Afterlives of Systems

Introduction

Under the impression of today's global crisis and the rise of ecological thinking, confronted with smart, ubiquitous technosystems and the impression of interconnectedness, there appears a new urge to excavate the remnants of the past. The articles of this issue suggest that in order to understand present technologies, we need to account the systems thinking that fostered their emergence, and that we cannot gain insight into the afterlives of systems without exploring their technologies.

The nine contributions ask how these debates and affective states survive and live on in today's discussions of media ecologies, environmentalism, object-oriented philosophies, computer simulations, performative art, and communication technologies. In this sense, they take the renaissance of systems thinking in the late 20th and early 21st Century as an effect of various system crisis and explore new media technologies as stabilizing 'cures' against the dystopian future scenarios that emerged after World War II. The articles of this issue suggest that in order to understand present technologies, we need to account the systems thinking that fostered their emergence, and that we cannot gain insight into the afterlives of systems without exploring their technologies.

Articles

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Introduction

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systems theory, afterlife, history, warburg, technology

Under the impression of today's planetary crises, the rise of ecological thinking, as well as technologies of smart, ubiquitous systems and the impression of global interconnectedness, there appears a new desire to excavate the remnants of the past. To investigate the historical and epistemological foundations of current systems thinking promises to lead to an understanding of the current condition that we are in – and its technological groundings.

When system-oriented thinking emerged within biological contexts in the first half of the 20th Century, it came along with universal pretensions: the concepts of *ecosystems* (Tansley) and *general systems theory* (von Bertalanffy) were both immersed in longstanding struggles between materialism and holism. The introduction of principles like feedback (Wiener) and self-organization (Maturana/Varela/von Foerster/Luhmann) through cybernetics and neocybernetics after the Second World War seemed to offer an alternative to the futile opposition of mechanistic or atomistic perspectives on the one side and holistic, organicistic or vitalistic perspectives on the other side within system-oriented thought. But underlying the subsequent institutionalization of system-oriented thought were diverse models of the relationship between a system and its parts, and alongside with that a renaissance of holistic concepts, e.g. holocoen (Friedrichs), biosphere (Vernadsky), noosphere (de Chardin), synergetics (Fuller), or Gaia (Lovelock). In a certain sense, system oriented thinking never lost its universal pretense.

The nine articles of this issue ask how these debates and affective states survive, perhaps thrive, in today's discussions of media ecologies, environmentalism, object-oriented philosophies, computer simulations, performative art, music, bionics, and communication technologies. They take the renaissance of systems thinking in the early 21st century as an effect of various system crises and explore new media technologies as stabilizing 'cures' against the dystopian future scenarios that emerged after World War II. In this sense, this issue suggests that in order to understand the present challenges, we need to account the discourses of systems thinking that fostered their emergence, and that we cannot gain insight into the afterlives of systems without exploring their technologies.

Applying Aby Warburg's and Walter Benjamin's historiographical concept of *afterlife*, this issue of *communication+1* investigates such recurrences of systems thinking and respective technologies since the Second World War. It attempts to describe the transformations and iterations the concept of systems has traversed to become productive at specific moments in time. Though the term 'systems' of course is much older than the 20th century, it is obvious that it became a common denominator since the formulation of genuine systems theories in the 1920s. By contextualizing different approaches to systems with earlier formations from the interwar period, we want to draw the attention to some aspects of systems thinking that remained unthought – and consequently returned as afterlives. While systems thinking in the 20th century and until today usually conceives itself as something new and innovative, this issue shows its historical groundedness.

For Warburg and Benjamin, an afterlife is more than the persistence of specific ideas, motives or concepts over a certain duration of time. As Warburg has shown for example in his famous picture atlas *Mnemosyne*, the cultural imaginary is haunted by anachronisms: ideas or images can return after long periods of 'slumber'.[1] Warburg is interested in the different layers of time such an afterlife has traversed: its origin in the past in which it was formed, its recurrence in a later time, at which it becomes plausible and productive again, and of course the present of the historian who connects these times.[2] As an anachronism of duration, the afterlife of a cultural object such as a concept, a picture, a model, etc. is more than a return of knowledge: it indicates the desires that lurk behind this knowledge and make it appear when the moment is ripe.

Historiographically, the concept of afterlife, in Warburgs and Benjamin's sense, traverses the order of narratives and times. Thus, as Georges Didi-Huberman has shown, the hybridity of every present becomes visible and the synchronous coherence of an epoch is questioned.[3] Histories become readable not only as propagations of knowledge, but as returns and losses, as layers of tensions between different pasts which are not directed towards the present in a teleological manner. Their visible surface constitutes the present. The aim of historians of afterlives is not to uncover an archetypal past that determines the present, but to continue a project of excavation and a sense for the singular. Such excavations of afterlives show, contrary to the usual perspective of the distant, invisible historian, the importance of his present for the constitution of the past.

Consequently, taking a specific idea, concept or motive – such as systems – for granted results in a loss of depth and all those disturbing effects are negated. In an afterlife, there is always something that cannot be transferred seamlessly into the present context. It always carries something that does not correspond to the current classification or even blows up its coherence. In this sense we understand this special issue of *communication+1* as a history of afterlives within modern media and communication theory.

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[1] Aby Warburg, *Der Bilderatlas MNEMOSYNE*. Edited by Martin Warnke and Claudia Brink. (Berlin: Akademie, 2000).

[2] See Thomas Brandstetter. "Vom Nachleben in der Wissenschaftsgeschichte," *Zeitschrift für Medienwissenschaft*, 1 (2009): 73–79.

[3] Georges Didi-Huberman, *L'image survivante: Histoire de l'art et temps des fantômes selon Aby Warburg* (Paris: Minuit, 2002).

The contributions of this issue are sorted into three sections. Following different conceptions of environments and ecologies, the first three articles broach topics like Bill Mollison's and David Holmgren's permaculture design, enviromental art of Alan Sonfist and the re-design of communication systems in the Canadian Arctic under seemingly post-colonial conditions.

The second perspective deals with simulations and takes up the technological impacts of systems analysis on computer games such as SimEarth and their correspondence to Gaia-theory, on the relation of ecological concepts and the algorithmic Game of Life by John Conway, and finally on the construction of nuclear power plants in Western Germany.

The final section investigates the psychic-cybernetic strata of second order cybernetics of Heinz von Foerster and systems theory in the United States as well as their relegation to biotechnical and bionic technologies in Germany before and after Second World War. The field report of a musicological archaeology introduces an autopoietic understanding of David Tudors electronic instruments.

Addressing diverse but interrelated topics, all these essays demonstrate not only how media histories today struggle with the double-bind of systems thinking which is part and parcel of the political agency within modern control societies (Deleuze) and biopolitical governmentality (Foucault), but also how they open a new vector for research and methods that promise to bridge the theory-practice divide in our scholarly lives and debates. With this issue we hope to keep this field open to a diversity of perspectives and interdisciplinary discourses, instead of flattening the surface of present systems thinking.

We wish to thank the authors of this issue for their informative and inspiring research, and for being patient with the German guest editors and their moments of struggle with the online publishing system. We also wish to thank the anonymous reviewers that donated their time in order to make this a true peer-review issue, and last but not least we wish to thank the editors of *communication+1*, Briankle Chang and Zach McDowell, for giving us this wonderful opportunity to publish these essays here and for their steady support throughout the process.

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Environment between System and Nature: Alan Sonfist and the Art of the Cybernetic Environment

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Abstract
This paper examines the role of systems thinking in environmental(ist) art and activism through a close reading and contextualization of *Army Ants: Patterns and Structures* (1972), an installation by Alan Sonfist, one of the leading figures in U.S. land art and environmental art of the 1960s and 1970s. It challenges a commonly held retrospective understanding of "environmental art" as being inherently about bringing nature into art (or into the gallery) by showing how important systems thinking, which blurred the natural-cultural divide, was to Sonfist and other artists of the time. It suggests that these two understandings of the environment -- one focused on nature, the other on systems -- were both allied and in tension, and that the unexpected technical problems faced by *Army Ants* can be attributed at least in part to a failure to acknowledge those tensions. Similarly, the paper suggests, the legacy of glossing over these different understandings of the environment has been at the root of broader conceptual problems with environmental art and activism.

Keywords
environmental art, land art, environmentalism, ecology, cybernetics, systems theory, Alan Sonfist

Cover Page Footnote
This is a revised version of a paper that was first delivered as part of a speaker series on "Ökologie und die Künste" sponsored by the Internationales Graduiertenkolleg InterArt at the Free University of Berlin, a German-language version of which is being published in a volume of the same name edited by Erika Fischer-Lichte and Daniela Hahn (Wilhelm Fink Verlag, 2014). I am grateful to the editors of that volume for their generosity in allowing this English revision to be published. I am also grateful to Peter Collopy, Bernard Geoghegan, Daniela Hahn, Tina Plokarz, Christina Vagt, and John Tresch for conversations that helped significantly in the development of the argument presented here.

Alan Sonfist is an environmental artist and landscape designer whose work in the 1960s and 1970s tread the blurry line between two conceptions of the environment: one centered on nature, the other on systems and cybernetics. Much of his work from this early period, when something called the "environmental movement" was still emerging, can be aptly described as "environmental art" both because it made use of natural objects and processes (taken from "the environment") and because the pieces themselves could be described as "environments," as Sonfist himself sometimes did.[1]

But what kind of environments were they, and what did Sonfist and others who used the term "environment" in this context mean by it? The answers shed light both on the history of the distinct but interrelated art movements that have gone under the names of earth art, land art, ecological art, and environmental art and on the place of systems thinking in the environmental movement. They suggest that the environment has been an enormously productive concept but also one whose multiple and contradictory meanings have made it possible to avoid certain hard questions about humans, nature, and the relationship between them.

One of Sonfist's best-known installations from this period, *Army Ants: Patterns and Structures* (1972), provides a particularly clear window onto the intersections of art, systems thinking, and environmentalism in its varied forms and meanings. Sponsored by the Architectural League of New York, the installation opened in March 1972 in the gallery of the Automation House on Manhattan's Upper East Side. At the time, Sonfist was a "blue-eyed, bushy-bearded, and soft-spoken" 25-year-old artist just beginning to exhibit his work in solo shows. For the Automation House installation, he constructed a 16- by 24-foot, sand-filled, plastic-lined enclosure within which he released between one and two million army ants of the species *Eciton hamatum*.[2] At the center of the

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[1] Although Sonfist resists being labeled an "environmental artist" (personal communication, 16 Dec. 2013), he is often described as such, as well as being described as a land artist, earth artist, or eco-artist. See, for example, Alan Sonfist, ed., *Art in the Land: A Critical Anthology of Environmental Art* (New York: Dutton, 1983); Baile Oakes, ed., *Sculpting with the Environment: A Natural Dialogue* (New York: Wiley, 1995); Sue Spaid, *Ecovention: Current Art to Transform Ecologies* (Cincinnati, Ohio: Contemporary Arts Center, 2002); Ben Tufnell, *Land Art* (London: Tate Publishing, 2006); Jeffrey Kastner and Brian Wallis, *Land and Environmental Art* (New York: Phaidon Press, 2010); Robert Rosenblum and Alan Sonfist, "Introduction: Interview with the Artist," in Alan Sonfist, *Nature, the End of Art* (Florence, Italy: Gli Ori, 2004), pp. 8-16; Jeffrey Kastner, ed., *Nature* (London: Whitechapel Gallery; Cambridge, Mass.: MIT Press, 2012).

[2] For contemporary press coverage of *Army Ants*, see Richard F. Shepard, "Going Out Guide," *New York Times*, March 1, 1972, p. 26; "Talk of the Town: Ants as Art," *New Yorker*, March 4, 1972, p. 30; "Seeing Things," *Print* 26, no. 2 (March 1, 1972): 62-

enclosure was a small wooden frame, meant to serve as the ants' home base. Each day Sonfist rearranged four separate food sources within the enclosure and drew and videotaped the patterns of movement that resulted as the ants sought them out. As one newspaper article explained, "[The ants] make the designs according to the conditions which he sets up."[3]

Sonfist later explained that he saw *Army Ants* as "an environment of army ants paralleling human civilization."[4] As part of the installation, he displayed his drawings of food locations and ant movements along with a video of humans moving en masse within the city. In the following pages I argue that *Army Ants* was one manifestation of what might be called the "environmentism" of the era: an interest in the relationships between individuals (or groups) and their environments that was not necessarily committed either to environmental determinism or to a political program for saving the environment — the two senses in which the term "environmentalism" has conventionally been used.

This "environmentism" embodied a tension between two understandings of environment that were common at the time. One of them was the understanding that was then being institutionalized by the environmental movement in the United States and elsewhere, particularly in governmental agencies and ministries of the environment but also in many environmental activist organizations. This was an understanding of the environment as the set of physical factors influencing human wellbeing, with the "natural" environment often being identified as an ideal away from which humanity had fallen and to which it should, so far as possible, return. This was, in other words, *the* environment. The other was an understanding of the environment as a system; that is, a set of interrelated objects and processes defined in relationship to a focal individual, community, or population. This was the environment *of* something or someone.

Whereas the first understanding tended to reduce a singular environment to nature, the second tended to expand multiple environments without limits.

66; Barbara Ford, "Army Ants: Fiends from Hell or Man's Best Friend?" *Saturday Review*, April 15, 1972, pp. 54-59; Lewis Thomas, "Notes of a Biology-Watcher: Antaeus in Manhattan," *New England Journal of Medicine* 286 (May 11, 1972): 1046-1047. It is discussed briefly in Marga Bivjoet, *Art As Inquiry: Toward New Collaborations Between Art, Science, and Technology* (New York: Peter Lang, 1997), p. 127; Barbara C. Matilsky, *Fragile Ecologies: Contemporary Artists' Interpretations and Solutions* (New York: Rizzoli International, 1992), p. 33.

3 Norman Nadel, "Artist 'Draws' Army Ants into Design," *Pittsburgh Press*, March 13, 1972, p. 6.

4 Carol Siri Johnson, "Interview with Alan Sonfist, Environmental Sculpture," *Essays in Arts and Sciences* 20 (1991): 85-95, on p. 93. The Whitney drawing can be seen in Alan Sonfist, *Nature, the End of Art* (Florence, Italy: Gli Ori, 2004), p. 154.

Conceptually, the environmental movement emerged at the meeting-point of these two tendencies, incorporating older concerns with nature conservation with newer, more expansive concerns about humanity's "total environment" and the environments of nonhuman forms of life. *Army Ants* illustrates the productive tension between these two understandings and the limits of systems thinking in the environmental art of the era.[5]

"Nature's Boy" Meets Systems Theory

I have chosen to focus on *Army Ants* because it illustrates these themes with particular clarity, but it does not represent a major discontinuity in Sonfist's œuvre. On the contrary, it is consistent with his efforts to bring found objects and processes into the gallery beginning with his earliest publicly exhibited works from the mid-1960s. These works include the *Crystal Monuments* series (1966-1972), in which crystals within glass enclosures changed phase in response to the ambient temperature.[6]

Like some of the work of his contemporaries, notably Hans Haacke, Sonfist's pieces from this period were often about interactions between objects and their gallery environments and the changes that those interactions led to over time. These included living things, such as bacteria growing and changing in response to heat, light, and moisture on the window of a gallery or snails leaving tracks in a plastic enclosure.[7]

This kind of art was environmentist in the sense I have described above; it was not necessarily a contribution to a political campaign to save nature (the most common meaning of "environmentalism" in English after the 1960s), nor did it assume that the environmental factors had a larger influence on behavior or biology than hereditary factors (the typical meaning of "environmentalism"

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5 For related intersections of art, systems, and environment in the work of Dan Graham and Robert Smithson, respectively, see William Kaizen, "Steps to an Ecology of Communication: *Radical Software*, Dan Graham, and the Legacy of Gregory Bateson," *Art Journal* 67, no. 3 (2008): 86-107; Reinhold Martin, "Organicism's Other," *Grey Room*, no. 4 (Summer 2001): 34-51. On the emergence of a similar set of questions around environment in Japan during this period, see Midori Yoshimoto, "From Space to Environment: The Origins of Kankyō and the Emergence of Intermedia Art in Japan," *Art Journal* 67, no. 3 (2008): 24-45.

6 Glueck, "Auction Where the Action Is," p. D26.

7 Described in Sonfist, *Nature, the End of Art*.

before the 1960s).[8] Nonetheless, it was centrally focused on the relationship between individuals and their environments.

In later works, Sonfist continued to experiment with processes that unfolded in time and with framing devices that called attention to the relation between objects and their environments. These works were often staged in settings outside the gallery, and they increasingly blurred the lines between land art and landscape design. His best-known work, *Time Landscape* (1965-1978), restored some of the pre-colonial vegetation of Manhattan on a small plot of land on the Lower East Side framed by fencing and pavement. Sonfist presented this as the first of a series of public monuments to nature. By the late 1970s, he had effectively positioned himself at the border between land art and landscape architecture, where he continues to work today.[9]

One of the first profiles of Sonfist to appear in the popular press, by art critic Grace Glueck for the *New York Times*, took pains to emphasize the artist's concern with nature while also situating him within a trajectory of twentieth-century modern art. Identified in the article as "Nature's Boy," Sonfist was quoted as identifying Marcel Duchamp as an important influence. Whereas Duchamp had "claimed man-made objects as works of art," however, Sonfirst argued that he was claiming "natural phenomena." Glueck stressed the activist nature of Sonfist's art, noting that two of his recent pieces had involved mobilizing viewers to mail "pieces of pollution" to their Congressional representatives and sending tin cans back to their manufacturers with notes asking for them to be recycled.

In Sonfist's work — at least as seen through the eyes of one art critic — a Duchampian questioning of the conventional boundaries of art and its conditions of exhibition was thus linked to a political commitment to the preservation of nature. Sonfist's idea of nature was, however, not the pristine nonhuman space of some of his contemporaries. Beginning with his earliest public statements, Sonfist consistently emphasized that he had little interest in uninhabited landscapes or in pristine nature, in contrast to certain other practitioners of what was coming to be called "land art" and "earth art." His experience growing up in New York had focused his attention instead on the nature to be found within densely settled landscapes, including both the woods of Bronx Park that he explored as a child and the dioramas on display at the American Museum of Natural History.[10]

8 These are the two definitions of "environmentalism" given in the current edition of the *Oxford English Dictionary*.

9 Jonathan Carpenter, "Alan Sonfist's Public Sculptures," in *Art in the Land*, ed. Sonfist, pp. 142-154; Bijvoet, *Art as Inquiry*, 132-134; Tufnell, *Land Art*, pp. 99-101.

10 Christine Terp, "The Primeval Forest Returns to Manhattan," *Christian Science Monitor*, Dec. 18, 1979, p. B4; Carol Hall, "Environmental Artists: Sources and

Nonetheless, even as he rejected some of the frontier theatrics of contemporaries such as Robert Smithson, Nancy Holt, and Michael Heizer, Sonfist's understanding of the category of "nature" remained largely untroubled: "I always get violently upset when I see people destroying nature," he told Glueck. To preserve "the environment" was, among other things, to preserve the kinds of urban woods and natural scenes that had inspired him as a child — that is, to preserve "nature" in the midst of the city.

The usage of the term "environment" as a near-synonym for "nature" was not unusual. Historians of the U.S. environmental movement have emphasized the importance of this new word for activists in the 1960s and 1970s who sought to differentiate themselves from an older generation of "nature conservationists".[11] (In German, the replacement of *Natur* by *Umwelt* tracks a similar shift.[12]) As Adam Rome notes, the phrase "environmental movement" only began to be used widely in the United States around the time of the first Earth Day.[13] However, this new word often obscured significant continuities. The environmental movement that emerged from Earth Day — "a national Environmental Teach-In" held in 1970 — and from similar demonstrations and protests in other countries typically saw the environment as effectively equivalent to "nature."[14] More precisely, the

Directions," in *Art in the Land: A Critical Anthology of Environmental Art*, ed. Alan Sonfist (New York: Dutton, 1983), pp. 8-59, on p. 52; Robert Rosenblum and Alan Sonfist, "Introduction: Interview with the Artist," in Alan Sonfist, *Nature, the End of Art* (Florence, Italy: Gli Ori, 2004), pp. 8-16, on p. 9.

11 Christopher Sellers, "Body, Place and the State: The Makings of an 'Environmentalist' Imaginary in the Post-World War II U.S.," *Radical History Review* 74 (1999): 31-64.

12 On the German conservation and environmental movements, see Thomas M. Lekan, *Imagining the Nation in Nature: Landscape Preservation and German Identity, 1885-1945* (Cambridge, Mass.: Harvard University Press, 2004); Frank Ueko□tter, *The Age of Smoke: Environmental Policy in Germany and the United States, 1880-1970* (Pittsburgh: University of Pittsburgh Press, 2009); Christoph Mauch, ed., *Nature in German History* (New York: Berghahn, 2004).

13 Adam Rome, *The Genius of Earth Day: How a 1970 Teach-in Unexpectedly Made the First Green Generation* (New York: Hill and Wang, 2013).

14 Gaylord Nelson, "National Teach-In on the Crisis of the Environment," *American Libraries* 1, no. 2 (1970): 140-141. The origins and impact of Earth Day are discussed in depth in Adam Rome, *The Genius of Earth Day: How a 1970 Teach-in Unexpectedly Made the First Green Generation* (New York: Hill and Wang, 2013). On the history of the U.S. environmental movement, see Samuel P. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985* (New York: Cambridge University Press, 1987); Robert Gottlieb, *Environmentalism Unbound: Exploring New Pathways for Change* (Cambridge, Mass.: MIT Press, 2001); Hal K. Rothman, *The Greening of a Nation? Environmentalism in the United*

environment of the environmental movement was nature damaged, contaminated, or threatened by humanity. A similar understanding of environment as nature was central to Sonfist's work and persona.

At the same time, an alternative understanding of environment as system was also part of his work, and the two understandings both complemented each other and came into conflict, as they did in environmental art and activism of the era more broadly. In the same article by Glueck cited above that described him as "Nature's Boy," Sonfist was quoted as describing his artworks as "ecological systems."[15] The phrasing is important: Sonfist was not saying that the artworks were about ecological systems, but that they were themselves such systems.

Sonfist's use of systems language here was imprecise, as much systems talk of the time was, whether it was being generated by scientists, artists, or activists. When the art critic Jack Burnham wrote about the rise of a new "systems esthetics" in *Artforum* in 1968, for example, he did not mean to claim allegiance to the sociological theories of Talcott Parsons or Niklas Luhmann, to the ecosystem theory of Howard and Eugene Odum, or to any other particular theory or theorist. On the contrary, he drew eclectically on sources as varied as Ludwig von Bertalanffy's general systems theory and the systems analysis of E.S. Quade, a theorist at the U.S. military think tank RAND.[16]

In the postwar United States, one did not have to be a self-identified systems theorist — someone like Parsons, Luhmann, Quade, Bertalanffy, the Odums, or the management theorist Herbert Simons, all of whom developed ambitious theoretical frameworks and conducted research aimed at determining the basic principles governing systems in the abstract — or even to know precisely what systems theory was to its academic practitioners to embrace the language of systems. It was precisely the vagueness of systems talk and its capacity to be applied to a wide variety of domains and to mean different things to different people that made it so widespread.[17]

States since 1945 (Fort Worth: Harcourt Brace College Publishers, 1998); James Morton Turner, *The Promise of Wilderness: American Environmental Politics since 1964* (Seattle: University of Washington Press, 2012); Christopher C. Sellers, *Crabgrass Crucible: Suburban Nature and the Rise of Environmentalism in Twentieth-Century America* (Chapel Hill: University of North Carolina Press, 2012).

15 Grace Glueck, "Auction Where the Action Is," *New York Times*, Nov. 15, 1970, p. D26.

16 Jack Burnham, "Systems Esthetics," *Artforum* (September 1968): 30-32.

17 On the multiple intellectual origins and ideological debts of mid-twentieth-century systems theory, see Robert Lilienfeld, *The Rise of Systems Theory: An Ideological Analysis* (New York: Wiley, 1978). On the adoption of systems talk by the American counterculture, see Fred Turner, *From Counterculture to Cyberculture: Stewart*

Nonetheless, systems talk was not totally unconstrained, and Sonfist's use of the term "ecological systems" to describe his artworks provides a clue to a tension around environment that was built into *Army Ants*. Sonfist's public persona was and remains that of a committed environmentalist in the now-conventional sense of the term, but his artwork from the 1960s and 1970s reveals an interest in environments that links him to contemporaries whose environmental art was not necessarily founded on opposition to the human destruction of nature, and could even sometimes be seen as contributing to it. For these environmental artists, the key concern was not "nature" per se but rather "environment" as an object of human control and as a determinant of human nature.

For "environmentists" in this sense, the main issue that needed to be addressed both in politics and in art was humanity's power to shape the environment that shaped humanity itself. This perspective often, but not always,

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Brand, the Whole Earth Network, and the Rise of Digital Utopianism (Chicago: University of Chicago Press, 2006). On systems theory in postwar art, architecture, and design, see Pamela M. Lee, *Chronophobia: On Time in the Art of the 1960s* (Cambridge, Mass.: MIT Press, 2004); Marga Bijvoet, *Art as Inquiry: Toward New Collaborations between Art, Science, and Technology* (New York: Peter Lang, 1997); Peder Anker, *From Bauhaus to Ecohouse: A History of Ecological Design* (Baton Rouge: Louisiana State University Press, 2010); Caroline Jones, "System Symptoms," *Artforum*, Sept. 2012, http://www.artforum.com/inprint/issue=201207&id=32014; Felicity Scott, "Limits of Control," *Artforum*, Sept. 2013, http://www.artforum.com/inprint/issue=201307&id=42636; Felicity Dale Elliston Scott, *Architecture or Techno-Utopia: Politics after Modernism* (Cambridge, Mass.: MIT Press, 2007); Luke Skrebowski, "After Hans Haacke: Tue Greenfort and Eco-Institutional Critique," *Third Text* 27, no. 1 (2013): 115-130; Edward A. Shanken, "Art in the Information Age: Technology and Conceptual Art," *Leonardo* 35, no. 4 (2002): 433-438. On the history of cybernetics in particular, see Geof Bowker, "How to Be Universal: Some Cybernetic Strategies, 1943-70," *Social Studies of Science* 23, no. 1 (1993): 107-127; N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999); Lily E. Kay, *Who Wrote the Book of Life? A History of the Genetic Code* (Stanford, California: Stanford University Press, 2000), especially pp. 73-127; Ronald Kline, "Where are the Cyborgs in Cybernetics?" *Social Studies of Science* 39, no. 3 (2009): 331-362; Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2010). On the emergence of ecosystem ecology, see Chunglin Kwa, "Representations of Nature Mediating between Ecology and Science Policy: The Case of the International Biological Programme," *Social Studies of Science* 17, no. 3 (1987): 413-442; Joel B. Hagen, *An Entangled Bank: The Origins of Ecosystem Ecology* (New Brunswick, NJ: Rutgers University Press, 1992); Stephen Bocking, *Ecologists and Environmental Politics: A History of Contemporary Ecology* (New Haven: Yale University Press, 1997).

led to interests that overlapped with those of the emerging environmental movement. It was possible to care deeply about humanity's changing environment without thinking that pollution, wilderness, or endangered species were the most important issues to address. For many environmentists both inside and outside the environmental movement, systems talk offered a seemingly rigorous way of understanding interactions among the diverse processes and objects that constituted humanity and its surroundings. [18] It was also a useful tool for contemporary efforts to bring aesthetics, technology, and civic activism together into a single, politically informed artistic practice.

Art's Technological Environments

By the time *Army Ants* opened in the spring of 1972, the language of systems was already circulating widely in the U.S. environmental movement. It had multiple sources and pathways of dissemination, including Buckminster Fuller's and Kenneth Boulding's imagery of Spaceship Earth, Stewart Brand's systems-infused *Whole Earth Catalog* (1968-1972), and the increasing public visibility of ecosystem ecologists such as the Odum brothers, who described ecological relationships in terms of circuits, signals, and feedback. Systems talk was also becoming increasingly present in the art world. *Army Ants* brought these two domains together, placing ecosystem science and what Burnham had called "systems esthetics" into a single frame.[19]

Sonfist had had an opportunity to become immersed in systems talk during his time as a fellow of the Center for Advanced Visual Studies (CAVS) at the Massachusetts Institute of Technology in the late 1960s and early 1970s, where he encountered a vision of civic art that was sensitive to environmental problems and conceived in terms of systems. Sonfist arrived as a fellow at the center in 1969 and remained affiliated through 1974. His interest in human-nature interactions in urban settings resonated with the vision of CAVS founder and director Gyorgy Kepes, a painter and art theorist who had followed the former Bauhaus master László Moholy-Nagy from Berlin to London and then to Chicago in 1937. In

[18] Fred Turner, *The Democratic Surround: Multimedia and American Liberalism from World War II to the Psychedelic Sixties* (Chicago: University of Chicago Press, 2013).

[19] Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: University of Chicago Press, 2006). On Fuller and Boulding, see Peder Anker, "Buckminster Fuller as Captain of Spaceship Earth," *Minerva* 45 (2007): 417-434; Peder Anker, "The Ecological Colonization of Space," *Environmental History* 10, No. 2 (2005): 239-268; Sabine Höhler, "The Environment as a Life Support System: The Case of Biosphere 2," *History and Technology* 26, no. 1 (2010): 39-58.

1947 Kepes had taken a position at MIT, where he founded a new program in the visual arts.

Two decades later, Kepes established CAVS to encourage the collaboration of technologists and artists and to advance his vision of "civic art": a technologically sophisticated, publicly engaged form of artistic practice that was, in Kepes's words, "prophetic of a new world outlook pervaded by a sense of continuity with the natural environment and oneness with our social world."[20] As Kepes used it, the term "environment" referred both to the natural environment, as in the quote above, and to artificial environments, including those constructed by artists.[21] The form of art practice that Kepes envisioned was "civic" because the artist, by creating or calling attention to environments, acted as an interpreter and critic of changes in the total human environment. It was systems-oriented because it focused on relationships and processes rather than on objects and drew on Kepes's engagement with cybernetics dating back to the 1950s.[22]

This political-esthetic vision was similar to that of Burnham, who was one of the first fellows that Kepes invited to CAVS. It was immediately before and during his time at MIT that Burnham published his major book *Beyond Modern Sculpture* (1968) and wrote his essays on "Systems Esthetics" and "Real Time Systems" for the contemporary art magazine *Artforum*. Like Kepes, Burnham argued that the "systems approach to environmental situations" was the most promising way forward for art and for modern society.[23]

More narrowly, systems talk provided a way for Burnham to capture what he saw as a shift from static forms to dynamic processes in the practice of many contemporary sculptors. The object as such, Burnham thought, was becoming increasingly unimportant; it was the system in which the object participated as a whole that mattered. Perhaps not surprisingly given his interest in moving beyond the static object, Burnham coupled his discussion of "systems" with the idea of "environments." If the idea of system implied the tightly coupled, dynamic

[20] Gyorgy Kepes, "Towards Civic Art," *Leonardo* 4, no. 1 (1971): 69-73, quote on p. 72. The title of a collection of essays that Kepes edited in 1972 suggests how central the environment was to his vision: Gyorgy Kepes, ed., *Arts of the Environment* (New York: G. Braziller, 1972).

[21] Reinhold Martin, "Environment, c. 1973," *Grey Room* 14 (2004): 78-101.

[22] Reinhold Martin, "The Organizational Complex: Cybernetics, Space, Discourse," *Assemblage* 37 (1998): 102-127.

[23] Burnham, "Systems Esthetics," p. 35; see also the discussion of the environment and information processing in Jack Burnham, "Real Time Systems," *Artforum*, no. 8 (1968): 49-55; Jack Burnham, *Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of This Century* (New York: G. Braziller, 1968). On systems thinking in Kepes, Burnham, and Haacke, see Jones, "System Symptoms."

relationships between objects, artists, and audiences, environment implied the general context within which those relationships were formed.

Barbara Mitalsky has argued that the movement called “environmental art” emerged in the late 1960s as artists “turned to nature and began interpreting its life-generating forces to create radically new kinds of art.”[24] However, this interpretation of the environmental in environmental art focuses on only one half of a two-part development that simultaneously figured environment as nature and as “system,” in Burnham’s sense of the word.

As Fluxus artist and theorist Kenneth S. Friedman would argue in a contribution to an anthology on land art and environmental art edited by Sonfist in 1980: “Only false romanticism or thin analysis can imagine environmental art to be related exclusively to ‘the natural.’”[25] The concerns of Sonfist, Kepes, and others working in environmental art, even those who were deeply concerned about environmental problems, cannot be reduced to the kinds of concerns that would become the near-exclusive focus of environmental agencies and activist organizations in the following years: air and water pollution, open space, wilderness areas and national parks, endangered species and biodiversity, and so forth. They did often share these concerns, but only as part of a broader understanding of the environment as an all-encompassing system.

The venue in which *Army Ants* was exhibited, Automation House, illustrates the potential of systems talk to bridge the worlds of science, art, and politics. The project of labor lawyer Theodore W. Kheel, Automation House was described upon its opening in 1970 as “a symbol and demonstration of man’s wish to shape his future in a world of bewildering change,” specifically technological change. As in Kepes’s vision for civic art, “environment” was a key term: “While machine age tools may give him [i.e., man] more control over his environment than ever before, they sometimes leave him powerless to control his fate.” At its opening, Automation House served as the headquarters for three organizations: the American Foundation on Automation and Employment, the Institute of Collective Bargaining and Group Relations, and Experiments in Art and Technology, the last of which was headed by Robert Rauschenberg and Billy Klüver.[26] These organizations each represented a different strategy for addressing

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24 Matilsky, *Fragile Ecologies*, p. 36.

25 Kenneth S Friedman, “Words on the Environment,” in Alan Sonfist, ed., *Art in the Land: A Critical Anthology of Environmental Art* (New York: Dutton, 1983), pp. 253-256, quote on p. 256.

26 Automation House announced its opening in 1970 in a special advertising section in the *New York Times* funded by its corporate sponsors; see “Automation House: A Philosophy for Living in a World of Change,” *New York Times*, Feb. 1, 1970, p. AS2.

the challenges posed by technology: the first focused on the individual worker, the second on unions and corporations, and the third on art and culture.

The centrality of systems thinking and of "environmentism" to the projects based at Automation House is evident in the building itself. Its promotional materials described it as a multimedia environment equipped with "the technology of tomorrow," particularly the latest in communications devices and automated environmental systems.[27] The artworks displayed in Automation House's first-floor gallery space made visible the principles already embodied in the operation of the building: they were environments within an environment that sought to make humanity's relationship to its environment visible. On the artistic front, Experiments in Art and Technology was not merely about artists using technology but also about the transformative effects of new technologies on humanity's relationship to its environment. As Klüver explained to one journalist in 1968: "We are, in all respects, responsible for the technology that will form our environment tomorrow."[28]

The art that took place under the umbrella of EAT did not always or even usually transcend the fascination with gadgetry of which it was often accused, nor was it able to escape the limits imposed by its heavy reliance on corporate sponsorship. Institutional critique it was not. Even in its most superficial and unreflectively technophilic moments, however, EAT conveyed a consistent message: that technological advancement had made humanity capable of reshaping the environments that in turn shaped humanity, and that art could help humanity understand its new responsibilities.[29] The projects conducted under its

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The initial plans for Automation House are described in "Art & Technology Make It Official," *Wall Street Journal*, Oct. 11, 1967, p. 16.

27 "Automation House: A Philosophy for Living in a World of Change," *New York Times*, Feb. 1, 1970, p. AS2. A special advertising section announced the opening of Automation House in the *New York Times* in 1970 with support from its corporate sponsors.

28 Roderick Nordell, "'We're Not Interested in Art,' the Man Said," *Christian Science Monitor*, May 13, 1968, p. 4.

29 The first exhibit in Automation House's gallery space was *The Magic Theater* (1970), a show of environmental art previously exhibited in Missouri and Ohio; see George Ehrlich, "'The Magic Theater' Exhibition: An Appraisal," *Art Journal* 29, no. 1 (1969): 40-44; Nancy Moran, "Art and Technology Merge at Exhibit," *New York Times*, Mar. 3, 1970, p. 43; Heidi Sinick, "'The Magic Theater' Takes You on a Trip to Mystery Land," *Washington Post, Times Herald*, Mar. 15, 1970, p. H3. In 1970 Automation House was also host to Projects Outside Art, described in one article as consisting of projects "concerned with the environment (e.g., education, health, housing, natural environment, transportation, communication, etc.)"; John H. Holloway, "International Science-Art News," *Leonardo* 3, no. 4 (1970): 481-488,

umbrella were rarely environmentalist in tone, and even when they did address environmental problems, they tended to focus implicitly or explicitly on technological solutions. Nonetheless, whatever their stance on such issues, they were clearly "environmentist."

The Army Ants of *Army Ants*

Like the history of the venue in which *Army Ants* was exhibited, the background of Sonfist's choice of army ants as the living organisms whose "patterns and structures" would become the subject of his installation provides some context for understanding how systems talk infused understandings of the environment and of environmental art at the time.

