Computers and the Expansion of Scientific Knowledge

In considering what to write about in this editorial, I cast my mind back to two books, *The Death of Science*, Andrew Holster (2016): *A Companion*

Study to Martin Lopez Corredoira's *The Twilight of the Scientific Age* (2013). When I wrote about this back then, I concluded that although many of their concerns were valid, that these authors were too negative. Their main arguments were that Science is at a crisis for the scientist working within modern organizations. It is also at a crisis for philosophy, for the role of natural science to help inform our world view. The author of *The Death of Science* concludes that most meaningful scientific research has now been completed, and that the 'new research' being undertaken is derivative and a waste of time. And referees for journal articles are apparently corrupted. It is nice to learn again that I have been wasting my time as Editor in Chief of two Engineering and Scientific journals over the last forty years: the *Noise Control Engineering Journal* — 1973–1994 and the *International Journal of Acoustics and Vibration* — 1996–2016. Also I was surprised to learn that the anonymous referees were all corrupted.

I hate to think that my own volunteer work over the 40-year period and that of the independent anonymous referees over these forty years could be regarded as a waste of time. Most of the articles in the journals were discussing analytical models which can be used to predict the sound and vibration field phenomena observed in practice and which can be verified through experimental observations. If the authors of the two books are correct, then how do they explain scientific studies continuing by physicists to understand the Cosmos? And also if their hypotheses are true, how do they explain away the successful scientific efforts in many countries to design and make safe vaccines to fight the Covid-19 virus?

In looking back again over a lifetime, one can't help being impressed by the rapid development of our computational abilities and the resulting expansion in scientific knowledge. Some might call this applied science. Although our understanding of the acoustics, noise, and vibration fundamentals has remained largely unchanged, in the last sixty years or so (1960–2020) we have seen dramatic changes in our ability to make calculations, useful predictions, and measurements. Before the wide availability of electronic calculators (1975), most calculations were made using log tables and slide rules. Large, expensive computers did not appear until the 1960s and 1970s. Personal computers and laptops only became available in the early 1980s. Now computers big and small are everywhere. Computational advances have revolutionized our ability to make acoustics, noise, and vibration calculations.

I first came across computers in 1958 as a young engineering undergraduate. We were given the task of writing a few steps on a piece of paper to give to a very primitive vacuum tube computer. It took the computer several seconds to carry out one simple calculation. My next exposure to computation was at Vickers-Armstrongs Aircraft in the UK in 1962. There large computations were carried out on a machine with multiple gear wheels and operated by a hand crank. I was also working on the flap loads of the Vickers Super VC-10, a four jet-engine passenger airliner. I used a planimeter to measure the area of a plot recorded from wind tunnel measurements to calculate the takeoff and landing flap loads.

My next exposure to computation was during a visit to NASA Langley in 1962. Here I saw a beautiful scale model of the Saturn V. Everything was meticulously constructed to one-tenth scale – even the rivets. The model was then vibration-tested to determine its scaled natural frequencies and mode shapes, which could be scaled up to the full-scale Saturn V. In those days large expensive computers were just coming into use. These computers, costing a million US dollars or

more, took up a whole large air-conditioned room up to 30 ft by 40 ft (10 m by 13 m). In those days, most design verification was done by experimental model testing. The computers used vacuum tubes and included multiple nine-inch whirling magnetic tapes.

In 1965, I was working in a small team of scientists and engineers in Huntsville, Alabama. We used one of these large first generation computers to control the vibration-testing of a full-scale section of the Saturn V, mounted in a pit in Huntsville, Alabama. There was also considerable interest and concern in those days about the impending use of supersonic passenger aircraft. About the same time, I wished to calculate the multimodal time-history response of a thin flat plate (or window) to a sonic boom (known as an N-wave.) Again, even moderate size computers were not in wide use. I calculated that it would take me 100 years to do this with log tables and a slide rule, or 100 people one year. I asked for the use of a computer. A programmer was sent to me. So far, the computer had never been used for scientific calculations, only for keeping payrolls. The programmer was unable to help me. I purchased a small Fortran manual and succeeded in programing and calculating the multimode time-history plate response in three days and getting correct results with the computer in a few minutes instead of in 100 years.

During the 1960s the cost of large computers was coming down significantly. My next exposure to computers was when I was at Liverpool University. The theory that I had developed was not very computer-calculation-intensive. It used the theory I had developed called Statistical Energy Analysis (SEA) first developed by Dick Lyon and his colleagues in the early 1960s for use in noise and vibration studies on spacecraft. My calculations involved SEA theory I had developed to predict the sound transmission loss of single layer and double layer partitions. Although SEA simplifies calculations since space, time and frequency averages are taken, the calculations would still be tedious if done by hand.

Early in the 1970s I started to work on acoustical models of mufflers (silencers). While at Purdue University my work was supported by a company that made most of the original equipment manufacturer (OEM) mufflers for cars in the USA. Until then, analytical models could only deal with mufflers that had chambers that were axisymmetric with the tube axis. Together with a doctoral student, I developed Finite Element Model (FEM) theory to predict the transmission loss of non-axisymmetric chambers. Our FEM theory and modeling was the first in the world to predict the acoustical behavior of non-axisymmetric muffler chambers. We programmed the FEM using punch cards and a large digital computer. We were able to check the calculations first by comparing the transmission loss predictions with those made using a classical approach. We were also able to increase the number of finite elements until the predictions did not change, thus setting a minimum number of finite elements necessary. Then we used the computer to make finite element FEM predictions that could deal with complicated mufflers of non-concentric geometry. We used the FEM approach to make predictions on a whole series of non-axisymmetric mufflers and checked the predictions with a series of experimental measurements. None of these studies discussed in this editorial could have been carried out without digital computers. Digital computers have rapidly increased scientific knowledge over the last sixty years. I believe there is still a bright future for applied scientific research.

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