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# SPECIAL TECHNOLOGICAL SESSION (STS05)

# TRANSITION LOCATION EFFECT ON SHOCK WAVE BOUNDARY LAYER INTERACTION

## ORGANIZER: PIOTR DOERFFER

**Title of the Presentation:** DNS and Stability Analysis of a Transitional Shock-Wave/Boundary-Layer Interaction at M = 1.5

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## ABSTRACT

The prediction of transition is a fundamental step in order to estimate loads and heat transfer rates on aerodynamic surfaces and turbomachinery components. Starting from small-amplitude disturbances, transition to turbulence involves several stages: a receptivity stage where external disturbances are internalised, followed by a linear growth stage and finally a non-linear evolution of the perturbations with eventual breakdown to turbulence [1]. However, it is still not clear how the natural transition influences the separated region due to the interaction of an oblique shock-wave/boundary layer configuration (Fig. 1), taking into account non-linear and non-parallel effects. The transition in a boundary layer can be seen as a stability problem, in the sense that it is strongly affected by small disturbances coming from the outer flow. For supersonic flows the most unstable modes are 3D oblique waves (skewed with respect to the x-direction of an angle $\Phi$) [2]. Fasel *et al.* [3] found numerically that two oblique instability waves with equal but opposite wave angle can rapidly cause transition in the so called oblique breakdown mechanism. Also Sandham and Adams [4] and Sandham *et al.* [5] found that, with respect to secondary instability, this breakdown mechanism requires lower disturbance amplitudes for developing the non-linear growth of the triads.

In the present work, simulations using in-house codes based on linear stability theory (LST) and parabolised stability equations (PSE) will be compared with direct numerical simulations (DNS) of a transitional shock-wave/boundary-layer interaction at M=1.5. The validity of LST and PSE models will be tested for three different scenarios where non-parallel effects become increasingly significant: a growing boundary-layer, a marginally separated boundary-layer and a boundary-layer with a large separation bubble. The cases with shock-induced separation have strong variation of the flow in the streamwise direction. Three-dimensional DNS will be presented of separated boundary-layers where transition occurs within the separation bubble. According to the selected base flow, the most unstable modes selected from local linear stability analysis are applied at the inlet to obtain a “modal” forcing technique. Low amplitude

forcing of Tollmien-Schlicting waves are chosen to produce disturbance growth rates that can be compared with the linear stability models. For the 3D shock-induced separation bubble case a higher amplitude forcing is used to obtain transition where 3D oblique modes superimposed onto a plane 2D mode are applied.

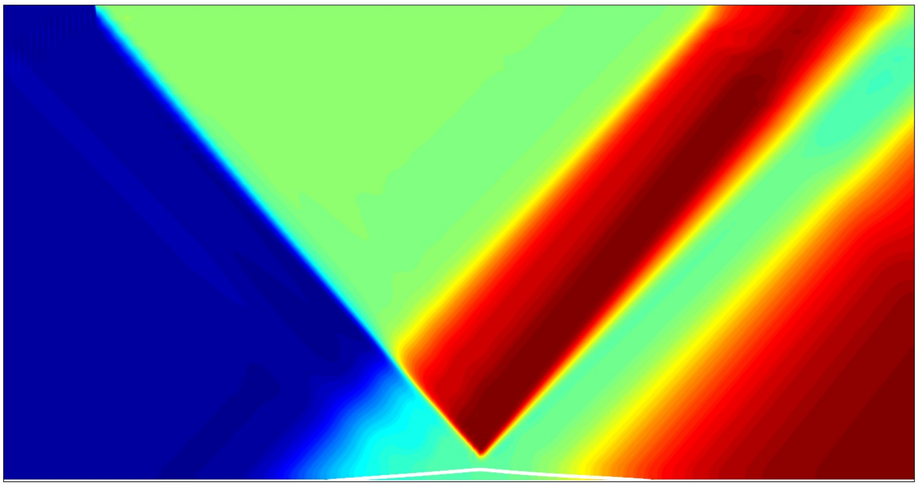

Figure 1: Schematic view of an oblique shock-wave/boundary-layer interaction direct numerical simulation at M = 1.5

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