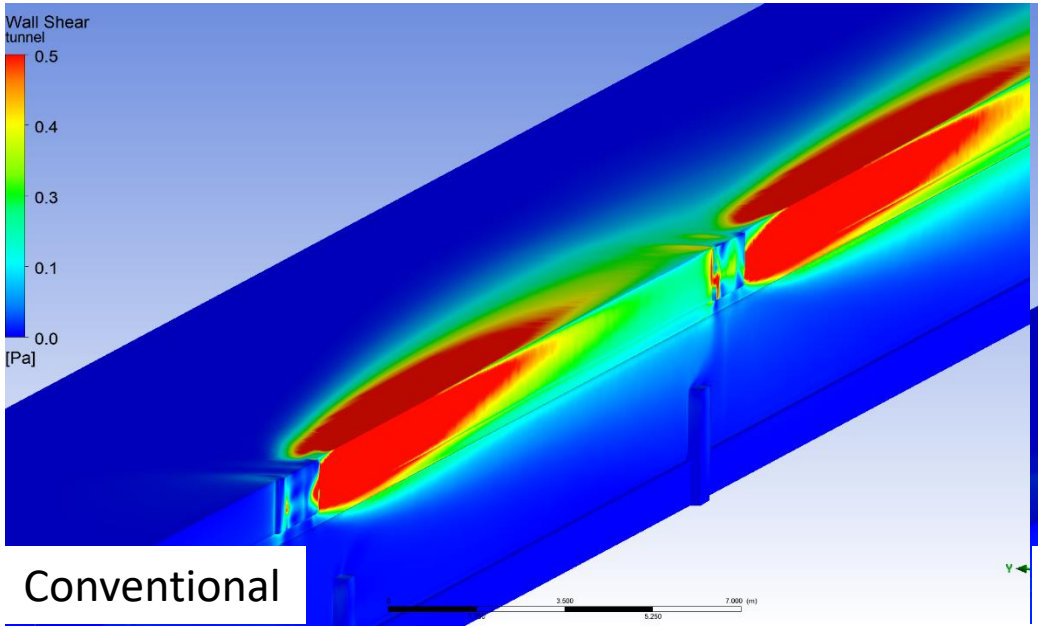


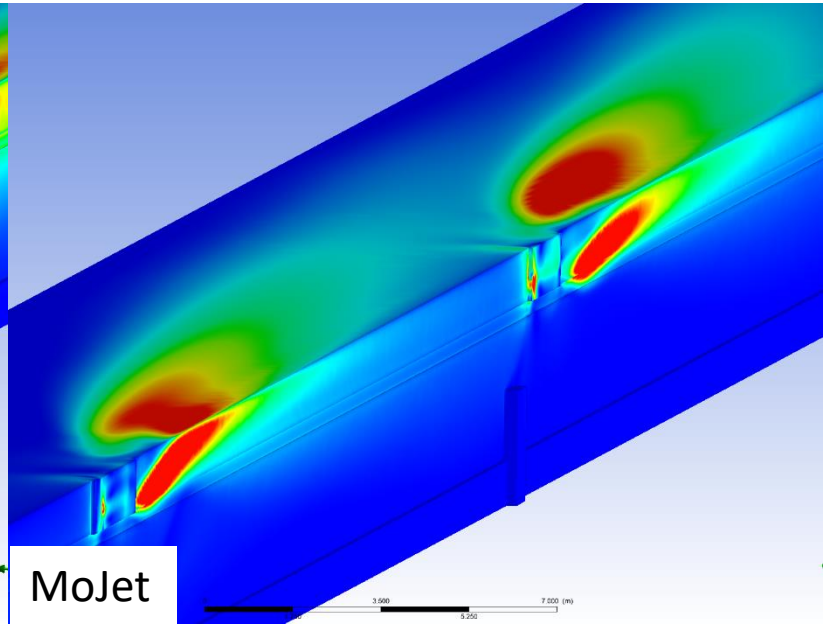
Iso-Surface Comparison



Wall shear stress

- A decrease in wall shear stress on the tunnel walls is noted with the MoJet.





Flow Distribution

- A comparison of the flow leaving the first fan (location 20) shows the MoJet having better distribution within the tunnel.
- The flow from the conventional fan remains attached to the tunnel ceiling and walls, thereby reducing efficiency.
- The flow from the conventional jetfan (at location 20) also gets re-ingested by the downstream fan (location 18).

