**The Cold War and Random Processes:**

**Of Spectral Control and Noise**

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**Abstract:** The conversion of dynamic systems from impediments to strategic advantages played a substantial role in the U.S. military’s technological research and development during the Cold War. From signal interpretation with remote sensing systems to telecommunications to algorithms, media and information theory, harmonic systems, and even the weather, the unintended consequences of both dynamic systems in nature and technological attempts to control the same led to innovations and accidents, aesthetic developments and prediction advances that furnish large swaths of our current global sensorial domain. The role of randomness within complex dynamic systems accounts for the opportunities and impediments these systems offer. This article looks at a range of unlikely and seemingly disparate sites of technological development by the Department of Defense and national governmental propaganda projects during the Cold War, including electronic music, avant-garde composition, information theory and weather. The constant drive for superiority in C3I (command, control, communications and information) within the episteme that constituted Cold War thinking, discourse and institutions emerged in failed attempts at control, especially full-domain control, that provided unforeseen opportunities for aesthetic production and complex prediction modelling of natural forces.

**Keywords: Randomness, Causality, Dynamic Systems, Cold War Technology, Cold War Sound Labs, Military Research and Development, Artistic Production**

**1. Generative Noise**

The message about the end of all messages is clear: From noise you came, more noise you made, and to noise you shall return.

Geoff Winthrop-Young, ‘Wotan’s Stormtroopers’ **[[1]](#footnote-1)**

Off the coast of the Bikini Atoll, the site of the first hydrogen bomb test, a small fishing boat from Japan called *The Lucky Dragon* sailed near the Marshall Islands on the first of March 1954 and thus unwittingly through the test detonation fallout. Akichi Kuboyama served as the ship’s radio transmissions operator, and due to radiation exposure determined by atmospheric conditions, wind patterns, and sheer random placement, he had the misfortune of becoming the first thermonuclear weapon fatality.[[2]](#footnote-2) Although safely placed outside the 86-mile designated ‘steer clear’ test zone, the bomb proved much more powerful than planned, causing gusts of winds and ‘white rain’ to coat the crew in ash that covered their skin, hair, eyes, ears and mouths.[[3]](#footnote-3) Due to these mistaken military calculations, the crew soon exhibited the symptoms of dizziness, vomiting, bleeding gums and fever that indicate ‘acute radiation disease’ contracted from the ash-saturated rain.[[4]](#footnote-4)

The U.S. military’s desire capacity to predict and occasionally control micro-elements of complex, dynamic systems almost always ran up against their capacity to so predict. This desire and failure merge belatedly in Kuboyama’s fate. Experimental applications of the Fast Fourier Transform (FFT) in geoacoustic surveillance migrated from nuclear testing verification of Soviet explosions in Kazakhstan to electronics labs for recorded and transmitted speech, and eventually decades later to wind turbulence in battlefield conditions, all in an effort to convert random dynamic processes into predictable, manipulable phenomena. Attempts to alter and control dynamic systems such as speech and wind direction converge unironically in the ill-starred radio operator on board *The Lucky Dragon*. Through becoming a tragic exemplar and repository of advanced military research and development (R and D) projects – from second-generation nuclear weapons to sound and wind prediction – Kuboyama prefigures the multiple crosscurrents of our collective fate within post-World War II global regimes: a random figure who figures randomness incarnate.

Kuboyama’s recorded voice later became source material for a piece of experimental electronic music composed at the WDR (Westdeutscher Rundfunk) lab in Cologne, where composers used large Cold War investments in sound labs worked with atomistic building blocks of sound – transforming, manipulating and scaling these in their compositions. Phonemes and the sine wave became techniques of aleatoric composition and avant-garde musical experimentation emanating from these telecommunications lab.[[5]](#footnote-5) Herbert Eimart’s ‘Epitaph for Aikichi Kuboyama’ (1957–1962) is a work composed of tape loops and electronics using spoken word, looped utterances and electronic manipulations to create a darkly chaotic soundscape that mimetically invokes the dissolution of the voice and corporeal frame of *The Lucky Dragon*’s radio operator. An underlying logic of micro-framing by slicing complex dynamic systems into isolated and manipulable minute elements of them are found in the granular synthesis work of the FFT in remote acoustic sensing for treaty verification, the Lattice-Boltzman field turbulence prediction processes, and sound windowing in Eimert’s composition. Each provides a variation on the same military R and D technic of extracting infinitely repeatable, spatially storable micro-elements found in complex, chaotic and temporal phenomena. The process intends to render their randomness predictable and alterable. Eimert choose to return this signal in the sonic noise to static as an invocation of both Kuboyama’s disintegrating body and critique of the unintended return to randomness in this Promethean military agenda.

The fallout from a nuclear bomb blast and the distribution of its deadly radioactive isotopes ultimately falls to the random generating nature of nature in the aleatoric systems of wind and water flows, of stratified wind patterns, storm fronts and hydrological cycles embedded in food chains comprised of soil, vegetation and animals. This posed an obvious problem for military planners, who will also always seek advantage in apparent problems, and thus the desire to control the random effects of dynamic systems constituted an important strategic goal for their technological research. One way this goal manifested itself can be found, somewhat surprisingly, in audio experimentation conducted at Cold War funded sound labs in the U.S., the Soviet Union, Europe, and South America – labs interested in a host of audio analysis and synthesis projects to exploit machinic and human production of yet another wind-borne dynamic system: speech. And this experimentation in the desire of controlling random elements constitutive of dynamic systems can be heard hauntingly enough in Eimert’s harrowing elegy for Kuboyama, in which the play of phonemes merges with Cold War investment in phonetics research and emerges in mimetic evocations of radioactive decomposition of a human’s cellular composition. The composition decomposes the cellular corpus right before our very ears.

The logics operating in Eimert’s piece include heavily invested research in phonetics and audio spectra at electronic sound labs, including WDR in Köln where Eimart worked and made this piece, as well as investments in early attempts to predict or control, even if briefly, apparently random phenomena. The desire to find a signal in noise has long been an important part of military strategy and tactics. Produced in a laboratory exploring electronic manipulation of audio signal and noise for telecommunications, cryptography, and geoacoustic surveillance, Eimert’s work explored audio spectra isolation of voice (words composed of phonemes) and manipulation by tape and electronic modification that found form eventually in the FFT, a widely used algorithm in scientific imaging and sound analysis-synthesis (as well as electronic music).

