APPLICATIONS OF A LASER VELOCIMETER IN THE LANGLEY 4- BY 7-METER TUNNEL

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4- BY 7-METER TUNNEL

This paper will describe the dedicated laser velocimeter (LV) system that has been installed in the Langley 4- by 7-Meter Tunnel and will provide several examples of how an LV has been used to support research in the facility. The 4- by 7-Meter Tunnel is a closed circuit, single-return, atmospheric wind tunnel which can be operated in either an open or closed test section configuration. The test section is 14.5 ft (4.42 m) high, 21.75 ft (6.63 m) wide and 50 ft (15.24 m) long. In the open test section configuration, the side walls and ceiling are raised to the top of the test chamber to form a closed-on-bottom-only configuration as shown in the bottom left photograph.

The tunnel supports several research programs, such as high-lift/wake vortex investigations and aerodynamic and acoustic testing of rotorcraft, as well as providing data for general aerodynamic theory development and validation. Examples of some typical tests are shown in the bottom left and right photographs. In recent years, the tunnel has also been used to test several proof-of-concept LV systems, including a 3-component, coaxial backscatter system, shown in the bottom center photograph.

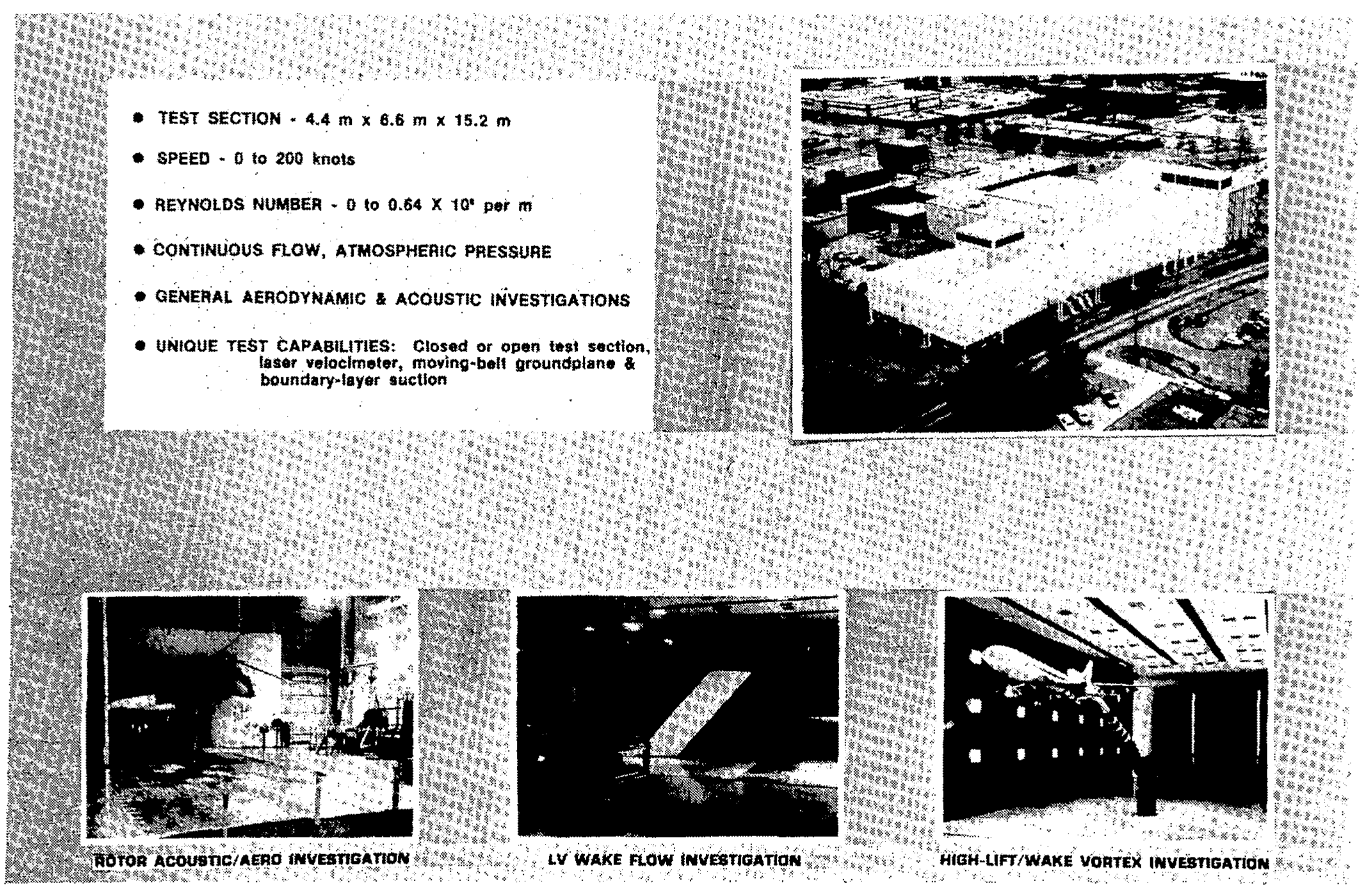

Figure 1

LASER VELOCIMETER SYSTEM

The present LV system has benefited from the knowledge gained from testing earlier proof-of-concept systems. The system was designed to provide mean flow velocity measurements of the longitudinal and vertical velocity components. The LV has a sample volume less than 1 cm long and approximately 0.2 mm in diameter