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Velocity & Thrust Comparison

- The average velocity at the Northern portal (outlet) was:
  - Conventional
    - Flow speed 1.59 m/s
  - MoJet
    - Flow speed 2.28 m/s (+44%)
    - Thrust increase +106%

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Experimental Measurements

Aerodynamic Measurements

- A 5×5 grid of Kiel probes, supported by vertical struts, at north portal
- Three pitot/static probes arranged at different heights on the central strut, at north portal. Mid-height static pressure probe was reference pressure for all measurements
- Ultrasonic probe at the middle of the southbound tunnel chainage

Measurements Undertaken

- Steady-state measurements with conventional jetfans 16, 18 and 20 switched on for 10 minutes
- Steady-state measurements with MoJets 16, 18 and 20 switched on for 10 minutes

Kiel Probe

Ultrasonic Probe

Measurement Grid at North Portal

Measurement Results – Air Velocities

	Average velocity at north portal (m/s)	Average wind-induced velocity (m/s)
Conventional jetfans	3.650	1.495
MoJet	4.914	1.386

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In-Tunnel Thrust & Power

- MoJet/Conventional jetfan thrust ratio: 2.0
- MoJet 1% lower power consumption than conventional jetfan

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Reversible MoJet Tests

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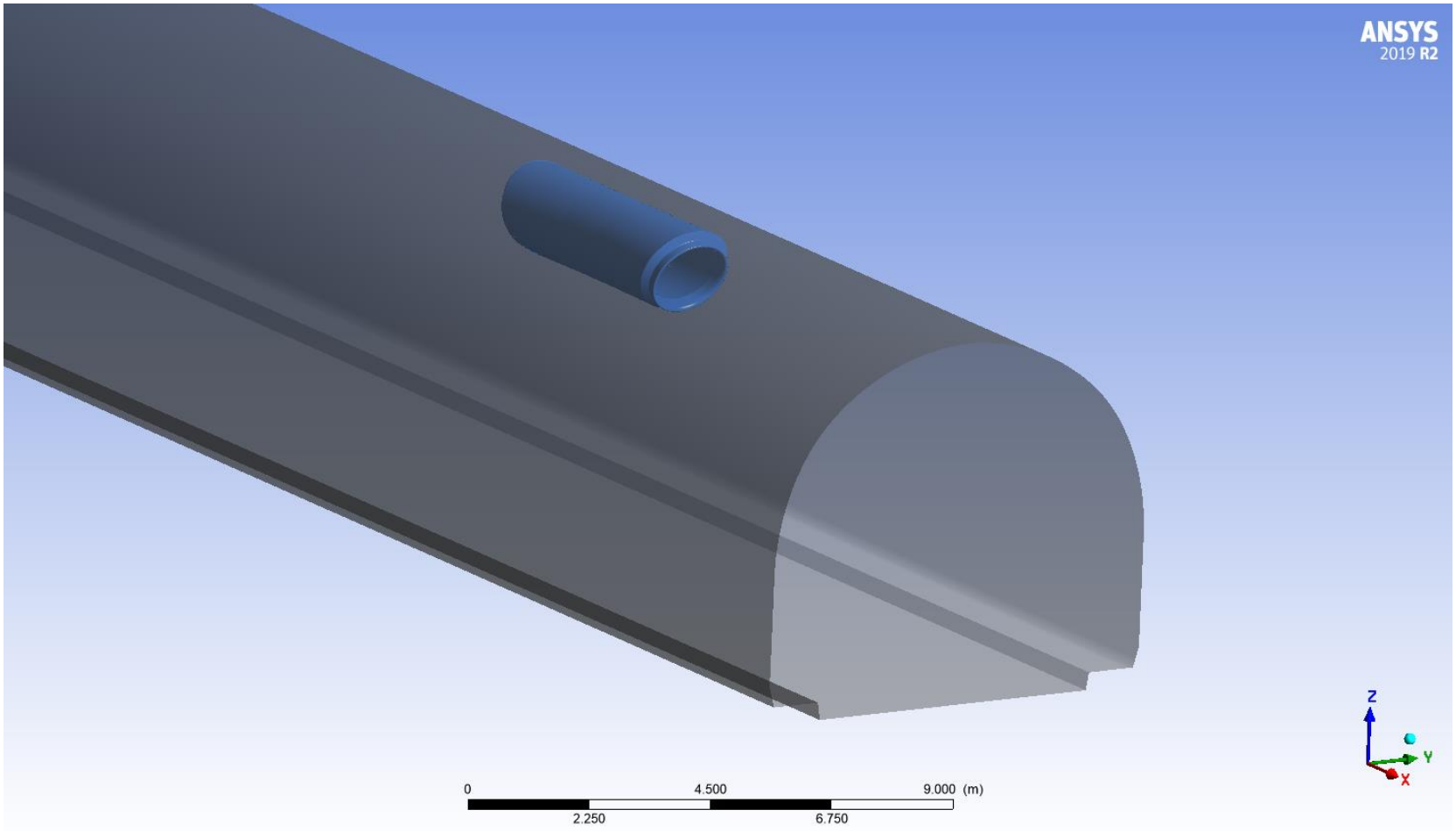
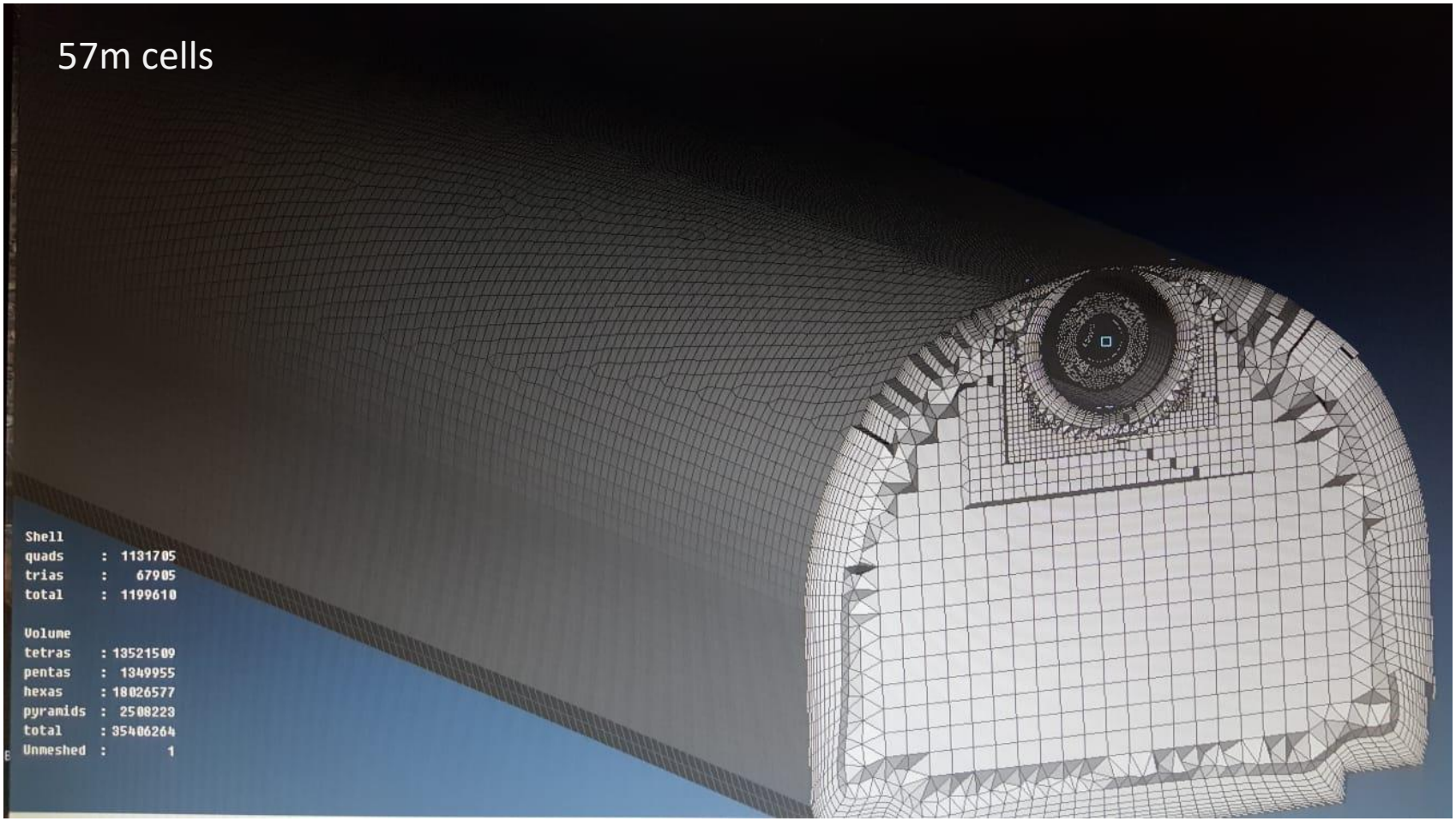
Mersey Queensway Tunnel, Liverpool