The gradual shift in Western physics from a mechanistic universe to one dominated by chance ironically afforded humans an aspect of control over nature and their fate within it, a fate previously sealed by the laws of the universal machine. This shift, beautifully charted in Ian Hacking’s *The Taming of Nature,* meant the random elements within our understanding of natural causality could be tallied in probabilistic statistical analysis that avoided the apparent folly of human agency wrought by the determinist demands of a universe ruled by mechanistic laws. The random and the aleatoric seemed to provide a more accurate view of nature and physics than the unwavering mechanistic one. The rise of measurement, modelling and positivism helped ‘the imperialism of probability’ come to the fore but ‘could only occur as the world itself became numerical’.[[6]](#footnote-6) Thus, the digital logics and manipulations afforded by numbers and alphabetic letters were turned to problematic systems such as hydraulics and wind, and increasingly for military ends.[[7]](#footnote-7) Where once noise reigned, signal in the noise could be gleaned. Eimert’s avant-garde work produced in labs to find, secure and generate such signals in the noise brutally performs these century-long drives in all their glorious collapse. However, to paraphrase W.H. Auden’s elegy for W.B. Yeats: experimental music makes nothing happen.

**2. From Noise to Signal to Noise: How to Differentiate the Two**

There is a large class of phenomena in which what is observed is a numerical quantity, or a sequence of numerical quantities, distributed in time. The temperature as recorded by a continuous recording thermometer, or the closing quotations of a stock in the stock market, taken day by day, or the complete set of meteorological data published day to day published by the Weather Bureau are all time series, continuous or discrete, simple or multiple.

Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine*[[8]](#footnote-8)

The musical harrowing of Kuboyama’s voice and body in Eimert’s work finds an echo in Friedrich Kittler’s analysis of Richard Wagner’s *Ring* Cycle. Geoff Winthrop-Young offers a reading of Kittler on the cycle that argues a trajectory of phonemic development from the nineteenth century to later in the twentieth century determined by developments in Kittlerian discourse networks. The trajectory begins with the aquatic gibberish in the opening of the first opera in the cycle *Das Rheingold,* gibberish which emerges eventually as baby talk that terminates in the *rauschen* conjured by raven wings at Siegfried’s funeral pyre at the cycle’s cataclysmic end. The key in this reading is the verb *rauschen,* ‘one of the most beautiful of German verbs,’ evoking as it does ‘rustling hedges, windswept trees, rushing water’ as well as rustling crow wings near the pyre.[[9]](#footnote-9) This verb, as Winthrop-Young reminds us, converts into its nominal form that German scientists use to identify frequency spectrum impediments in English known as noise.[[10]](#footnote-10) *Rauschen* encompasses the entire journey of speech (and music) in the *Ring*, ‘from murmuring waves and weird words to rustling wings and flickering flames’, or so Kittler’s careful filtering would so shape it.[[11]](#footnote-12) It is a journey of return but without progress per se. Winthrop-Young pithily puts it thusly: ‘The message about the end of all messages is clear: “From noise you came, more noise you made, and to noise you shall return” – the end of the world sounded in “static and flame”’.[[12]](#footnote-13)

If the military continually seeks to find a signal in noise, and if the aleatory in nature as well as human speech generates much of that noise, we can ask how to differentiate noise from randomness. One answer might be that randomness has long been understood as generative (for good and ill) while static has not been interpreted so positively. However, not only do communications channels always contain noise that signal or communication can overcome (a la Shannon), but also that ‘messages can be generated as selections or filterings of noise’.[[13]](#footnote-14) The divisions between signal and noise, between randomness and control, rapidly and easily blur, and in almost all cases become a matter of judgement or value, what we might call aesthetics instead of aisthesis.[[14]](#footnote-15) Nonetheless, randomness equals noise in most applied cases – but when modelled as semi-randomness (or targeted randomness), it can be converted into a signal with a specific intervention. This is where control can result from noise, and the parameters of control prove key.[[15]](#footnote-16)

Such practices that harness the generative capacity of semi-random phenomena have a long lineage in creative works as found in linguistic and sound games. Some examples run the gamut from Jonathan Swift’s satiric take on empiricism in *Gulliver’s Travels* where the Grand Academy at Lagoda houses a random word generating frame in which wisdom is sought by the turn of a crankshaft, to Tristan Tzara’s spoken word performances scripted by pulling words from a hat to the surrealist Exquisite Corpse game to John Cage’s 1957 ‘Concerto for Prepared Piano and Orchestra’ – which uses dice rolls for performance development (as well as Cage’s *I Ching* compositions) to Karlheinz Stockhausen’s ‘Klavierstück XI’ to William Burroughs ‘cut-outs’ and up to Leharen A. Hiller and Leonard Isaacson working probabilistic structures of musical sequence for one of the first computer music compositions ‘Iliac Suite’ (1951) – an early step in AI.[[16]](#footnote-17)

This list, of course, merely scratches the surface of delimited random processes. These examples offer a sense of the sustained logic that leverages the generative and productive capacities of semi-random phenomena, ones designed to create the happy accidents engineered by military planning from the mid-20th century to the present. Whether as pattern recognition of data or actuarial and probabilistic statistics, a contained randomness and the capacity to convert it to strategic advantage is how the U.S. military approached the daunting challenges posed by dynamic systems: that is, by interpreting them as opportunities rather than impediments. The same is true of so-called generative systems, such as Large Language Models (LLM) and generative music. Each of these builds on algorithms from the 1950–60s ‘in physics, engineering and psychology’ that are articulated now as ‘pattern recognition, data mining or machine learning’.[[17]](#footnote-18) These form the basis of AI modelling, and they provide powerful digital/ micro-means of finding signals in random, noisy systems.

