TECHNOPHANY
A Journal for Philosophy and Technology

Technophany Vol.4 No.2

The Exteriorization of Knowledge: Reporting on Knowing as a Distributed Practice

Maaike Bleeker

Abstract

In *The Postmodern Condition,* Lyotard observes that "technological transformations can be expected to have a considerable impact on knowledge," including "a thorough *exteriorization of knowledge* with respect to the 'knower' at whatever point he or she may occupy in the knowledge process." Lyotard's observation anticipates new materialist elaborations on the entanglement of matter and meaning in practices of knowing, particularly Karen Barad's understanding of knowing as a distributed practice that includes the larger material arrangement. Building on Mark Hansen's media philosophical insights into the role of technology in "expansions of the sensible" beyond the human sensorium, I show how the shift towards the operationality of the system's performance (its performativity) with regard to the legitimization of knowledge, as observed by Lyotard, and the shift towards performative alternatives to representationalism theorized by Barad are two different aspects of what Jon McKenzie describes as "the becoming performative of knowledge itself."

Keywords: Knowledge, Technology, New Materialism, Media Theory, Performativity

 Corresponding author: Maaike Bleeker, m.a.bleeker@uu.nl

ISSN 2773-0875

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In *The Postmodern Condition,* Lyotard observes that "technological transformations can be expected to have a considerable impact on knowledge," including "a thorough *exteriorization of knowledge* with respect to the "knower" at whatever point he or she may occupy in the knowledge process."[1] This exteriorization of knowledge with respect to the knower is my concern, and more specifically, how Lyotard's observations in this by now canonical text resonate with a new materialist understanding of the entanglement of meaning and matter and the decentering of the human knower. Written almost three decades before the publication of Karen Barad's magnum opus *Meeting the Universe Halfway* (2007), Lyotard's observations anticipate their conceptualization of knowing as a distributed practice that includes the larger material arrangement.[2] His analysis of how technological developments affect our understanding of the very nature of knowledge helps to see how developments since the time of his writing bring Barad's observations into greater relief. Useful here is Mark Hansen's (2015) media philosophical analysis of how the late 20th and early 21st century development of information and communication technology expands the sensible while also putting humans increasingly in a situation in which their modes of perceiving and experiencing are implicated in larger apparatuses. Furthermore, drawing attention to aspects of the modus operandi of the larger socio-historical apparatuses in which knowledge comes about that are less addressed by Barad, Lyotard's *Report on Knowledge* (as its subtitle reads) offers a valuable complementary perspective on the workings of these apparatuses as well as on the notion of performativity that also plays a key role in Barad's agential realism.

In *The Postmodern Condition*, Lyotard introduces the notion of performativity as part of his account of how technological developments affect the legitimization of knowledge and reinforce what he famously describes as the end of the metanarratives. Whereas Lyotard looks at knowledge claims and observes a shift towards performativity as what legitimizes them, Barad directs attention to the performativity of scientific practices and how these are "social-material enactments that contribute to and are part of the phenomena that we describe."[3] For Barad, performativity offers an alternative to representationalism in how it invites a shift in focus from questions of correspondence between descriptions and reality to matters of practices, doings, and actions. Performativity, in her account, thus provides a connection between insights from quantum physics (in particular Niels Bohr's quantum physics philosophy) and the performative turn in the humanities and social sciences. Both

1 Jean-Francois Lyotard, *The Postmodern Condition: A Report on Knowledge* (Manchester: Manchester University Press, 1984 [1979]), 4, my italics.

2 Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham: Duke University Press, 2007), 379.

3 Barad, *Meeting the Universe Halfway*, 26.

move towards an understanding of matter as an active participant in the world's becoming and in how knowledge comes to matter.

