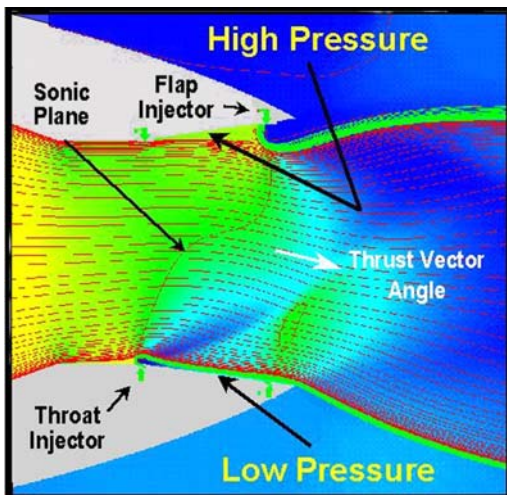




Gridgen Helps Save \$750K in Fighter Design

Gridgen helped save \$750,000 in the development of an advanced fluidic thrust vectoring exhaust system for a future generation of fighter aircraft beyond the Joint Strike Fighter (JSF). Fluid thrust vectoring is a new design concept that provides the same benefits as the mechanical thrust vectoring system used in the new F-22 and JSF fighters without the added weight and expense. Developing this scheme required intensive investigation of the effects of internal nozzle contour, injector geometry, and flow properties on performance. Evaluating effects using conventional physical testing would have required building a considerable number of test entries, each costing between \$250,000 and \$500,000. Lockheed Martin engineers used computational fluid dynamics (CFD) to simulate the per-

formance of many alternate designs to optimize vectoring performance, saving a considerable amount of time and money and producing a much better design than could have been achieved with experimental methods.



Lockheed-Martin used CFD to reduce number of tests for new nozzle design.

on vectoring. The use of CFD to evaluate a wide range of concept design alternatives provides similar and even more extensive results than physical testing at far lower time and expense. However, simulating a geometry as complex as a fluidic vectoring nozzle to the level of accuracy required here is a considerable challenge. The primary difficulty is developing a grid that is dense enough in critical areas such as the sonic plane to accurately capture design performance yet coarse enough in less critical areas to reduce the computational challenge.

Building a grid of this magnitude using conventional methods would have probably taken longer than the time to physically build a test entry. In order to compress the design cycle, Lockheed Martin engineers used Gridgen and their in-house developed Falcon CFD code. They selected Gridgen because of its unique hierarchical grid generation method, which allows the engineer to quickly select grid topologies, then proceed in a systematic method to define progressively the grid. Other advantages include its easy to use graphical user interface and extensive suite of automated grid definition and refinement tools, including elliptic and hyperbolic partial differential equation methods.

When the final optimized multiaxis vectoring configuration was completed, a static thrust test was conducted to demonstrate the concept. Experimental test results of nozzle discharge coefficient, thrust coefficient and divergent flap pressures were within a few percent of CFD predictions. Test measurements of thrust vectoring effectiveness were about 20% lower than CFD predictions. The simplicity of this concept design reduces parts count, weight and cost, making it possible to combine the capabilities of an F-22-class nozzle with the integration benefits of a fully fixed nozzle by controlling the aerodynamic flow of the jet. The ability to easily predict performance of design alternatives without having to build a test entry was the key to the speed with which it was developed.

From AIAA Paper 99-0365, "Fluidic Throat Skewing for Thrust Vectoring in Fixed Geometry Nozzles", by Dan Miller, Pat Yagle, and Jeff Hamstra of Lockheed Martin.

Demonstrating the validity of this approach required that key design parameters - internal nozzle contour, injector geometry and flow properties - be configured in order to optimize vectoring performance. Ideally, changes in injected flow should have a substantial and uniform effect