The big lesson for removing signal from noise and making the random strategically advantageous is: *the narrower the parameters, the greater the control.* Following on from this lesson is its correlate: *the micro unit equals containment of random elements*. Such narrow parameters reside conveniently in numbers and letters, which return us to the enduring appeal of atomistic logic in the Western tradition. The logic holds that the smallest element of any large-scale system can potentially predict its operation and alter said functioning. This combination of noetic techniques emerges powerfully with the slow demise in the West of the machinic universe, a demise that allowed for non-traditional experimentation in thermodynamics in the nineteenth and early twentieth centuries. Militaries around the world took notice, and the complex intertwining technics eventually found form in the U.S. military’s stated goal for the Cold War: C3I (communication, command, control and information). The centrality of this overarching agenda can be noted in the establishment of the journal *Information and Control* in 1957, which included an article by Claude Shannon on coding for noisy channels in its inaugural issue.[[18]](#footnote-19) Such academic investments helped further a nexus of language, communication, information and control that continues to the present. And of course, the subtitle for Wiener’s authoritative statement about cybernetics for the general public reads: ‘*or Control and Communication in the Animal and the Machine*’.The goal of control became codified in the Department of Defense (DoD) and its external research branch, DARPA (Defense Advanced Research Projects Agency), whose motto in the first decades of the twenty-first century reads ‘Creating and Preventing Strategic Surprise’.[[19]](#footnote-20)

The 2025 call for DARPA Young Fellow Awards presents an example of the DoD’s abiding interest in finding signals in processes where others can only find noise. This research calls for promising new scholars includes a strategic area described as ‘Disruptive Emergent Technology’ to ‘examine the potential for emergent technology to disrupt the tactical battlefield in non-obvious ways’. This particular research agenda offers a list of ‘Key Areas of Interest’ that could potentially become important parts of future DARPA projects. The list includes ‘Position, Navigation, and Timing (PNT)… flow control, tactical power (production, harvesting, storage, and distribution), and Imaging’, each of which pertain to the control of complex spectral ranges within dynamic systems applicable to a battlefield. Also flagged up is ‘flow control’, which can be read in its most capacious sense. Flow control can include a range of complex temporally determined phenomena such as telecommunications, remote sensing networks, information channelling, logistics, personnel, and climate and environmental conditions such as those thermodynamic systems studied in the 19th century that helped clarify human positioning within an aleatoric universe.[[20]](#footnote-21)

Issues of ‘flow control’ and also ‘techniques and tools’ (another key area in the DARPA list of targeted research goals) harken back to specific historical instances that return us to Eimert’s stunning musical work, specifically the concerns presented to the military by the Kennedy Administration’s concerted efforts to ratify a Nuclear Test Ban Treaty with the Soviet Union. The treaty was staunchly opposed by many, if not most, of the Pentagon’s top brass, due to concerns around verification. How could each side trust the other, but more to the point, how could the U.S. trust the Soviets and covertly place them under surveillance to ensure compliance? Into that breach in 1964, stepped a Bell Labs researcher advising the administration, an algorithm, and the sudden and rapid growth of a new field of research: geoacoustics.

**3. Geoacoustics and Sound Labs**

a. establishment of a world-wide standardized seismic research network; b. basic and applied research into the generation and propagation of seismic waves and their detection; c. construction of experimental of seismological observatories and a data analysis center; d. monitoring program for obtaining seismic signatures from the present U.S. series of underground nuclear detonations; e. test and evaluation of on-site inspection techniques

Dr. Charles C. Bates at the 1962 Symposium on the Detection of Underground Objects outlining the goals of the Vela Uniform underground nuclear test detection program[[21]](#footnote-22)

I quickly realized that for me this was the future for computers. Computers seen not as ways of crunching huge quantities of data or storing enormous ready-made forests of material, but computers are the way of growing little seeds

Brian Eno, ‘Generative Music’[[22]](#footnote-23)

The problem the Kennedy administration confronted with its specific barrier to a nuclear test treaty ban lay underground. Since the Vela Project initiative instigated by the Eisenhower administration to provide monitoring of nuclear explosions within the entire biosphere, the Soviet response echoed that of the U.S. by moving nuclear testing under the earth’s surface and thereby defeating extant remote sensing capacities.[[23]](#footnote-24) The Soviets, though, added a further noisy twist by placing their primary testing site in Kazakhstan where geological phenomena such as earthquakes tossed more static into teletechnological tracking. The challenge demanded a means to render random audio (and indeed visual) spectra more predictable and malleable than in the wild of nature’s physics and extract a signal from that exceptionally noisy channel. Ideally this process would be one that could rely on extant remote sensing data and convert it quickly into information, from static to signal. How to accomplish this feat resulted in the resuscitation of a centuries-old mathematical formula sped up for fast calculations – a development that resulted in one of the most ubiquitous algorithms of the past half century. The Fast Fourier Transform’s contemporary provenance resides in telecoms R and D, military geology and sound synthesis research undertaken at the Pentagon and Bell Labs. Its spectral corralling capacities means it is used for audio and visual signal analyses and manipulation from audio signal processing, electronic music, medical imaging, data visualization, radar, telecommunications, spectral identification, pattern recognition, and scientific imaging practices of all stripes, amongst other areas.[[24]](#footnote-25) As such, it leads straight from ’s scientific committee’s remit to the sound labs where Eimert produced his work on Kuboyama.

John Tukey, a Bell Labs engineer seconded to the administration’s scientific committee working on test verification problems, in collaboration with James W. Cooley, developed the FFT as the answer for monitoring subterranean activities in Kazakhstan. (Tukey also coined common computational terminology such as ‘hardware’, ‘software’, and ‘bits of information’ – with bits being a contraction of binary digits.) For most of the twentieth century, Bell Labs functioned as a corporate and government research hub for experimentation and technological innovation in telecommunications and computation. In the 1950s, Bell made the first attempts to produce sound analysis and synthesis using computer technologies, particularly to convert telephonic speech into digital patterns,[[25]](#footnote-26) involving spectral analysis that had been successfully used with the vocoder in earlier decades. This research environment led Tukey to explore spectral analysis as derived from the FFT as a source for test verification, a process that eventually constituted the field of geoacoustics.[[26]](#footnote-27) The FFT afforded spectral controls that could alter understandings of how audio waves might affect human engagements with space (remote sensing, Cold War geology, telecommunications) and time (temporal manipulation) in both military and artistic applications.[[27]](#footnote-28)

