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APPLICATION OF DATA TO PILOTED SIMULATORS

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INTRODUCTION

In this paper, I will address the application of a further-developed analytical model and JAWS data to a piloted simulator. What I have to say comes from the viewpoint of a user of wind shear data. I became involved with wind shear models back in the late 1970's in the course of several accident investigation simulations, and in participation with the FAA wind shear programs at NASA Ames. Later, I used wind shear models in the course of evaluating cockpit displays. At one point, shortly before the JAWS Project, I was using a simple three-dimensional outflow model. I am sure there are others trying the same approach in piloted simulation.

Our objectives at Ames arose as a target of opportunity. We now have a new facility established by our Human Factors Group. It includes a new 727 simulator--Singer-Link advanced technology system--and is a duplicate of a recent acquisition by Delta Airlines, with Phase-2 specifications. It was an attractive opportunity to provide a facility for the development of piloting procedures, and for the selection of training scenarios, as well as for any objectives that might result from a workshop such as this. Currently the system is operational with the new shear models and comprehensive data output. It has been demonstrated to a group from United Airlines, many of whom are participating in this workshop; and in early May, it was reviewed by the Ad Hoc Committee. As we have not conducted any studies with the system to date, this is basically a progress report.

In this simulator, we have wind shear models from three sources. With the simulator, of course, came FAA wind shears. In our particular mechanization, we are using four of the six available. We have three JAWS corridor sets from the August 5 data, i.e., AB, IJ, and KL. We have five computed wind fields which are derivations of the simple outflow model that I was using in the R&D simulation. These various models are presented in the context of 34 test scenarios. We have both light- and heavy-weight takeoff and landing configurations which can be flown in a number of wind fields defined by the three types of models. Each of the wind fields within the scenario can be gained up or down in amplitude; i.e., all the wind variations are gained up or down simultaneously. A turbulence model is added, and its output can also be gained up or down. In the simulator, it is just a matter of calling up with the keyboard the desired scenario, adjusting the variables if we wish to change them from the nominal, and flying the takeoff and/or approach. The system will usually give us hard copy data within a short period of time.

This is a training simulator; we were dealing with facility and support personnel unaccustomed to the constant software changes seen in the R&D simulators, so we wanted to keep additions as simple as possible. That is why we used a two-plane corridor model from the JAWS August 5 data base. A turbulence model adds three components of turbulence. We are not equipped with the fourth component of turbulence which is often added into simulation, i.e., the spanwise gust variation which gives a discrete rolling input. Neither have we introduced gradients into the pitch and yaw rate damping terms, which are also usually in our research simulators. We use

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the basic Dryden turbulence model filters that accompany FAA wind shear models. Turbulence intensity and turbulence scale length are defined as functions of wind velocities and attitude similar to MIL SPEC 8785C (reference 1).

I am not concerned about the consequences of not adding the gradients to the system. This position is based on what we have seen in our research simulators as we operated with and without them. Yes, they do have a measurable effect; but in terms of the piloted simulation (the pilot's ability to deal with the shear and turbulence), I am not convinced that they are of major significance. We will be very interested in all the other experience that is assembled at this workshop on that matter. If and when we find that these gradients are essential to the objectives of our simulations, we will find some way of adding them.

The JAWS model has been described in some detail at this workshop. I will just reiterate that I used a two-plane model: 250 feet on either side of the nominal approach path is a defined plane, and we interpolate between them. As long as the pilot is not more than 250 feet on either side of the centerline, he is seeing as much as he would in the full data set.

Figure 1 describes the computed downburst model. We assume an axially symmetric downdraft column with a vertical velocity variation with respect to the axis that varies in the manner indicated in Figure 2. Below a defined height, vertical velocity varies with attitude as an exponential function, and the principle of continuity is used to define a horizontal dispersion of the flow. It's fairly simple; we define the radius, the altitude at which the dispersion starts, and the vertical velocity above that altitude. These values define the individual downburst field. I want to say that this model has no connection with the real world, except that it follows the laws of continuity. It is strictly a mechanism with which to create a wind profile in simulation of observed phenomena, i.e., a particular piece of JAWS data, or a particular profile recorded in an accident. It is not atmospheric science.

In Figure 3, the outflow starts at 1,600 feet; above that altitude, the downdraft is 20 kts. The radius of 2,000 feet defines the extent of the shear. The wind velocity profile near the ground is shown with respect to the axis at 6,000 feet. A total shear of 46 kts is shown. If I want to model something more elaborate I can, in our particular simulation, model up to five of these downbursts and add their effects to produce a particular sequence of along-path winds. Figure 4 is an attempt to simulate the August 5 AB corridor. We can come fairly close, but we get some downdrafts that are somewhat stronger than were shown in the August 5 data.

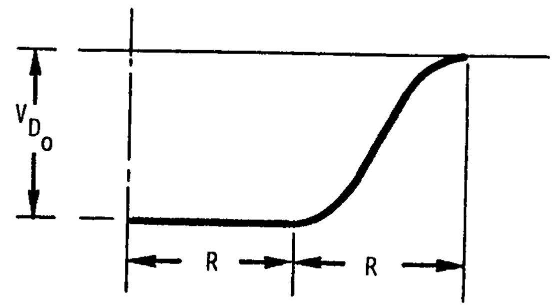
In Figure 5, the circles represent the four downbursts constituting the computed version of the JAWS shear. This construction is done empirically until the gradient being sought is achieved. The flow model on the right is actually an updraft, a change of sign on the vertical wind to produce a flow convergence.

Our model shown in Figures 6 and 7 attempts to match data on the New York/ Kennedy shear recorded prior to the accident of 1975. In this case, the downdraft actually appeared before the shear and was fairly abrupt. The computed values shown don't include turbulence. The flight-recorded data did not refer to the accident airplane; it was from data gathered by an L-1011 a few minutes before the accident.

- Distance from downburst center, $r = (X^2 + Y^2)^{1/2}$
- Downdraft velocity:

  If $R < r < 2R$:

  $V_{D_r} = V_{D_o} \left(1 - \cos \frac{r}{R} \pi\right)/2$



- Variation with altitude, H, below H_T:

  $$V_D = V_{D_r} \left[1 - \left(\frac{H_T - H}{H_T}\right)^2\right]$$

- Reference radial velocity at $r = R$: $V_{R_o} = \frac{R \times V_{D_o}}{H_T} \left(\frac{H_T - H}{H_T}\right)$

- Local radial velocity: If $r < R$: $V_R = \frac{r}{R} \cdot V_{R_o}$

  If $R < r < 2R$: $V_R = V_{R_o} \left[\frac{r}{R} - 1.3 \left(\frac{r}{R} - 1\right)^3 + .45 \left(\frac{r}{R} - 1\right)^6\right]$

  If $r > 2R$: $V_R = 2.3 \frac{R}{r} \cdot V_{R_o}$

- $V_x = \frac{x}{r} \cdot V_R, \quad V_y = \frac{y}{r} \cdot V_R$

Figure 1. A simple downburst model.

