Understanding Noise in Twentieth-Century Physics and Engineering

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Noise is a common experience in the contemporary world. Din from traffic, construction sites, factories, and neighbors bother urban residents. Radio listeners, television watchers, and mobile phone users have to endure statics and fading from time to time. Music lovers have debated whether jazz, atonal composition, rock and roll, rap, and abstract expressionism are art or nuisance. Scientists try to retrieve genuine signals from fluctuating data. Engineers design devices, software, or systems to filter out disturbance to the normal functioning of technology. Mathematicians and physicists examine randomness. Traders and economists attempt to predict markets’ future trends beneath highly irregular commodity prices. Decision makers cope with all kinds of uncertainty. No matter whether we understand the term as annoying sound or random fluctuations, we simply cannot live a life without encountering noise.

Despite its ubiquity in modern times, noise has rarely been a focus of historical studies of recent science and technology. There may be an obvious reason for this lack of attention: noise largely reveals what science and technology are not, instead of what they are. Noise is an environmental plight of industrialization, an obstacle to the advancement of scientific knowledge, a subversive force to technology, a barrier to prediction, estimation, and control, and a symptom of disorder. As a result, noise often exposes the limitations of science and technology. While such limitations have played an important part in the development of science or technology, they are generally conceived as a background to this development, and thus scarcely become the subject of close investigations.

A number of recent historiographical turns, however, have begun to change this situation. Inspired by the cultural histories of senses that flourished...
in the past few decades, historians and sociologists of technology have developed the area of sound studies. Scholars working in sound studies have examined closely various issues related to the generation, interpretation, and control of acoustic noise, ranging from the noise abatement movements and the treatment of noise as a diagnostic tool for mechanical problems to the use of mechanical noise in music composition and the measurement of hearing loss due to noisy ambience. Moreover, historians and philosophers of science have paid increasing attention to random fluctuations. They have either looked into the studies of noise (in the abstract, mathematical sense), such as Brownian motion and electronic noise, in several branches of physics investigated scientists’ statistical criteria for judging an experimental claim from noisy data, or explored the roles of such stochastic noise in self-organization or biological evolution. Finally, owing to the ongoing interest in the history of information science and technology, how engineers and scientists dealt with noise in communication, control, and computing systems has been a notable research question.

Built upon the aforementioned literature, this special issue of Perspectives on Science presents six case studies of noise. The disciplines under consideration include acoustics, statistical mechanics, applied mathematics, quantum electronics, electronic and telecommunication engineering, and computer science. The time spans the two World Wars and the Cold War, while the geographical regions encompass North America and Europe. Roland Wittje takes up a subject that has been studied by historians: acoustical noise. He points out the importance of understanding the term’s various meanings in relation to the applications within which these meanings were deployed. Nineteenth-century scientists dealt with noise within the framework of musicology. But the First Great War demanded that they reframe it in terms of the sounds of the battlefield. Scientists worked to develop sound-ranging systems that could, for example, pick up the signal from a particular artillery piece while filtering out the din of other fighting. In other situations, noise itself became the signal as acousticians experimented with receivers that could register the sounds of the pumps, propellers, and engines of enemy submarines. Meanwhile, in the war and postwar years, research into acoustical noise began to merge with electrical engineering in the context of electro-acoustic technologies like telephony and radio.

Niss’s, Yeang’s, and Bromberg’s articles are concerned with physicists’ research on random fluctuations due to molecular thermal agitation, the

shot effect, or quantum uncertainty. Martin Niss supplements the current historical works on the familiar pioneers of electronic noise, such as Walter Schottky, John B. Johnson, and Harry Nyquist, by focusing on the Swedish scientist Gustaf Ising’s work. In line with the tradition of his time and country, Ising sought the maximum possible sensitivity in instruments used for electrical measurements. In working with electrometers and galvanometers, however, he became convinced that Brownian motion imposed an unavoidable floor on such sensitivity. These Brownian fluctuations, Niss shows, became assimilated after World War II into a broadened concept of noise.

Chen-Pang Yeang points out that physicists and mathematicians in the early twentieth century adopted two distinct approaches to deal with Brownian-type random fluctuations. The time-domain method was influenced by statistical mechanics and emphasized the modeling of a stochastic process’s time evolution and the prediction of future events based on such modeling. In contrast, the frequency-domain method was shaped by electrical engineering. It sought to identify the spectral properties of a stochastic process and it was closely tied to the development of telecommunications technology.