The temporal elements of sound as measured in a sine wave became the visible evidence to differentiate an earthquake from an underground nuclear explosion. However, the sine wave often privileged frequency over duration – a spatial compression of temporal phenomena into its longer, predicted temporal span. As Phil Thomson explains it, ‘the brevity of the time scale involved’ in the creation of ‘micro-sound’ sine waves destabilizes frequency’s dominance over time per se.[[28]](#footnote-29) The FFT similarly can provide a small window that allows for accurate time resolution at the cost of frequency resolution, while a bigger window gives the opposite result: frequency resolution at the loss of time resolution[[29]](#footnote-30). ‘In other words’, Thomson writes, ‘there is an uncertainty principle in the relationship between frequency and time, which is particularly noticeable at the micro-level’.[[30]](#footnote-31) The micro-level is where long-distance geoacoustic surveillance operates, and the uncertainty in which analyses are made must convert the noise of random uncertainty into the micro-level granular signal of controllable, or least interpretable, spectral activity. As Wolfgang Ernst explains about micro-sounds and micro-temporalities, which become the atomistic site for understanding, predicting and influencing the operations of dynamic systems: ‘Events that occur in the domain of micro-seconds can no longer be consciously perceived by human senses, and they thus fall into the realm of pure measuring electronics’.[[31]](#footnote-32) Repetition offered by the FFT and granular audio synthesis renders nano-temporality perceivable. As a result, random spectra become manageable and malleable in the windowing processes these technologies afford researchers.

Different rates of time dilation allow different applications of the technics involved, ranging from military to artistic.[[32]](#footnote-33) The desire on the part of the military for reconnaissance purposes to achieve a reading of sounds wave in which the rate = 0, allowing assurance of the signal’s information. However, when the rate = ? (or is a variable) it becomes an artistic opportunity. The vagaries of these technics in operation become ripe with artistic applications (military dual use rationale but of a different order). The FFT is intended to translate time into the spectral domain, converting the unwieldy time event into a visual spectral representation that can be rendered compact, efficient and communicable in short statements (such as ‘440Hz for 20 seconds’) and thus reproducible. The reproducibility means that it can be manipulated in other incidental ways: secondary or tertiary orders of applicability that find form in artistic works. This variable and alterable dilation of time serves artistic projects and further acoustic research at Bell and other sound labs by composers and acousticians alike and in tandem, working with specific overlaps in the domain and rubric of ‘experimentation’.[[33]](#footnote-34)

Some of the logics behind the FFT also had been realized in very specific and limited ways for technologies that pre-date its algorithmic formulation. Sound analysis-synthesis systems precede the FFT by some four decades and reach into the present with information theory, fibre optics and light as a data conveying medium. The FFT immediately merged with and accelerated sound analysis-synthesis developments of the sort Eimert and others enjoyed at sound labs such as the one in Cologne at the WDR. Eimert’s use of the Tempophon electronic device allowed him to capture speech and compress it into a spatial object rather than a temporal process (as with FFT slicing) without losing pitch: the moment infinitely repeatable and possibly expanded into static. Spiraling around these labs were the crosscurrents of research developed by Claude Shannon and others at Bell Labs, building on developments pertaining to cybernetics research. Shannon’s information theory provided ‘a very synthetic discourse’ for the composers assembled in European audio labs to consider message size, compression, analysis, technological challenges and affordances, encoding, transmission, and the limits of human perception.[[34]](#footnote-35) It also allowed them to think critically about ‘technology, predictability and perception’, all of which mirrors the interests of the Macy Conferences in cybernetics.[[35]](#footnote-36) In this confluence resides the basic aesthetic choice of determining, or predetermining, the signal one seeks in the noise.

Once a top-secret covert tool for remote surveillance, the FFT resides in most off-the-shelf computer software packages containing music composition programs. The micro-sound manipulations became compositional building blocks for avant-garde composers working in global Cold War sound labs. The roster of such composers includes a list of leading N. American and European avant-garde experimentation. Less studied in most strands of Western musical history are similar audio labs set up in the former Soviet Union and South America. Regardless of locale, these composers shared interests in expanding sound production possibilities afforded by tape machines and, more importantly, through aural signal manipulation resulting from audio frequency alteration with a greater amount of reproducible control, all of which now could also be turned to compositional ends.[[36]](#footnote-37) The governments, corporations and foundations that bankrolled this research primarily held other agendas but nonetheless brought together researchers in linguistics, structuralism, experimental literature, cybernetics, information theory and telecommunications engineering for their greater causes. In this heady combination of complementary pursuits charged, literally, with electronic potentialities, the Cold War sound labs institutionally embodied the legacies of harnessing randomness for its untapped futural promises not espied on the horizon of a mechanistic universe. The generative possibilities of semi-random processes became their playground, and it was but one kind of site in a cornucopia of such experimentalist, outside-the-box, semi-utopian gatherings taking place beneath, and indeed in the hope of staving off, nuclear mushroom clouds.

**4. Cybernetics, Chance, and Control**

Planck’s eventual explanation of this easily observable phenomenon was, however, not simple. It was associated with ideas concerning mathematics and thought in general which go back to the end of the seventeenth century, during a period when an important intellectual battle was being fought between the atomists, who believed in the discreteness of matter, and those who believed that matter is continuous. There were various philosophical considerations which made this debate especially critical

Norbert Wiener, *I Am a Mathematician*[[37]](#footnote-38)

In the epigraph to this section, the co-founder and most prominent proponent of cybernetics, Norbert Wiener, lays out an argument central to the early moments of modernity that attempted to use ancient philosophical traditions to strike a modern resistance to dogma. The resistance included a trust in empiricism as well as faith in the efficacy of discrete entities found in atomist thought. Essentially the philosophical argument is the same one found in digital analysis and logics (discrete entities) versus continuous ones (analog matter). Thus emerges a return to Leucippus, Democritus and other atomist thinkers found in the pre-Socratics. Coterminous with such thinking is the belief that atoms scale. In such scalability comes the attendant opportunity to influence the larger formation of the atomic and molecular assemblage by manipulation of its micro-components. Small, discrete phenomena – such as atoms, numbers and alphanumeric writing technologies – take on increased import and influence from these positions, and they coincide with other scientific shifts toward evidence of the universe being more random than mechanically predetermined.

