Nature of Radio Signals

Interview with Douglas Kahn

Douglas Kahn is a historian and theorist, author of Noise Water Meat: A History of Sound in the Arts *(1999), and* Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts *(2013). He is Honorary Professor at the University of Sydney and Professor Emeritus at both the University of California, Davis, and the University of New South Wales, Sydney. The interview was conducted by Selena Savić in January 2021 and revised in March 2023*

Selena Savić: Your book *Earth Sound Earth Signal*[1] was one of the primary sources of inspiration for the project on *Radio Explorations*. Your writing on the way radio was heard before it was invented can be taken as the guideline for problematizing our knowledge of radio signals and the technicity of listening practices. Because radio can be 'natural' as in electromagnetic energy emitted by lightning, it extends beyond applied engineering knowledge. You mentioned, however, that it would be difficult to consider any radio signal 'natural' because the realignment of weather systems and increase in extreme weather events means a reconfiguration of the incidence of naturally occurring emissions, as discussed in the 1999 article by Reeve and Toumi.[2] Investigating correlation between global lightning activity and global temperature, the authors found a significant correlation between the global increase in temperature and in

1 Douglas Kahn, *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts* (Berkeley: University of California Press, 2013).

2 N. Reeve and R. Toumi, "Lightning Activity as an Indicator of Climate Change," *Quarterly Journal of the Royal Meteorological Society* 125, no. 555 (1999): 893–903, https://doi.org/10.1002/qj.49712555507.

lightning activity, in the Earth's northern hemisphere. Would you say that everything changes with global warming because all electromagnetic energy that affects the Earth is in a way 'filtered' by our ionosphere, whose properties are changing with increasing heat?

Douglas Kahn: The natural in natural radio denoted terrestrial radio that was not generated by humans, and it can refer to extraterrestrial radio in that respect. It was radio that could be heard and otherwise detected but not sent by anyone, radio using communications technologies but not communicating. *Sensing* is a better term and, indeed, so-called telecommunications technologies in the nineteenth century were used both wittingly and unwittingly, scientifically and aesthetically, as sensing devices within the frame of technological variability discussed in the book, that is, a technology designed for one function used for another. Early encounters with natural radio were on the telephone where, in effect, telephone lines and grounds became antennas before antennas. The 'natural' in this case was bolstered by how very low frequency (VLF) radio generated by lightning and other phenomena fell into the audio-frequency range of human hearing with only simple transduction available in pre-radiophonic technologies. It was heard while listening for other things. Naturalness was retained even after radiophonic technologies, no matter from where the original signal emanated with respect to normative hearing.

The full spectrum electromagnetic bursts of lightning strikes generate dominant forms of natural radio, travelling (transmitting) great distances, bouncing between the ionosphere high in the Earth's atmosphere and the surface of the Earth and, at times, catching a ride on magnetoionic flux lines out into the magnetosphere that reach out about six Earth radii into outer space, and then looping over to the opposite hemisphere, sometimes looping back. When transduced, these huge arcs can be heard as delicate glissandi, a crisp little whistle to the thunder's basso profundo. They are unlikely upper register products of the massive amounts of energy released with lightning. They can travel in the magnetosphere from one 'conjugate point' to another in the opposite hemisphere, a kind of conjugal planetary eroticism. At

this very moment we stand one big spark away from gently whistling to our planetary partner, and vice versa. It is not a great relationship because they don't talk often. The flux lines are diaphanously transient and temperamentally dependent upon geomagnetic activity and solar winds, with weather and space weather twisted into an orbital torque. Whistling at Earth magnitude has many moving parts.

The redistribution and severity of weather events involving lightning within an anthropogenically changed climate is the main reason natural radio is less, or no longer, natural. Severity has not merely increased, as predicted decades ago, but accelerated on older models, and incidence of lightning, its spatial and temporal concentration, has changed accordingly. The static, sliding tones, and glissandi now have human content. Lightning's audible anthropogenesis in radio and thunder is an astounding transformation. Lightning was once associated mythologically with the destructive power and moralism of the gods; now it is more of a self-suicidal pact or, rather, asymmetrical omnicide carried on by a tiny class that ignores the logical conclusion of its own fate. The gods are now bourgeois, corrupt and criminal, with a political power that has mated with and mutated lightning to create monsters. They promise everything is under control, but they are not able to control something as down to earth as lightning. They have instead gone troppo, Australian slang for going mad due to hot tropical conditions, Doctor Moreaus in their troposphere. Their lightning makes it difficult to call this radio natural. What does the dry lightning igniting a forest rendered kindling by prolonged drought sound like, or the lightning generated by a pyrocumulus cloud fed by the forest creating its own weather? I saw one such cloud ten kilometres from my home in the Blue Mountains during the recent fires in Australia.