In *The Postmodern Condition*, Lyotard, too, refers to quantum physics as a challenge to conventional humanist conceptions of knowledge. For Lyotard, this challenge is a matter of how quantum physics brings about a shift in what counts as a knowledge statement. For Barad, on the other hand, the challenge posed by quantum physics is given in how it forces us to confront fundamental epistemological and ontological issues (as well as their entanglement), "such as the conditions for the possibility of objectivity, the nature of measurement, the nature of nature and meaning making, and the relationships between discursive practices and the material world."[4] This brings them to their understanding of knowing as "a direct material engagement, a practice of intra-acting with the world as part of the world in its dynamic material configuring."[5]

Both challenges are reflected in the decades-long search for the Higgs boson at CERN, as well as Rolf Heuer's announcement of its discovery. Taking this announcement as my starting point, I will show how we may understand the shift towards the operationality of the system's performance (its performativity) with regard to the legitimization of knowledge, as observed by Lyotard, and the shift towards performative alternatives to representationalism theorized by Barad as two different aspects of what Jon McKenzie (2001) describes as a qualitative transformation of knowledge that results in "the becoming performative of knowledge itself."[6] The following elaborates this point via a diffractive reading of Lyotard's *The Postmodern Condition* and Barad's *Meeting the Universe Halfway* that brings in Hansen and McKenzie to show how the complementarity outlined above is foregrounded by how technological developments since Lyotard's time of writing (and of which CERN presents an example) have intensified the exteriorization of knowledge observed by him and contribute to a situation in which human knowers participate in what Lyotard in his *Report on Knowledge* refers to as the "knowledge process."

4 Barad, *Meeting the Universe Halfway*, 24.

5 Barad, *Meeting the Universe Halfway*, 379.

6 Jon McKenzie, *Perform or Else. From Discipline to Performance* (New York and London: Routledge, 2001), 14.

Perform-or Else

On 4 July 2012, Rolf Heuer, the then director-general of CERN, announced the discovery of the Higgs boson.[7] He did so with a remarkable statement: "As a layman, I would now say, I think we have it, do you agree?" His statement performs a complicated speech act. For what, actually, is Heuer saying? What is being stated, or not?

When Heuer makes his statement, an old man in the audience sheds a tear. This is Peter Higgs. Fifty years and billions have been spent proving the theory he penned down as a relatively young and unknown scientist. And now the proof is there. Or is it? Heuer's announcement follows an explanation of the complex probability calculations based on which the existence of the Higgs boson is being claimed. His statement, "As a layman, I would say," is both ironic -for, obviously, the director of CERN is not a layman- and a way of reaching out to an audience of non-specialists, explaining that the probability calculations are quantum physics' way of saying "I think we have it." Heuer thinks "we have it" based on calculations that show the probability of the particle's existence. We may thus read his statement as a struggle with the complications of legitimization posed by quantum physics as addressed by Lyotard. As a quantum physicist, these calculations convince Heuer to the point that, as a layman, he would say: "I think we have it." But apparently, he senses that this may not be convincing enough, for it is followed by a question directed to his audience of fellow scientists present at the presentation: "Do you agree?" Their applause confirms his statement and acknowledges the validity of his claim. The existence of the Higgs particle is thus presented as a matter of probability that requires an intersubjective confirmation to be acknowledged and accepted as valid. With their applause, the scientific community expresses its participation in this moment of celebration while also confirming the validity of the decades-long process that led to the production of this 'proof' of the particle's existence.

Thus, instead of stating that they proved the existence of the boson, Heuer performs a speech act constructed to performatively bring about such understanding without actually stating it. Stating that "as a layman, I would say I think we have it" allows him to avoid saying this as the scientist he is. As a scientist, he would have to say that the calculations suggest there is a high probability they have detected the Higgs particle. However, as a scientist, he also faces what McKenzie describes as the pressure to "perform-or else." As Lyotard points out, legitimation as a criterion is based on optimizing the system's efficiency. The application of this criterion "necessarily entails a certain level of terror, whether soft or hard: be operational (that is, commensurable) or disappear."[8] Building on Lyotard, McKenzie observes that performativity as the criterion for success puts both

7 https://www.youtube.com/watch?v=0CugLD9HF94 "The Moment: CERN Scientist Announces Higgs Boson 'God Particle' Discovery"

