

New wind tunnel operates quietly at Mach 6, helps shape future aircraft

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Image: Steven Schneider, an aerospace engineer and professor in Purdue's School of Aeronautics and Astronautics, operates the university's one-of-a-kind wind tunnel, which runs quietly at Mach 6, or six times the speed of sound. (Purdue photo/David Umberger)

Purdue University engineers have developed a wind tunnel that is the only one of its kind in the world capable of running quietly at "hypersonic" speeds, helping researchers to design advanced aircraft and missiles.

No other wind tunnel runs quietly while conducting experiments in airstreams traveling at Mach 6 - six times the speed of sound, said Steven Schneider, an aerospace engineer and professor in Purdue's

School of Aeronautics and Astronautics.

Researchers will use the \$1 million wind tunnel to help design advanced aircraft that travel at hypersonic speeds, or faster than Mach 5, which is about 4,000 miles per hour at sea level.

Purdue engineers will present a paper about the wind tunnel on Thursday (Jan. 12) during the American Institute of Aeronautics and Astronautics' Aerospace Sciences Meeting and Exhibit in Reno, Nev. The paper was written by Schneider and graduate research assistants Matthew P. Borg and Thomas J. Juliano.

A team of Purdue engineers led by Schneider finished assembling the wind tunnel in 2001.

"After four years of debugging, recent tests have shown that it does, indeed, run quietly at Mach 6," Schneider said. "The wind tunnel airflow has about one-tenth to one-thirtieth of the noise in other high-speed wind tunnels."

The quiet operation is critical for recreating the smooth, or laminar, flow of air over the surfaces of aircraft, spacecraft or missiles re-entering the Earth's atmosphere. Data from tests with models studied in the wind tunnel will lead to a better understanding of when and how the air flowing over a surface changes from smooth to turbulent. Engineers must better understand this transition from smooth to turbulent flow if they are to design improved aircraft and missiles. One aim is to design aircraft that heat up less from atmospheric friction as they re-enter the atmosphere.

"Laminar airflows can have eight times less heating than turbulent ones," Schneider said.

Designs that heat up less would require less shielding, enabling engineers to build lighter-weight, lower-cost vehicles.

"Designers are considering a new re-entry vehicle with a metal skin," Schneider said. "This would eliminate the tile system used on the space shuttle, which is expensive to maintain."

Another major application will be to design a generation of aircraft that will use "scramjets" to travel more than 7,000 mph, allowing them to leave the atmosphere and fly halfway around the world in a few hours.

A future fleet of space planes using scramjets might be far less expensive to operate than the current space shuttles, making it more affordable to haul payloads into orbit. Unlike rockets, which must carry their own supply of liquid oxygen to combust fuel, scramjets would scoop oxygen out of the atmosphere.

For scramjets to work properly, however, a steady, smooth flowing supply of air must be moving continuously at hypersonic speeds into the engine's combustion chamber. Poor control of turbulence near the aircraft's surface might disrupt this crucial air supply, and turbulent flow over the front of the vehicle would cause excessive heating.

Engineers need high-quality data to predict how well certain scramjet designs would function, Schneider said.

"A quiet wind tunnel more closely simulates flight," he said.

Wind tunnel research also may help engineers design more accurate missiles because the effects of excessive heating can nudge missiles off course.

Quiet wind tunnel operation requires laminar flow on the walls of a

tunnel segment called the nozzle. Turbulent flow in this segment radiates noise onto the test model, interfering with experiments. Sometimes, however, turbulence does occur in the nozzle, and the researchers study the transition from laminar to turbulence to better understand how to prevent it and also to watch its effects on the model.

Researchers will use the wind tunnel to study how the transition from smooth to turbulent airflow affects the current space shuttle's heat-resistant tiles as the spacecraft re-enters the atmosphere.

The quiet Mach 6 wind tunnel is not the first of its kind. The National Aeronautics and Space Administration previously operated a wind tunnel capable of similar performance, but that wind tunnel is not currently in operation.

The tunnel is relatively inexpensive to operate because each "run" is only about eight seconds. First, air is pumped out of a large tank that is connected to one end of the wind tunnel, creating a vacuum inside the tank. Then a valve is opened between the tank and the wind tunnel, sucking a burst of air through the wind tunnel at high velocity. The short run time requires less expensive equipment, unlike the large compressors needed for other wind tunnels that pump air continuously.

Modern computer technology and sensors have made the low-cost wind tunnel possible, Schneider said.

"Thirty years ago eight seconds of data would have been useless because you couldn't measure anything in such a short time," he said. "But nowadays, with all the computers and electronics and sensors, you can collect an enormous amount of data in eight seconds."

To obtain quiet flow, the throat of the Mach 6 nozzle must be polished to a near-perfect mirror finish, eliminating roughness that will trip the flow

near the wall from laminar to turbulent. Then, for the wind tunnel to remain quiet, it must be entirely free of particles. Even a single piece of sand could cause turbulence inside the wind tunnel, damaging the finish and ruining the quiet effect.

To help ensure this ultra-clean condition, engineers enlisted the help of an undergraduate student who is a spelunker. The slender student crawled through a 120-foot section of the wind tunnel, wearing a suit like those worn by technicians in clean rooms, and wiped down the inside of the stainless-steel pipe. The pipe is only 18 inches in diameter.

"It's pretty tight quarters," Schneider said. "If you are claustrophobic, this would not be the right job for you."

The wind tunnel, which has been funded by the Air Force Office of Scientific Research, the Ballistic Missile Defense Organization and the Boeing Co., is named the Boeing/AFOSR Mach 6 Quiet Tunnel.

Source: Purdue University

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