Like many I find natural radio beautiful, and I love lightning and thunder. One night where I live there was so much lightning, for several minutes it seemed like day interrupted by flashes of darkness. I was on top a hill running home, so danger pushed it into the sublime. During thunderstorms I sometimes tune an old transistor radio between stations to listen to the static bursts of lightning, which gives a feeling of being enfolded by weather beyond the horizon; as spatial experience it's

much cheaper than wave field synthesis, and in a much larger space. Nevertheless, the beauty is like seeing a sunset and realizing its colours are due to air pollution from a factory in the region. The polluters of natural radio are global, with regional offices. Several years ago, climate modelling became sophisticated enough to validate climate attribution studies, that is, the ability to identify sources and degrees of responsibility for extreme weather events, narrowing it to certain industrial sectors, all of which have ensembles of power populated with individuals and family estates. Oceans tighten around their island tax havens. They have not merely stigmatized the sky and its radio, they are responsible for massive destruction, none of it with the old-fashioned moral authority of myth. They have removed weather events from the list of natural disasters, where earthquakes not caused by fracking remain. I discuss them in my essay, "What is an Ecopath?"[3]

Perception can shift technically, conceptually, and experientially to statistical and turbulent means adequate to hearing the toxicity of this (certain) human content. Playing with perceptual registers is what many artists do; others shift apperception to migrate content toward the tacit. Musicians not only sink sound into muscle memory, they sink hearing. Those who do not play also perform hearing. We are already thinking about and experiencing environments dynamically, in fields and systems, to be ecological in the first place. The frenzy of statistics in AI is already salting the daily lives of many, and quantum computing will begin to range influence once it quits perpetually promising. People hear and otherwise perceive adaptively in many models. In whatever trajectory, we should be able to sense intergenerationally and render dynamic homeostasis with the planet routine. A major experiential conundrum of climate catastrophe is its latency, the delayed effects of emissions released currently, or how ecopaths murder now but hide the bodies in the future. As kids we know the latency of lightning, the distance involved until the thunder arrives. Although we don't always

3 Douglas Kahn, "What Is an Ecopath?," *Sydney Review of Books* Climate Crisis (March 3, 2020), https://sydneyreviewofbooks.com/essay/what-is-an-ecopath

see the flash, the simultaneous static heard is beyond our sight. What is the human content, its care and corruption, across the land in the distance travelled? If music is the art of time, what of latency now that the storms have hit?

SS: The starting point for Henri Lefebvre's theory of rhythmanalysis had a medical connotation: it was about observing vibrations in bodily organs to detect anomalies. Do you think that has also changed?

DK: Lefebvre's rhythmanalysis had musical inspiration tied to his abilities as an amateur pianist of Western art music with Mozart at the top. His short book, co-written in part by Catherine Régulier,[4] was one of his last writings, so his lifelong musical loyalties would have ruled the day. Since he didn't have time to develop or demonstrate his analysis from closer examination of the sciences and (other) cultural traditions, he defaulted to an abstract and universalist approach. He talks about the rhythms or, rather, polyrhythms of the body as a garland of rhythms, which is merely a simple gesture to what occurs. I would recommend *Rhythms of Life* by Russell Foster and Leon Kreitzman for starters.[5] His own culturally-bound music was a triad of melody-harmony-rhythm, and he thought the third item was most neglected, so neglected that it deserved a new, dedicated branch of knowledge: rhythmanalysis. Another triad, time-space-energy, described the cosmos, and rhythm fit in thusly: "Everywhere where there is interaction between a place, a time and an expenditure of energy there is rhythm."[6] I don't live in that universe. Among the physical and conceptual fields of energies, repetition

4 Henri Lefebvre and Catherine Régulier, "Le projet rythmanalytique," *Communications* 41, no. 1 (1985): 191–99, https://doi.org/10.3406/comm.1985.1616.