8 Lyotard, *The Postmodern Condition,* xxiv.

humans and technologies under constant pressure to "perform-or else." This challenge pertains to both how knowledge, identity, and other phenomena come into being, or, as McKenzie (following Martin Heidegger) puts it, are challenged forth, and how what is challenged forth is legitimized. This pressure to "perform–or else", McKenzie predicts, "will be to the twentieth and twenty-first century what discipline was to the eighteenth and nineteenth, that is, an onto-historical formation of power and knowledge."[9]

As the director of CERN, Heuer represents an institution under extreme pressure to perform and meet the expectations of international communities of scientists, politicians, and other financiers of their research. To perform here means to convince fellow scientists as well as the general audience and meet the needs and desires of politicians and others on whose support (financial and otherwise) the possibility of research like this depends. Heuer's announcement thus not only reflects the complexity of legitimizing knowledge in the postmodern condition but also draws attention to how such legitimation is integrally part of the scientific apparatus, and how such apparatuses (as Barad points out) are not merely laboratory set-ups but open-ended practices extending far beyond the laboratory. Based on the probability calculations, Heuer may think it is possible to say we have it, but for this to be indeed the case, he needs the scientific community's agreement: do you agree? Meaning not only do you agree with me as a person, but also, do you acknowledge how what counts as proof here has come about? Furthermore, the complexity of legitimization that Heuer faces is directly related to how the techno-scientific practices of CERN present an extreme example of the technologically induced exteriorization of knowledge, a phenomenon that Lyotard witnessed in its early stages.

Performativity and the Legitimation of Knowledge

Lyotard's prediction, in *The Postmodern Condition*, that technological transformations will contribute to "a thorough exteriorization of knowledge with respect to the 'knower'"[10] brings to mind Bernard Stiegler's reading of paleoanthropologist Andre Leroi-Gourhan and his understanding of how tools allow for preserving impersonalized, collective memory traces.[11] Tools make possible a new 'third kind' of memory separate from the internally acquired memory of individual human brains and the biological evolutionary memory we inherit. As a result, humans are defined by pasts that they themselves, as individuals, have not experienced. Technological objects, such as tools, embody the knowledge of our ancestors that is passed on to newer generations. Drawing, writing, and other media enable human experiences to manifest outside of human consciousness, thus acting as a

9 McKenzie, *Perform or Else,*18.

10 Lyotard, *The Postmodern Condition*, 4.

11 Bernard Stiegler, *Technics and Time, 1. The Fault of Epimetheus*. trans. Richard Beardsworth and George Collins (Stanford: Stanford University Press, 1998).

kind of prosthetic extension of memory. They provide "access" to the experience of others and make it possible to circulate these externalizations.

In *The Postmodern Condition*, Lyotard similarly observes a technologically induced exteriorization, not of memory but of knowledge. He foresees the becoming obsolete of "the old principle that the acquisition of knowledge is indissociable from the training (*Bildung*) of minds."[12] The technological developments he refers to as "computerization" set the stage for the massive circulation of knowledge and, thus, for an extension of knowing beyond personal experience and *Bildung*. He also predicts that these technological developments will affect the direction that new research and knowledge production will take and eventually affect the very nature of knowledge, as "anything in the constituted body of knowledge that is not translatable in this way will be abandoned," and "the direction of new research will be dictated by the possibility of its eventual results being translatable into computer language."[13]

Lyotard's text was first published in French in 1979 (the English translation followed in 1984). That is, his observations date from a moment in which knowledge cultures were already shaped by a long history of the externalization of memory by writing and print, and only at the very early stages of the transformations that would be brought about by digital and networked technology, or what he refers to as "computerization". The very first PCs had only recently become available, and precursors of what we now know as the Internet were only accessible to specific academic and research institutions. Lyotard foresees that these technological innovations, which were, at the moment of his writing, still in their infancy, would resonate with and reinforce the effects of social-historical developments that he describes as the end of the metanarratives. His observations have proven immensely relevant for understanding this entanglement of technological and discursive systems and how this entanglement has brought about what Yuk Hui describes as an "epistemological rupture taking place in science and technology" as technological developments profoundly affect not only how knowledge is produced, acquired, and circulated, but also how it is legitimized, and how all of this affects our understanding of the very nature of knowledge.[14]