As the nineteenth century progressed, interest in random and apparently unpredictable processes such as thermodynamics gave increased empirical credibility to chance and randomness as an important, if not the central, operational means of the universe. An important result of this line of inquiry resulted in the emergence of statistics and probabilistic analyses as a site for human society to exert a kind of agency. The philosophical atomism that Wiener invokes differs from but informs atomistic logic outside of philosophical systems. The influence of micro-materiality due to its indivisibility and capacity for metonymic scaling found capacious application beyond philosophy. Its role in such widely disparate models as indeterminacy and the aleatory in contrast with probability and the stochastic gave atomism several counterintuitive connections between apparently different but related phenomena. The turn to statistical models and biometrics in the late nineteenth century, as spearheaded by Francis Galton, helped elevate both the law of indeterminism *and* the control it afforded. In the chaos and noise, pattern and signal could be discerned without having to cede to universal determinates: causality yields to statistical calculation.[[38]](#footnote-39) As Shannon and later Kittler argued, the paradox of indeterminism is resolved in understanding noise as the necessary channel in which a signal can be found, and indeed with noise taking on the potential to be signal in and of itself. The role of randomness within complex dynamic systems accounts for the opportunities and impediments these systems offer.

The conversion of dynamic systems from impediments to strategic advantages has long played a substantial role in the U.S. military’s technological research and development. From signal interpretation with remote sensing systems to telecommunciations to algorithms, media and information theory, and the weather, the unintended consequences of both dynamic systems in nature and technological attempts to control them led to innovations and accidents, developments and prediction advances that furnish large swaths of our current global sensorial domain. The study of dynamic systems and the means by which influences of their smaller component parts can scale in predictive and potentially influential ways created an understanding of the relationship between a mechanistic and a probabilistic world. Finding patterns present in micro and deep structures revealed an ‘orderly disorderly’ (or semi-randomness) operative in empirical and material complexities.[[39]](#footnote-40) As such audio and visual spectra provide a productive site of sustained scientific and technological inquiry, and the FFT appears on the scene. With mathematical roots back to 19th century speculative formulations, ‘Fourier’s solution of all continuous functions (including musical notes) into sums of pure sine harmonics was achieved before Heimholz and Edison’,[[40]](#footnote-41) originally with the late eighteenth century Swiss mathematician Gauss. The insight offered by Fourier underscores the discrete entities that constitute apparently continuous phenomena: a digital base of analogue events. It remained an interesting but not terribly useful mathematical formulation until Tukey’s 1960s FFT.

Kennedy’s committee, the FFT as an accelerated form of the Discrete Fourier Transform, and the Cold War sound labs were all forged in the continuing influence of cybernetics and its import across virtually every realm of academic research. As it emerged out of the Macy Conferences in the 1940s, cybernetics engaged with strands of probabilistic analyses and logics. The keys provided by probabilities allowed for the intensification of prediction and optimization. Although charting even a few of the interconnections at play with cybernetics’ histories and continued relevance fills volumes, a thumbnail sketch of its three orders developed over several decades of the twentieth century helps us to understand the ever-increasing importance of randomness in cybernetics’ development. Biological (including human), machine and human-machine systems in first-order cybernetics work through feedback loops to achieve states of homeostasis. As such, they mechanistically sort out imbalances. Second-order cybernetics grew out of academic dissatisfaction with the mechanistic nature of feedback and eventually emerged most influentially in the late 1970s. Second-order cybernetics explores the necessary relationship between observers of systems as *systems themselves*. Thus, a kind of chiasmatic set of systemic observations watch each other in operation, resulting in a recursivity of systemic interaction, development, and observation. The context in which systems function becomes inseparable from the systems and their operations, which is also true for any observers. This development marks an important return of 1930s systems theory in biology, as articulated by von Bertalanffy, and its influence on the founding of cybernetics led to third-order cybernetics with its emphasis on living systems, cognition and self-making (or autopoiesis). Third-order cybernetics’ formulations of autopoiesis held great appeal for thinkers concerned with generative systems in multiple domains, from computation, language models and musical composition. The links between third-order cybernetics, generative systems and autopoiesis helped the co-development of each of these fields, though the role of random phenomena and the drive to control them differed widely.

**5. Kuboyama Resurfaces: from Eimert to Eno**

Classical music, like classical architecture, like many other classical forms, specifies an entity in advance and then builds it. Generative music doesn't do that, it specifies a set of rules and then lets them make the thing…generative music is out of control, classical music is under control. Now, out of control means you don't know quite what it's apt to do. It has its own life…Generative music is unpredictable, classical music is predicted. Generative unrepeatable, classical repeatable. Generative music is unfinished, that's to say, when you use generative you implicitly don't know what the end of this is

Brian Eno, ‘Generative Music’ [[41]](#footnote-42)

The continuous flow of uninterrupted human speech is dismantled in Eimart’s avant-garde elegy for Kobuyama. The analog continuity of speech’s component parts cracks into the discrete units of phonemes, each of which became a unit of musical experimentation in the Cold War audio labs. A range of canonical avant-garde compositions evidence the appeal of phonetics for these composers, many of whom were also propelled by James Joyce’s linguistic experimentation. The most famous and indicative of these might be the Luciano Berio and Cathy Berberian’s 1958–59 collaboration for voice and tape *Thema (Omaggio a Joyce).* (The novelist himself became a sort of random-generating linguistic machine in *Finnegans Wake,* but one bent on the total control of cross-language puns and jokes.) The list of phonetics-inspired works to emerge from these experimental acoustics labs runs the gamut from Karlheinz Stockhausen to Iannis Xenakis, Mauricio Kagel, John Cage, Eimert and many others.[[42]](#footnote-43) Thrown into the mix of reading and lecture materials in the European sound labs were Saussurean linguistics and information theory. The effects of Saussurean phonology and its structuralist agenda to parcel up sounds into quantifiable units that can be analysed in a quantifiable manner made phonemes convertible to machinic manipulation that could alter and render unique all of their spectral qualities. Phonemes were in the air, in the labs, and in the ledgers of funding bodies interested in telecommunications, cryptography and surveillance. One appeal phonetic appeal for composers was their malleability in terms of tone, timbre and pitch as they formed playful strings that could fly in the face of deterministic analogue flow. Phonemes provided the digital building blocks for the indeterminate and apparent randomness found in reconstructing speech. The resultant defamiliarizing process made for generative semi-random patterns of speech that sounded simultaneously alien and familiar when striking the cochlea.