5 Russell G. Foster and Leon Kreitzman, *Rhythms of Life: The Biological Clocks That Control the Daily Lives of Every Living Thing* (New Haven: Yale University Press, 2005).

6 Russell G. Foster and Leon Kreitzman, *Rhythms of Life: The Biological Clocks That Control the Daily Lives of Every Living Thing* (New Haven: Yale University Press, 2005).

is common but not intrinsic and plenty of places among my musical loyalties where one or all of melody, harmony, and rhythm may go missing.

Lefebvre's concept appealed to Gaston Bachelard's earlier writing on rhythmanalysis. Bachelard in turn cited as his touchstone a Lúcio Alberto Pinheiro dos Santos text known only through his quotation of it, since nobody had seen it or could find it since (that may have changed). The 'vibrations in bodily organs' you mention are pharmacologically manifested in his discussion of Pinheiro dos Santos' 'wave biology,' a reference to homeopathy. Bachelard is rightfully suspicious but suspends his doubts to explore the abstract reasoning behind it. His thoughts on rhythmanalysis in general occupy a conflicting, if not convincing, meeting ground of his philosophy of science and elemental poetics, presuming rigor of the former and license of the latter, a schism that Michel Serres pointed out in his published conversations with Bruno Latour.[7]

Lefebvre's elaboration of Bachelard created its own fields of study. What his text lacked ecologically has been introduced by Gordon Walker in *Energy and Rhythm: Rhythmanalysis for a Low Carbon Future*, with the notable goal for remediation through a "general principle of reconnection and return to natural rhythm-energies."[8] It certainly has implications for design. Rhythmanalysis has also played a less practical role in cultural theory over the last decade too, where it has been coupled with 'vibrational ontology,' sound, and music. I distinguish this theory from cultural history in my essay "On Vibrations: Cosmographs."[9] Steve Goodman drew attention to Bachelard and Lefebvre by giving rhythmanalysis its own chapter in *Sonic Warfare*.[10] It is a long way from Mozart to Goodman's electronic dance music. Both moved into a discursive space

7 Michel Serres and Bruno Latour, *Conversations on Science, Culture, and Time*, trans. Roxanne Lapidus (Ann Arbor: University of Michigan Press, 1995).

8 Gordon Walker, *Energy and Rhythm: Rhythmanalysis for a Low Carbon Future* (London: Rowman & Littlefield, 2023), p 169.

9 Douglas Kahn, "On Vibrations: Cosmographs," *Sound Studies* 6, no. 1 (January 2, 2020): 14–28, https://doi.org/10.1080/20551940.2020.1713509.

10 Steve Goodman, *Sonic Warfare: Sound, Affect, and the Ecology of Fear* (Cambridge, Massachusetts: MIT Press, 2012).

that had been vacated by tropes of social harmony, frequency standing in for proportionality, and neither differ significantly from claims made by the Western symphonic repertoire of having privileged access to the universe. Goodman's 'ecology' is free of pollution, climate disruption, species extinction, etc., which would seem required for staging grand panoramas.

Moreover, having music as fundamental for rhythmanalysis seems reductive; energy positions it more appropriately. In Bachelard's *The Psychoanalysis of Fire*, in what may be a first appeal to Pinheiro dos Santos, the concept occurs within a discussion of how the unconscious may be sought in situ in two forms of 'primitivism,' the familiar colonial one, and another populated by those who try to make sense of new scientific and engineering developments without the proper education, laboratories, or professional networks to do so. [11] The latter primitivism mapped an elementary fire onto electricity that produces in the mid-eighteenth century an electrical fire and forms the basis for an electrical theory of the sexes, having the general outlines of those of Wilhelm Reich in the twentieth century derived from Freud's libidinal energetics.[12] Bachelard kindles his own flame explaining the thermal, kinetic, and sexual energies involved in how friction generates fire, whether flint producing a spark, rubbing sticks together long enough, in stormy winds rubbing trees together to set forests ablaze, in the warmth of a caress, or the to-and-fro friction involved in sexual copulation. The repetitive routine of the tasks of rubbing finally sets the stage for passing approval of Pinheiro dos Santos' rhythmanalysis. It seems like a stretch, but it is certainly less bizarre than Freud in *Civilization and its Discontents* talking about the homosexuality of 'primal man' pissing on the phallic flames of a fire while 'woman' is held captive physiologically bearing 'the hearth.'[13] Apart from Bachelard's brief speculation that it was during the prolonged 'gentle

