Readers' Forum

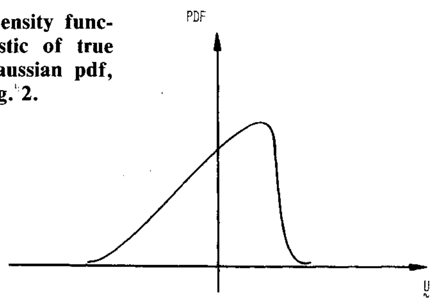
Comment on "Monte Carlo Turbulence Simulation Using Rational Approximations to von Kármán Spectra"

George Treviño*
Michigan Technological University
Houghton, Michigan

I CONGRATULATE Dr. Campbell on his very clever and efficient Monte Carlo simulation scheme.[1] The problem he is tackling is certainly of cardinal importance in the field of aviation safety. However, there is serious doubt that his simulated output is really "turbulence." The output is indeed *random* and its spectrum does approximate the von Kármán; however, the true test of its turbulent nature is not in the mere characterization of second-order moments such as $\langle w(t)w(t+\tau)\rangle$. On the contrary, the proof of the pudding is in how well it emulates the *physical* forces actually present in the hydrodynamic fluid. After all, these forces are what the airplane undeniably "senses" during a turbulence encounter. To this end, any Gaussian time history cannot recreate the "self-interaction" eminently characteristic of any true turbulence. This self-interaction is engendered of the *nonlinear* convective term present in the Navier-Stokes equation; to neglect this effect means that the turbulence is nothing more than diffusion.[2] A Gaussian time history requires that odd-order moments be indentically zero and, therefore, that the pdf be symmetric about $u=0$. This symmetry is also characteristic of the modern "modified" Gaussian time-history approach. For such cases, correlations such as $\langle w(t)u(t)w(t+\tau)\rangle$, $\langle w(t)v(t)w(t+\tau)\rangle$, and $\langle w(t)w(t)w(t+\tau)\rangle$ cannot exist, and these are the terms that unfortunately introduce the all-important culprit convective effect explicitly into the turbulence structure.

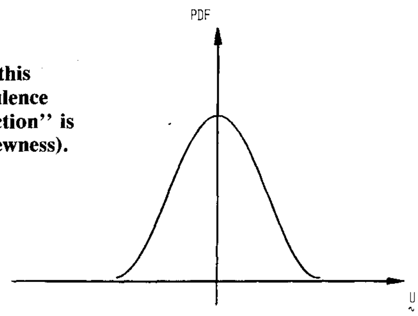
In short, there is no such species as Gaussian turbulence, at least not in the atmosphere (see Figs. 1-3), and the analysis of same does not even provide a viable "limiting case" analysis of the phenomenon. This is perhaps why pilots subjected to Gaussian "simulands" in state-of-the-art

Fig. 1 Probability density function more characteristic of true turbulence than a Gaussian pdf, such as depicted in Fig. 2.



Received Feb. 10, 1986.
*Associate Professor of Engineering Mechanics. Member AIAA.

Fig. 2 Gaussian pdf; this pdf characterizes turbulence only when "self-interaction" is negligibly small (no skewness).



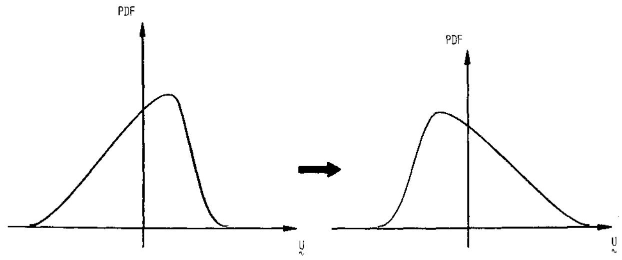


Fig. 3 Possible spatial evolution in the pdf due to the nonhomogeneous nature of turbulence.

flight simulators often complain that the simulated input does not have the right "feel" of atmospheric turbulence. A quite common pilot description of the simuland is that it lacks the "element of surprise." The necessary nonsymmetry and its importance have been reported by the author as the result of related work,[3] and the effects of ground-level wind shear on turbulence are currently under investigation.[4] Skewness values for modeled wind gusts are reported in Ref. 5.

