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Delay of high-speed boundary-layer transition by isolated roughness[1] REZA JAHANBAKHSHI, Florida Inst of Tech, TAMER ZAKI, Johns Hopkins University — Direct numerical simulations of Mach 4.5 boundary layers demonstrate sensitivity of transition to turbulence to the placement and shape of roughness elements. The examined elements alter the growth rate of second-mode instabilities relative to flow over smooth plates, with minimal impact on the first-mode instability. Two key flow parameters influence the outcome: (i) the relative position of synchronization of the slow and fast modes and (ii) the height of the near-wall region where the second-mode phase speed is supersonic relative to the flow. Downstream of synchronization protruding roughness effectively delays transition, whereas cratering the surface is more effective upstream of synchronization. Post-synchronization, the protrusion thickens the supersonic region leading to stabilization, but the same thickening pre-synchronization is destabilizing. Using ensemble-variational optimization of the roughness height, width and slope, we effectively mitigate the nonlinearly most dangerous route to turbulence (Jahanbakhshi, R., and Zaki, T. A., Nonlinearly most dangerous disturbance for high-speed boundary-layer transition, J. Fluid Mech. 876 (2019): 87-121), and maintain laminar flow throughout the computational domain.

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Reza Jahanbakhshi
Florida Inst of Tech

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