over the 10- to 20-ft focal length of the system. A 12-W argon-ion laser provides the light source and is typically operated at 4 W output (in all lines) at the exit of the laser. The transmitting and receiving optics packages are commercially available, 2-component, 2-color units. The zoom lens system consists of a 3-in. clear aperture negative lens and a 12-in. clear aperture positive lens. The negative lens can be moved under computer control, as shown in the figure, to provide the capability of positioning the sample volume laterally across the test section. In addition, the final folding mirror can be panned and/or tilted under computer control, as shown in the figure, to provide additional traversing capability. Bragg cells are incorporated in the system to alleviate directional ambiguity in each of the velocity components.

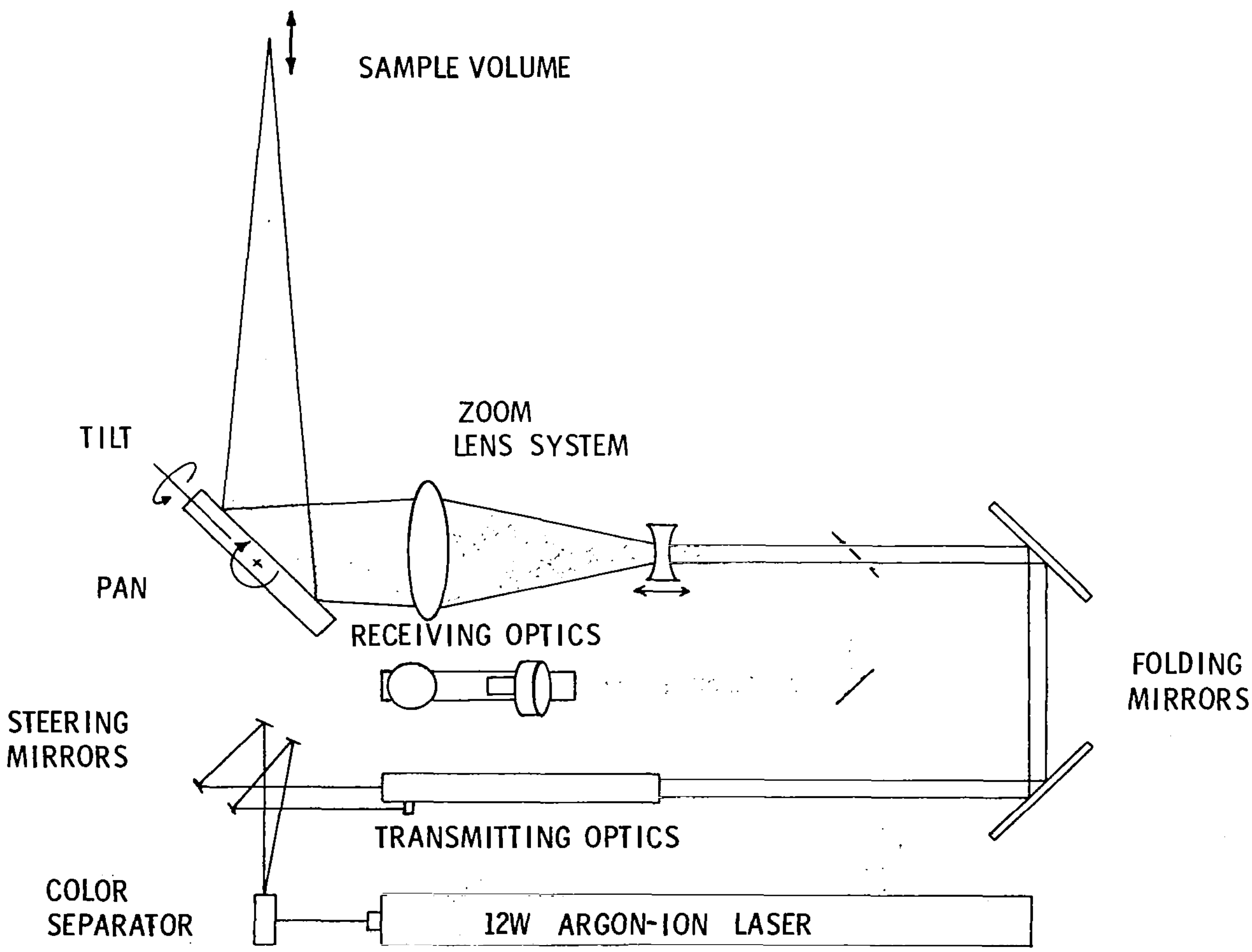

Figure 2

LV DATA ACQUISITION SYSTEM

The existing LV system can acquire two channels of LV data and one channel of auxillary data. During helicopter testing, the auxillary channel typically provides data relating to helicopter rotor position. The signals from the photodetectors are input to high-speed burst counters, which are interfaced to a 16-bit minicomputer by a laser velocimeter autocovariance buffer interface (LVABI). The LVABI can store up to 4096 data points for each channel in individual buffers. When either of the two LV data buffers are filled or a preset kick-out time is exceeded, the LVABI sends the data to the minicomputer via direct memory access (DMA). The minicomputer processes the data, stores it on a disc and magnetic tape, and displays the results on a graphics terminal and line printer.