Drawing as it did on a tradition stretching back to antiquity, the choice of social insects such as ants, bees, or termites as analogs for human society was hardly original.[30] Beyond the general appeal of the insect metaphor, however, Sonfist turned to army ants because of particular characteristics that distinguish them among the thousands of species of social insects. Rather than constructing permanent nests out of found materials, colonies of *Eciton hamatum* use the living bodies of their members as building blocks for nests, bivouacs, bridges, and other infrastructural elements. Shirley Strum and Bruno Latour have argued that baboons are constantly testing the nature and boundaries of their society because they have only themselves and their bodies to rely on rather than the complicated institutions, expectations, and artifacts that stabilize human society.[31] Army ants have far more rigid social roles than baboons, but in the realm of material

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quote on p. 482. The very range of subjects considered to be part of the environment suggests the broad meaning of the term as used here.

30 On the use of social insects as metaphors for human society, see Charlotte Sleigh, *Ant* (London: Reaktion Books, 2003) and *Six Legs Better: A Cultural History of Myrmecology* (Baltimore: Johns Hopkins University Press, 2007); Janine Rogers and Charlotte Sleigh, "'Here Is My Honey-Machine": Sylvia Plath and the Mereology of the Beehive," *Review of English Studies* 63, no. 259 (2011): 293-310; Jussi Parikka, *Insect Media: An Archaeology of Animals and Technology* (Minneapolis: University of Minnesota Press, 2010).

31 S.S. Strum and Bruno Latour, "Redefining the Social Link: From Baboons to Humans," *Social Science Information* 26, no. 4 (1987): 783-802. See also Bruno Latour, "A Well-Articulated Primatology: Reflections of a Fellow Traveler," in *Primate Encounters: Models of Science, Gender, and Society*, eds. Shirley C. Strum and Linda Marie Fedigan (Chicago: University of Chicago Press, 2000): 358-381. For an earlier expression of a relate idea about the purity of nonhuman sociality, Gregory Bateson, "Problems in Cetacean and Other Mammalian Communication," in *Steps to an Ecology of Mind* (Chicago: University of Chicago Press, 2000), pp. 364-378.

construction they are similarly flexible, constantly adapting and reforming their structures in response to internal and external factors.[32] It is not hard to see why an artist as interested as Sonfist was in how form emerges from biological processes would have found them an appealing subject.

There was another reason that army ants were particularly good choices for bringing together environmental art and activism through the language of systems. As Charlotte Sleigh has shown, army ants played a surprisingly important role in the development of postwar cybernetics; she argues that in the immediate postwar years, "ants in their then-favored forms of representation helped to create cybernetic science."[33] Among other things, they were key examples in mathematician Norbert Wiener's *Cybernetics: Or Control and Communication in the Animal and the Machine* in 1948, and they were a recurring subject of discussion at the Macy conferences on cybernetics in the 1940s and 1950s, which had served as an inspiration not only for many scientists but also for artists and designers, including Kepes.[34]

For cyberneticians, ants, and specifically army ants, provided a seemingly clear biological model of the emergence of complex behaviors from the interactions of simple agents. They also provided a powerful metaphor. The organization theorist and artificial intelligence researcher Herbert Simon, for example, used the ant in his 1969 book *The Sciences of the Artificial* to suggest that the internal structure of an agent was largely irrelevant to understanding its macroscopic behavior, inasmuch as the latter reflected its adaptation to a

[32] For a recent study of army ant architecture, see Simon Garnier, Tucker Murphy, Matthew Lutz, Edward Hurme, Simon Leblanc, and Iain D. Couzin, "Stability and Responsiveness in a Self-Organized Living Architecture," *PLoS Computational Biology* 9, no. 3 (2013).

[33] Sleigh, *Six Legs Better*, p. 163.

[34] On Kepes's understanding of cybernetics and his communications with Wiener and others involved in its development, see Orit Halpern, "Perceptual Machines: Communication, Archiving, and Vision in Post-War American Design," *Journal of Visual Culture* 11, no. 3 (2012): 328-351; Martin, "Organizational Complex." On the role of ants in cybernetics, see Sleigh, *Six Legs Better*, p. 157; Norbert Wiener, *Cybernetics; Or, Control and Communication in the Animal and the Machine* (New York: J. Wiley, 1948). Wiener also discusses ant colonies as analogies for fascist human societies in *The Human Use of Human Beings: Cybernetics and Society* (Boston: Houghton Mifflin, 1950), pp. 51-52, 58.

particular environment. For Simon, as for many cyberneticians, the relevance of such models for understanding human behaviors and societies was clear.[35]

The cyberneticians' adoption of the ant as model ironically entailed a rejection of the theoretical position of the scientist upon whose empirical work they drew most heavily: T.C. Schneirla, an animal psychologist at the American Museum of Natural History in New York. Although Schneirla's studies of army ants were central to the cyberneticians' discussions, and although he and his students actively participated in the Macy conferences, Schneirla was skeptical of attempts to build universal models on the backs of ants. In an article in *Scientific American* in 1948, he and his coauthor argued that the effect of one ant's behavior on another's "resembles the action of a row of dominoes more than it does the communication of information from man to man."[36]

For Schneirla, the human capacity for flexible symbolic communication placed human society in a different realm than rigid, mechanical ant societies. By the early 1970s, however, despite Schneirla's opposition and a backlash against the term "cybernetics" itself, the cyberneticians' focus on communication and information had come to dominate ant biology and evolutionary biology more broadly.[37]

It was a former graduate student and collaborator of Schneirla's at the American Museum of Natural History named Howard Topoff who provided Sonfist with expert advice and the opportunity to collect army ants for *Army Ants*. Topoff shared many of his mentor's research interests as well as his skepticism toward cybernetic universalism. In February 1972, Sonfist accompanied Topoff and his team to the Smithsonian Institution's research station on Barro Colorado Island in the Panama Canal Zone. After three weeks of sweat and struggle, including a fall that knocked Sonfist unconscious and required several days of hospitalization, they succeeded in collecting the colony of *Eciton hamatum* that would soon become the centerpiece of an art installation in Automation House.[38]

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35 Herbert A. Simon, *The Sciences of the Artificial* (Cambridge, Mass.: MIT Press, 1969), p. 23-25. Simon also noted that "almost every element in our environment shows man's artifice" (p. 3).

36 T.C. Schneirla and Gerard Piel, "The Army Ant," *Scientific American* 178 (June 1948): 16-23, quote on p. 22.

37 On Schneirla, see Sleigh, *Six Legs Better*; Tania Munz, "The Bee Battles: Karl von Frisch, Adrian Wenner and the Honey Bee Dance Language Controversy," *Journal of the History of Biology* 38, no. 3 (2005): 535-570; Marga Vicedo, *The Nature and Nurture of Love: From Imprinting to Attachment in Cold War America* (Chicago: University of Chicago Press, 2013), p. 97.

38 Sonfist, *Nature, the End of Art*, p. 155.

The significance of the connection between artist and scientist in this case is not that Topoff transmitted a cybernetic or systems-theoretic understanding of ant behavior to Sonfist, who then designed an art installation around those principles. On the contrary, Topoff had learned from Schneirla to be skeptical of the cyberneticians' attempt to turn communication into a master concept with universal reach. To the extent that *Army Ants* manifested certain cybernetic or systems-theoretic understandings of the organism-environment relationship, it was despite Topoff and Schneirla rather than because of them.

Even Sonfist's idea of using food sources to redirect the ants' movements was a departure from Schneirla's and Topoff's core research interests. In fact, much of Schneirla's career had been devoted to demonstrating that the social organization of army ant colonies had more to do with the internal physiological dynamics of the colony than it did with the availability of food or other external factors.[39] In any case, it does not seem that Topoff and Sonfist's conversations were of a particularly intellectual nature. Sonfist relied on Topoff and his team for practical advice about where to find army ants and how to get them to Manhattan and keep them alive.[40]

Nonetheless, there is more than an accidental connection here between art and science. Sonfist's choice of army ants was informed by his understanding of the environment as both nature and system, which in turn had been influenced by cybernetics and systems theory, which in turn had been influenced by the studies of ants carried out by Schneirla and his students. *Army Ants* represented the fruition in artistic form of a cybernetic vision of ant and human society in which simple agents behaved in complex ways in response to changing conditions. It was a system, moreover, in which the bodies and behaviors of ants and humans became constituent parts of the relevant environment. Just as army ants made bivouacs and bridges out of their own bodies, so did the human visitors to Automation House serve as living components of the installation.

Not all observers were impressed by this kind of art or its ability to contribute to an environmental awakening. In 1971, Sonfist had had a show at London's Institute of Contemporary Art that included pieces featuring living worms, locusts, and snails within enclosures. The ICA was an important node in the art and technology network, having organized the groundbreaking Cybernetic Serendipity exhibition in 1968.[41] A scathing review of Sonfist's show in *New*

[39] T.C. Schneirla, *Army Ants: A Study in Social Organization*, ed. Howard Topoff (San Francisco: W. H. Freeman, 1971).
[40] Personal communication, Howard Topoff, 12 Dec. 2012.
[41] Rainer Usselmann, "The Dilemma of Media Art: Cybernetic Serendipity at the ICA London," *Leonardo* 36, no. 5 (2003), pp. 389-396.

Scientist described him as a "propagandist for the new technological ideology of environmentalism" who was unwittingly contributing to "the coming ecocatastrophe" by implicitly celebrating human mastery over nature, despite his claims to the contrary.[42]

While overdrawn, this criticism was not entirely unfounded. If one considers the relevant "environment" of *Army Ants* to be the enclosure in which they were kept, the implicit message does seem to be one of human technological mastery, whatever Sonfist's consciousness-raising ambitions may have been. The process of rearranging food sources and observing the resulting movements can be interpreted as inviting the ants to participate as co-authors of the artwork, but it is an invitation that the ants cannot refuse. They may "make the design," but the privilege to set up the conditions remains that of the artist, who stands outside the system. Meanwhile visitors to the installation enjoy the opportunity to observe the system without participating in it. Sonfist's decision in the following years to focus on site-specific works outside of the gallery suggests that he may have recognized the limits and contradictions involved in bringing natural objects and processes into the gallery in order to heighten viewers' awareness of environmental interconnectedness.

However reasonable such a critique may be, I think it gives Sonfist and *Army Ants* too little credit. As with the *Crystal Monuments* series, the environment inside the ants' enclosure mattered mainly because it participated in processes that linked it to the environment outside of the enclosure — that is, to the larger environment that also contained the artist, the drawings and videos, and the visitors to the exhibit. Rather than being imposed from the outside, changes in this larger environment took place through rearrangement of materials, energy, and information within the system. The artist was still the designer, but one subject to the feedback (including criticism and misunderstanding) of the other participants.

It was in this sense that Army Ants was an environment *of* ants rather than simply an environment *for* ants. It may still have been an unfortunate development for the ants concerned, but it did not place them on the other side of an abyss separating them from the artist or from humanity. Visitors who entered the exhibit did not merely view an adaptive system on display; they became part of one. Like the ants they came to see, they were provoked into generating new "patterns and structures" as they moved through the exhibit.

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42 Francis Arnold, "Alan Sonfist," *New Scientist*, 5 Aug. 1971, pp. 336-37; see also the rebuttal from the Institute for Contemporary Art: Jonathan Benthall, "Sonfist's Art," *New Scientist*, 12 Aug. 1971, p. 389.

Army Ants thus illustrates one of the contradictions of environmental art of the time. Inasmuch as it understood environment as nature, it tended to implicitly celebrate human mastery of and separation from the natural world in the very process of transforming natural objects and processes into works of art. Inasmuch as it understood environment as system, in contrast — a seemingly far more technocratic and potentially anti-environmental idiom, with roots not only in the biological thought of Bertalanffy or the Odums but also in military and economic decision theory — it tended to emphasize interdependence. The political environmentalism that emerged in the 1960s oscillated between these two understandings, attempting to save nature from humanity even while assuming that humanity was part of nature.

An Untimely Ending

After all of the careful planning and great expense that had gone into mounting *Army Ants*, it was an environmental system of a very pedestrian sort that turned out to play a decisive role in the fate of the installation. *Army Ants* had been scheduled to run for two weeks, but all of the ants died only a few days after it opened. The apparent cause of the catastrophe was the much-touted temperature control system of Automation House, which automatically lowered the temperature within the building over the weekend — unfortunately, in this case, to a level below that which the tropical ants could survive. For the remainder of the two-week exhibit, the "environment" of *Army Ants* was reduced to videos, drawings, and an empty enclosure.[43]

However disappointing it may have been, and however much it may have reflected a lack of care or foresight, the death of the colony should not have come as a great surprise. Even the ant experts at the American Museum of Natural History had trouble keeping tropical ant colonies alive for long, and in any case the ants' fate had been sealed the moment they were removed from their native forest on Barro Colarado Island. Perhaps understandably, however, Sonfist did not appreciate this demonstration of the importance of the environment, instead threatening to sue Automation House for negligence. The leadership of Automation House eventually apologized, and Sonfist did not follow through on his threat.[44]

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[43] On the ants' death, see Richard F. Shepard, "Going Out Guide," *New York Times*, March 3, 1972, p. 28.

[44] The American Museum of Natural History lost most of a colony on exhibit due to low temperatures a few years later; "Museums Army Ants Succumb to the Cold," *New York Times*, October 24, 1974, p. 38. On Automation House's response and Sonfist's

It is tempting to read the ants' early demise as a parable about the risks of trying to isolate one component of an ecosystem from the others upon which it depends, as the writer and physician Lewis Thomas did in one of his regular columns for the *New England Journal of Medicine*, punningly titled "Antaeus in Manhattan." Despite having not seen the installation himself, Thomas felt he could imagine the scene: "The ants were, together with the New Yorkers, an abstraction, a live mobile, an action painting, a piece of found art, a happening, a parody, depending on the light."[45] Skeptical of the claim that Automation House's heating system was to blame, Thomas thought there was a deeper reason: separated from the sustaining earth, the ants had simply lost their strength, like Antaeus in the grip of Hercules. For Thomas, the problem with the "environment" of *Army Ants* was that it was not natural enough.

It would be equally reasonable, though, to argue that the problem with *Army Ants* was not that it was not natural enough but that it was not systemic enough. As the operation of the heating system had demonstrated, the system of *Army Ants* had been too narrowly imagined to encompass all of the factors that were vital to its success. The exhibit was an attempt to bring nature ("the environment") into the gallery and then to construct a system ("an environment") around it, which failed when the system that had been constructed proved to be fatally dependent on another system whose complexities had not been included in the original design. Caught halfway between "nature" and "system," between privileging nonhuman actors and establishing a system that included both humans and nonhumans, the environment of *Army Ants* proved to be not quite environmental enough. At the crucial moment, when the system generated something truly unexpected (if also unfortunate, within the parameters of the installation), its borders were closed and the surprise was declared a failure.

It was not an accident that the term "environmental art" was used during this period to describe both art that created environments and art that was environmentalist in its politics or subject matter. Environmentalism in its political sense was a subset of the broader perspective that I have been inelegantly calling "environmentism": that is, a concern with humanity's environment and its power to shape it and perhaps even destroy it. Nor was it an accident that both aspects of environmental art as they emerged in the 1960s and 1970s, nature-saving and environment-creating, were often conceived and described in terms of systems. The language of systems provided a way to speak with apparent rigor about inherently open-ended subjects, in part by making it possible to establish

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eventual decision not to pursue legal action, see Grace Glueck, "Out Is In on Columbus Circle," *New York Times*, May 28, 1972, p. D18.

45 Lewis Thomas, "Antaeus in Manhattan," *New England Journal of Medicine* 286 (1972): 1046-1047, quote on p. 1046.

boundaries between systems and their environments that always nonetheless remained subject to revision. As in the case of *Army Ants*, the language of systems left the door — or the air-conditioning vent — open to the recognition of new factors and new actors. Environmentalists' commitment to the category of nature, in contrast, often closed the door to a further expansion of whatever system was under examination.

Environmentalist thinking of the era was distinguished by this tension between nature and system. The belief that humanity's power had grown to the point that it threatened the existence of nonhuman nature was put in dialog with the belief that all things, human and nonhuman alike, were interconnected and mutually constituted. In response, some artists tried to bring natural objects and forces into the gallery in order to call attention to the agency, complexity, and vulnerability of the nonhuman world, while others tried to transform the gallery into an environment in order to call attention to the importance of the relationships between individuals and their surroundings.

Army Ants is worth considering because it tried to do both. It brought army ants captured in a Central American forest into a Manhattan gallery space and made them into components of an artistic system that included various material artifacts, the artist, and the visitors to the gallery. Its failure — by which I mean both the premature death of the ants and the failure to understand the cause of that death as part of the artwork itself — suggests the difficulty of thinking in terms of systems while holding onto nature. Not unlike preserving wilderness or saving endangered species, putting "natural" objects or processes on display in the gallery could manifest an interest in (and, often, a deep concern for) nature while also disavowing the nature that humans and their artifacts, too, were made of.

After all, if the aim had been to put a product or process of nature in the gallery, then a traditional painting — a composite of wood, fiber, oil, minerals, and animal and plant products changing slowly over time in response to heat and moisture — might have served just as well. The understanding of "environment" that tempted Sonfist and visitors to Automation House to see the army ants of *Army Ants* as more natural than a Jackson Pollock painting or than the gallery space itself, I would argue, ultimately limited not only the impact of Sonfist's piece but also of much of the environmental art and activism of the time. As unwilling to follow the expansive idea of systems to its logical conclusion as they were to fully embrace nature in all of its nonhuman excess and emptiness, its practitioners all too often remained stuck somewhere in the middle, worrying about the air-conditioning.[46]

[46] Luke Skrebowski, "All Systems Go: Recovering Hans Haacke's Systems Art," *Grey Room* 30 (Winter 2008): 54-83; Luke Skrebowski, "After Hans Haacke: Tue

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Arctic Infrastructures: Tele Field Notes

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Abstract
This article contextualizes the conditions of rural "connectivity" in the Canadian Arctic. It examines the emergence of satellites, fibre optic cables, and intranets as modes of social infrastructure at the outset of the twenty-first century. At present, Nunavut, the Northwest Territories, and the Yukon are all at a complicated confluence in that their current and inadequate telecommunications infrastructures are in the process of being renegotiated, re-designed, and re-allotted across civic, governmental, and corporate interests. The article shows how it is at sites of friction that the overlapping if fading legacies of systems-based thinking are emerging: satellites orbiting over fibre optic cable lines; corporate actors competing rather than coordinating with government agencies; and neoliberal rationales of mapping, division, and speed creating disjointed local markets. More broadly, these sites also demonstrate how indigenous forms of "connection" across the globe are increasingly experiencing telecommunications' lags and temporal disjunctures that are having very material effects on their supposedly post-colonial lives.

Keywords
Telecommunications Infrastructure, Arctic, Nunavut, Time, Media Theory

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Operation Nanook

In August of 2009, "Exercise Operation Nanook," [1] an annual Canadian government-sponsored military training initiative took place in and around Iqaluit, the capital city of the territory of Nunavut. On the 22nd of the month, Prime Minister Stephen Harper, then-Defense Minister Peter McKay, and Commander Alex Grant, assembled on the port bow of the HMCS Toronto, stationed in Frobisher Bay. In a video clip of the occasion,[2] a clear blue sky hangs above them. In the middle distance stand the impeccably placed Canadian Coast Guard ship the Pierre Radisson and HMCS Cornerbrook, one of Canada's four submarines. Seemingly on cue, three F-18 fighter jets in formation cruise by the three men. Seeing the event in real time, rather than through the various photographs that have captured the staging in the national press, emphasizes the symbolic, quite nearly propagandistic dimensions (and import) that the current Canadian government is placing on Arctic sovereignty and its demonstration through military presence. The behind-the-scene nature of the clip also gets at the unseen underpinnings of Operation Nanook as a whole. While it was widely considered a "successful" demonstration of Canadian search and rescue capacity, military ability, and the government's general ease of access and mobility in the Arctic more broadly, the operation also signaled the significant inadequacies of the country's northern telecommunications infrastructure. During an exercise involving hundreds of soldiers, emergency responders, and other government personnel, their communications activity overwhelmed and immobilized Iqaluit's telecommunications network.

Key

Over the past number of years, USB keys have been circulating around the Arctic at an increasing rate, both via airmail and on the bodies of corporate and government personnel. The nexus of high-cost bandwidth in northern Canada and the increasing prevalence of data-intensive government and corporate services supported by updatable software programs, are turning Arctic telecommunications

[1] "Operation Nanook," National Defence and the Canadian Armed Forces, accessed March 12, 2014, http://www.forces.gc.ca/en/operations-canada-north-america-recurring/opnanook.page#tab-1391073900791-5.

[2] "Frobisher Bay Fly Past," David Akin, youtube.com, accessed March 12, 2014, http://www. youtube.com/watch?v=9m96k_2swUI.

data transfer into a material mode of transportation. Chris Kalluk, an employee of Nunavut Tungavik Incorporated, the territory's cultural and economic organization based in Cambridge Bay, relates how his organization, instead of auto-updating their software, rents server space in Edmonton, a city in northern Alberta, downloads the necessary updates there, and has a local colleague mail a USB key to Cambridge Bay.[3] Nunavut's newly developed on-line driver's licensing system faces significant delays in issuing new licenses as, due to bandwidth limitations, driver information cannot be sent over the internet. Rather, USB keys with the necessary driver data are sent via airmail. As Kathleen Lausman, a deputy minister in Nunavut's Department of Community and Government Services, put it: "We have a state-of-the-art vehicle pulled by a team of dogs."[4]

Anomaly/Outage

At 6:36 am on October 6th, Nunavut and parts of the Northwest Territories and the Yukon went dark.[5] For sixteen hours, telecommunications services were nonexistent for the region's resident population. The outage was due to a malfunction on Telesat Canada's Anik F2 satellite—a "technical anomaly" in the company's estimation. Long distance and local phone services, the internet, cellular connections, and automated banking services were all unavailable. Many banks closed for the day as the sole connection between northern branch locations and southerly headquarters had been rendered inoperative. Retail debit and credit transactions could not be processed. Airlines decided to ground flights departing from Nunavut due to the loss of radar and weather services. Without fibre optic landline connections, Nunavut and the extra-metropolitan regions of the Northwest Territories and the Yukon are all satellite dependent. Nunavut's state

3 Omar El Akkad, "Fast, affordable Internet? The North is still waiting," *The Globe and Mail*, December 10, 2013, accessed March 12, 2014, http://www.theglobeandmail.com/report-onbusiness/breakthrough/fast-affordable-internet-the-north-is-still-waiting/article15855643/.

4 "Canada's Arctic a 'telecommunications backwater:' report," *Nunatsiaq Online*, August 30, 2011, accessed March 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674canadas_arctic_a_telecommunications_backwater_report/.

5 "Northern telecom service restored after 16-hour Telesat Canada satellite glitch," *Nunatsiaq Online*, October 6, 2011, accessed March 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674telesat_canada_screw_up_knocks_out_northern_telcoms/.

of *tele* (at a distance) disconnection, prompted Premier Eva Aariak to ask the Government of Nunavut to go into emergency mode, which entailed having essential services activate their iridium satellite phones in order to establish alternate channels of communication. For the duration of the outage, the Canadian Broadcasting Corporation's radio service was transformed into "Nunavut's communications lifeline" as it was the most readily available means of reaching all of the territory's communities.[6] The outage was caused by Telesat Canada losing control of the Anik F2 satellite, having it accidentally shift its orientation and turn away from Nunavut. The Anik F2, Anik F1R and Anik F3 are the three satellites upon which northern Canada is dependent.

Collapse

NEWS: Nunavik November 06, 2012 - 6:03 am
Lousy telephone service puts Nunavik at risk, doctor says
"It's as if the telecommunications network in the region was beginning to collapse"

"We call, we wait, nothing happens. It's like we're suspended in outer space. Or sometimes a loud noise blasts our eardrum. At other times, it's the 'South' calling: the line rings. Hello? Hello? No one. But the line rings and rings again later. Without call display, there's no way to know who is trying to call," [Dr. François] Prévost said.[7]

Flux

Canada's northern telecommunications infrastructure is in a state of flux. With new federally-subsidized satellites slated for launch in the next five to ten years, having the express goal of targeting and servicing the country's Arctic regions; the installation of more comprehensive fibre optic cable networks on the near if still tenuous horizon; alternative modes of telecommunications production, distribution, and consumption being created on the ground in the Arctic, largely

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[6] Ibid.
[7] Jane George, "Lousy telephone service puts Nunavik at risk, doctor says," *Nunatsiaq Online*, November 6, 2012, accessed March 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674lousy_telephone_service_puts_nunavik_at_risk_doctor_says/.

by indigenous actors; and, finally, the ongoing renegotiation of existing corporate and government telecommunications regulatory regimes a recurring reality, this state of flux signals to what extent Arctic telecommunications infrastructures are a matter of concern for the region's resident population, federal and territorial government personnel, agencies, services, and programs, and regional corporate actors, from multinational mining conglomerates to locally-owned tour operators. This constellation of issues, actors, geographies, and interests, demonstrates to what extent infrastructures can be contested ground across civic, political, and ideological domains. As Susan Leigh Star would have it, this makes of infrastructures both "ecological" and "relational" objects of study in that they point to the distributed constituencies, that are often local and agonistic, that such seemingly mundane and invisible pipes, road networks, and telecommunications systems subtend. "The image becomes more complicated," as Star writes, "when one begins to investigate large-scale technical systems in the making, or to examine the situations of those who are *not* served by a particular infrastructure."[8] In this sense, I am working out from the importance of "relation" in so much systems-based thinking, and arguing that infrastructures tend towards "open," quasi-ecological systems of emergence and instability rather than cybernetic loops and circuits.[9] At present, Nunavut, the Northwest Territories, and the Yukon are all at just such a complicated confluence in that their current and inadequate telecommunications infrastructures are in the process of being renegotiated, re-designed, and re-allotted across civic, governmental, and corporate interests. The question of who *will* be served by these restructuring efforts is an open one that I will put under investigation here.

A recent body of largely outstanding scholarly work has addressed what could be thought of as the expanded field of communicative practices and protocols of which infrastructure is increasingly an integral part. These range across analyses of infrastructural systems,[10] satellites,[11] and meteorological data.[12]

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[8] Susan Leigh Star, "The Ethnography of Infrastructure," *American Behavioral Scientist*, 43 (3) (November 1999): 380.

[9] To some extent, this is a return to the biological systems mapped by Ludwig von Bertalanffy in *Modern Theories of Development: An Introduction to Theoretical Biology*, trans. by J.H. Woodger (London: Oxford University Press, 1933).

[10] See Lisa Gitelman, ed., *"Raw Data" is an Oxymoron* (Cambridge, Mass.: MIT Press, 2013); Jeremy Packer and Stephen B. Crofts Wiley, eds., *Communication Matters: Materialist Approaches to Media, Mobility and Networks* (London: Routledge, 2012); Lisa Parks, "Around the Antenna Tree: The Politics of Infrastructural Visibility," *Flow TV* 9(9) (2009), http://flowtv.org/2010/03/flow-favorites-around-the-antenna-tree-the-politics-of-infrastructural-visibilitylisa-parks-uc-santa-barbara/; Mimi Sheller, "Infrastructures of the Imagined Island: Software, Mobilities and the Architecture of Caribbean Paradise," *Environment and Planning A* 41 (2009): 1386-1403; Nicole

While this work has been generative in my own thinking on the ways in which infrastructural systems develop, coalesce, and establish regimes of signification and material access, they have often not directly addressed the ways in which infrastructures, to return to Star, are sited ecological-relational practices, and this might predominantly pertain to telecommunications infrastructures in the Arctic region. While much of Star's work, and that undertaken with Karen Ruhleder in particular, [13] has focused on the relationships between types of labour, technological frameworks, and infrastructural systems, it nonetheless marks the important ways in which infrastructures are embedded in given social practices and technologies; become transparent via recurrent deployment and extend their reach beyond a phenomenon of single use; create forms of learned membership; establish links with preexisting modes of practice in a given system; embody regulated standards; telescope both backwards and forwards to interact with past and future systems; become visible in moments of breakdown; and signal the ways in which their forms of organization overshoot a single agency of control, thus incorporating incremental and diffuse forms of change.[14]

My primary goal here is to situate these contested characteristics of telecommunications infrastructures as they pertain to the Arctic as an emergent site of regional, national, and transnational connection. I aim to describe the sites

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Starosielski, "'Warning: Do Not Dig': Negotiating the Visibility of Critical Infrastructures," *Journal of Visual Culture* 11(1) (2012): 38-57, "Critical Nodes, Cultural Networks: Re-mapping Guam's Cable Infrastructure," *Amerasia* 37(3) (2012): 18-27, and "Beaches, Fields, and other Network Environments," *Octopus Journal* 5 (2011): 1-7; Nicole Starosielski, Braxton Soderman, and Cris Cheek, eds. "Network Archaeology [Special Issue]," *Amodern* 2 (2013), http://amodern.net/issues/amodern-2-network-archaeology/.

[11] See Lisa Parks, *Cultures in Orbit: Satellites and the Televisual* (Durham: Duke University Press, 2005), "Earth Observation and Signal Territories: Studying U.S. Broadcast Infrastructure through Historical Network Maps, Google Earth, and Fieldwork," *Canadian Journal of Communication* 38(3) (2013): 285-307; Lisa Parks and James Schwoch, eds., *Down to Earth: Satellite Technologies, Industries, and Cultures* (New Brunswick, N.J.: Rutgers University Press, 2012); Chris Russill, ed., "Earth-Observing Media [Special Issue]," *Canadian Journal of Communication* 38(3) (2013).

[12] See Chris Russill and Zoe Nyssa, "The Tipping Point Trend in Climate Change Communication," *Global Environmental Change* 19(3) (2009): 336-344; Chris Russill, "Forecast Earth: Hole, Index, Alert," *Canadian Journal of Communication* 38(3) (2013): 421-442.

[13] See Susan Leigh Star and Karen Ruhleder, "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces," *Information Systems Research* 7(1) (1996): 111-134.

[14] Star, "The Ethnography of Infrastructure," 381-382.

of "friction" into which these states of communicative emergence are cohering, whether they pertain to extractive industries such as iron ore mining or the changeable constitution of on-the-land indigenous ontologies. As Anna Tsing writes:

> Speaking of friction is a reminder of the importance of interaction in defining movement, cultural form, and agency. Friction is not just about slowing things down. Friction is required to keep global power in motion. It shows us (as one advertising jingle put it) where the rubber meets the road. Roads are a good image for conceptualizing how friction works: Roads create pathways that make motion easier and more efficient, but in doing so they limit where we go. The ease of travel they facilitate is also a structure of confinement. Friction inflects historical trajectories, enabling, excluding, and particularizing.[15]

In a first section, "Indigene," I examine the Digital Indigenous Democracy project, based in Nunavut, and its role in the approval of the Baffinland iron ore mine. In the next section, "Satellite Futures," I consider the role such corporations as Telesat Canada are playing in the establishment of "local" conditions of broadband connectivity in the Arctic. Finally, in "Incidental Connection," I describe the currently proposed creation of an extensive fibre optic network across eleven communities in Nunavut by Arctic Fibre Incorporated, with this last section opening onto a concluding note on how we can go about studying both these infrastructural materialities and conditions of the present with a view to establishing more coherent anthropological approaches to these sites of connection.

While each section offers an Operation Nanook-style scenography of the actors and issues at play in each seemingly distinct geographic region and timeframe, they nonetheless seek to cohere into emblematic sites of "friction" that demonstrate how infrastructural systems constitute emergent relationships across a number of agonistic constituencies that are marking the expanded field of the Canadian communications landscape. It is at these sites of friction that the overlapping if fading legacies of systems-based thinking emerge: satellites orbiting over fibre optic cable lines; corporate actors competing rather than coordinating with government agencies; and neoliberal rationales of mapping, division, and speed creating disjointed local markets. More broadly, these sites demonstrate how indigenous forms of "connection" across the globe are

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15 Anna Lowenhaupt Tsing, *Friction: An Ethnography of Global Connection* (Princeton: Princeton University Press, 2004), 6.

increasingly experiencing telecommunications' lags and temporal disjunctures that are having very material effects on their supposedly post-colonial lives.

Indigene

The Digital Indigenous Democracy (DID) network was launched in 2012 by Isuma TV.[16] The network was created by Norman Cohn and Zacharias Kunuk, the latter best known as the director of *Atanarjuat* (2001). DID is a networked media platform designed to foster Inuit-forms of consensus building in the Arctic, though largely operating at present only in Nunavut. The project was launched in response to an Environmental Review (ER) of the proposed Baffinland Iron Mines Corporation mine site at Mary's River on North Baffin Island, which, if approved, would become one of the largest open-pit iron ore mines in the world.[17] In order to facilitate the timely and transparent undertaking of the ER and the necessary sharing of information that this entails amongst the communities affected by the mine, Isuma launched the DID as part of its Angiqatigingniq Internet Network (AIN), a media platform operating across community radio, local television, DIY filmmaking, and two-way high-speed internet. With typically low and costly speeds of broadband access in the majority of these communities, DID installs mediaplayers in each of the seven communities impacted by the ER that then stream Inuktitut-language Isuma TV programs, facilitate the uploading of user-generated content, and, across its other media platforms, informs the collective process of community consultation. The ultimate goal of the consensus process is a "multimedia Human Rights Impact Assessment" that will determine, in part, the costs and benefits of the Baffinland mine to and for the residents around Mary's River.[18] While, presumably, the AIN will continue to operate beyond the completion of the ER process, the work of the network raises some important questions around the relationships between

[16] Digital Indigenous Democracy, "About", accessed March 12, 2014, www.isuma.tv/en/DID/About.

[17] With the pace of northern resource development increasing, the twin poles of negotiation and convenience primarily characterize the relationship between diverse indigenous groups and the Canadian government. The former touches on the territorial independence achieved and the concomitant mineral rights held by indigenous groups, while the latter addresses the narrow, resource-driven policy frameworks through which many governmental actors view a large part of northern Canada. Moreover, it is large-scale mining projects that offer one of the only prospects of secure and medium term wage-labour to members of local communities.

[18] Ibid.

resource extraction and community-appropriate norms of consultation; the instrumentalization of new media technologies and the existential stakes of certain cultural formations; as well as the need for "transparent" modes of communication and local forms of governance. In many ways, the DID and the AIN mark the typically grey ethical shapes that certain forms of de-colonizing knowledge production can take: preserving and disseminating knowledges of longevity and situation while mediating new relationships with one's land-as-territory, as well as the adaptable ontologies and futural markets that it contains.

The DID network is an example of an infrastructural project that, at once, facilitates the development of such extractive industries as iron ore mining, while also creating a sense of pan-community-scale cohesion by enabling Inuktitut-language programming and information-sharing to bind geographically distinct communities together. On March 18, 2014, the Nunavut Impact Review Board (NIRB) approved the Baffinland Iron Ore Mines Corporation's Early Revenue Phase Proposal (ERPP).[19] This was the second phase of the consultation process, as the NIRB had already given its approval to the Mary River Project Proposal, which outlined Baffinland's intention of reclaiming an already existing mine site at Mary River, as well as building a one hundred and fifty kilometre railway to a newly built mine port at Steensby Inlet. The main purpose of the ERPP review was to ascertain the mine's potential effects on the region's surrounding ecosystem and socio-economic conditions. Along with a host of other federal and territorial governmental agencies, such as Environment Canada, Transport Canada, and the Pond Inlet Hunters and Trappers Organization, the NIRB also consulted with local residents through Isuma's DID network, granting Kanuk and Isuma TV intervenor status.[20] The NIRB's report emphasizes that Kanuk and Isuma TV wanted to see international human rights standards be integrated into Baffinland's corporate responsibility policies.[21] It credits Kanuk with facilitating a wide spectrum of public participation, and for ensuring that a mine project-specific web portal will "support oral Inuktitut communications."[22]

The DID doubles as both an economic and cultural facilitator, and the disseminator of a dialogue-based method that strives to create a mediated form of Aajiiqatigiingniq (deciding together), Inuit consensus building. It employs what could be thought of as a strategy of infrastructural opportunism in that the

[19] "Public Hearing Report: Mary River Project: Early Revenue Phase Proposal," Nunavut Impact Review Board, accessed March 22, 2014, http://www.isuma.tv/sites/default/files/attachments/140317-08mn053nirb_12_8_2_public_hearing_report-oede.pdf.
[20] Ibid., 11.
[21] Ibid., 52.
[22] Ibid., 52.

network gained a foothold in local communities by taking advantage of the slow and costly bandwidth connections that are prevalent. It largely functions as an extensive intranet that incorporates some modes of two-way communication, with the backbone of the network reliant on Isuma TV Inuktitut-language programming. Yet whom does this process serve? According to the DID, its constituencies include:

> lawyers who are solicited to deliver vast amounts of complex information in clear terms; company representatives that are struggling to understand the people, the culture and the challenges relating to land they are seeking to mine; governments and international organizations that are required to monitor and regulate land development and other indigenous peoples that face similar situations on their homelands and who can replicate the DID model in their own community.[23]

These layers of facilitation all rely on the DID's infrastructural intervention into the consensus building process, as well as into the pre-existing forms of mediatic organization specific to the Inuit communities surrounding Mary's River. Isuma TV filled an infrastructural gap left by a lack of adequate telecommunications systems in this part of the Arctic, and in filling that gap, incorporated a media-centric network that could both bolster Inuktitut-language use, ties, and presumably generational sharing, and facilitate forms of community-consultation that such extractive industries must rely on to gain territorial and federal regulatory approval. As Paul Edwards contends, infrastructures co-construct "the conditions of modernity."[24] In doing so, these infrastructures actively intervene in the production of comprehensive sociotechnical systems that facilitate the circulation of given ideologies, whether of micro-scale cultural development or resource extraction and use.