Lyotard famously theorizes this epistemological rupture in terms of increased incredulity towards the metanarratives that previously served to legitimize science, "such as the dialectics of Spirit, the hermeneutics of meaning, the emancipation of the rational or working subject, or the creation of wealth."[15] He observes that without epic stories

12 Lyotard, *The Postmodern Condition*, 4.
13 Lyotard, *The Postmodern Condition*, 4.
14 Yuk Hui, "Lyotard, After Us," *Lyotard and Critical Practice.* eds. Kiff Bamford and Margret Grebowicz (Bloomsbury, 2022), 126.
15 Lyotard, *The Postmodern Condition*, xxiii.

providing outside authority, legitimization shifts towards the *operationality of the system's performance, its performativity*. As the example of CERN demonstrates, this pertains to the legitimization of knowledge and research practices, as well as how the system of scientific practice is institutionalized and funded. The performativity criterion "excludes in principle the adherence to a metaphysical discourse; it requires the renunciation of fables; it demands clear minds and cold wills; it replaces the definition of essences with the calculation of interactions," and it makes scientists "assume responsibility not only for the statements they propose but also for the rules to which they submit these statements to render them acceptable."[16]

This operationality of the system's performance, its performativity, Lyotard observes, is reinforced by widespread technological developments that mediate ways of circulating knowledge. Optimizing the system's performativity requires knowledge to be translatable into computer language, and vice versa, translatability supports the success of knowledge. Translatability will thus dictate the success of knowledge produced and even the direction of new research, thus setting in motion a feed-forward mechanism. Also, "along with the hegemony of the computer comes a certain logic, and therefore a set of prescriptions determining which statements are accepted as 'knowledge' statements."[17] Such grounding of legitimacy outside the human and in the systems' operationality results in a certain dehumanization, as it induces the adaptation of individual aspirations to the system's ends. It "makes individuals 'want' what the system needs to perform well."[18]

From Externalization to Technological Expansions of the Sensible

Looking back more than forty years later, we can begin to see how the technological developments that Lyotard witnessed in the very early stages have led to much more radical exteriorizations of knowledge than could have been foreseen at the time of his writing as these exteriorizations of knowledge brought about by technological developments are not only a matter of how digitization and the rise of networked technology mediate in an unprecedented storage, accessibility, and circulation of information, but also and increasingly of how technology governs knowledge production. Writing in 2001, McKenzie observes that:

> [T]he global emergence of technological media—television, tape recorders, satellites, copy machines, faxes, beepers, and most profoundly,

16 Lyotard, *The Postmodern Condition*, 62.
17 Lyotard, *The Postmodern Condition*, 4.
18 Lyotard, *The Postmodern Condition*, 62.

> interconnecting and overwriting them all, information technologies such as digital computers and electronic networks (…) affects all cultures, all organizations, all technologies, for the digitization of discourses and practices enables them to be recorded, edited and played back in new and uncanny ways. Highly localized ensembles of words and gestures can now be broken apart, recombined and hyperlinked to different ensembles in ways unlike anything in the past at speeds incredible from all perspectives except those of the future.[19]

McKenzie traces "a radical transformation of our reading machines, an epochal shift in the citational network of discourses and practices" brought about by the socio-historical transformations and technological development of which Lyotard witnessed an earlier phase.[20] With "reading machine" (which he uses interchangeably with the term "lecture machine"), McKenzie refers to the assemblages of technological and material systems, discourses, and practices in and through which human modes of experiencing and understanding come about, thus expanding on Lyotard's notion of language games and towards Barad's notion of the apparatus as material-discursive configuration that produces differences that matter.[21] He too points to the future-orientedness of these reading machines: how understanding their modes of operation requires a shift in focus away from how they mediate in ways of knowing a world that preexists them and towards what they performatively bring about.