11 Gaston Bachelard, *The Psychoanalysis of Fire*, trans. Alan C. M. Ross (Boston: Beacon Press, 1964).

12 Bachelard, pp 21–28.

13 Sigmund Freud, *Civilization and Its Discontents* (New York, NY: Norton, 2010), Section III, footnote 3.

task' of rubbing sticks together that "man learned to sing," there was no mention of music in this field of energies.[14]

There is also an idealization at the crux of Lefebvre's notion of rhythms that is no longer tenable. Ecological catastrophe hobbles it. In his attempt to get away from 'thingness,' he sought anchorage for rhythms in two grand cycles: the seasons and the diurnal (circadian). Without seasons only one remains. Since the circadian depends upon the rotation of the planet, and position (orbit, tilt) in relation to the sun, it has proven difficult to ruin, although it hasn't escaped entirely: shifts of weight due to melting glaciers and polar caps, and expansion of oceans, has resulted in minute changes to the wobble in the Earth's axis. On the circadian embodiment by humans, Lefebvre was too early and too abstract to integrate discoveries in sensory and corporeal rhythms. During the 1990s and early 2000s the existence of a third retinal cell was established, and a greater sophistication regarding circadian cells and processes throughout the body was developed. Rods and cones had been familiar to every school kid, but intrinsically photosensitive retinal ganglion cells were unknown to everyone. These *solar retinals*, as I have called them, are non-imaging receptors (actually, they have a miniscule role) that are the main mechanism to entrain, that is, sluggishly synch, our bodies to the sun. They were described with increasing detail just as synching with screens became obsessional.

The source of all but 1/4000 of the energy for life on Earth radiates from the sun. In the evolutionary biology of the eye, the sun was enfolded from the skin in response to its radiant and ambient light. In an odd Platonic way, the sun causes vision, causes time, but to see rhythm as primarily temporal is to forget that lived time is a spatial function of our position in the solar system. No need for clockwork time to be the straw dog for arguments about temporality when spatiality is absent. *Solarception* is the name I have given the sensory process of the internalization of the sun to locate this basic energy relation. Just as there is a way to hear statistically and turbulently, I also think there is a way of transfiguring the

14 Bachelard, *The Psychoanalysis of Fire*, p 28.

circadian from an autonomic to a somatic sense within an ecological effort. Long distance air travel already does this. It operates multimodally in the field notion of *transperception* introduced in *Earth Sound Earth Signal*. I first observed it in Henry David Thoreau hearing the sound of a train or bells over a distance, or seeing a mountain through intervening mist, and in Alvin Lucier hearing the enormous power and earth magnitude in the delicate glissando of a whistler, a type of natural radio. It supplements and supplants cause and effect, linearity, and indexicality found in models of perception and sensation with fields, and forces with energies. Again, transperception has and can become tacit. Lucier heard differently and transperceived sensibly in the mid-1960s due to geophysical radio science research from the previous decade. Solar retinals have had a quarter century head start.

SS: It is interesting to observe the engineering task in the medium of radio telecommunication, because radio signals are not flows or highways or any sort of linear information transmission channels, but a broadcast of energy going in all directions. This requires a different paradigm of control. Radio, at the same time, was always a very controlled medium, it was about broadcasting and receiving by engineering choice.

DK: I wouldn't say paradigms of control are due to an intrinsic counter nature of radio signals. Radiation patterns are the basis of antenna design and there are ways to map and estimate the 'footprint' of broadcasts and narrowcasts. It used to be a dark art where steel suspension bridges and regional forests were influencing factors. I remember being in New York in the early 1980s and seeing the World Trade Center towers ghosted in a television image. Subtlety and precision are impressive now, and there has been a fascinating relationship between signal transmission with energy scavenging. It is a micro version of Tesla's free energy, yet still big enough for regulations against sapping signal strength. The patterns pertain to property rights, after all, let alone military dominion, national sovereignty, geopolitics, and other activities. As I discuss in *Earth Sound Earth Signal*, the surge in environmental sensing was a byproduct of military and intelligence activities during the Cold War. It

was also part of an effort to control natural processes in weapons systems at local and planetary scales, as detailed in Jacob Darwin Hamblin's surprising and sobering book, *Arming Mother Nature: The Birth of Catastrophic Environmentalism*.[15]

