Fact Sheet

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Langley Research Center
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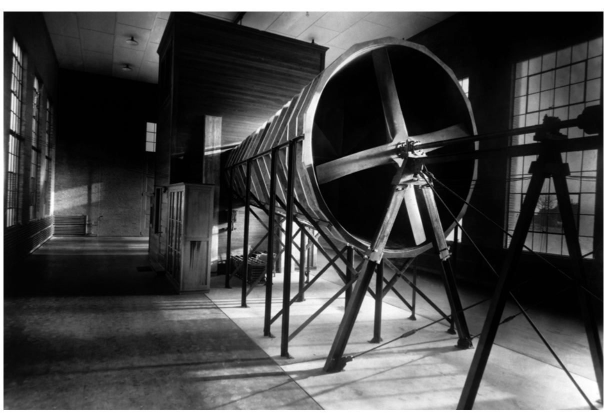
Wind Tunnels at NASA Langley Research Center

The first major U.S. Government wind tunnel became operational in 1921 and was located at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics (NACA), which became NASA Langley Research Center in 1958. This wind tunnel was crude when compared to the tunnels used at NASA Langley today. Like the aircraft tested in them, wind tunnels evolve as researchers discover ways to more accurately duplicate flight conditions.

Wind tunnels help researchers understand the forces acting on an object as it moves through the atmosphere. They are also used to measure and minimize the noise produced by aircraft and to optimize engine efficiency. Although primarily used for aircraft, other objects such as spacecraft, automobiles, ships, trucks, and wheelchairs have been tested in Langley wind tunnels.



First wind tunnel at Langley.

Why Wind Tunnels Are Used

At Langley, models in wind tunnels are used in conjunction with computers and flight simulators to learn about the flight characteristics of new aircraft designs and modifications. Components such as structural materials, wings, ailerons, horizontal stabilizers, fuselages, power systems, engine cowlings, and landing gear all affect the flight characteristics of aircraft. Small changes to one component can result in the modification of another component of the aircraft. All effects of the changes may not be clear until the aircraft experiences flight conditions. Tests with models in wind tunnels allow the study of aircraft designs without risk to a pilot or the expense of building a new full-size test aircraft for every design improvement. Measurements, or data, from wind tunnel tests are also used to refine computer programs that predict the forces that act on a new aircraft or aircraft components.

How Wind Tunnels Simulate Flight

The forces that act on an aircraft are the same whether the aircraft is moving through the air or the air is moving past a stationary aircraft. Typically for wind tunnel tests, aircraft models are stationary and the air flows past. Basically, a wind tunnel is a tube through which air or some other gas flows so that the effects of an object moving through an air stream can be determined. A wind tunnel may be open and draw air from the room into the test section, or the wind tunnel may be closed with the air continuously circulating through the test section. To obtain meaningful data, the researcher must insure that the airflow in the wind tunnel is very similar to that found in flight. In the tunnel, the researcher can control airflow conditions, such as speed, temperature, humidity, density, and viscosity. In continuous flow wind tunnels, the airflow is most often produced by a large fan. For very high speed “blowdown” tunnels, the air is collected in pressure vessels and released into the tunnel.

Because wind tunnels are in buildings (and the actual aircraft flight environment is not!), care must be taken to avoid introducing airflow abnormalities from the tunnel itself. To accurately simulate flight, the airflow in a wind tunnel must be smooth. Wind tunnels must also be free of the effects of turbulent or unsmooth airflow, which can be caused by forcing the air around the tunnel circuit. Devices such as turning vanes, screens, and slots in tunnel walls help to maintain smooth airflow.

Simulating airflow at flight conditions in a wind tunnel is complex. Wind tunnels usually specialize in simulating a particular aspect of flight. Subsonic speed wind tunnels study flight that is slower than the speed of sound. Transonic speed tunnels study flight that is slightly below, at, and slightly above the speed of sound. Supersonic speed tunnels examine flight faster than the speed of sound and hypersonic speed tunnels look at flight more than five times the speed of sound. There are special tunnels for propulsion research, aircraft icing research, aircraft spin control research, and even full-scale model tests. The speed of airflow in a wind tunnel is usually expressed as a Mach number. For example, moving at twice the speed of sound is Mach 2, moving at half the speed of sound is Mach 0.5.

