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Unsteadiness of Shock Wave / Boundary Layer Interactions[1]

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Shock wave / boundary layer interactions are an important feature of high-speed flows that occur in a wide range of practical configurations including aircraft control surfaces, inlets, missile base flows, nozzles, and rotating machinery. These interactions are often associated with severe boundary layer separation, which is highly unsteady, and exhibits high fluctuating pressure and heat loads. The unsteady motions are characterized by a wide range of frequencies, including low-frequency motions that are about two orders of magnitude lower than those that characterize the upstream boundary layer. It is these low-frequency motions that are of most interest because they have been the most difficult to explain and model. Despite significant work over the past few decades, the source of the low-frequency motions remains a topic of intense debate. Owing to a flurry of activity over the past decade on this single topic we are close to developing a comprehensive understanding of the low-frequency unsteadiness. For example, recent work in our laboratory and others suggests that the driving mechanism is related to low-frequency fluctuations in the upstream boundary layer. However, several recent studies suggest the dominant mechanism is an intrinsic instability of the separated flow. Here we attempt to reconcile these views by arguing that the low-frequency unsteadiness is driven by *both* upstream and downstream processes, but the relative importance of each mechanism depends on the strength (or length-scale) of separation. In cases where the separation bubble is relatively small, then the flow is intermittently separated, and there exists a strong correlation between upstream velocity fluctuations and the separation bubble dynamics. It appears that superstructures in the upstream boundary layer can play an important role in driving the unsteadiness for this case. It is not clear, however, if the upstream fluctuations directly move the separation point or indirectly couple to a global instability. In cases where the separation is strong (and the bubble large) then the bubble pulsates owing to a global instability, as has been suggested by other researchers. In this case upstream turbulence may serve mainly as a source of broadband fluctuations that seed the large-scale instability of the separated flow.

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