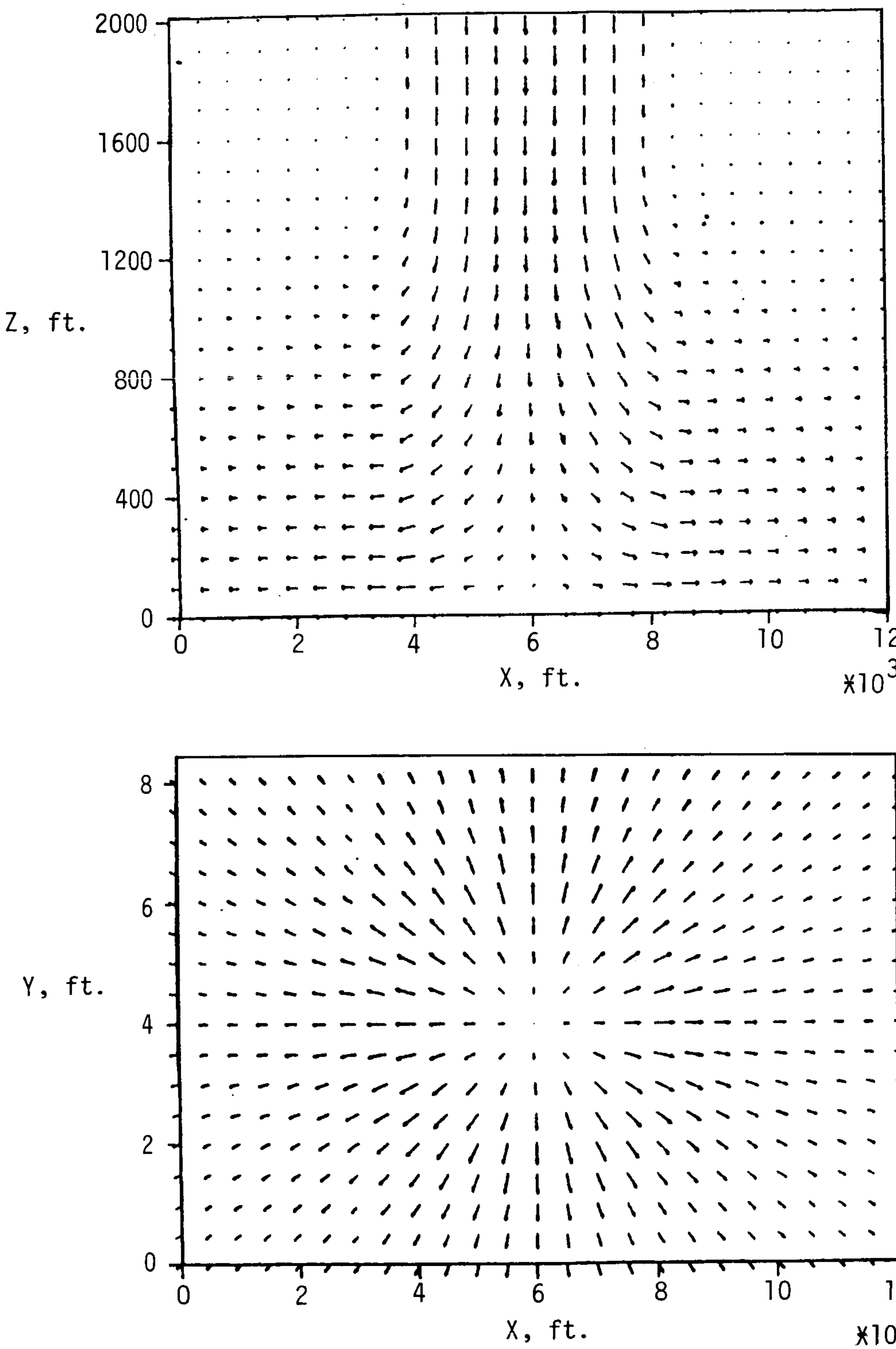


Figure 2. Elements of a Downburst.

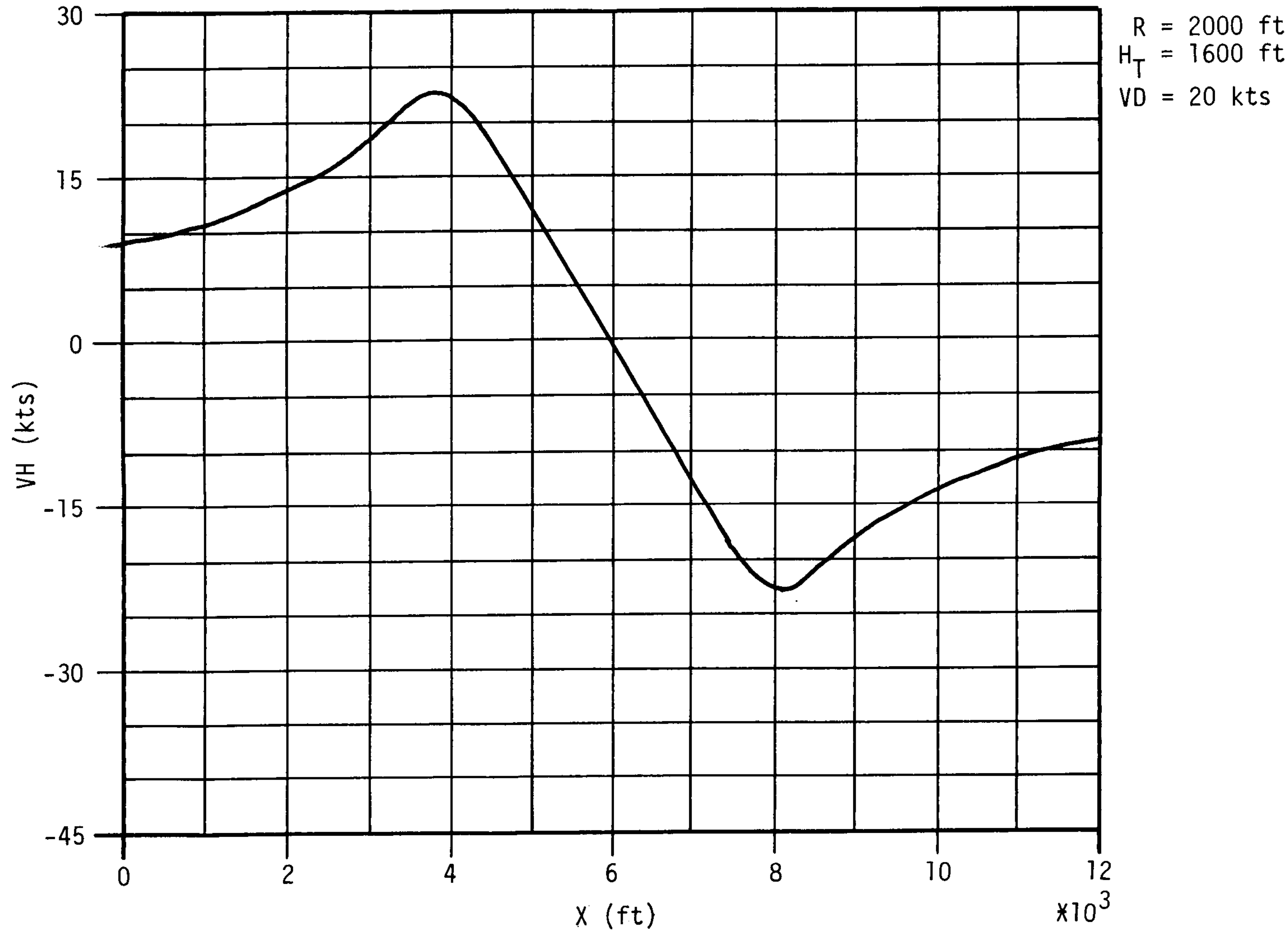


Figure 3. Wind Velocity.