Engineering has control issues, in that its native control paradigm has issued into places where it does not belong. For example, Friedrich Kittler's media theory was engineered, as it applied to knowledge, philosophy, history, literature, and media. Its importance, which is undeniable, was both validated by and contributed to a period of digital and media technological development, and no doubt will be revivified increasingly with the spread of AI. However, contemporary relevance is severely limited because of the negligible roles that ecology and the sciences played at the core of his work. In "The City is a Medium," published around the same year as US vice president Al Gore was talking about the information superhighway but before any Inconvenient Truth, Kittler wrote about all things related to the city as informational.[16] Everything is informational because there is control: "whether networks transmit information (telephone, radio, television) or energy (water supply, electricity, highway), they all represent forms of information. (If only because every modern energy flow requires a parallel control network.)"[17] His contest with humanism had no ecological impetus, which is a problem because there is no outside. Engineering put the post in his posthumanism, reinventing invention narratives in the progress of media studies and media theory founded on a fundamental sociality that had no nature. What other area of knowledge has shown such sturdy immunity to recent critiques of anthropocentrism? Its strength was legible in a media ecology with no ecological content. What is remediation now? Its strength is also measured in the lateness of any challenge in me-

15 Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (Oxford; New York: Oxford University Press, 2013).

16 Friedrich A. Kittler, "The City is a Medium," *New Literary History* 27, no. 4 (1996): 717–29.

17 Kittler, p 718.

dia theory, only a decade ago, with Jussi Parikka's *A Geology of Media*,[18] John Durham Peters' *The Marvellous Clouds*,[19] and my *Earth Sound Earth Signal*.[20] There is now no shortage.

SS: Michel Serres writes on noticing the balancing polarities: there is always softness and hardness to both matter and information, and these are the kinds of transformations that matter is going through. This is quite interesting and also very hard to make actionable in terms of engineering.

DK: When I presented a talk several years ago in Copenhagen about the *Earth Sound Earth Signal*, I was asked how it might relate to the digital in telecommunication and computation. I didn't have a good answer. Perhaps the expectation for expertise came from the earlier book I edited with Hannah Higgins, *Mainframe Experimentalism*, but that was on early computing and the arts, far from the digital we inhabit now.[21] I was planning to explore the notion of survivable communications, but that project went on the back burner as I took a step back as it became evident to me the engineering default of information as data and signals needed to go upstream scientifically to its physical status to dispose it differently to ecological understandings. The decentralization of the Internet was developed under this aegis of survivable communications in a military context. It was a means to foil the efficacy of a nuclear attack by structuring backup measures into the system. There is plenty of precedent in the history of military communications. George O. Squier was an officer rising in the ranks, although he is most known, oddly, for Muzak. He looked to trees as grounds and antennas when

18 Jussi Parikka, *A Geology of Media* (Minneapolis; London: University of Minnesota Press, 2015).

19 John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago; London: the University of Chicago Press, 2015).

20 Kahn, *Earth Sound Earth Signal*.

21 Hannah Higgins and Douglas Kahn, eds., *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts* (Berkeley: University of California Press, 2012).

the soil was too dry to form a good ground for his telegraphy gear, and then researched the possibilities for trans-Atlantic wireless tree communication.[22] The presence of trees does not make it ecological, but it is likewise not merely allegorical. Beyond carbon accounting, mineral extraction, and equations of infrastructure with materiality, what would survivability mean in an ecological rather than military sense?