The LVABI has an additional feature that enhances data processing. The LVABI has the capability of only accepting data from the counters when the measurement of each velocity component occurs within a 1-μsec coincidence window. The auxillary data channel and the coincidence window provide the capability for conditional sampling during data processing.

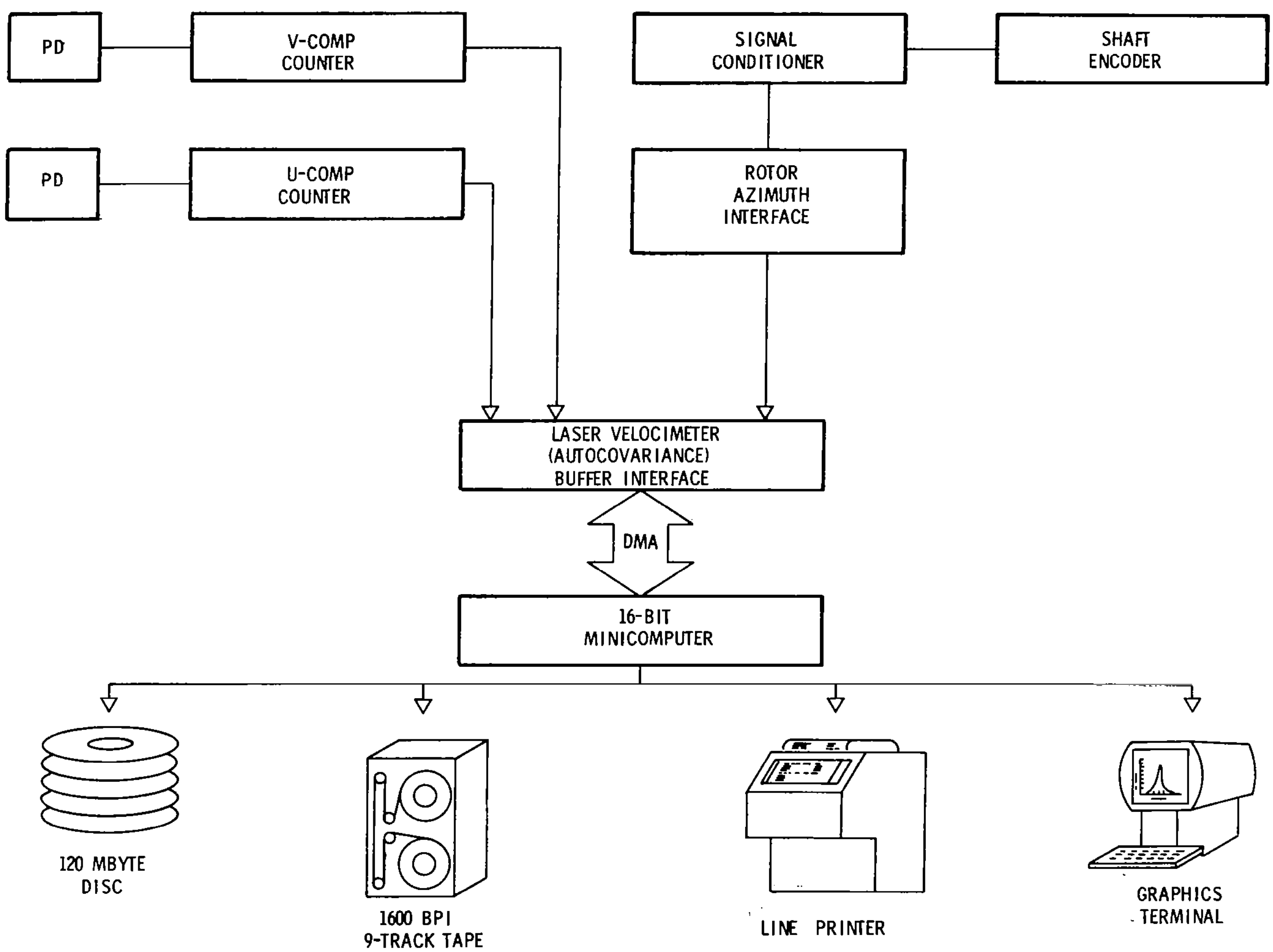

Figure 3

LV TRAVERSING SYSTEM

The LV has its own dedicated, computer controlled traversing system. The majority of the traversing which takes place during an LV test is accomplished with the x-y traversing rig shown in figure 4(a). The optical pan and tilt capability is used to make minor adjustments in sample volume position to provide optical access to critical areas. The unit was designed to provide approximately 