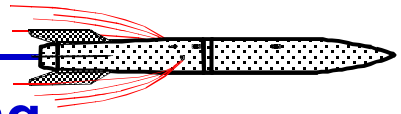
SAND2014-16717PE

Test Before Flight:

Wind Tunnel Technology for Aerodynamic Testing



Aerosciences Department
Engineering Sciences Center
Sandia National Laboratories
Albuquerque, NM

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NNSA National Nuclear Security Administration

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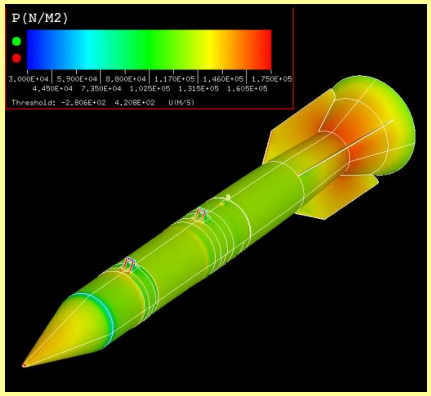
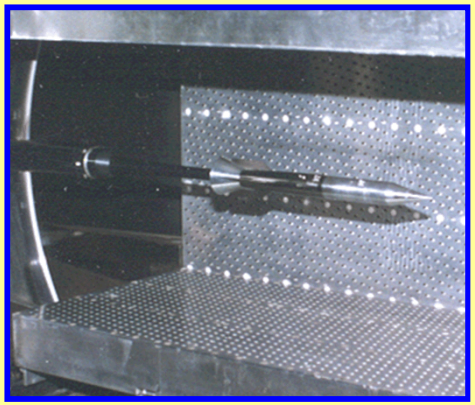
The Role of the Wind Tunnels



Flight Test



Modeling & Simulation

Ground Test

We support Sandia's aero needs by:

- Aerodynamic characterization of vehicles or flight components
- Investigating fundamental aerospace physics
- Providing data to develop and validate computational models

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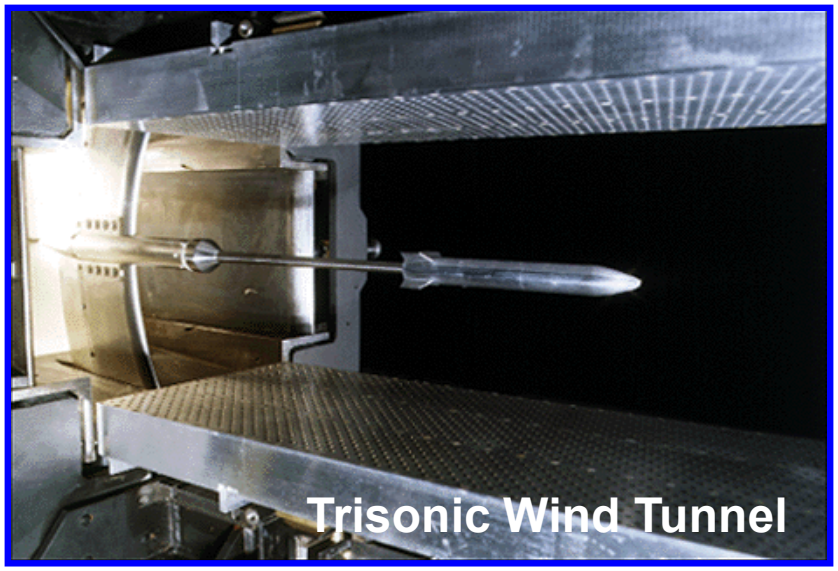
Experimental Aerosciences Facility


Trisonic Wind Tunnel


Hypersonic Wind Tunnel

Trisonic Wind Tunnel (TWT)

- Mach 0.5 – 3
- Gravity bombs, missiles, commercial aerospace

Hypersonic Wind Tunnel (HWT)

- Mach 5, 8, 14
- Re-entry vehicles, rockets

High-Altitude Chamber (HAC)

- Satellite components

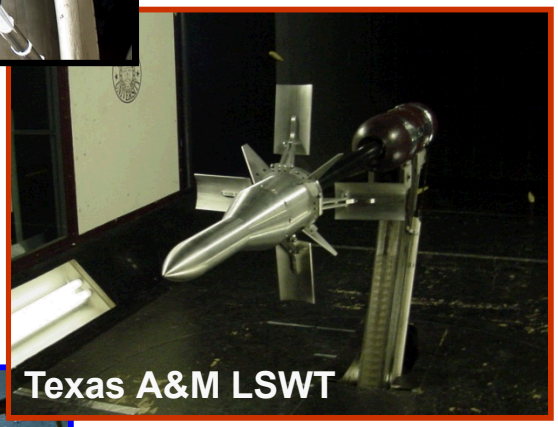

High-Altitude Chamber

External Wind Tunnel Testing

Sandia also conducts tests in external wind tunnels when necessary.