Eimert’s piece perfectly invokes the chronotope of the Cold War sound labs moment. Like Brownian molecules in constant collision and motion, the phonemes in Eimert’s montage bounce in and out of aural focus within their static-ridden soundscape. The voice as conveyor of a semantic signal eventually descends into unrecognizability – unidentifiable even as voice much less message. The particles of phonetic sounds emerge in their particulate specificity before dissolving into indecipherable blips, a cryptography with little apparent signal except the crypt to which radiation victims are carcinogenically consigned – their fate sealed by the truly aleatory forces of wind and currents that (mostly) elude military strategic control, and which most decidedly did in the Bikini Atoll.[[43]](#footnote-44) Eimert’s work hauntingly and beautifully simulates chaos while invoking cellular-level disintegration of voice and body, therefore commenting on and critiquing the high-stakes mid-century geopolitical game for which the toys the composers played with in the sound labs were made.

The kinds of controlled randomness converted into sonic play found in the sound labs merged with the larger disruption of music’s tonal systems begun early in the twentieth century that resulted in newer pattern-generating possibilities (such as serial, twelve-tone music). As noted above, third-order cybernetics pertains directly to the kind of ‘semi-randomness’ found in generative systems. Even if generative systems and autopoiesis seemed to constitute the future as formulated in the last quarter of the century, essential elements had begun decades earlier. The generative half of the ‘generate-and-test’ function in machine intelligence, including generative AI, dates to Alan Turning’s work in the first years of the 1940s,[[44]](#footnote-45) and the hypothesis of machinic selection between various data points such as one finds in checkers or chess. The clear point of this research was to minimize or remove random decisions. To do so, the process includes the narrow windowing of random possibilities through heuristics and rules to guide the semi-agential selection.

Generative and apparently stochastic software works with a limited number of variants and thus variations can and still do generate an apparently infinite number of combinations – or certainly enough to seem infinite when considered from the perspective of limited human interaction with the work. Randomness is programmed into the software, leaving us with the second-order cybernetic oxymoron of controlled randomness. This in turn takes a leap to third-order cybernetic autopoiesis systems or environments that supposedly avoid the dialectic synthesis of the two lower orders to become a third system operating at a different level of complexity.

Generative systems, such as AI, aspire to and claim a manifestation of such an autopoietic condition. Addressing machinic autopoiesis in the context of third-order cybernetics, N. Katherine Hayles pointedly invokes the work of Dorion Sagan and Lynn Margulis to counter the claim that machinic autopoiesis is even possible. Paraphrasing these scholars, Hayles echoes their recognition ‘that machines are not self-making or self-producing, hence not autopoietic’.[[45]](#footnote-46) Sagan and Margulis argue that machines cannot make themselves and require people to produce them while humans are already autopoietic in that regard; that is, humans can generate themselves while machines cannot, rendering the latter allopoietic.[[46]](#footnote-47) Generative music is much closer to Jack Burnham’s systems aesthetics than to third-order cybernetics and autopoiesis.[[47]](#footnote-48) Setting up a process, or several processes, within contained parameters and allowing these to unfold over time within the controlled environment is the gist of Burnham’s system aesthetics. Its influence in semi-random musical composition can be found in works such as Terry Riley’s ‘In C’, which contains a list of seven instructions for performers. The work consists of 53 patterns to be played in a sequential and linear order, but performers are free to repeat the patterns as many times as they wish, and if any pattern proves too difficult to play, the performer can go to the next one. The instructions encourage active listening on the part of the performers – for them to pause, get a sense of group progression, and to attempt a close coherence in the trajectory. Performers can choose any instrument they desire, including voice, and the number of performers is open. Similarly, the piece ends with the last pattern, which is repeated until all performers arrive at it. The performers determine the duration and conclusion, not the composer beyond the instructions list.

A performance of Riley’s ‘In C’ or attending a Brian Eno generative sound and projection exhibition reminds us of lessons the military establishment knew long ago and indeed helped bring to fruition: everything is noise until it isn’t; everything is random until a pattern is discerned, or projected as such. The true random element might reside in that aesthetic choice.

**6. Coda: The Taming of Randomness**

Once the mechanistic universe and its undergirding principles began to wobble, they wobbled everywhere, especially in physics. Challenges to base knowledge that draws on a mechanical universe include the assumptions held by Newton and Einstein that gravitation was a constant across the universe, a challenge posited by the physicist Robert Dicke that gravitational pull might not be a constant but rather be affected by the unequal, or random, distribution of mass in the universe

Kendrick Oliver, ‘“The Lucky Start to Today’s Cosmology?”’[[48]](#footnote-49)

A narrative that runs through this article could bear the title, ‘the taming of randomness’ – a title that clearly rephrases Ian Hacking’s *The Taming of Chance.* The wide-ranging narrative invites deeper dives at every moment of its unfolding with a few on offer here. One link in the narrative connecting its disparate elements and uncommon collaborators in telecommunications experiments, military remote sensing, electroacoustic research, electronic music, the vocoder, Cold War geology and nuclear test verification is the spectral analysis activities derived from the FFT. It presents a particularly fecund way of tracking the long road to control so coveted by military R and D scientists, Cold War planners and sound artists alike. A Cold War logic of control *of* and *through* random phenomena obtainable by the isolation of temporal processes into spatial storage of infinitely repeatable units – digital marks – allows for prediction and control of said temporal processes to emerge as possibilities. The insights provided by atomic logics and units constitute the taming of randomness as immaterial desire and material manifestation from covert operations to avant-garde experimentation and quotidian daily experience for many in the post mid-century world. The lesson these teach is that the noise in which we dwell is random only by virtue of our decision to categorize it as such.