This future-orientedness is also addressed in Felicity Coleman et al.'s *The Ethics of Coding. A Report on the Algorithmic Condition* (2017), in which they expand Lyotard's analysis towards a code of conduct for assessing and evaluating algorithmic systems and networks. Their title, "The Algorithmic Condition," captures how the technologically induced thorough externalization of knowledge with respect to the human knower, more than only being a matter of the circulation of human-produced knowledge, involves outsourcing the processing of data beyond human modes of interpreting. They point out that algorithms and the mathematical models behind them produce what they will have referred to (when studied retrospectively)[22] because "algorithms put data into a coded state of performance" that "not only effects a practice-based shift in knowledge production and acquisition, but also produces a logic which is symbolic but also which manifests as a reality."[23] They contribute to performatively bringing about the world they describe.

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19 McKenzie, *Perform or Else*, 22.

20 McKenzie, *Perform or Else*, 21.

21 Barad, *Meeting the Universe Halfway*, 146.

22 Felicity Coleman, Vera Bühlmann, Aislinn O'Donnell, and Iris van der Tuin. *Ethics of Coding. A Report on the Algorithmic Condition* (H2020-EU.2.1.1. – INDUSTRIAL LEADERSHIP – Leadership in enabling and industrial technologies – Information and Communication Technologies. Brussels: European Commission, 2018), 8. https://cordis.europa.eu/project/rcn/207025_en.html, 22.

23 Coleman et al., *Ethics of Coding,* 9.

Not addressed by Coleman et al. is how this expansion also pertains to what can be captured as data in the first place. That is, the exteriorization of knowledge is also a matter of how technologies like micro-sensors, data processing, search engines, and other digital and networked media detect intensities, differences, fluctuations, and patterns that, in Hansen's words, "open up an expanded domain of sensibility" beyond and below the thresholds constitutive of human perceptual experience."[24] These technologies provide access to an expanded domain of sensibility that can enhance human experience". To access this domain of sensibility, however, "humans must rely on technologies to perform operations to which they have absolutely no direct access whatsoever."[25]

In *Feed Forward: On the Future of Twenty-First-Century Media* (2015), Hansen traces how these technological developments catalyze a profound decentering of human experience and demand that we "embrace our subjective implication in a plethora of processes of all sorts and all scales."[26] That is, they require an understanding of human experience and meaning-making as a dimension of larger environmental processes of which humans are a part, but which are only partly accessible to them. Like Lyotard, Hansen observes a reversal in the relationships between humans and their technologies, noting that this decentering process began with analog technology. He quotes Villém Flusser describing this development as follows:

> Certainly, for the time being, most apparatuses are not so completely automatic that they can go along without human intervention. They need functionaries. In this way, the original terms *human* and *apparatus* are reversed, and human beings operate as function of the apparatus. A man gives an apparatus instructions that the apparatus has instructed him to give. In this way, a powerful flood of programs is unleashed, a flood of software with which people no longer pursue any particular intention but rather use it to issue instructions as a function of an earlier program. As the programs become more and more complex and clever, they demand faster, smaller, and cheaper apparatuses, more congenial hardware. And so one generation of apparatuses after another appears. With each new generation, human intention recedes further into the background—the intention, that is, that produced the first generation of apparatuses.[27]

This development gained increased momentum with what Hansen terms "twenty-first-century media," with which he does not refer to specific technologies but to tendencies

24 Mark B.N. Hansen, *Feed Forward. On the Future of Twenty-First-Century Media* (Chicago: The University of Chicago Press, 2015), 4.

25 Hansen, *Feed Forward,* 4-5.

26 Hansen, *Feed Forward,* 17.

27 Villém Flusser quoted in Hansen, *Feed Forward,* 75.

that can be observed in today's information and communication technology, namely that they "operate at microtemporal scales without any necessary—let alone direct—connection to human sense perception and conscious awareness."[28] Whereas the modes of operating of nineteenth and twentieth-century recording media like photography, film, the gramophone, and the tape recorder are more directly coupled and synchronized to human experience and sense perception, more recent technologies "not only resist any form of direct synchronization but question the viability of a model of media premised on a simple and direct coupling of humans and media system."[29] Their modes of operating bypass human perception and consciousness as they can register what is inaccessible to human senses and process data at scales and in ways radically different from humans. Therefore, their modes of operating can no longer be understood as prosthetic extensions of human perceptions and modes of processing information, nor can what gets captured and circulated by these media technologies be understood as traces of human experiences and memories. Instead, how these technologies expand the sensible is radically inaccessible to humans. Whereas there is still a (relatively) strong correlation between the modes of operating of older media like photography, film, and the gramophone, and human modes of sensory experience (they can be understood to circulate traces of human experiences), the modes of operating of more recent media technologies are, to a much larger extent only indirectly correlated to human modes of experience and increasingly "impact the general sensibility of the world prior to and as a condition for impacting human experience."[30]