Early work in fluid mechanics, or the study of how fluids and gases behave and their effect on objects in a flow, indicated that the airflow around a scale model would not correspond exactly to the flow around a full-scale aircraft. To ensure the correlation of model data to full-scale aircraft data, researchers also determine the Reynolds number of flow in a wind tunnel.

Mach Number

The ratio between the speed of a craft and the speed of sound in the surrounding medium (the atmosphere) is called a Mach number. The speed of air flowing through a wind tunnel is usually expressed in terms of the speed of sound, which is approximately 761 miles per hour at sea level. However, the speed of sound through the atmosphere varies with temperature. Sound travels more slowly through cooler air. Aircraft usually fly at higher Mach numbers in the upper atmosphere where the air is colder.

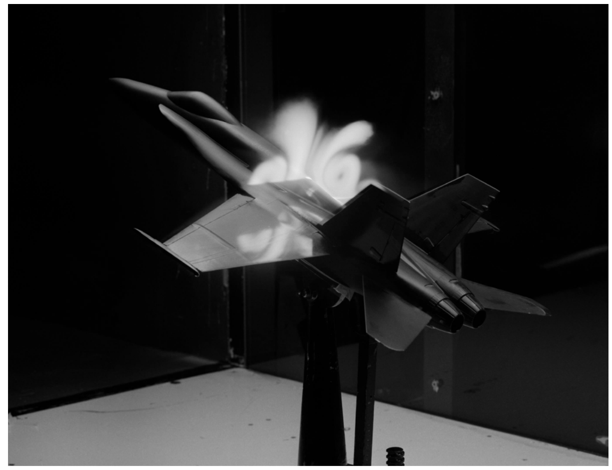
Reynolds Number

Reynolds number is a nondimensional parameter representing the ratio of the momentum forces to the viscous forces in fluid (gas or liquid) flow. Reynolds number expresses the relationship of the density of the fluid, velocity, the dimension of an object, and the coefficient of viscosity of the fluid relationship. Osborne Reynolds (1842-1912) demonstrated in experiments that the fluid flow over a scale model would be the same for the full-scale object if certain flow parameters, or the Reynolds number, were the same in both cases.

For example, the Reynolds number of 1/4-scale models tested at flight velocities at atmospheric pressure would be too low by a factor of 4. Because the Reynolds number is also proportional to air density, a solution to the problem could be to test 1/4-scale models at a pressure of 4 atmospheres. The Reynolds number would then be the same in the wind tunnel tests and actual full-scale flights.

Measurement Systems

In addition to Mach number and Reynolds number, researchers measure airflow around a model or specific parts of a model, pressure exerted on the model, lift, drag, and engine thrust. There are many techniques that researchers use to obtain these measurements from wind tunnels and models.



Vortical flow visualized by doppler global velocimetry.

Some models have small ports with pressure transducers that measure pressures on the model at specific locations. These force measurements can be recorded at a high rate of speed by a computer with data acquisition software. Strain gauges can also be used to measure pressure at specific locations. Pressure sensitive paint (PSP) can acquire pressure measurements on the entire model or entire sections of a model. The model may be mounted on a balance to directly measure the aircraft lift or drag. A wake rake, or a row of transducers, can also measure drag. Model attitude or the angle of the aircraft to the airflow is measured using either a sensitive angular encoder or high-precision accelerometer.

Various flow visualization techniques, such as ultraviolet oil, paint, or fluorescent minitufts (short strings) are used to investigate airflow at specific locations on the surface of model. Video cameras can be used to record aspects such as airflow visualization, wing deformation, and model angle of attack measurements at normal video recording speeds, or at high speed to provide more detailed motion analysis. Schlieren and shadowgraph systems, infrared photogrametry, and laser velocimeters are used to visualize and document airflow.

Thermocouples measure temperatures either on the model or inside the tunnel at specific locations. Temperature sensitive paint (TSP) can be used to determine temperature changes on broader areas. Measurements can be made with a focused microphone array to determine noise levels produced by specific components of an aircraft.

0.3-Meter Transonic Cryogenic Tunnel

The Langley 0.3-Meter Transonic Cryogenic Tunnel is used for testing airfoil (wing) sections and other models at Reynolds numbers up to 100 x 10^6 per foot and Mach numbers from 0.1 to 0.9. The adaptive walls, floor, and ceiling in the test section can be moved to eliminate or reduce effects of air around the model being artificially constrained by the tunnel walls, thus better representing flight in the atmosphere. The Mach number, pressure, temperature, angle of attack, and adaptive wall shapes are automatically controlled by the tunnel computer system. The normal test medium is gaseous nitrogen. Air can be used as the test medium at ambient temperature.

