Introduction to AAE520 Forebody/LDV Lab

- Learn to use a water tunnel
- Learn about the laser doppler velocimeter (LDV), use it for some measurements
- Learn about flow visualization
- Learn about subsonic forebodies at high angle of attack

Introduction to Water Tunnels

- Air and water are both Newtonian fluids. Water sometimes used to simulate air. Hydrodynamics is also important for ships, torpedos, etc.
- Flow visualization is easy in water tunnels
- LDV is easy in water tunnels – particles are ubiquitous
- Water leaks cause a lot more trouble than air leaks
- Water often hastens corrosion
- Surface waves can cause problems

Introduction to ASL Water Tunnel

•Obtained surplus from Boeing ca. summer 2002

•Installed, wired, plumbed, fixed in 2002-2003. Motor and controller replaced in 2005-2006. Traverse improved in 2006.

•AAE520 Spring 2004 was first real use

•Goes up to 1 foot/second, fairly slow

•15x20-inch test section is good sized

•Nice dye system. Tunnel built for flow viz.

•Presently not covering test section, will get surface waves

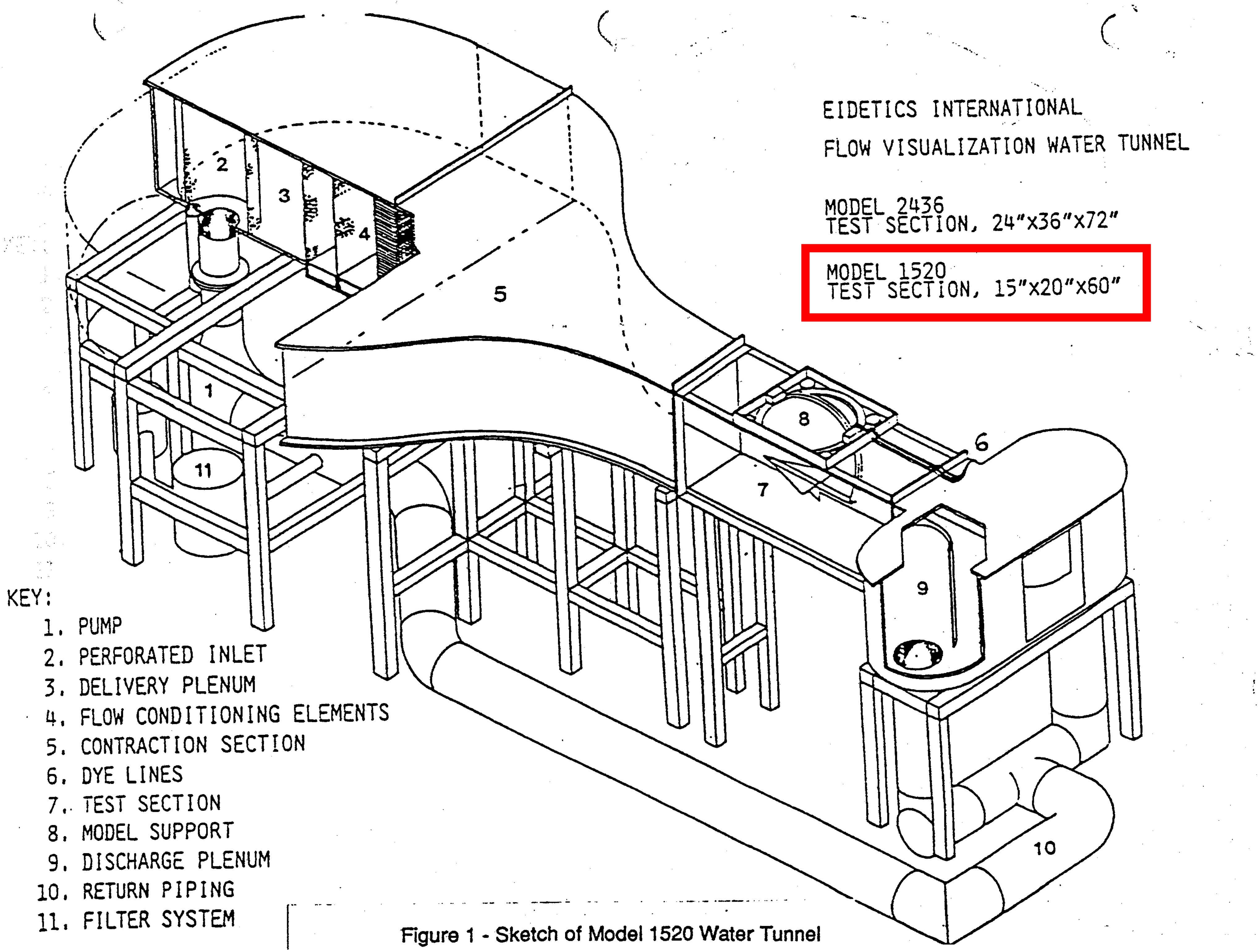


Figure 1 - Sketch of Model 1520 Water Tunnel

Water Tunnel Operations

- Read the manual summary
- If turn off, wait til motor stops before restart
- Potentiometer on operations panel controls speed
- Flowmeter supposedly calibrated to show test section speed
- Don’t go above 12 inch/sec, pump will <u>cavitate</u> and may be damaged if left that way for long
- Leave filter off (and unpressurized) to retain particles for LDV.

Water Tunnel Operations, 2

- We may need to clear air from the honeycomb (see p. 18 of manual). But usually not.