Hansen's observations are part of his rethinking of what mediation entails beyond understanding mediation as a prosthetic extension of human faculties. Whereas "mediation once named the technical inscription of human experience […] today mediation must be redirected to the task of composing relations *between* technical circuits *and* human experience."[31] Because twenty-first-century technologies "work directly on physical signals prior to their conversion into phenomenologically accessible forms," additional mediation (what Hansen terms *secondary mediation*) is required, "this work being the very mediation necessary to bring the physical into the domain of experience."[32] These characteristics of mediation brought to the fore by contemporary media technologies are not unique to them. Rather, they are "revealed to us *and* intensified by the computational technologies constituting twenty-first-century media"[33] after having been obscured by an understanding of mediation as a matter of recording and circulating representations of a world similarly available to human perception.

28 Hansen, *Feed Forward*, 37.
29 Hansen, *Feed Forward*, 37.
30 Hansen, *Feed Forward*, 6.
31 Hansen, *Feed Forward*, 43, italics in original
32 Mark Hansen, "Medium Oriented Ontology" *ELH* 83:2 (2016): 384.
33 Hansen, *Feed Forward*, 6, italics in original.

Hansen writes about media technologies, yet his observations are also most relevant regarding how they offer a non-prosthetic approach to the role of technologies in scientific research. Knowing increasingly happens in interaction with instruments that, in Hansen's terms, expand the sensible and put humans and their perceptions and experiences in a position of being implicated in larger apparatuses that, to a considerable extent, operate outside their awareness and in ways they have no direct access to. As Jussi Parikka points out, "[o]ur relations with the earth are mediated through technologies and techniques of visualization, sonification, calculation, mapping, prediction, simulation, and so forth: it is through and in media that we grasp earth as object for cognitive, practical, and affective relations. Geological resources used to be mapped through surveys and field observation, now through advanced remote sensing technologies."[34] This development engenders a shift in hierarchy between humans and technologies, moving towards a situation in which humans operate in complex feedback loops with technology. These technologies used by scientists, too, make humans increasingly part of apparatuses that, although they expand the sensible, also increasingly bypass and marginalize human sensory experience in how they no longer operate as prosthetic extensions of the human sensorium but instead make humans part of larger apparatuses operating in ways that are inaccessible to them. This situation requires developing awareness of how human perception and experience are implicated in larger apparatuses and an understanding of knowing as, in Barad's words, "a distributed practice that includes the larger material arrangement" in which humans participate as part of the larger material configuration of the world and its ongoing open-ended articulation."[35]

Barad opposes an understanding of scientific apparatuses in terms of mediation because, in their understanding, this would suggest that the measuring instrument mediates between an autonomous knower and a world with inherent determinate properties. However, such an understanding of mediation as something in between an autonomous observer and a world with inherent determinable properties is precisely what is challenged by non-prosthetic approaches to mediation as developed by Hansen, Parikka, and others. Non-prosthetic approaches to mediation share with Barad a critique of representationalism, a focus on the enactment of material relations, and an acknowledgment of the co-constitutive role of technology and matter with regard to how things come to be known. Furthermore, they help to understand how technological developments change relationships between humans and devices, and how this affects their modes of participating in distributed practices of knowing.