- Different speed regime
- Larger scale
- High temperature

We are simultaneously a facility operator, our own internal customer, and an external customer.



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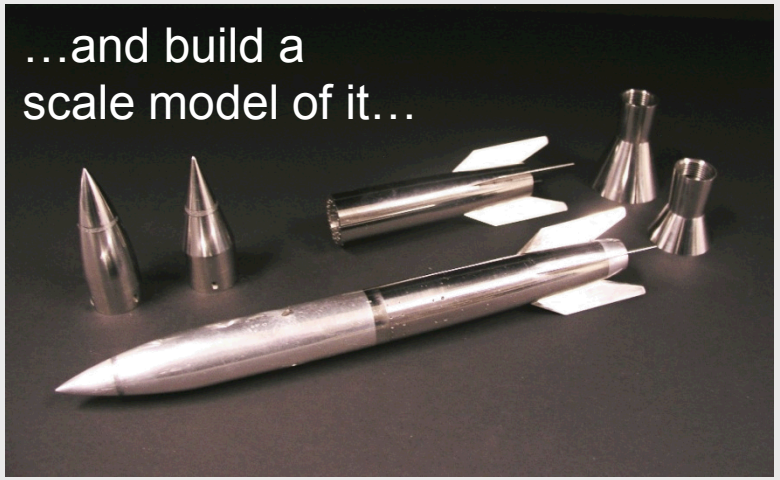
Wind Tunnel Models

Take an actual flight vehicle…

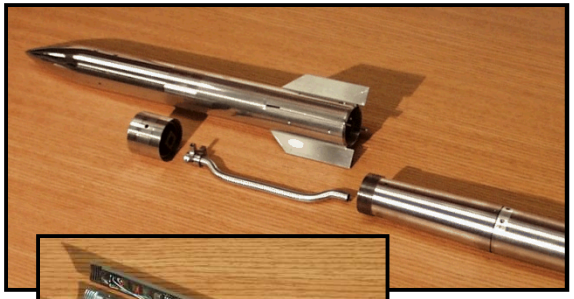
…and build a scale model of it…

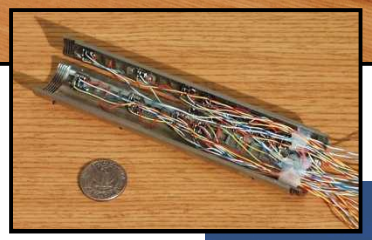


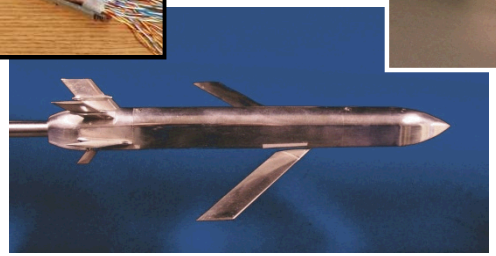
…which has features such as:

- Instrumentation
- Geometry changes
- Spin testing

Some other models tested at Sandia:







By necessity, a small model does not exactly replicate the full-scale version.

Part of a wind tunnel engineer's job is to understand such scaling issues.