7-ft (2.134-m) vertical and ± 3-ft (0.914-m)horizontal traversing capability of the entire optics package. A unique suspension and control system enables the optics package to be placed, with 0.020-in. (0.051-cm) accuracy, anywhere in the traverse range. The traverse system can be operated either manually or under computer control with a traversing speed of 10 in/min (0.254 m/min). The optics package, shown in the close-up photograph (fig. 4(b)), is mounted under a horizontal platform that moves vertically inside the exterior framework. The entire traverse system is mounted on wheels and can be rolled into various positions along the test section. The unit is 11 ft (3.35 m) high, 16 ft (4.88 m) long, 8.5 ft (2.59 m) wide, and weighs 6000 lb (2721.6 kg).

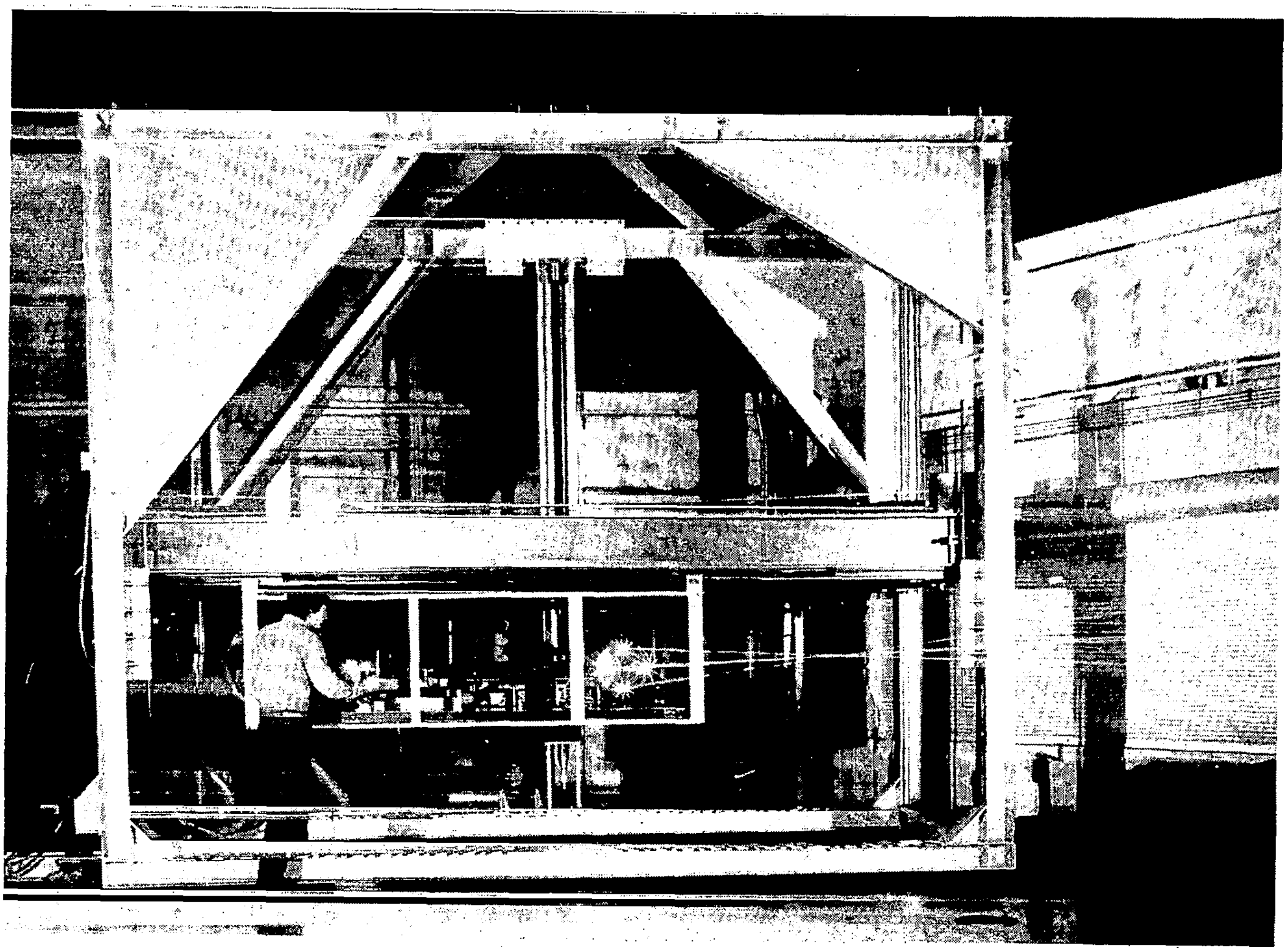

Figure 4(a)

