This is an F/A-18 Hornet fighter jet. Look here. There are forward extensions of the wing called leading edge strakes or leading edge extensions. Why were the wings designed this way? In this video, you'll find out.

This video is part of the Representations video series. Information can be represented in words, through mathematical symbols, graphically, or in 3-D models. Representations are used to develop a deeper and more flexible understanding of objects, systems, and processes.

Hi, I'm Dave Darmofal, and I'm a Professor in the Department of Aeronautics and Astronautics at MIT. In this video, we're going to see an example that helps you to visualize the air velocity around an airplane body using smoke flow visualization. You will see that at low angles of attack, the velocity field is independent of time, while at high angles of attack the velocity field depends on space and time.

After watching this video: * You will know that flow quantities around bodies are often analyzed using an Eulerian frame. * You will recognize that flow velocity is a vector field which depending on the application can be not only a function of space but also time.

This is Dick, he's the Senior Technical Instructor here in the department of Aeronautics and Astronautics. He is in charge of the Wright Brothers wind tunnel.

* Wind tunnels are used to simulate the airflow around a variety of objects including buildings, cars, trains, and of course aircraft.

* The Wright Brothers Wind Tunnel is an example of a closed-circuit wind tunnel, which uses a fan to circulate the air. The test section of the Wright Brothers Wind Tunnel has an oval cross-section that is 7 feet high by 10 feet wide. The top velocities we typically use are around 100mph. While somewhat higher speeds are possible, the noise is increased rapidly with increased fan speed.

* We will visualize the air velocity vector field using smoke visualization. We seed smoke in the tunnel through a handheld probe. The smoke follows the local air velocity allowing us to "see" where the flow is going. This smoke flow visualization techniques works best at lower wind speeds, so we will be testing at about 25 mph. In other words, the speed in the tunnel test section upstream of the model will be approximately 25 mph.

* The model we will be using is based on an F-16 aircraft. Several years ago, Lockheed Martin was investigating increasing the size of the F-16 wing. A key issue with the increased wing size, especially at the higher speeds the F-16 flies at, is the potential for aeroelastic instability due to coupling between the aerodynamic forces and the wing structure. In other words, because the wing is not a completely rigid structure, aerodynamic forces can cause the wing to vibrate, which can cause big problems during flight. To study this issue, Lockheed developed the following simplified geometry. In the department of Aeronautics and Astronautics at MIT, we have also used this

model for various labs and projects in our undergraduate subjects.

* The model has three main parts to it: ** The fuselage, which is a body of revolution with a pointed tip and a bluff end ** The trapezoidal wing ** Leading edge strakes, sometimes also called leading edge extensions * The leading edge strakes help stabilize the flow at high angles of attack by creating a strong vortex over the wing. This vortex is a region swirling velocity and low pressure and generates a significant amount of lift. Thus, strakes can provide significant performance benefits for aircraft that require high angle of attack maneuverability. We will look at the vortices created by these strakes today.

In many aerodynamic applications, engineers analyze flows using an Eulerian frame in which flow quantities such as velocity, pressure, temperature, etc are viewed as fields: i.e.

functions of space and often the space of interest is fixed to the objects frame of reference. In our case, this frame of reference is also the wind tunnels frame of reference.

When you watch a river flowing downstream, an Eulerian view of the water flow is to watch the flow through a fixed point of space, as the water flows past you. For this demonstration, we will be visualizing the velocity which is not just a field, but in particular a vector field. Further, depending on the flow conditions, the velocity can be a function of time in addition to space. So, we'll think of an air velocity vector field, v = v(x,t).

* We will start by visualizing the flow at a low angle of attack that would be typical of a cruise condition, specifically we are at X degrees angle of attack. In particular, the flow at this low angle of attack is, to good approximation, "steady". This means that the flow quantities do not depend on time, though they do depend on space. In other words, the velocity field in this case is * I'll begin by putting the smoke probe relatively high above the model. You can see the smoke travels in essentially a straight line downstream. Note that the line does not change in time indicating the flow is steady.

* Now, I'll move the probe slowly down toward the model. As I do, note that the smoke flow starts to show curvature, roughly pointing upwards in front of the model and then pointing downwards behind the model. This clearly shows that the direction of the velocity field changes depending on where we look. Further, note that the smoke lines are again steady. That is, when I hold the probe tip at a fixed location, the shape of the smoke line doesn't change in time. Thus, we see that the air velocity for this condition is a "steady" or time-independent vector field, i.e. v = v(x).

* Finally, let's take a look at the flow that travels near the leading edge strakes to see if there is any evidence of a vortex. [Ad lib] UNSTEADY FLOW VISUALIZATION: TIME-DEPENDENT VECTOR FIELDS * Now, let's increase the angle of attack to Y degrees. At this angle of attack, we will see that the smoke lines in some regions will no

longer be fixed in time, even though the probe location is fixed. This indicates that the velocity vector field is time-dependent, i.e.

* We'll start by placing the probe again relatively high above the model. We again see straight and steady smoke line.

* As we again move the probe slowly toward the body, we again see the curvature of the smoke lines. Relative to the low angle of attack case, note that the curvature has increased.

The smoke is still steady as we approach the body, however, ...

* When we start to get much closer to the body, we start to see that the smoke lines change in time. In fact, they change so rapidly that the smoke tends to "mix out". Clearly, v = v(x,t) * Let's look at the flow by the leading edge strake. Now we can see the vortex, which is characterized by the swirling or corkscrew-like behavior of the smoke line. Also note that the smoke line is changing shape with time, again indicating that v = v(x,t) Flow visualization is used to help engineers understand what is happening in a flow. Usually, flow visualization is combined with other measurements such as force and moment measurements on the body to arrive at a more complete picture. In the high angle of attack condition we just explored, a key question is when the strake vortex becomes unsteady, where is the unsteadiness?

For example, is it over the fuselage, over the wing, etc? This is important because the unsteady velocity is usually tied to unsteady pressures acting on the aircraft, which can then drive the aeroelastic instability and lead to decreased life of parts of the aircraft.

An example of this actually happened to the F-18 in which the tail of the aircraft was subject to unsteady forces caused by fluctuations in the strake vortex.

This caused the first F-18's to be limited to only a few hundred flight hours as opposed to the thousands of flight hours the Navy desired. A flow visualization of the F-18 strake vortex is shown here.

Here's a quick summary of what we saw in this demonstration: * Flow quantities around bodies are often analyzed using an Euler frame.

* The flow velocity is a vector field which depending on the application can be not only a function of space but also time.

* For the aircraft model, we saw that at low angles of attack, the velocity vector field was steady (though did depend on space). At high angles of attack, the velocity field was unsteady, i.e. depending on space AND time.