1. Geoffrey Winthrop-Young, ‘*Wotan’s Stormtroopers and the Total Art Machine: Kittler’s* Ring of the Niebelung’, in David Trippett (ed.), *Wagner in Context* (Cambridge: Cambridge University Press), 405 [↑](#footnote-ref-1)
2. I would like to thank Ranjan Ghosh for inviting me to contribute to this special issue of *Philosophy, Politics, Critique.* The article has benefited from numerous interlocutors including, but not limited to, Jussi Parikka, Robert Pietrusko, John Beck, Cera Tan, Orit Halpern, Ian Dawson, Louise Siddons, Sean Cubitt, Alessandro Ludovico, Tsvetelina Hristova, Kendrick Oliver, Anna Englehardt and my terrific colleagues at the Winchester School of Art at the University of Southampton. [↑](#footnote-ref-2)
3. David Ropeik, ‘How the unluck Lucky Dragon birthed an era of nuclear fear’, *Bulletin of the Atomic Scientists,* February 2018. Available at *<*<https://thebulletin.org/2018/02/how-the-unlucky-lucky-dragon-birthed-an-era-of-nuclear-fear/>> (last accessed 03 January 2025). [↑](#footnote-ref-3)
4. Ibid. [↑](#footnote-ref-4)
5. See Ryan Bishop, ‘Eyes, Ears, Mouths: A Sensorial Military Triptych (with satellite, electronic music and vocoder)’, in Jens Bjering, Anders Engberg-Pedersen, Solveig Gade, and Christine Strandmose Toft (eds.), *War and Aesthetics: Art, Technology, and the Futures of Warfare* (Cambridge, MA and London: MIT Press, 2024), 151–169; Jennifer Iverson, *Electronic Inspirations: Technologies of the Cold War Musical Avant-garde* (Oxford: Oxford University Press, 2019); Mara Mills, ‘Media and Prosthesis: The Vocoder, the Artificial Larynx, and the History of Signal Processing’, *Qui Parle,* 21.1 (2012), 107–149. [↑](#footnote-ref-5)
6. Ian Hacking, *The Taming of Chance* (Cambridge: Cambridge University Press, 1990), 5. [↑](#footnote-ref-6)
7. Ibid. [↑](#footnote-ref-7)
8. Norbert Wiener, Norbert, *Cybernetics, or Control and Communication in the Animal and the Machine,* (Cambridge MA and London: MIT Press, 1948). [↑](#footnote-ref-8)
9. Winthrop-Young, 405. [↑](#footnote-ref-9)
10. Ibid. [↑](#footnote-ref-10)
11. Ibid. [↑](#footnote-ref-12)
12. Ibid. [↑](#footnote-ref-13)
13. Friedrich Kittler, *The Truth of the Technological World: Essays on the Genealogy of Presence*,trans. Erik Butler (Stanford: Stanford University Press, 2014), 169. [↑](#footnote-ref-14)
14. See Bishop, ‘Eyes, Ears, Mouths’. [↑](#footnote-ref-15)
15. For more on how this work leads to sound analysis and synthesis technologies, as well as the advent of electronic music, see Manfred R. Schroeder, *Computer Speech: Recognition, Compression, Synthesis*, 2nd ed. (Berlin: Springer, 2004; Curtis Roads, ‘Sound Transformation by Convolution’, in *Music Signal Processing*, Curtis Roads, StephenTravis Pope, Aldo Piccialli and Giovanni De Poli (eds.) (New York   and London: Routledge, 2013) 411-43; and Curtis Roads, *The Computer Music Tutorial*, (Cambridge MA: MIT Press, 1996). [↑](#footnote-ref-16)
16. See John R. Pierce, *An Introduction to Information Theory: Symbols, Signals and Noise,* 2nd rev. ed. (Garden City NY: Dover Press, 1980); Hannah B. Higgins and Doulas Kahn (eds.) *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts* (Berkeley: CA University California Press, 2012); Lejaran A. Hiller and Leonard A. Isaacson, *Experimental Music. Composition with an electronic computer* (New York: McGraw-Hill, 1959). [↑](#footnote-ref-17)
17. Adrian Mackenzie, ‘Simulate, Optimise, Partition: Algorithmic Diagrams of Pattern Recognition from 1953 Onwards’, in John Beck and Ryan Bishop (eds.), *Cold War Legacies: Systems, Theory, Aesthetics* (Edinburgh: Edinburgh University Press, 2016), 50. [↑](#footnote-ref-18)
18. Claude Shannon, Claude, ‘Certain Results in Coding Theory for Noisy Channels’, *Information and Control*,1 (1957), 6–25. [↑](#footnote-ref-19)
19. DARPA (Defense Advanced Research Projects Agency). Available at <<http://www.darpa.mil>> (last accessed 22 April 2025). [↑](#footnote-ref-20)
20. ‘DARPA Seeks Innovative Proposals from Early Career Researchers at US Institutions’. Available at <<https://www.darpa.mil/news-events/2024-10-24a>> (last accessed 15 April 2025). [↑](#footnote-ref-21)
21. Charles C. Bates, ‘Two Years of VEAL UNIFORM – A Progress Report’, *Proceedings: Symposium on the Detection of Underground Objects, Materials and Properties,*  US Army Engineer Research and Development Lab, Ft. Belvoir: Virginia (1962) 45-72 [↑](#footnote-ref-22)
22. Brian Eno, Brian, ‘Generative Music’ (1996). Available at <<http://www.inmotionmagazine.com/eno1.html>> , 1996 (accessed 03/01/2025). [↑](#footnote-ref-23)
23. Begun in 1959 by Eisenhower’s administration, the Vela Project provided a substantial investment in remote sensing and surveillance technologies and science to eventually secure a partial nuclear test ban treaty with the Soviet Union. The treaty would ban nuclear tests underwater, on land, in the atmosphere and outer space. Missing from the treaty, and thus making it a partial ban, was underground testing, which also caused the greatest challenges for extra-national monitoring. [↑](#footnote-ref-24)
24. D.N. Rockmore, ‘The FFT: An algorithm the whole family can use’, *Computing in Science and Engineering*,2.1 (2000), 60. [↑](#footnote-ref-25)
25. Mills, ‘Media and Prosthesis’, 189. [↑](#footnote-ref-26)
