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# Readers' Forum

*Brief discussion of previous investigations in the aerospace sciences and technical comments on papers published in the* AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

## Comment on "Large-Eddy Simulation of a Turbulent Compressible Round Jet" vis-à-vis Lighthill's Theory of Jet Noise

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THE study of Ref. 1 appears to be an advance in the use of computational fluid dynamics for the prediction of the properties of a turbulent jet. It yields details of the instantaneous flow patterns and, in addition, two-point space-time correlations of velocity components. These components govern the sources of sound in Lighthill's[2] theory of jet noise (and in its extension[3] to deal with wave convection, hence refraction); further, their correlations are required in the integral for the spectra and mean square radiated sound pressure. (This is amplified further in the following.) It appears from the Abstract and presentation that the present work is motivated by these considerations in the context of Lighthill's theory.

Although rms properties of a round jet must be axisymmetric, instantaneous values are not. These large-eddy simulation (LES) computations of the instantaneous velocity field show striking deviations from axisymmetry. The deviations are consistent with those found in the radiated sound field by Maestrello[4] in 1976. He measured electronically the correlations between the signals of a pair of microphones, say, A and B, at a fixed distance from the nozzle, separated in angle. For A and B in a plane at the nozzle normal to the axis, the correlation decayed with separation in azimuth angle to zero at 90 deg and then increased again to about 0.1 at 180 deg, that is, when A and B were on opposite sides of the jet. In other examples, correlations showed similar, but less extreme, decay as one microphone was moved away from the other along a circle of latitude. The low A:B correlations signify, of course, a marked departure from instantaneous sound field axisymmetry.

The Lighthill theory can be extended to these two-microphone correlations as well: such an extension (involving approximation) showed general—in some cases striking—agreement with Maestrello's experimental curves: in broadband[5] and in narrow frequency bands.[6] The dominant feature governing all of the correlations is the difference in acoustic travel times to microphones A and B from a noncentral source eddy in the jet turbulence. In the first-discussed case of the last paragraph, the peculiar variation with azimuth angle is accounted for by the source directivity.

An examination of the noise sources postulated in the Lighthill theory leads to a suggestion for further work. The far-field sound pressure radiated from unit volume of the jet turbulence is proportional to $\partial^2/\partial t^2$ (Lighthill stress tensor). In the cited extension the Proudman[7] form of the stress tensor (a very useful contraction) was used; it takes the form of the component in the direction of the far-field observer at $\boldsymbol{x}$:

$$T_{xx} = \rho_o v_x v_x = \rho_o\left(u_x^2 + 2u_x U_x + U_x^2\right), \qquad v_x = u_x + U_x$$

where $u_x$ refers to the turbulence and $U_x$ refers to the mean flow. The constant term $U_x^2$, of course, generates no noise. The other two terms are identified as noise generators. It is suggested that the present LES simulation be extended beyond just $u_x$ to obtain the full terms and their two-point space-time correlations. Chu's[8] hot wire measurements, mentioned by the authors, could serve for guidance as to scope and format, and for quantitative comparison.

The postulated source terms have been subjected to direct experimental test. Richarz[9] measured instantaneous values of $u_x^2$ and $u_x U_x$ via laser Doppler velocimeter and electronically cross correlated them with a microphone signal. Contours of equal cross correlation (misleadingly labeled) respectively resembled contours of equal $\langle (u_x^2)^2\rangle$ and $\langle (u_x U_x)^2\rangle$, as predicted by a further development of the Lighthill theory in Ref. 9. (The correlation curves were labeled "Contours of Equal Relative Contribution per Unit Volume to ... Noise from a Slice of Jet ...," an equivalent interpretation arising from the theory.) This supports the credibility of $\rho_o u_x^2$ and $2\rho_o u_x U_x$ being correlated (via the $\partial^2/\partial t^2$ operation) with valid source terms for jet noise. These terms are respectively responsible for "self noise" and "shear noise" (the mean flow shear dominating the two-point correlation of $U_x$). In the current climate of reexamination of the whole issue of jet noise sources, the powerful source identification features of Richarz's[9] work—by direct experimental cause-and-effect correlation[10]—seem to have been completely overlooked.

### References

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