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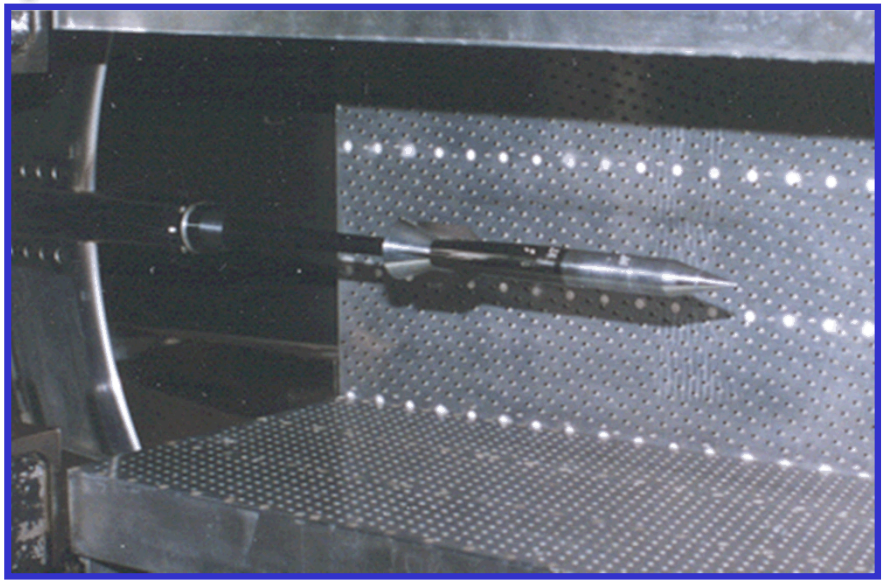
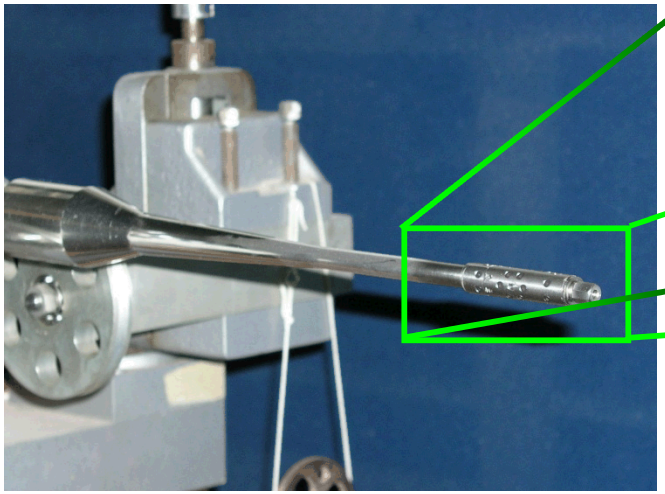
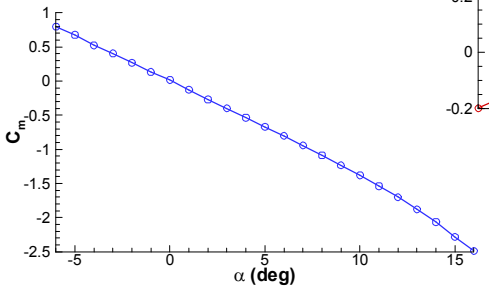
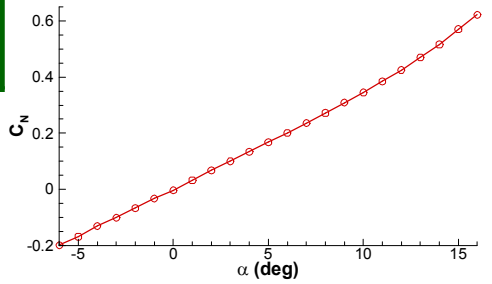
Aerodynamic Measurements



- Determine the aerodynamic forces and moments using an internal strain-gage balance placed inside the model.
- Balance elements flex as they are loaded, producing a measurable signal.
- Vary parameters such as tunnel Mach number, model angle-of-attack, model geometry, etc.