34 Jussi Parikka, *A Geology of Media* (Minneapolis: University of Minnesota Press, 2015), 12.

35 Barad, *Meeting the Universe Halfway*, 379.

Human Nodes in Technological Networks

Hansen's analysis supports Lyotard's observation that technological developments (of which his account in *The Postmodern Condition* represents an early stage) contribute to an increased decentering of human experience in how the world comes to be known. Technological developments "catalyze a shift in the economy of experience itself" as they increasingly make humans part of systems that "register the environmentality of the world itself before, and without any necessary relation with, human affairs"[36] This shift confronts us with what Donna Haraway, Barad, and other new materialist thinkers describe as the *situatedness* of human ways of knowing in larger apparatuses, as well as the question of how to account for the relationship between these non-human modes of registering and processing and human experience, and how this affects our understanding of the very nature of knowledge. Here again, the search for the Higgs particle at CERN presents an example.

CERN is a technological system that, to speak with Hansen, expands the sensible without any necessary—let alone direct—connection to human sense perception and conscious awareness. On the one hand, this is a matter of the enormity of the amount of data and the scale of non-human data processing necessary for the probability calculations supporting Heuer's claim that, as a layman, he would say they have it. In the Nikhef Annual Report for the year 2012 (the year that the discovery of the Higgs boson was proclaimed), Wouter Verkerke, head of statistical analysis at Nikhef (the Dutch partner of CERN), explains that:

> Calculation of the production rate of Higgs bosons shows that at the LHC roughly one in 5 billion collisions will result in a Higgs boson. Thus, to collect a sample of a few hundred collisions with a produced Higgs boson, more than a trillion proton-proto collisions will need to be produced and examined. To meet this requirement, the LHC collides protons 40 million times per second. It is impossible to record the detector data for a trillion collisions as each event results in about 200MB of data. Thus, events are preselected in real-time with a three-level 'trigger system' that rapidly examines recorded collision data and discards the large majority of events that are deemed uninterested … The first-level selection is built on custom hardware that reduces 40 million events per second to approximately 100.000 events per second. The next two levels are software-based and further reduce the rate to about 600 events per second. Despite the aggressive data reduction through

36 Hansen, *Feed Forward*, 8.

> online trigger pre-selection, a few petabytes (=1000 terabytes) worth of information is produced every year the LHC runs. It requires about 10.000 years of computing time to reconstruct all these events.[37]

On the other hand, this is also a matter of the enormity of the material apparatus—the Large Hadron Collider at CERN—used to produce the proof, and the inaccessibility to human experience of what happens inside it. The collider is approximately 27 kilometres in circumference and is located in a tunnel at a depth of 175 meters. Inside the accelerator, thousands of magnets are used to direct two particle beams traveling at close to the speed of light around and make them collide. This requires chilling the magnets to 271.3°C, colder than outer space.

The incompatibility of the scale and modes of operating of the accelerator to the human scale and human experience, and both of them to the scale of what happens inside the accelerator, is beautifully visualized and made tangible in the film *Higgs: Into the Heart of Imagination* (2009/2012) by Hannie van den Bergh and Jan van den Berg.[38] The film portrays humans as small nodes in vast technological networks, each serving distinct aspects of the technological apparatus through their respective specializations. Human scientists here are functionaries (Flusser) implicated in the modes of operating of CERN as a massive apparatus that decentres human experience. Making the system work and achieving the desired results requires adapting individual aspirations to the system's ends and, as Lyotard wants it, "makes individuals 'want' what the system needs to perform well."[39]

The film also presents an image of CERN as a materialization of Barad's understanding of knowing as a distributed practice in which humans participate, each engaging from the perspective of their specialization, and none of them being in the position of the distant observer having the overview. Interesting in this respect is an interview with Heuer on the occasion of the tenth anniversary of the announcement of the discovery of the Higgs boson. Looking back, Heuer frames his self-identification as a layman as an acknowledgment that he, as a director too, was not in a position of ownership or overview with regard to the discovery. He states, "I had no direct role in the discovery of the Higgs particle, other than as director of the laboratory where it all happened."[40]

The film *Higgs: Into the Heart of Imagination* captures the excitement of different scientists about what they think (and hope) might happen in the experiments with the particle accelerator, as well as the complexity of relating the inaccessibility of what happens in

