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SIMULATOR SYSTEMS INTEGRATION

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INTRODUCTION

This paper will discuss the implementation of available wind shear data into general aviation flight training simulators.

Currently, we have 11 simulators with wind shear models installed involving some nine different aircraft models. Retrofits to other systems that we put out earlier are currently under way, and of course, all the new simulators we put out will have wind shear available for the instructors to use for demonstrations and training. We have three types of computer systems involved through all of this, and two different types of instructor stations. Most of the systems we have with wind shear, to date, are the CRT-type displays. Our older simulators involve a mechanical station which requires digi-wheels for wind shear numbers and an activation button of some type. This means that a little bit of hardware change as well as software load is required to get wind shear working in systems that have been in service for some time. We've used the 10 SRI profiles that we received some years ago, which basically involves a two-dimensional table lookup process.

The first application we had was to a Bell 222 helicopter which happened to be using a high-speed computer that was specially designed for table lookup; we took the brute-force approach there. It computes the wind shear components for all 10 shears all the time. When the instructor selects one, a non-zero multiplier is applied to make that wind shear profile come into effect.

The other systems for the fixed-wing aircraft involve a PDP 11/55 computer; and a little more sophistication, if you will, had to be incorporated to make wind shears usable. When the selection is made of a wind shear on these systems, a particular file is pulled off disk and then utilized. So more interface was needed with the instructor, hardware, and so forth. The G-III happened to have the same computer system as the Bell 222 and used, again, the brute-force method. The other simulators coming out are, by and large, Perkin-Elmer computers using Fortran. We are currently at the stage of getting the wind shear operations checked out and functional so the data can be loaded into simulators that are on the floor now and coming out to go into training.

Essentially, the mode of operation is that the instructor selects a certain profile that he wants to use on this approach and we require that the ILS be tuned into the NAV 1 receiver. The purpose for this is that existing NAV calculations could provide the reference point and runway heading to be used for the wind shears. Usually the approaches are made down an ILS, so making winds dependent upon navigation doesn't really represent much restriction. It's bad enough that they are dependent on aircraft accident investigations which back out estimates of wind from aircraft response. Then, of course, the simulator must be flown within range (distance and altitude) of the data base we have in order to have these winds occur.

As for the equations of motion, I've just listed the process we go through. Basically, we operate in the inertial frame system. Assuming we start with the point where we can calculate forces and, consequently, accelerations in the body axis, then we are in a position where these body axis accelerations can be transformed to earth axis and, then, integrated to get earth axis or earth frame velocities for the aircraft itself. At that point, the wind components, which are in the earth reference frame, can be added. When that is done, we can transform the summation of airframe and wind speeds back through the Euler angles to the body axis and thereby calculate angle of attack, side slip, total velocity, dynamic pressure, Mach number, etc. This then provides the inputs through which the aerodynamic coefficients can be calculated then multiplied by dynamic pressure to generate the forces used when going back through the loop. So, the inputs for wind come in as a straight linear addition to airframe velocity in the earth axis and they show up then through the aerodynamic forces only by their transformation back to body axes for the relations for the relations for α, β, etc.

We have assumed through this that the airframe is a point mass and that the wind is composed of three linear components acting at that point. No time variation on the wind is considered. We use turbulence to get something when conditions are desired to be a bit rough. This might look like it would present a problem if you hovered a helicopter at any given location on the approach. Then, there would be no wind shear because the winds would be constant at that point as far as the time variation that the pilot is seeing.

As for turbulence, we operate with white noise from a random number generator, and perhaps a first-order filter on that, without getting into too much detail with Dryden turbulence processing of that white noise. We'd like to see some studies done on research simulators concerning what the significance of turbulence modeling is to handling qualities evaluations, and what model is then worth installing for training. The amplitude of the turbulence is really carried as a constant which is under instructor control. Making that part of the wind shear approach would probably be the next step in refining or developing our operations here.

Some of the refinements which might be worth considering would be to provide aerodynamic moments due to linear wind variation (this is our wind shear slope, if you will), since a spanwise variation is essentially equivalent to a roll rate that will produce a roll damping moment, and perhaps then to get wind shear and turbulence terms put into the $\dot{\alpha}$ and $\dot{\beta}$ calculations. We have some use for $\dot{\alpha}$ calculations in flight dynamics; $\dot{\beta}$ is more prevalent, although it's on the order of one-fourth (or less) that of pitch rate damping. Finally, the Dryden turbulence equations, or perhaps von Karman or some type which are easy to program, implement, and checkout, could be put under consideration.

From a brief check on some of the experience we've had with wind profiles, we do find to some extent that fixed profiles can be learned rather quickly. If you go through the trip another one or two times, there will no longer be a lack of surprise about where and how the wind shear will occur, and this is felt to be rather unrealistic. However, in practice, the pilot who is in for initial or recurrent training is only going to encounter one or perhaps two wind shear approaches during the week or two that he is there. After all, wind shear can be considered one weather malfunction, and there are up to 150 other types of aircraft malfunctions that have to be covered in this span of time. Wind shear is on the syllabus and is something that will be shown to the student, but it is not something that they run through enough times to gain a lot of experience on where and how this wind shear will occur. Our weather cues come from the visual system in terms of visibility and so forth, and are controlled strictly by the instructor. Coordinating wind shear maps with visibility is not considered to be an important thing to try to implement. Clear air turbulence obviously exists and things like microbursts may occur more in clearer conditions than they would when breaking out from under the clouds.

The student may be a bit too successful at recovery during a wind shear encounter in a simulator. First of all, when they go into a session, they are briefed concerning what types of things they are going to see during the two- to three-hour session on the simulator; they will, thereby, be anticipating wind shear and looking for the symptoms that would occur in terms of airspeed, altitude, and so forth. The students then may come up with quicker recognition and recovery in the simulator than they might have during actual weather and aircraft practice. Our concern to some point is that this success and recovery may encourage flight into wind shear when, in fact, it should be avoided.

New data bases that would be useful at this point would be profiles for takeoff. Perhaps the SRI profiles could be modified to set up a takeoff operation. Obviously, the microburst will be a good one that can be applied if we get a profile to operate at the takeoff end of the runway. It looks as if the microburst, or the JAWS data, would provide a good model to add or maybe even replace some of the calm SRI profiles we now have that see little use. The three-plane data for corridors from the JAWS data looks as if it could provide a good lateral dimension as an expansion to our current two-dimensional operation and might well be worthwhile.

Finally, how turbulence is modeled and how much it is worth in terms of programming time to implement it, and computer time to run it, will depend largely on how much difference the pilot would see in the simulator affecting handling qualities and touchdown accuracy.