Joan Bromberg broadens our scope from classical to quantum noise by looking at the theoretical research of some American maser pioneers in the 1950s. These men were inventing electrical apparatus whose working substance—like ammonia molecules—was to be treated quantum-mechanically. In general, these inventions were low noise devices. But did the laws of quantum physics, for example, the imprecision dictated by the uncertainty principle, impose on them an irreducible minimum of noise? Bromberg suggests that physicists’ struggle with this problem also reveals some of the ways in which microwave engineering and quantum physics were melded together in the early post-World War II period.

Shawn Bullock’s and Aaron Sidney Wright’s articles explore links between the histories of noise and of information technology. Bullock shows how AT&T engineers for the SAGE air defense system faced the need of sending data over telephone lines. This brought them to invent the modem. A key part of that invention, as Bullock emphasizes, was the need to reduce the levels of noise in radar images and transmission lines: levels that, in transmission lines, had been acceptable for voice communication, but was detrimental for data transmission. Wright investigates some aspects of the thermodynamics of computation that were explored by IBM researchers during the 1950s–80s. Inspired by Claude Shannon’s information theory, this line of research first treated the error-prone magnetic core memory as an embodiment of a noisy information system. This idea then led to the introduction of what would be called Landauer’s Principle, which asserted that erasing the content of a register in computation increases the entropy.
Landauer’s Principle has been largely invoked in highly abstract debates concerning the nature of the second law of thermodynamics and “Maxwell’s demon,” Wright reminds us of the practical, material context from which this physics of computation originated. It included IBM’s pursuit of magnetic core arrays for memory storage and the company’s drive for miniaturization.

It is worth noting that although noise is now generally identified as random errors, the ways of handling noise in all of the six historical case studies were nonetheless different from the standard statistical approach scientists have adopted to deal with random errors. Such standard statistical techniques, including the method of least squares, regression, the procedure of randomized control, and maximum likelihood detection, had been widely used in astronomical observations, sociological surveys, as well as experiments in psychology, genetics, biometrics, and medicine since their introduction in the nineteenth century. But they were not systematically deployed in experimental physics and electrical engineering, the main areas of interest in this issue, until World War II or even afterwards. For example, Allan Franklin points out that the standard error range of five sigmas particle physicists now demand on their experimental data did not arise until the 1960s (Franklin 2013). This delay of experimental physicists’ and electrical engineers’ comprehensive employment of statistical data analysis is consistent with what is revealed in the six articles: the scientists and engineers in these stories were much more interested in exploring and analyzing particular sources of noise and their physical mechanisms than suppressing their effects on measurement with statistical techniques. Wittje’s protagonists focused on the acoustic nature of annoying sound. Yeang’s and Niss’s historical actors examined different manifestations of Brownian motion. Bromberg’s and Wright’s major characters were concerned with the implications of the fundamental principles in quantum or classical statistical mechanics in creating observable fluctuations. Even though the engineers in Bullock’s story showed a stronger interest in reducing the effects of noise, they still paid close attention to the physical characteristics of radar clutter and transmission-line noise. In brief, the histories of noise presented in this volume are not the episodes in which the “empire of chance” conquered various realms of experimental and observational sciences by examining data under statistical treatments in order to eliminate or reduce uncertainty. Rather, the stories unveil some situations in which researchers were significantly more enthusiastic to explore the nature of the uncertainty.

Inevitably, the juxtaposition of these six papers raises new historical questions. Wittje urges us to think more about how the sense of noise

as sonic disturbance came to fuse together with the sense of noise as irregular fluctuations in the historical context of acoustic and electro-acoustic research. Bullock’s and Wright’s works point to the desirability of looking into the role of post-World War II information technology in other aspects of the science of fluctuation phenomena. Niss and Yeang both drive us to ask how useful the physics and mathematics of shot noise and classical thermal noise were to studying other realms of phenomena. Coupled with Bromberg’s article, they point to the question of how they influenced the history of concepts of quantum noise. Niss’s study of Brownian fluctuations as a limit to the sensitivity of galvanometers suggests we look at other instruments: one example from the post-war period is radiation fluctuations as a limit to the sensitivity of photodetectors. Both Niss’s and Bromberg’s articles call attention to the need for more study of how wartime research influenced the study of noise, including how pre-war studies of Brownian motion fluctuations came to be assimilated to a more general concept of noise. The reader will surely add other topics.

All these papers hint at the social and economic contexts of noise research and the desirability of more research on them. All in all, work remains to be done. It is our hope that this issue will play a part in motivating it.

References