- Dye colors the water. Bleach (not too much) reduces color, also controls algae growth, but more trouble than it's worth for us. Limit dye usage, will need to replace water anyway
- Draining takes about 25 mins. Filling takes about 1/2 hour when no one else is using the water. (New automated fill line and new drain line).
- **Keep water away from electrical/electronic apparatus! Don't rely on the GFI!**

Water Tunnel/Cone Operations, 3

- Don't get the water too blue, doing flow viz! There's no time in the schedule for changing the water, which takes about an hour during which someone must be around. Dilute dye! About 1 part dye: 10 parts water. Plan for a drain-&-fill between groups – start drain when finished, so morning group loses 1/2 hour and afternoon group also loses 1/2 hour.
- Look at vortices with dye. Can vary: 1) tunnel speed, 2) cone AOA, 3) cone roll angle, 4) cone height in tunnel, 5) axial location of cone support (is this worth it?) 6) spanwise location of cone (does this matter?), 7) dye injection parameters (dye density, pressure, flow rates). Take photos.

Water Tunnel/Cone Operations, 4

- Always use 2 people to adjust the cone, one to hold the cone and the other to tighten the screws, one on each side of the tunnel. A safety precaution so the cone doesn’t slip while you tighten.
- Measure cone angles with inclinometer.
- Watch out for the LDV rig when you move the cone.

Water Tunnel/Cone Operations, 5

- Can release the air bubbles from dye reservoir inside cone by removing tube from the back of the cone while cone is in the water.
- Please tilt the cone out of the water at the end of the day to let it dry. This minimizes corrosion in the aluminum. Aluminum will corrode if in constant contact with water.