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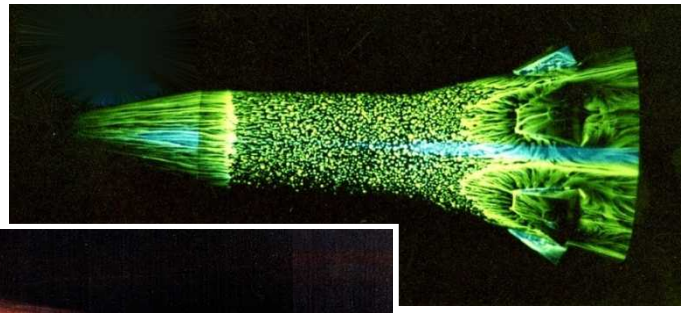
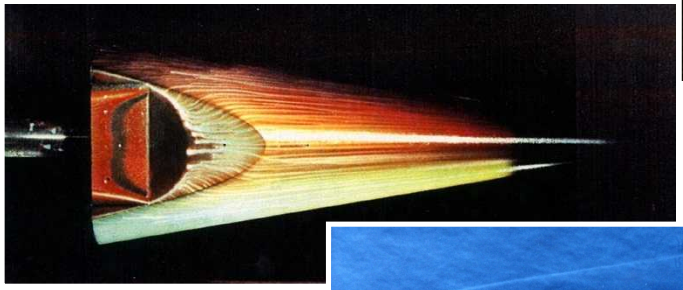
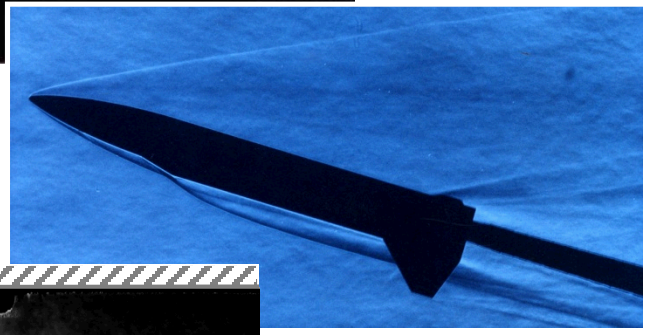
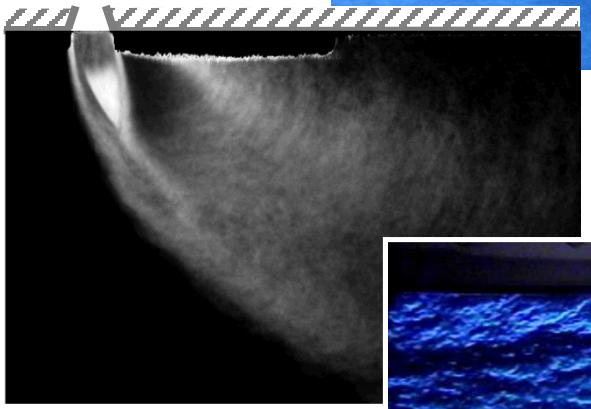
Flow Visualization

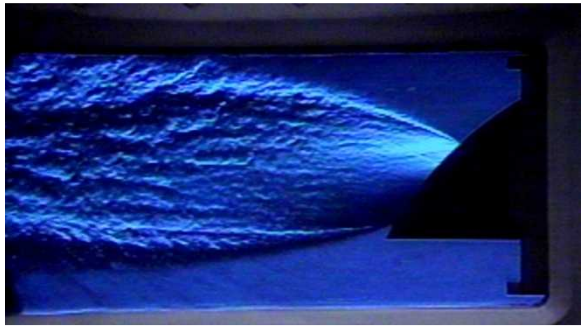
- Complement balance measurements with visualization of the gas flow over the model.
- Helps to provide an understanding of the underlying fluid dynamics.
- Can visualize:
  - Shock waves
  - Surface streamlines
  - Gas mixing











- These images are nice, but we need quantitative flowfield measurements.
- Improved technologies allow modern wind tunnel tests to accomplish much more than in the past.

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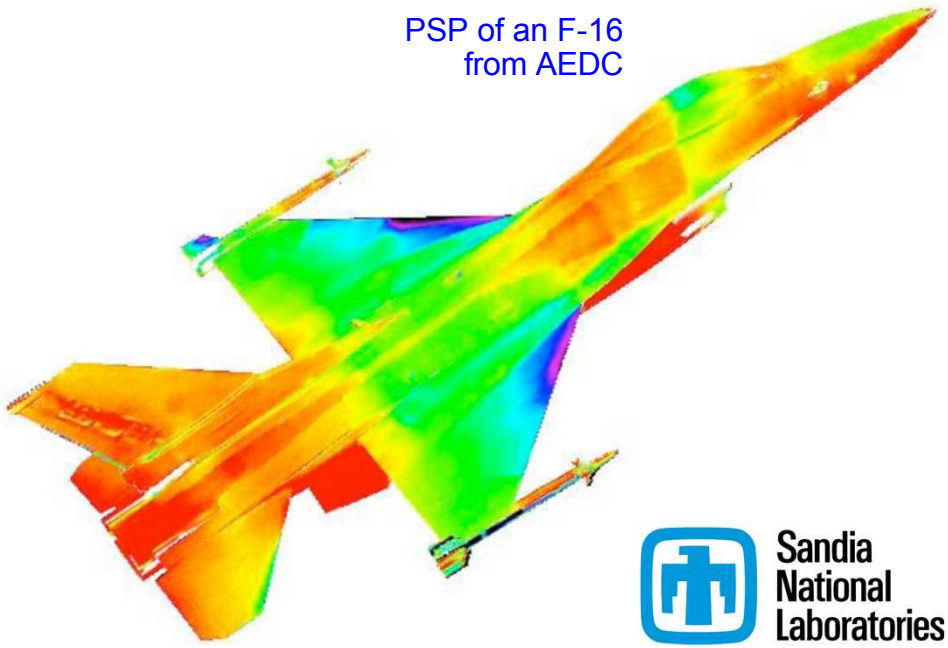
Temperature/Pressure Sensitive Paint (TSP/PSP)