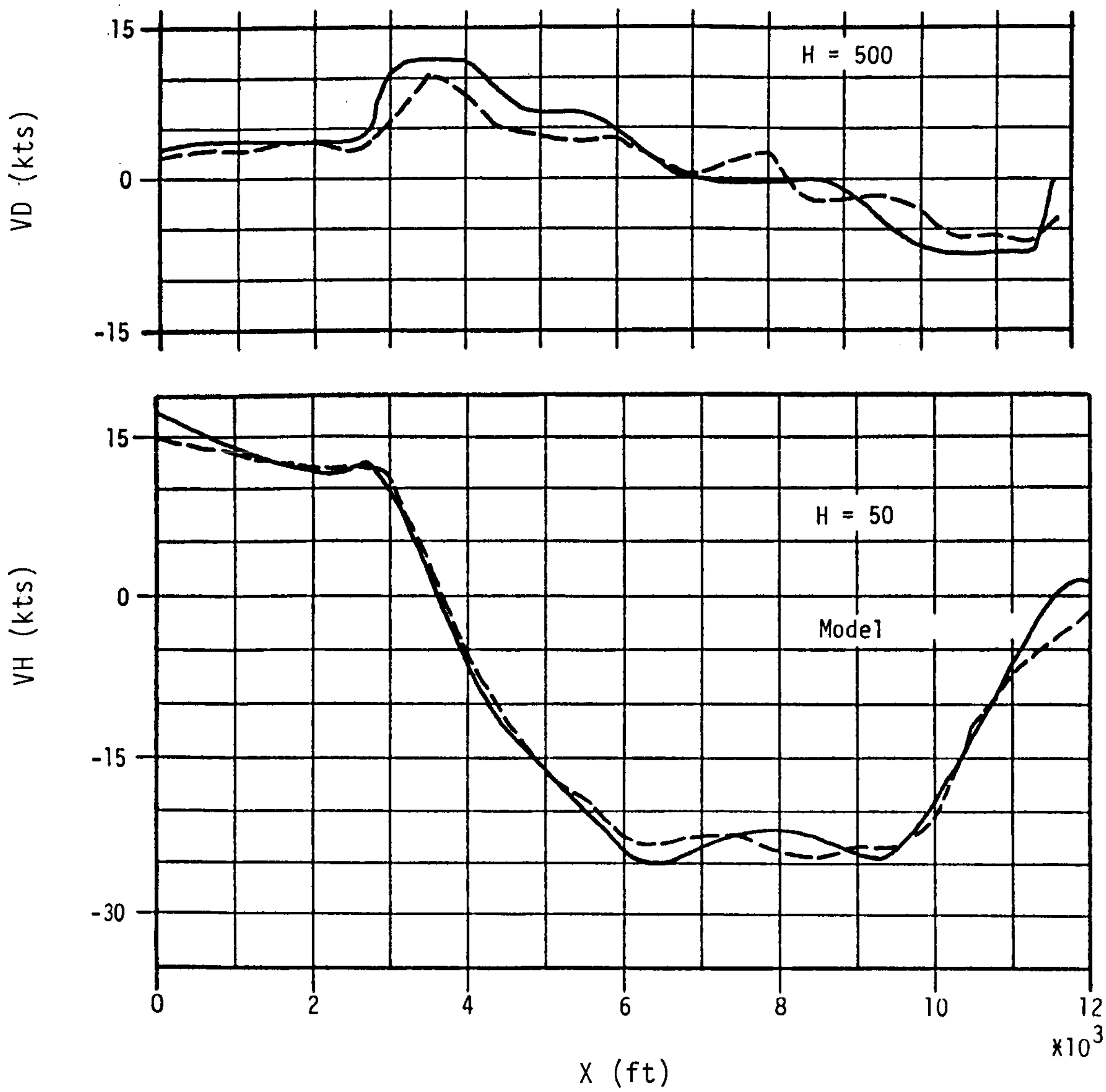


Figure 4. JAWS August 5 AB Modeled.

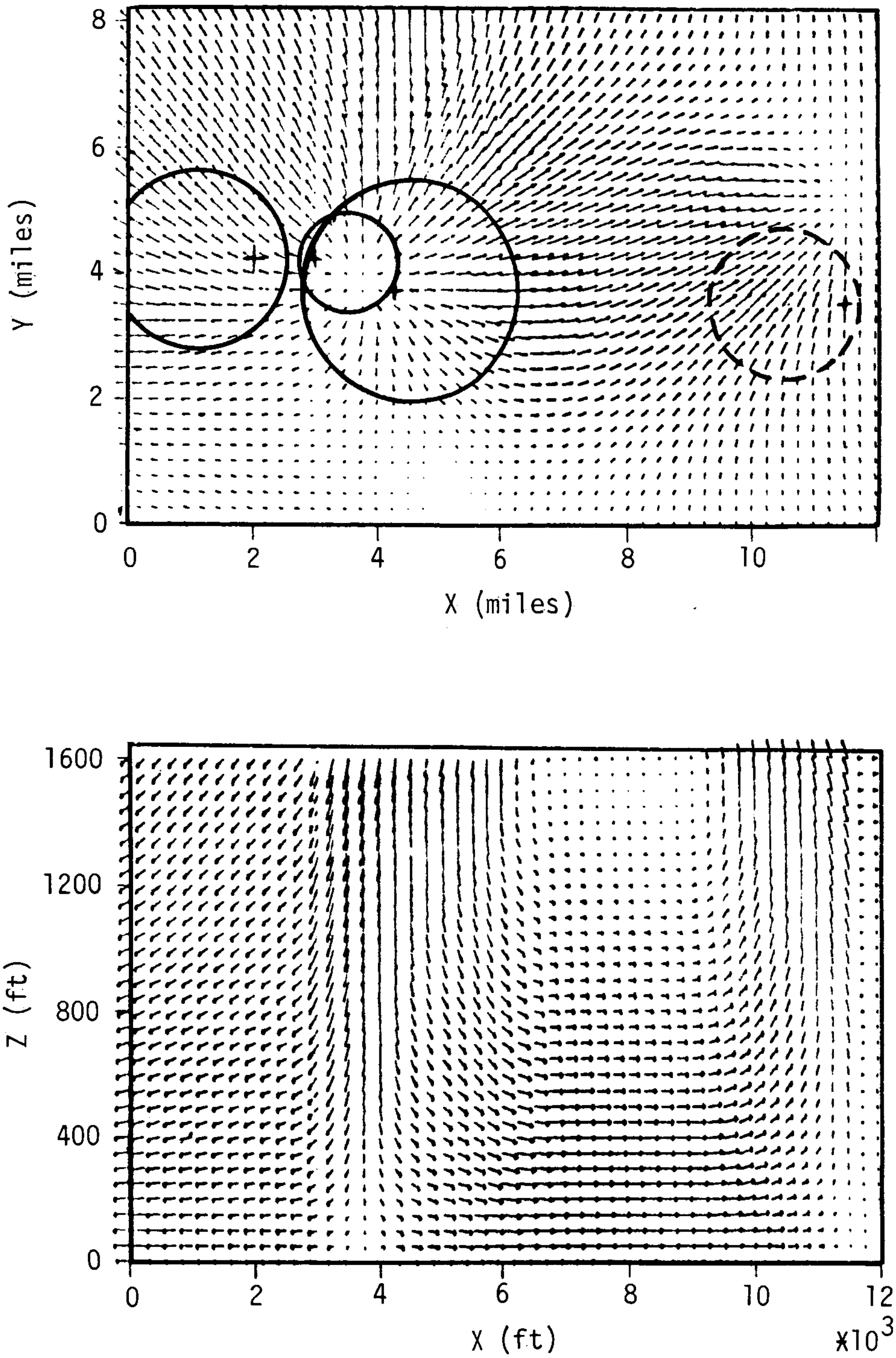


Figure 5. Modeling JAWS August 5 AB.

