Abstract of the thesis: "Enhancement of the control effectiveness of a transverse jet in a supersonic crossflow"

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The interaction of sonic or supersonic side jet with an external supersonic crossflow generates a complex flow structure that has been a subject of much interest to the aerospace community. Such flows are encountered in reaction control systems, divert thrust motors for interceptors, secondary injection thrust vector control systems, retro motor assisted stage separation systems and scramjet engines. This interaction significantly alters the surface pressure distribution over the vehicle and consequently the lateral force and moment generated by operating the jet.

In this dissertation, the basic features of this jet interaction over bodies of revolution are studied using computational fluid dynamics. After verifying the simulation methodology through grid independence studies and validating the results with published experimental data, a series of studies were carried out to quantify the effects of several key parameters on the interaction flow field and on the effectiveness of the jet in producing the desired control forces and moments. The preliminary studies were followed up with more elaborate studies into the role of parent body curvature and external flow environment on the interaction flow field and the associated jet effectiveness. These studies have enabled a detailed analysis of the differences in the interaction flow structures on flat and curved parent bodies and their dependence on the flight altitude.

The insights gained from these detailed studies have led to the exploration of several techniques for improving the jet effectiveness on curved parent bodies. These techniques include changes to the location of the injected jet, employing jets in tandem and injecting pilot jets ahead of the primary jet. Injection of a control jet from the aft regions of the vehicle resulted in an increase in the effectiveness of the jet as compared to injection from a forward location. Tandem injection of multiple jets caused an amplification of jet thrust in the near-field of the jet. These gains in the near field were partially offset by unfavourable interaction further downstream of the injections. Injecting small pilot jets ahead of the main jet resulted in an enhancement of jet effectiveness by 10%–12% which persisted significantly downstream of the injection.

Finally, the transient behaviour of the jet interaction flowfield over the vehicle due to a reaction control pulse and the overall effect of the initial and tail-off transients on the control effectiveness are studied using unsteady simulations.