What the DID signals is how infrastructural relation can render operative a cross section of actors that are all implicated in the unequal standards of a telecommunications system. Rendering them "modern" entails renegotiating the terms by which a shifting sense of indigeneity can conform to emergent land-use practices, with these last often stemming from structural dependencies that make such (extractive) outcomes seem like inevitable ones. Here, "being" indigenous means being beholden to an infrastructural opportunism that implies connective ties to cultural and economic forms of participation that equally contain: the past,

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[23] Digital Indigenous Democracy, "About".

[24] Paul Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," *Modernity and technology*, Thomas J. Misa, Phillip Brey, and Andrew Feenberg, eds. (Cambridge, Mass.: MIT Press, 2003), 186.

as consensus building, the present, as mediating, language-based participation, and the future, as emergent relationships to the land.

Satellite Futures

Another latent interpretation of that now infamous photo op that Prime Minister Harper anchored, is that of the ways in which it flagged the profound disparities between southern and northern standards of communications infrastructure. Over the past twenty years or so, the infrastructural "digital divide" between these two distinct and unevenly populated regions has been perpetuated by the high cost of media connectivity in such places as the Arctic. While Operation Nanook signaled the need for an improved local telecommunications infrastructure in Iqaluit, its improvement was geared towards its eventual instrumentalization by military and other government departments in the perpetuation of Canadian sovereignty claims in the Arctic.

One outcome of Operation Nanook's communications failure was the Arctic Communications Infrastructure Assessment Report (ACIA) published in April of 2011. It was funded by the Canadian Northern Economic Development Agency, and sought to address the development and continued improvement of communications infrastructures in the Arctic for the 21st Century. Although the ACIA largely focused on the infrastructural needs of government departments and services, with emergency response and military strategy figuring prominently, it made a number of significant recommendations that framed communications for residents of the Arctic as "a matter of survival."[25] The ACIA report noted how, at present, "[t]here is currently no comprehensive strategy for connecting all Arctic communities to the level of service required within communities or between communities," equally across the Northwest Territories, the Yukon, and Nunavut.[26]

With this disparity at the forefront of the report's findings, its first recommendation called for government and corporate actors to readily commit to service parity across Arctic communities, as well as to ensure minimum connectivity standards for all Arctic communities to equal those offered in southern metropolitan centres, thus ensuring service parity across the entirety of

[25] "A Matter of Survival: Arctic Communications Infrastructure in the 21st Century," Northern Communications & Information Systems Working Group, April 30, 2011, accessed March 12, 2014, http://www.aciareport.ca/resources/acia_full-v1.pdf, 9.
[26] Ibid., 10.

Canada's territory, regardless of geographic location.[27] Given that the federal government has been the single largest purchaser of bandwidth in the Arctic, the ACIA also recommended that the government outline an Arctic-specific communications strategy to lower the cost of bandwidth and to address the severe shortage of bandwidth in communities served by both terrestrial (microwave and fibre optic) and satellite telecommunications systems. Finally, the report addressed the strengthening of essential communication services in the Arctic, seeking to create redundancies across the developing network in order to eliminate the possibility of blackouts and prolonged gaps in service, especially in emergency response type situations. Overall, the ACIA frames the Arctic as a location-specific market that cannot sustain important levels of corporate competition, and that, for the near future at least, is reliant on satellite-dependent telecommunications systems.

The rural Arctic's (extra-metropolitan Yukon, the Northwest Territories, and the entirety of Nunavut) reliance on what is, in essence, a monopolistic form of service provision by Telesat Canada, a privately owned company, means they are linked to a single type of privatized media connection that is both highly centralized and poorly regulated. This condition of Arctic "rurality" is in part defined by the lack of road infrastructure that connects many of these communities. This absence, that essentially (financially and infrastructurally) precludes the possibility of large-scale fibre optic or microwave forms of service delivery, makes satellite latency an important issue. As the ACIA notes, with delays ranging from eight hundred milliseconds to four seconds, such on-line services as videoconferencing or certain types of webpage retrieval will not work.[28] The conjunction between the rural Arctic's satellite dependency and its technical propensity towards latency, makes of rurality a condition of lag across several dimensions of tele-connection; ranging from modes of viewership and on-line/real time participation to broader concerns around community social justice issues. For instance, while Operation Nanook marked a system-wide problem for the Canadian military's communications infrastructure, on a more localized scale, some people in remote communities who suffer or have suffered from forms of domestic violence, fear for their safety because such a basic telecommunications service as call-display is unavailable on their phone lines.[29] In the context of Arctic rurality, the forms of learned membership, to return to Star, that its existing infrastructural conditions foster are, by and large, those of a deferred time lag caught in the bandwidth capacities of the early 2000s. Yet these practices and experiences of lag, as the example noted above indicates, taken in conjunction

[27] Ibid.
[28] Ibid., 86.
[29] Ibid., 161.

with the structural conditions of satellite-dependency, that are felt just as much across modes of cultural production and interaction as strategies for economic development, co-construct the real and perceived communicative limits of many communities in the Arctic.

"Despite the centrality of satellite technologies and services in so many aspects of contemporary life," as Lisa Parks and James Schwoch write, "the histories and practices key to these systems and services remain, by comparison to other means of global electronic information and entertainment, relatively unknown to most observers."[30] For Arctic residents, government personnel, and various scales of commercial actors, satellites are in fact front of mind, and are readily seen as contested technological ground. While different satellites perform different functions, including earth-observation, communications, and scientific (largely physics- and astronomy-related) data collection, without, as the ACIA notes, a comprehensive Arctic communications infrastructure strategy, each function remains in its own regulatory and policy vacuum. A new initiative put forward by the Canadian Space Agency (CSA) is trying to serve the High Arctic region through the Polar Communications and Weather Mission. This would comprise the deployment of two satellites operating in a highly elliptical orbit that targets the High Arctic; unlike the majority of geostationary satellites that orbit the earth along its equatorial plane.[31] The CSA's mission goals bring together both communications and meteorological improvements which range across operational capacities for federal departments with Arctic interests, the facilitation of natural resource exploration and exploitation, the enhancement of "connectivity of northern communities to the broadband information backbone infrastructure," and the provision of "high-quality operational data" to assess meteorological phenomena.[32] The conflation of all these interests demonstrates to what extent satellites can act as generative objects of inquiry that, following Parks and Schwoch, "necessitate revisiting communication theories of time/space and the very definition of 'media' itself."[33]

Satellite dependency is a condition that brings forward not only the competing, and seemingly at odds, group of actors in what could be thought of as the connection economies of the Arctic, but also manifests the differing forms of ontological presence that are emergent in the Arctic at present. From high-resolution meteorological capture, to data destined for natural gas exploration, to strengthening Arctic sovereignty claims by enabling long-term, futural lines of

[30] Parks and Schwoch, "Introduction," 2.
[31] "Polar Communication and Weather Mission," Canadian Space Agency, accessed March 12, 2014, http://www.asc-csa.gc.ca/eng/satellites/pcw/default.asp.
[32] Ibid.
[33] Parks and Schwoch, "Introduction," 6.

connection between and beyond indigenous lands, all these presences are captured within the complex of functions that satellites offer. With the subsidy that Industry Canada currently provides Nunavut Broadband Corporation's Qiniq telecommunications network set to expire by 2016, Telesat Canada also seems willing to acknowledge that the problem is just as much economic as technical. In a 2012 interview, Jim Bush, then vice-president of Telesat claimed that "[w]e don't have to build anything. The satellites exist today to [address the telecommunications gap between North and South]. There is a perception that there is no capacity available in the North. That's absolutely not true. The challenge is an economic one, not technical."[34] While the CSA's PCW project partly contradicts and supersedes Bush's claim, it also conceals the fact that regulatory regimes could enable more equitable forms of telecommunications access. The ACIA report, in searching for best-practice models, flags the government of Australia's establishment of a minimum standard of service of 12 MB/s. The Australian National Broadband Network, with an investment of $43 billion (AUS) over eight years, aims to build a comprehensive backbone network of both satellite and fibre optic infrastructure that will foster forms of dispersed competition as corporate actors will have access to the public network.[35] These sorts of enabling infrastructure strategies also have the effect of shaping the forms of presence that can take shape in such remote regions.

It is telling that the ACIA does indeed deem Arctic communications infrastructure "a matter of survival." "A sovereign Canadian Arctic requires Canadian citizens to live in it," as the report's authors programmatically note. "Resource exploration and extraction is made affordable in part because of the presence of communities with airstrips, hotels, and local workers. The military relies on a network of Rangers to patrol much of the Arctic. These national efforts require national support."[36] In this case, infrastructure begets infrastructure. Yet the social ontologies underpinning these infrastructural processes are also evolving in tandem. "Living" in the Arctic clearly means different things to different people. Lines of connection can be drawn and redrawn, equally across national claims, territorial lands, and an ever-expanding orbit of entrenched interests. The satellite bands, microwaves, and fibre optic cables that are being newly built and contested will, at once, both conceal and symbolize to what extent

[34] Jim Bell, "Telesat mounts Nunavut PR offensive to prove satellites still have a future," *Nunatsiaq Online*, September 24, 2012, accessed March 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674telesat_launches_nunavut_pr_offensive_to_prove_satellites_still_have_a/.

[35] Northern Communications & Information Systems Working Group, "A Matter of Survival," 174.

[36] Ibid., 191-192.

the Arctic is a highly networked environment where people not only survive, but live the experiences of satellite-dependency, tele time lag, and infrastructural opportunism.

Tele-, *comb. form*

1. (Before a vowel properly **tel-**, but more often in the full form), repr. Greek *τηλε-*, combining form of *τ□λε* afar, far off; used in numerous (chiefly recent) scientific and technical terms, mostly denoting or connected with special appliances or methods for operating over long distances; also in several terms connected with psychical research, denoting actions or impressions produced at a distance from the exciting cause, independently of the normal means of communication.[37]

Incidental Connection

After the devastating 1999 avalanche in Kangiqsualujjuaq, Nunavik, a coroner's report recommended that many Arctic communities should have at least one satellite phone for use in emergencies. In the immediate aftermath of the avalanche, residents faced overloaded long-distance telephone lines (all sixteen of them) when attempting to place calls to emergency responders in other communities. As such, the report also recommended the creation of long-distance telephone lines dedicated to emergency services.[38] As is so often the case, it took disaster with a human toll to reveal the tenuous reliability of telecommunications connections between such remote communities and better-provisioned centres to the south. In Inukjuak, in 2012, there were sixteen long-distance lines for a population of two thousand people. Today, many emergency organizations are forced to make appeals via public radio to ask someone to hang up to free a line to address the emergency situation at hand. The question of satellite dependency returns as the majority of northern telephone traffic moves through the limited number of currently orbiting satellites. This minimal level of service, that the ACIA report addressed across internet and telephone connections, makes Arctic

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[37] *Oxford English Dictionary*, comb. form "Tele-," accessed March 12, 2014, http://www.oed.com/view/Entry/198666?isAdvanced=false&result=7&rskey=4us4Hm&.

[38] George, "Lousy telephone service puts Nunavik at risk, doctor says."

communities into figurative satellites of a kind in their own right—seemingly caught in their own territorial orbits with costly, unreliable, and low speed forms of connection between them.

On October 30, 2012, Arctic Fibre Inc. announced an amendment to their plan to install an undersea fibre optic cable connecting London, New York, and Tokyo, with a crucial segment of the cable passing through the Canadian Arctic.[39] The amendment sought to have a backbone connection of the cable pass through the eastern edge of Hudson Bay from Cape Dorset to Kuujjuaraapik and Chisasibi.[40] From there, the cable would go through James Bay Cree territory and continue on to Montreal and New York. The advantage of having the backbone of the cable pass through this part of the Canadian Arctic lies in its reducing the distance between Tokyo and New York by several hundred kilometres, thus providing the trading networks that sign on to Arctic Fibre's cable system with profitable micro-temporalities that could lead to market gains. Along with the backbone connection, Arctic Fibre is proposing a series of spur lines that could benefit communities in Nunavik and Nunavut, as well as the James Bay Cree. Madeleine Redfern, the former mayor of Iqaluit, whose consulting firm undertook regulatory and land claims agreements on behalf of Arctic Fibre upon leaving office, noted that the main backbone proposed by Arctic Fibre would connect fifty-two percent of Nunavut's population to the more reliable and higher speed fibre optic system. Arctic Fibre is looking for provincial and federal governments to contribute one hundred and sixty-one million dollars to create spur lines for the communities adjacent to the backbone.[41]

By July of 2013, Arctic Fibre was organizing a series of community meetings set for late August in the seven locations along the proposed backbone connection in Nunavut.[42] The company was after local knowledge and input in determining the most appropriate landing sites for the cable spurs, taking into account ice conditions, distance from common anchorages, and wildlife migration

[39] "Arctic Fibre Applies For Canadian Landing Licence," Arctic Fibre Inc., October 3, 2012, accessed March 12, 2014, http://arcticfibre.com/arctic-fibre-applies-for-canadian-landing-licence/.

[40] Jim Bell, "Arctic Fibre to extend high-speed undersea backbone past Nunavik," *Nunatsiaq Online*, November 5, 2012, accessed March 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674arctic_fibre_to_extend_high-speed_ undersea_backbone_past_nunavik.

[41] Ibid.

[42] "Arctic Fibre ramps up cable project with seven-community Nunavut tour," *Nunatsiaq Online*, July 26, 2013, accessed March 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674arctic_fibre_ramps_up_cable_project_with_seven-community_ nunavut_tour/.

routes, amongst other factors. During one of these August meetings at the Hotel Arctic in Iqaluit, Doug Cunningham, president and CEO of Arctic Fibre, said "I think there's a lot that can happen in this community and I think we are creating a great public service that will be a great economic driver."[43] Earlier in the day, Cunningham and a group from Arctic Fibre took Iqaluit community leaders to the proposed landing site of the cable at Apex beach, on the outskirts of the town. The site lies just beyond the access road that leads down to the beach, and would have the cable make landfall at the foot of a few fading Hudson's Bay Co. buildings. Arctic Fibre officials assured Iqaluit's community leaders that the cable would be covered with a protective shield over the entirety of its length running along the tidal flats, with the cable itself laid in a submerged trench in order to ensure that it would not be damaged by ice-scouring. The officials claimed that the only visible infrastructure at the site itself would be the covered manhole needed to receive the cable.[44] In order to gain the necessary cable landing licenses from the federal government, Arctic Fibre first had to go through the approval processes of the Nunavut Impact Review Board (NIRB) and the Nunavut Planning Commission (NPC). On January 23, 2014, the NIRB announced that Arctic Fibre's project did not require an environmental hearing, but imposed fifty-two terms and conditions primarily touching on the protection of local ecologies.[45] According to Arctic Fibre, construction of the project will begin in May 2014.[46]

Arctic Fibre, in foregrounding its apparent "Arcticness," is placing a certain emphasis on this middle ground of the fibre optic infrastructure's systemic coverage. By taking the undersea cable through the Northwest Passage, Arctic Fibre is laying claim to a very tangible form of infrastructural connection predicated on the reduction of distances and times, and, by extension, the associated political economic benefits that can be derived from such a reduction. According to Arctic Fibre, the six hundred and twenty million dollar project is to be primarily financed by the emergent Asian, largely Chinese, broadband and cellular markets, who are increasingly after G3 and G4 services. "It is international carriers who are paying the freight here," Cunningham claims. "Our leading tenants will be the Chinese top three telephone companies. Third [sic] will be South Korea, then the Japanese and the Taiwanese."[47] In this calculus,

[43] Ibid.
[44] Ibid.
[45] Nunavut Impact Review Board, "Screening Decision Report NIRB File No.: 13UN035," January 23, 2014, accessed March 12, 2014, http://ftp.nirb.ca/01SCREENINGS/2014%20DECISIONS/12.4.4%20SCREENINGS/13UN035Arctic%20Fibre%20Submarine%20Cable/140123-13UN035-Screening%20Decision%20Report-OT3E.pdf.
[46] "Home," Arctic Fibre Inc., accessed March 12, 2014, http://arcticfibre.com/.
[47] Jim Bell, "Arctic undersea cable could end Nunavut's dependence on satellites,"

Nunavut and Nunavik would seem to be getting all the benefits of an incidental connection—an infrastructural geography that just so happens, for reasons of present and future economic expediency and profitability, to pass through their territories. According to Arctic Fibre, a single unit of satellite bandwidth, equivalent to a gigabit, provided by Telesat Canada can cost Arctic consumers up to two thousand five hundred dollars at present. By way of contrast, that same amount of data delivered via the proposed fibre optic cable would cost between one hundred and one hundred and twenty dollars within three years.[48] What Arctic Fibre would seem to be bringing to these Arctic communities are direct, quasi-immediate connections across internet-, television-, and telephone-platforms, all at a lower cost. In this schematic plan, latency would no longer be an issue. Local residents would be living in tandem, both in and at the same temporalities as Canadian communities to the south—their time lag would disappear, equally across digital as well as material realities.

While the Arctic Fibre proposal has also met with substantial opposition from corporate and government interests in Nunavut with an investment in satellite telecommunications systems, notably from the SSI group, a Yellowknife-based company that owns Qiniq Internet, one of the principal service providers in Nunavut, it nonetheless marks the emergence, for the first time, of a potentially *reliable* telecommunications infrastructure in the Arctic. Yet this seemingly beneficial and anodyne quality of fibre optic infrastructural "reliability," also signals the emergence and slow concretization of corporate and government actors that had, by dint of circumstance, neglect, disconnect(ion), and self-interest, left these Arctic communities to their own (ontological) devices. The ACIA report makes this clear by framing equal-access to broadband as first and foremost a military and emergency-response problem, and from there, addressing a long list of new federal needs across a number of departments and programs, from the Canadian Coast Guard and Corrections Canada, to Indian and Northern Affairs Canada and NavCanada; while also, and somewhat incidentally, providing a real and symbolic series of media connections to Arctic residents. These governmental "needs," which range from building a new port for military use, the development of permanent military ground stations to monitor satellite data transfer, and on to the implementation of an Environment Emergency Management System (E2MS) at a northern site, or providing support to the future distribution of "status cards" in local communities, they all signal the expansion of an infrastructural governmentality that can instrumentalize incidental

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Nunatsiaq Online, September 24, 2012, accessed March, 12, 2014, http://www.nunatsiaqonline.ca/stories/article/65674arctic_undersea_cable_could_end_nunavuts_dependence_on_satellites/.

[48] Ibid.

connections such as spur lines.

This governmentality is an instrument that is shaping the ongoing lives of indigenous residents in Arctic communities. It presupposes that the mere fact of indigenous land claims and local forms of government have righted the not so *post*-colonial imbalance between the exigencies of site-specific northern communities and the interests of a more diffuse group of global corporate and government actors that simultaneously extend both social services as well as forms of social sanction that often reorient or negate the stated interests of Arctic residents. Here it is important to examine, following Star and Ruhleder, the ways in which the projection of futural (and existing) infrastructural systems can lay claim to sited ecological-relational practices. Infrastructural "connection," in being incidental, raises questions around the attendant and often unforeseen relationships that these forms of connection will build in such regions as the Arctic. By consulting with Nunavut's residents and community leaders to determine where best to place the cable, Arctic Fibre is merely promoting, producing, and ultimately concealing the "existing visibilities" of its infrastructural system, and thereby sanctioning their intervention into these communities' material environments.[49] Moreover, these "negotiations of visibility" should include the political and cultural subjectivities that are co-shaping what "connection" means in their lives.[50] Thus, in this optic, a "politics of infrastructural visibility" for the Arctic can also make sense of the mutually enabling relational interconnections between resource extraction and government services that underpin the development of telecommunications infrastructure.[51]

It is in this sense that the building of the Arctic Fibre undersea cable is also an "environmental" issue, in that it points to the ways in which indigenous communities still retain vital if morphing connections to the land.[52] This is not to claim that this connection exists as a metaphysics, but rather that it is an evolving worldview that has not yet received appropriate or extensively formalized political, economic, and cultural forms of recognition. The incidence of the connection, in this reading, becomes a form of "slow violence" in that it touches on the important ways in which projects of infrastructural connection, much like environmental catastrophes such as climate change, "present formidable representational obstacles that can hinder our efforts to mobilize and act

[49] Starosielski, "'Warning, do not dig,'" 39-40.
[50] Ibid., 41.
[51] Parks, "Around the Antenna Tree."
[52] See Hans Carlson, *Home Is the Hunter: The James Bay Cree and their Land* (Vancouver: University of British Columbia Press, 2008).

decisively."[53] When a telecommunications infrastructure is deemed "essential," a "matter of survival," whether for the support and perpetuation of military activities, emergency response, or corporate action, the attendant social relationships that get built out from its seemingly inevitable implementation need to be examined for inequalities by asking who will benefit, how, and when? "We need to account for how the temporal dispersion of slow violence affects the way we perceive and respond to a variety of social afflictions," Rob Nixon writes.[54] When it comes to infrastructure in the Arctic, incidental connection may be just such an affliction.

Friction

Friction emerges. Anna Tsing's conceptualizing of a metaphorical "friction" is a useful device for slowing down subject-object relations in a given time and space. This shifting of speeds, when it comes to Arctic telecommunications infrastructures, is important as the infrastructural pace of northern development is framed in terms of being both urgent and overdue—"catching up with the times" can sometimes conceal much. To examine such diverse actors as the Digital Indigenous Democracy project, Telesat Canada, and Arctic Fibre Inc., requires investing in a politics of the delay that is an attempt to understand how communities can and do come to cohere in a non-teleological fashion. This delay could be a situation specific to late capitalism, in that communities, especially those in supposedly remote regions, seem under greater pressure to succumb to international networks of trade, particularly around natural resource economies dependent on fluctuating production cycles.

To move out of the teleology of "development," "connection," and "economic progress," is not to sidestep the evolution of a networked, non-essentialized indigeneity that is in constant flux in Arctic communities. Rather, it is to acknowledge that there are real, metaphorical, and ontological frictions that adhere to the implementation of telecommunications systems that are framed as being equitably beneficial across the spectrum of a societal conjuncture. This recognition could make more room for thinking about the discursive and political instabilities of post-colonial infrastructures that go beyond dams and roads, and can begin to incorporate telecommunications systems reliant on satellites, fibre

[53] Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, Mass.: Harvard University Press, 2011), 2.
[54] Ibid., 3.

optic cables, and microwave transmitters.[55] Thinking about these infrastructures as part of a post-colonial spatial politics for the present might also, on the level of method, call for more experimentation and cross-disciplinary affiliations. Lisa Parks and Nicole Starosielski have foregrounded the open methodological questions and possibilities raised by the study of communications infrastructure, yet these are, precisely, generous and open questions that are calling for more attention and generative forms of scholarly practice that attend to the temporal, social, and phenomenological conditions of emergence and lag that many indigenous communities are grappling with today.

In working through a series of "tele field notes" in this essay, I wanted to acknowledge how forms of fieldwork inspired by, if not strictly adhering to, anthropological methodologies might offer just such generative practices that can allow for the site-specificities of infrastructural connections to emerge. These field notes "at a distance" have prepared the ground for my undertaking "fieldwork" (of a kind) throughout the Canadian Arctic in order let these emergent cases of friction cohere across the continuum of actors involved in a literal "broadband" of sited interests. This bridging of distance, and, in the process, spending time in the thick of the Arctic's infrastructural moment, is important in that it not only complements the documentary and mediating biases of reports, the news media, scholarly production, etc., but also, for the communications scholar in particular, allows for understanding to potentially come into being through, if not participant-observation, then a sited experiential dimension that might disrupt the often stabilizing semiotic and political narratives of the Canadian telecommunications industry.[56] This method has a marginal if both recent and relatively distant tradition in the study of Canadian communications, with the latter perhaps best embodied in Harold Innis' "dirt research."[57] Yet how, unlike in Innis' smoothly dense descriptions of incremental

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[55] A recent example includes Julia Tischler's *Light and Power for a Multiracial Nation: The Kariba Dam Scheme in the Central African Federation* (Basingstoke: Palgrave Macmillan, 2013), however one of the best known books that addresses this question is Arundhati Roy's *The Cost of Living* (New York: Modern Library, 1999).

[56] See Darin Barney, "To Hear the Whistle Blow: Technology and Politics on the Battle River Branch Line," *TOPIA: Canadian Journal of Cultural Studies* 25 (Spring 2011): 5-28; and Peter van Wyck, *The Highway of the Atom* (Montreal: McGill-Queen's University Press, 2010).

[57] See William Buxton, ed., *Harold Innis and the North: Appraisals and Contestations* (Montreal: McGill-Queen's University Press, 2013); Jody Berland, *North of Empire: Essays on the Cultural Technologies of Space (*Durham and London: Duke University Press, 2009); and Charles Acland and William Buxton, *Harold Innis in the New Century: Reflections and Refractions* (Montreal: McGill-Queen's University Press, 1999).

and decisive societal change, to make the "dirt" show?[58] In other words, how to allow for the contest of subject-object relationship making to be captured with a valence approaching that of a discursive documentary photograph? How to describe living emergent frictions?

Paul Rabinow, in a 2007 Preface to *Reflections on Fieldwork in Morocco*, a "classic" of scholarly anthropological literature originally published in 1977, looks back to when he started writing the book and how at that time ethnographic fieldwork, while an obligatory "*rite de passage*" for every anthropologist, had more or less attained the status of a taken-for-granted method.[59] It was what anthropologists did. *Reflections* caused a scandal amongst anthropologists because in it Rabinow lifted the veil on how, why, and under what circumstances the anthropologist conducted fieldwork. He turned a documentary lens on the natures of anthropological fieldwork and in the process quite literally showed what values cohered in "being-there." While Rabinow has since turned to a more Foucauldian engagement with the anthropologization of philosophy,[60] this early work is valuable here because it shows that "fieldwork" is not a constrained or circumscribed practice. Rabinow's "fieldwork" renders the marks of its making visible. As such, to write a politics of infrastructural visibility into being for the Arctic requires living its infrastructures' social practices and sited technologies. This entails going beyond the visual in order to document how such phenomena as bandwidth speed, data delays, and other communicative marks of incidental connection are lived across communities in the Arctic by asking: how are infrastructures peopled? It also entails going there, not as an observant outsider, but as one more relation in the field of actors, issues, interests, and geographies that are co-shaping an infrastructural relationality that is fast becoming unproblematically indigenous.

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[58] See Harold Adams Innis, *The Idea File of Harold Adams Innis*, William Christian, ed. (Toronto: University of Toronto Press, 1980).

[59] Paul Rabinow, *Reflections on Fieldwork in Morocco* (Berkeley: University of California Press, 2007), xi.

[60] See Paul Rabinow, *Essays on the Anthropology of Reason* (Princeton: Princeton University Press, 1996), and *Marking Time: On the Anthropology of the Contemporary* (Princeton: Princeton University Press, 2008).

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Permaculture Design: On the Practice of Radical Imagination

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Abstract
Permaculture design is a concept that aims at transforming not only agriculture, but also city planning, architecture, development, etc. In short it aims to change human habitats. It is part of a new ecological paradigm that is currently spreading in popularity from the urban gardening movement to various other alternative movements such as the slow movement, sustainable architecture, etc. Permaculture design defines itself as building on systems theory (as formulated in particular by Howard Thomas Odum and Christopher Alexander). However I would like to propose that the afterlife of systems theory as expressed in the concept of permaculture, first developed by Bill Mollison and David Holmgren, should not only be sought in theoretical and analytical discourse. Instead we can understand permaculture as a form of figurative, ecological reasoning; a form of radical imagination drawn from the composite knowledge of a heterogeneous network of actors. Permaculture is thus neither a branch of environmental science nor an environmental political movement. Rather the philosophy of permaculture design questions the division between theory and practice or between rationality and sensibility. In permaculture design, these modes of knowledge are inextricably linked in explorations of patterns.

In this article, I attempt to delineate the ways in which permaculture design is rooted in the practical knowledge of systems. I shall limit myself to exploratory drilling, as it were, in three aspects of permaculture design thought. First, I describe permaculture thought as a form of practical knowledge that generated through a kind of visual thinking in patterns. Second, I describe permaculture thought as a type of thinking in which radical imagination and speculation play an active role. Third, I present permaculture thought as systems theory thought. However it departs from the idea of control inherent to systems theory, drawing instead from the equally popular (and colorful) Gaia hypothesis, which posits Earth as an intelligent, material assembly that modifies thought processes.

Keywords
Permaculture, ecological movement, ecology, system theory, Gaia, intelligencing, wild thinking

Permaculture design is a concept that aims at transforming not only agriculture, but also city planning, architecture, development, etc. In short it aims to change human habitats. It is part of a new ecological paradigm that is currently spreading in popularity from the urban gardening movement to various other alternative movements such as the slow movement, sustainable architecture, etc. Permaculture design defines itself as building on systems theory (as formulated in particular by Howard Thomas Odum and Christopher Alexander). However I would like to propose that the afterlife of systems theory as expressed in the concept of permaculture, first developed by Bill Mollison and David Holmgren, should not only be sought in theoretical and analytical discourse. Instead we can understand permaculture as a form of figurative, ecological reasoning; a form of radical imagination drawn from the composite knowledge of a heterogeneous network of actors. Permaculture is thus neither a branch of environmental science nor an environmental political movement. Rather the philosophy of permaculture design questions the division between theory and practice or between rationality and sensibility. In permaculture design, these modes of knowledge are inextricably linked in explorations of patterns.

In this article, I attempt to delineate the ways in which permaculture design is rooted in the practical knowledge of systems. I shall limit myself to exploratory drilling, as it were, in three aspects of permaculture design thought. First, I describe permaculture thought as a form of practical knowledge that generated through a kind of visual thinking in patterns. Second, I describe permaculture thought as a type of thinking in which radical imagination and speculation play an active role. Third, I present permaculture thought as systems theory thought. However it departs from the idea of control inherent to systems theory, drawing instead from the equally popular (and colorful) Gaia hypothesis, which posits Earth as an intelligent, material assembly that modifies thought processes.

Axioms of practical knowledge

Bill Mollison, a biogeographer[1] and autodidact born in Australia in 1928, is considered the founding father of the permaculture movement, together with his student David Holmgren.[2] In 1978, Mollison founded the Permaculture Research

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[1] Biogeography combines aspects of biological and geographical analysis and mediates between bioecology and geoecology.

[2] Holmgren met Mollison in 1973 at the Environmental Design School in Hobart, Tasmania and became his student. His doctoral thesis on sustainable agriculture became the basis for his famous 1978 book, Permaculture One. Bill Mollison, *Permaculture: A Designers' Manual*

Institute and in 1981 he received the Right Livelihood Award, the alternative Nobel Prize. Mollison's seminal book, *Permaculture: A Designers' Manual*, in which he outlines his novel idea of permanent agriculture, appeared in 1988. Motivated by the growing environmental, social, and political movements of the 1970s, Mollison developed the concept of permaculture as a response to the forceful warnings issued by the Club of Rome in their 1972 book *The Limits to Growth* and to the crisis of 'peak oil', which geologist Marion King Hubbert predicted would occur in 1995.[3] The permaculture concept is not simply an environmental protection measure or an organic farming principle, but rather a form of ecosystem design. As Mollison writes:

> This book is about designing sustainable human settlements, and preserving and extending natural systems. It covers aspects of designing and maintaining a cultivated ecology in any climate […].[4]

Mollison's idea was to design 'natural' ecosystems as they appear in 'nature' permaculture understands itself as a school of design based not on the ingenuity of human's capacity for abstraction, but on 'nature's genius' and on knowledge transfer between different systems via imitation. This is also expressed in the design concept developed by Mollison and Holmgren, which follows what they call the 12 permaculture design principles, based on creating and developing patterns. This principles are 1) Observe and interact; 2) Catch and store energy; 3) Obtain a yield; 4) Apply self-regulation and accept feedback; 5) Use and value renewable resources and services; 6) Produce no waste; 7) Design from patterns to details; 8) Integrate rather than segregate; 9) Use small and slow solutions; 10) Use and value diversity; 11) Use edges and value the marginal; 12) Creatively use and respond to change.[5] All processes within a system are regulated by these principles, which Mollison understands as "axioms".

> Let us look at the sets of principles that govern these systems. These principles, rules and directives are based on the study of natural systems. Axioms are established principles or self-evident

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(Sisters Creek, Tasmania: Tagari Publications, 1988), accessed April 4, 2014, http://de.scribd.com/doc/54165878/Permaculture-A-Designers-Manual-by-Bill-Millison, IXf.

[3] M. King Hubbert, "Nuclear Energy and the Fossil Fuels" (paper presented at the spring meeting of the Southern District, American Petroleum Institute, Plaza Hotel, San Antonio, Texas, March 7-8-9, 1956), accessed April 4, 2014, doi: http://www.hubbertpeak.com/hubbert/1956/1956.pdf.

[4] Mollison, *Permaculture*, forward.

[5] David Holmgren, *Permaculture. Principles and Pathways Beyond Sustainability*. (Hampshire: Permanent Publications, 2002), accessed April 4, 2014. http://library.uniteddiversity.coop/Permaculture/Permaculture-Principles_and_Pathways_Beyond_Sustainability.pdf, VIII.

> truths. A principle is a basic truth, a rule of conduct, a way to proceed. A law is a statement of fact backed up by a set of hypotheses which have proved to be correct or tenable. Theses and hypotheses are ideas offered up for proof or discussion. There are also rules and laws laid down which are neither rules nor laws. They do not pay much attention to defining how they got there. Now I have evolved a set of directives which say: 'Here is a good way to proceed.' It doesn't have anything to do with laws or rules, just principles.[6]

As axioms, they need not be derived or deduced, or even proven. For Mollison, they are natural laws, substantiated by the practice of repeated empirical observation in nature. Permaculture design accords central importance to the position of the observer. The observer watches the constant flux of the ecosystem in a manner of "protracted and thoughtful observation".[7] Observation is the foremost principle of permaculture design.[8]

Pattern: Embodied Knowledge

In permaculture design, the observation of nature is a matter of pattern recognition.

> A process of continuous observation in order to recognize patterns and appreciate details is the foundation of all understanding. Those observed patterns and details are the source for art, science and design. The natural and especially the biological world, provides by far the greatest diversity of patterns and details observable without the aid of complex or expensive technology. Those patterns and details provide us with a great repertoire of models

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[6] Mollison, *Permaculture*, 8.

[7] Ibid., IX. "The philosophy behind permaculture is one of working with, rather than against, nature; of protracted and thoughtful observation rather than protracted and thoughtless action; of looking at systems in all their functions, rather than asking only one yield of them; and of allowing systems to demonstrate their own evolutions." Ibid., IXf.

[8] See for example Mollison, *Permaculture*, 12 and 43; "Observation, the first principle of Permaculture, is the key to making use of succession. Landscapes embody dynamic processes with a history and, to some extent, a future that can be read from the signs observable now. This ability is a critical observational skill that can be developed. Dynamic change in nature and landscape is easily accepted as an intellectual concept, but our direct visual experience of landscape is most commonly a static image or picture in which the past and future are invisible." Holmgren, *Permaculture. Principles and Pathways*, 247.

> and possibilities for the design of low energy human support systems.[9]

Patterns are thus a visual embodiment of nature's knowledge. Permaculture explores, observes and describes these patterns, and then transforms them into various systems. Concrete permaculture design involves dividing landscapes into zones (of daily life: people, machines, animals, houses, etc.) and sectors (present and future energy sources, wilderness, temperature, light sources, etc.). These zones and sectors are investigated for patterns. In the end, the area being landscaped should be designed to best fit a few underlying patterns:

> Patterns are all about us: waves, sand dunes, volcanic landscapes, trees, blocks of buildings, even animal behaviour. If we are to reach an understanding of the basic, underlying patterns of natural phenomena, we will have evolved a powerful tool for design, and found a linking science applicable to many disciplines. For the final act of the designer, once components have been assembled, is to make a sensible pattern assembly of the whole.[10]

The designer thus creates data (patterns) and then works from this basis. Mollison and Holmgren describe the process of permaculture design as one of assembling components to form a pattern:

> Definition of Permaculture Design: Permaculture design is a system of assembling conceptual, material, and strategic components in a pattern which functions to benefit life in all its forms. It seeks to provide a sustainable and secure place for living things on this earth.[11]

Patterns bundle complex knowledge in a visual form. Abstraction and the reduction of complexity are intertwined with imagery and thus imagination. Patterns are 'embodied' systems theory knowledge, as Holmgren says of the myths and legends of the Australian aborigines:

> Further, I believe many of the insights of systems thinking that are difficult to grasp as abstractions are truths that are embodied in the stories and myths of indigenous cultures.[12]

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[9] Holmgren, *Permaculture. Principles and Pathways*, 13.
[10] Mollison, *Permaculture*, 70.
[11] Ibid., 69.
[12] Holmgren, *Permaculture. Principles and Pathways*, XXVI.

