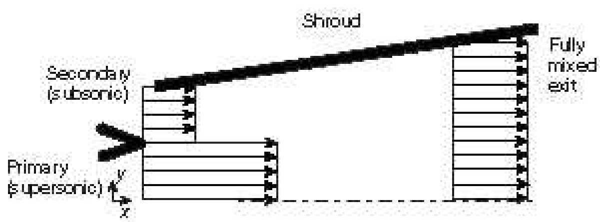
Combined Numerical/Analytical Perturbation Solutions of the Navier-Stokes Equations for Aerodynamic (Ejector Nozzle) Flows

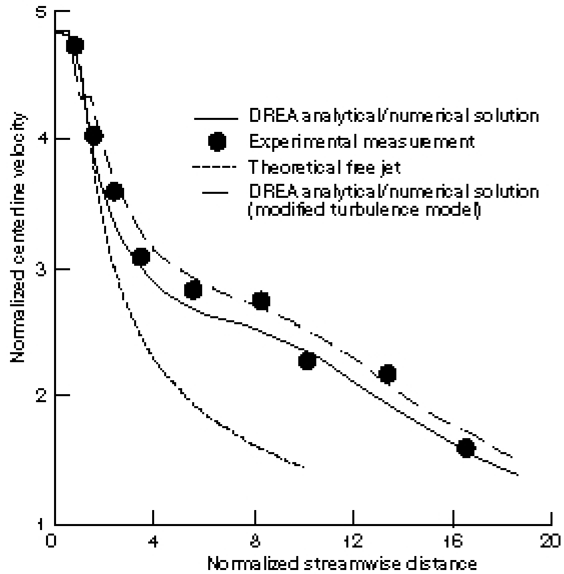
In spite of the rapid advances in both scalar and parallel computational tools, the large number and breadth of variables involved in aerodynamic systems make the use of parabolized or even boundary layer fluid flow models impractical for both preliminary design and inverse design problems. Given this restriction, we have concluded that reduced or approximate models are an important family of tools for design purposes. This study of a combined perturbation/numerical modeling methodology with an application to ejector-mixer nozzles (shown schematically in the following figure) is nearing completion. The work is being funded by a grant from the NASA Lewis Research Center (Grant NGT 51244) to Texas A&M University.



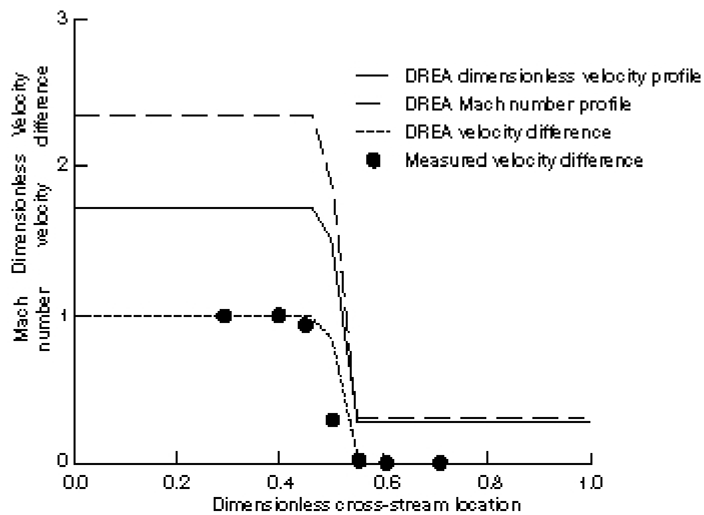
Ejector nozzle schematic. The high-speed primary jet (engine core) entrains fluid (viscous and local pressure differential), thus causing the secondary stream.

These ejector-mixer nozzle models are designed to be of use to the High Speed Civil Transport Program and may be adopted by both NASA and industry. A computer code incorporating the ejector-mixer models is under development. This code, the Differential Reduced Ejector/Mixer Analysis (DREA), can be run fast enough to be used as a subroutine or to be called by a design optimization routine. Simplified conservation equations--x-momentum, energy, and mass conservation--are used to define the model.

Unlike other preliminary design models, DREA requires minimal empirical input and includes vortical mixing and a fully compressible formulation among other features. DREA is being validated by comparing it with results obtained from open literature and proprietary industry data. Preliminary results for a subsonic ejector and a supersonic ejector are shown in the next two figures.

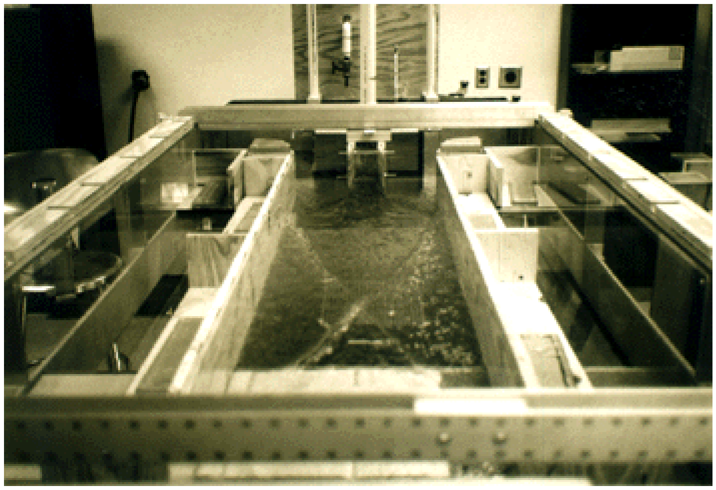


DREA subsonic ejector solution compared with two-dimensional ejector (ref. 1).



DREA supersonic ejector solution for a mixing problem compared with experimental results (ref. 2) at a streamwise location, X, of 50 mm.

In addition, dedicated experiments have been performed at Texas A&M. These experiments use a hydraulic/gas flow analog to provide information about the inviscid mixing interface structure (see the photo below).



Hydraulic analog model of an ejector-mixer nozzle.

Final validation and documentation of this work is expected by May of 1997. However, preliminary versions of DREA can be expected in early 1997. In summary, DREA provides a sufficiently detailed and realistic ejector-mixer nozzle model at a computational cost compatible with preliminary design applications.

References

1. Gilbert, G.B.; and Hill, P.G.: Analysis and Testing of Two-Dimensional Slot Nozzle Ejectors With Variable Area Mixing Sections. NASA CR-2251, 1973.

2. Goebel, S.G.; and Dutton, J.C.: Experimental Study of Compressible Turbulent Mixing Layers. AIAA J., vol. 29, April 1991, pp. 538-546.

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