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IMPLEMENTATION OF TURBULENCE MODELS INTO SIMULATORS

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In this paper, I discuss simulation of turbulence as it relates to the flight training environment. This is a remote discipline for many of you, and its requirements are significantly different from a research environment.

We find in flight training that an accurate depiction of the turbulence phenomenon is not a necessary end in itself. In fact, it is something that we do not often have the time or money to accomplish. Instead we are interested in a turbulence situation that feels good to the pilot, and perhaps what Dr. Houbolt was talking about was a very good description of where we need to go in that regard [1].

We consider all simulation enhancements in terms of training objectives. That is what we have to address, and we have a limited time to do it when a pilot that comes to the Training Center for only a three-day proficiency check each year. High-frequency sources of turbulence have to offer a distraction to the pilot. They should cause an oscillation of the instruments, and cause the simulator to move if it has a motion system. The exact scientific nature is really fairly unimportant. We do have some more specific training objectives, however, associated with the large magnitude large-scale turbulence that is often known as wind shear.

I will discuss the high-frequency turbulence issue first. We have several different examples of turbulence in the range of simulation at United Airlines at the present time. Our simulators range in age from 3 years to 25 years. Some of them merely put random white noise into the motion system, that is, of course, the most primitive. Some put random motion into the equations of motion and nothing else. There are two kinds of simulators that put the turbulence into the equations of motion. One type varies the period of the turbulence such that it does cause a disturbance of the instruments. It turns out to be pretty good. However, some newer simulators use white noise summed into the equations of motion but at the iteration rate of the simulator (30 Hz). As a result, nothing is seen in the instruments but the feel of the motion is good.

We do have two simulators in which we have implemented a more sophisticated approach. They are not limited to vertical turbulence but also incorporate pitch and roll moments. That, of course, is the best cost-effective depiction we have found. The tradeoff in implementation of turbulence in the flight training simulators comes with the interaction with the motion system. Motion systems are actually tuned so that gross maneuvers of the aircraft do not exceed the hardware limits. Consequently, in order to insert turbulence that feels adequate to the pilot, the levels are so high that they may be causing very undesirable effects in the aerodynamics. One thing that I am personally looking into at United at the present time is separately gaining the input of the turbulence to the motion system, so that a

lower level of turbulence--a realistic level of turbulence--will also produce a realistic level of motion.

With regard to wind shear, we started putting some different kinds of wind shear models into our simulators about three years ago associated with specific training objectives. We find it very important in the training environment, with more than 2000 crews passing through our simulators each year, that we have some consistency of the training product. Therefore, a microburst model which can be flown through many different ways becomes as much a hindrance as it is a benefit. While it may be a very realistic depiction of the microburst phenomenon, it nevertheless provides no two pilots with the same training experience because it can be flown through an infinite number of ways. Therefore, we have moved to simplified models based on microburst phenomena. For example, a slice through the JAWS data could be programmed into the simulator in a one-dimensional fashion. This would allow us to know that every pilot received exactly the same training experience while at the same time making sure that a level of technical realism is maintained.

In closing, one point that I would like to reference is something that is missing from our simulations right now. No appropriate level of high-frequency turbulence to go along with the microburst models has been defined. I understand that there is some work out on that now. One problem we have with our simple simulation models of wind shear is that the recognition for the pilot is not difficult at all because the airspeed suddenly begins moving and he knows immediately that he is in a wind shear. We would like to add to our wind shear simulations some appropriate levels of high-frequency turbulence to mask that and get the pilot used to what he might have to recognize in the real world.

Reference

1. Houbolt, J. C.: Example on How to Model and Simulate Turbulence for Flight Simulators, *Proceedings: Workshop on Atmospheric Turbulence Relative to Aviation, Missile, and Space Programs*, NASA CP-2468, 1987, pp. 159-178.