Mollison derives the technique of patterning from the aborigines.[13] In his view, patterns as embodied, visualized knowledge are not simply abstractions, but directly transport a complex knowledge of systems:

> Complex systems that work tend to evolve from simple ones that work, so finding the appropriate pattern for that design is more important than understanding all the details of the elements in the system.[14]

Holmgren describes this kind of knowledge transfer as osmosis or 'practical resonance':

> Apart from the ecological energetics of Howard Odum, the influence of systems thinking in my development of Permaculture and its design principles has not come through extensive study of the literature, but more through an osmotic absorption of ideas in the 'cultural ether' which strike a chord with my own experience in Permaculture design.[15]

Holmgren speaks of osmosis in the 'cultural ether' as a form of attaining knowledge. Thus permaculture knowledge is not scientific knowledge derived from systems theory, but axiomatic, practical, visual knowledge gained through osmosis. Mollison adds that permaculture thought within these patterns must be understood as a kind of empathy:

> As the design itself is a function of our understanding of the system, so does the yield also depend upon the degree to which we understand things. It is the intellect that decides all these things, rather than any extrinsic factors. I am not quite sure what the intellect is. I have put it as our ability to understand, which may not be intellectual but empathetical.[16]

Holmgren believes we must relearn the "ability to see, hear and otherwise recognize the patterns of nature".[17] In pattern analysis, taxonomical knowledge is generated though the observations of our senses. The aim is to create deeply subjective taxonomies that are able to work with Borgesian ambiguities. Whether

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[13] Mollison, *Permaculture*, 23; Bill Mollison, *Permaculture Design Course Pamphlet Series*. (Sparr, Florida: Barking Frogs Permaculture, 1981), accessed April 4, 2014, http://www.barkingfrogspermaculture.org /PDC_ALL.pdf, 74; Holmgren, *Permaculture. Principles and Pathways*, 22, 151f.

[14] Holmgren, *Permaculture. Principles and Pathways*, 127.

[15] Ibid., XXVI.

[16] Mollison, *Permaculture*, 9.

[17] Holmgren, *Permaculture. Principles and Pathways*, 128.

or not a pattern is recognized and transferred to other zones or sectors is completely random. For this reason, Mollison describes speculation as a basic modus of permaculture ordering:

Many speculations can arise from one observation! Speculations are a species of hypothesis, a guess about which you can obtain more information. To further examine these speculations, several strategies are open to the observer.[18]

Permaculture design's speculative, fuzzy pattern recognition is drawn from the work of the practical and theoretical architect and systems theorist Christopher Alexander.[19] Alexander understood patterns, unlike models, not as analytical abstractions, but as representations of human activity – as practical knowledge. Alexander linked patterns to emotional fulfillment, rather than rational analysis or theoretical clarity. His search for patterns was informed by the hypothesis that there are archetypical forms and relationships that have established themselves as proven, enduring, and 'good' architecture. He looked for those structures that had over time taken the form of practical knowledge. Alexander never clearly defined 'pattern'. However, in *A Pattern Language*, he did describe 253 concrete patterns that are linked through language.[20] He saw these patterns as proposals that were picked up by others and adapted to new situations. For Alexander, to work with patterns was to take existing conditions seriously, whether they were the result of environment, city planning, societal or architectural constraints. He therefore argued for designing on-site rather than making an abstract blueprint.[21] He would go to a site and build a full-size prototype with poles and fabric.[22] For Alexander and for permaculturalists, planning is a hands-on, on-site process, and design is a kind of environmental analysis that is speculative because it develops patterns from existing situations and conditions. Patterns are thus the speculative result of imagination – in Alexander's work and in permaculture design.

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[18] Mollison, *Permaculture*, 44; see also Holmgren, *Permaculture. Principles and Pathways*, 247.

[19] Mollison, *Permaculture*, 102; Holmgren, *Permaculture. Principles and Pathways*, 127.

[20] Christopher Alexander, *A pattern language, Towns, Buildings, Construction* (New York: Oxford University Press, 1978).

[21] "[...] do not try to design on paper!" Alexander, *Pattern language* 267.

[22] In the "The Textility of Making," Tim Ingold also suggests that design and architecture should evolve not from abstract planning, but from the materiality of the site. Material thus gains active status in the process of design. Tim Ingold, "The textility of making," *Cambridge Journal of Economics* 34 (2010): 91.

Radical Imagination

The term speculative (from lat. *speculari* – to observe) is always connected to the visual production of knowledge. However, I am using speculation in a broader sense to mean a radical imagination as delineated by Hannah Arendt. In permaculture design, patterns are those 'images' that exist "beyond or between thought and sensibility".[23] They provide an avenue which "allows us to think the possibility of something beyond the epistemic demand of deciding the true and the false […]".[24]

The possibility of interrupting and altering the system of representation in which we decide the question of true and false involves the faculty of presentation or figuration, that is, the capacity to create forms or figures which are not already given in sensible experience or the order of concepts.[25]

And in fact, in past years cultural studies, media studies and the study of science have discovered design as a practice of knowledge. Some even speak of a 'design turn'.[26] The claim is that design, at the junction of science and art, utilizes practical knowledge of creation. The underlying theory is explicated by, for example, Joseph Vogl when he says that "every epistemological explanation […] is preceded by an aesthetic decision." Unlocking new areas of knowledge or insight is "always dependent upon the form of their staging."[27] Here, the production of knowledge is understood as a cultural and material practice constituted of medial technologies, aesthetic preferences, technical skills, and implicit, experiential knowledge.

This is the sense in which I propose understanding permaculture design as the creation of patterns or visual representations of practical knowledge, assembled from heterogeneous elements and built at and for a specific site for which certain scenarios seem plausible, meaningful, and productive. In this process, the environment is just as involved in generating knowledge as the designer or the plants. The milieu thus created itself decides whether linkages are interesting, surprising or practicable. Patterns are speculations, varieties of radical imagination that engender unexpected communities. The pattern of the spiral for

[23] Hannah Arendt, "Die Einbildungskraft", in *Das Urteilen. Texte zu Kants Politischer Philosophie*, ed. Hannah Arendt (München, Zürich: Piper, 1998), 82.
[24] Ibid.
[25] Linda M. G. Zerilli, *Feminism and the Abyss of Freedom* (Chicago: University of Chicago Press, 2005), 59.
[26] Wolfgang Schäffner, "The Design Turn. Eine wissenschaftliche Revolution im Geiste der Gestaltung," in *Entwerfen – Wissen – Produzieren*, ed. Claudia Mareis et al. (Bielefeld: Transcript, 2010), 33–45.
[27] Joseph Vogl, introduction to *Poetologien des Wissens um 1800*, by Joseph Vogl (München: Wilhelm Fink Verlag, 1998), 13-4.

instance stands for cyclical processes and is found in permaculture design in, for example, herb spirals. Herb spirals combine our knowledge of light, shade, soil moisture, types of herbs, and insects in a very small space. They bring knowledge of what plants need to our attention and are therefore popular tools for teaching an other agriculture to children and youth with a very industrial ideas of where our food comes from.

Patterns are not strictly a form of knowledge, but rather forms of transferring, transforming and recontextualizing the way in which we see things. They change our thinking without any claim to truth. Isabelle Stengers, a philosopher, therefore characterizes the practice of environmental activists as situated because it aims at the "production of values, to the proposal of new modes of evaluation, new meanings".[28] "But those values, modes of evaluation and meanings." Stengers continues: "do not transcend the situation in question, they do not constitute its intelligible truth. They are about the production of new relations that are added to a situation already produced by a multiplicity of relations"[29]. In this sense, permaculture design is also an 'ecologic practice', but a practice that aims to *assemble*.

Material assembly and thinking organism

The manner in which the radical imagination of permaculture pattern analysis generates knowledge is not so by reading (from lat. *legere* – choose, select) or interpreting ('read' from Old English *r□dan* – to counsel, advise, consult, interpret) patterns, but rather through acts of assembly. 'Assembly' combines the Old French *assembler* – come together, join, unite, gather – with the Latin *assimulare* – to make like, liken, compare, copy, imitate, feign, pretend. Gilles Deleuze and Félix Guattari delineate 'assemblage' as a dynamic structuration of multifarious and nevertheless singular connections, conditions, objects, and practices that work both to recode and to decode.[30] These do not become concrete in a physical or discursive form, but rather refer to the interrelations of varying systems, technologies, processes, bodies, actions, and passions. Assemblages bring together symbolic systems and physical systems as well as expression and content. They cannot be subsumed under a greater order or assigned to a subject.

[28] Isabella Stengers, *Cosmopolitics I*, trans. Robert Bononno (Minneapolis: University of Minnesota Press, 2010), 33.
[29] Ibid.
[30] Gilles Deleuze and Felix Guattari, *A Thousand Plateaus*, trans. Brian Massumi (Minneapolis: University of Minnesota Press, 1987), 71, 88-91, 323-37, 503-5; see also Manuel DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity* (London: Bloomsbury Publishing, 2006), 9.

Assemblages do however express the dependence of practices and artefacts on spatial settings. The nomad rides in the steppe and the man-horse is coded by this spatial ordering as smooth and then recoded as striated.[31] From this it necessarily follows that settings can change assemblages. In the case of permaculture patterning, we must therefore say not only that the pattern 'reads' knowledge from nature, but also that it itself is an assemblage that generates knowledge.

The generation of knowledge in permaculture patterning is thus not only discursively drawn from writing and language, but also from practices, technologies, collectives, the environment, etc. It is passionate, situational, contextual, and dynamic. The manner with which permaculture generates knowledge through structures could also be described with Nigel Thrift as "intelligencing":

> First, I take it that intelligence is not a property of an organism but of the organism and its environment. I want to move, therefore, beyond obvious organismal boundaries and towards the 'superorganismal' idea that organisms are integral with the world outside them as put forward by writers like Tansley and Whitehead (1920) in an earlier time.[32]

In this form of intelligencing —and this is the point I want to explore—the environment becomes an agent in a joint act of understanding and shaping the world.[33] Earth 'sends,' so to speak, its characteristics and in this way regulates the designer's behavior through the patterns thus created. Mollison speaks of "interactive processes" and the "resonance of things"[34]. Mollison and Holmgren see their role as permaculture designers as three-fold. Their actions are directed not at people, but rather at the earth.[35] Their design is not merely the result of human action and creativity and, third, it is a form of intelligencing—thinking between multiple human and non-human actors:

> We care for the environment and wildlife. In all our design work, we side with that 'super client,' Gaia, which is an old Greek word

[31] Idem, "1440 – The Smooth and the Striated", chapter 14 of *A Thousand Plateaus*.
[32] Nigel Thrift, "From born to made: technology, biology and space," *Royal Geographical Society* 30/4 (2005): 464.
[33] "The site itself tells you what happens there." Mollison, *Permaculture Design Course*, 72.
[34] Ibid., 10.
[35] "Though our immediate interest is the client, people are merely a temporary event on the site. Our real, underlying interest is the site itself, though we may not choose to tell everyone that." Ibid., 64.

> for the Mother Earth Goddess. Earth was conceived of then as a living, thinking organism, a biological entity.[36]

Gaia

In this quote, Mollison is referring to the Gaia hypothesis, which he understands as a way of moving away from the idea of 'Spaceship Earth' and towards an understanding of the environment that put the earth in the position of an intelligent agent.

> The Gaia hypothesis, as formulated by James Lovelock, is that the earth less and less appears to behave like a material assembly, and more and more appears to act as a thought process. Even in the inanimate world we are dealing with a life force, and our acts are of great effect. The reaction of the earth is to restore equilibrium and balance. If we maltreat, overload, deform, or deflect natural systems and processes, then we will get a reaction, and this reaction may have long-term consequences. Don't do anything unless you've thought out all its consequences and advantages.[37]

In Mollison's interpretation, Gaia is a "material assembly" that acts as a "thought process". This living mindset is focused on the conditions under which complex systems or organisms can develop. Living systems are said to be able to organize themselves. This is the starting point of the permaculture designer's efforts. She supports the earth's efforts to organize itself. Rather than trying to direct these processes, he builds on Gaia's self-regulating processes. This is in direct contradiction to Fuller's concept of Spaceship Earth:

> […] Spaceship Earth implies that we have the power and wisdom to manage the earth. The Gaia hypothesis of James Lovelock and Lynn Margulis has provided a brilliant example of whole-system science that makes it clear that the earth is a self-organized system.[38]

Mollison and Holmgren's understanding of the ecosystem as a "thinking organism" is a decided refusal of the concept of Spaceship Earth popularized by Richard Buckminster Fuller, an architect and philosopher, in his 1969 book *Operating Manual for Spaceship Earth*.[39] Fuller's theory can be seen as another

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[36] Ibid., 61.
[37] Mollison, *Permaculture*, 10f.
[38] Holmgren, *Permaculture. Principles and Pathways*, 3.
[39] Richard Buckminster Fuller, *Operating Manual For Spaceship Earth*, (Carbondale, IL: Southern Illinois University Press, 1969), accessed June 28, 2014, http://designsciencelab.com/resources/OperatingManual_BF.pdf.

transfiguration of the afterlife of systems theory. His regulatory second-order cybernetics concept was most successfully propagated by the American environmentalist Stewart Brant. Fuller and Brant understood the earth as a system (spaceship) that can be regulated, managed, and improved via technology. This approach, also known as the 'Californian ideology',[40] propagates an aerial, godlike view of the earth that turns the planet into an object of regulatory knowledge. Holmgren and Mollison are not interested in steering Spaceship Earth. Like Eugene Odum, they see a difference between a spaceship and the earth in that not all of the components and relationships of earth are known and understood, and not all systems are closed.[41]

The open und unforeseeable nature of the system is concurrent with its ability to self-organize, but also with its vulnerability: "In this understanding, ecosystems are self-regulating and self-organizing systems which are, however, instable due to their variable components (climate, soil, organisms) and thus [as Tansley says] 'extremely vulnerable'"[42] Eugene Odum had already proposed seeing ecosystems as a site at which the powers and energy of diverse agents and figures converged – be they animal, technical or inorganic— not just human spaceship pilots.[43] Earth as an ecosystem cannot be controlled from above. Mollison and Holmgren in contrast, in their elaboration upon the Gaia hypothesis, credit earth with a form of intelligence and with an active role in the design process. But what exactly does the Gaia hypothesis state?

The Gaia hypothesis was formulated in the 1960s by Lynn Margulis, a microbiologist, together with the chemist, biophysicist and medical doctor James Lovelock.[44] They proposed understanding the biosphere as a living creature, since

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[40] Richard Barbrook and Andy Cameron, "The Californian Ideology," *Mute* 3 (1995), accessed June 4, 2014, http://w7.ens-lyon.fr/amrieu/IMG/pdf/Californian_ideology_Mute_95-3.pdf.

[41] Benjamin Bühler, "Entgleitende Regulierungen. Zukunftsfiktionen der Politischen Ökologie," in *Selbstläufer/Leerläufer. Regelungen und ihr Imaginäres im 20. Jahrhundert*, ed. Stefan Rieger, Manfred Schneider (Zürich: Diaphanes, 2012), 186.

[42] Benjamin Bühler, "Zukunftsbezug und soziale Ordnung im Diskurs der politischen Ökologie," *Politische Ökologie. Zeitschrift für Kulturwissenschaft* 2 (2009): 40; Eugene P. Odum, *Ecology and Our Endangered Life-Support System* (Sinauer: Stanford, CT, 1989), 257. The Odum brothers' ecological tradition follows Arthur G. Tansley's ecosystem concept. The concept of ecosystems stresses dynamic balances within an ecological system made up of plants, animals and physical forces.

[43] Bühler therefore proposes studying the actor network theory to uncover its ecological roots. Bühler, "Entgleitende Regulierungen", 186.

[44] Lovelock and Hitchcock were able to prove that the atmosphere of Mars was in a state of chemical equilibrium. Earth's atmosphere in contrast is in a state of disequilibrium. The relative homeostasis of Earth's atmosphere is the result of intensive feedback loops which are kept in dynamic equilibrium at the earth's surface by biochemical processes (especially the production

the surface of earth is a dynamic, self-organizing system able to maintain equilibrium through various feedback mechanisms. The hypothesis is applied in the main to surface temperature, the chemical composition of the ocean, freshwater levels, and the composition of the atmosphere. It draws from a systems theory understanding of life and living organisms as open systems that react to their environment and regulate themselves according to their own needs as well as the needs of that environment.

As Lovelock wrote:

> The entire range of living matter on Earth from whales to viruses, and from oaks to algae, could be regarded as constituting a single living entity, capable of manipulating the Earth's atmosphere to suit its overall needs and endowed with faculties and powers beyond those of its constituent parts.[45]

Mollison and Holmgren embraced the Gaia hypothesis enthusiastically:

> The Gaia hypothesis of the earth as a self-regulating system, analogous to a living organism, makes the whole earth a suitable image to represent this principle. Scientific evidence of the Earth's remarkable homeostasis over hundreds of millions of years highlights the earth as the archetypical self-regulating whole system, which stimulated the evolution, and nurtures the continuity, of its constituent lifeforms and subsystems.[46]

At the same time, the concept of the earth propagated within permaculture design is full of contradictions, as Bruce Clarke has pointed out.[47] Lovelock remained firmly within the cybernetic discourse of control, because he understood the living system of Earth as possessing a tendency towards homeostasis regulated by negative feedback. Lynn Margulis however, building on Francisco Varela and Humberto Maturana's concept of autopoiesis, stressed processes of random, continuous, creation.[48] Margulis's Gaia does not aim to self-regulate, but is an "emergent property of interaction among organisms, the spherical planet on which

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of O2. This was one of the starting points of the Gaia hypothesis. James Lovelock, D.R. Hitchcock, "Detecting planetary life from Earth," *Science* (1967): 2-4.

[45] James Lovelock, *Gaia. A New Look at Life on Earth* (New York: Oxford University Press, 1979), 9.

[46] Holmgren, *Permaculture. Principles and Pathways*, 71.

[47] Bruce Clarke, "Neocybernetics of Gaia: The Emergence of Second-Order Gaia Theory," in *Gaia in Turmoil: Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis*, ed. Eileen Crist, H. Bruce Rinker (Cambridge: MIT Press, 2009).

[48] Clarke, "Neocybernetics of Gaia", 295ff.

they reside, and an energy source, the sun"[49]. Holmgren in particular often points out opportunities to control systems through positive and negative feedback and transfers the cybernetic dispositif of control to the economy, to management techniques, and to government activity.[50] Mollison, on the other hand, stresses the uncertainty of feedback processes:

> Thus, stability in ecosystems or gardens is not the stability of a concrete pylon; it is the process of constant feedback and response that characterizes such endeavours as riding a bike. We are also in an area of uncertainty about the concept of end states or climax in systems - the state to which they tend to evolve. II is doubtful if any such state ever existed, as inexorable climatic change, fire, nutrient leaching, and Invasion deflect systems from their apparent endpoints.[51]

For Mollison, feedback and response is a continuous process. He doubts that it is possible to have total control, if only because the final horizon is not the survival of humanity, but of Gaia:

> All these effects are under some human control in a developed ecosystem. Protection from fire, positive nutrient supply to plants, and long-term evolutions are possible in terms of human occupancy. In the longer term, however, we too will be gone, and other species will arise to replace us (unless we take the earth with us, as megalomaniacs would do if we give them that chance: "If I can't take it with me, l'm not going…!") Just as it was the habit of kings to be buried with their riches, horses, and slaves, so modern warlords threaten to bury all humanity as they depart.[52]

Gaia will continue, whether with or without us. Bruno Latour emphasizes the lack of unity and sovereignty within the concept of Gaia:

> The great thing about Lovelock's Gaia is that it reacts, feels and might get rid of us, without being ontologically unified. It is not a superorganism endowed with any sort of unified agency. It is

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[49] Lynn Margulis, *Symbiotic Planet: A New Look at Evolution* (New York: Basic Books, 1999), 119.

[50] "This principle [apply self-regulation and accept feedback, K.R.] deals with self-regulatory aspects of permaculture design that limit or discourage inappropriate growth or behaviour. With better understanding of how positive and negative feedbacks work in nature, we can design systems that are more self-regulating, thus reducing the work involved in repeated and harsh corrective management." Holmgren, *Permaculture. Principles and Pathways*, 71.

[51] Mollison, *Permaculture*, 33.

[52] Ibid.

> actually this total lack of unity that makes Gaia politically interesting. She is not a sovereign power lording it over us.[53]

In any case, Mollison has created a model of nature that is not defined by culture as an antipode. Mollison's Gaia undermines the concept of the earth as passive, mechanical matter and humans as reasoning subjects by adding uncertainty, chance and the limits of human control into the mix—as well as the dynamics of the ecosystem as an intelligent system. At the same time, Mollison does not see Gaia as the primordial site of nature, but as a "thinking organism"[54], a "material assembly" that "appears to act as a thought process"[55]. Understanding nature as an assembly of material, intelligent processes turns 'nature' into a highly artificial entity of heterogeneous and relational actors and artifacts in a continuous process of creating itself (artifact, from lat. *arte*, by skill and *factum,* thing made).

Permaculture design was attracted to the Gaia hypothesis because it stresses the 'ecology' of knowledge. Here knowledge is not only found within nature, but nature itself is an actor in the generation of knowledge in the form of an assemblage. I believe this 'ecology of knowledge' is an important figure within the afterlife of systems theory. It replaces questions of controlling, regulating and steering systems – the concerns of first-order cybernetics – with questions of the materiality, embodiment, and visuality of dynamic processes of knowledge guided not solely by rationality, but by speculation in the form of radical imagination. The afterlife of systems theory in permaculture design therefore presents the history of science with significant challenges. How can we describe a history of knowledge that operates "beyond or between thought and sensibility"[56]? Particularly when this knowledge mingles discursive forms and visual patterns, it cannot be subsumed under a master theory or an ontology but takes the form of speculation and assemblage. When it is not guided by a sovereign power, but influenced by multiple actors. How can the afterlife of systems theory then be narrated?

The most logical answer would be to describe the creative practice of permaculture design – in the sense of a practical cultural technique of patterning – via practical transformations rather than via the texts and theories of its founders. This I have not done; nevertheless I do hope to have made a case for the recognition of the popular, practical knowledge of permaculture design. Systems

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53 Bruno Latour, "Waiting for Gaia. Composing the common world through art and politics" (paper presented at the French Institute for the lauching of SPEAP in London, November 2011), accessed April 4, 2014, http://www.bruno-latour.fr/sites/default/files/124-GAIA-LONDON-SPEAP_0.pdf, 10.

54 Mollison, *Permaculture Design Course*, 61.

55 Mollison, *Permaculture*, 10.

56 Arendt, "Die Einbildungskraft", 82.

theory lives on not only in the rationality of knowledge. The afterlife of systems theory in permaculture design expands our horizons to include a type of ecological thought that is based neither on cybernetics nor biology nor systems theory nor mathematics nor the like, but rather uses scraps of theory to generate a figurative and applied practical knowledge that is perhaps better described as non-knowledge.

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Gaia's Game

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Abstract
James Lovelock's vision of Earth as a living cybernetic system is popular again. The surprising new preacher of Gaia is Bruno Latour. He uses the concept to refer to a holistic understanding of Earth, in which mankind is situated as integral part. Gaia becomes the catalyst and fundament for his philosophical attempt to design a new believe-system in the time of ecological crisis. But the concept of Gaia is characterised by a tension between the idea of a powerful but indifferent nature and a grandiose vision of total control over it. This tension reveals itself to be deeply rooted in cybernetic thought. It is not only apparent in Lovelock's own writing, but also in simulation programs based on the Gaia hypothesis such as the Daisyworld model and the computer game "SimEarth: The Living Planet" (1991). The article will distinguish Lovelock's from Latour's concept of Gaia and relate them to first- and second order cybernetics as well as to two different approaches to computer simulation: system dynamics and cellular automata.

Keywords
Gaia, Latour, Lovelock, SimEarth, Simulation, Climate, Evolution

Introduction

> I would try to be a God that surprised himself. (Laughter.)
> I think being the all-knowing God would be, you know, hell.
> - *Will Wright, creator of SimEarth*[1]

The figure of Gaia plays a prominent role in Bruno Latour's recent publications. The Gaia hypothesis, first formulated by James Lovelock and Lynn Margulis in the mid-1960s, can be understood as pinnacle of system thinking.[2] It describes Earth as one cybernetic system, determined by the interplay of biosphere, atmosphere and geosphere. For Latour, Gaia is a catalyst that forces mankind to attain a novel understanding of the relation between culture and nature. But the Gaia hypothesis contains a peculiar tension between the image of a sublime nature, utterly indifferent to the needs of human beings, and the grandiose vision of total control over the system Earth. This tension is not only apparent in theoretical writing, but also in simulation programs based on the Gaia hypothesis, such as the Daisyworld model and the computer game *SimEarth: The Living Planet* (1991). The following article will carve out how Lovelock's Gaia differs from Latour's and discuss how these perspectives relate to two substantially distinct approaches to cybernetics (first-order and second-order) and computer simulations (system dynamics and cellular automata).

Latour's use of Gaia

In his recent book *An Inquiry into Modes of Existence* (2013), acclaimed French sociologist and philosopher Bruno Latour sketches out a quite spectacular research program: He demands nothing less than to overcome the modern preoccupation with objective scientific truth and to rediscover the plurality of vastly different modes of existence (like religion, morality or law). He does not only want to deconstruct the scientific worldview, he wants to redesign it. Latour repeatedly states one reason, why this is needed at this very moment: "Gaia approaches".[3]

For Latour, "Gaia" is a concept that holds the potential to redefine the relation between *society* and *nature* in the time of an ecological crisis. Gaia implies a

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[1] In: Celia Pearce, "Sims, BattleBots, Cellular Automata God and Go: A Conversation with Will Wright by Celia Pearce," *Game Studies* V2 I2 (2002), accessed July 3, 2014, http://www.gamestudies.org/0102/pearce/.

[2] The first paper, in which the principles oft he Gaia hypothesis were formulated has been James E. Lovelock and C. E. Giffin, "Planetary Atmospheres: Compositional and Other Changes" Associated with the Presence of Live," *Advances in Astronautical Sciences* 25 (1969), accessed June 30, 2014, http://www.jameslovelock.org/page19.html.

[3] Bruno Latour, *An Inquiry into Modes of Existence: An Anthropology of the Moderns* (Cambridge: Harvard University Press, 2013), 13.

holistic understanding, in which humankind and Earth's biosphere are being comprehended as tightly coupled and intertwined. When he evokes its imminent approach, he refers to the necessity to adopt this new way of thinking in order to face the impending crisis of climate change. But in Latour's phrasing, Gaia is more than just a conceptual object, it's the subject of the sentences: Gaia approaches. For him, Gaia is an actor with whom humankind enters into confrontation.[4] Thus, Gaia is both: a concept and a real power. The factuality of the climate change forces the sciences to rethink their conception of nature. But at the same time, this factuality is fabricated by the sciences themselves via measurements, models and computer simulations. The concept of Gaia, that could guide their rethinking, is not less fabricated.

For Latour, mankind stands before the dilemma between *modernising* and *ecologising*.[5] Shall we keep on with the technoscientifical objectivation of Earth, shall we further aim at the mastering of a lifeless nature? Or shall we redefine ourselves as an integral part of a living global ecology? He advocates the latter but is well aware that a mere deconstruction of modern values is not enough to motivate change. What would be needed, instead, would be a positive assemblage of values, a new way of thinking, a novel ecological belief-system - based on the figure of Gaia:

> It is now before Gaia that we are summoned to appear: Gaia, the odd, doubly composite figure made up of science and mythology used by certain specialists to designate the Earth that surrounds us and that we surround, the Möbius strip of which we form both the inside and the outside, the truly global Globe that threatens us even as we threaten it.[6]

For Latour, the concept of Gaia has a scientific as well as a mythological dimension: it derives from measurements, data, and modelling but it also incorporates an abundance of mythological connotations as its name evokes the Greek goddess of Earth. Fittingly, Lovelock's hypothesis received its name by a poet: William Golding, the author of *Lord of the Flies* (1954) and one of Lovelock's neighbours, suggested it. It is therefore not surprising that the name carries a substantial ambiguity that irritated several members of the scientific community, who feared an animistic anthropomorphisation of Earth.[7] But for Latour, that's exactly the point:

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[4] Ibid., 10.
[5] Ibid., 8.
[6] Ibid., 9f.
[7] See for example: Ford W. Doolitle, "Is Nature Really Motherly?" *The CoEvolution Quarterly* Spring (1981).

the concept of Gaia defies the belief in an objective science that studies nature as a passive and de-animated object.

In Latour's view, the metaphysics of Western modernity, with their assumed divide between nature and society, their focus on reason, the one truth, and expanding technological control over the world, would have led directly into the current ecological crisis. But such metaphysics of technological progress would now become useless - and new ones would be needed:

> We have to fight trouble with trouble, counter a metaphysical machine with a bigger metaphysical machine. (…) why not transform this whole business of recalling modernity into a grand question of *design*?[8]

Latour writes about the "*recalling* of modernity, in all senses of the word 'recall' (including the meaning it has in the automobile industry)".[9] Recalling modernity implies to remember and question its underlying assumptions but also to bring it back to the workbench in order to re-design it. For Latour, modernity's metaphysics are broken and have to be replaced like the defect motor of a car. But such a re-design cannot be simply attempted by a single philosopher. Latour recognises that a diplomatic approach is in place. He therefore envisions a grand negotiation process, in which all possible modes of existence enter with equal rights. Religion, Science, Law etc. should openly discuss their logics, presumptions, and premises. He does not claim to have brand-new and ready-to-work metaphysics at hand but insists on their necessity and the need for a general debate. Thus, his whole inquiry is just the beginning of a process that ideally should have novel metaphysics as its outcome. The enigmatic figure of Gaia is the catalyst of this process.

Two Faces of Gaia

The notion of Gaia has been coined by the chemist and inventor James Lovelock[10] in close collaboration with evolutionary biologist Lynn Margulis.[11] In its essence it describes the biosphere, atmosphere, hydrosphere, and geosphere of the planet Earth as an interconnected system that attains and creates the conditions for con-

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[8] Latour, *Modes of Existence*, 23.
[9] Ibid., 16.
[10] Especially in his monographies: James E. Lovelock, *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 2000 [1979]). And: James E. Lovelock, *Ages of Gaia* (Oxford: Oxford University Press, 1995 [1988]).
[11] For example in: James E. Lovelock and Lynn Margulis, "Atmospheric Homeostasis by and for the Biosphere. The Gaia Hypothesis," *Tellus* 26 (1974).

tinuous life via feedback-loops. Thus, the beings of the biosphere themselves secure the requirements for their own survival.[12] The obvious objection to this hypothesis is that such a regulation would demand some voluntary action - and thus a planetary consciousness. Several of the original critics of the Gaia hypothesis stressed the impossibility of such a thing.[13] But Lovelock disagreed wholeheartedly. For him Gaia is a cybernetic system with the capacity for self-regulation, therefore, no consciousness would be needed. In his view, Gaia shows characteristics similar to biological systems like beehives:

> Gaia is best thought as a superorganism. These are bounded systems made up partly from living organisms and partly from nonliving structural material. A bee's nest is a superorganism and like the superorganism, Gaia, it has the capacity to regulate its temperature.[14]

The cybernetic vocabulary in Lovelock's prose is immediately evident: Gaia is being described as "active adaptive control system", consisting of feedback-loops that maintain homeostasis. However, Lovelock can only define Gaia as superorganism because organisms themselves had already been described as adaptive systems in cybernetic theory.[15] Lovelock himself is very well aware of Gaia's

[12] Lovelock and Margulis identified several such cycles between life and its environment. The most striking one concerns the atmosphere and the global temperature: the chemical disequilibrium of the atmosphere is adhered because of the constant production of oxygen by the life-forms on the planet. But the composition of the Atmosphere changed since the advent of life. Surprisingly, geological findings indicate a slow descend of the average concentration of CO^2, thus reducing the greenhouse effect, effectively cooling down the planet. At the very same time the energy provided by the Sun increased about 25%, thus constantly heating up the planet. According to Gaia hypothesis, these two developments not only counterbalance each other but are not accidental either. Instead, the live-forms on Earth themselves would have regulated the amount of CO^2 in the atmosphere: „(...) the total ensemble of living organisms which constitute the biosphere can act as a single entity to regulate chemical composition, surface pH and possibly also climate. The notion of the biosphere as an active adaptive control system able to maintain the Earth in homeostasis we are calling the 'Gaia' hypothesis." (Lovelock and Margulis, "Atmospheric Homeostasis".)

[13] For example: Doolitle, "Is Nature Really Motherly?". And: Richard Dawkins, *The Extended Phenotype: The Long Reach of the Gene* (Oxford: Oxford University Press, 1982). Here, especially chapter 13.

[14] Lovelock, *Ages of Gaia*, 15.

[15] See: Norbert Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1948). And: Ludwig von Bertalanffy, *General System Theory: Foundations, Development, Applications* (New York: George Braziller, 1968).

roots in cybernetics as he explicitly compares it to biological, logistical, and engineered systems alike:

> (…) whether we are considering a simple electric oven, a chain of retail shops monitored by a computer, a sleeping cat, an ecosystem, or Gaia herself, so long as we are considering something which is adaptive, capable of harvesting information and of storing experience and knowledge, then its study is a matter of cybernetics and what is studied can be called a 'system'.[16]

For Lovelock, Gaia's most powerful memory bank are the genomes of its life-forms: "By transmitting coded messages in the genetic material of living cells, life acts as repeater, which each generation restoring and renewing the message of the specifications of the chemistry of early Earth".[17] In a certain way, Gaia works as a immense computer witch exceptionally long processing cycles – but it is clearly not adhering to the von Neumann architecture as it doesn't possess a central processor. Instead, its information processes emerge out of an interplay of connected but independent components.

The relation of Gaia to cybernetics and computer technology becomes even more apparent if one considers that the strongest back-up for Lovelock's hypothesis consists in a computer simulation: the famous *Daisyworld* model, through which Lovelock tried to exemplify the mechanism of planetary self-regulation.[18] To accomplish this, he created a highly abstract model of a planet, on which only daisies exist: black and white ones. During the run of the simulation, the intensity of the sun increases constantly (as it is the case with all suns), heating up the planet. The interplay between black daisies, white daisies, the sun, and the planet is modelled through coupled differential equations from population ecology and physics: At the beginning black daisies have an evolutionary advantage as they absorb more heat. Thus, they will spread, amplifying the heating up of the planet. But with growing intensity of the sun, white daisies prove to be better suited as they reflect more light. Therefore, they spread and supplant their black cousins. Their reflection of the sunlight, the so-called albedo effect, is effectively cooling down the planet. When the sun is heating up even more, even the white daisies will die out. The result of this dynamic is quite surprising: At first, the black daisies amplify the heating-up through positive feedback, but later, the white daisies diminish it via negative feedback. Both feedbacks together establish a surprisingly

[16] Lovelock, *Gaia*, 57.
[17] Lovelock, *Ages of Gaia*, 164.
[18] In: James E. Lovelock, "Biological Homeostasis of the Global Environment: The Parable of Daisyworld," *Tellus* 35 (1983). Compare also: Lovelock, *Ages of Gaia*, 41ff.

long lasting temperature plateau in spite of a constant grow of solar radiation. Thus, the dynamics of Daisyworld result in temperature self-regulation.

Daisyworld is structurally very similar to the system dynamics models by Jay Forrester.[19] Such models also consist out of coupled differential equations that form complex feedback-loops. The modelling technique emerged directly out of the cybernetic discourse in the 1950s. A famous example is the *World 3* model, based on Forrester's *World Dynamics* (1971), that was used by the Club of Rome to study the diminishing natural resources, leading up to the much discussed book *The Limits to Growth* (1972).[20]

As it becomes obvious, Gaia is not only rooted in cybernetic theory, its main evidence consists in an engineered prototype of its cybernetic mechanism. From this perspective, Gaia seems to be the epitome of cybernetic thought. But surprisingly, Latour understands the concept in quite a different way:

> The term proposed by James Lovelock to define a composite being corresponding to the character Earth (the Ge of mythology). Feedback loops highlighted by Lovelock evoke the possibility of a living Earth not in the sense of an organism or even an organization but in the sense of a simple assemblage of loops that achieve equilibrium by chance, according to the Darwinian model proposed in the name "Daisyworld". This character's particular interest derives from the precise fact that she is not unified (…) [21]

The feedback-loops of Latour's Gaia hint at an origin in cybernetics, but he consciously decides not to call it a system. Instead, he defines Gaia as a "composite corresponding to the character Earth", thereby personifying Earth as agent – however, not as a unified whole, but a composition of parts. To make this seeming contradiction even more explicit, Latour clarifies that he envisions Gaia as "a simple assemblage of loops that achieve equilibrium by chance". In this reading, moments of equilibrium or homeostasis are the consequence of an ongoing emergent and unpredictable process – small islands of stability in a constant dynamic flow.

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[19] Jay Forrester, *Urban Dynamics* (Waltham, MA: Pegasus Communications, 1969). Jay Forrester, *World Dynamics* (Cambridge, MA: Wright-Allen Press, 1971).

[20] Donella H. Meadows et al., *The Limits to Growth* (New York: Universe Books, 1972).

[21] Definition of "Gaia" in the vocabulary section of www.modesofexistence.org, accessed June 6, 2014, http://www.modesofexistence.org/inquiry/index.php#a=SEARCH&s=0&q=Gaia

This understanding of Gaia builds the foundation for a "Political Theology of Nature"[22], thus the subtitle of Latour's 2013 Gifford lectures "Facing Gaia" that in many ways forms the counterpart to *An Inquiry into Modes of Existence* (2013). Here, Latour glorifies James Lovelock as the new Galileo and Pasteur[23], and explains why he deems the Gaia hypothesis to be so revolutionary: Traditionally, nature would be characterised as being *outside* (independent from the subject), *unified* (one whole), *de-animated* (while it might shelter living beings, nature itself is not alive), and *undisputable* (the touchstone of truth). Quite similar, god would be characterised as being *exterior*, *unified*, and *undisputable*. The only difference to nature being that god wouldn't be de-animated, but o*ver-animated* – he is not only alive, he is the essence of life.[24] Consequently, Latour claims that in modernity the idea of one undisputable Nature substituted the believe in one undisputable god.