Because of the large operational temperature envelope, one end of the tunnel is free floating and is allowed to contract and expand along the length, width, and height. The fan housing section is the fixed point for the tunnel and encloses the 12-blade aluminum fan. The tunnel has interlocks and fail-safe systems that shut down and vent the appropriate systems when electric, lubrication, hydraulic, cooling water, pneumatic systems failures, or gas leaks are detected.

8-Foot High Temperature Tunnel

The Langley 8-Foot High Temperature Tunnel (8-Ft HTT) is a combustion-heated hypersonic blowdown-to-atmosphere wind tunnel that provides simulation of flight enthalpy (relationship of an object, its environment, and energy) for Mach numbers of 4, 5, and 7 and Reynolds numbers from 0.3 x 10^6 to 5.09 x 10^6 per foot, depending on the Mach number. The test section will accommodate air-breathing hypersonic propulsion systems and structural and thermal protection system components. A radiant heater system can be used to simulate ascent or re-entry heating profiles.

Control room of the 8-Foot High Temperature Tunnel.

14- by 22-Foot Subsonic Tunnel

The Langley 14- by 22-Foot Subsonic Tunnel (14- by 22-Ft ST) is an atmospheric, closed-return tunnel that can reach a velocity of 348 ft/s. The Reynolds number ranges from 0 to 2.2 x 10^6 per foot. Test section airflow is produced by a 40-ft diameter, 9-blade fan. Tunnel configurations include a fully closed test section, a closed test section with slotted walls, and an open test section closed only on the floor.

The tunnel provides an improved understanding of the aerodynamics of vertical and short takeoff and landing (V/STOL) aircraft. The 14- by 22-Ft ST is also ideally suited for low-speed tests to determine high-lift stability and control, aerodynamic performance, rotorcraft acoustics, turboprop performance, and basic wake and airflow surveys.

16-Foot Transonic Tunnel

The Langley 16-Foot Transonic Tunnel (16-Ft TT) is an atmospheric, closed-circuit tunnel with a Mach number range of 0.2 to 1.25 and a Reynolds number range from 1 x 10^6 to 4 x 10^6 per foot. The test section of the tunnel is octagonal with a distance of 15.5 ft across the flats. The twin 34-ft diameter drive fans have counterrotating blades. The 16-Ft TT has capabilities for conducting propulsion airframe integration (PAI) and has supported most major military programs both in the developmental stage and in on going propulsion integration research. The F-14, F-15, F-18, and B-1, as well as the more recent Navy Advanced Technology Fighter (NATF), the AX, and the Joint Advanced Strike Technology (JAST) Program have been tested in this tunnel. The tunnel has also supported NASA programs by doing extensive tests for the Space Shuttle and X-33, X-34, X-37, X-38, Hyper-X, and experimental programs such as the Unmanned Air Combat Vehicle (UCAV).

Airflow turning vanes in the 16-Foot Transonic Tunnel.

20-Foot Vertical Spin Tunnel

The Langley 20-Foot Vertical Spin Tunnel (20-Ft VST) is a closed-throat, annular return wind tunnel operating at atmospheric conditions. The test section velocity can be varied from 0 to approximately 85 ft/s. Test section airflow is produced by a 3-blade, fixed-pitch fan. The motor allows rapid changes in fan speed, which result in maximum flow accelerations in the test section of -25 ft/s^2 to 15 ft/s^2.

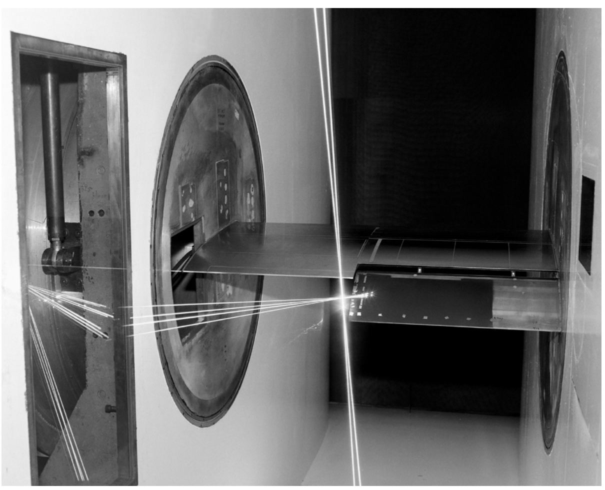
Dynamically scaled, free-flying aircraft models can be tested for spinning, tumbling, and other out-of-control situations. Spacecraft models can be tested for free-fall and dynamic stability characteristics. The spin-recovery characteristics of aircraft are studied by using remote actuation of the aerodynamic control surfaces of the models. Emergency spin-recovery parachutes systems for flight test aircraft can also be determined.

