



## Analysis of Nozzle Jet Plume Effects on Sonic Boom Signature

Highly underexpanded nozzle flow provides reduction in tail shock strength.

*Dryden Flight Research Center, Edwards, California*

An axisymmetric full Navier-Stokes computational fluid dynamics (CFD) study was conducted to examine nozzle exhaust jet plume effects on the sonic boom signature of a supersonic aircraft. A simplified axisymmetric nozzle geometry, representative of the nozzle on the NASA Dryden NF-15B Lift and Nozzle Change Effects on Tail Shock (LaNCETS) research airplane, was considered. The highly underexpanded nozzle flow is found to provide significantly more reduction in the tail shock strength in the sonic boom N-wave pressure signature than perfectly expanded and overexpanded nozzle flows. A tail shock train in the sonic boom signature, similar to what was observed in the LaNCETS flight data, is observed for the highly underexpanded nozzle flow. The CFD results provide a detailed description of the nozzle flow physics involved in the LaNCETS nozzle at different nozzle expansion conditions and help in interpreting LaNCETS flight data as well as in the eventual CFD analysis of a full LaNCETS aircraft. The current study also provided important information on proper modeling of the LaNCETS aircraft nozzle.

The primary objective of the current CFD research effort was to support the LaNCETS flight research data analysis effort by studying the detailed nozzle exhaust jet plume's imperfect expansion effects on the sonic boom signature of a supersonic aircraft. Figure 1 illustrates the primary flow physics present in the interaction between the exhaust jet plume shock and the sonic boom coming off of an axisymmetric body in supersonic flight. The steeper tail shock from highly expanded jet plume reduces the dip of the sonic boom N-wave signature. A structured finite-volume compressible full Navier-Stokes CFD code was used in the current study. This approach is not limited by the simplifying assumptions inherent in previous sonic boom analysis efforts. Also, this study was the first known jet plume sonic boom CFD study in which the full viscous nozzle flow field was modeled, without coupling to a

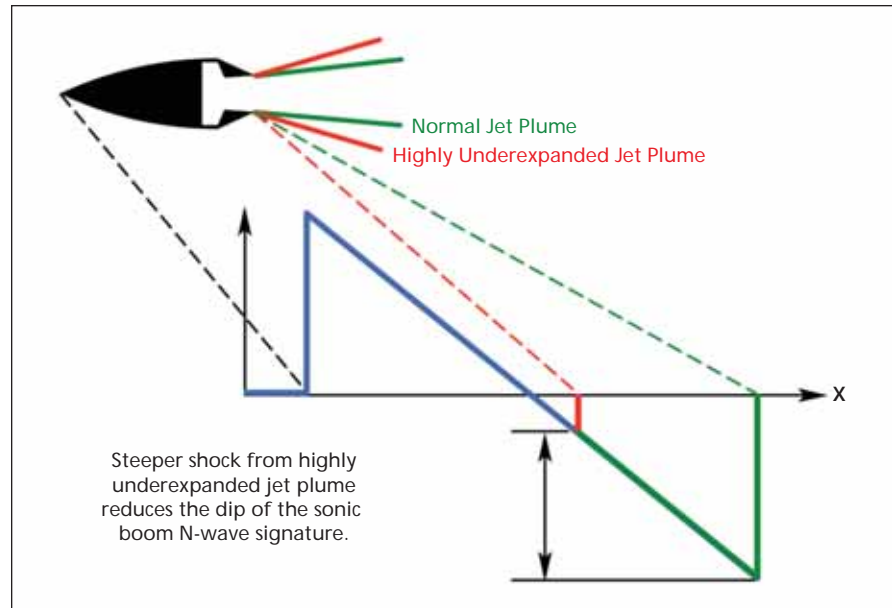


Figure 1. Jet Plume Shock—sonic boom interaction flow physics.

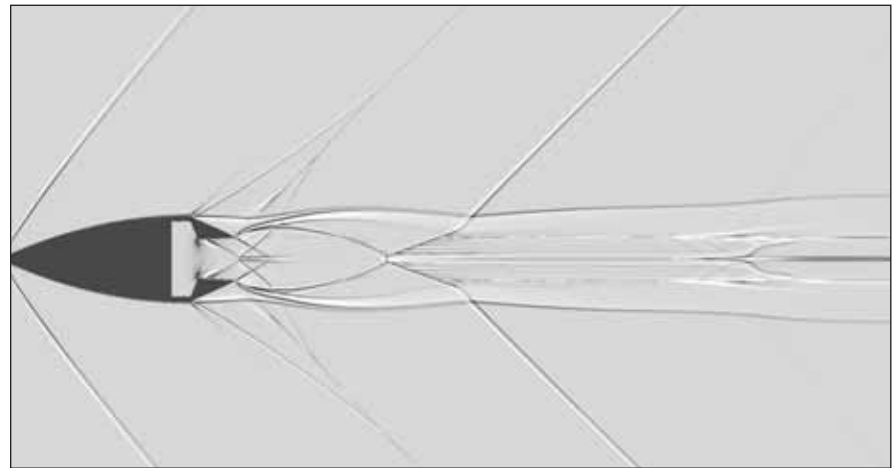


Figure 2. A CFD Shadowgraph visualization of imperfectly expanded jet plume effects.

sonic boom propagation analysis code, from the stagnation chamber of the nozzle to the far field external flow, taking into account all nonisentropic effects in the shocks, boundary layers, and free shear layers, and their interactions at distances up to 30 times the nozzle exit diameter from the jet centerline. A CFD solution is shown in Figure 2. The flow field is very complicated and multi-dimensional, with shock-shock and shock-plume interactions. At the time of this reporting, a full three-dimensional CFD study was being conducted to evaluate the effects of nozzle vectoring on the aircraft tail shock strength.

This work was done by Trong Bui of Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-009-032