Uses paints containing a luminophore.

- Illuminated by high-UV / deep-blue light, imaged by a specialized camera.
- Luminescence intensity is a function of the presence of oxygen – hence, pressure, or on temperature.
- Of course, there are numerous biases and complications to address.

Advantages:

- Enormous spatial resolution.
- Removes expense and complexity of pressure taps and thermocouples on model.
- Can instrument thin control surfaces.
- Compute loads on various surfaces.



PSP of an F-16
from AEDC

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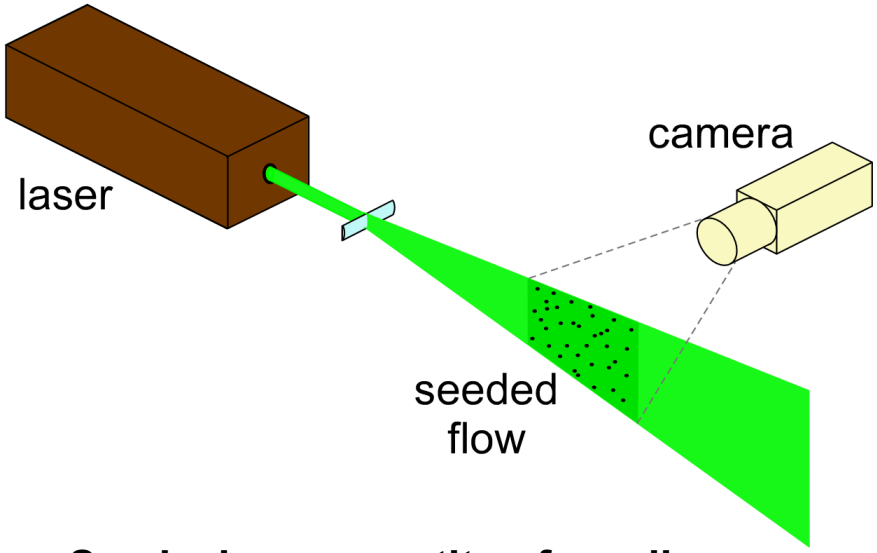
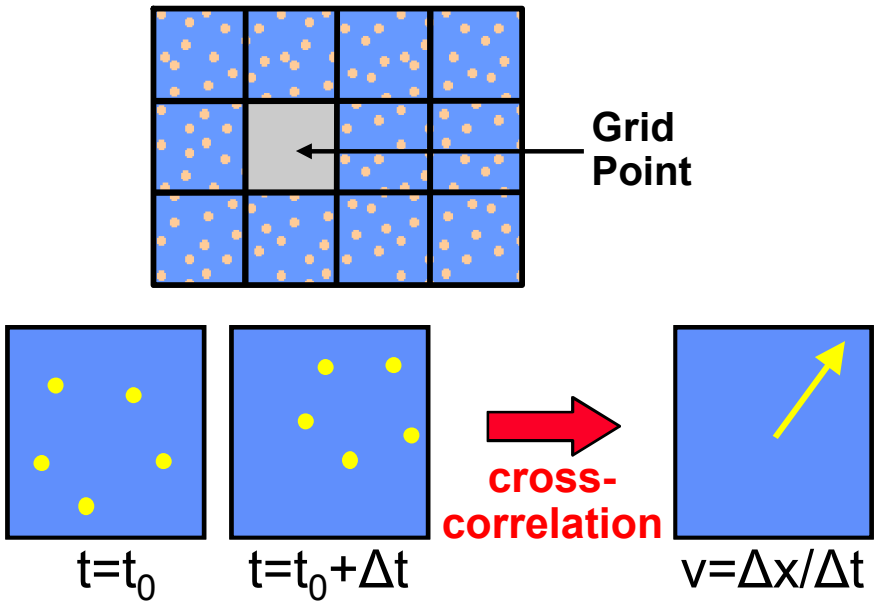
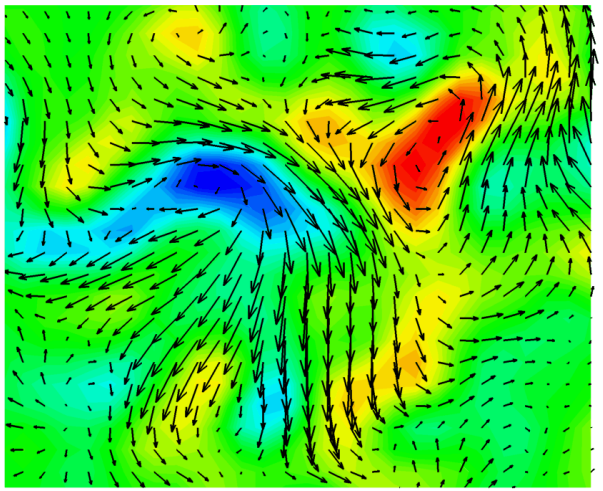
Particle Image Velocimetry (PIV)