In stark contrast to both, God and Nature, Latour's Gaia is an ever-evolving composite of living agents (e.g. bacteria) and non-living agents (e.g. rocks) as well as disputed hypotheses, locally situated measurements and technical instruments alike. Gaia would be immanent in everything: an assemblage of entities that is fully animated deeply intertwined with society – and highly contested as a hypothesis. Gaia, therefore, becomes the great alternative to god and nature alike (see: table 1).

But what irritates is that Latour describes Gaia as essentially anti-cybernetic. For him, Gaia's cybernetic roots are problematic as he considers cybernetics to be deeply bound to the traditional ideals of science that he wants to contest: objectivity, universality, and the strive for the control of nature.[25] And indeed, there's no denial that the original cybernetics as envisioned by Norbert Wiener[26] is a theory of control, and that system theory as written by Ludwig von Bertalanffy[27] has the unification of the sciences as its explicit goal.

[22] The subtitle refers to *Politische Theologie. Vier Kapitel zur Lehre von der Souveränität* by Carl Schmitt (1922). However, it could also be understood as an ironic inversion of *Natural Theology or Evidences of the Existence and Attributes of the Deity* by the British theologian William Paley (1802) who made an argument for the intelligent design of the living beings on Earth – refuted by the evolutionary biologist Richard Dawkins (1986) in *The Blind Watchmaker* nearly two centuries later.

[23] Bruno Latour, "Facing Gaia: Six Lectures on the Political Theology of Nature. Being the Gifford Lectures on Natural Religion (Presented at Edinburgh, February 18-28, 2013), 53ff.

[24] Ibid., 24ff.

[25] Ibid., 65ff.

[26] Wiener, *Cybernetics.*

[27] Bertalanffy, *General System Theory*.

Ideal Nature (according to Latour)	**Ideal God** (according to Latour)	**Latour's Gaia** (own interpretation)
Outside (transcendent)	Exterior (transcendent)	Inside (immanent)
Unified	Unified	Multiple
De-animated	Over-animated	Animated
Undisputable	Undisputable	Disputable

Table 1 – Nature, God, and Gaia

There exists a curious tension between Latour's reading of the Gaia hypothesis and Lovelock's own wording that makes one wonder if they are actually writing about the same thing. This disparity might be explained by the development of cybernetic thought itself: Lovelock developed his original hypothesis under the influence of what has been called *first-order cybernetics*. He doesn't refer to the concept of *recursion* by von Foerster[28] or the one of *autopoiesis* by Maturana & Varela[29] – and neither does Latour. But as Bruce Clark points out, the Gaia hypothesis does indeed incorporate concepts of *second-order cybernetics*:

> Simply put, first-order cybernetics is about control; second-order cybernetics is about autonomy. (…) Unlike a thermostat, Gaia - the biosphere or system of all ecosystems - sets its *own* temperature *by* controlling it. (…) In second-order parlance, Gaia has the operational autonomy of a self-referential system. Second-order cybernetics is aimed in particular, at this characteristic of natural systems where circular recursion *constitutes the system* in the first place. (…) natural systems - both biotic (living) and metabolic (super organic, psychic, or social) - are now described as at once *environmentally* open (in the non equilibrium thermodynamic sense) and *operationally* (or organisationally) closed, in that their

[28] See for example: Heinz von Foerster, "On Constructing a Realty," in *Understanding Understanding: Essays on Cybernetics and Cognition* (New York: Springer, 2002 [1973]). The notion of *recursion* undermines the idea of causality. It postulates a mutual and iterative effect of the interplay of systems components: organisational structures emerge out of recursion not simple causes.

[29] See for example: Humberto R. Maturana and Francisco J. Varela, *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht, Boston, London: Reidel Publishing, 1980 [1972]). The concept of *autopoisis* describes the self-organisational capacity of living systems: the autopoietic entity creates and maintains itself in a recursive loop.

> dynamics are autonomous, that is, self-maintained and self-controlled.[30]

According to Clark, Margulis, influenced by Varela, overcame the metaphor of the thermostat in her latter works and focussed on the autopoietic qualities of Gaia.[31] From this perspective, Gaia is not primarily a system of feedback-loops that can be described, analysed, controlled, and maybe even build; it is an ever evolving and becoming entity that emerges out of a co-evolutionary interplay between life and non-living matter. This autopoietic concept of Gaia is quite similar to Latour's understanding of an animated, evolving assemblage.

Moreover, in this view of Gaia, the structure and components of the earth system are not given, they emerge out of geohistorical events and contingent trajectories. Latour emphasises this point when he interprets Lovelock's reasoning about the influence of early bacteria on the composition of the atmosphere:

> If we now live in an oxygen-dominated atmosphere, it is not because there is a preordained feedback loop. It is because organisms that have turned this deadly poison into a formidable accelerator of their metabolisms have spread. Oxygen is not there simply as part of the environment but as the extended consequence of an event continued to this day by the proliferation of organisms.[32]

Latour's reading of the role of oxygen in evolution makes it apparent how insufficient Lovelock's Daisyworld model is in regard to *his* understanding of Gaia: The feedback-loops of Daisyworld are products of an engineer, they exemplify a mechanism, they do not emerge out of contingent and changing conditions. Therefore, Daisyworld cannot surprise: only a few possible pathways can be realised during repeated runs of the simulation. To take up a notion from computer game theory: the *possibility space* of Daisyworld is very limited.[33]

But Daisyworld fits to Lovelock's view on cybernetics. After all, he is an inventor, who always liked to engineer his own research instruments. He describes feedback-loops and mechanisms – and who does so might fantasise about controlling them. And indeed, Lovelock does write about the possibilities for

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[30] Bruce Clark, "Neocybernetics of Gaia: The Emergence of Second-Order Gaia Theory," in *Gaia in Turmoil: Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis*, ed. Eileen Crist and Bruce H. Rinker (Cambridge: MIT Press, 2009), 296.

[31] See for example: Lynn Margulis and Dorion Sagan, *What is life?* (Oakland, CA: University of California Press, 2000).

[32] Latour, "Facing Gaia", 71.

[33] See: Katie Salen and Eric Zimmerman, Eric, *Rules of Play: Game Design Fundamentals* (Cambridge, MA: MIT Press, 2004), 67.

geoengineering[34], and even co-authored a book about the terraforming of Mars.[35] Thus, Lovelock's original first-order Gaia hypothesis must be differentiated from a second-order Gaia hypothesis, developed in the latter works of authors like Margulis. While first-order Gaia can be observed from the outside to some degree (Lovelock repeatedly refers to the view from space)[36], is a unified system, and might partially allow controlling its feedback-loops, second-order Gaia is a emergent property (see: table 2).

First-order Gaia	Second-order Gaia
Exterior	Inside
Unified	Multiple
Animated	Animated
Disputable	Disputable

Table 2 – First- and second-order Gaia

If first-oder Gaia is the product of a cybernetic engineer and found its incarnation in the computer-model of Daisyworld, the question arises how second-order Gaia might manifest *in silico*. This question is not just pure speculation as the concept of Gaia revealed itself to be bound to specific technological conditions: If the cybernetic thermostat is the original model for Gaia, and if the Daisyworld model follows the system dynamics approach, what would be a second-order equivalent?

This question entails a reversal of perspective as system dynamics can be characterised as a top-down approach that does not completely fit to second-order cybernetics. Such simulation models might produce contra-intuitive outcomes but their structures and feedback-loops have necessarily to be pre-defined – like the circuits of a thermostat. There are, however, other modelling techniques, e.g. on the basis of cellular automata, that allow for emergent structures: Only a small set of rules for very simple components are being defined, but when they interact with each other in the run of a simulation, complex and unpredictable patterns and dynamics emerge. Surprisingly, there exists an implementation of Gaia theory in a

34 James E. Lovelock, *The Vanishing Face of Gaia* (New York: Basic Books, 2009), 139ff.

35 James E. Lovelock and Michael Allaby, *The Greening of Mars* (New York: Warner Books, 1985).

36 For example: James E. Lovelock, preface to *Gaia: A New Look at Life on Earth* (Oxford: Oxford University Press, 2000 [1979]), XII.

program that makes use of cellular automata. Even more surprisingly it is not a scientific simulation but a commercial computer game: Will Wright's *SimEarth – The Living Planet* (1991).

SimEarth and the Player-God

In *SimEarth*, the player takes over the control of Earth – from the Pre-Archean to the Anthropocene (if the notion had been coined in 1991). She controls the atmosphere, the geosphere, and the biosphere, forms continents, lets meteors rain, and observes how humanoid and non-humanoid civilisations rise and fall. She can choose to play specific scenarios on Earth, to terraform Mars and Venus or to explore Lovelock's Daisyworld model. In all cases, the planet is presented as a map with several layers. In a menu on the left, tools can be chosen to change the surface, unleash catastrophes or plant animals and biota at specific places.

Every of such actions costs energy (called "Omega"), from which only a limited budget exists. Life-forms do generate more energy that can be invested in turn. And the more intelligent these life-forms are, the more energy they deliver. Thus, an evolutionary economy is implemented in the game, in which the player aims to optimise the return of investment.

SimEarth also allows it to manipulate some of its models that define the principles according to which the planet reacts. The player can e.g. choose to switch off the mutation rate for life-forms in the *biological model*, to enforce the cloud production in the *atmosphere model*, and to speed up the continental drift in the *geosphere model*. In the *civilisation model*, she can define how an intelligent species shall invest its allocated resources: whether in science, medicine, philosophy, agriculture or art. All domains have to be carefully balanced: while investments in science e.g. lead to technological advancement, it will also cause devastating wars and plagues if not counterbalanced with investments in philosophy (preventing wars) and medicine. Thus, *SimEarth* effectively implements two tightly interconnected economic models: one for *nature* and one for *culture*.

The development of every planet is structured into succeeding ages or levels. To progress in the ages, the player has to achieve defined victory conditions. The game starts in the *geological age*, enters the *evolutionary age* after the appearance of life-forms, continuous to the *civilisation age* when intelligent life arises, and progresses to the *technological age* with the beginning of the industrial revolution. The highest level is the *nano-tech age* that allows the civilisation to leave the planet. In this case it falls back to the evolutionary age, opening up the possibility for a new cycle of evolution with a different outcome. This emigration from Earth is what comes closest to a goal in *SimEarth*.

Biological and cultural evolution takes on various forms in *SimEarth*, but is always directed towards growing intelligence and complexity. Starting out with Prokaryotes (single celled life-forms without a nucleus), 15 classes of life-forms can evolve, which each differentiate in up to 16 possible species. The evolvement of species with certain intelligence is often the precondition for the emergence of a new class: Avians (birds) e.g. evolve out of dinosaurs, which evolve out of reptiles. The interrelated classes and species form a multi-linear phylogenetic tree.[37] Civilisations do not need to be human, they can evolve out of amphibians, reptiles, dinosaurs, insects, carniferns, avians, cetaceans (whales), and trichordates. Regardless of the species, the atmosphere and biosphere are heavily effected by the civilisation from the technological age on.

SimEarth is obviously not a conventional game. Johnny L. Wilson, the author of the official strategy guide *The SimEarth Bible*, calls it “a laboratory on a disk”.[38] James Lovelock describes it in a similar way in his preface to the same book:

> SimEarth itself is neither a game nor a science based model. (...) it represents an original form; a convenient dynamic map (...) of a planet, displayed in time as well as space – something on which speculative games or models can be played, a test bed for all those „what-ifs“. It is a wonderful and timely integration of our newly developed capacity to make personal computer models with our need to use them to understand the earth and ourselves. (…) SimEarth gives you the chance to enter the Gaia argument as a player.[39]

[37] The existence of such a prescriptive evolutionary tree indicates that *SimEarth* does not really simulate evolutionary processes but just mimics them. The tree defines trajectories through a limited possibility space of evolutionary development. Every trajectory is contingent but nevertheless predefined. In contrast, there are no pre-existing pathways in real evolution. *SimEarth* simply cannot simulate the processes of evolution properly because this would require simulating heredity on the level of individuals and their genomes. The simulation model of *SimEarth* is to macroscopic to allow for such detail. Nevertheless, it is possible: The next game in the Sim-series *SimLife: The Genetic Playground* (1992) did simulate ecological systems on a much smaller scale and included a genetic model of heredity. In a perfect simulation of Gaia the microscopic and the macroscopic simulation of ecology would have to be merged into one – but this was technically impossible in the early 1990s and probably still is.

[38] Johnny L. Wilson, preface to *The SimEarth Bible*, by Johnny L. Wilson (New York: Osborn McGraw-Hill, 1991), XIII.

[39] Ibid., XI.

But *SimEarth* is not only a laboratory on a disk, it also is a playground for scientifically tamed would-be gods. The phantasms of omnipotent control is shinning through the sales arguments on the backside of the game's packaging:

> Take the charge of an entire planet from its birth until its death – 10 billion years later. Guide life from its inception as single-celled microbes to a civilization that can reach for the stars.
>
> Rule an infinite number of worlds.
>
> Control your planet's Geosphere, Atmosphere, Biosphere and Civilizations.
>
> Place life-forms on the land and in the seas. Put various levels of civilization where you want them. Use special Terraforming Tools to change an inhospitable world into a paradise.
>
> Unleash volcanoes, earthquakes, meteors, tidal waves, and other natural (and unnatural) powers to reshape your planet
>
> Promote life. Move mountains. Create and destroy continents. Terraform hostile worlds. Influence evolution. Cultivate intelligent life-forms. Create civilized dinosaurs, mollusks, mammals, and more. Guide your intelligent species through the trials of war, pollution, famine, disease, global warming, and the greenhouse effect.

Such claims obviously allure the potential player with promises of almighty power. *SimEarth* seems to put her in the place of God. This impression is supported by *The SimEarth Bible*: Its deeply religious author struggles to reconcile his creationists viewpoints with the evolutionary model inscribed in the game but finds obvious fun in using pseudo-quotes from the bible as headlines for chapters, e.g. "And God Called the Dry Land Earth: The Geosphere Model"[40] or "Behold, I Create New Heavens: The Biome Factory".[41] In headlines like this, religion is coupled with science in the most obvious way imaginable.

In fact, all games of the Sim-series were on the one hand simulations, based on specific scientific theories and models,[42] but established at the same time a

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[40] Ibid., 66.
[41] Ibid., 138.
[42] *SimCity* (1989) is based on Forrester's *Urban Dynamics* (1969). *SimLife: The Genetic Playground* (1992) incorporates many elements from the Artificial Life discourse (cp.: Christopher Langton, "SimLife from Maxis: Playing with Virtual Nature," in *The Bulletin of the Santa Fe Institute* Vol 7 (1992).) as well as the evolutionary thinking that Richard Dawkins presented in *The Blind Watchmaker* (1986). *SimAnt: The Electronic*

whole genre of video games, commonly known as "god games".[43] Such games are characterised by the indirect control of semi-autonomous agents and a panoptic view on a virtual world, which can be interacted with without spatial restrictions.[44] The label "god game" should, of course, not be taken literally. The concept of God by Christian theologians implies omnipotence, which is simply impossible within the constraints of any given computer program. Even if the player would transcend her role to become a programmer, the programming language and the hardware would limit her capabilities. But *SimEarth* offers far more options to change the workings of its rules and processes than most other so-called god games. *Populous* (1989), for example, puts the player in the role of an actual god or goddess that has to take care of worshipers in order to gain karma (the resource for godly-acts and wonders). But in contrast to this narrative, the player's potency is strictly restricted to a very limited numbers of actions that have to be performed to overcome adversary gods. *Populous* is agonistic with little room for experimentation. The game's rules are strict and cannot be changed. In contrast, *SimEarth* sets no predefined goals and allows the player to substantially alter the underlying models of the simulation.

From this perspective, *SimEarth* appears as the epitome of the grandeur of the technosciences that Latour sets out to critique: The simulation elevates the experimenter to a position close to a god. The world is simulated in order to gain control over it. It therefore is not surprising that Donna Haraway views the Sim-Games quite critically:

> The popular Maxis Corporation games SimAnt, SimEarth, SimCity, SimCity 2000, and SimLife are all map-making games based on computer simulation software. In these games, as in life itself, map-making is world-making. Inside the still persistent Cartesian grid convention of cyber-spatialization, the games encourage their users to see themselves as scientists within narratives of exploration, creation, discovery, imagination and intervention. Learning data-recording practices, experimental protocols, and world design

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Ant Collony (1991) is influenced by Bert Hölldobler and E. O. Wilson, *The Ants* (New York: Springer, 1990).

[43] The notion of "god game" is defined in: Mark Hayse, "God Games," in *Encyclopedia of Video Games: The Culture, Technology, and Art of Gaming. Volume One A-L*, ed. by Mark J. P. Wolf (Santa Barbara, Denver, Oxford: Greenwood, 2012), 264.

[44] Compare: Britta Neitzel, "Point of View und Point of Action: Eine Perspektive auf die Perspektive in Computerspielen," in *Computer/Spiel/Räume: Materialien zur Einführung in die Computer Game Studies*. Hamburger Hefte zur Medienkultur, published by Institut für Medien und Kommunikation des Departments Sprache, Literatur, Medien SLM I der Universität Hamburg, ed. by Klaus Bartels and Jan-Noel Thon (2007).

> is seamlessly part of becoming a normal subject in this region of technoscience.[45]

It is a curious contradiction: *SimEarth* is possibly the closest manifestation of the Gaia hypothesis that one could imagine. It was created, after all, under the watchful eyes of James Lovelock himself. But how can this be the same hypothesis from which Latour claims that it would hail a new type of science that would finally overcome the technoscientific phantasm of control? How can it be that one and the same hypothesis can on the one hand be interpreted as epitome of scientific megalomania and on the other as pioneer of a humble worldview?

The seemingly obvious explanation would be that *SimEarth* is an incarnation of first-order Gaia hypothesis. The immediate assumption being that if incarnated *in silico*, Gaia must manifest in a form that dramatically emphasises its first-oder cybernetics origins and its focus on controllability. After all it has been modelled on a computer that is cybernetic by definition and has to conform to the conventions of games, which are all about control. But at a closer look, *SimEarth* reveals itself to be more complex.

From God to Gardener

A close reading of the aforementioned sales arguments helps to gain a new perspective (see: table 3): While some of the words used promise total control over an powerless object, others seem to circumscribe a very different regulation of a partly independent agent. On the one side, Earth is presented as an object to be controlled (by the player-god). On the other side, Earth is presented as a living agent with its own will that has to be carefully guided and regulated.

Control	Regulation
Create, Destroy, Take Charge, Control, Rule, Terraform, Unleash	Guide, Cultivate, Promote, Influence
World as object	World as assemblage of semi-independent agents

Table 3 – Control and Regulation in SimEarth's Sales Arguments

[45] Donna Haraway, "Gene. Maps and Portraits of Life Itself," in *Modest_Witness@Second_Millenium. FemaleMan_Meets_OncoMouse. Feminism and Technoscience*, ed. by Donna Haraway (New York, London: Routledge, 1997), 132f.

The player is promised the role of God but also the one of someone close to a gardener. The metaphor of gardening has been used by Will Wright himself to describe the experience of playing *SimCity* - a city building simulation that shares a lot of structural similarities to *SimEarth*:

> (…) SimCity, most people see it as kind of a train set. (…) when you start playing the game, and the dynamics become more apparent to you, a lot of time there's an underlying metaphor that's not so apparent. Like in SimCity, if you really think about playing the game, it's more like gardening. So you're kind of tilling the soil, and fertilizing it, and then things pop up and they surprise you, and occasionally you have to go in and weed the garden, and then you maybe think about expanding it, and so on. So the actual process of playing SimCity is really closer to gardening.[46]

The metaphor is striking: A garden is all but a de-animated passive object, it is an assemblage of living and non-living agents that interact in complex ways that have to be anticipated by the gardener. But nevertheless, the gardener is in a position of tremendous power towards herbs and vegetables. Unlike a god, he cannot do to the garden whatever pleases him. He has to gain a deep understanding about the interrelatedness of all its agents and to anticipate their possible reactions. A garden cannot be fully controlled but it can be carefully regulated. And if it would be possible to speed-up the feedback that a garden offers to its gardener in such a way that a continuous rhythm between planting, growing, and weeding could be realised – then a garden could indeed be played.

Quite similarly, in playing *SimEarth*, the world is being experienced as anything but as passive object. Frequently, the player's actions have curious and at first glance counter-intuitive results that only close inspection of the various graphs can clarify. Moreover, the consequences of the actions are repeatedly being rendered insignificant by the dynamics of the program – similar to weed that just reoccurs. The player might plant dozens of volcanoes on her Earth to push CO2 into the atmosphere to heat it up. But it might very well be that this effect is quickly counterbalanced: The raising temperature lets the ice melt, creating new landmasses in which boreal forests can spread that in turn bind CO2, counterbalancing the greenhouse effect.

Such counter-intuitive outcomes are one of the cornerstones of system dynamic models, as e.g. Jay Forrester claims.[47] But Daisyworld, being such a model,

[46] Will Wright in an interview with Celia Pearce in: Pearce, "Sims, BattleBots, Cellular Automata God and Go".

[47] Jay Forrester, "The Beginning of System Dynamics," Banquet Talk at the international meeting of the System Dynamics Society Stuttgart, Germany (July 13, l989), transcript

offers these insights only for a fleeting moment. Soon, the user has tried out all existing variables and understands the mechanism. *SimEarth*, however, constantly surprises the player by showing unpredictable behaviour. The reason being that *SimEarth* combines system dynamics with *cellular automata*.

As mentioned above, cellular automata can be considered as the bottom-up counterpart to system dynamics: where in the latter the structure of the system is predefined, in the former, it emerges in unpredictable ways out of just a few rule sets. A cellular automata program consists of a grid of cells, where each cell is programmed to use the input of its neighbouring cells and to process it according to rules. The interplay of a huge number of such cells can produce unpredictable patterns.[48]

Like most of Maxis' Sim-games, *SimEarth* has a cellular automata module built into its core. It is coupled with five system dynamics models, that represent the Lithosphere, Aquasphere, Atmosphere, Biosphere, and the Civilisation on the planet.[49] Some of them can be tweaked and twisted by the player as explained. All of these models, however, are affecting one huge cellular automata module with 128 horizontal and 64 vertical tiles. The map, the player is interacting with, is the visual representation of its several layers. The description by Fred Haslan, the co-designed of *SimEarth*, gives a good impression of its complexity:

> The basic model in this game is a state-based cellular automata. Cells maintain information on all five systems mentioned above. Our cells are organized into a number of two-dimensional arrays collectively called "the map." Generally speaking, cells are only affected by themselves and the eight adjacent cells—although there are exceptions. There are also a number of global values.

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accessed July 28, 2014, http://clexchange.org/ftp/documents/system-dynamics/SD1989-07BeginningofSD.pdf.

48 The best known example of cellular automata is Conway's "Game of Life" that abstractly exemplifies how complexity can emerge out of a few evolutionary principles (cp. Martin Gardner, „Mathematical Games: The fantastic combinations of John Conway's new solitaire game ‚life'," in *Scientific American* 223 (1970)). The early Artificial Life experiments by Christopher Langton (cp. Langton, „Studying Artificial Life") were also built on the basis of cellular automata. From the 1980s on, the mathematician and physicist Stephen Wolfram explored the epistemological potential of cellular automata – a research that culminated in his controversial book *A New Kind of Science* (2002), where he suggested a paradigm shift in science via experimentation with cellular automata.

49 Explained in: Fred Haslam, "SimEarth: A Great Toy," in *Integrated Global Models of Sustainable Development, Volume 3: Encyclopedia of Life Support Systems*, ed. by Akira Onishi (Oxford: EOLSS Publishers, UNESCO, 2009).

> These values record systemic state changes (such as the current era), summarized values (such as biomass or zoomass), and cumulative values (such as fossil fuels or nitrogen levels). (…) Each cell has 10 bytes of information. Here is a list of the values each tile contains: terrain altitude, magma drift direction, magma drift speed, ocean existence bit, ocean temperature, ocean motion direction, ocean motion speed, air temperature, air motion direction, air motion speed, air cloud density, random events, biomes, creatures, sapient objects, and a city preclusion bit.[50]

The outcome of the complex coupling of two very different approaches to simulation is striking: compared to the simple Daisyworld model, *SimEarth* holds much more potential for surprising outcomes that puzzle the player. Its possibility space is huge. In every run, it shows divergent emergent behaviours. The player doesn't always have the impression of being in control of the planet. Quite often, it feels, like Gaia is taking charge. The Earth can be played only to a certain degree, because at the same time it is playing with the player. As Haslam writes, this brings *SimEarth* actually in conflict with being a game in the traditional sense:

> Another limitation on the simulation was our desire to make the resulting application into a game. We had to consider what would be interesting for the player, and we had to give him the power to change the environment. Ironically, we sort of failed in our initial attempt to make SimEarth into a game. Players could frequently win without touching a key.[51]

A simulation might run on its own (after receiving input values) but surely not a game. *SimEarth* therefore dwells precisely at the threshold between being a game and a quasi-scientific simulation. One could maybe call it a popular simulation - like one speaks of popular science books.

Even if not qualifying as a proper game, *SimEarth* surely allows to play with Gaia. McKenzie Wark describes a peculiar but fitting playing style.[52] He started the program every day before work with differing configurations, let it run, and returned in the evening to observe what happened to his planet: sometimes the world stayed barren, sometimes civilisation rose and fell, sometimes a nuclear winter froze the world, sometimes the greenhouse effect cooked it to death.

> SimEarth gamers tell amazing stories: About the time the lid blew off the biosphere, but up rose a strain of intelligent robots. Or the

[50] Ibid., 48f.
[51] Ibid., 47f.
[52] McKenzie Wark, *Gamer Theory* (Cambridge: Harvard University Press, 2007), §201ff.

> time it ticked over for months, populated with a million sentient cetaceans, all using nanotechnology to run their watery utopia.[53]

In its capacity to surprise with unpredictable outcomes, emergent evolutionary paths, and geohistorical trajectories, *SimEarth* comes surprisingly close to Latour's autopoietic understanding of Gaia. It is not perfect in this regard: evolution occurs on multilinear but predefined ways, and the structures of its models (governing atmosphere, geosphere etc.) are fixed. The player might change the weight of specific factors, but she cannot change their coupling. Thus, the importance of e.g. oxygen for the prospering of higher life-forms is not contingent in this game. *SimEarth* remains a hybrid between a pure bottom-up and a top-down simulation. But this is exactly what opens up the possibility to play.

Can Gaia be Played?

Lovelock's hypothesis was always heavily contested and often criticised for being too vague or not falsifiable.[54] But it became at least partly respectable because he made Gaia's principles explicit by translating his reasoning into equations that produced a seemingly objective and visual outcome, when processed. The recursion into mathematical notation and the implementation into a computer model proved that Gaia could actually work – it could be build and therefore exist. The incarnation of Gaia *in silico* was much more than an illustration; it was a proof of concept.[55]

But the modelling approach of system dynamics used to build Daisyworld is not fit to exemplify Latour's Gaia. The reason being that the structure of such simulation models have to be predefined, what contradicts the emergent character of an autopoietic Gaia. A simulation built out of cellular automata, however, could very well create the unpredictable and contingent patterns, cycles and feedback-loops that Latour describes.

Such a simulation, where all forms of life as well as their environment and the feedback-cycles between them emerge out of the interplay of digital equiva-

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[53] Ibid., §213.

[54] For an overview of the common points of critique see: James W. Kirchner, "The Gaia Theory: Fact, Theory, and Wishful Thinking," in: *Climatic Change* 52 (2002), accessed June 30, 2014, http://seismo.berkeley.edu/~kirchner/reprints/2002_55_Kirchner_gaia.pdf.

[55] Moreover, the mathematical model allowed for a much more substantial critique of its premises – Gaia could become an object of critical discussion within the sciences. See, e.g., Kirchner's discussion of the premises of the Daisyworld model in the aforementioned article.

lences to (bio)-chemical molecules, is, of course, utterly impossible at the present state. And even if it would be created, its emergent complexity would be so huge that it could hardly be analysed. It would therefore be nearly impossible to verify its validity. The perfect simulation of Gaia would be as bottom-up, as complex, and as opaque as the real world.

But if, nevertheless, someone would try to model this kind of Gaia, it could be quite similar to *SimEarth*. While the inclusion of civilisations out of robots or dinosaurs in this game surely springs out of joy of pulp literature, its playful approach might be adequate to Gaia. The enormous variance in possible world histories that emerge out of the interactions with the game shows what Gaia is about: The fact that this or that specific cycle of nitrogen or CO^2 can be modelled in neat cybernetic feedback-loops is maybe not so relevant after all. The provocative power of the Gaia hypothesis lies in the description of a constantly emerging and contingent entity. Gaia cannot be built, it has to emerge. Such a view of Earth is not well suited for the fabrication of hard knowledge that can be put in explicit and non-ambiguous equations. The Gaia hypothesis (at least in Latour's reading) might not be fit to become a proper theory for the natural sciences. But it could deliver a good foundation for the exploration of various possible historical trajectories. The facticity of our world would thus become contingent. In such an understanding it is impossible to control Gaia - but maybe it can be played with.

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Rewriting the Matrix of Life. Biomedia Between Ecological Crisis and Playful Actions

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Abstract
The paper discusses concepts of 'nature' and 'life' as subjected to historical changes. The 21st century seems to be obsessed with 'life' and 'nature', which are reconfigured as objects of simulation practices and of a multitude of technoscientific enterprises as well as of political struggle. The historical influences and epistemological shifts of systems thinking are significant within two distinctive and interwoven fields: On the one hand the discourse of environmentalism with the paradigm of ecological crises, centered around ideas of resource management, sustainability, the general idea of an 'endangered nature' and the interconnectedness of global politics and individual actions. On the other hand the optimistic promises of artificial life, with synthetic biology and digital cyborg technologies as its avantgarde, which are very much driven by the idea of technoscientific mastery to surpass natures 'weakness' and by desires to improve 'life' and to even refashion 'life itself'.

On the field of historical ecology, concepts of systems thinking are traced back to the middle of the 19th century, where ecological thought emerged at the intersections of biology and geography. Meandering between vitalistic, holistic, and mechanistic concepts, between living and non-living elements, systems ecology finally substitutes 'nature', which in turn is re-established in its new 'gestalt' as computer simulated world model since the early 1970s. Resurrected as an interrelation of system variables at the level of global simulations 'nature' strikes as a zombie.

As a second turning point of the rewriting of the matrix, of life we will discuss the advance of 'games' since the early 1970ies, with the example of 'Game of life' ('Life') as a significant landmark. When 'life' becomes 'Life', it is by computerized modeling in terms of dynamic processes. Computer games can be thought of as instances of the popularization of cybernetic system thinking, functioning as interdiscoursive fragments between the specialized discourse of system theories and the sphere of 'common sense' (Nohr 2008), where the specific "gaming situation" (Eskelinen 2001) foregrounds playful individual action and manipulation of system objects within a set of given rules or the manipulation of system rules itself on the level of the 'code'.

We will argue that both, the ecological discourse and the algorithmic model of self-reproduction of 'Life', are historically and systematically related manifestations and mediations of system theory. While they can be regarded as referring to different scales of application (macro-economic reasoning in the case of global eco-systems, modeling of bottom-up-complexity on a micro-level in the case of 'Life') and belonging to distinctive disciplines (economic and ecological research vs. mathematical theory of automata and artificial life studies), they share some common ground in being "algorithmic media" (Marks 2014) that are functional as "rhetorical software" (Doyle 1997) and as "allegorithms" (Galloway 2006) of the new compositions of the techno-biological and techno-ecological situation of the 21st century.

Keywords
ecology, media studies, biomedia, historical epistemology, system theory, cybernetics, games, computer games, allegorithm, algorithmic media, life, game of life, simulation, artificial life, knowledge, discourse analysis, interdiscourse, environment, ecosystem, anthropocene

Introduction

One of the characteristic features of systems thinking can be seen in its unifying approach, where organisms and technological artifacts, ecological relations and man-made infrastructures shall all be described with a common set of concepts. As a consequence, systems thinking can destabilize traditional western ontologies, even those that seemed to have essential value for ethical and political orientation: The very concepts of 'Nature' and 'Life' itself are rewritten by the historical influences and epistemological shifts of systems theory.

This becomes especially significant within two distinctive yet interwoven fields of knowledge: environmentalism and artificial life. As the discourse of 'global warming' illustrates, the impact of systems thinking is not limited to scientific research but on the contrary popularized on a global scale. To understand the historical interconnection of systems thinking with the rise of the ecological paradigm, it is important to see how central elements of systems thinking can be traced back to the emerging ideas of ecological thought in the latter half of the 19th century, and how this thought assumes its current shape under the influence of the media technology of the computer in 20th century.

The concepts of 'Nature' and 'Life' are thus fundamentally irritated by the inclusion of the artificial. In particular, the understanding of natural processes and qualities as well as the concept of 'life itself' become dislocated under the influence of systems thinking combined with computer technologies of modelling, simulation, and manipulation. Furthermore, as we will discuss later with the prominent example of 'Game of Life', it can be argued that the rise of 'games' as part of computer culture since the early 1970s is a significant landmark for the popularization of systems thinking as well as for the transformation of concepts of 'life itself'.

Risk and Closure

Starting with 'Nature', the globalized geopolitical, economic, and ecological crises of the 20th century make evident that space as well as time for humankind as a biological species might be limited. Within geology, the ecological effects of this historical development have led to the assumption of an epochal shift from the holocene to the "anthropocene".[1] The holocene, which had provided the climatic conditions for the development of stable cultures and civilizations, is assumed to be superseded by the anthropocene, as indicated by a significant

[1] Cf. Paul J. Crutzen, "Geology of Mankind," *Nature*, 415 (3. Jan. 2002): 23; Jan Zalasiewicz et al., "Are We Now Living in the Anthropocene?" *GSA Today*, 18.2 (2008): 4–8.

increase of CO_2 found in air entrapments of the arctic ice since the end of the 18th century. Since then, population growth and industrialization with increasing consumption of fossil energies and other natural resources lead to the situation that human behavior engenders significant changes within the biosphere. For the first time, man made history and natural history converge in a paradox way, only to confirm the long standing tradition of theories that assume a circular causality between anthropological and geophysical processes, ranging from ancient cosmogonies over the romantic concept of 'Weltseele' and Hegel's 'Weltgeist' to Vernadsky's 'noosphere' or Teilhard de Chardin's 'omega point', also including versions of Gaia theory that have become influential for ecologic thinking. It is thus not by coincidence that ecology is close to spiritual affairs.

The anthropocentric perspective seems the more inevitable as in the context of globalization, ecological damages amount to a self-impairment of world society. At present, ecological hazards tend to become universal and irreversible, and are moreover supposed to yield boomerang effects, sooner or later turning back on their originators on a global scale. In this context, Ulrich Beck has developed the concept of "world risk society," where global conflicts get more and more centred on the distribution of risks rather than the distribution of resources.[2] According to the German sociologist Niklas Luhmann, the concept of risk has to be distinguished not from the notion of safety, but from the concept of endangerment: External dangers are not caused by the affected person or institution but are attributed to an intransparent environment; the notion of risk, on the other hand, links an undesirable situation to some previous decision, which could have been made otherwise.[3] Contingencies are thus transformed into potential consequences of conscious behavior, so that occurrences such as hurricanes or floods might become symptoms of anthropogenic climate change. Mediated by the concept of global risk, the most influential Aristotelian distinction between *physis* (following internal goals) on the one hand and *téchne* (following human purposes) on the other – which lay at the heart of the distinction between nature and culture – in effect collapses. In the anthropocene driven by a world risk society, human decision making and control gain vital importance on a global scale, while nature as an independent causal force and element in its own right paradoxically disappears. Essentially the same diagnosis is attained with respect to technoscientific endeavours such as genetic engineering and synthetic biology, where the distinction between natural and artificial objects is also increasingly blurred. Thus on the macro level of ecological risk as well as on the micro level of bio-technological mastery, "life itself" becomes a technological

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[2] Cf. Ulrich Beck, *Weltrisikogesellschaft. Auf der Suche nach der verlorenen Sicherheit* (Frankfurt/M.: Suhrkamp, 2008).

[3] Cf. Niklas Luhmann, *Soziologie des Risikos* (Berlin/New York: de Gruyter, 2003), 30f.

enterprise. Media theorist Marshall McLuhan links this modern condition of ecology to the historical moment of space exploration:

> Perhaps the largest conceivable revolution in information occurred on October 17, 1957, when Sputnik created a new environment for the planet. For the first time the natural world was completely enclosed in a man-made container. At the moment that the earth went inside this new artifact, Nature ended and Ecology was born. 'Ecological' thinking became inevitable as soon as the planet moved up into the status of a work of art.[4]

In this passage, McLuhan draws on a topological inversion: man is no longer surrounded by nature, which is instead encircled by human technology. The exclusion of nature from society turns into its complete technical inclusion or enclosure, as it were, in an artificial container that is represented both by the Sputnik's shape and by its orbit. In terms of this picture, the era of ecology ends that of nature, and ecology is a matter of technology and art. Alluding to Shakespeare as well as military terminology, the globe becomes a theatre which allows no external perspective. That there are no spectators but only actors, as the title of McLuhan's text suggests, again points to the central notion of closure: There is no outside of society resp. technology.

