NWTF
NATIONAL WIND TUNNEL FACILITY

Engineering and Physical Sciences Research Council

UNIVERSITY OF OXFORD

New Facilities @ Oxford

University of Oxford
Oxford Thermofluids Institute



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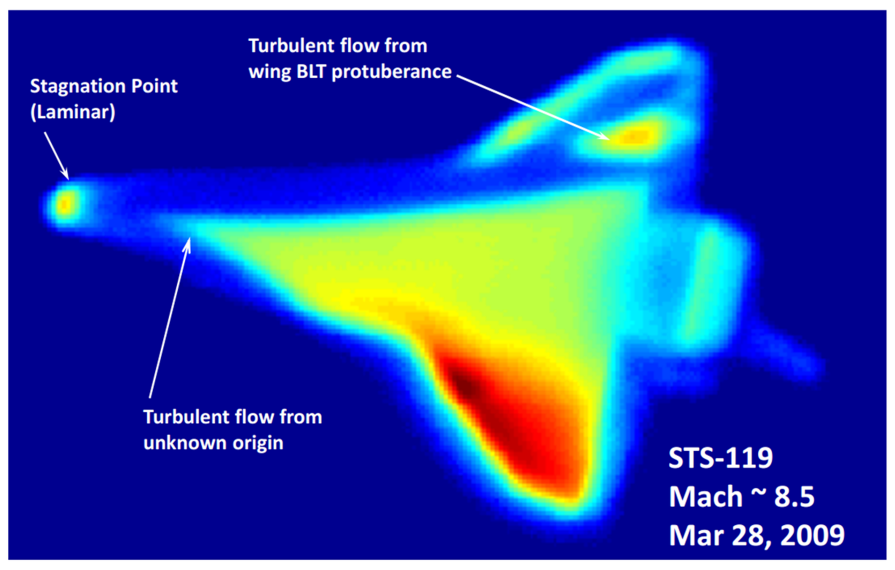
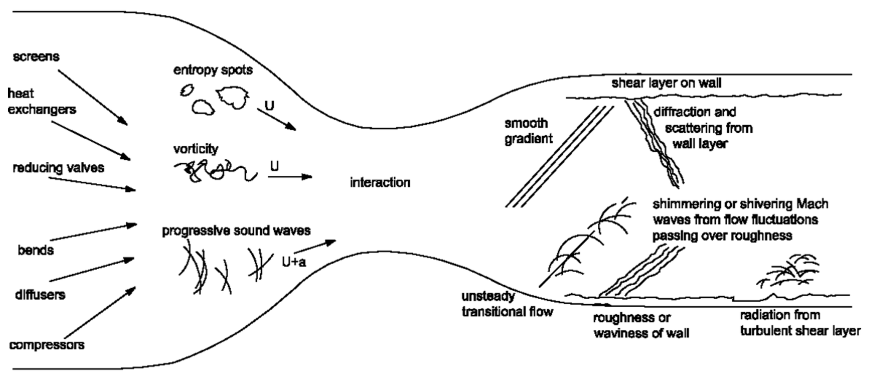
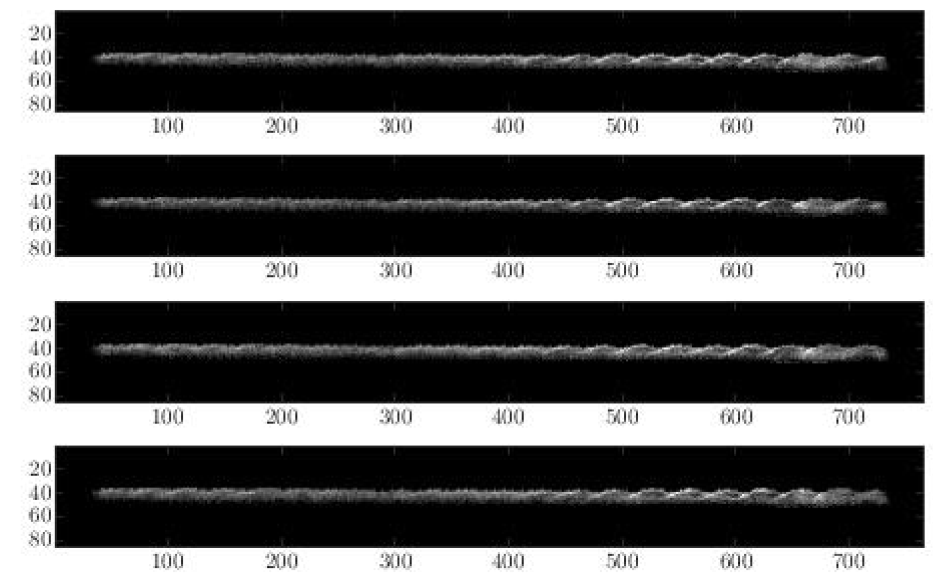
Hypersonic Quiet Tunnel

- Boundary layer transition is one of the most influential parameters in design of hypersonic vehicles (# 1 unknown – need fundamental to applied experiments).
- Heat flux, shear stress and control
- Most hypersonic tunnels are noisy
- Largest source being a turbulent nozzle wall BL, though also in core flow
- Only capability in US (closed). Need highlighted in working group & FAR paper by Steelant et al. 2019.
- Active academic interest in UK
- Strong interest from Government & Industry
- Possibility of extension to wider UK needs







Top Left: Asymmetric transition observed on space shuttle re-entry. Source: NASA.