Laser Doppler Velocimeter

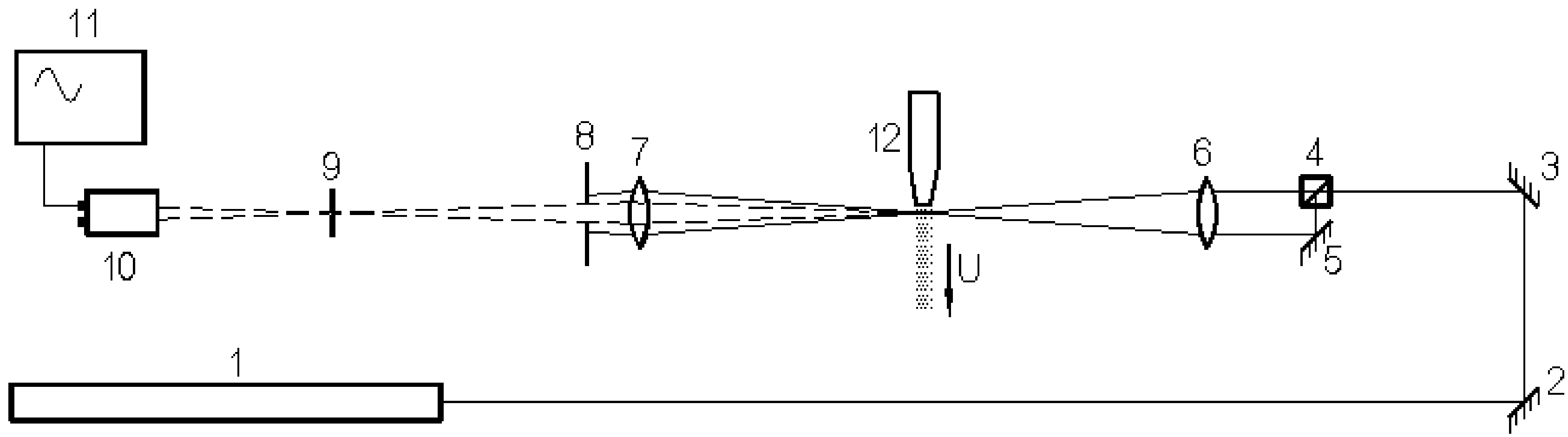
- See notes on website, followup lecture, section by Ron Adrian in <u>Fluid Mechanics Measurements</u>
- Most common optical technique for measuring velocity. Several vendors sell off-the-shelf systems
- Nonintrusive operations. Requires particles
- Forward scattering operation, as here, enables use of lower cost ($2K) and relatively safe laser
- **Keep the laser beam out of your eyes! And those of others!**

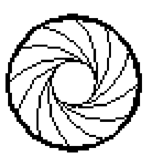
Laser Doppler Velocimeter, 2

- Our first real experience with LDV
- Sullivan built a laser and an LDV for his Ph.D. thesis
- Present setup adapted from 333L demo. by Collicott
- No automated doppler processor, sample photodiode signal with digital scope and process doppler bursts in your own software or with FFT averaging

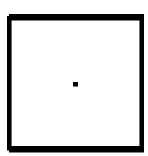
Sketch of LDV Apparatus Used in 520 & 333L

Developed by Prof. Collicott. For 520, split transmitting and receiving optics, place water tunnel test section in between, in place of item 12.