After completing *Earth Sound Earth Signal*, I began reading Serres and he became important for my work, but I am a reader rather than a serious student of his work per se. I look to Christopher Watkin, Steven Connor, and others for a broader view. I haven't formed an opinion on his hard and soft tropes, just that they are at times at odds with one another, and because I am suspicious of polarities. Instead, I have spun his work to emphasize a conditionality associated with what he calls world-objects, and to amplify the energy in the triad matter-energy-information, which is something I do as a matter of course with other thinkers. 'Matter' is both a constituent of and collective term for matter-energy-information, so it can be confusing where and how its transformations might occur. I am interested in their configured activities rather than an umbrella of matter since it allows an analytical isolation of energy. Amplification is not dissimilar to Lefebvre singling out rhythm in the melody-harmony-rhythm triad on the basis of its neglect. If matter-energy-information were the Holy Trinity, matter and information are the two guys with beards who seem to be everywhere, but no one has a clue about the Holy Ghost. Lefebvre has a passage on the analytical advantages of such triads but, unlike Lefebvre's enterprising rhythm, no new branch of knowledge is necessary. Old-school energetics asserted a dominance or centrality of energy in something of a power play and generated plenty of intellectual paranoia in its wake. Historical and cultural analysis obviously has no such designs; scientism may be a topic, but not hardware to wave around. Philosophically, Michael Marder emphasizes that fundamentally challenging how energy is understood is of utmost

22 George O. Squier, "Tree Telephony and Telegraphy," *Journal of the Franklin Institute* 187, no. 6 (1919): 657–87

importance; perhaps his work could be called a 'survivable philosophy'? I agree but do not work in philosophy.

Tripartite configurations are convenient, crude emblems. Their legitimacy might be judged through their elemental status but, in any case, are preferable to poles and other binaries because they are more amenable to a type of field-thinking required to approach complex situations. It was routine in nineteenth century physics but doesn't often make its way into academic vernacular. The way Serres' writing resists pull quotes and epigrams is the result of field thinking, of saying several things at once. I first developed a preference for fields as a math major in university. It was a matter of words, concepts, events, sensations, etc. eventually adhering to the points and planes and vectors darting around in n-dimensions that I used to daydream about. Serres revels in a correlation of mathematics and the physical cosmos, and even starts his book on religion with the virtuality of mathematics, and incredibly finished the manuscript a day before he dies. The script would be too corny for Hollywood. Math lapsed for me when it proved to be an insufficient explanatory system for the systemic cruelty and violence I encountered while hitchhiking through the backroads of the United States. But I then found fields in Walter Benjamin's constellations, and both Benjamin and Serres keep power and trauma in focus. Benjamin finds barbarism in the documents of civilization, and much of Serres derives from Hiroshima, his metonym for nuclear annihilation.

Hiroshima was his first world-object. Although he didn't give credence to Bachelard's epistemological break, Hiroshima had a similar philosophical function for him in the break of humans facing for the first time a global self-realization for potential self-annihilation. This object belongs to his lexicon of objects, with Latour animating his quasi-objects in actor-network theory, along with the small class of cosmic objects. I have no idea why his world-objects never caught on, since they resemble Timothy Morton's hyperobjects, which made their way in the world. In *Hermes* Serres wrote about the world-object being the product of a thanatocratic expansion of capability arising from an unprecedented coordination of three socio-political players: the state/military, industry, and science – what Latour called the iron

triangle. Sometime in the late 1980s, as far as I can tell, global warming becomes his other major world-object. Since Hiroshima is the planetary dimension of energy, the same would apply to global warming, one as instant incineration and the other a not-so-slow burn. Not all his world-objects would conform to annihilation at this scale, but his two main ones do. President Truman warned Japan hours after Hiroshima that the United States now has the power to bring the sun down to earth and unleash it once again, while now a revanchist sun comes down to earth to bake us. Under guises of mastery, these two dominant world-objects demonstrate a spasmodic lack of control. Their death reflex needs to be undercut with revised notions of energy, and triangulated with however matter and information may convert or relate to one another.

SS: When you speak of information pertaining to its physicality and the laws of physics, it seems to be about understanding data as found versus actively made. In pragmatic knowledge theories, such as the controversially hierarchical DIKW knowledge pyramid, information is simply the meaningful part of data.[23] But how could we really talk about the data? To go back to Serres, while I might not be able to get specific enough in terms of the way he talks about data, my impression is that data for him is this thing which is really dug up from the ground, and it is always material because it is always acquired through some kind of agency. It is the act of acquiring data that is giving it an 'orientation'; if data is always oriented, it is never 'neutral' nor inactive. Materiality of information therefore can be established with a quantum-physical understanding of communication theory. So rather than thinking of information with Shannon's information theory, I would be curious about other ways to address materiality of information. For example, we could say that the German

23 The Data Information Knowledge Wisdom pyramid is a model for structural and/or functional relationships between data, information, knowledge, and wisdom stacked in a hierarchical order that suggests increase in value through scarcity, from bottom (data) to top (wisdom): https://en.wikipedia.org/wiki/DIKW_pyramid [accessed 10.03.2021].

media theory addresses this materiality through the networks and technicality of mediating information. What is your take on this?