Rendel Street Branch

MoJet Installation



3D CFD Calculations



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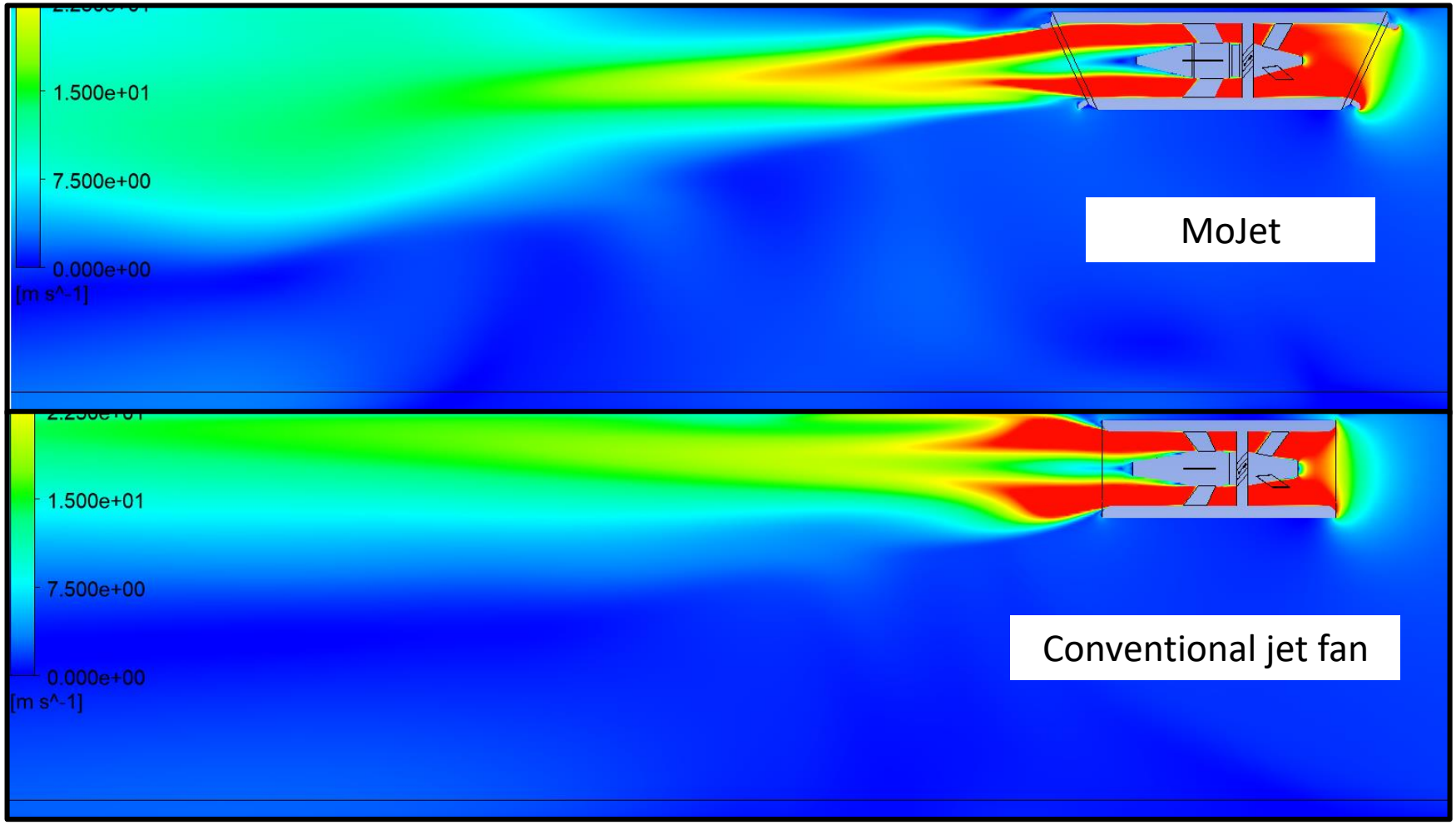
CFD Results



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Conclusions

- Significantly enhanced in-tunnel thrust is possible with the MoJet, for a reduced power consumption
- Further CFD & full-scale tunnel measurements with reversible MoJets are planned

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