Front view of an aperture (8) :
the diameter is adjustable

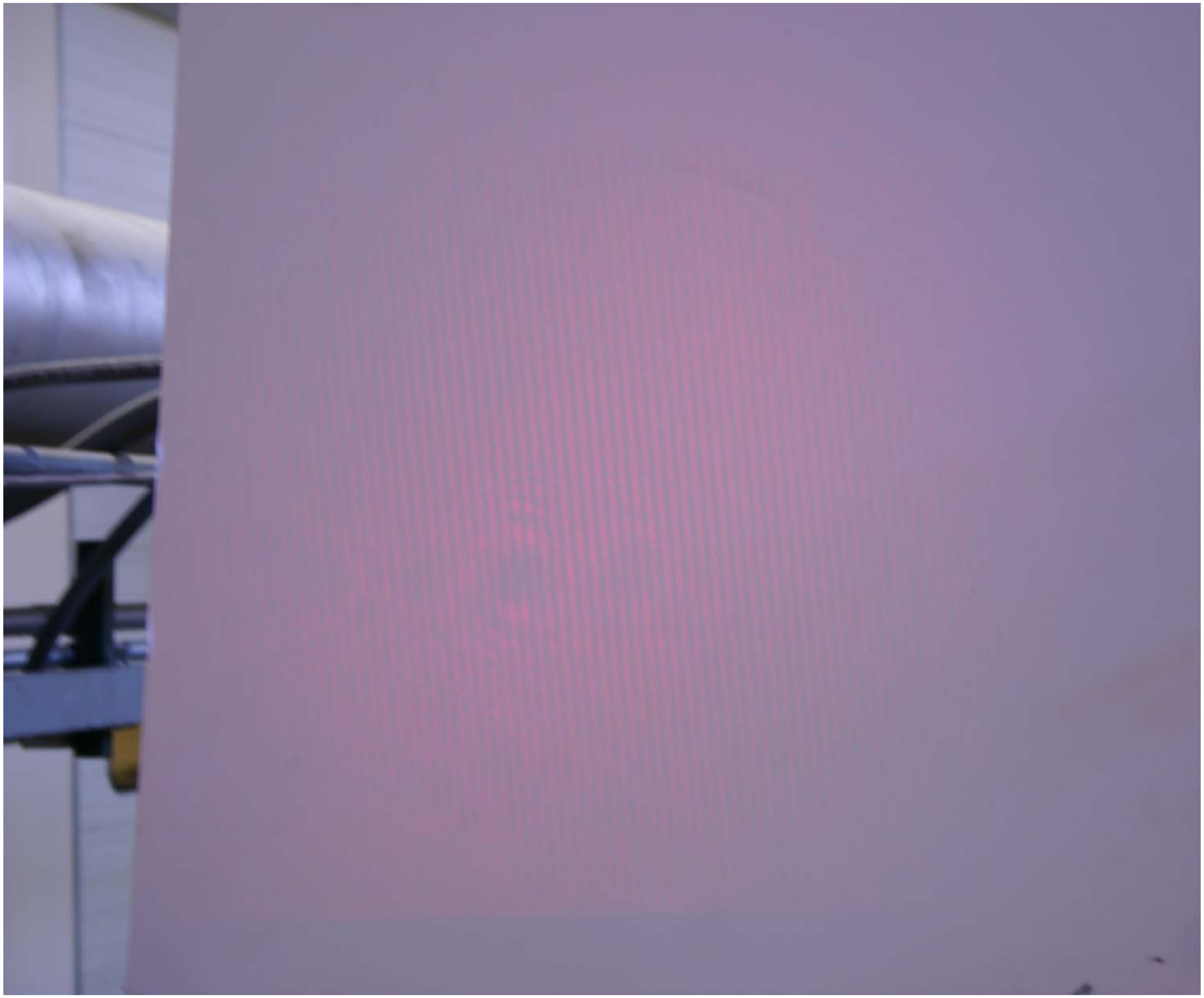


Front view of a pin hole (9) :
the diameter is fixed and close
to that of the focus point

1. He-Ne Laser
2. Mirror 1
3. Mirror 2
4. Beam splitter
5. Mirror 3
6. Lens 1
7. Lens 2
8. Aperture
9. Pin hole
10. Photo diode
11. Oscilloscope
12. Outlet of the particle source