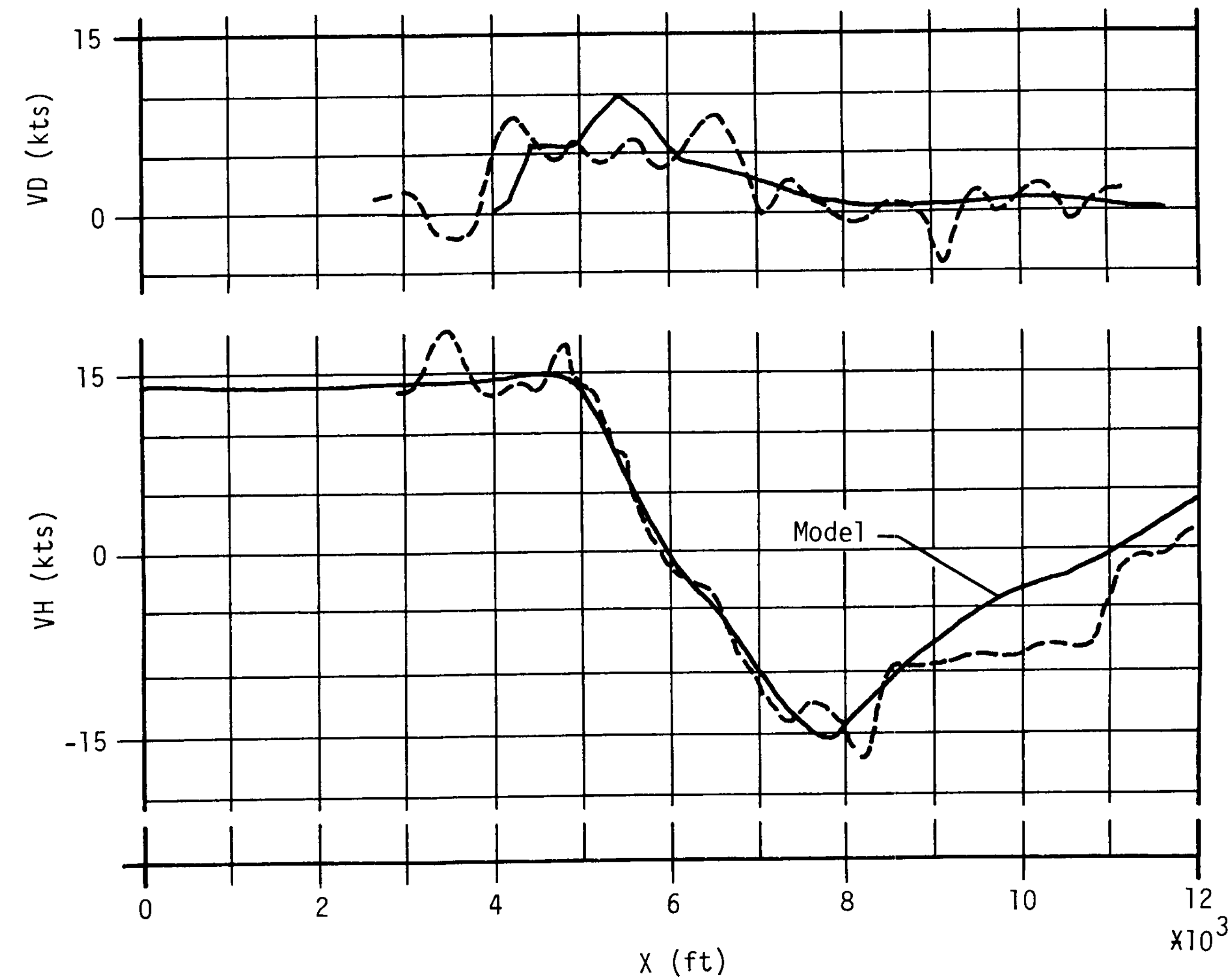


Figure 6. New York Shear Modeled.

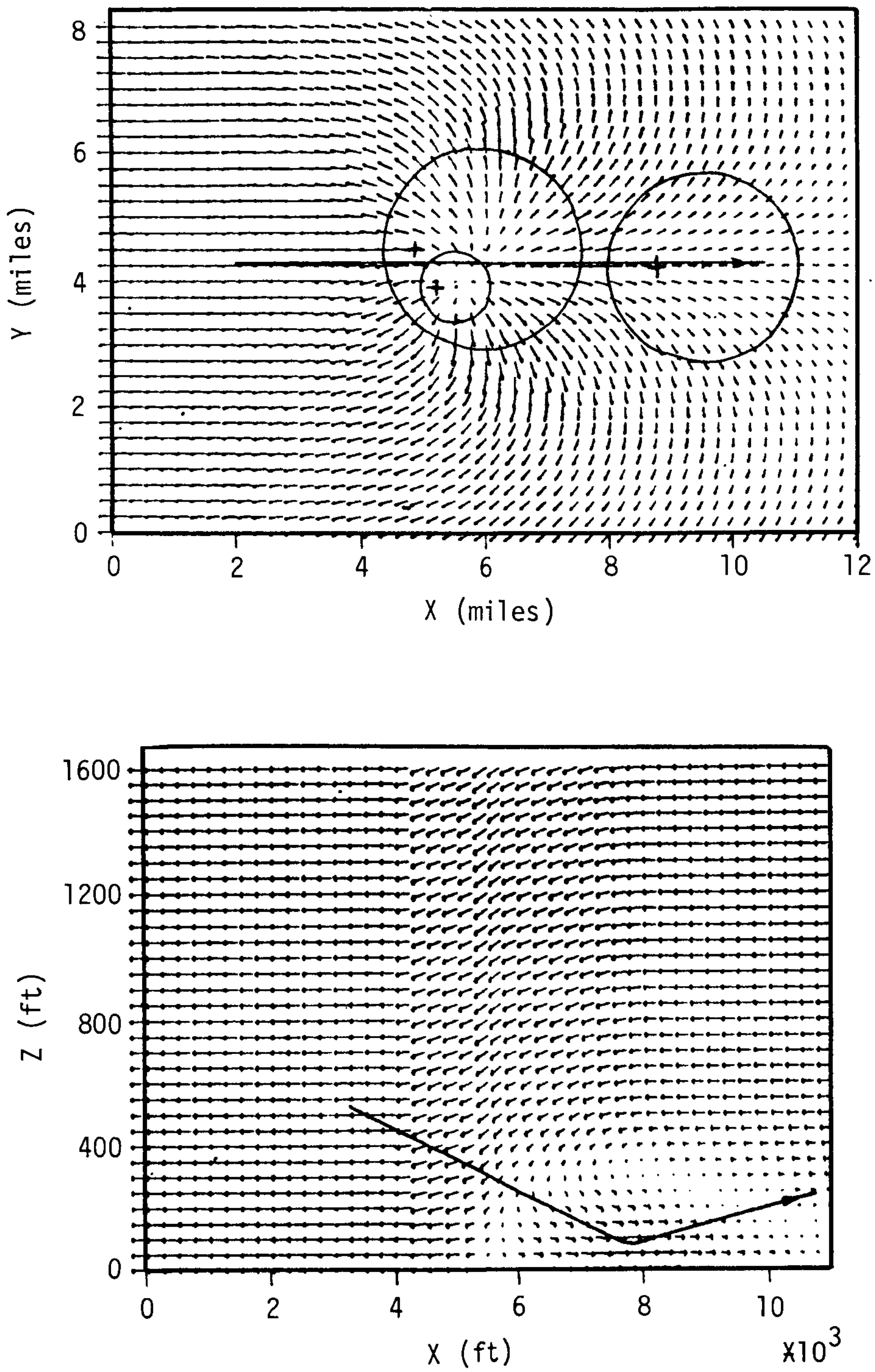


Figure 7. New York Shear Model.

An incident occurred in Tucson in 1977 where the pilot encountered a shear before he could achieve rotation speed, which was about 128 kts. The recorder data indicated he ran down the runway for a good 10 seconds with no increase in speed. He finally got an increase in speed, rotated, lifted off, then proceeded to lose speed with no climb, and flew through high-tension wires. He should not have survived, but he did. This is just an example of the variety which is out there. From that event, a wind model or profile can be deduced showing an interruption in the shear gradient, as represented by the dashed line in Figures 8 and 9. We model this particular profile with one large outflow model and a small upflow model in the middle of it to cancel the gradient.

We have not done a lot of systematic work with these models in the 727 simulator, but Figures 10 through 15 depict data from some approaches and takeoffs, with time in seconds shown along the bottom. The lowest of the plots shows the three components of wind. We have described the first case, Figure 10, as scenario 14. It is a heavy takeoff--a 727 at 175,000 lbs--flying through JAWS I (which is AB in this case) and moving 5,000 feet down past the glidepath intercept point on the runway, or actually 6,000 feet from threshold. In this case, we have applied a gain factor of 1.3 to the winds. The winds shown come out of the JAWS data with the addition of some turbulence. We have a head wind of about 30 fps reducing to 25 fps; then there is a very rapid shear to a 50 fps tail wind. In this case, we are getting a total of about 52 or 53 kts of shear, and there is, of course, some vertical and lateral wind. The airplane was accelerated to 139 kts rotation speed, smoothly rotated to about 14°, then encountered the shear. We see about 30 lbs of stick force during that rotation, with the release of stick force as the takeoff attitude is attained. The speed attained is V-2 plus 10. The airplane is climbing nicely; but then off comes the airspeed as the shear is encountered, the nose drops from about 13° to about 7° attitude. The pilot is starting to sense that the aircraft is dropping and is adding back pressure; but the nose drops and the descent rate continues. The shear ends, speed increases, and flight path is recovered but not before the aircraft is back down to 50 feet. This is reasonable reproduction of what happened in New Orleans. Figure 11 is a repeat; the same profile. You will notice a few detail differences because the turbulence is going to make small high-frequency differences in the model. There isn't the release in the stick force, and, in fact, the nose isn't allowed to drop below about 11°. We see loss of airspeed by a few more knots which is not a great deal. In this case, emergency thrust was added at minimum airspeed, and there is a flyaway with essentially no altitude loss. These data comprise a demonstration of optimum versus non-optimum performance in the particular circumstance.