26. As part of the very large Vela Project, Vela Uniform concentrated on underground testing, and thus seismology suddenly became a strategic science in the eyes and ears of DoD. Begun under the Eisenhower administration in 1950, as noted above, and most but not all of the documents and research conducted by Vela Uniform were ever classified to indicate U.S. commitment to nuclear testing as a global geopolitical project. For a sustained overview of seismology and Vela Uniform, see K. H. Barth, ‘The Politics of Seismology: Nuclear Testing, Arms Control, and the Transformation of a Discipline’, *Social Studies of Science*, 33.5 (2003), 743–781, which was part of a special issue entitled ‘Earth Sciences in the Cold War’. Part of the Seismic Acoustics work that fell under Vela Project is represented in the proceedings of the Symposium on Detection of Underground Objects, Materials and Properties conducted by the U.S. Army Engineer Research and Development Labs at Fort Belvoir, Virginia (1962). Some of the papers and reports given include work on soil, hydrology, underground explosions, infrared photography, digital recording of spectro-radiometric information, magnetic detection, geochemical auras, mine detection and aerial photographic interpretation of vegetation, among other topics. I am indebted to Robert G. Pietrusko for this archival material. [↑](#footnote-ref-27)
27. Once again, thanks go to Robert G. Pietrusko for showing me the link between the Vela Uniform and the computer music experimentation at Bell Labs, especially with regard to the Fast Fourier Transform. My connection between them here is to merely point to the spatial elements of military technological inquiry into aesthetics and some artistic applications of the same. This material around Vela Uniform and computer music at Bell will be developed more fully in a project Pietrusko and I intend to work on together. My conversations with Bobby have been very fecund and a terrific catalyst for many parts of this paper. [↑](#footnote-ref-28)
28. Phil Thomson, ‘Atoms and Errors: Towards a History and Aesthetics of Microsound’, *Organized Sound,* 9.2 (2004), 207. [↑](#footnote-ref-29)
29. Ibid. [↑](#footnote-ref-30)
30. Ibid. [↑](#footnote-ref-31)
31. Wolfgang Ernst, *Chronopoetics: The Temporal Being and Operativity of Technological Media,* trans. Anthony Enns (London: Rowman and Littlefield, 2016), xxi. [↑](#footnote-ref-32)
32. This is a point John Phillips and I explored at length in *Modernist Avant-garde Technologies and Contemporary Military Technology: Technicities of Perception* (Edinburgh: Edinburgh University Press, 2010). [↑](#footnote-ref-33)
33. I am indebted to Bobby Pietrusko for this explanation of the processes involved here that can then be applied for artistic experimentation. [↑](#footnote-ref-34)
34. Iverson, *Electronic Inspirations,* 111. [↑](#footnote-ref-35)
35. Ibid. [↑](#footnote-ref-36)
36. See Higgins and Kahn, *Mainframe Experimentalism*; Iverson, *Electronic Inspirations*; and Robin Maconie, *Other Planets: The Music of Karlheinz Stockhausen* (Lanham MD, Toronto, Oxford: The Scarecrow Press, 2005), among others. [↑](#footnote-ref-37)
37. Norbert Wiener, *I am a Mathematician,* (Cambridge, MA and London: MIT Press, 1964). [↑](#footnote-ref-38)
38. Hacking, *Taming,* 2. [↑](#footnote-ref-39)
39. N. Katherine Hayles, *Chaos Bound: Orderly Disorder in Contemporary Literature and Science* (Ithaca and London: Cornell University Press, 1990). [↑](#footnote-ref-40)
40. Kittler, *Truth,* 48. [↑](#footnote-ref-41)
41. Brian Eno, ‘Generative Music’ <http://www.inmotionmagazine.com/eno1.html> (1996) (last accessed 23 April 2025) [↑](#footnote-ref-42)
42. See Bishop, ‘Eyes, Ears, Mouths’; Iverson, *Electronic Inspirations*; Mills, Media and Prosthesis’. [↑](#footnote-ref-43)
43. For a discussion of military attempts to and successes at predicting turbulence in battlefield conditions for strategic advantage see Ryan Bishop, ‘The Military Aleatory: Weaponizing Winds’, *Media+Environment* 6.2 (2024). Available at <<https://mediaenviron.org/article/123341-the-military-aleatory-weaponizing-winds>> (last accessed 23 April 2025) Some of the phrasing in this paragraph comes from that piece. [↑](#footnote-ref-44)
44. Jack Copeland (ed.), *The Essential Turing: Seminal Writings in Computing, Logic, Philosophy, Artificial Intelligence, and Artificial Life* (Oxford: Clarendon Press, 2004), 354–7. [↑](#footnote-ref-45)
45. N. Katherine Hayles, ‘Detoxifying Cybernetics: From Homeostasis to Autopoeisis and Beyond’, in Yuk Hui (ed.), *Cybernetics for the 21st Century: Epistemological Reconstruction* (Hong Kong: Hanart Press, 2024), 91. [↑](#footnote-ref-46)
46. Ibid. [↑](#footnote-ref-47)
47. See John Beck and Ryan Bishop, *Technocrats of the Imagination: Art, Technology and the Military-Industrial Avant-garde* (Durham NC: Duke University Press, 2020); Jack Burnham, *Beyond Modern Sculpture: The Effects of Science and Technology on Sculpture* (New York: George Braziller, 1968); Jack Burnham, ‘Systems Esthetics’, *Artforum,* 7.1 (1968), 30–35; Jack Burham, *Dissolve into Comprehension: Writings and Interviews 1964-2004,* Melissa Ragain (ed.), Hans Haecke (foreword) (Cambridge MA: MIT Press, 2015); Edward A. Shanken, ‘The House that Jack Built, *Leonard Electronic Almanac* 6.10 (1998). [↑](#footnote-ref-48)
48. Kendrick Oliver, ‘“The Lucky Start Toward Today’s Cosmology”? Serendipity, the “Big Bang” Theory, and the Science of Radio Noise in Cold War America’, *Historical Studies in the Natural Sciences,* 49.2 (2025), 151–93. [↑](#footnote-ref-49)