For 520, drop mirrors 1 and 2

Magnified Image of LDV Probe Volume
Note Interference Fringes



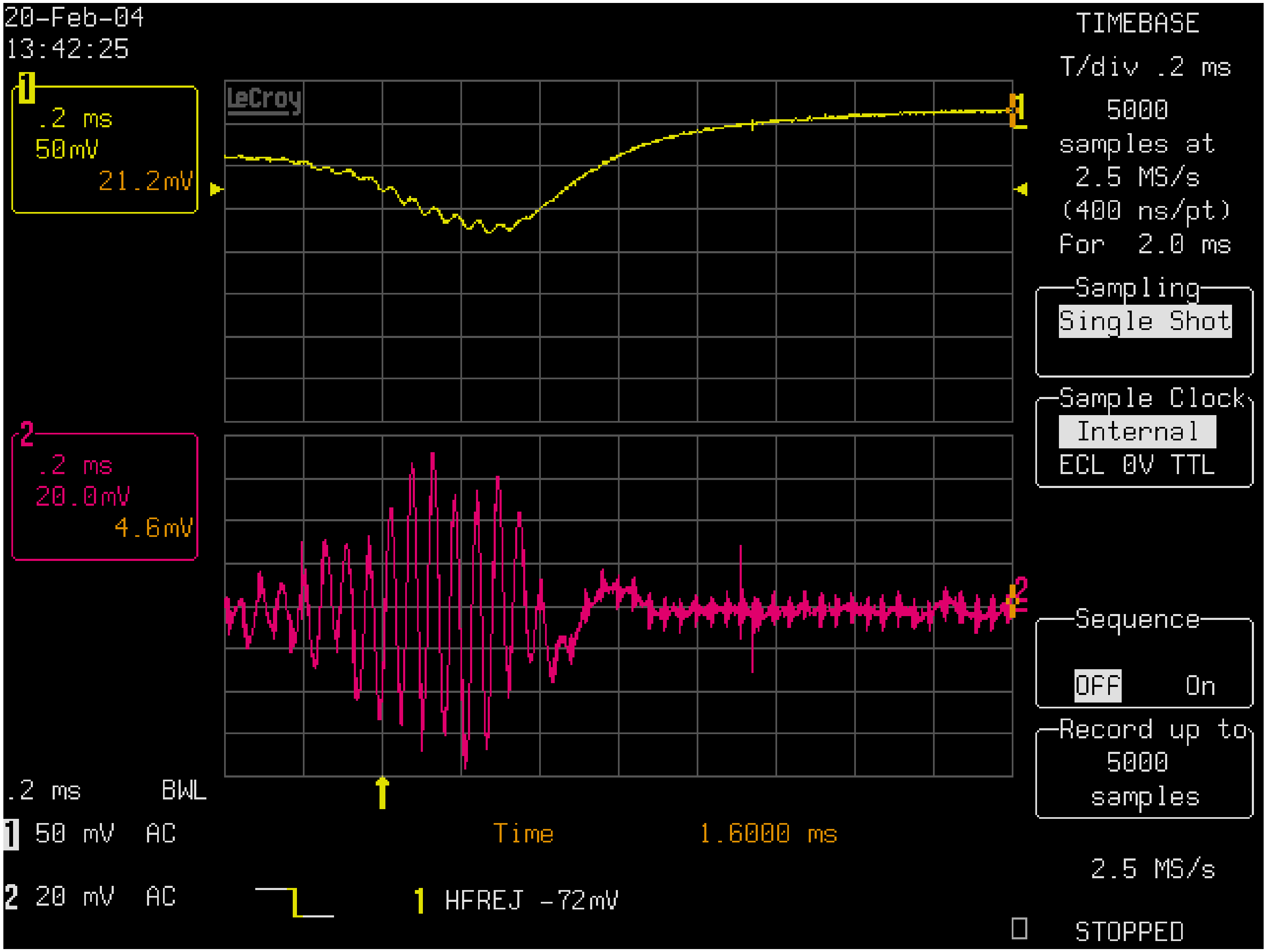
Particles traverse fringes in flow, scatter light at a frequency proportional to their axial speed.

First-surface mirror placed before test section, deflect beam into DISA microscope objective at beam intersection, project on cardboard card.