References

[1]Campbell, C. W., "Monte Carlo Turbulence Simulation Using Rational Approximations to von Kármán Spectra," *AIAA Journal*, Vol. 24, Jan. 1986, pp. 62-66.

[2]Batchelor, G. K., *Theory of Homogeneous Turbulence*, Cambridge University Press, Cambridge, 1967.

[3]Treviño, G., "Turbulence for Flight Simulation," *Journal of Aircraft*, Vol. 23, April 1986, pp. 348-349.

[4]Treviño, G., "Airplane Flight Through Wind Shear Turbulence," *Journal of Aircraft*, to be published.

[5]Schiess, J. R., "Composite Statistical Method for Modeling Wind Gusts," *Journal of Aircraft*, Vol. 23, Feb. 1986, pp. 131-135.

Reply by Author to G. Treviño

C. Warren Campbell*
The BDM Corporation, Huntsville, Alabama

THE author thanks Dr. Treviño for his comments regarding Ref. 1. Before referring to Dr. Treviño's comments,

Received March 13, 1986.
*Principal Staff Member.

some general remarks are in order. The von Kármán approximant (VKA) method is *not* a stand-alone turbulence simulation model, but should be used with models for gust standard deviations and integral length scale. These parameters have considerable influence on simulation realism. The VKA method is intended for real-time simulations, and the designation "real time" imposes severe restrictions on computational complexity. Dr. Treviño has made several points, each of which I will consider in turn.

Dr. Treviño refers to the emulation of physical forces in turbulence acting on aircraft. Strictly speaking, the only hope of achieving a totally realistic simulation of turbulence with all physical mechanisms accurately modeled is by large-eddy or direct simulation of turbulence using the unmodeled, time-varying, Navier-Stokes equations. Large-eddy simulation provides exciting results, however, with present computer limitations is can model only relatively simple, low-Reynolds-number flows. Some of the simulations at NASA Ames Research Center require more than 100 h of supercomputer time. Alternatives are to use real measured turbulence for simulations or to use Monte Carlo methods to capture most of the phenomena affecting the response of the aircraft. The use fo real turbulence presupposes measurements at high resolution over a two- or three-dimensional field (for realistic simulations).

Dr. Treviño refers to the Gaussian nature of the VKA and other simulation methods as unrealistic and provides figures showing highly skewed distributions, which he claims are more characteristic of atmospheric turbulence. He believes that Gaussian analyses do not even provide a viable limiting-case analysis of the phenomenon. No one will argue that turbulence is Gaussian, but, in some instances, one-point statistics closely approximate Gaussian behavior (see, for example, Ref. 2, p. 170, Fig. 8.1). In many instances, turbulence has a larger than Gaussian value of kurtosis, and almost none of the skewing indicated in Dr. Treviño's figures.[3-5] These higher values of kurtosis can be simulated by modulating the turbulence with a stochastically varying gust standard deviation.[6-8] Modulation techniques should be applied to VKA turbulence.

Dr. Treviño implies that the nonlinear convection term is ignored in Monte Carlo turbulence simulation, and states that without it, "...turbulence is nothing more than diffusion." His statement is remarkable for three reasons: first, the fundamental physical basis for a $-5/3$ fall off with frequency is the predominance of inertial forces,[3] hence, the genesis of the phrase *inertial* subrange; second, all turbulence simulators require the frozen turbulence hypothesis, which excludes diffusion; and third, the creation of a chaotic process from the linear diffusion equation is difficult to accept. The destruction terms in the turbulent kinetic energy equation arise from the diffusion terms in the Navier-Stokes equations. Dissipation is predominant in the dissipation subrange at frequencies of little interest for most simulations.