Not by coincidence, the Sputnik also is a symbol of cold war; the notorious 'shock' that supposedly accompanied its appearance for the Western World in the context of technology and arms race is associated with a historical situation characterized by strict external boundaries (Iron Curtain) and internal paranoia (Manchurian Candidate) of political blocks, a climate which was surely inspiring for cybernetic systems thinking with its fascination by operational closure and autopoiesis.

Ecology: Life in space and time

While McLuhan surely provides a clear sighted definition of modern systems thinking, the latter's historical roots can be traced back to ecological ideas emerging within geography and biology in the second half of the 19th century. In the following sections, we shall highlight some important concepts and developments in this complex discoursive field which are related to our argument – without claiming to provide a thorough or complete history of ecology, of course. Central for ecological thought is the assumption that organisms enter into

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[4] Marshall McLuhan, "At the moment of Sputnik the planet became a global theater in which there are no spectators but only actors," *Journal of Communication,* 24.1 (1974): 48–58, 49. Actually, Sputnik I was launched on October 4, 1957.

functional relations to their surroundings und thus cannot be studied in isolation, an idea which is constitutive for the first definition of ecology given by the German biologist Ernst Haeckel (1834-1919) in 1866.[5] Inspired by Darwin's theories of descendence and natural selection, Haeckel develops a strictly mechanist theory, according to which the morphology of organisms and the development of species are completely determined by environmental factors he calls conditions of existence ("Existenz-Bedingungen"), encompassing inorganic factors such as soil and climate as well as organic factors which are mainly given by the surrounding organisms.

Ecological considerations like these allow a fundamental shift of focus from the evolutionary relation between individual organisms and species under the determining influence of their milieus towards collective forms of life in a given spatial environment. In the context on his work on Frisian oyster banks, the German zoologist Karl August Möbius (1825-1908) introduces the concept of biocoenosis ("Lebensgemeinde"), which foregrounds the complex interactions and interdependencies of co-existing individuals and species.[6] In his seminal paper "The Lake as a Microcosm" Stephen A. Forbes uses the notion of 'community of interest' as a central point of ecological reference.[7] Corresponding assumptions are found in the context of botany and plant geography. The first and most influencing text book on ecology published by the Danish botanist Eugen Warming (1841-1924) draws on the notion of 'plant community'. Warming's "Plantesamfund. Grundtræk af den økologiske Plantegeografi" (1895) is translated to German in 1896 and to English in 1909 ("Ecology of Plants. An Introduction to the Study of Plant-Communities"). The German limnologist August Thienemann postulates an organic unity between biocoenosis and biotope ("Lebensraum, Milieu") in 1916.[8]

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[5] Ernst Haeckel, *Generelle Morphologie der Organismen. Allgemeine Grundzüge der organischen Formen-Wissenschaft, mechanisch begründet durch die von Charles Darwin reformirte Descendenz-Theorie, Bd. 2: Allgemeine Entwickelungsgeschichte der Organismen. Kritische Grundzüge der mechanischen Wissenschaft von den entstehenden Formen der Organismen, begründet durch die Descendenz-Theorie* (Berlin: Reimer, 1866), 286ff.

[6] Karl August Möbius, *Die Auster und die Austernwirthschaft* (Berlin: Wiegandt, Hempel & Parey, 1877).

[7] Stephen A. Forbes, "The Lake as a Microcosm," *Bull. of the Scientific Association (Peoria, IL)*, (1887): 77–87.

[8] Cf. Kurt Jax, "Holocoen and Ecosystem – On the Origin and Historical Consequences of Two Concepts," *Journal of the History of Biology,* 31 (1998): 113–142.

At the beginning of the 20th century, the shift from classical autecological to synecological approaches[9] combines with philosophical ideas of holism and organicism, which is reflected by such concepts as the "holocoen" developed by the entomologist Karl Friederichs (1878-1969), or the ecological gestalt-systems ("ökologische Gestalt-Systeme") of Richard Woltereck (1877-1944).[10] Drawing on Frederic E. Clements' (1874-1945) work on the evolutionary succession of plant communities,[11] the South African ecologist John Phillips promotes the concepts of "complex organisms" resp. super-organisms,[12] combining views of Clements with the theory of holism popularized by the South African statesman, general and philosopher Jan Christian Smuts (1870-1950).[13]

The central holistic assumption of the priority of some (physical, biological, or social) 'whole' over its 'parts' is reflected not only in ecological theories of super-organisms from animal and plant collectives to some versions of the Gaia theory developed by James Lovelock and Lynn Margulis in the 1960s and 1970s.[14] Holistic and vitalist thought also prepare the ground for what might be called proto-constructivist theories of the relation between organisms and their environments. In particular, the determining influence of the milieu originally suggested by Haeckel is called into question. In Haeckel's mechanistic framework, the morphology and dynamics of life are supposed to be completely reducible to *causas efficientes* of the physical world imposed on some organism. Contrary to this claim, the Scottish physiologist John S. Haldane (1860-1936) in

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[9] The terms "Autökologie" and "Synökologie" were introduced around 1900 by Carl Schröter, see Carl Schröter and Oskar von Kirchner, *Die Vegetation des Bodensees*, Vol. 2, (Lindau: Verein für Geschichte des Bodensees und seiner Umgebung, 1902).

[10] Cf. Jax, "Holocoen and Ecosystem."

[11] Frederic E. Clements, *Plant Succession. An Analysis of the Development of Vegetation* (Washington 1916); Frederic E. Clements, "Nature and Structure of the Climax," *Journal of Ecology,* 24 (1936): 252–284.

[12] John Phillips, "Succession, Development, the Climax, and the Complex Organism: An Analysis of Concepts. Parts I-III," *Journal of Ecology*, 22.2 (1934): 554–571; 23.1 (1935): 210–246; 23.2 (1935): 488–508.

[13] On the historical relations of ecological thought to imperialism and colonialism, see Peder Anker, *Imperial Ecology. Environmental Order in the British Empire, 1895-1945* (Cambridge, Mass./London: Harvard University Press, 2001). On the affinities of the German holistic tradition around Thienemann and Friederichs to geopolitics and even fascistic ideologies of blood and soil, see Benjamin Bühler, "Zukunftsbezug und soziale Ordnung im Diskurs der politischen Ökologie," *Zeitschrift für Kulturwissenschaften,* 2009/2: 35–44, 38f.

[14] Cf. Bruce Clarke, "Neocybernetics of Gaia: The Emergence of Second-Order Gaia Theory," In *Gaia in Turmoil: Climate Change, Biodepletion, and Earth Ethics in an Age of Crisis,* edited by Eileen Crist and H. Bruce Rinker (Cambridge: MIT Press, 2009), 293–314.

an early paper from 1884 points to the purpose driven and goal oriented behavior of living beings and argues that the causal link between the organism and its environment has to be thought of in terms of a reciprocal instead of a one way relation.[15] Similar considerations lead the Baltic zoologist Jakob Johann von Uexküll to the assumption that the environment is not simply given as an objective milieu at all, but rather construed by each organism in accordance with its perceptive and motor faculties. Thus the worlds of a cow, a tick, and a black bird differ substantially, although these animals might be found in spatial vicinity. In order to account for these differences, Uexküll draws a systematic distinction between the terms "Umwelt" (environmental world), which is a essentially the projection of an organism's construction plan ("Bauplan"), and "Außenwelt" (external world), which can only be construed by a detached observer.[16] The systemic relation between a living being and its "Umwelt" is analyzed by Uexküll as a feedback loop between perceptive and motor activities and their respective environmental correlates. The concept of linear causality following the model of the unconditioned reflex is thus replaced by the cybernetic idea of circular causality – Uexküll uses the term "Funktionskreis" (functional circle) – as general explanatory principle for the relation between life and its milieu.[17]

Ecoystems

Thus at the beginning of the 20th century, basic elements of a proto-cybernetic view of ecology as systems theory are already widely established, when the term "ecosystem" is introduced by Arthur George Tansley (1871-1955) in 1935.[18] Tansley develops the concept in a critical discussion of the holistic approaches of Clements and Phillips.[19] For Tansley, an ecosystem consists of both biotic and non-biotic elements such as soil or water, atmosphere and climate; he therefore rejects the notions of complex or super-organisms with their vitalist implications, proposing the term "quasi-organism" instead. With respect to the ontological and epistemological status of ecosystems, Tansley furthermore argues that they are

[15] Cf. John Scott Haldane, "Life and Mechanism," *Mind,* 9.33 (1884): 27–47.

[16] Johann Jakob von Uexküll, *Umwelt und Innenwelt der Tiere* (Berlin: Julius Springer, 1909), 1–10, 191–196, 248–253 et. pass.

[17] Cf. Johann Jakob von Uexküll, *Theoretische Biologie* (Berlin: Julius Springer, 1928), ch. 5.

[18] The term "ecosystem" was actually suggested to Tansley in the early 1930ies by Arthur Roy Clapham, then a young colleague of Tansley's at Oxford; cf. A. J. Willis, "The Ecosystem. An Evolving Concept Viewed Historically," *Functional Ecology,* 11.2 (1997): 268–271, 268.

[19] George Arthur Tansley, "The Use and Abuse of Vegetational Concepts and Terms," *Ecology,* 16.3 (1935): 284–307.

not given or objective entities, but ‘mental isolates’.[20] The identification of ecosystems relies on heuristic boundaries that are introduced by an observer rather than representing real physical closures. The first consequent application of the ecosystem concept is ascribed to Raymond Laurel Lindeman (1915-1942), who in a seminal study scrutinizes the trophic dynamics of a small lake in Minnesota, taking the lake as an energy system made up of living and non-living elements.[21] Lindeman’s use of quantitative and statistical methods is inspired by his teacher, the noted limnologist George Evelyn Hutchinson (1903-1991). Hutchinson later takes part in the Macy Conferences and publishes a paper on “Circular Causal Systems in Ecology”.[22]

Historically, the notion of ecosystem thus reflects an important shift in ecological thinking. The ecosystem concept made possible a reconfiguration of central assumptions developed in the frameworks of holism and vitalism, seemingly avoiding teleological and metaphysical implications while at the same time allowing to maintain basic explanatory principles such as the irreducibility of the whole to its parts or the existence of emergent properties. In terms of ecosystems, nature becomes an object of mathematical, technical and economic analysis, and ecology turns into a knowledge which is essentially concerned with resource management. In this form, ecosystem thinking became institutionalized as the most influencing branch of ecology. One of its renowned proponents is Eugene P. Odum, who advocates and further develops the ecosystem concept in his textbook *Fundamentals of Ecology*. First published in 1953, this book remained the standard work of academic teaching until the 1970s.[23] The book was co-authored by Eugene’s brother Howard T. Odum, who also was a pioneer of ecosystem ecology and, like Lindeman, a disciple of Hutchinson. Mainly under the influence of Howard T., the *Fundamentals*, especially in their third edition of 1971, make extensive use of cybernetic concepts and vocabulary such as input

[20] Ibid. 299f.

[21] Raymond L. Lindeman, “The Trophic-Dynamic Aspect of Ecology,” *Ecology*, 23.4 (1942): 399–417; on the background of this paper and Lindeman’s work, see Robert E. Cook, “Raymond Lindeman and the Trophic Dynamic Concept in Ecology”, *Science*, New Series 198.4312 (1977): 22–26.

[22] Cf. Peter J. Taylor, “Technocratic Optimism, H. T. Odum, and the Partial Transformation of Ecological Metaphor after World War II,“ *Journal of the History of Biology*, 21.2 (1988): 213–244, 215ff.

[23] Eugene P. Odum and Howard T. Odum, *Fundamentals of Ecology* (Philadelphia: W.B. Saunders, 1953; 2nd ed., 1959; 3rd ed., 1971; 4th ed., 1983, 5th ed., 2005) The book was translated in more than thirty languages. On the reception of the *Fundamentals*, see Joel B. Hagen, “Teaching Ecology during the Environmental Age, 1965-1980,“ *Environmental History,* 13.4 (2008): 704–723.

and output relations, control and feedback, organization and complexity to describe the flows of energy and material in natural systems.[24]

Eugene P. Odum did not share his brother's addiction to energetic reductionism, but he surely also was a technocratic optimist. Influenced by his father Howard D. Odum, a noted sociologist, and by the political visions of the New Deal, Eugene P. Odum understood ecology as a theory with broad implications, bridging between natural and social systems, and believed in the possibility of sustainable resource management. Accordingly, he favored such biological concepts as mutualism and co-operation over competition.[25]

In the 1950s and 1960s, ecosystem ecology, which had so far been a rather technical academic subdiscipline of biology, enters into complex relations with environmentalism as a new form of popular and political concerns about the conditions of existence under global industrialization and capitalism. Ecological hazards caused by smog, the use of pesticides, radioactive fallout, and ecocidal warfare, combined with global shortages of grain and oil reserves, led to a growing public awareness of environmental problems.[26] One of the most suggestive settings for the popularization of ecological consciousness was the planetary perspective offered by space exploration, which is reflected by McLuhan's recourse to the Sputnik. In 1965, the economist Kenneth E. Boulding coined the metaphor of "spaceship earth" and contrasted the model of a wasteful "cowboy economy" with that of a sustainable "spaceman economy" aware of strictly limited resources and the potential finiteness of existential conditions.[27] The metaphor of spaceship earth, which replaced that of the lifeboat,[28] soon gained popularity and was developed further by Buckminster Fuller and others. Photographs of the earth taken from satellites, later by Apollo astronauts, provided icons for environmental consciousness. The blue marble figured on the cover of Stewart Brand's "Whole Earth Catalog" in 1968. Consequently, Eugene P. Odum's book "Ecology and Our Endangered Life-Support Systems", published

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[24] Cf. Taylor, "Technocratic Optimism," 224. On the Odum brothers and the historical relations between cybernetics and ecosystems thinking, see Claus Pias, "Paradiesische Zustände. Tümpel – Erde – Raumstation," in *Stehende Gewässer. Medien der Stagnation*, ed. by Butis Butis (Zürich, Berlin: Diaphanes, 2007), 47–66.

[25] On Eugene Odum's intellectual background, see Hagen, "Teaching Ecology", 704–709.

[26] Cf. Mauricio Schoijet, "Limits to Growth and the Rise of Catastrophism," *Environmental History*, 4.4 (1999): 515–530, 517f.

[27] Cf. W. Patrick McCray, *The Visioneers. How a Group of Elite Scientists Pursued Space Colonies, Nanotechnologies, and a Limitless Future* (Princeton and Oxford: Princeton University Press, 2013), 23.

[28] Cf. Hagen, "Teaching Ecology“, 709–713.

in 1989, begins with a prologue on the Apollo 13 disaster as a general allegory of ecology.

Probing the Limits

By these discoursive transformations, ecological questions in general and the dominant ecosystems approach in particular become increasingly concerned with the problem of finiteness. When the Club of Rome set out to model the future dynamics of economic growth in the 1970s, the term ecology advanced to a universal synonym for the limitations of nature itself, abandoning the historical ideas of perfectibility and infinite progress as constitutive for human nature. In 1970, the Club issued a paper entitled "The Predicament of Mankind. Quest for Structured Responses to Growing World-wide Complexities and Uncertainties,"[29] which aims at developing tools for analyzing the existential conditions of humankind on a global scale. The leading assumption is that particular problems such as population growth, scarcity of resources, pollution, food shortage, and educational deficits can no longer be treated in isolation and locally, but rather represent a complex setting of interacting hazards that requires a systemic analysis and treatment. The future of humankind is embedded into a horizon which the Club of Rome dubs "world problematique". This "problematique" is defined by its global scale, dynamic and complex character, and especially by its temporal urgency.

The paper on the 'predicament of mankind' laid the foundations for the famous report *The Limits to Growth*, published in 1972, which was prepared for the Club of Rome by a team of researchers of the Systems Dynamics Group of the Sloan School of Management at the MIT under the direction of Jay W. Forrester.[30] Technically, the study is based on a model (dubbed "World3") that covers important global scale anthropogenic effects in mathematical terms and allows to experiment with the temporal interaction of these effects by means of computer simulation.[31] Central to this approach are cybernetic considerations

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[29] The Club of Rome. *The Predicament of Mankind. Quest for Structured Responses to Growing World-wide Complexities and Uncertainties. A Proposal* (Genf, 1970).

[30] Donella H. Meadows, Dennis L. Meadows, Jørgen Randers and William W. Behrens III, *The Limits to Growth. A Report for The Club of Rome's Project on the Predicament of Mankind* (New York: Universe Books, 1972).

[31] During the years, two updates of the *Limits* have been published, providing some revisions and changes of the simulation methods and prognoses, cf. Donella H. Meadows et al., *Beyond the Limits* (Post Mills: Chelsea Green, 1992) and Donella H. Meadows et al., *Limits to Growth. The 30-Year Update* (White River Junction: Chelsea Green, 2004).

concerning the role of positive and negative feedback on progressive growth rates. Assuming that the carrying capacity of the earth is limited, exponential growth of parameters such as world population, fertilizer consumption, industrial capital savings, or pollution lead to a global “overshoot” that is predicted to cause more or less catastrophic changes until the world system settles to a new state of equilibrium.[32] The report to the Club of Rome thus transports the Malthusian scenario of natural limits imposed on exponential population increase to the digital age.[33] The idea of limitations to growth provides a stable frame of reference which remains valid for ecological thought up to the present. Recent approaches to the concept of global sustainability and resilience, e.g., draw on the concept of “planetary boundaries”, trying to define threshold values for parameters such as species diversity, pollution, and population, with the goal of “estimating a safe operating space for humanity with respect to the functioning of the Earth System.”[34]

As a central innovation, the world model used in the *Limits to Growth* follows a logic of simulation to the effect that ecology is no longer descriptive, but rather construed as an operational setting that demands experimental interaction. Tuning parameters such as population growth or industrial capital rate, and observing the non-predictable outputs, is open to assume qualities of playful action, which explains the affinities of scientific ecological modelling to computer games of world simulation such as the “Daisy World” of Andrew Watson and James Lovelock, or “SimEarth”.[35]

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[32] For critical discussion of the background and the reception of the *Limits*, cf. Schoijet, “Limits to Growth”; Francis Sandbach, “The Rise and Fall of the Limits to Growth Debate,” *Social Studies of Science*, 8.4 (1978): 495–520; Vaclav Smil, “Limits to Growth Revisited: A Review Essay”, *Population and Development Review,* 31.1 (2005): 157–164.

[33] In his book *An Essay on the Principles of Population* (London: J. Johnson, 1798), the English cleric and political economist Thomas Robert Malthus (1766-1834) developed an influencing though controversial theory of the relation between population growth and limiting factors such as famine and disease. According to Malthus, population multiplies geometrically, while food supply increases only arithmetically, leading to catastrophic future scenarios. Present Neo-Malthusian approaches extend the argument from population growth and food shortage to other critical resources and environmental factors. On historical discussion and recent debates in the context of the “Limits to Growth”-reception, see Schoijet, “Limits to Growth”.

[34] Cf. Johan Rockström et al., “Planetary Boundaries: Exploring the Safe Operating Space for Humanity,“ *Ecology and Society*, 14.2 (2009): 32, http://www.ecologyandsociety.org/vol14/iss2/art32/

[35] One of the earliest and prototypical large-scale ecological simulation environments is Buckminster Fuller’s ‘World Game’ of the 1960s, cf. Christina Vagt, “Fiktion und

While the *Limits to Growth* of 1972 are commonly supposed to have substantially contributed to the rise of ecological consciousness,[36] they did so mainly by popularizing a specific scientific approach to ecological modelling, and by drawing on a specific technical medium, the computer. The normative impact of the "Limits" does not aim at a cautious treatment of nature, but rather serves to promote the ideas of technical and social engineering.[37] Which leads to the master mind of the project. Jay Wright Forrester, electrical engineer and systems researcher, started his career at MIT during World War II with the development of servomechanisms for radar antennas and gun mounts. At the end of the war, Forrester directed the development of an aircraft flight simulator. The work on this project stimulated the design of the first digital computer, the Whirlwind system, which laid ground for experimental research on military combat information systems that resulted in the renowned SAGE (Semi-Automatic Ground Environment) air defence system for North America.[38]

In the 1950s, Forrester turned from military environments to economic management and in this context developed his theory of Dynamic Systems, which is concerned with modelling and simulating complex systems that exhibit a non-linear behavior. In the following years, Forrester applied his theory on different scales, publishing books on "Industrial Dynamics" (1961), followed by the broader socio-political context of "Urban Dynamics" (1969), and finally by the global context of "World Dynamics" (1971). In the latter book, Forrester outlines the computer model that underlies the World3 simulation of the "Limits to Growth", which was published nine months later. Supported by the seeming authority of the most advanced and promising technology, computer modelling here gains the status of a universal tool of scientific explanation as well as practical management, irrespective of the domain or scale of application.

In retrospect, ecological systems thinking presents itself as a field where the technical figuration of life and of nature becomes inseparable from the naturalization and animation of technology. This reversibility, which is characteristic already for the parallel conception of machines and human

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Simulation. Buckminster Fullers *World Game*," *Archiv für Mediengeschichte,* 13 (2013): 117–145.

[36] In fact, the appearance of the report was well planned and announced in ways which would trigger public interest in advance, cf. Sandbach, "The Rise and Fall of the Limits to Growth Debate."

[37] This also applies to earlier cybernetically inspired systems ecology, cf. Taylor, "Technocratic Optimism".

[38] Cf. Forrester's autobiographical description, Jay W. Forrester, *The Beginning of System Dynamics. Banquet Talk at the International Meeting of the System Dynamics Society Stuttgart, Germany July 13, l989.*

(working) bodies in the industrial age, is even more characteristic for the information age, where computer programming, modelling, and simulation become dominant techniques of knowledge as well as biopolitic practice, both on the macroscopic level of ecology ('world dynamics') and on the microscopic level of organisms, finally on the molecular basis of 'life itself'.

From Ecological Systems to the Transformation of 'Life'

One of the most prominent examples for the modelling and simulation of features of 'life' on a micro-level is the algorithmic artefact 'Game of Life'. The media history of 'Game of Life' (in the following abbreviated 'Life') also brings forward how the rise of 'games' as part of computer culture since the early 1970s is interconnected with the popularization of systems thinking.

'Life' is commonly understood as a game that provides an example of emergence and self-organization, therefore supporting concepts like 'autopoiesis' and 'emergence' that were brought into debate from thinkers of the second wave of cybernetics.[39] It is also known to be the most popular version of a cellular automaton. It was first presented in Martin Gardner's popular column in Scientific American in October 1970. The basic algorithm was developed by British mathematician John Horton Conway between 1968 and 1970. The original game is played on a 2-dimensional grid, similar to a checkerboard that is populated with so called 'cells'. The development of any 'Life' pattern is determined by Conway's "genetic laws" for births, deaths, and survivals of the cell population. The rules of the game are quite simple, and its very simplicity is part of its success. Gardner listed the complete rules in his article from 1970:

> 1. Survivals. Every counter with two or three neighboring counters survives for the next generation.
> 2. Deaths. Each counter with four or more neighbors dies (is removed) from overpopulation. Every counter with one neighbor or none dies from isolation.
> 3. Births. Each empty cell adjacent to exactly three neighbors--no more, no fewer--is a birth cell. A counter is placed on it at the next move.[40]

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[39] Cf. B. Clarke and M. B. N. Hansen, "Neocybernetic Emergence: Retuning the Posthuman," *Cybernetics and Human Knowing*, no. 16 (2009): 83–99.

[40] M. Gardner, "Mathematical Games – The Fantastic Combinations of John Conway's New Solitaire Game 'Life,'" *Scientific American*, no. 223 (October 1970): 120–23, 120.

By repeated application of the rules to the subsequent generations of cells, different patterns occur on the checkerboard. Because of the way patterns seem to evolve to 'life-like' behavior the game was often described as 'fascinating' and 'surprising'.

While it could be argued that computer games in general are an offspring of cybernetics and therefore means of the proliferation of cybernetic systems thinking, this certainly fits as a description of 'Game of Life'.[41] When 'Life' became more and more popular during the 1970s, it attracted significant interest in different scientific disciplines, like computer science, economics, mathematics, philosophy, physics and biology. Since 'Life' started just in time with the growing distribution of a new generation of minicomputers it also became a part of the hobbyist computer culture. The influential American microcomputer magazine BYTE discussed 'Life' prominently already in its first issue in 1975, and editor Carl Helmer dedicated an ongoing column called LIFE-line to the game. A later issue (1978/3/12) gave detailed instructions for "Life with your computer" and encouraged its readers to develop their own version of 'Life'.

Until today, the *computer* is the essential medium of 'Life' and the game is used to teach programming skills as well as to study pattern generating algorithms and 'emergent behavior'. It remarkably crosses and interconnects scientific research with hobbyist computer culture, computer science with biology, cybernetic ideas with simulation techniques. Within various scientific disciplines it supports the transformation of epistemic practices that combine aspects of 'playful experimentation', simulation techniques and computer programming. A contemporary example for this function of the game can be found in the price awarded scholarly book "Self-Organization in Biological Systems", published in 2003 in the series Princeton Studies in Complexity and edited by Scott Camazine. In this book, 'Life' is used as an example for complexity and self-organiziation and at the same time as a software-tool to teach simulation techniques. Interestingly, the authors feel obliged to clarify that 'Game

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[41] While games where already present in early cybernetic theory, with prominent examples like von Neumann's interest in the mathematical theory of games as a possible application to economic theory, Turing's references to chess as a testing ground for advances in artificial intelligence or Shannon's obsession with all kinds of playful machines, it is not until the 1970s that computer-based games found their way to popular culture. For a more detailed discussion of the relevance of games in early computer discourse cf. Serjoscha Wiemer, "Strategiespiele und das Medium-Werden des Computers. Computerschach als Faktor der Rekonzeptionalisierung des Computers als programmierbare Maschine zwischen 1945 und 1960", in *Diskurse des strategischen Spiels. Medialität, Gouvernementalität, Topografie*, ed. by Rolf F. Nohr, Serjoscha Wiemer, and Stefan Böhme (Münster: LIT, 2014), 83–112.

of Life' "is merely a stylized model of the dynamic evolution of a population of organisms and without real biological relevance". Nevertheless it is repeatedly used as a point of reference, because "its simplicity makes it a good didactic example."[42] 'Life' can be found in a list of programs for the simulation software StarLogo, together with simulations of pattern formation in slime molds, synchronized flashing among fireflies or colony thermoregulation in honey bees.

Within the broader field of digital culture, 'Life' is part of the distribution of programming skills in conjunction with ideas of self-organization and emergence as well as with 'entertainment' in the sense of fun and playful practice. It is a striking example of a decentered distribution of knowledge and its (re)production by algorithmic media.[43] Algorithmic media like 'Life' can be seen as elements of todays 'nature-database', re-codifying concepts of nature and information.[44]

Ludic Function as Interdiscourse and Naturalization

The broad application of 'Life' from scientific research to entertainment can be understood with regard to its specific features as a *game*. To further explore this

[42] See Scott Camazine, *Self-Organization in Biological Systems* (Princeton, New Jersey: Princeton University Press, 2003), 81.

[43] Within the field of cultural and media studies scholars like Laura Marks, Alexander Galloway, and Jussi Parikka among others have contributed to a theoretical understanding of "algorithmic media", but the concepts are still in a flux. One common aspect could be seen in the drive towards a neo-materialistic understanding of algorithmic media that tries to overcome a traditionally staged "opposition between mechanistic and vitalist understandings of (dead versus lively) matter". Cf. Diana H. Coole and Samantha Frost, eds., *New Materialisms: Ontology, Agency, and Politics* (Durham [NC]; London: Duke University Press, 2010), 11. For the approaches of Marks and Galloway cf. Laura U. Marks, „Thinking like a carpet: embodied perception and individuation in algorithmic media", in *Ent-Automatisierung*, ed. by Annette Brauerhoch and Anke Zechner (Paderborn: Fink, 2014); Alexander R. Galloway, *Gaming: Essays on Algorithmic Culture* (Minneapolis: Univ. of Minnesota Press, 2006).

[44] Referring to concepts of new materialism, German Duarte proposed the term 'nature-database' to describe the new relation between materiality and information that evolves from the intensified interrelation of 'nature' and 'technology'. As Duarte states "nature-database can be understood as a new codification of 'reality' from which non-fix meaning derives and in which biological (material) and non-biological (technology and information) coexist and are in constant transformation." German Duarte, "New-Materialism and Reification in the Infoproduction Era," *Communication +1*, no. 2 (September 8, 2013), http://scholarworks.umass.edu/cpo/vol2/iss1/4.

idea we will draw on Rolf F. Nohrs concept of the "naturalization" of knowledge and Gerald Voorhees' concept of computer games as "game of truth".[45] German media scholar Rolf Nohr discusses the function of games within a general framework of the discoursive circulation of knowledge.[46] According to Nohr, a characteristic discoursive function of computer games is that of "naturalization" which is realized by "translating" elements of special discoursive knowledge to the level of the common sense.[47] A key attribute of this theory is the importance of the *ludic function* of games as a performative process and how a general idea is transferred to the level of individual perception and belief. By playing a game one activates its aesthetic dimension not as an abstract, but as an *individual, temporal* experience, where a game unfolds as something that is more or less defined in relation to one's active involvement and *configurative actions*.[48] In other words: to play a game is the *subjective* instantiation of an abstract form as a sensual experience and therefore coupled with the temporality of perception and subjectivity. According to Nohr, this "sensualization" should be interpreted as an element of "naturalization", which leads to the translation of special discourse knowledge to common sense. Therefore computer games realize a "procedure of integration" which is part of their function as "interdiscourses".[49] While Nohr points to the function of games for the *transfer* of knowledge, this idea can be complemented by Gerald Voorhees' concept of the epistemological function of games.[50] Adopting the term 'game of truth' from Foucauldian discourse analysis and applying it to the study of computer games, Voorhees points to the epistemological relevance of games: "digital games model the discursive formations that give shape to what is reasonable, what is possible and what is

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[45] Gerald Voorhees, "Discursive Games and Gamic Discourses," *Communication +1*, no. 1, http://scholarworks.umass.edu/cpo/vol1/iss1/3.

[46] Rolf F. Nohr, "The Naturalization of Knowledge. Games Between Common Sense and Specialized Knowledge," in *Logic and Structure of the Computer Game*, ed. Michael Liebe, Dieter Mersch, and Stephan Günzel, vol. 4, DIGAREC Series (Potsdam: University Press, 2010), 130–43.

[47] With reference to Jürgen Link's theory of 'critical discourse analysis', Nohr distinguishes between 'special discourses' of highly specialized knowledge, for example in scientific discourses of economics, biology, mathematics etc., and a level of 'shared' or 'common' knowledge being part of the everyday of a given society (for Link's theory cf. Siegfried Jäger, *Kritische Diskursanalyse: Eine Einführung*, 6th ed., Edition DISS 3 (Münster: Unrast, 2004)).

[48] Markku Eskelinen, "The Gaming Situation," *Game Studies. The International Journal of Computer Game Research*. 1, no. 1 (July 2001), http://www.gamestudies.org/0101/eskelinen.

[49] Nohr, "The Naturalization", 137.

[50] Gerald Voorhees, "Discursive Games".

foreclosed in a given historical moment, enabling critical scholars of communication to better conceptualize the operation of power."[51]

Game of Truth: Cybernetic's Concept of Self-Reproduction and the Invention of Cellular Automata

Following Voorhees' suggestion to ask about the "given historical moment" when 'Game of Life' came into existence, it is not sufficient just to name the publication of the rules and descriptions in Martin Gardner's column on recreational mathematics in *Scientific American* in October 1970. Understood as an expression of a certain "epistemological force"[52], one has to take the conceptual foundation of 'Life' as an example of cellular automata more serious.[53] This leads to the epistemological presuppositions of 'Life' and to the question how Conway's rules of the game refer to the historical epistemology of cybernetics. Media scholar Jussi Parrika identified Conway's work as part of an epistemological idea "to see nature as a computational process" and, in particular, "as part of the history of mathematical organisms and simulations". [54] When Parikka discussed 'Game of Life' in "Digital Contagions", his seminal study of computer viruses, he pointed to the "key role" of self-reproduction and to the fact that with cellular automata, the concept of self-reproduction was combined with "principles of universal computation".[55] The crucial point is that 'Life' is a leading example of the idea of the *computability of nature* by the means of systems theory.

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[51] Ibid., 16.

[52] Voorhees, "Discursive Games", 13.

[53] Since 'Game of Life' itself refers to the notion of 'life', it is of great importance to reconstruct the concept of life that leads to the possibility of 'Game of Life' and to be sensitive to the historical movement that 'Life' is involved in, how it is enmeshed in the struggle of the reconceptualization of life as 'information'. To look at 'Game of Life' as a 'game of truth' in this sense might imply to try to reconstruct the 'discoursive formation' that gave shape to the game. Including questions like "What are the necessary conditions to make the formation of this specific game possible?", "What are the epistemological articulations and the power relations, that are specific to the game in a given historical moment?", "What were the epistemological concepts that could lead to the formulation of cellular automata?", "What was their theoretical function within the 'game of truth' that cybernetics played in the 1940s and 1950s?", "What was their 'strategic' value?", "What were the questions and theoretical problems that lead to the concept of cellular automata?".

[54] Jussi Parikka, *Digital Contagions: A Media Archaeology of Computer Worms and Viruses* (New York [u.a.]: Peter Lang, 2007), 232f.

[55] Ibid.

The basic idea of cellular automata was formulated by John von Neumann in the 1940s.[56] Von Neumann's first approach to a theory of self-reproducing automata was about an automaton that could *materially* reproduce itself.[57] In addition to this concept of a "Universal Constructing Machine" (also called "kinematic model") he later developed a second model of self-reproducing automata, which does not pose the mechanical and material problems of the first and which became known as the theory of *cellular automata*: In this approach, the automata are based on a two-dimensional array of elementary "cells."[58] This concept finally led to the invention of 'Game of Life' by Conway.

It is remarkable that von Neumann developed his initial idea of automata as self-reproducing structures when he tried to find a mathematical description of *complexity*. Self-reproduction and the theory of biological evolution served as a key to von Neumann's understanding of the meaning of 'complexity'. He argued that while natural organisms would show the ability for increasing complexity, which would be the case with "long periods of evolution", the artificial automata would suffer from a "degenerating tendency" and a "decrease of complexity".[59]

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[56] Claude Shannon summoned von Neumann's ideas in 1953. The following paragraphs are based on his subsumption of von Neumann's approach. Cf. Claude E. Shannon, "Computers and Automata," *Proceedings of the IRE* 41, no. 10 (1953): 1234–41, 1240.

[57] Von Neumann thought that, analogous to Turing's universal computing machine, it could be possible to "design a kind of universal construction machine […] The universal constructing machine can be fed a sequence of instructions, similar to the program of a digital computer, which describe in a suitable code how to construct any other machine that can be built with the elementary components. The universal constructing machine will then proceed to hunt for the needed components in its environment and build the machine described on its tape." Ibid., 1240.

[58] Claude Shannon gave a short and very precise description of the general mechanism of von Neumann's initial conception of cellular automata: "Each cell is of relatively simple internal structure, having, in fact, something like thirty possible internal states, and each cell communicates directly only with its four neighbors. The state of a cell at the next (quantized) step in time depends only on the current state of the cell and the states of its four neighbors. By a suitable choice of these state transitions it is possible to set up a system yielding a kind of self-reproducing structure." Ibid.

[59] "Organisms are indirectly derived from others which had lower complexity", but "a certain degenerating tendency must be expected, some decrease in complexity as one automaton makes another automaton." See John von Neumann, "The General and Logical Theory of Automata," in *Collected works*, ed. Abraham Haskel Taub, vol. V (Oxford; New York [etc.]: Pergamon, 1976), 288–326, 312. This statement is logical, if one assumes that in order for an automaton A to produce another automaton B it must have contained a complete description of B together with some instructions how to build it and therefore A must have a higher degree of "complication" than B. (ibid., 312). After von Neumann sketched the logical and mathematical description of an

Looking at how von Neumann presents his argument in "The General and Logical Theory of Automata", one recognizes that at the beginning he is very strict and careful to develop his theoretical comparison of 'natural organism' and artificial automata only as means of *interpretation* for certain problems regarding the understanding of complexity. But later that relation is reversed when he takes the self-reproduction of automata as a model for the explanation of the self-reproduction of genes and the production of enzymes.[60] It is precisely at this point that an *epistemological operation* becomes functional, which Lily E. Kay analyzed as "cyborg dialectic". Cyborg dialectic points to a procedure where machines and organisms are taken as a model to mutual explain the other and at the same time narrowing both concepts, so that their distinction becomes more and more blurred. According to Kay this specific cross-identity-conceptualization of machines and biological systems is one of the characteristics of the first wave of cybernetics.[61] As Kay has shown in her writings about the history of science, this *cyborg dialectic* can be found explicitly in the formation of the concepts of the 'genetic code' and the reconceptualization of 'life' in modern molecular biology. Within the ontological framework of cybernetics, 'life' was not only regulated by cybernetic mechanisms of feedback and homeostasis, but it finally became thinkable to understand 'life itself' as pure 'information'.

Thus, at the time when British mathematician John Horton Conway started his work on 'Game of Life' around 1968, he entered an already established array of mutual conceptualizations of 'living organisms' and 'artificial automata'. At the end of the 1960s the idea of taking self-reproducing automata as a model for the understanding and 'calculation' of biological processes of cellular

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automaton with the ability of self-reproduction that could possibly be a solution to the degenerating tendency, he proposed a direct comparison of the process of self-reproducing automata and living organisms, declaring "the copying mechanism B performs the fundamental act of reproduction, the duplication of the genetic material, which is clearly the fundamental operation in the multiplication of living cells." (ibid., 317).