DK: There are many interesting artists addressing these issues, and no doubt enterprises that could mobilize them into media systems and engineering at scale. There is no shortage of talent and tools. I don't have anything to say beyond what others have said about the capitalist ecstasy of data mining having the same extractivist frame of transformations of matter at the root of environmental catastrophe. It would be interesting to apply Serres' notion of pollution as an expansion of territory rather than waste. The capitalist maw that chews up the Earth and spits it back out is a technique of possession in the manner that one owns someone else's bowl of soup by spitting in it. What does it possess after chewing up and spitting out data banks? He states advertising is pollution, which is hard to argue against, but it is just one form of monetization that wastes and possesses enormously for little social and ecological good. It is a question now whether non-extractivism occurs before catastrophe imposes it.

Materiality old and new is sold in so many flavours now, that the presumed virtues can be difficult to identify, and are often too simple when they can. For me, any smattering of matter needs to be accompanied by historical materialism, but also one not dependent on the archives that produce history. How 'data' exists and is produced by and against indigenous cultures, and what does and does not need to be known to survive and maintain integrity, are key, among all the records suppressed, destroyed, or never produced in the first place. I am living on Aboriginal land belonging to the longest continuing culture on Earth, over sixty thousand years, which makes this evident in a way that I don't know if Europeans who think of Greece as antiquity can appreciate.

I do find remarkable one understanding of an operative materiality of data. Key features of solar retinals I mentioned were hypothesized and validated among the circuits of data banks, long before weather research. The functional protein melanopsin active in solarception was shown that it had to exist, and it did, and its evolutionary biology was described in a similar manner. This is old news, of course, but as

Przemysław Prusinkiewicz and Aristid Lindenmayer signalled in *The Algorithmic Beauty of Plants*, it was inevitable that models in computational biology went past the point of scientists contributing their research to them, to conducting their research within them.[24] So, in a way, certain things exist more completely in data. The Delphic oracle of climate modelling is located there, Pythia proclaiming the future sitting on her tripod inhaling greenhouse gas fumes.

I am not familiar with the DIKW or its controversies but, if I had to choose among simple geometric explanations, I would go for the self-amplifying iron triangle. I find the wisdom placed at the pinnacle funny. Perhaps an eye could fit on top, like the pyramid on the US dollar bill? I wonder what self-abnegation and meditative practice of enlightenment is required to attain the wisdom of managerialist Bodhisattvahood? And what will shareholders think if it evaporates into full Buddhahood? Buddha will be fine because he comes from wealth, but what about the employees? Obviously, if this wisdom were truly wise, then it would already have the situation sorted out ahead of time. Somehow, I think it will end up instead in AI systems hacking each other's infrastructures.

I have failed to keep up with media theory from Germany since completing the book over a decade ago, so I am very much out of that loop. Even then it was primarily Kittler, whose historical basis for theorization I held in high regard, if not always the specific content. However, his penchant for engineering placed limits on the science, ecology, power, and trauma necessary to be broadly relevant. In a seminar I taught at University of California, we tested the limits of Kittler's ideas by examining war crime snapshots by American soldiers in Vietnam. Despite data, information, and knowledge, evidence has a hard climb to justice, let alone wisdom.

I wonder too what proximity experience would have in or with the DIKW pyramid. In my essay in *Energies in the Arts* I analyse the energy field performances of the Australian artist Peter Blamey through the notion of experiential physics. Other branches of science or forms of knowledge may become experiential through knowing or believing to know.