Figure 12 involves the same JAWS profile moved into a landing situation. In this case, it is not gained up, and there is no turbulence. The wind has very little high-frequency component. It was successfully flown through, but with the use of full takeoff thrust. It certainly would have been appropriate to go-around; the whole path was disturbed. In fact, I am not sure that a go-around didn't result from this; but, at least, the touchdown area of the runway was reached. In this case, without the amplification of the JAWS data, we are getting about 40-42 kts total shear. In Figure 13, we used the analytical model to produce a similar profile. Again, no turbulence was used. The shear is flown through with similar results. This airplane is running into the shear at about 250 feet altitude.

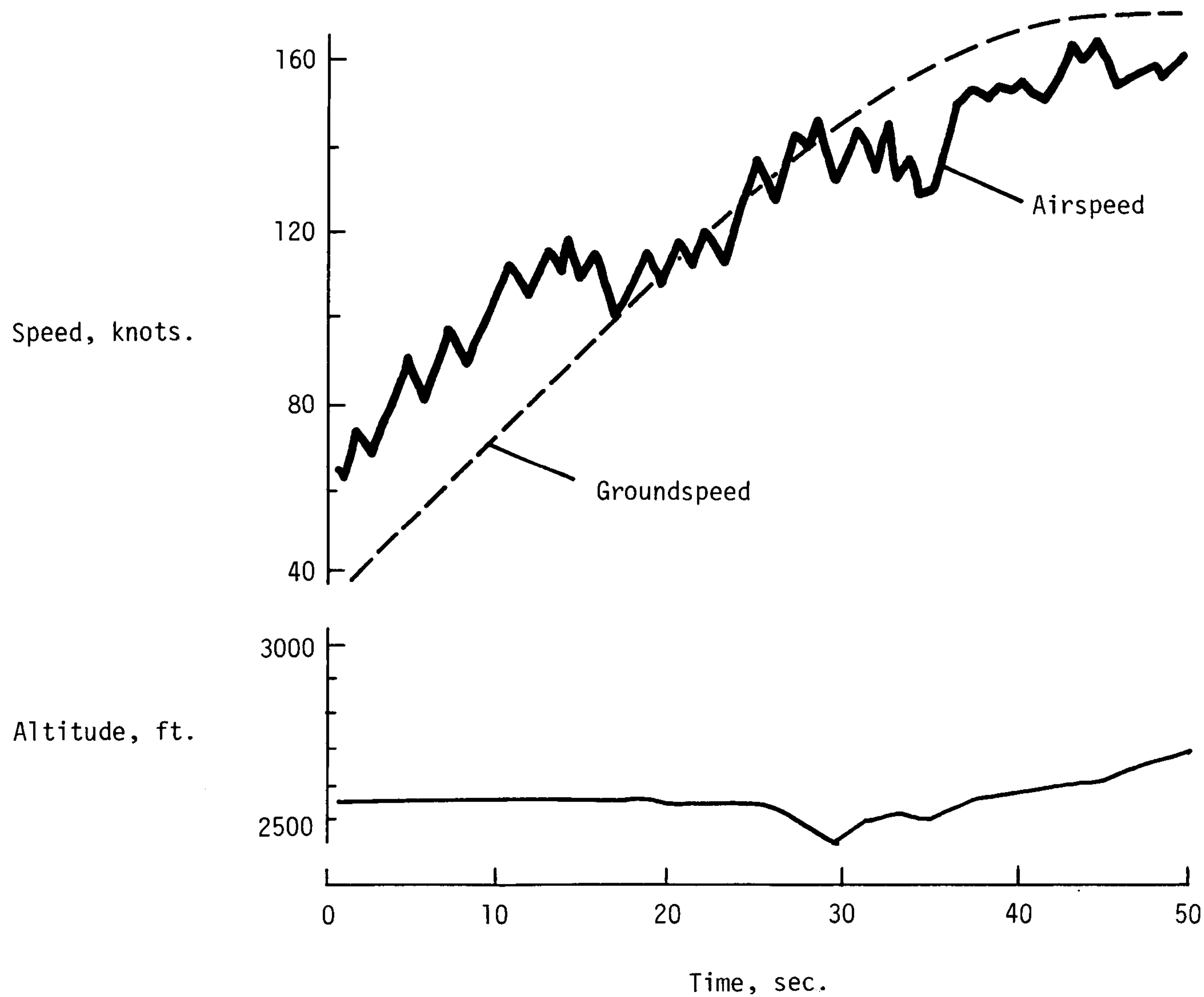


Figure 8. Takeoff Encounter, Tucson, 1977.

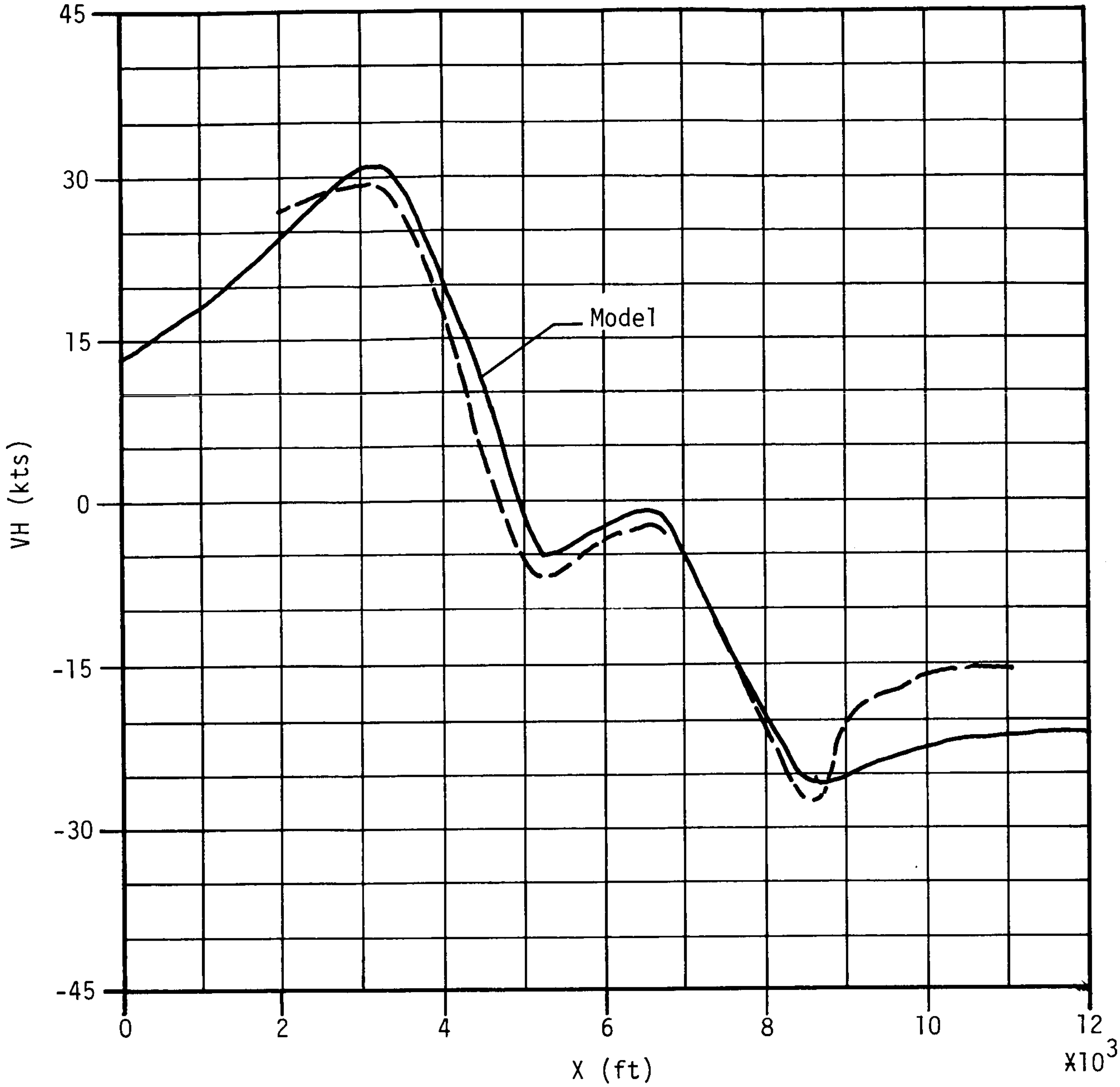


Figure 9. Tucson Shear Model.

