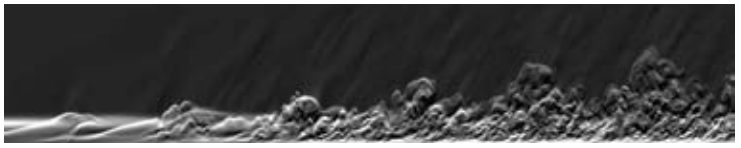
Space Travel

Transition in High-Speed Boundary Layers: Numerical Investigations Using DNS

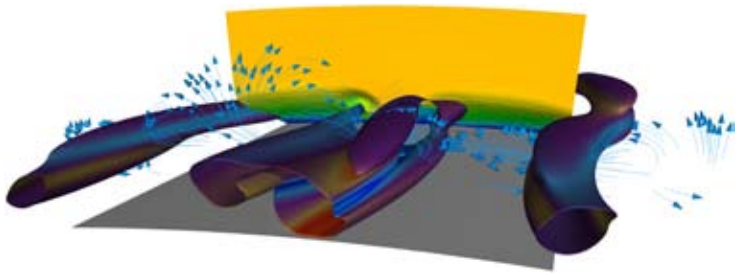
Transition in supersonic and hypersonic boundary layers is a major unresolved topic in fluid dynamics. Considerable progress towards the understanding of high-speed boundary layer transition is required to develop reliable transition prediction methods that can be used for the design and safe operation of future flight vehicles. Although significant advancements have been made in recent years, crucial aspects of the transition physics are still in the dark.

In the past, engineers used a rather conservative approach for design of thermal protection systems—the turbulent boundary layer was assumed to be present over an entire thermal protection system. Therefore, reliable transition prediction made using current approaches will reduce the design margins of high-speed, advanced flight vehicles leading to either an increase in range or payload. Examples include NASA's Hyper-X Program, as well as the Constellation Program with both the Orion Crew Exploration and Ares Crew Launch Vehicles.

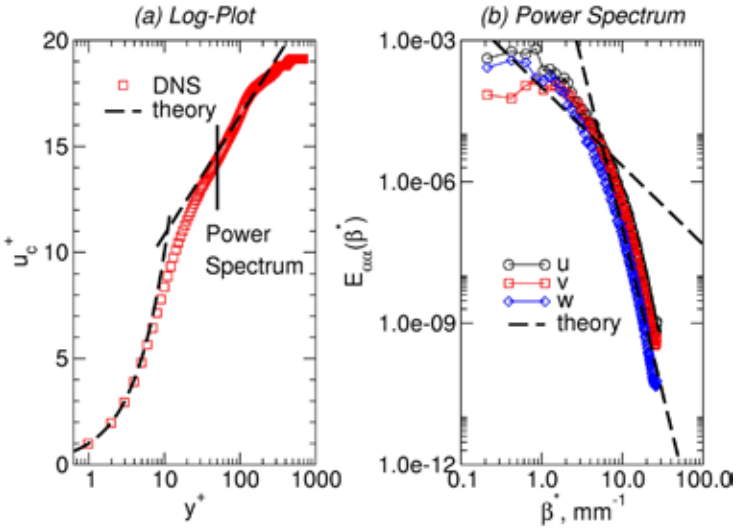
Accurate direct numerical simulations (DNS) of the entire transition process—from the linear stage to breakdown to turbulence, including the turbulent regime—pose a formidable challenge in computational aerodynamics. Typical simulations require grid sizes approaching a half-billion grid points and take several weeks to complete on 256 processors. Only the combination of highly optimized research codes and high-end supercomputing systems, such as NASA's Columbia supercomputer, make these simulations possible and enable study of the underlying physical mechanisms leading to turbulence in supersonic boundary layers.



Transition to turbulence initiated by "oblique breakdown" for a Mach 3 flat-plate boundary layer. Wall-normal density gradient indicating breakdown to turbulence. (Ref: AIAA-2009-3558)



Transition to turbulence initiated by "oblique breakdown" for a cone boundary layer at Mach 3.5. Detailed view of vortex structures early in the transition process visualized by isosurfaces of Q = 100. Also shown are isocontours of streamwise velocity and velocity vectors.



Transition to turbulence initiated by "oblique breakdown" for a Mach 3 flat-plate boundary layer. Comparison of log plot (a) and power spectrum (b) with theory. (Ref: AIAA-2009-3558)

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