- Seed a large quantity of small particles into the wind tunnel
- Illuminate with a double-pulsed laser sheet and image with a specialized digital camera
- Grid the images into smaller windows
- In each grid window, track a pattern of particles as they move from the first exposure to the second
- Compute a field of velocity vectors



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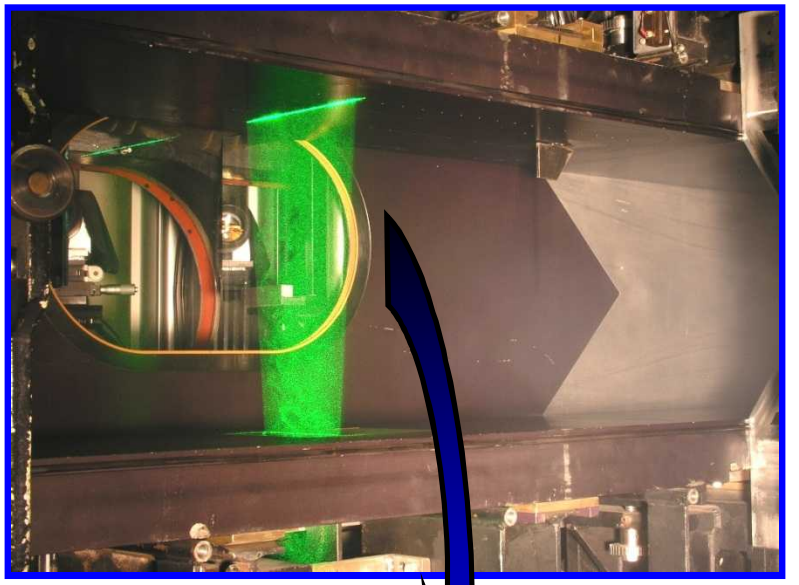
How Is PIV Useful?

What data does PIV provide?