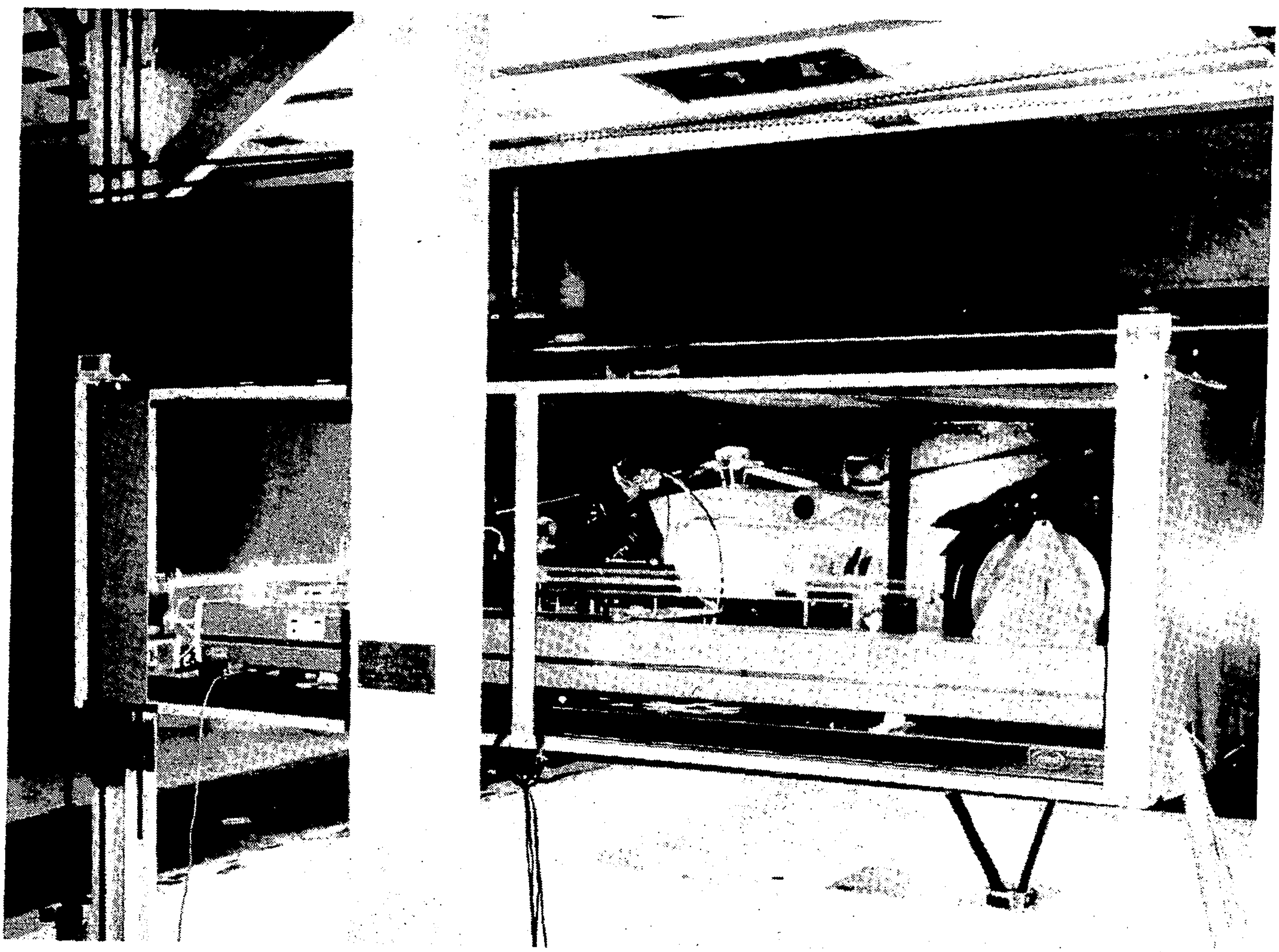

Figure 4(b)

PARTICLE GENERATING SYSTEM

The particle generator currently in use at the facility is a kerosene smoke generator. Liquid kerosene, under pressure from a nitrogen tank, is forced through a wand where it is heated, vaporized, and expelled through a nozzle that was sized to maximize the number of 2 -µm particles in the smoke. Positioning of the smoke wand in the settling chamber is accomplished by manually pulling the smoke wand up and down on cables using pulleys mounted on the floor and ceiling of the settling chamber. Particle generation and the placement of the particles in the flow is the most time consuming problem hampering the efficient operation of the laser velocimeter in the 4- by 7-Meter Tunnel.