[60] Ibid., 318.

[61] The concept of cyborg dialectic is developed as part of Kay's analysis of the epistemological shift of neuroscience in the theoretical works of Warren S. McCulloch and Walter Pitts that played a crucial role in the 'cognitive turn' of the 1950s: "McCulloch-Pitts neural nets and Turing's machine became the twin pillars of early automata studies and computer design [...]. And just as with Wiener's cybernetics, in which the nervous system became a model for negative feedback machines and, in turn, the machine a model for biological systems, this cyborg dialectic obtained also in logical automata." Lily E. Kay, "From Logical Neurons to Poetic Embodiments of Mind: Warren S. McCulloch's Project in Neuroscience," *Science in Context* 14, no. 04 (2001): 591–614, 602.

reproduction on a molecular level was already in circulation.[62] Some of these conceptions privileged the phenomenon of 'self-reproduction' as paradigmatic feature of 'life', while others were more structured by concepts of information, program, feedback or complexity.

Artificial Life

While 'Game of Life', until today, is used for modeling 'natural' and 'lifelike' processes and as algorithmic medium for theoretical research across a broad range of disciplines,[63] a very distinct and specific role of 'Life' can be found within *artificial life research*. Christopher Langton, one of the founding figures of artificial life (also abbreviated A-Life) as an academic field of study, proposed to acknowledge non-organic entities as 'alive' and proclaimed cellular automata as preferred research tool.[64] The 'lifelike' behavior of Conway's 'Life' is a much used 'visual' argument for this approach.[65] It seems plausible that much of the game's continuous attraction is related to its *visual attributes*, how it "offers direct

[62] As Evelyn Fox Keller has shown, 'program' and 'computer' became influential as metaphors for the understanding of biological development during the 1960s, namely with regard to genetic research and molecular biology. Cf. Evelyn Fox Keller, "Beyond the Gene but beneath the Skin," in *Arguing about Science*, ed. Alexander Bird and James Ladyman (New York: Routledge, 2012), 125–39, 129f. Stahl is one of the early researchers who also referred directly to the idea of self-replicating machines as theorized by von Neumann; Apter (1966) emphasized the importance of logical or computer models of genetic control and differentiation mechanisms, after François Jacob and Jacques Monod, who had applied cybernetic concepts of 'regulation' and 'control' successfully to the description of biochemical mechanisms of enzyme synthesis, were awarded with the Nobel Price in Medicine in 1965 (together with André Lwoff). Cf. Walter R. Stahl, "A Computer Model of Cellular Self-Reproduction," *Journal of Theoretical Biology* 14, no. 2 (1967): 187–205; Michael John Apter, *Cybernetics and Development*, International Series of Monographs in Pure and Applied Biology. Div.: Zoology; 29 (Oxford: Pergamon Press, 1966).

[63] An ongoing interest in 'Game of Life' can be observed in mathematics, physics, biology, chemistry, music theory, simulation theory, and other disciplines. A collection of different approaches, with a certain emphasis on mathematics, can be found in Andrew Adamatzky, ed., *Game of Life Cellular Automata* (London; New York: Springer, 2010).

[64] Christopher G. Langton, "Studying Artificial Life with Cellular Automata," *Physica D: Nonlinear Phenomena*, Proceedings of the Fifth Annual International Conference, 22, no. 1–3 (October 1986): 120–49.

[65] The reference of A-Life to ‚Life‘ has been discussed in more detail in Sherry Turkle, *Life on the Screen* (New York: Simon & Schuster, 1995).

visual evidence of how simple rules can generate complex patterns”.[66] In this regard, it is possible to identify at least two different aspects of the visual qualities of ‘Life’: a) the aesthetic experience of movement or animation and b) the pleasing unpredictability of pattern development with a rich diversity of reoccurring ‘organisms’ (specimens) and designs in constant flux.

While the geometrical and topological features of ‘Life’ may be regarded as a direct outcome of its specific mathematical foundation, this does not hold true for its visual aspects, since the visibility and its perceivability as well as perceptibility in general is not only an outcome of its mathematical structure but also very much of its materialized processing by *computer media* and the related graphical displays. This is an important aspect that exemplifies how algorithmic media are relying on *material processes*, where ‘matter’ and ‘information’ are not opposed but entangled. If ‘Life’ can be regarded a significant historical landmark concerning the rewriting of the matrix of life, it is because its main feature is not on the level of the ‘symbolic’ or in the register of ‘representation’, but how it brings together concepts, code, algorithm, material calculation, and perception in a dense process of mediation. At least from the perspective of new materialisms or materialist media theory[67] it would be wrong to treat ‘Life’ as an example of the ‘immaterial’ essence of ‘life itself’ – since the very mechanism of computer technology is the specific arrangement of ‘matter’ for the purpose of calculation. Computers are essentially material devices, as media scholars have often emphasized.[68] One of their material features is the ability to *display* structures of information and rule based processes.

To See It is to Know It - Aesthetic-Epistemological Power

Regarding the importance of computers as *visual media*, Sherry Turkle’s description of her first encounter with ‘Life’ is an instructive example of how the

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[66] John Johnston, *The Allure of Machinic Life: Cybernetics, Artificial Life, and the New AI* (Cambridge, Mass.: MIT Press, 2008), 10.

[67] According to Milla Tiainen and Jussi Parikka, the new materialist approach can be characterized by a “commitment to developing models of immanent and continuously emergent relationality” as well as by a certain *materialist* understanding of media as a “network of concrete, material, physical and physiological apparatuses and their interconnections”. See Jussi Parikka and Milla Tiainen, “What Is New Materialism-Opening Words from the Event,” accessed April 1, 2014, http://machinology.blogspot.de/2010/06/what-is-new-materialism-opening-words.html.

[68] For example Frank Hartmann, *Mediologie: Ansätze einer Medientheorie der Kulturwissenschaften* (Wien: Facultas Universitätsverlag, 2003), 11. Hartmann points to the fact that „digital“ in the realm of the computer means that binary arithmetic is switched electronically, which implies electronic engineering and material processes.

aesthetic function of computer mediated mathematical processes structures and rules the perception of a game's 'epistemological' message. In *Life on the screen* Turkle recalls how 'Life' began to challenge the way she thought about 'life itself':

> When I first came upon it, the Game of Life was running on a small, unattended screen. Things came together and flew apart, shapes emerged, receded, and reemerged. I remember thinking about fire and water. The French philosopher Gaston Bachelard had written about the universal fascination of watching fire, which, like watching moving water, is something that people seem drawn to across all times and cultures. There is repetition and sameness, surprise and pattern. Fire and water evoke eternal patterns of life, and now, so could a computer screen. In 1977, I stood alone at the screen, watched the Game of Life, and felt like a little girl at the oceans' edge. At the same time I assumed that all life had to be carbon based. […] But as I came to understand how he Game of Life could be reset to generate complexity from initial randomness, it took on another level of fascination. I saw how this evolving, unfolding visual display might challenge my simple preconceptions. Perhaps something about life could be understood in terms of these evolving forms. I was intrigued by the idea but resisted it.[69]

From a perspective of media theory, Turkle's fascination with the visual movements, reminding her of "eternal patterns of life" by resembling the experience of watching *fire and water*, should not be understood as the analogue to a "universal fascination" that is essential the same "across all times and cultures". Rather it should be understood as an effect of 'animation' specifically related to the medium of the computer. It is precisely the visual display that is in the center of Turkle being "intrigued by the idea" of life as formations of evolving patterns and informational description of complexity. However, Turkle's dense rhetorical scene is not only instructive regarding the rhetorical potential of the game to translate visual qualities into intriguing ideas, but also regarding the reference to eternity, fire and water. As physical phenomena fire and water do not fall into the realm of common ontologies of 'life' or 'living organisms'. And more so, "life" is commonly understood as limited, since mortality is one of the essential properties of "life", which is very much in contrast to Turkle's awestruck invocation of "eternal patterns".

[69] Turkle, *Life on the Screen*, 155.

In fact, Turkle's description seems to be closer to a familiar cultural concept of 'nature' than of 'life'. This might become even more obvious regarding the overlap between Turkle's affirmation of '(L)life' and Hans-Georg Gadamer's description of "play" which he developed in his theory about the artwork: Gadamer's ideas about 'play' are directed against any individual or 'subjective' aspects of games, trying to reflect on 'play as such', apart from personal experience or idealistic tradition. "Play" is described in direct correspondence to "the mobile form of nature".[70] For Gadamer, nature itself is understood as a play – without the necessity of human subjects involved:

> If we examine how the word 'play' is used and concentrate on its so-called metaphorical senses, we find talk of the play of light, the play of the waves, the play of gears or parts of machinery, the interplay of limbs, the play of forces, the play of gnats, even a play on words. In each case what is intended is to-and-fro movement that is not tied to any goal that would bring it to an end. Correlatively, the word 'Spiel' originally meant 'dance', and is still found in many word forms (e.g., in Spielmann, jongleur).[71]

In a manner that could be evocative of aspects of 'Life', Gadamer further explains his idea about "play as such":

> The movement of playing has no goal that brings it to an end; rather, it renews itself in constant repetition. The movement backward and forward is obviously so central to the definition of play that it makes no difference who or what performs this movement. The movement of play as such has, as it were, no substrate. It is the game that is played—it is irrelevant whether or not there is a subject who plays it. The play is the occurrence of the movement as such.[72]

Gadamer's philosophy of play can help to explain how Turkle's fascination with 'Life' transcended into a fascination of 'nature'. The similarities between Gadamer's approach to play and Turkle's narration of her impressions of 'Life' seem to culminate in the affirmation of certain aesthetic qualities of movement. The patterns of 'Game of Life' can be attributed the quality of 'dancing' light, visible on a computer screen. In Turkle's description, 'Life' resembles "the mobile form of nature" that Gadamer calls 'play'.

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[70] Hans-Georg Gadamer, *Truth and Method*, 2nd ed., Continuum Impacts (London: Continuum, 2006), 105.
[71] Ibid.
[72] Ibid.,104.

However, Turkle's contribution to the discourse of 'Life' is more or less a byproduct of her interest in the scientific project of artificial life (A-Life). Christopher Langton, one of the prominent advocates of A-Life, follows the credo that "the 'molecular logic' of life can be embedded within cellular automata".[73] As Langton states, the principle assumption made in A-Life-research is that "the 'logical form' of an organism can be separated from its material basis of construction, and that 'aliveness' will be found to be a property of the former, not of the latter".[74] For Langton, of course, this logical form is equivalent to an algorithm, and therefore the "ideal tool" for the study of life is exactly the computer.[75] Following the ideas of a bottom-up approach, where "emergent behavior" is thought of as an outcome of the dynamic interaction of rather simple "low-level primitives",[76] A-Life discourse takes 'Life' as an essential reference. Because it is not just a metaphor, but an 'algorithmic machine', it implies the promise to bridge the gap between biological studies on complexity and self-organization in natural organisms or "biological systems"[77] and the computer based understanding of life as complex systems of information processing.

As the example of 'Life' shows, there is an ongoing translation between epistemological and aesthetic reasoning, where the rhetorical function depends very much on the specific mediality of games. While on the one hand, 'Life' may be used as an example for the conceptual shift from a notion of 'life' as carbon based to the idea that "'information' can be 'life'"[78], on the other hand it can point to the importance of aesthetic qualities as fundamental aspects of the notion of 'life' or 'nature'. From a perspective of media theory, it is important to notice the fact that the game's 'meaning' is not only determined by its context and its rhetorical instrumentalization for different strategic goals within the 'game of

[73] Christopher Langton, "Studying Artificial Life with Cellular Automata," *Physica D: Nonlinear Phenomena*, Proceedings of the Fifth Annual International Conference, 22, no. 1–3 (October 1986): 120–49, 120.

[74] Christopher Langton, "Artificial Life. Introduction," in *Artificial Life: Proceedings of an Interdisciplinary Workshop on the Synthesis and Simulation of Living Systems*, ed. Christopher Langton (Reading, Mass.: Addison-Wesley, 1988), 1–47, 11.

[75] Ibid., 2.

[76] Ibid., 2–3.

[77] See Camazine, *Self-Organization in Biological Systems*. Due to its simplicity with only a few rules to calculate the status of a single cell, determined by the status of its neighbors, 'Life' is suited to the propagation of a hands-on approach to simulation techniques, as it is common practice not only to experiment with the initial state of the system, that is the specific distribution of cells on the two-dimensional grid, but to *alter* the rules themselves.

[78] Richard Doyle, *On Beyond Living: Rhetorical Transformations of the Life Sciences* (Stanford University Press, 1997), 110.

truth', but that the meaning-making properties have slid to the process of translation or mediation between 'information' and perception.

Final Prospect

Ongoing debates about biomedia show the traces of systems thinking on several levels. Remarkably, it is not only the historic relevance of systems theory's epistemological project that irradiates contemporary ontologies, but also a strong drive to use simulations and games as means of popularization. The world models of system ecology and the games of 'lifelike' patterns both underline the relevance of algorithmic media as part of the production and interpretation of (our shared) reality. While the genealogy of systems thinking can be traced back to the emerging ecological thought of the late 19th century, it is the technoscientific approach of simulation that re-folds biology, ecology and systems thinking onto another. Finally, the afterlife of systems thinking becomes more or less undistinguishable from the afterlife of 'nature'. Does this mean that world modelling should be identified as the historical vanishing point of 'nature', since system-ecological thinking is incapable of rendering anything outside as relevant counterpart? Or how might one think any 'outside' of the ecological paradigm? The debates between poststructuralism, systems theory and actor-network-theory are haunted by the ghost of nature. A zombielike afterlife: It seems likely that system-ecology aka "undead nature" keeps revisiting contemporary theory.

Following an argument of gender-and-media scholar Marie-Luise Angerer, algorithmic media might circumscribe a new kind of mediatechnological state, where the 'interval of perception' is 'played' in a way that technology and life become "soldered" („verlötet") in accordance to the conditions of electronic affective temporality. This could lead, as Angerer argues, to a point where technology and life, the social and the somatic, loose their mutual differentiation.[79]

[79] Cf. Marie-Luise Angerer, "Die 'Biomediale Schwelle'. Medientechnologien und Affekt," in *Situiertes Wissen und Regionale Epistemologie: Zur Aktualität Georges Canguilhems und Donna J. Haraways*, ed. Astrid Deuber-Mankowsky and Christoph F. E. Holzhey, Cultural Inquiry 7 (Wien: Verlag Turia + Kant, 2013), 203–22, 210. This idea of a biomedial threshold („biomedialer Schwelle") is based on Angerer's reading of George Canguilhem's philosophy of technology. Canguilhem developed his philosophy of technology in distancing himself from the cybernetic "pursue of hegemony" (ibid., 209). Angerer follows Canguilhem's proposal to understand technology as "universal biological phenomenon" (ibid., 208), as Canguilhem argued in his essay *Machine and Organism*. Unlike in cybernetics, for Canguilhem technology is not identical with rationality and teleological thinking. The assumed rationality of

Referring to Foucault's concept of the productivity of power, Richard Doyle describes algorithmic media as elements of the "practice and tactics (what Foucault has dubbed a 'technological ensemble')" that are involved in the game of truth where "life gets networked, located, and articulated through a computer screen".[80] In addition to the onto-aesthetical, epistemological, and rhetorical functionality of algorithmic media, Alexander Galloway theorized their allegoric power. He states that "to interpret a game means to interpret its algorithm (to discover its parallel 'allegorithm')"[81], but the playful actions that are necessary to discover a game's possible worldings are not acts of hermeneutic exegesis and interpretation, but can be called 'playacts'. Within algorithmic media, the allegorical dimensions of a game are less on the level of representations but communicate as playful actions: playacts refer to this situation of algorithmic media, where we "do" allegory, rather than comment and reflect on it.

As part of the new compositions of the techno-biological and the techno-ecological situation of the 21st century, the example of 'Life' can help to avoid some of the epistemological pitfalls and misconceptions that arise with the ideology of simulation and the afterlife of systems theory in ecological modeling of 'Gaia' and synthetic biology. 'Life' should remind us of the allegorical qualities of algorithmic media, where the game of truth has not been played through, but still requires ongoing playacts.

technology that is brought in opposition to life and is used as a model to gain control and power over the living would then be an anthropocentric illusion. For Canguilhem's critique of anthropocentric concepts of technology cf. Astrid Deuber-Mankowsky, "Kritik des Anthropozentrismus und die Politik des Lebens bei Canguilhem und Haraway," in *Situiertes Wissen und Regionale Epistemologie: Zur Aktualität Georges Canguilhems und Donna J. Haraways*, ed. Astrid Deuber-Mankowsky and Christoph F. E. Holzhey, Cultural Inquiry 7 (Wien: Verlag Turia + Kant, 2013), 105–20.

[80] Doyle, *On Beyond Living*, 110.

[81] Galloway, *Gaming: Essays*, 91.

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Plutonium Worlds. Fast Breeders, Systems Analysis and Computer Simulation in the Age of Hypotheticality

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Abstract
This article examines the media history of one of the hallmark civil nuclear energy programs in Western Germany – the development of Liquid Metal Fast Breeder Reactor (LMFBR) technology. Promoted as a kind of perpetuum mobile of the Atomic Age, the "German Manhattan Project" not only imported big science thinking. In its context, nuclear technology was also put forth as an avantgarde of scientific inquiry, dealing with the most complex and 'critical' technological endeavors. In the face of the risks of nuclear technology, German physicist Wolf Häfele thus announced a novel epistemology of
"hypotheticality". In a context where traditional experimental engineering strategies became inappropiate, he called for the application of advanced media technologies: Computer Simulations (CS) and Systems Analysis (SA) generated computerized spaces for the production of knowledge. In the course of the German Fast Breeder program, such methods had a twofold impact. One the one hand, Häfele emphazised – as the "father of the German Fast Breeder" – the utilization of CS for the actual planning and construction of the novel reactor type. On the other, namely as the director of the department of Energy Systems at the International Institute for Applied Systems Analysis (IIASA), Häfele advised SA-based projections of energy consumption. These computerized scenarios provided the rationale for the conception of Fast Breeder programs as viable and necessary 'alternative energy sources' in the first place. By focusing on the role of the involved CS techniques, the paper thus investigates the intertwined systems thinking of nuclear facilities's planning and construction and the design of large-scale energy consumption and production scenarios in the 1970s and 1980s, as well as their conceptual afterlives in our contemporary era of computer simulation.

Keywords
Computer Simulation, Systems Analysis, Scenario Building, Trial and Error, Fast Breeder Reactor, Epistemology, Atomic Age, Media History

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Wolf in Wonderland

Located in a sparsely populated region not far from the border to the neighboring Netherlands, the small German town of Kalkar could well have remained in a state of comfortable oblivion. As the city's website tells its visitors, Kalkar preserved a touch of medieval charm from its founding years in the 1230s and had his heydays in the 15th century – followed by a rapid decline in the 16th century. However, after having fallen into a 500-years-long Rip van Wrinkle sleep, Kalkar was woken up by a belated and unexpected *wirtschaftswunder* at the beginning of the 1970s. Typical for sparsely populated and structurally backward regions, it became the object of quite dubious governmental and business games. Sometimes, such regional development initiatives result in the establishment of provincial airports or amusement parks, sometimes in industrial parks or – at least in 1970s Western Germany – even in the set-up of nuclear power plants. And in some especially illustrious cases two of these possible advancements overlap. Kalkar just happens to be such a case, effected by the construction and history of Germany's first large-scale Liquid Metal Fast Breeder Reactor (LMFBR) *SNR-300*. The project, being promoted as a kind of *perpetuum mobile* of the Atomic Age, and thus funded with about 7 Billion Deutsche Mark (DM), initially was the reason for Kalkar's delayed economic miracle. But from the start it became clear that SNR-300 – the number indicated the intended power output of 300 Megawatts – was challenged by tremendous technical predicaments. And from the mid-1970s onwards, it also faced fierce resistance as the German public grew more and more critical and sensitive on nuclear technology. Completed in 1985, the Fast Breeder was set in 'partial operation'. The cooling systems run for years, but the plant never received nuclear material and hence did not produce energy. Finally, on March 21, 1991, former Bundesforschungsminister Heinz Riesenhuber announced the termination of the LMFBR. And as an effect, the remains of this epitome of FRG's nuclear technology were bargained to a Dutch scrap merchant and investor for the alleged amount of 2,5 Million DM. Since then, the site drags out its afterlive as an amusement park called *Wunderland Kalkar*, with its brute, up to 93 meters tall concrete architecture and its mascot 'Kernie' as eerie remembrances of its past.

The paper examines the SNR-300 project from a historical and epistemological media studies perspective. It is conceptually situated in a specific context of New German Media Theory[1] which explores the epistemic impact of (novel) media technologies in different scientific fields. In this line of thoughts the case study thus concretely investigates the implementation of a novel epistemology in

[1] See *Grey Room 29: New German Media Theory*, ed. Eva Horn (Cambridge: MIT Press 2007)

nuclear sciences. In the face of the involved highly dangerous nuclear processes, uncertainties and scaling effects in civil nuclear energy projects, traditional experimental and engineering approaches became utterly inadequate. The LMFBR programs called for media technologies which would provide a space for 'virtual experimentation' – and this call was met by computer simulations. The hypothesis of this article is that the German LMFBR program is informative for a conception of an afterlife of systems in a twofold way: First, the SNR-300's techno-history can be perceived as an outstanding example for an era in which some apostles of civil nuclear energy production portrayed nuclear technology as the avantgarde of scientific research. Western Germany's physicist and 'father of the Fast Breeder', Wolf Häfele, celebrated the leading-edge status of nuclear technology precisely because it had to deal with inevitable uncertainties: For Häfele, the Atomic Age was characterized by a thorough "hypotheticality": "The process of iteration between theory and experiment which leads to truth in its traditional sense is no longer possible. Such truth can no longer be fully experienced. This means that arguments in the hypothetical domain necessarily and ultimately remain inconclusive".[2] When traditional methods of experimenting and modelling became inappropriate, and when a conventional, experimental trial-and-error-based knowledge production was entirely prohibitive because of the involved nuclear endangerments, Häfele demanded an epistemology which was able to describe the modes of the 'hypothetical domain.' Due to the fact that the 'test mode' of a facility like a Fast Breeder was always at the same time the 'case of emergency', the construction, risk management, and control of LMFBRs required the development and employment of CS. These opened up extended knowledge spaces as virtual experimenting and testing grounds and provided a synthetic perspective on multiple non-linear dynamics in the planning and engineering of such highly complex systems.

Second, the application of computer simulations in the technical planning and operational set-up of power plants strongly relates to yet another computer simulation paradigm. In 1973, Wolf Häfele also became director of the department of Energy Systems at the newly founded *International Institute for Applied Systems Analysis* (IIASA) in Laxenburg, located closely to the Austrian capital of Vienna. Building upon social simulations in the tradition of *systems analysis* – the most prominent at that time had been Jay W. Forrester's modellings for David Meadows's epochal publication *The Limits to Growth* – Häfele's working group developed possible (world-wide) energy production scenarios. Thereby, it depicted the indispensable role of nuclear technology for an endurable planetary future. While contemporary critics described these as obnoxious 'plutonium

[2] Wolf Häfele, "Hypotheticality and the New Challenges," in *Facing up to Nuclear Power*, ed. John Francis and Paul Albrecht (Edinburgh: St Andrews Press, 1976), 55.

worlds' (Robert Jungk) which would ruin the future of all mankind and called for a complete change of direction in the assessment of nuclear energy, these CS scenarios nevertheless provided the rationale for the extended engagement in 'avant-garde technologies' like Fast Breeders.

The article thus investigates the intertwined system thinking of two CS paradigms: On the one hand, nuclear facilities' planning and construction, and on the other the design of large-scale energy consumption and production scenarios in the 1970s and 1980s. This perspective not only enables a critical evaluation of the afterlife of such systems in actual 'sustainable' energy production models and simulations. It also argues that in a time of hypothetical thinking and research strategies, the technocratic vanguards of the Atomic Age simply forgot to include one paramount factor into their simulation scenarios which – at least in Western Germany – finally brought their systems thinking to the fall: That is, the incorporation of social and political acceptance.

The German Manhattan Project

Wolf Häfele was involved in the development of the SNR-300's technology in leading positions since the beginning of the 1960s. As a speaker of the early German Fast Breeder research projects KNK-I and II (Compact Natrium-Cooled Nuclear Facility Karlsruhe), he realized that the successful implementation of Big Science depended on professional marketing and political lobbying strategies. It was not a coincidence that he referred to the US-American *Manhattan Project* when promoting the German Fast Breeder program. In order to organize a giant leap forward on contemporary high-tech terrain, Häfele announced an era of "project science" in the FRG. His "German Manhattan Project"[3] was designed to catch up with other industrialized countries after years of restrictions regarding nuclear technologies which followed World War II – or to even outperform these countries. As the heart of a 'sustainable' nuclear energy production system, the development of LMFBRs thus can be seen as a birthplace of big science in Germany. According to a critical review in the news magazine *Der Spiegel* in 1981, Häfeles project thereby turned former research logics upside down: It would first define the desirable results, and then start to initialize the means and the research initiatives to achieve these outcomes. At the same time, the advocates of nuclear science asserted that the program would put the country in a global leadership role for the mastering of future energy needs of industrialized societies in the face of diminishing natural resources.

[3] See Werner Mayer-Larsen: "Der Koloss von Kalkar" In: *Der Spiegel* 43 (1981), 42-55.

But Häfele not only emphasized the need for thinking big (science). He also underlined the epistemological "pathfinder role" of nuclear technologies for scientific thinking as such. For the 'Breeder-Professor', the relevant questions for science consisted of describing complex relations and contingent events and – incorporated as the research in nuclear technologies – had to leave behind classical epistemic strategies:

> The traditional engineering approach to eliminating risks […] which are integral to contingency – is trial and error. The engineer learns by experience to make better and safer machines. This is close to the scientific approach: a hypothesis is made which is followed by experiments, which in turn lead to an improved hypothesis, which again is followed by experiments. In this way a theory evolves which is true, i.e. is in touch with reality […]. It is precisely this interplay between theory and experiment, or trial and error, which is no longer possible for new technologies which are designed to master unique challenges.[4]

The SNR-300 project exemplarily illustrates the epistemological layout of this novel practice of scientific inquiry: As soon as nuclear technologies transform from notes on paper to actually constructed plants and technologies, they are characterized by an irreducible contingency.[5] Since nuclear reactions are not to any amount scalable down to laboratory experiments because of the involved critical masses of nuclear fuels, realistic test runs oftentimes can only be initiated in the already completed facility. The test case thus moves from a preparatory side to the actual and 'serious' operation of a facility.[6] As an effect, nuclear technology becomes a research area of "interactive complexity" and "tight coupling", as Charles Perrow notes in his classic *Normal Accidents. Living with High Risk Technologies*.[7] And this happens long before the field of Complexity Science starts to emerge in the 1980s. First and foremost, a highly complex facility like a LMFBR demands research and engineering strategies which cannot longer be

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[4] Häfele, "Hypotheticality," 53-54. The IIASA associate Philipp Pahner advances Thomas Kuhn's notion of a *paradigm shift* in order to describe the scientific culture of the Atomic Age. See Philipp D. Pahner, "Risk Assessment in the Nuclear Age," *IIASA Working Paper* WP-75-58: 1975: 3-4.

[5] Häfele, "Hypotheticality," 53.

[6] Olson McKinley e.g. describes unsuccessful test series with a 25-cm reactor model, see Olson McKinley, *Unacceptable Risk: The Nuclear Power Controversy* (New York: Bantam Books, 1976).

[7] Klaus Traube, "Vorwort," in *Normale Katastrophen. Die unvermeidbaren Risiken der Großtechnik,* ed. Charles Perrow (Frankfurt am Main/New York: Campus Verlag, 1987), xi.

elicited in the framework of traditional strategies of theorizing and experimentation – be it with regard to the regulation of physical chain reactions or the constructional realizations. Second, these technologies raise immense difficulties in estimating possible effects on the building materials and the environment. These become subject to projective risk assessments. And third, LMFBR technology only gains its status as a 'logical', desirable and economically feasible alternative energy source in the course and context of broader, also projective global energy consumption scenarios which are based on a specific set of underlying (and questionable) assumptions.[8]

No wonder that the systematic nescience which surrounds these potentially extremely dangerous technologies evoked severe criticism, with Häfele serving as a primary target. The Austrian author Robert Jungk picked him apart in a chapter of his anti-nuclear energy pamphlet *The Nuclear State*,[9] entitled "The Players". The section refers to those nuclear physicists who, at that time, proclaimed a lucent and clean new industrial age fuelled by the development of an immense future system of nuclear facilities.[10] Häfele served as their figurehead, not only as the doubt-relieved advocate of the German nuclear energy program, but also as a deputy director and head of the Energy Systems department at IIASA. This unique think tank was run as a joint-venture of initially twelve participating nations, including the USA and the USSR. Across the frontier of the Iron Curtain, IIASA's research groups developed global scenarios in the areas of population dynamics, environmental issues, nutrition, and energy markets.

In both fields, Häfele eagerly inseminated the novel epistemology which would hold for an operational handling of complexity, uncertainty and nescience – or, to use his neologism: for the domain of *hypotheticality*:

> Hypotheticality, of course, is not a word in the regular usage but its logic expresses precisely what must be expressed in the line of reasoning presented here. Its logic is the same as that of the word 'criticality', for example, a term which is familiar to reactor engineers. […A] reactor can become critical or a situation can be considered as hypothetical. The process of iteration between theory and experiment which leads to truth in its traditional sense is no longer possible. Such truth can no longer be fully experienced.

[8] See Wolf Häfele, ed., *Energy in a Finite World. A Global Systems Analysis* (Cambridge: Ballinger Publishing Company, 1981).

[9] Robert Jungk, Der Atomstaat. Vom Fortschritt in die Unmenschlichkeit (München: Rowohlt, 1977), 41-69.

[10] Jungk, Der Atomstaat, 41-69.

> This means that arguments in the hypothetical domain necessarily and ultimately remain inconclusive.[11]

However, in order to generate an operational account for this "hypothetical domain", he called for novel media-technological procedures and modes of "abstraction".[12] These would help to execute the dynamical and processural effects in question, and would exceed the heuristics of theorizing and experimentation. Only techniques like scenario building, systems analysis (as prominently featured on all levels at the IIASA), and advanced computer simulations were capable to operationalize the problem contexts, possible security precautions, or estimates of future developments of the nuclear technologies in question. Without (analogue) techniques like scenario building and (digital) media technologies like computer simulations, the domain of hypotheticality would remain inaccessible for calculations of realistic threats and possible events. Häfele no longer connected 'knowledge' to 'truth'; in the domain of hypotheticality, 'knowledge' became a function of 'sufficiently accurate' calculations, statistical evaluations, and simulation results. In this context, CS provided an intermediate area, a differential space by generating 'virtual', dynamical test case scenarios which would prevent (catastrophic) eventualities in the 'real world'. As an effect, CS were devised to contribute to the elimination of the potentiality of such catastrophes to happen. In other words, and quite paradoxically, these media technologies were designed to hamper the realization of catastrophic outcomes of nuclear energy facilities *by realising* such occurrences in rather 'playful' ways inside their 'virtual' media environments.

Messy Systems

"[F]uture engineers may attempt the design of robots not only with a behavior, but also with a structure similar to that of a mammal. The ultimate model of a cat is of course another cat, whether it be born of still another cat or synthesized in a laboratory."[13] With this example, Norbert Wiener referred to the transforming apprehension and status of computer simulations after 1945. After World War II, computer technology provided the synthetic environment in which CS unfolded as "the process of representing a dynamic behavior of one system by the behavior of another system"[14] and gained their significance in current scientific cultures. Or,

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[11] Häfele, "Hypotheticality," 55.
[12] Häfele, "Hypotheticality," 63.
[13] Norbert Wiener, Arturo Rosenblueth and Julian Bigelow, "Behavior, Purpose and Teleology," *Philosophy of Science* 10 (1943): 18–24: 21.
[14] Michel Serres and Nayla Farouki, ed., *Thesaurus der Exakten Wissenschaften* (Frankfurt am Main: Zweitausendeins, 2004), 252.

to put it another way: A paradigm which Michael Gibbons once termed "Mode-1"-sciences – alluding to disciplines which were based on the experimental and mathematical mechanics of Newton – transformed into "Mode-2"-sciences whose non-linear problems had to be conceived of as a "behavioral science of systems".[15] Admittedly, Fast Breeders are not quite a sub-category of the abovementioned 'cats.' But as complex objects of inquiry they show a high degree of "interactive complexity" and "tight coupling". Charles Perrow described these instances as a sudden, unforeseeable concurrence of distant and independent system characteristics. In one of his diverse examples from nuclear reactor incidents, a simple faucet inside a reactor's containment structure which had not properly been closed by a cleaning brigade initiates a complex and non-linear succession of unlikely events of backflows and pressure modulations which finally resulted in a release of radioactive material into the structure. These interactions in the piping system, writes Perrow, were unforeseeable for the cleaning staff, as well as for the operators in the control room and the designers of the system. Only in an ex-post and step-by-step manner, the sequence of such hazardous incidents could be reconstructed.[16] And possible reciprocal effects of the manifold system elements can only be evaluated up to a certain degree:

> The more complex the system and the interactions between its components, the more likely is the occurrence of unexpected disturbances, the more ambivalent and thus misreadable are the signals which indicate the state of the disturbed system, and the more destabilizing instead of stabilizing can the reactions of operators or of automatic control systems become. The closer the individual components of the system (in terms of time, space, function) are coupled, the greater becomes the probability that local disturbances affect further elements of the system […].[17]

In the course of the development process of SNR-300 and his predecessors KNK-I and II, the interdependencies e.g. of nuclear fuels, cooling systems and building materials which cannot be sufficiently calculated by applying the classical theorems of theoretical physics, have been extensively discussed. In a 1977s expert roundtable on the SNR-300 project at the German Ministry for Research and En-

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[15] See Michael Gibbons, "The Emergence of a New Mode of Knowledge Production," in *Social Studies of Science in an International Perspective. Proceedings of a Workshop*, ed. Ulrike Felt and Helga Nowotny (Wien: Institut für Wissenschaftstheorie und Wissenschaftsforschung, 1994), 55-66. See Bernd Mahr, "Modellieren. Beobachtungen und Gedanken zur Geschichte des Modellbegriffs," in *Bild Schrift Zahl*, ed. Horst Bredekamp and Sybille Krämer (München: Wilhelm Fink Verlag, 2003), 59-86.

[16] See Perrow, *Normale Katastrophen*, 113.

[17] Traube, "Vorwort," xi.

ergy, Häfele states that "physicians […] generally underestimate how difficult it is from an engineering perspective to get even only one single reactor type going. [...] The physics is quickly done, but the engineering and the commercial implications are only to be accomplished with great expenditures of time and money."[18] However, the eerie thing is that these experiments – similar to the case of atomic bombs – have lasting effects on the real world since they are not contained within a laboratory setting. Furthermore, before their actual completion as a running reactor, the myriads of their components cannot be tested as a whole system.[19] This contradicts not only traditional engineering approaches such as the trial-and-error-based learning from past experience and the resulting step-by-step-improvement of a technical solution. It also unsettles the interplay of scientific hypotheses and experimental proofs. According to Häfele, contingency intervenes as the basic obstacle: "We can always improve our knowledge about contingent elements, but we can never make it complete. This restates the proposition that the residual risk can be made smaller than any given small number but it can never be reduced to zero."[20]

Nevertheless, the advocates of a bright nuclear energy future aimed at exploring the phenomena of interactive coupling as detailed as possible – with the help of the aforementioned 'behavioral science of systems'. Their narrative proposed the degrading of the system-immanent residual risks of a nuclear power plant to an insignificant level.[21] In the case of SNR-300, this predicament resulted in two distinct procedures: First, the enforcement of extensive physical large-scale component tests. These involved large numbers of interacting sub-systems and helped to reduce the amount of unforeseeable events and variables in the interactive coupling processes. The second procedure consisted of the application of systems analysis and computer simulation. These technologies enabled the engineers to build up an 'archive' of various computational scenarios of (hazardous) incidents and systems disturbances. In the case of a real accident, it would have been feasible to refer to one or more similar scenarios from the database, in order to initiate appropriate anticipatory actions to the developing effects of the accident. Such novel computer-generated scenario techniques outperformed the traditional pen-and-paper techniques known e.g. from cold war strategy planning in think

[18] Hans Matthöfer, "Schnelle Brüter, pro und contra." (Protocol of a Hearing at the Federal Ministry for Research and Technology, Villingen-Schwenningen, Germany, May 19, 1977), 58. [Transl. SV].
[19] Jungk, *Der Atomstaat,* 48f.
[20] Jungk, Der Atomstaat, 53.
[21] See Lars Koch and Christer Petersen, "Störfall – Fluchtlinien einer Wissensfigur," *Störfälle. Zeitschrift für Kulturwissenschaften* Nr. 2 (2011), ed. Joseph Vogl, 7.

tanks like RAND.[22] Supported by computer technology, it became possible to calculate a multiplicity of cases. Following diagrammatical decision-tree structures, the researchers fathomed the eventualities and conditions of different courses of events in a narrative way. Henceforth, computer-assisted scenario building on the one hand fostered the comprehension of plurality, of decisive moments, of causality and non-linearity, and on the other promised to stagger the researchers with generating complexity even from restricted set of rules and involved factors. As an outcome, computational scenarios not only separated the heuristic coupling of trial and error, since the computer experimental trials only generated 'modelled errors', discharged possible hazardous effects, and thus conveyed trial and error-processes into the area of nuclear technology. Computational scenario building also coupled different trial-and-error elements – or IF/THEN-decisions – in decision trees.[23] Their diversified paths and results then became subject to evaluation processes according to a relational decision matrix. This made the definition of 'realistic', 'preferred' etc. cases possible. And more often than not, the 'extremata', the less probable and most deficient scenarios proved to hold the best heuristic value – a value which could be yielded without jeopardizing the environment by experimenting with hazardous nuclear technology.