24 Prusinkiewicz and Lindenmayer, *The Algorithmic Beauty of Plants*.

You know that photosynthesis is occurring in plants, not just that they flower or are green. Photosynthesis may have initially leapt off a school desk, but it has since become tacit in what you can see (perceive, understand, experience) and what some sense without saying. Living in the sun moves without the baggage of a vital force. You can feel a forest as massive absorption, as an aspect of transperception. Fusing existing and new knowledges with tacit experience de facto exists in adaptative behaviours, but also in different cultures. The Wadjiginy, Emmiyangal, and Mendheyangal people on the coast of the Northern Territory of Australia, for example, see microseasonally where other cultures merely see weather. Knowledges built up in labs or data sets have certain advantages, but what informs knowledge built up over thousands of years? Just knowing that, it becomes clear that macroseasonal disruption is part of an ongoing dispossession and genocide.

SS: To wrap up, would you say that speaking of energy implies also always speaking of its manifestation as matter and information? Are they always present in your thought of how energy becomes manifested in the arts? In the case of Serres' world-object being in some extent created by humans, which is exceptional in the way it uses up life and resources: it is using all of it up, an ultimate reproduction.

DK: The matter-energy-information schema is productive in a theme-and-variation way that philosophers will stress test concepts with different classical elements. Marder did that recently with fire and political power in his *Pyropolitics*, instead of the presumed Earth with its territories, properties, sovereignty, and the geo- in geopolitics. Even Serres, who makes fun of Bachelard's schism between matter/energy (without the benefit of Shannon's information) and classical elements, makes recourse to them to replace the United Nations with "an objective institution, the WAFEL, whose initials would mean in English not men, nor nations, nor the species, but the world: Water, Air, Fire, the Earth, and

the Living. One more step, and we have a cosmocracy."[25] For a physical model, I like to remind myself of their intricate relationships in Raman scattering, in the interactions of photons, electrons, molecular vibrations, and heat in the chemistries of why, in infinitesimal part, the sky is blue. Luckily, the sky is big enough to lend the infinitesimal some presence. I also like to think of the relatively free and easy energy ride of a photon from the sun, unencumbered by too much information, until it reaches the retina, whereupon it crosses into intricate information universe of ion exchanges, like a complicated knot at the end of a very long string, both for imaging in vision and for spatial-temporal position in the solar system. Perhaps because I concentrate on the arts and privilege (trans)perceptual matters, I limit energy and information interaction to the sensory membranes of the cochlea, retina, and skin, their cellular surface transduction and ion exchanges. The other huge matter-energy-information site is metabolism, but that would get too complicated too quickly for me at the moment, so I stay with the superficiality of sensory membranes.

Pia van Gelder from the Australian National University and I are presently completing a book collection, *The Energies Artists Say*, which is an exercise in engaging a physical, cultural, and linguistic breadth of energies in historical and cultural analyses. Artists said 'energy' in many ways during the twentieth century, but they did not mean fossil fuels and their alternatives until the 1970s, in the United States at least, in the wake of the Santa Barbara oil spill and the OPEC embargo, the so-called energy crisis. That is, artists did not say energy in the way energy humanities means it until recently, in an historical sense, and during and since this meaning has interacted with other energies and, in turn, matter and information, in specific ways. The book will introduce the energies artists say as one method within the development of an energy reading, which is beginning to take shape.

I wonder why Serres' world-objects began with Hiroshima. Its existential motivations make sense, but global telecommunications

25 Michel Serres, *Malfeasance: Appropriation through Pollution?*, trans. Anne-Marie Feenberg-Dibon (Stanford: Stanford University Press, 2011), p 84.

unfolding in the mid-nineteenth century, its lines arcing over horizons, would be an obvious place to start. Natural radio has arced over the equator for about 3.5 billion years, but Serres' world-objects are human-made or -generated one way or another. The glissandi of whistlers generated along these flux lines were heard on early telecommunication lines, long perceived as nature, but now they broadcast their human content. If telecommunications require existential coordinates to be a world-object, then their deadly role in colonial expansion, military subjugation, and domestic repression, aided by messages at the speed of light, should suffice. If this is insufficient and global annihilation remains the metric, then we must wait for the DEW Line in the 1950s, which I believe was the largest media infrastructure up to that point. In the 1950s, militarized sensing at earth magnitude developed in parallel with an environmental sensing that itself hearkens back to the nineteenth century, when telegraph systems were used not only in communication but as large sensory arrays for the study of magnetic storms. Sensing and telemetry were on the same device, and there is no shortage of either at present. How to make them survivable is another question.