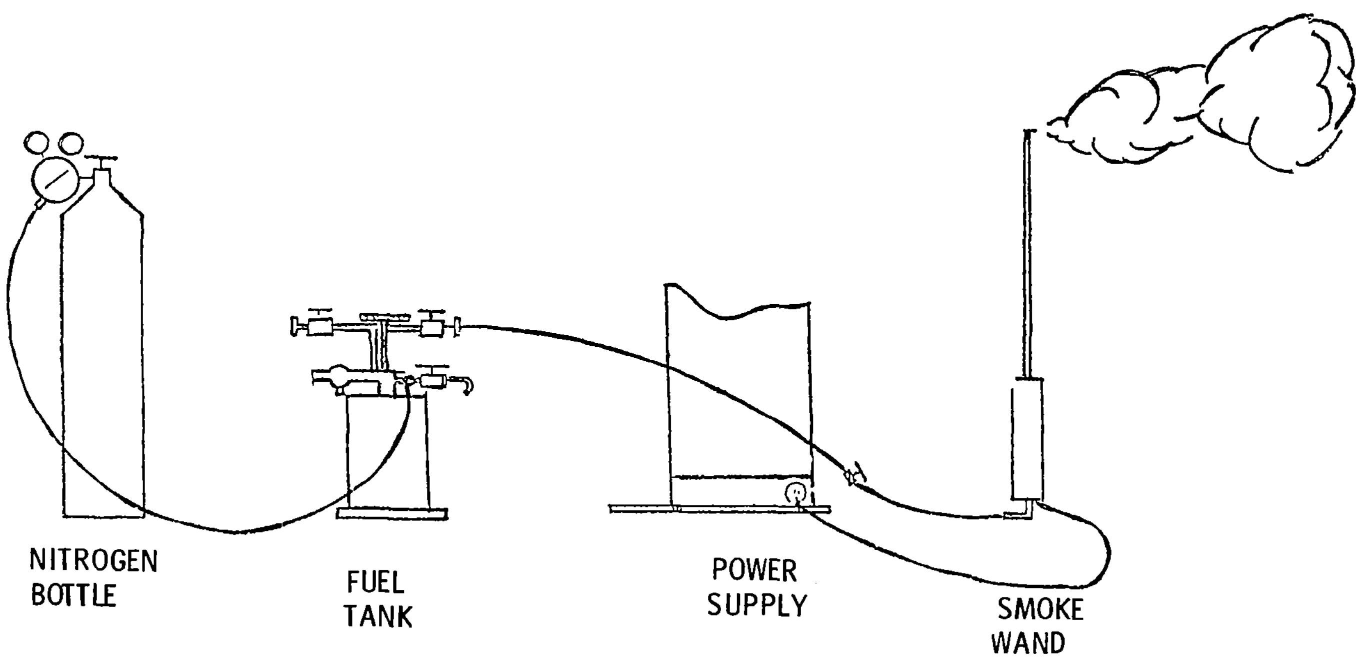

Figure 5

LV APPLICATIONS - NEAR-FIELD WAKE DETAILS

The small sample volume associated with the LV gives the aerodynamicist the capability to probe flow fields in great detail. Of particular interest is the near-field wake generated by lifting surfaces. A very small wake is generated, at low angles of attack, behind the 12-in. (30.48-cm) chord NACA 0012 wing shown in the upper left of figure 6. An example of the wake defect measured by a LV is shown in the graph in the lower left of the figure. A standard 1/4-in. (0.638-cm) pitot-static probe is also shown for a size comparison. The pitot-static probe is too large to measure the steep gradients and would, therefore, provide uncertainty in drag computations based on the wake defect.

The measurement of the flow field around a wing is another application for which the LV is ideally suited. An example of the complex flow field measured around the same NACA 0012 wing, at $\alpha = 19.4^{\circ}$, is shown in the upper right of the figure. The laser velocimeter was able to measure, in great detail, the broad shear layer dividing the free-stream and the separated flow regions, as well as the reverse flow in the separated region. An enlargement of the trailing edge area of the wing is shown in the lower right of the figure and demonstrates that the LV was able to provide great detail in regions of severe velocity gradients. The above data were obtained from an earlier proof-of-concept LV system as reported by Hoad, Meyers, Young, and Hepner (refs. 1 to 3). The earlier LV system did not have the positional accuracy of the present system; therefore, we expect to be able to provide even more detail in the future.