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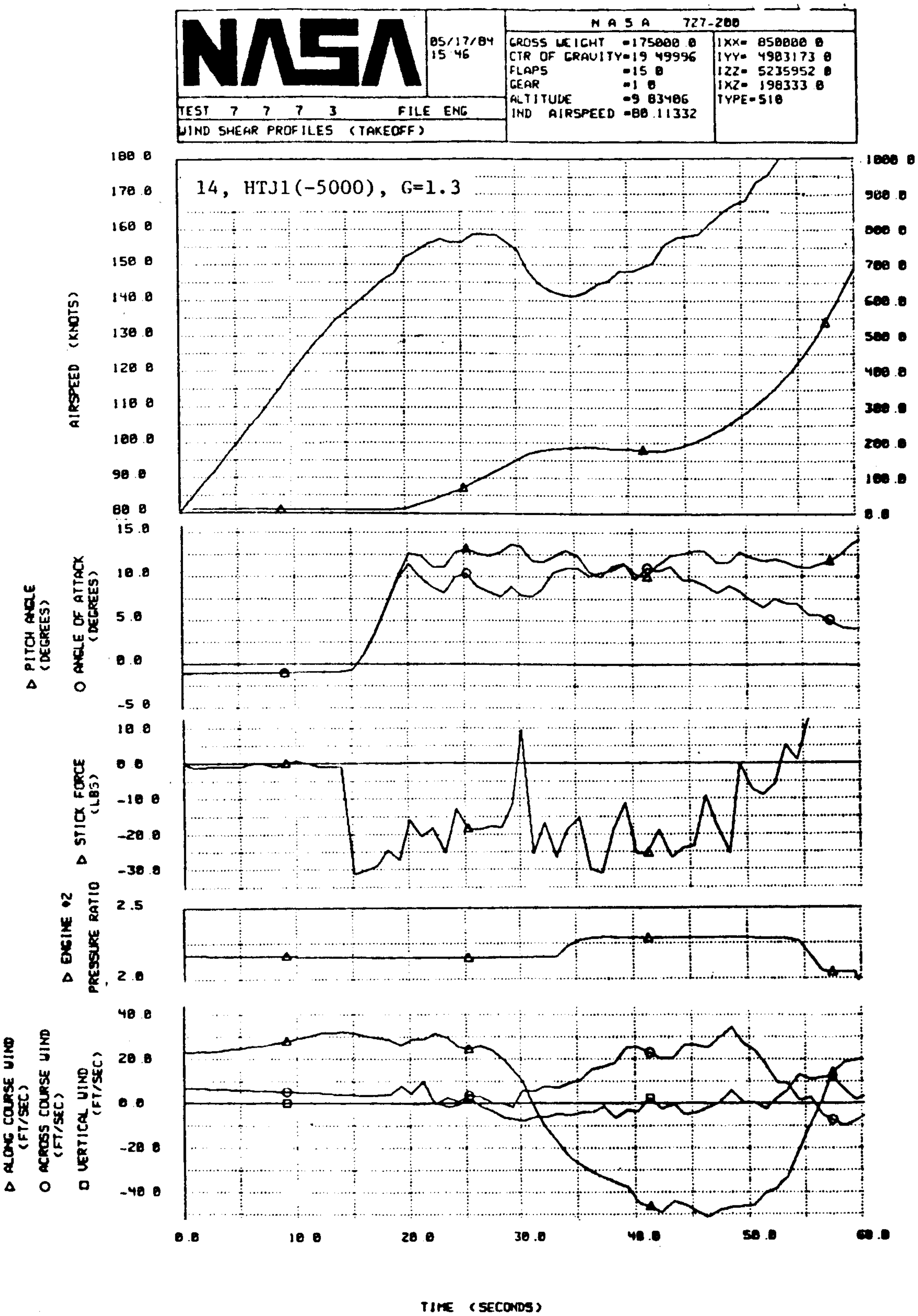

Figure 10. Simulated Takeoff in Wind Shear--5/17/84, 15:46.

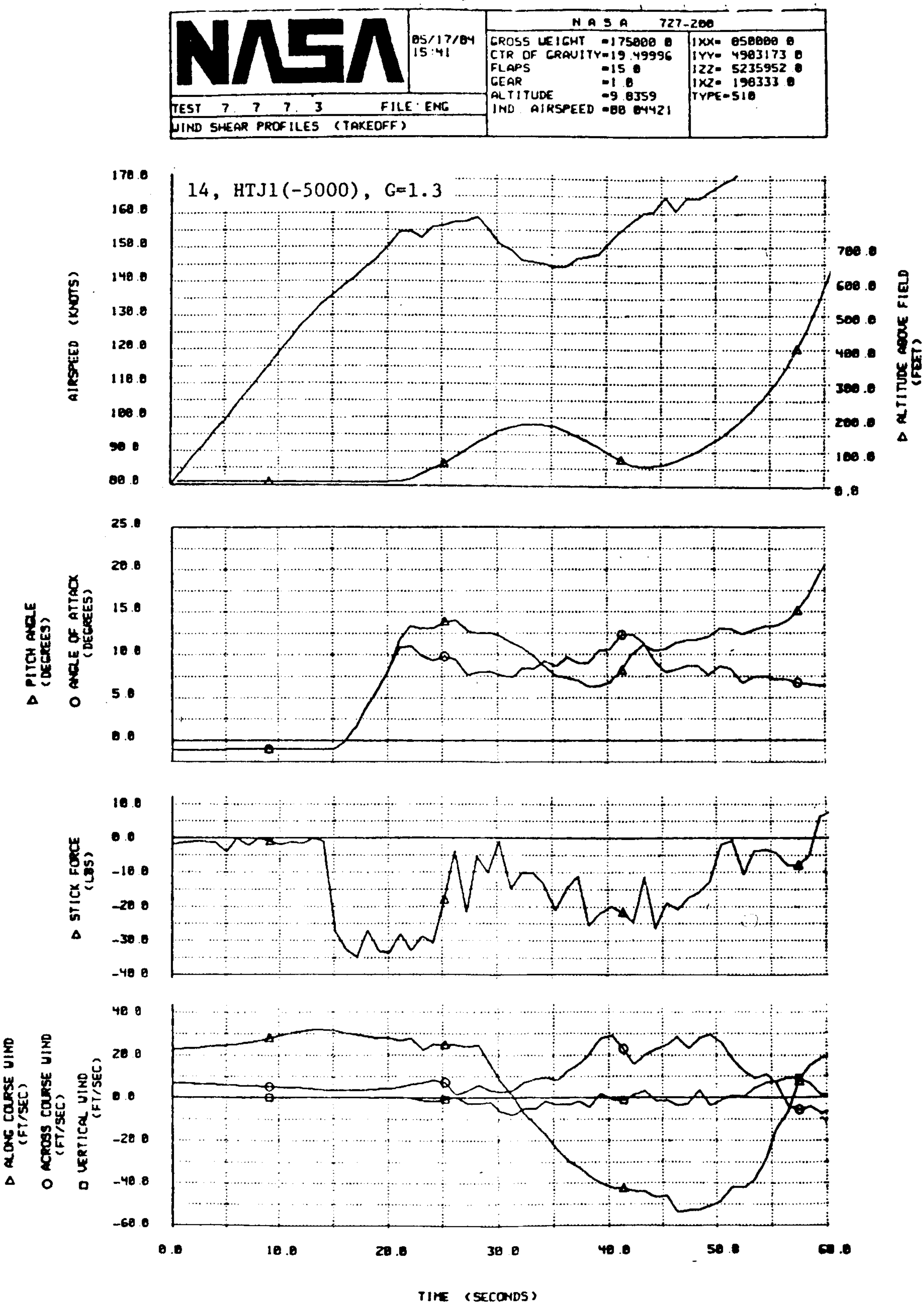

Figure 11. Simulated Takeoff in Wind Shear--5/17/84, 15:41.

