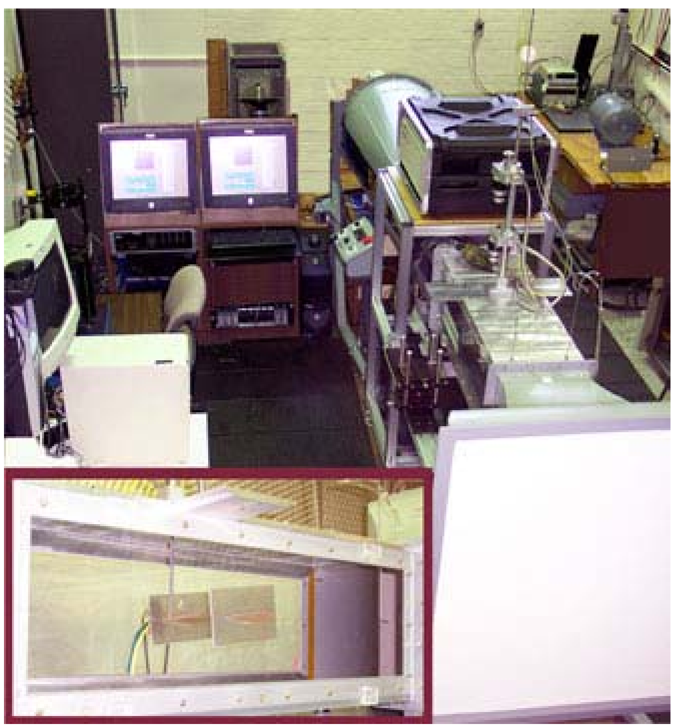
Low-Speed Active Flow Control Laboratory Developed

The future of aviation propulsion systems is increasingly focused on the application of control technologies to significantly enhance the performance of a new generation of air vehicles. Active flow control refers to a set of technologies that manipulate the flow of air and combustion gases deep within the confines of an engine to dynamically alter its performance during flight. By employing active flow control, designers can create engines that are significantly lighter, are more fuel efficient, and produce lower emissions. In addition, the operating range of an engine can be extended, yielding safer transportation systems. The realization of these future propulsion systems requires the collaborative development of many base technologies to achieve intelligent, embedded control at the engine locations where it will be most effective.

NASA Glenn Research Center’s Controls and Dynamics Technology Branch has developed a state-of-the-art low-speed Active Flow Control Laboratory in which emerging technologies can be integrated and explored in a flexible, low-cost environment. The facility allows the most promising developments to be prescreened and optimized before being tested on higher fidelity platforms, thereby reducing the cost of experimentation and improving research effectiveness.

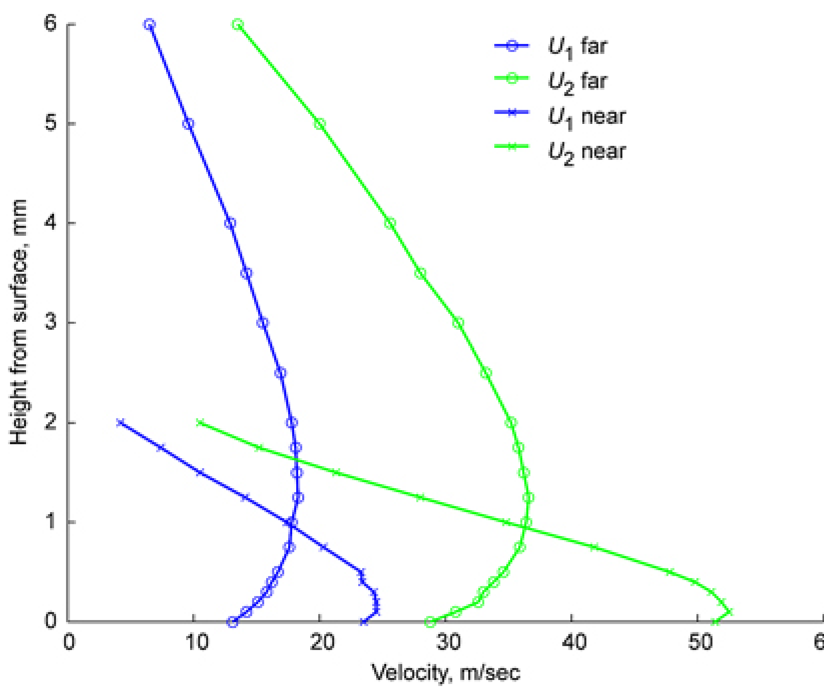


Active Flow Control Laboratory. The inset shows the test section, which is 12 in. square and supports velocities up to 40 m/sec.

Long description of figure In the foreground is the bellmouth with a 12:1 contraction cone. The test section immediately follows. The top cover is instrumented with pitot-static probes and movable plates that allow a motorized probe to access the length and width of the test section. Downstream is the diffuser, driven by a 2-horsepower fan. Several data acquisition and control screens are shown in the operator area..

The laboratory includes a low-speed wind tunnel (shown in the preceding figure), with a calibrated test section that can be used to evaluate advanced flow-control actuators and sensors, and a state-of-the-art real-time control development platform for designing and testing closed-loop algorithms. A variety of precision instrumentation is available for evaluating and quantifying performance metrics. Two-dimensional flow-field visualization is provided by particle imaging velocimetry. A high-speed data-acquisition system and a variety of actuation mechanisms are available for investigating unsteady flow-field phenomena.

This laboratory has been instrumental in developing techniques to quantify the performance and optimize the design of injector configurations for the flow-control technologies currently under development. The following graph shows an example of the characterization of an injector design used in compressor experiments. The objective in this instance was to energize the boundary layer flow by maintaining a high velocity along the wall yet minimizing jet penetration into the free-stream flow path. The design considers many factors including jet source pressure, injection mass flow requirements, and the complexity of manufacturing the components.



Example of the velocity profile of an injector design for a separation control application in a compressor. Note the identification of the peak velocity in the near and far field and its spread as it propagates downstream. The parameter U_1 is the flow rate of the low-velocity jet, and U_2 is approximately twice the initial velocity. In applications related to turbine film cooling, control mechanisms are being explored that increase the effectiveness of cooling flows while reducing the mass flow requirement, potentially leading to increased operating efficiency.

Long description of figure Graph of the height from the surface in millimeters versus the velocity in meters per second for the far-field and near-field U sub 1 and U sub 2.

Find out more about this research at http://www.grc.nasa.gov/WWW/cdtb/

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