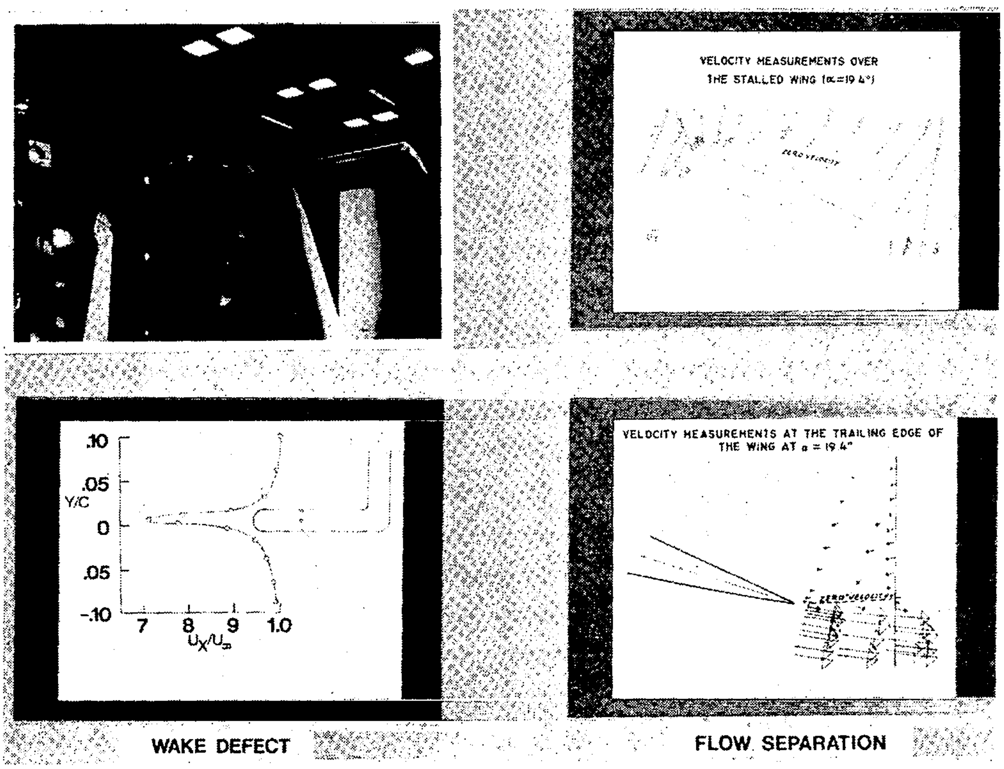

Figure 6

LV APPLICATIONS - ROTOR WAKE SURVEYS

The nonintrusive character of the LV makes the measurement of complex flow fields possible in places where conventional measurement techniques are not practical. An example of this capability and of the type of data obtained with the LV are shown in figure 7.

A test was conducted in the Langley 4- by 7-Meter Tunnel to measure the flow field in several longitudinal planes ahead of the vertical fin of a helicopter. The model used in the test was a 1/4-scale UH-60 helicopter as shown in the upper left of the figure. A sketch of the measurement grid is shown in the upper right of the figure to show the relative position of the helicopter blades, body, and fin to the region where measurements were taken. Data were obtained on the model centerplane and 6 and 12 in. off the centerplane, with the tunnel operating at a free-stream velocity of 41.19 m/sec (80 knots).

The centerplane data were taken in two configurations. In the first configuration, the blades were rotating at 1200 rpm with an advance ratio of 0.219. In the second configuration, the blades were off and a scaled rotor hub was rotating at 600 rpm. The data taken off the centerplane were obtained with the rotating hub only. Typical data obtained during the test included flow-field velocity vectors and probability histograms of the u and v components of velocity. The histograms are plotted on-line using a graphics terminal to enable the operator to assess data quality and assist in setting thresholds in the high-speed burst counters.

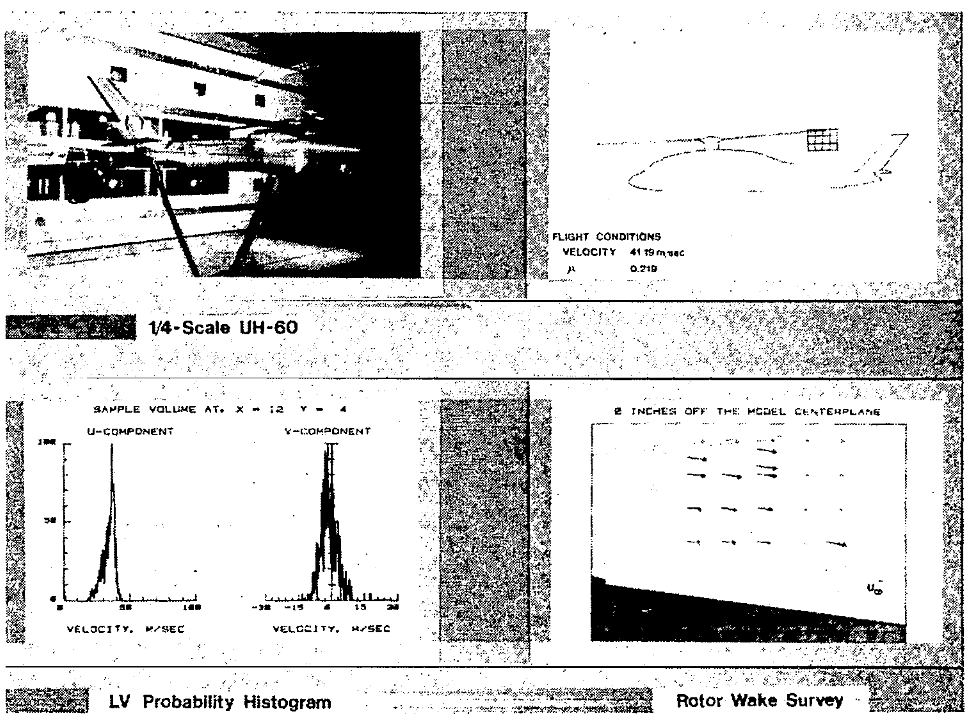

Figure 7

Figure 8 shows a comparison between the flow field measured at the model centerplane with the blades on and off. The dashed arrows represent the velocity vectors measured with the blades off, and the solid arrows represent the velocity vectors obtained with the blades on. The sizes of the diamond and square symbols represent the turbulence intensity. The squares represent the blades on data, and the diamonds represent blades-off data. Reference symbols and vectors are included at the lower left to illustrate a free-stream velocity of 41.19 m/sec and 25 percent turbulence intensity.