37 Wouter Verkerke, "Higgs Bosons Tracked From Collision To Publication," Nikhef Annual Report 2012, 16–16.

38 https://higgsfilm.com/ https://www.youtube.com/watch?v=o8o_GA9v0P4

39 Lyotard, *The Postmodern Condition*, 62.

40 https://www.nikhef.nl/en/10-years-higgs-interview-with-rolf-heuer/

the experiment to human experience. Lyotard hints at this complexity, wondering: "What constitutes a scientific observation? A fact that has been registered by an eye, an ear, a sense organ? Senses are deceptive, and their range and powers of discrimination are limited. This is where technology comes in."[41] Lyotard thus connects the (registration of) proof to registration by the senses and presents technology as a means to solve the problem of the limitations of human sensorium. The example of CERN shows that how technology compensates for the limitations and deceptiveness of human sense organs is not a matter of prosthetic extensions of human modes of sensing, but instead of expanding what can be sensed without this being accessible to human sense perception. CERN thus can be considered an example of a technological system that, to speak with Hansen, expands the sensible without any necessary—let alone direct—connection to human sense perception and conscious awareness. In line with Hansen's argument about twenty-first-century mediation, additional (secondary) mediation is required to provide humans access to this expanded domain of sensibility.

Participants in the 'Knowledge Process'

CERN is an example of how contemporary techno-scientific developments radicalize the externalization of knowledge with respect to the "knower" observed by Lyotard. The scientific apparatus in place exemplifies what Hansen describes as the constitutive doubleness of twenty-first-century technologies: "their simultaneous, double operation as both mode of access onto a domain of worldly sensibility, and a contribution to that domain of sensibility."[42] The technologies that provide access to events outside the scope of human perceptual consciousness simultaneously contribute to the growth of this very domain of expanded sensibility. They performatively bring about what they measure. These technological developments catalyze a decentering of human experience and demand that we "embrace our subjective implication in a plethora of processes of all sorts and all scales."[43] That is, they require an understanding of human experience and meaning-making as a dimension of larger environmental processes of which humans are a part, but which are only partly accessible to them. By doing so, they bring to the fore aspects of scientific apparatuses that are not unique to them but (to paraphrase Hansen's observations on how twenty-first-century media technology instigates a rethinking of mediation) are revealed and intensified by them. Technology here can no longer be understood as a means to extend and circulate traces of human experience and human ways of knowing; increasingly, it is a means to expand the sensible in ways that align with Barad's onto-epistemological understanding of scientific practices. Technological developments highlight how human knowers participate in distributed practices of

41 Lyotard, *The Postmodern Condition*, 44.
42 Hansen, *Feed Forward*, 6.
43 Hansen, *Feed Forward*, 17.

knowing that encompass the broader material arrangement, and how scientific practices are social-material enactments that contribute to and are part of the phenomena being studied.

Lyotard's observations in his *Report on Knowledge* anticipate Barad's onto-epistemological approach while also offering a perspective on performativity that complements Barad's observations on the entanglement of knowing and being with an analysis of what McKenzie, two decades later, would describe as an onto-historical formation of power and knowledge. Both are aspects of the "becoming performative of knowledge itself" and how this raises fundamental questions about the nature of knowledge. Lyotard's prediction that "we may thus expect a thorough exteriorization of knowledge relative to the 'knower' at whatever point he or she may occupy in the knowledge process" tentatively points towards how this becoming performative of knowledge itself destabilizes an understanding of knowledge as object (reflected in Lyotard's reference to 'the knowledge process' instead), and towards the position of humans and the character of their participation in knowledge as a process, as crucial to answering these questions. How do the apparatuses in which humans participate compose relations between technical circuits and human experience and understanding? What does it mean to know if knowing is (to paraphrase Barad) a distributed practice in which humans participate? Barad writes of knowing, not of knowledge, yet their description equally raises the question of how to conceive of knowledge if knowing is a practice in which humans participate.

This productive tension between Lyotard's report on knowledge and Barad's understanding of knowing as distributed practice thus points to the complexity of conceptualizing what it means to know and who is the subject of this knowledge in a situation in which human experience and meaning-making are dimensions of larger environmental processes of which humans are a part, but which are only partly accessible to them.

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