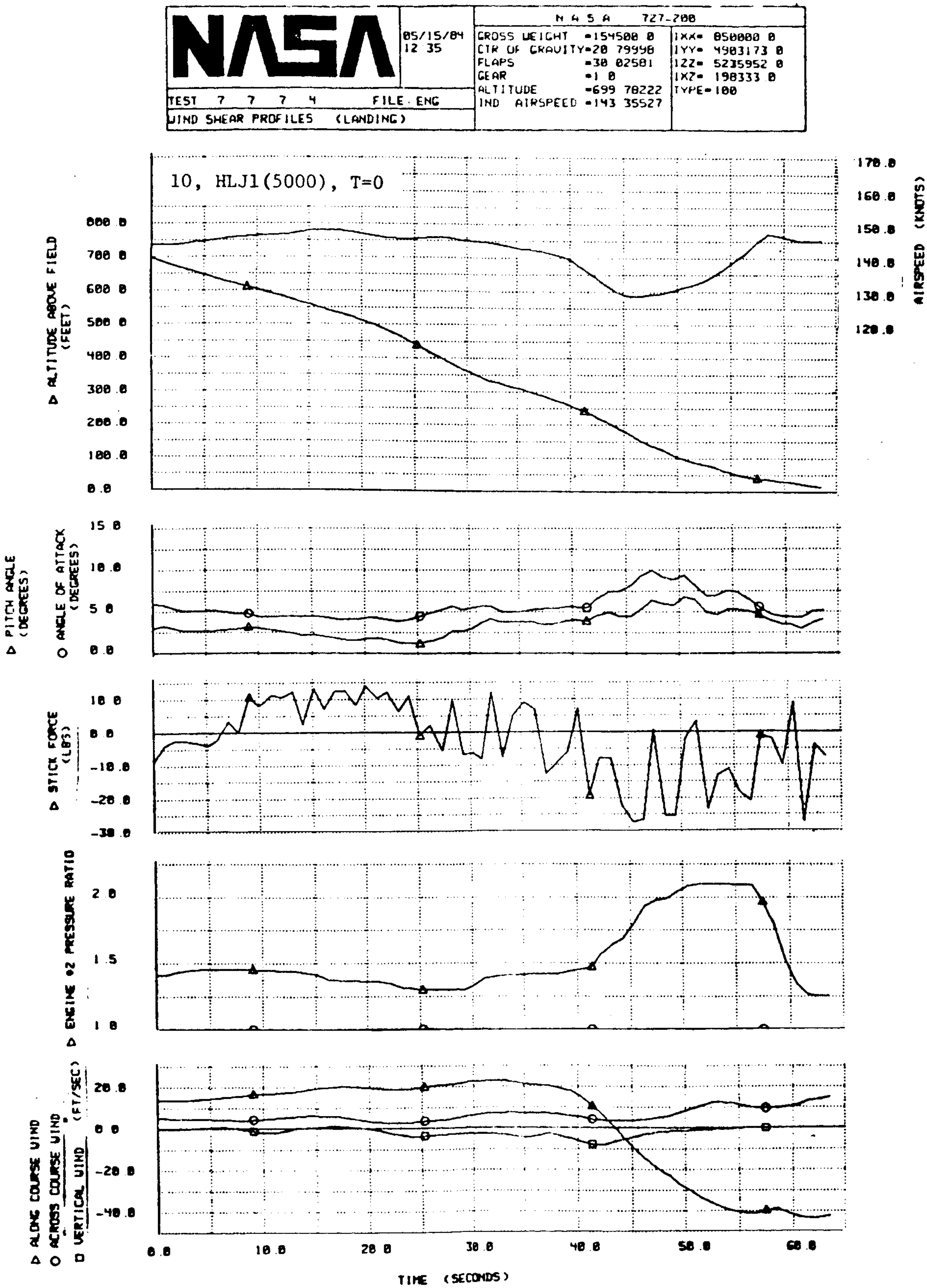

Figure 12. Simulated Landing in Wind Shear--5/15/84, 12:35.

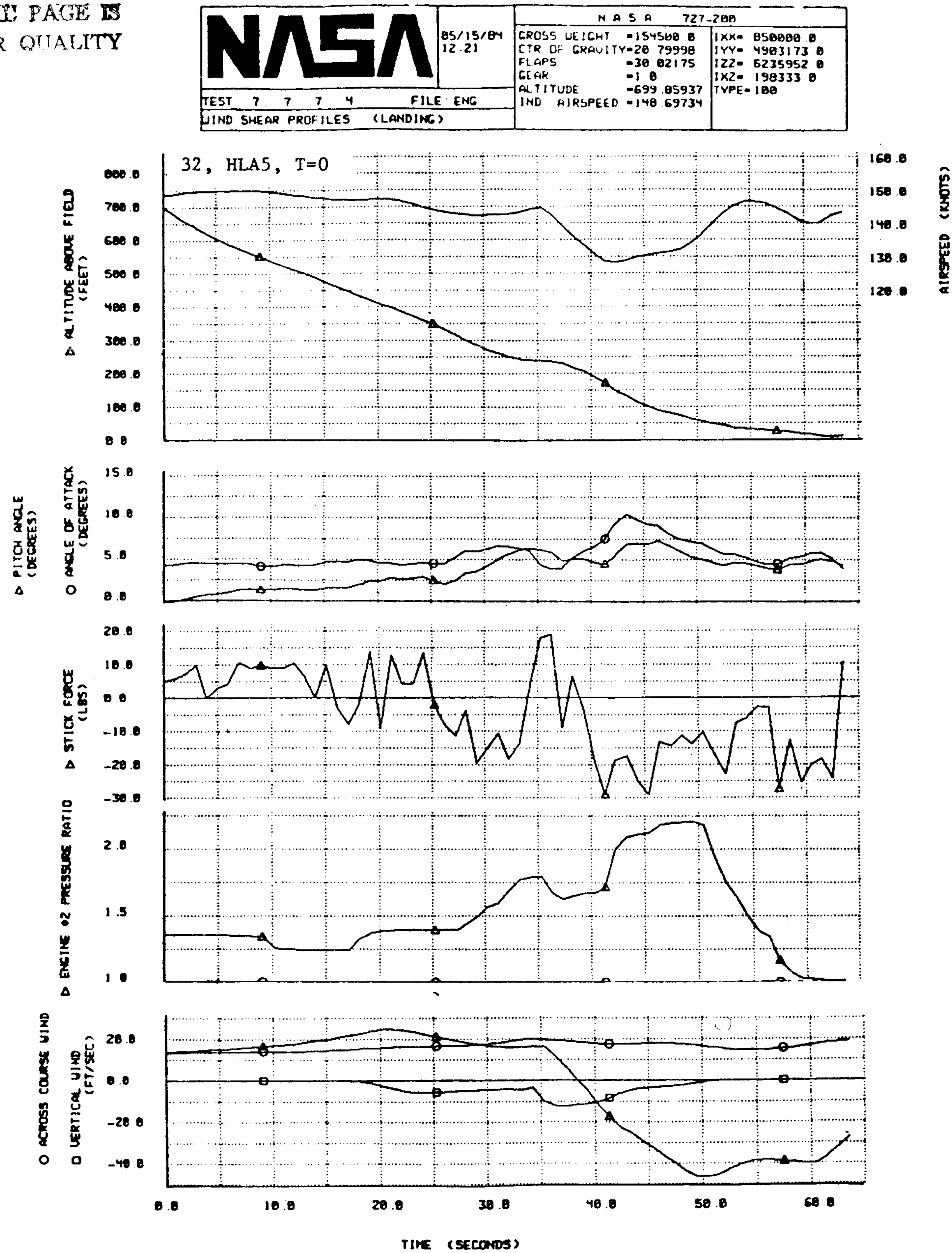

Figure 13. Simulated Landing in Wind Shear--5/15/84, 12:21.

Figure 14 shows the simplest possible model; a single downburst model with a distortion factor which makes the outflow move in one direction more than the other. We see a small increase in head wind, the gradient down to the peak tail wind component, and then the build-up on the other side. With the downdraft that goes along with the shear, we see the same piloting problems experienced in the previous takeoffs conducted with more complex models.

Figure 15 involves a Tucson-type of model where the airspeed has built up then has stopped increasing prior to rotation speed. The shear ends briefly, and the aircraft accelerates to rotation speed; the pilot rotates, encounters the other part of the shear, can't climb, and sits there flying just off the ground as the end of the runway approaches.