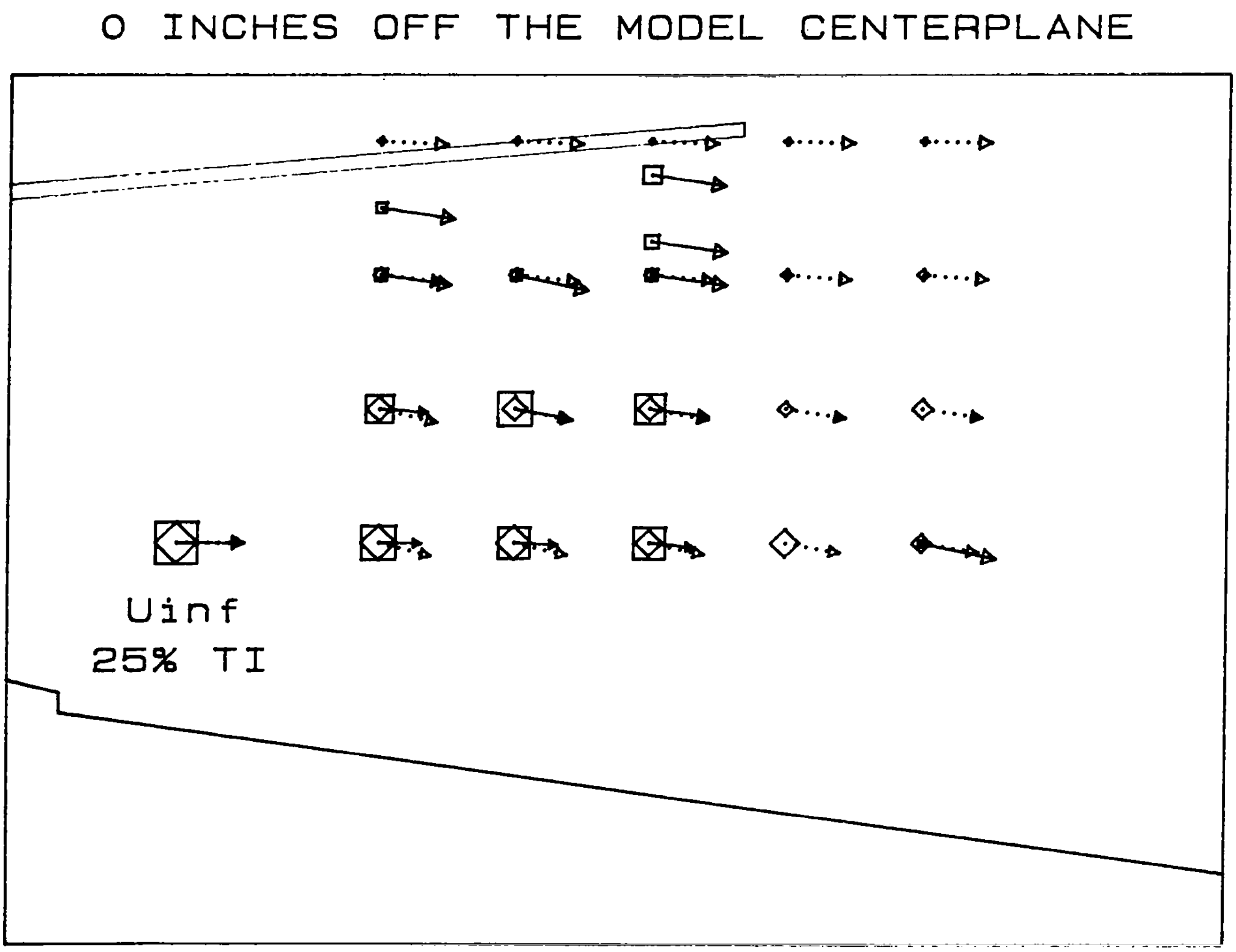

Figure 8

CONCLUSIONS

A dedicated LV system is operational at the Langley 4- by 7-Meter Tunnel facility. Improvements are needed to further enhance the operation, however. These include improved particle generation and enhancements to the LVABI.

The goal is to provide the facility with a nonintrusive velocity measurement capability around arbitrary shapes.

REFERENCES

1. Hoad, Danny R.; Meyers, James F.; Young, Warren M., Jr.; and Hepner, Timothy E.: Correlation of Laser Velocimeter Measurements With Results of Two Prediction Techniques. NASA TP-1168, 1978.

2. Young, Warren H., Jr.; Meyers, James F.; and Hoad, Danny R.: A Laser Velocimeter Flow Survey Above a Stalled Wing. NASA TP-1266, 1978.

3. Meyers, James F.; and Hoad, Danny R.: Turbulent Wake Measurements With Laser Velocimeter. AIAA Paper 79-1087, June 1979.