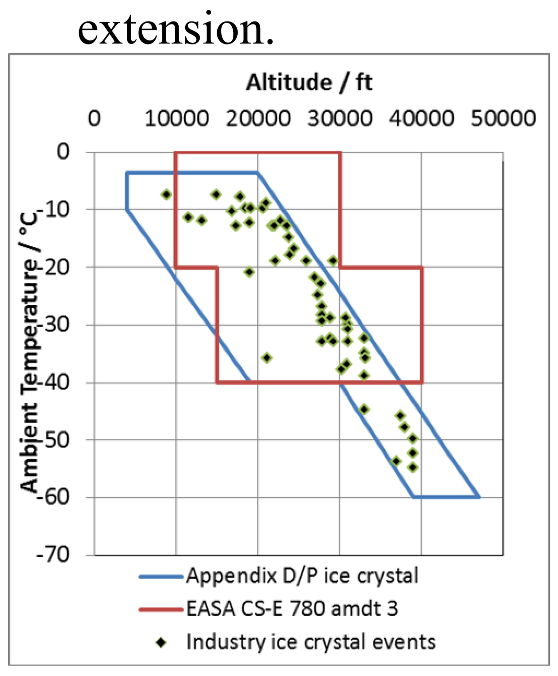
Top Right: 2nd Mack mode boundary layer instabilities measured at Mach 7 in the Oxford High Density Tunnel.

Bottom Left: Sources of noise in a hypersonic wind tunnel. Source: S. Schneider

Aimed facility attributes:
- ~20 bar total pressure (10 bar cap on "Quiet" operation)
- ~600 K total temperature
- Run time 2-5 s
- Nozzle exit ~500 mm

Ice Crystal Icing and Altitude Tunnel

- FAA and EASA require demonstration by test, analysis, or combination certification of acceptable operation for turbojet, turbofan, and turboprop engines in mixed phase and ice crystal icing. FAA 33.68 Appendix D (2015)
- The EASA and FAA icing envelopes shown are similar and subject to extension.

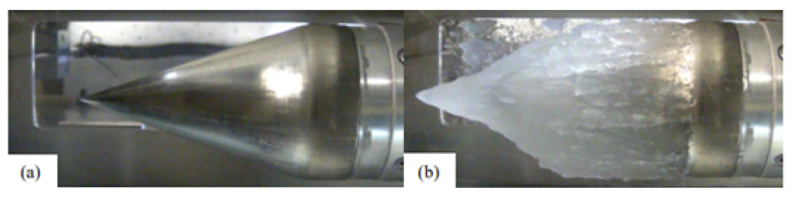


Altitude test facilities which facilitate ice crystal icing are only available outside Europe, with limited capacity, and Mach number capability.

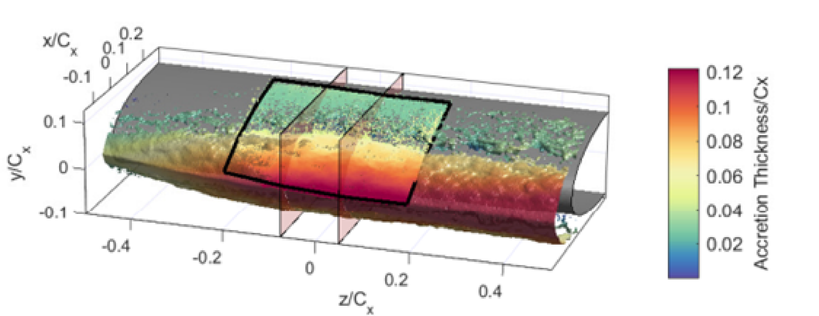
Modelling of induced ice in jet engines particularly needs this capability for validation

- The new facility will measure ice accretion and shed on aerodynamic probes and engine sub-systems in Ice Crystal Icing conditions, to allow validation of commercial products, and ice accretion modelling codes. Fundamental understanding of ice icing phenomena will be gained.
- Designed to investigate accretion and changing aerodynamics
  - Mach numbers up to ~0.6
  - High altitude representative pressure (0.1 - 1 bara)
  - Total Air Temperature -40 – 20 °C
  - High air mass flow (up to1 kg/s,)
  - Glaciated ice injection (0 – 12 g/m^3)
  - Engine-scale testing of component sub-systems and probes
  - Real Time Optical Accretion Measurement systems
  - Independent RH and Total Temperature Control in Tunnel.
  - Dry altitude testing available

Typical Test Articles:



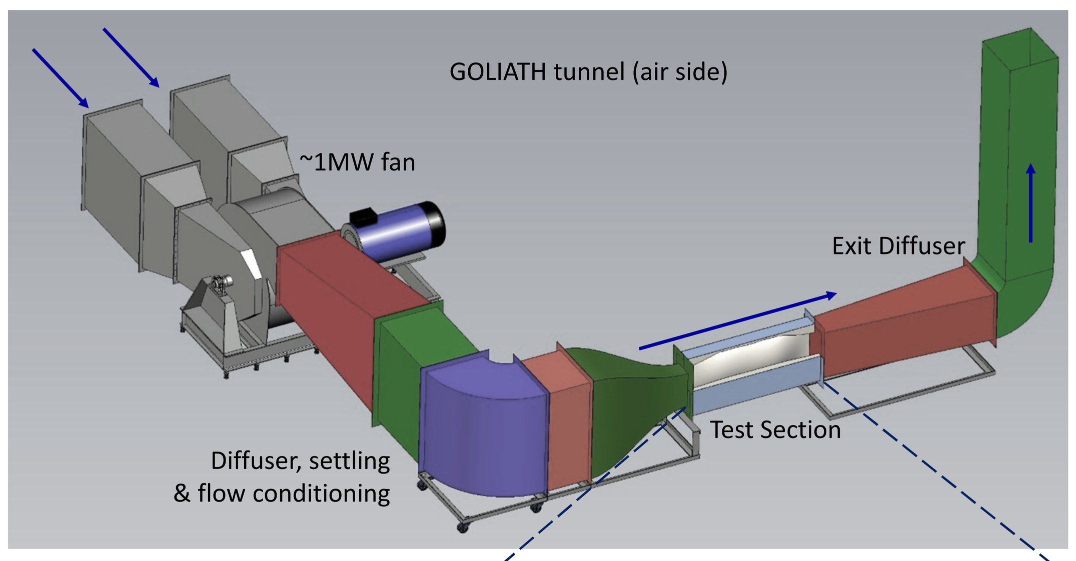
Canonical Studies of Ice Icing Accretion by OTI researchers in the NRC RatFac Facility

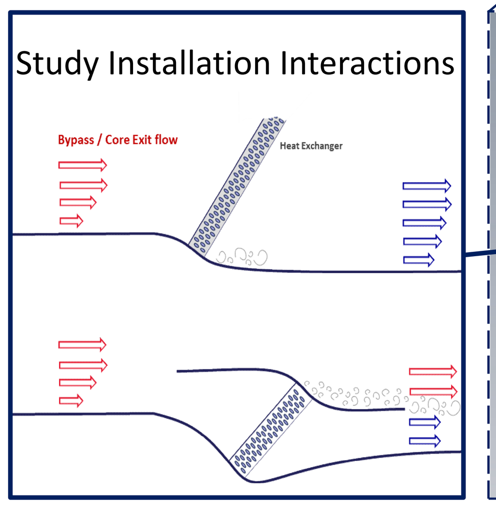


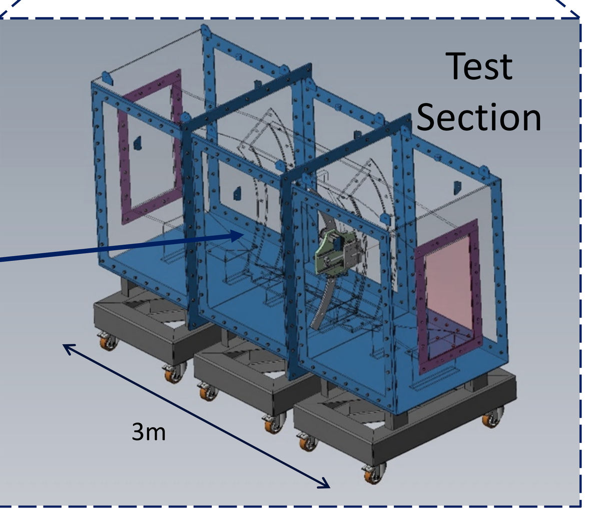
Full 3D Accretion measurements using OTI DIC imaging developments (taken in NRC AIWT facility).

Thermal Systems and Liquid Hydrogen Tunnel

- Future aircraft engines require new thermal systems, e.g.:
  - Thermal Management of Cryogenic Hydrogen
  - Advanced Cycles (e.g. Recuperated, Condensing)
  - Cooling for Geared Fans
  - Cooling for Electric/Hybrid propulsion
- These systems need to be optimally integrated to maximise overall performance
- New tunnel designed to investigate thermals and aerodynamics
  - Mach numbers up to ~0.6
  - High air mass flow (~50kg/s)
  - Cryogenic / supercritical fluids system
  - Engine-scale testing
- Tunnel is highly flexible with a range of applications for internal and external flows
- Research projects planned with multiple industrial partners







Tunnel Air Side, configured for turbofan bypass flow

Centrifugal Fan (~1MW)

Application Examples