That is where we are right now. We are awaiting the results of this conference to tell us the best direction in which to go relative to the use of this particular capability. This is not the facility in which to conduct detailed research on the second-order effects of gradients. Training simulators do not have the desired software and data acquisition flexibility; but it does seem an obvious place to develop training scenarios and piloting techniques. We hope to find some good work for it.

QUESTION:

To what extent can your model be shifted with respect to the runway?

RESPONSE:

Just along the path. It can be shifted longitudinally along the approach or takeoff path.

REFERENCE

1. Military Specification--Flying Qualities of Piloted Airplanes. MIL-F-8785C, November 5, 1980.

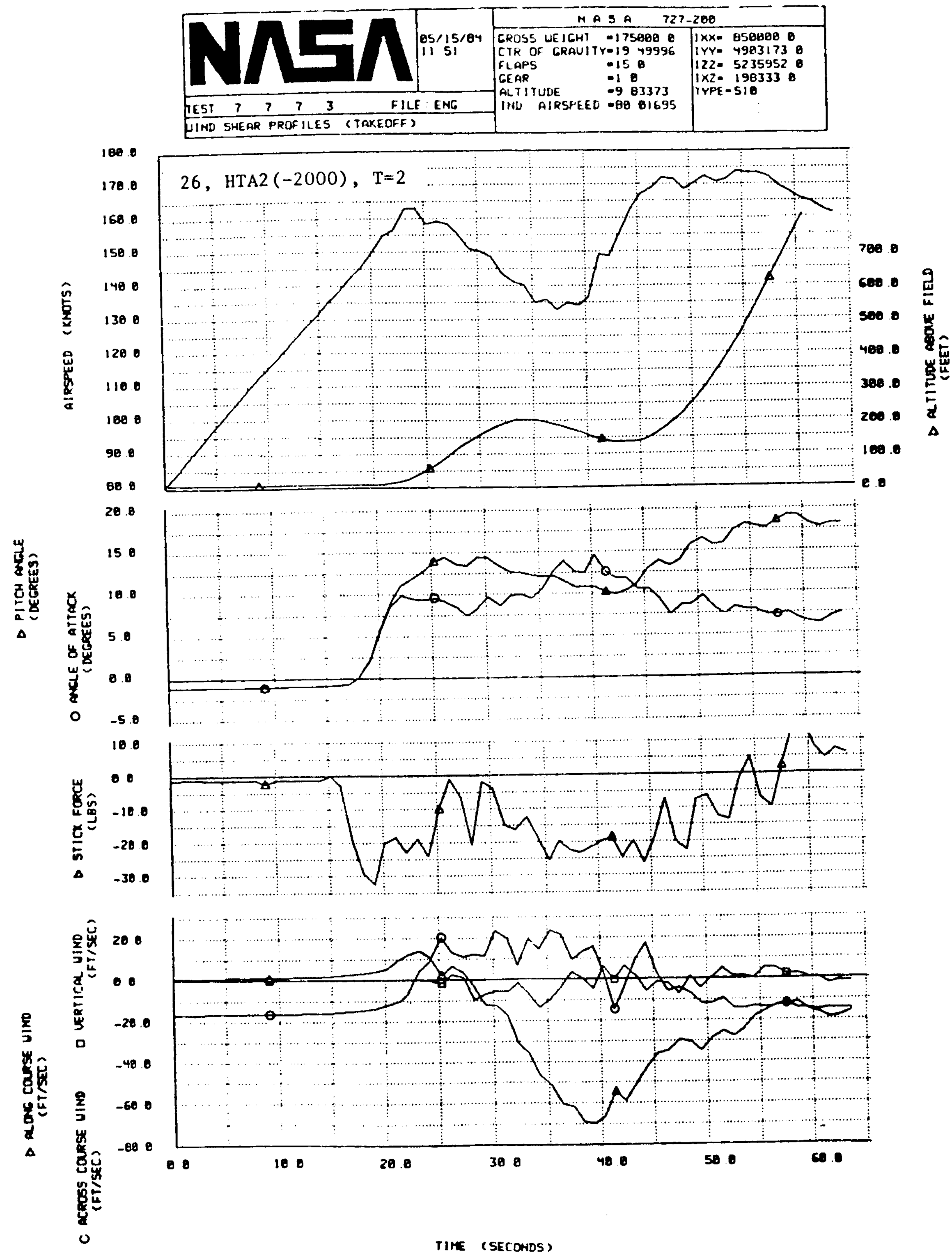

Figure 14. Simulated Takeoff in Wind Shear--5/15/84, 11:51.

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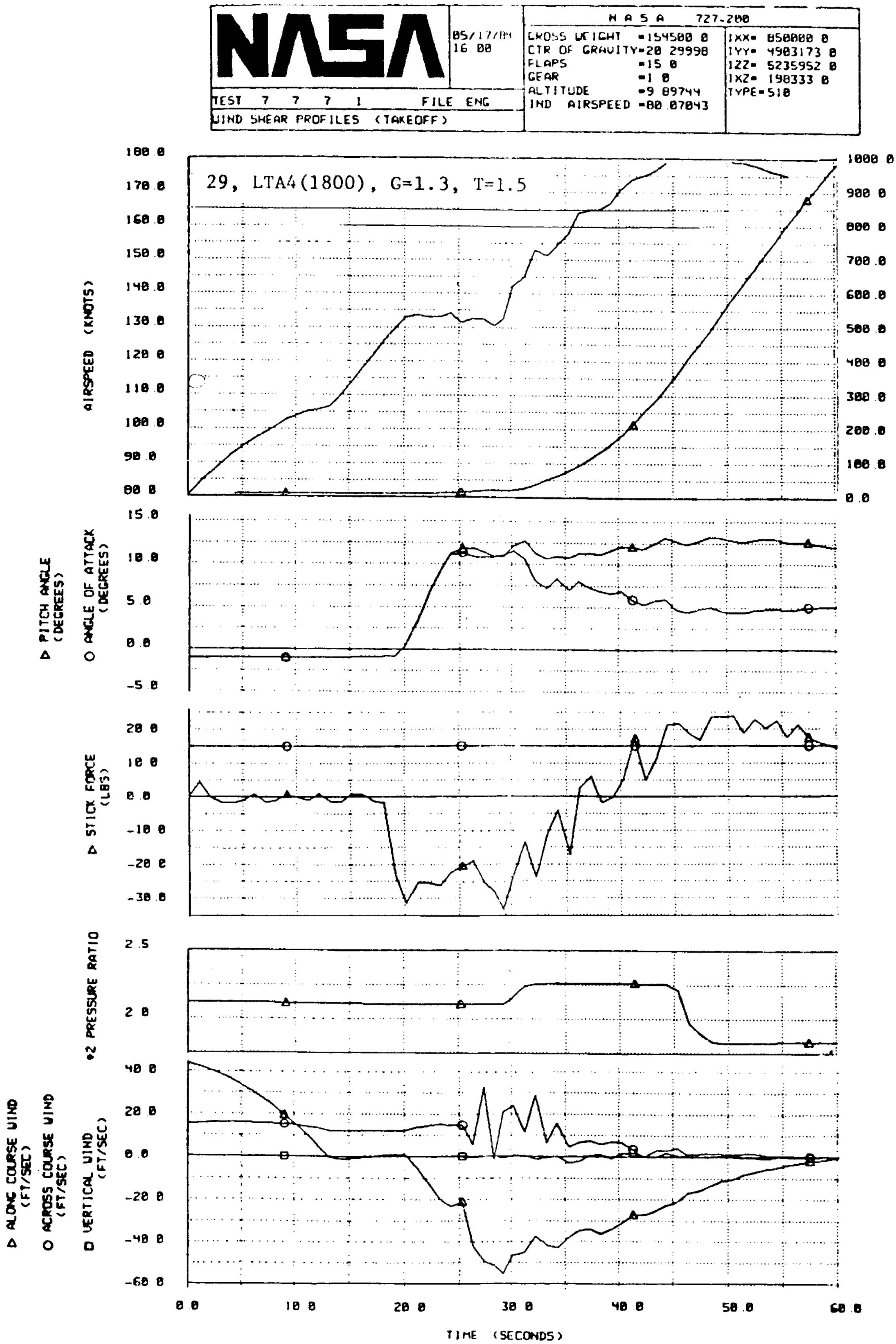

Figure 15. Simulated Takeoff in Wind Shear--5/17/84, 16:00.