8 Feb. 2006 SPS.

Sample Output from LDV at 4.5 in./sec

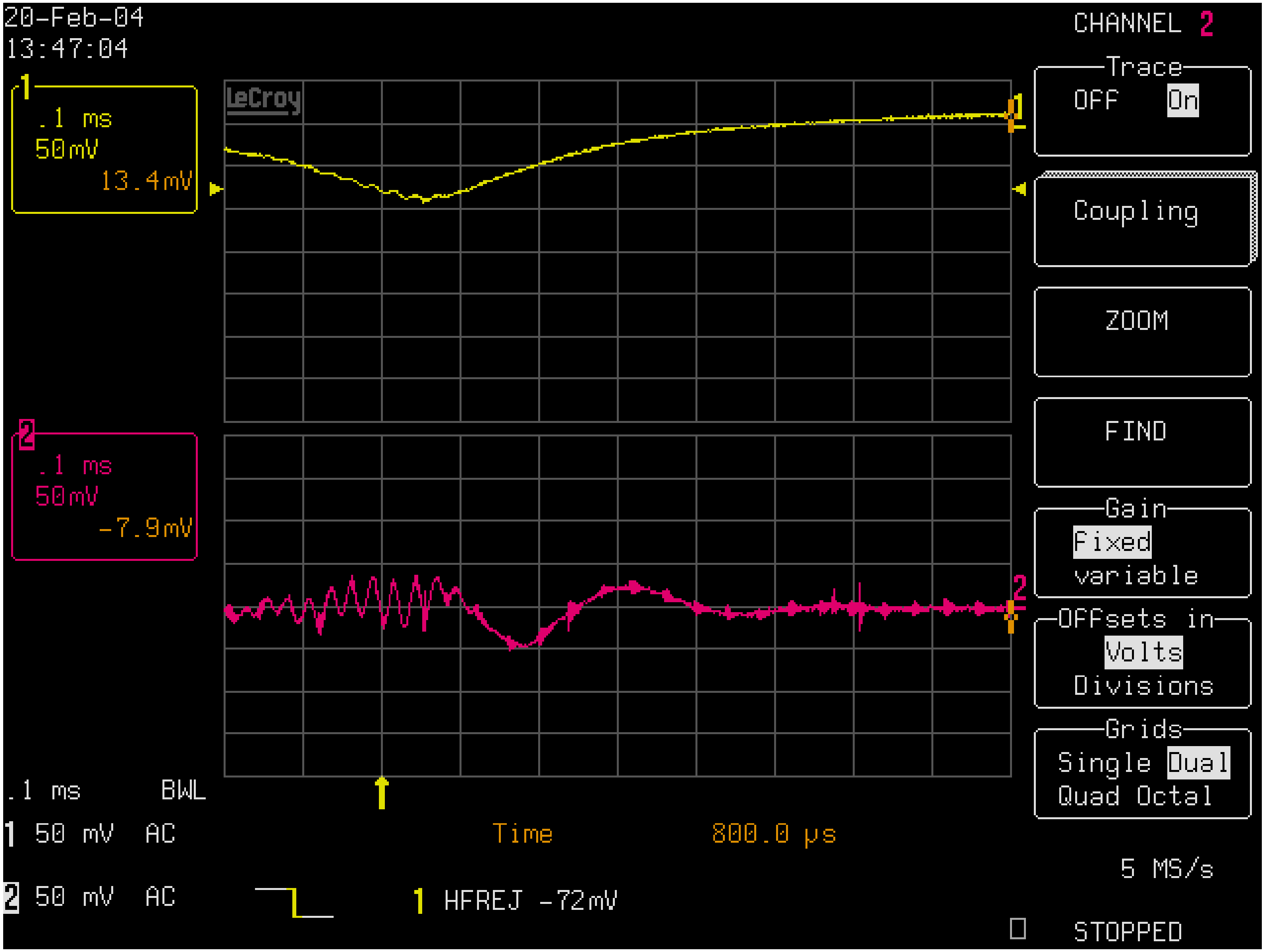
LDV output reading from scope at 4.5 inches/sec. in water tunnel, 20 Feb. 2004 Fairly typical to good particle doppler shift. Upper signal from photodiode direct, lower signal is high-pass filtered at about 4 kHz to show doppler burst better.



Sample Output from LDV at 9 in/sec.

LDV output reading from scope at 9.0 inches/sec. in water tunnel, 20 Feb. 2004 Upper signal from photodiode direct, lower signal is high-pass filtered at about 4 kHz to show doppler burst better.

Double the frequency at 4.5 in/sec (note scale!)



