Liquefied Bleed for Stability and Efficiency of High Speed Inlets

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Purpose

To quantify the design parameters of a liquefied bleed concept to enhance system performance of high-speed inlets for aircraft. Elements of the task include: 1) Physical configuration and thermal balance requirements to cool the bleed air, 2) Capture and processing of the liquefied bleed air, 3) Scheme to prevent potential icing of the bleed air cooling system, 4) First order effects of cooling on the outflow of the bleed air, and 5) Core flow (propulsive flow path) boundary-layer flow quality. The first year is to assemble tools, conduct preliminary analyses and prepare test plans.

Background

Bleed air has traditionally been used for mixed-compression inlets at moderate to high supersonic flight speeds for stability and improved performance.

At higher speeds, however, the increased flight enthalpy causes extreme difficulties in using bleed. The bleed air drawn off of the propulsive flowpath is both hot and at low pressure. Bleed ductwork becomes hot and large, and the bleed air produces increased vehicle drag. Therefore, un-cooled bleed causes thrust loss and increased drag for supersonic propulsion and cannot be effectively used for hypersonic engine designs. However, if the bleed air were to be cooled, the ductwork would become cooler and the size requirement would be reduced. Cooling of the bleed air would be provided by the cryogenic fuels that are required by high-speed vehicles. The research effort is investigating the feasibility and effect of intensely cooling the bleed air to the point of liquefaction.

To date, prior studies have focused on the effect of cooled walls on boundary-layer development. They have not coupled these studies with bleed flow extraction nor examined the system level benefits of liquefied bleed. The potential benefits of the concept include greatly reduced bleed duct sizing, reduced shock-wave/boundary-layer interaction extent, and oxidant storage for other phases of a flight mission. The concept could enable greatly improve performance and robustness of airbreathing propulsion and thereby enable new design options for high-speed flight.