Dr. Treviño refers to pilots' complaints that Gaussian simulated turbulence does not have the right "feel" to it, and lacks the element of "surprise." The element of surprise can readily be added by modulating the Gaussian turbulence. Although Gaussian turbulence may be "bland," Etkin[9] points out that pilot ratings on the Cooper-Harper scale show the expected trends with increasing turbulent intensity. Physical processes other than the stochastic nature of turbulence may contribute to its "feel." In a conversation some years ago, Carl Terry, an engineer with United Airlines, pointed out that the "feel" of turbulence may be in large part due to airframe vibrational response. Airframe ringing is difficult to build into a simulator.

Dr. Treviño suggests that third-order moments strongly influence aircraft turbulence response and should be added to turbulence simulations. Unfortunately, he does not offer a means for doing this. To my knowledge, no one has done this yet, especially not for a real-time simulation. A simpler but similar application illustrates some of the problems that may be encountered in attempts to improve simulation models; a problem of filter overspecification was encountered and overcome, but the resulting filters were not realizable.[10] Dr. Treviño's problem is easier said than done.

References

[1]Campbell, C. W., "Monte Carlo Turbulence Simulation Using Rational Approximations to von Kármán Spectra," *AIAA Journal*, Vol, 24, Jan. 1986, pp. 62–66.

[2]Batchelor, G. K., *Theory of Homogeneous Turbulence*, Cambridge, University Press, London, 1967.

[3]Dutton, J. A., "Effects of Turbulence on Aeronautical Systems," *Progress in Aeronautical Science*, Vol. 11, edited by D. Kuchemann, Pergamon Press, New York, 1970, pp. 67–109.

[4]Campbell, W., Camp, D. W., and Frost, W., "An Analysis of Spanwise Gust Gradient Data," Ninth Conference on Aerospace and Aeronautical Meteorology, American Meterological Society, June 1986, pp. 303–309.

[5]Frost, W., Lin, M-C., Chang, H-P. and Ringnes, E., "Analysis of Data from NASA B-57B Gust Gradient Program," Final Report under NASA Contracts NAS8-36177 and NAS8-35347, Sept. 1985.

[6]Reeves, P. M., "A Non-Gaussian Turbulence Simulation," AFFDL-TR-69-67, Nov. 1969.

[7]Reeves, P. M., Campbell, G. S., Ganzer, V. M., and Joppa, R. G., "Development and Application of a Non-Gaussian Atmospheric Turbulence Model for Use in Flight Simulators," Sept. 1974, NASA CR-2451.

[8]Reeves, P. M., Joppa, R. G., and Ganzer, V. M., "A Non-Gaussian Model of Continuous Atmospheric Turbulence for Use in Aircraft Design," NASA CR-2639, Jan. 1976.

[9]Etkin, B., "Turbulent Wind and Its Effect on Flight," *Journal of Aircraft*, Vol. 18, pp. 327–345.

[10]Campbell, C., "Adding Computationally Efficient Realism to Monte Carlo Turbulence Simulation," NASA TP 2469, May 1985.

Comment on "The Role of Damping on Supersonic Panel Flutter"

Alexander H. Flax*
National Academy of Engineering, Washington, D.C.

LOTTATI[1] has analyzed the effect of a form of viscoelastic damping on the flutter speed of a two-dimensional simply supported panel in supersonic flow, employing piston theory for the aerodynamic forces. The results obtained indicate that even for infinitesimally small values of the damping coefficient, there is a value of the speed (or Mach number) parameter above which the system becomes unstable. This result is similar to the one obtained by Zisfein and Frueh[2,3] for "structural" damping as typically used in flutter analyses in this country. "Structural" damping is rigorously defined only for motions harmonic in time but can be used to determine the boundary between stable and unstable motions. On the stability boundary, an equivalence, which is flutter-frequency-dependent, can be established between the "structural" damping and any form of linear viscoelastic damping. Thus, it is not surprising that similar characteristics are found for the effects of viscoelastic and structural damping on panel aeroelastic stability.

Zisfein and Frueh[2,3] arrived at a relatively simple criterion for the onset of panel instability in terms of the shape of the frequency-velocity curve for the undamped system, corresponding to Lottati's Fig. 1. The validity of this simple criterion was established by intricate calculations of the mo-

Received Dec. 3, 1985.

*Home Secretary.