ERRATUM: The following *Citation Classic* was listed on the cover of *CC/ET&AS* 22(36), 9 September 1991, and was mistakenly displaced by a *Classic* from another edition.

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Lighthill M J. On sound generated aerodynamically. I. General theory. *Proc. Roy. Soc. London Ser. A* 211:564-87, 1952.
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A theory was initiated, based on the equations of motion of a gas, for the purpose of estimating the sound radiated from a fluid flow, with rigid boundaries, which as a result of instability contains regular fluctuations or turbulence. [The *SCI*® indicates that this paper has been cited in more than 660 publications.]

Flow Noise Science

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One day in 1949, Britain's assistant director of scientific research convinced me—then a 25-year-old senior lecturer in applied mathematics at Manchester University—that the problem of understanding noise emitted by jets from aero-engines was at the same time a matter of great practical importance and an exceptionally exciting theoretical challenge. A jet, after all, was one of the classical turbulent flows, hitherto viewed as a complex pattern of vorticity completely free of those fluid dilatations that, on the other hand, must mediate observed sound emissions. Sitting the next day in the London train, I could not stop wondering how to characterize jets in a new way that would permit estimation of their noise fields.

Like most mathematicians, I normally write down too many equations! But on that railway journey, I fortunately had only the proverbial back of an envelope with me; so I really was forced to think. The theory's essential idea emerged before my journey's end.

It depended first of all on a choice of the right dependent variable: not the pressure, whose relationship with turbulent velocity fluctuations had been shown to be so complicated, but the density. This was needed for a theory concentrating not so much on the turbulence itself, where density variations hardly matter, as on the sound emissions where they must necessarily be significant.

On the envelope's modest back, a first equation could then be written down, specifying local rate of change of density as the inward component (minus the divergence) of mass flux. What could be said, however, about the rate of change of mass flux? Careful thought was needed to recognize that an answer (the next writing on the envelope) might be given by the momentum equation not in the standard Euler form but in a much less standard form due to Reynolds. Later, I appreciated how fortunate for my theory was the fact that flux of mass is identical with density of momentum. I was content on that train to contemplate adiabatic processes only! For these, the momentum flux had just two components.

Delightedly, I recognized that a linear equation connected acoustic density fluctuations to the quadratic turbulent quantity described as its momentum transport or instantaneous Reynolds stress. The classical Kirchhoff solution to this linear equation could be applied in its simplified far-field form to give the radiated sound.

This idea, after much refinement, finally "saw the light" in my 1952 paper. The longer-term development of jet engines, aimed (successfully) at giving civil aircraft ever higher thrusts while avoiding increases in noise levels, was helped especially by that paper's dimensional analysis of the Kirchhoff solution. These developments have been rather widely beneficial by significantly reducing the cost of air transport in real terms without increasing the resulting noise nuisance.

This paper initiated a new scientific subdiscipline, variously called "flow noise" or "aeroacoustics," which lies at the boundary between aerodynamics and acoustics. It is widely applied to many areas of engineering, including, especially, the jet-noise problem.[1-3]

[Editor's note: In 1975, Sir M. James Lighthill became the first recipient of the American Institute of Aeronautics & Astronautics's Aeroacoustic Award.]

1. **Lighthill M J.** Jet noise: the Wright brothers lecture. *AIAA J.* 1:1507-17, 1963. (Cited 65 times.)
2. **Goldstein M E.** *Aeroacoustics.* New York: McGraw-Hill, 1976. (Cited 105 times.)
3. **Dowling A P & Williams J E F.** *Sound and sources of sound.* New York: Wiley, 1983. 321 p. (Cited 30 times.)

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