More on Laser Doppler Velocimeter

•Most groups have been able to get data, although sometimes the doppler bursts are not great

•Alignment is tricky (and we are still learning about how to do it). LDV drifts in and out of alignment from day to day. Sullivan says it will drift as you traverse and image through different parts of the window

•Some groups had little or nothing, first week in 2004. But it nearly always works well enough to get data.

•Save multiple particle-doppler velocity data at a given location. What is the probability distribution (histogram)? The rms and mean? Look at the statistics. Look at the effects of processing methods.

More on Laser Doppler Velocimeter

- For week 1, leave the probe volume in the middle of the tunnel, run the speed up and down, and check the LDV speed against the flowmeter speed.
- For week 2, we will be a little more aggressive in using the LDV. Suggest you move the traverse to put the probe volume at various locations in the wake, try to do a wake profile.
- As of 2006, the traverse can move the LDV probe volume through most of the water tunnel test section.
- You can move the LDV table and probe volume in 3D, using the hand cranks. Don’t move the heavy cart itself.
- Be careful moving the table around, don’t ram the optics into anything.
- Don’t move too much in week 1. If optics go out of alignment, move back.

Aligning the Laser Doppler Velocimeter

- Source optics must be carefully aligned to keep beams coplanar and put the intersection and focus where you want the probe volume. Beams must be collimated before first lens

- Beams then intersect again and focus on the pinhole. Pinhole must be exactly at the focus, so both beams go through it. Then when the iris blocks the main beams, the pinhole is at the focus of the light scattered from the beam intersection.

- Need to see not only blips with light scattered from particles, but blips with wiggles showing doppler-shift light scattered from particles. Blips w/o wiggles are from particles that aren’t in the probe volume

Studying the Laser Doppler Velocimeter

- Receiving optics covered to block 633 nm from the lights
- Transmitting optics are tricky to align
- So probably should not have students adjusting either right now. What can you do?
- Look at the signals
- Measure the included angle of the beam, for computing the particle speed from the doppler frequency.
- Block one beam at a time, look at the result

Laser Doppler Velocimeter, 3

•Leave the laser on all day, turn it off at the end of the day. But turn the lever that blocks the beam, when you aren't using it, to improve safety.

•LDV is set up as an instrument to study and make a few measurements, not as a production instrument. Look at the doppler bursts (not always easy to get, the alignment is very sensitive, ask for help if you get nothing), see how the instrument works, get particle velocities from the doppler bursts you can save.

•Leave the water filter off! We need some big particles to scatter light for the LDV.