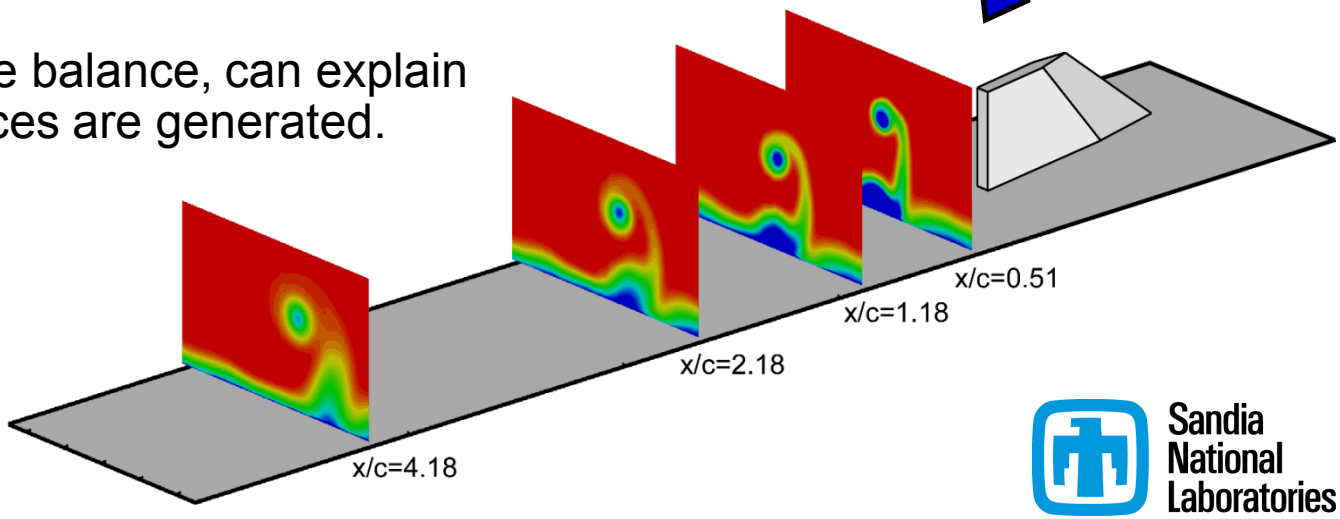
- Measures a plane of three-component velocity vectors.
- Offers time-resolved data.
  - Can be reduced to mean velocity fields, turbulence quantities, flow structures, etc.
- Movies are possible with a high-speed PIV system (we don't have one yet).

PIV provides CFD-like quantitative flowfield definition, but with experimental data.

- Offers detailed description of the off-body flow fields.
- Combined with a force balance, can explain how aerodynamic forces are generated.



(for example)



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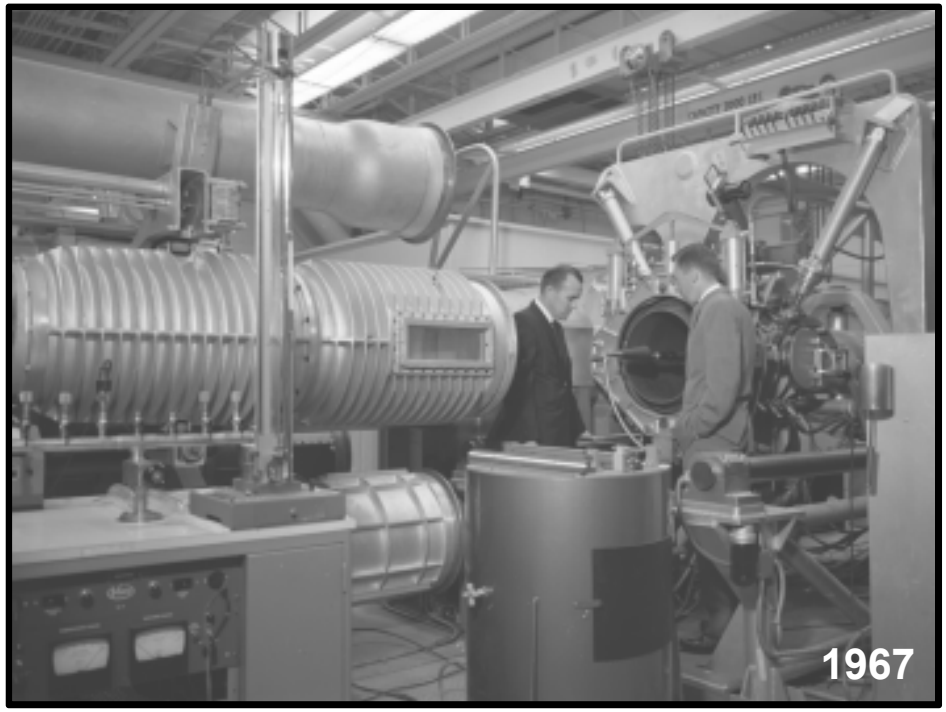
Summary

Sandia's wind tunnels have a long history of contributing to the nation.



Even in an era of computational simulation for engineering practice, wind tunnels are key to aerospace technology.

New experimental technologies allow us to do things we never could have imagined a generation ago.

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