Jet Exit Test Facility

The Langley Jet Exit Test Facility (JETF) is a ground test stand. Engine nozzle mass-flow rates and nozzle axial thrust are measured. The nozzle test range provides nozzle pressure ratios that simulate static conditions for up to a Mach number of 3. The JETF has been used to test conventional and advanced aircraft propulsion system components.

Low-Turbulence Pressure Tunnel

The Langley Low-Turbulence Pressure Tunnel (LTPT) is a single return, closed-circuit tunnel that can operate from 1 to 10 atmospheres. The LTPT has been used for tests of high-lift airfoils, basic research, and theory validation. LTPT's capabilities of low disturbance, variable density tests and high-lift, multielement airfoil tests at Mach numbers from 0.05 to 0.5 and Reynolds numbers from 0.4 x 10^6 to 15 x 10^6 per foot are unique in the world. This tunnel is ideal for preliminary aerodynamic configuration screening because of low operational cost and relatively inexpensive models.



Laser velocimetry in Low-Turbulence Pressure Tunnel.

National Transonic Facility

The National Transonic Facility (NTF) at Langley is a high pressure, cryogenic, closed-circuit wind tunnel with a Mach number range from 0.1 to 1.2 and a Reynolds number range of 4 x 10^6 to 145 x 10^6 per foot. The test section has 12 slots and 14 reentry flaps in the ceiling and floor. To ensure minimal energy consumption, the interior of the pressure shell is thermally insulated. The drive system consists of a fan with variable inlet guide vanes for responsive Mach number control. In the variable temperature cryogenic mode, nitrogen is the test gas. In this mode, the NTF provides full-scale flight Reynolds numbers without an increase in model size. In the ambient temperature air mode, air is the test gas and a heat exchanger is used to maintain the tunnel temperature. The NTF provides tests in support of stability and control, cruise performance, stall buffet onset, and configuration aerodynamics validation.

Transonic Dynamics Tunnel

The Langley Transonic Dynamics Tunnel (TDT) is specifically dedicated to investigating flutter problems of fixed-wing aircraft. However, the tunnel has been used to investigate other aeroelastic phenomena such as fixed-wing buffet and divergence and to conduct rotary-wing tests that investigate the performance, loads, and stability characteristics of both helicopter and tilt-rotor configurations. Researchers also use the tunnel to determine the effects of ground-wind loads on launch vehicles. The effects of gusts on aircraft can also be studied in the TDT. The tunnel provides steady and unsteady aerodynamic pressure data to support computational aeroelasticity and computational fluid dynamics computer code development and validation.

The TDT is a closed-circuit, continuous flow, variable pressure wind tunnel. The tunnel is capable of using either air or R-134a as the test medium. Testing in R-134a has important advantages over testing in air, particularly for aeroelastic models. These advantages include improved full-scale aircraft simulation, higher Reynolds numbers, easier fabrication of scaled models, reduced tunnel power requirements, and in the case of rotary-wing models, reduced model power requirements. The tunnel can operate up to a Mach number of 1.2 and is capable of maximum Reynolds numbers of about 3 x 10^6 per foot in air and 10 x 10^6 per foot in R-134a.

The National Transonic Facility at Langley.

Unitary Plan Wind Tunnel

The Langley Unitary Plan Wind Tunnel is a closed-circuit, continuous flow, variable density supersonic tunnel with two test sections. Typical tests include force and moment, surface pressure measurements, and visualization of on- and off-surface airflow patterns. Tests involving jet effects, dynamic stability, model deformation, global surface and off-body flow measurements, and heat transfer are also performed.

One test section has a design Mach number range from 1.5 to 2.9 and the other has a Mach number range from 2.3 to 4.6. The tunnel can provide continuous variation in Mach number during operation. The maximum Reynolds number per foot varies from 6 x 10^6 to 11 x 10^6.