Flow Visualization

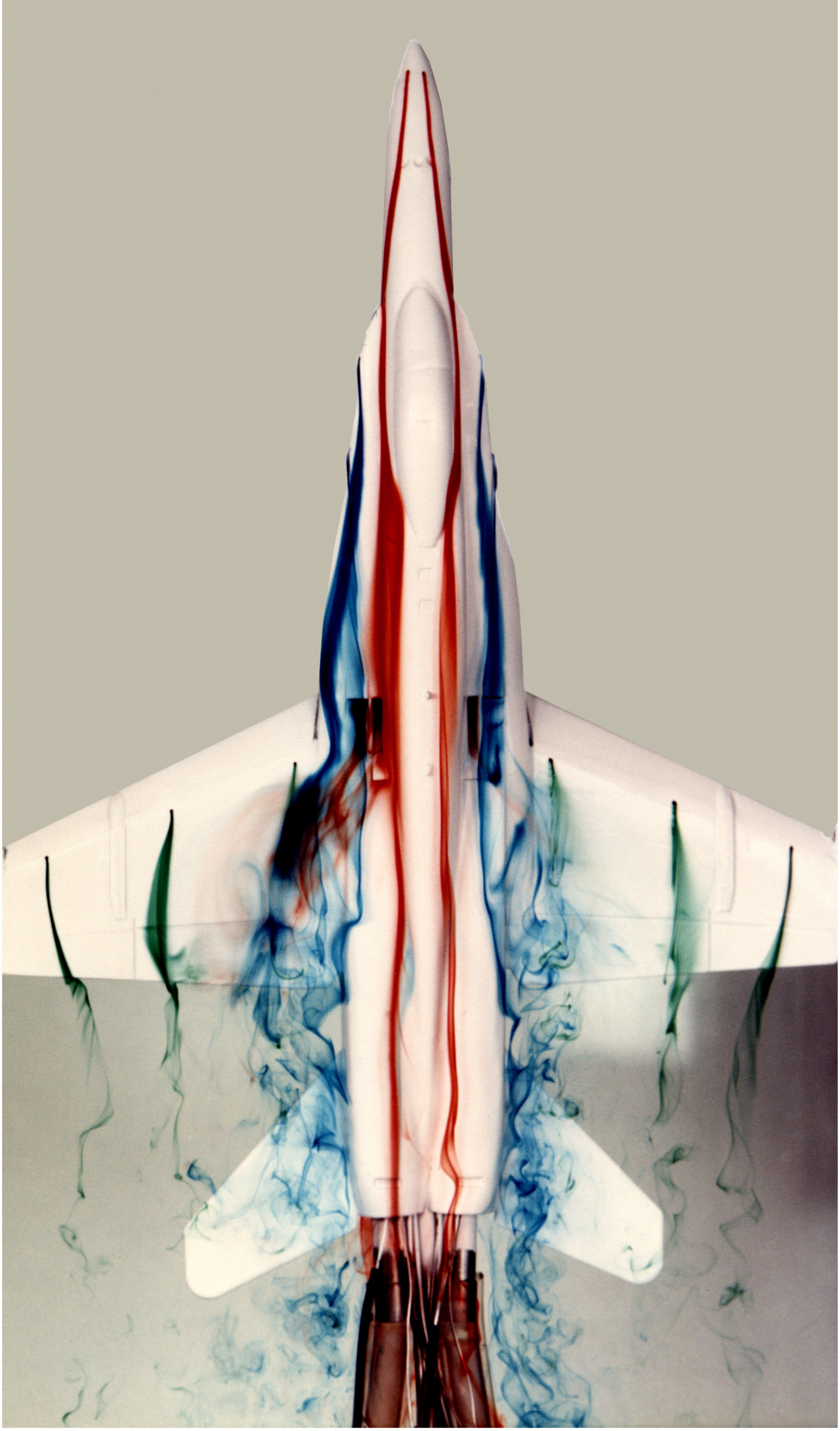
- Dye bled from cone into water
- Streaklines, streamlines, pathlines
- Can vary the flow rate of dye and the air pressure pushing the dye
- Too much dye will disturb the flow, color the tunnel water too rapidly
- Look for wake vortices, detachment positions, etc. See Bridges papers for some discussion, AIAA 93-2960 and AIAA 92-0406.

Forebodies at Angle of Attack

- Subsonic forebodies at AOA shed vortices, like cylinder in crossflow. Vortices may remain attached at LE if AOA not too high
- Vortices cause asymmetric lift. Vortex lift critical to high AOA maneuvers. Asymmetric vortices can cause side forces that can be hard to control
- Nose vortices impinging on F-18 vertical stabilizer causes structural problems
- An important issue for high AOA aerodynamics
- See for example, Bridges et al., AIAA Papers 93-2960 and 92-0406.

Suggestions for Lab Operations

- No procedures to hand out, except for manuals
- Study tunnel and instrumentation
- Vary tunnel speed, model position, model AOA
- Study wake vortices with dye. Record photographs with digital camera
- Do try to finish all your dye flow visualization in Week 1, so we don’t have to drain and fill the tunnel in Week 2.
- Study empty-tunnel mean flow with LDV
- Study wake with LDV. Some vertical and horizontal traversing is easy. If you traverse too far, the LDV may go out of alignment, if so it should come back when you traverse back.



Dryden Flight Research Center ECN 33298-036 Photographed 1985
F-18 water tunnel tests in Flow Visualization Facility NASA/Dryden