Happenings

Apart from such computational scenario techniques, the Western German LMFBR project made use of large-scale component tests in order to merge detailed physical test series of interacting sub-components with comprehensive theoretical considerations about their interactive couplings. These then were projected onto the functioning of the completed future power plant. Or, as Häfele put it:

> For instance, the integrity of a pressure vessel is investigated as a sub-problem, and so is the operability of control rods and pumps. [...] In combining such components, more contingent elements come into the picture. The aim is to minimize the impact of incomplete knowledge of contingent elements. Therefore [...] the largest possible units are sought.[24]

[22] See Thomas Brandstetter, Claus Pias and Sebastian Vehlken, "Think-Tank-Denken: Zur Epistemologie der Beratung," in *Think Tanks. Die Beratung der Gesellschaft* (Berlin, Zurich: Diaphanes, 2010), 17-58.

[23] See Wolf Häfele and Wolfgang Sassin, "Applications for Nuclear Power other than for Electricity Generation," *IIASA Working Paper RR-75-40* (1975), 33.

[24] Häfele, "Hypotheticality," 54

The tests were conducted in purpose-built experimental plants in Bensberg (FRG) and Hengelo (NL), where, for instance, steam turbines, cooling aggregates, detector systems against leakages, control panels, or the fluid dynamics of the cooling- and mediation circles were tested on a 1:1-scale.[25] Although, for financial and time-saving reasons, not all sub-systems of the SNR-300 would be tested in these experimental plants. Via cooperations with other international nuclear energy projects, SNR-300 profited from some of their findings, experiences and data. However, this implied questions about the transferability and adequacy of such data, since all these large-scale tests had been irrevocably limited to generate knowledge of only a restricted number of interactive couplings. Particularly, sensitive issues and hazardous scenarios remained in the area of theoretical reasoning and mathematical formalization – for example the diffusion of radioactive material into the atmosphere or the durability of shelter structures and containment measures. And quite ironically, some of the most reliable data which made its way into the mathematical modelling and assessment of the tests stemmed from past nuclear incidents.[26] Only to a very little extent, these sensitive issues could be approached by laboratory experiments due to their restricted scalability. As an effect, the *true* large-scale component 'test' in civil nuclear technology always implied the completed facility, and experimental reactors like KNK I and II served as indispensable precursors of SNR-300, which in itself was also conducted as only a preliminary stage for the development of a far larger future breeder, SNR-2. At the same time, the *true* large-scale *security* test is nothing else than the actual case of emergency, a case with an inherent, irreducible nescience: Or, as Häfele put it: "[...O]ne arrives at a situation where the truly large-scale test can only result in the statement that a given device functioned at a particular time and place. A general conclusion is impossible. [...O]ne may call such large-scale integral tests 'happenings'".[27] Not unlike a happening in the art world, this means that only those who were present are able to join in the conversation. And those who were not present know that the happening will not be repeatable in exactly the same way. Although, what gives the art aficionado a profit of distinction, only sets the scientist further back in the domain of hypotheticality. As an effect, in particular the branch which was concerned with disturbances in the interplay of various system components – later referred to as 'structural dynamics' – was

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[25] See Willy Marth, *Der Schnelle Brüter SNR 300 im Auf und Ab seiner Geschichte*, (Karlsruhe: Kernforschungszentrum Karlsruhe GmbH, 1992), 54-62. See P. Ludwig and B. Hus, "Some Results of the 50MW Straight Tube Steam Generator Test in the TNO 50MW SCTF at Hengelo," *Summary Report. Study Group Meeting on Steam Generators for LMFBR* Bensberg (1974), 269-281.

[26] See e.g. D. D. Stepnewski et al., *Proceedings of the Fast Reactor Safety Meeting*, ed. ANS Technical Group for Nuclear Reactor Safety, Beverly Hills, CA (1974).

[27] Häfele, "Hypotheticality," 54.

delegated to computer simulation models from the late 1960s onwards.[28] The next two sections will discuss these various systems analysis and computer simulation techniques.

Systems Analysis and World Energy Models

The FRG's research in civil nuclear energy of the 1970s was to a good part devoted to a computer modelling discourse which at the latest gained world-wide attention by Dennis Meadows's *Limits to Growth* (1972) – systems analysis. It developed as a method from the Operational Research (OR) techniques of World War II. As an interdisciplinary approach, OR connected formerly separated military domains in a quantitative and qualitative optimization strategy and consulting format for strategic planning, with anti-submarine warfare as its seminal example.[29] Systems analysis pursued this approach mainly in the context of economic and 'socio-technical' problems after 1945. Coined by Edward W. Paxson at RAND Corporation, the term baptized a whole think tank with the foundation of IIASA in 1973. Leen Hordijk, a former director of IIASA, characterized the think tank's systems analysis philosophy retrospectively according to the following scheme – with computer simulation playing an outstanding role on all its stages:

> First, we marshal all the information and scientific knowledge available on the problem in question; if necessary, we gather new evidence and develop new knowledge. Second, we determine what the goals of the stakeholders are, both of the people and the institutions. Third, we explore different alternative ways of achieving those goals, and we design or invent new options, where appropriate. Fourth, we reconsider the problem in light of the knowledge accumulated. Fifth, we estimate the impacts of the various possible courses of action, taking into account the uncertain future and the organizational structures that are required to implement our proposals. Sixth, we compare the alternatives by making a detailed assessment of possible impacts and consequences. Seventh, we present the results of the study in a framework that facilitates choice by the stakeholders. Eighth, we provide follow-up assistance. Ninth, we evaluate the results. Please note that computer modeling

[28] See Stepnewski et al., Proceedings of the Fast Reactor Safety Meeting, ix. See Wolf Häfele, Ferdinand Heller and Wolfgang Schikarski, The Principle of Double Containment and the Behavior of Aerosols in its Relation to the Safety of Reactors with a high Plutonium Inventory (Karlsruhe: Gesellschaft für Kernforschung M.B.H., 1967).

[29] See Claus Pias, *Computer Spiel Welten* (Zürich/Berlin: Diaphanes, 2002), 231-234, 244-249.

> is a useful device in helping obtain answers at any of the above stages.[30]

Scenaric *projections* – not *prognoses*, a distinction that already the authors of the *Report to the Club of Rome* underlined emphatically –, based on numerical computer simulations, become operative on two distinct levels: One the one hand, systems analysis was used to integrate Fast Breeder technology in world-wide energy production and consumption scenarios – with the department of Energy Systems at IIASA as an instructive example. On the other, it served as a technique for the concrete planning and assessment of the nuclear facility in Kalkar. Whilst Daniel Meadows's *Limits to Growth* – together with its underlying model of Jay W. Forrester's *World Dynamics* and its focus on "Resources", "Population", "Pollution", "Capital", und "Agriculture"[31] – only indirectly addressed the matter of energy supply, the scientists in Häfele's IIASA department explicitly centred around the latter.

In an attempt to anticipate the broad criticism that Meadows's demanding and far-reaching report was facing – for instance, its scenarios were perceived as mere toplofty computer games – the Energy Systems group was eager to emphasize that their scenarios only approached more concrete short- and mid-term projections, covering 15 to 30 years.[32] The individual studies of the group have been compiled to a sort of technical report, published under the title *Energy in a Finite World. A Global Systems Analysis* at the beginning of the 1980s.[33] The report was based upon a system of five simulation models which not only served as a 'projector' of two possible – and antagonistic – future 'energy worlds'. The models also synthesized a multiperspective analysis of attainable alternative energy sources and of technological developments with rather intuitive presumptions, for instance regarding the delivery rate of fossil fuels. Or, as the author of a commentary on the study put it: "The study makes use of scenario writing as a principal tool to investigate energy futures. These scenarios are not predictions, as the future is unpredictable; however, conducting studies such as these is necessary for responsibly dealing today with implications for tomorrow."[34] More concretely, the models can be differentiated along the following layout:

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[30] Leen Hordijk, "What is Systems Analysis?," in *Options Magazine* Winter 2007, accessed August 22, 2013, http://www.iiasa.ac.at/web/home/about/whatisiiasa/whatissystemsanalysis/what_is_systems_analysis.html.

[31] Donella H. Meadows et al., *The Limits to Growth* (New York: Universe, 1972), 89.

[32] See Paul S. Basile, "The IIASA Set of Energy Models: Its Design and Application," *IIASA Working Paper RR-80-31* (1980), 11.

[33] See Häfele, Energy in a Finite World.

[34] Basile, "IIASA Set of Energy Models", 2.

> The model set, long in development and following the initiative and guidance of Professor Wolf Häfele, includes several models: an accounting framework type energy demand model, a dynamic linear programming energy supply and conversion system model, an input-output model for calculating the impacts of alternative energy scenarios, a macroeconomic model, and an oil trade gaming model. The models have been designed into an integrated set for long-term, global analyses.[35]

This modelling strategy is significant for the research group precisely because it encompasses the possibility to generate a high level of interactive couplings, accounting for a far larger number of system parameters. One could state that the predicaments of data-driven science become prevalent decades before the contemporary discussions around big data technologies.[36] Already in the modelling process, it was crucial to assign to the output parameters an interpretable and not misleading amount of data in order to create novel *insights*. Further, this set of models produced instructive and reproducible *results*, because its basic logics were transparent and comprehensible. Such results, say the authors, could not replace but enhance careful reasoning. Moreover, computer simulations provided a *consistent environment* for the numerical calculation and classification of multiple, different scenarios. And last but not least, computer simulations enabled a self-critical and self-reflective *evaluation* of the results and the models by trial-and-error, as their formal structure could be 'validated' internally against comparative possible future scenarios, or externally against competing alternative simulation models.[37]

In these times of the *Limits to Growth* report, when the limitation of natural resources was perceived as the most pressing crisis for industrialized societies, the consideration of nuclear energy as a possible *solution* to societal needs instead of a *threat* to these societies becomes more reasonable. Thus, it is not a coincidence that Fast Breeders played a significant role in the nonchalantly devised future energy supply scenarios at IIASA: Calculating with an at least linear increase in world-wide energy demands, according to one scenario, a system of 3000 LMFBRs and High Temperature Reactors (with an output of 3300 MW per unit), combined with 650 temporary and 47 terminal nuclear waste repositories and various facilities for the production of chemicals and fuels (like hydrogen), would

[35] Basile, "IIASA Set of Energy Models", 2.

[36] See Joachim Müller-Jung, "Wird 'Big Data' zur Chiffre für den digitalen GAU?," *Frankfurter Allgemeine Zeitung*, March 04, 2013, accessed May 02, 2014, http://www.faz.net/aktuell/wissen/mensch-gene/bioforschung-an-grenzen-wird-big-data-zur-chiffre-fuer-den-digitalen-gau-12103088.html.

[37] See Basile, "IIASA Set of Energy Models," 4.

easily provide the world of 2030 with energy and useful by-products, manufactured by using the process heat of the plants. This, state the authors, would be realizable by an almost closed nuclear fuel cycle, demanding only 8500 tons of uranium or thorium. In comparison, a coal-based energy production would amount to a requirement of 18,3 billion tons.[38] And also solar energy is comparatively considered: However, if designed to meet the projected future energy needs, the area to be covered by solar panels would amount to "about 20 times the area of Germany"[39] – hardly a viable and environmentally sustainable way, the IIASA report asserts.

If one realizes how such encompassing CS made possible a quantified comparison of apples and oranges in the same computational framework, it becomes more understandable how someone would have developed the idea of constructing a 'messy' technology as a Fast Breeder in the first place: The dangers of any possible energy source are situated on the very same level and in a common matrix. As a part of a system of computer simulations, they become objects of the same media-technological condition of trial-and-error procedures which facilitate an 'adequate' and comparative assessment of their respective 'dangerous' potentials. It is only this combined quantification of data and its transformation into qualitative computational scenarios which let projects like the SNR-300 appear as reasonable options.

Alas, what on first sight would sound like a complete success story of a bright nuclear future becomes critical at the latest when more complex systems and more uncertainties of the real world break into the modelling logics of the involved systems analysis techniques. Take as an example that IIASA and the IAEA would only in hindsight realize certain apparent flaws in their reasoning: "Yet, together with the [...] IAEA an effort was made to understand the discrepancy between the 'objective' risks of nuclear power and its perception by the public."[40] Since the scenarios of the Energy Systems group and thus the projected outcomes and implications always rested upon speculative registers and were played out in the field of hypotheticality, they themselves became objects of competing (and far less optimistic) counter-scenarios. These counter-scenarios thematise for instance the fact that Fast Breeders produce not only nuclear fuels for other conventional reactor types, but also large amounts of weapons-grade plutonium – and besides, also of highly radiant plutonium waste. Not only for fervid critics of the breeder technology like Robert Jungk, this perverted the proclaimed image of a clean and peaceful Atomic Age into an uncontrollable 'plutonium-

[38] See Wolf Häfele, "The Comparison of Energy Options – A Methodological Study," *IIASA Status Report SR-80-2* (1980), 94.
[39] Häfele, "Hypotheticality," 57.
[40] Häfele, "The Comparison of Energy Options," 96.

based economy' and utterly doomed 'plutonium world'.[41] As a matter of fact, and due to the concentration of critical amounts of plutonium in its cores, fast breeders – unlike traditional reactors – not only run the risk of a nuclear meltdown, but also of a nuclear explosion. And even their location in sparsely populated and structurally backward regions would hardly account for this circumstance. Some ten years after the publication of the IIASA studies, discrepancies like these and an ever more accelerating anti-nuclear protest culture would not only bring computer-modelled plutonium worlds of a future FRG to the fall, but also its landmark and first concrete step into such a future: SNR-300.

Designing Hypothetical Nuclear Power Plants

Albeit, before its final decline in 1991, SNR-300 first had to surge – at least up to a certain point. And this concrete technical advancement had partly been based on systems analysis and computer simulations. The involved software applications more often than not were labelled with quite adventurous acronyms – until today, the invention of hilarious wordplays seems to remain an inextinguishable hobby of computer scientists, worth a separate paper. Already developed in the course of the KNK preliminary breeder projects, the software *MUNDO* (for MaximaleUNfallDOsis, translating to 'maximum accidental dose') simulated the diffusion of radioactive particles in the atmosphere after a hazardous incident. Its application, for instance, proved the essential benefit of double containment structures for reactor cores. These enabled filter- and disintegration processes of leaked radioactive material inside a second insulation structure. MUNDO calculated such internal processes along with the possible reduction of danger for atmospheric contamination outside of the facility. It leads to an active protection procedure which was highly relevant for plutonium-fuelled breeders, and which played a decisive role in the administrative approval in the early stage of the SNR-300 project. Complementary, and under the impact of the partial meltdown of the *Fermi-I* experimental breeder in Newport, MI, not far from Detroit, a team in the US developed the encompassing security software – nomen est omen – *MELT-III*. It nu-

[41] See Roland Kollert and Inge Schmitz-Feuerhake, "Die Plutoniumopfer eines ausgebauten Brütersystems. Versuch einer Abschätzung," in *Die Gefahren der Plutoniumwirtschaft*, ed. Günter Altner and Inge Schmitz-Feuerhake (Frankfurt am Main: Fischer, 1979), 43. H. Bonka et al., "Zukünftige radioaktive Umweltbelastung in der Bundesrepublik Deutschland durch Radionukleide aus kerntechnischen Anlagen im Normalbetrieb," *Berichte der Kernforschungsanlage Jülich* Nr. 1220 (1975).

merically modelled a variety of possible thermal and hydraulic reactions in the course of a nuclear meltdown.[42]

Other software tools simulated diverse operations in the abovementioned field of structural dynamics. These encompassed, among others, steam explosions, interaction between natrium cooling cycles and reactor fuels, the deformation of fuel rods by pressure variation in the cooling agents, heat exchangers,[43] the shielding capacity of different materials, the calculation of neutron collisions, or models of turbines.[44] Add to that the digital "scale model tests" of complete breeder facilities.[45] All these applications had one thing in common: They modelled processes whose exploration under a traditional paradigm of experimentation would have been too dangerous or plainly impossible. Although, this did not at all imply that the models would converge to *one* feasible and realistic procedure in the course of their iterated trial-and-error runs. Rather, they generated a comparability of multiple hypothetical cases and served as an advisory, as tools for thought for the apprehension of promising actions and constructional implementations.

But even in this regard, the computer programs were subject to multiple limitations. First and foremost, the development of the program codes was dependent on the "availability of effective calculating machines".[46] During the SNR-300 project, for instance, the "flow distribution of neutrons in the beginning could only be resolved in a one-dimensional diffusion approximation". Not before the acquisition of faster computer hardware, "one turned [...] to a two- and three-dimensional treatment."[47] Second, the latencies of software systems oftentimes

[42] See Ferdinand Heller, Wolfgang Schikarski and A. Wickenhäuser, "MUNDO – Digital Programm zur Berechnung von Unfalldosen in der Umgebung einer Reaktoranlage," *KFK*-653 (1967). See Wolf Häfele, Ferdinand Heller and Wolfgang Schikarski, "The Principle of Double Containment and the Behaviour of Aerosols in the Relation to the Safety of Reactors with a High Plutonium Inventory," *KFK*-669 (1967). See Johan F. van de Vate, "The Safety of the SNR-300 and the Aerosol Model; A Summary Report of the RCN Aerosol Research 1967-1971" *Working Paper RCN-174* (1972). See Alan E. Waltar et al., "Melt-III. A Neutronics, Thermal-Hydraulics Computer Program for Fast Reactor Safety Analysis, Volume I," *Hanford Engineering Development Laboratory Working Paper HEDL-TME 74-47 UC-79p, e, d, b*, (1974).

[43] See Stepnewski, Proceedings of the Fast Reactor Safety Meeting, 679-784.

[44] See Robert Avery, "Reactor Computation Methods and Theory," in *Applied Physics Division Annual Report* 1971, 367-456.

[45] See Stepnewski, *Proceedings of the Fast Reactor Safety Meeting*, 679-700. David Saphier, "A Dynamic Simulator for Nuclear Power Plants (DSNP)," *Argonne National Laboratory Memorandum ANL-CT-76-23* (1976).

[46] See Marth, *Der Schnelle Brüter SNR*, 53. (Transl. SV)

[47] See Marth, *Der Schnelle Brüter SNR*, 53. (Transl. SV)

inhibited the exploitation of already available computing resources. As late as 1973, more than 10 years into the "German Manhattan Project", the flexible and modular software system *KAPROS* replaced an apparently painstaking predecessor. *KAPROS* integrated, among others, the program suites *REX* and *FAUN-Z*, developed by the SNR-300 project group to explore so-called *Bethe-Tait Worst Case Scenarios*,[48] analogous to the US-American *MELT-III* software. The stage before the disintegration of a reactor was simulated by the software *CAPRI-I*, whose calculations relied on data input and model characteristics of sub-programs like the fuel rod simulation module *BREDA* or – and here again the acronym reads thoroughly self-deprecating – the boiling module *BLOW 3*. The simulation of the actual phase of disintegration and stress tests of the containment structures again involved further software applications[49] Hence, and despite such efforts in terms of modularizing the software, different processes continued to be modelled by a variety of specialized, independent CS programs. The respective white papers give little insight regarding their respective integrativity. It remains disputable whether these computer programs had been integrated to a similar extend as those of the IIASA energy studies and if they, as a result, provided a comparable analytic framework.

And finally, the mentioned programming and simulation efforts attached to a fundamental problem: How appropriate would their codes represent the real-world processes in question? In this regard, mathematician Keith Miller of Berkeley University publicly criticized the codes which were used in the US to generate scenarios of nuclear incidents. In Walter Cronkite's CBS news show on May 12, 1976, he stated that these were "totally inadequate to the complexity of the problem [..., and therefore] just as reliable as tomorrow's prediction of the weather, and I wouldn't trust my life on tomorrow's prediction of the weather."[50] To underline his statement, Miller elucidated the work flows of the respective code development processes. Some working groups dealt with "advanced codes" for future software versions. Other teams checked the correspondence of these codes to real-life-phenomena by verification studies. And further groups calculated the actually ongoing construction processes with antecedent – and therefore, already outdated – program versions. The mathematician furthermore added three observations: First, the codes used for calculating the construction processes oftentimes would not correspond with those employed for the evaluation of, for example,

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[48] Hans Bethe and J.H. Tait, "An Estimate of the Order of Magnitude of the Vigorous Interaction Expected Should the Core of a Fast Reactor Collapse," *UKAEA RHM* (56)/113 (1956).

[49] Marth, Der Schnelle Brüter SNR, 55-56.

[50] Philip M. Boffey, "Nuclear Safety: A Federal Adviser's Warnings Provoke Ire of Colleagues," *Science* 192 (1976), 978.

security measures. Second, the margins which defined the possible scope of identifying problematic incidents were set too narrow. And third, Miller demanded the application of a larger number of large-scale simulations. Even in the 'virtual', he stated, due to limited computing capacities, more often than not only sub-components and sub-systems were tested, and the risk potential of the large-scale system thus would only be extrapolated from these tests.[51]

Although, Miller's last argument was itself countered by another categorical remark: According to Richard T. Lahey, one of the leading nuclear experts of the US in the 1970s, the simulation of large-scale systems was "absolutely the worst test to run to get data". For the not even remotely comprehensible multiplicity of involved variables and factor combinations would inhibit the necessary, detailed identification and reconstruction of critical disturbances.[52] Analogue to the IIASA energy studies, the engineering simulations of actual nuclear facility constructions were also facing a tremendous big data-problem.

Making History, Changing Futures

A media history of nuclear technology in the 1970s, with Fast Breeder programs as its epitome, reveals some of the essential elements of an epistemology of computer simulation. As systematic approaches to conquer new fields of knowledge, CS developed into ground-breaking technologies in big science projects – especially in research fields with a high amount of hypotheticality. The complexity and criticality of nuclear technology seemed predestined for their application, be it in a broad framework of socio-economic systems analysis studies, or in the concrete case of a system of – more or less integrated – engineering simulations.

However, and despite the appliance of CS in construction and technological impact assessment, quite large problem areas remained a field for speculation: Fast Breeders came into existence as "happenings', they literally 'took place', be it inside of simulation scenarios or outside in the 'real world'. Such forms of happenings could only be flanked by passive or active security measures built in the physical constructions. But as we have seen, these are often themselves based on questionable codes and scenarios.

All these measures contain a structural residual risk larger than zero. How large exactly this residual risk was allowed to be was the subject of negotiation processes between technological, economical, and political factors and agents. These negotiations ultimately defined what was meant by 'safety', and which criteria would qualify 'safe' as *safe*. For advocates of the atomic age like Wolf

[51] Boffey, "Nuclear Safety," 978.
[52] Boffey, "Nuclear Safety," 979.

Häfele, the benefits of nuclear energy always clearly outnumbered their dangers. All other critical reservations were considered as inappropriate interpretations in the age of hypotheticality. And in the case of doubt, at least Häfele preferred to lead a wild and dangerous life in view of the potentials of the atom.[53]

The afterlife of this systematic appliance of computer simulations in critical environments and its effects on our contemporary situation on the one hand becomes obvious in the discourse of climate change. Not coincidentally, some scientists claimed a necessary world-wide 'renaissance of nuclear energy'.[54] On the other hand, the afterlife functions on a more fundamental level, driven by the temporal logics of these novel media technologies: CS *generate* a variety of possible futures and rationalities, and at the same time *describe* and *operationalize* them. Culminations like *residual risk, worst case scenario, climate catastrophe, peak oil* or the telling Cold War acronym *MAD* (for Mutual Assured Destruction) emerge precisely in those media-historical situations when computer simulations made feasible a *Thinking About the Unthinkable*[55] (Herman Kahn): by distinguishing between multiple projective scenarios, and by providing the conditions to evaluate and choose the most and least desirable futures. Moreover, CS delineate solution strategies for exactly the crises and catastrophes that only could have been formulated under their media-technological condition. CS thus gain their significance to a lesser extend in correspondence to 'real' events, but rather to the *prevention* of such events. Today, as ever more sophisticated CS model the behaviors and futures of complex systems across almost all scientific disciplines, they ever more impose a particular understanding of the world: Due to its future-orientation (and media-technological 'future-adjustability'), this world can only conceive of itself in terms of perpetual crises. Every present time now is faced with the haut gôut of deficiency, because it is permanently confronted with a multiplicity of futures. These are presently 'happening' as media-technological operationalizations, and thus force their technological principles of optimization, efficiency, and stability upon that very present time.

But at least in the 1970s, such a far-reaching age of hypotheticality remained utterly uncontrollable. And the media history of SNR-300 gives an impressive disclosure of this fact: Even the avantgarde of hypothetical scientific research and its media technologies proved incapable for dealing with the socio-economic dynamics of the emerging anti-nuclear movement in the FRG – a

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[53] See Jungk, *Der Atomstaat,* 49.
[54] See e.g. William C Sailor et al., "A Nuclear Solution to Climate Change?," *Science* 19 (2000), 1177-1178. J. Pacala and R. Socolow, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science* 305 (2004), 968-971. John Deutch et al., *The Future of Nuclear Power* (Boston: MIT, 2003), 1-13.
[55] Herman Kahn, Thinking about the Unthinkable (New York: Horizon, 1962).

movement which organized and radicalized itself precisely around megalomaniac nuclear projects like the Fast Breeder. Finally, the epistemology of hypotheticality was ultimately challenged as something actually *happened* in the 'happenings': The incidents of Three Miles Island (USA, 1979), and even more profoundly of Chernobyl (USSR, 1986) messed up all the former scenarios. In the face of these incidents, a normative power of the factual overwrote the variables of the "venturous speculative research styles"[56] of CS. This 'factual reality' generated – at least in the FRG and for the SNR-300 project – novel contingencies with ever more influential socio-political and ecological variables. And these underestimated 'risks' could not be reduced to a viable level by CS – there was no scenario for nuclear phaseout in the database of the "archpriests of the Atomic Age."[57]

After the anti-nuclear movement had opted against nuclear hypotheticalities and had brought the German Manhattan Project to the fall, alternative future scenarios came into being, sometimes even turning away from the doctrines of economic growth and technological progress. IIASA switched to the research of more sustainable energy sources and 'green technologies' in the post-Häfele era, eliminating Fast Breeders from the scenarios already in the mid-1980s. And at the beginning of the 1990s, after never having become equipped with radioactive material, let alone having become critical, the liquid natrium cooling cycles of SNR-300 – which had been desolately run for six years – were switched off, and the Breeder was shut down. From that moment on, the future of SNR-300 took shape as the utmost improbable and extremely hypothetical afterlife as an amusement park. But what remained undisturbed by this decline was the ever increasing relevance of computer simulations as media technologies and cultural techniques[58] which continue to set up or present futures and future present.

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[56] Jungk, Der Atomstaat, 50.

[57] Manfred Kriener, "Im nuklearen Fieberwahn“, *Greenpeace Magazine* 2 (2005), accessed August 22, 2014, http://www.greenpeace-magazin.de/magazin/archiv/2-05/atom-50er-jahre/

[58] See Sebastian Vehlken, "Zootechnologies. 'Swarming' as a Cultural Technique," *Theory, Culture and* Society 30 (2012), (Special issue *Cultural Techniques*, ed. Geoffrey Winthrop-Young, Jussi Parikka and Ilinca Irascu), 10-131.

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John Lilly, The Mind of the Dolphin, and Communication Out of Bounds

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Abstract
In this essay I develop a systems-theoretical observation of John Lilly's cybernetics of communication in his 1967 work *The Mind of the Dolphin*. The eight-year-old project that *The Mind of the Dolphin* recounts for public consumption details his aspiration to achieve an unprecedented breakthrough beyond companionate communion to fully abstract linguistic communication across species boundaries. Between 1959 and 1968 Lilly wagered and lost his mainstream scientific career largely over this audacious, ultimately inconclusive bid to establish and document for scientific validation "communication with a nonhuman mind." In that effort, however, he mobilized the best available tools, a cutting-edge array of cybernetic concepts. He leaned heavily on the information theory bound up with first-order cybernetics and operated with heuristic computational metaphors alongside the actual computers of his era. As I will elicit through some close readings of his texts, in that process Lilly also homed in on crucial epistemological renovations with a constructivist redescription of cognition that may have influenced and motivated his colleague Heinz von Foerster's more renowned formulations, arriving in the early 1970s, of a *second-order* cybernetics.

Keywords
communication, cybernetics, John Lilly, Heinz von Foerster, systems theory

Cover Page Footnote
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Since his death at the age of eighty-six in 2001, one can detect a bit of an upsurge of scholarly interest in John C. Lilly, M.D.[1] Up until the present millennium, Lilly would have been deemed more notorious than renowned, remembered more often for his later exploits as an extreme psychonaut than for the scientific career leading up to those self-documented "autobiographies of inner space." However, that notoriety followed upon a period of national prominence as a behavioral physiologist turned dolphin researcher and well-received author of the popular scientific volumes *Man and Dolphin* (1961) and *The Mind of the Dolphin: A Nonhuman Intelligence* (1967). Then, in a series of professional and personal memoirs spanning the 1970s—including his first research report on psychedelic self-exploration, *Programming and Metaprogramming in the Human Biocomputer* (1969), as well as *The Center of the Cyclone: An Autobiography of Inner Space* (1972), *The Dyadic Cyclone: The Autobiography of a Couple*, co-written with Antonietta Lilly (1976), and *The Scientist: A Novel Autobiography* (1978)—Lilly chronicled his own transition from lion of the international scientific mainstream to psychic pioneer scouting the cosmic reaches of the American counterculture.

The primary theme I will use to map a route through a small selection of Lilly's multifarious writings and personal transformations at the cusp of his mid-life transition is communication. When Lilly left his position as section head at the National Institutes of Mental Health (NIMH) in 1958 to concentrate on dolphin research, he named the private scientific operation he founded, with an office in Miami, Florida, and laboratories on the island of St. Thomas, the Communication Research Institute (CRI). While at the NIMH, Lilly had invented the isolation tank, the flotation chamber and sensory-deprivation device eventually made famous in the movie *Altered States*. In the mid-1950s Lilly embarked on a prolonged course of experimentation, largely upon himself, exploring the psychic states to be discovered floating in the tank. These

[1] See Nicolas Langlitz, "Tripping in Solitude: Introducing Honza Samotar by Way of John Lilly," in Katrin Solhdju, ed., *Introspective Self-Rapports: Shaping Ethical and Aesthetic Concepts 1850–2006* (Preprint 322) (Berlin: Max Planck Institute for the History of Science, 2006), 81-92; and Langlitz, *Neuropsychedelia: The Revival of Hallucinogen Research since the Decade of the Brain* (Berkeley: University of California Press, 2013), 215-17; Jeff Pruchnic, "Neurorhetorics: Cybernetics, Psychotropics, and the Materiality of Persuasion," *Configurations* 16: 2 (Spring 2008), esp. 186-94; D. Graham Burnett, *The Sounding of the Whale: Science and Cetaceans in the Twentieth Century* (Chicago: University of Chicago Press, 2012), 516-670; and John Shiga, "Of Other Networks: Closed-World and Green-World Networks in the Work of John C. Lilly," *Amodern 2: Network Archaeologies*, http://amodern.net/article/of-other-networks/.

researches formed a parallel experimental track during the years of dolphin research at CRI, from 1959 to 1968. His applications of LSD within both research programs began only in the mid-1960s. But their effects, I speculate, were instrumental in the way that his communications research devoted to interspecies exchange with dolphins eventually lapsed as he pursued a post-scientific round of therapeutic, sociopolitical, epistemological, and cosmological messages for his fellow humans. Lilly's scientific purpose of theorizing communication through experiments testing its species boundaries developed into the narration of phenomenal events beyond the bounds of any common human experience. However, in the period of the later 1960s I will focus on, Lilly's theorizations of communication arrived at innovative applications of first-order cybernetics and information theory. I will be particularly concerned to develop a systems-theoretical observation of Lilly's cybernetics of communication in *The Mind of the Dolphin*.

The Mind of the Dolphin

On October 24, 1967, Heinz von Foerster, the director of the Biological Computer Laboratory (BCL) in the Department of Electrical Engineering at the University of Illinois, prepared to send John Lilly a packet of professional correspondence. His cover letter began: "Dear John, I cannot tell you how grateful I am for your sending me your Eighth Annual Report. It gives me new fuel for my perpetual admiration of your work—if this refueling were necessary at all."[2] To tell from von Foerster's letter, it covered his own summary of recent BCL activities and some BCL reprints and lab reports with an explanation that clarifies to some extent the object of his admiration: "For us, your work on inter-species symbolic discourse was most significant in developing the concepts we tried to formulate." Von Foerster's packet also included a $5.00 check in response to a book notice Lilly had sent along for his popular trade volume just released by Doubleday, *The Mind of the Dolphin: A Nonhuman Intelligence*.[3]

The Mind of the Dolphin is no light read. The preface declares that its "main ideas and formulations are a theory to scientifically penetrate into the area of at least one nonhuman mind, that of the bottlenose dolphin" (xi). Left indeterminate by this statement is whether or not—since the very possibility of bringing about the contemplated event in actual practice had not yet been determined—the scientific penetration to be achieved is *only* theoretical. For

[2] Heinz von Foerster to John C. Lilly, typescript dated October 24, 1967, Heinz von Foerster papers, University of Illinois at Urbana-Champaign.

[3] John Cunningham Lilly, M.D., *The Mind of the Dolphin*: *A Nonhuman Intelligence* (Garden City, NY: Doubleday, 1967).

actual as opposed to theoretical penetration into a nonhuman mind would mean a successful instance of establishing interspecies communication through some as yet unknown or undiscovered relation by which that nonhuman mind would reveal its own thoughts to a human interlocutor in a mutually understandable medium. The eight-year-old project that *The Mind of the Dolphin* recounts in 1967 details the uncanny aspiration to achieve an unprecedented breakthrough beyond companionate communion to fully abstract linguistic communication across species boundaries.

Between 1959 and 1968 Lilly wagered and lost his mainstream scientific career largely over this audacious, ultimately inconclusive bid to establish and document for scientific validation "communication with a nonhuman mind" (xi). In that effort, however, he mobilized the best available tools, a cutting-edge array of cybernetic concepts. He leaned heavily on the information theory bound up with first-order cybernetics and operated with heuristic computational metaphors alongside the actual computers of his era. As I will elicit through some close readings of his texts, in that process Lilly also homed in on crucial epistemological renovations with a constructivist redescription of cognition that may have influenced and motivated his colleague von Foerster's more renowned formulations, arriving in the early 1970s at a *second-order* cybernetics.[4] In subsequent decades the discourse of second-order cybernetics —epitomized in the concept of autopoiesis—would provide Niklas Luhmann's social systems theory a conceptual base for its own discourse of communication. I will call upon Luhmann's work at times to compare with Lilly's earlier cybernetic discourse of communication. Embedded in the cetology of *The Mind of the Dolphin*, then, is an exotic anthropology of 1960s cybernetics, centered on an overburdened notion of communication.[5]

Penetration

Much of the weight Lilly rested on his discourse of communication in *The Mind of the Dolphin* came from therapeutic concerns inculcated by his medical and

[4] The classic text here is Heinz von Foerster, "On Constructing a Reality" (1973), in *Understanding Understanding: Essays on Cybernetics and Cognition* (New York: Springer, 2003), 211-27. See also Heinz von Foerster, *The Beginning of Heaven and Earth Has No Name: Seven Days with Second-Order Cybernetics*, eds. Albert Müller and Karl H. Müller, trans. Elinor Rooks and Michael Kasenbacher (New York: Fordham University Press, 2013).

[5] On the modern overdetermination of the concept of communication, see John Durham Peters, *Speaking into the Air: A History of the Idea of Communication* (Chicago: University of Chicago Press, 1999).

psychoanalytic trainings. This background informed his presentation of research into interspecies communication as administering to goals of individual and collective mental health with cures for human pathologies of communication. For instance: "one's own beliefs below his usual levels of awareness prevent complete communication with self and with other persons. Our species has not achieved equality of communication. . . . Communication with other peoples fails; we have international conflicts in most of the world" (xiii). However, the very breadth of Lilly's discourse of communication generated its own problems of equivocation, and ultimately, of conceptual overreach. In the remark just above, "complete communication" would indicate not just serviceable understandings concerning basic social matters of shared concern. Rather, such "completion" ought to issue in an "equality" of agreement or consensus to the point of complete mutual understanding or spiritual communion. As social systems theory would lead one to expect, the overdetermined ideality of communication in Lilly's treatment fomented equivocal oscillations between psychic and social references, amplified by putting "mind" and "communication" into such tight tandem without adequate conceptual means to account for their differentiation.

While ideals such as "equality of communication" underscored the liberal humanism residing in Lilly's overt scientific rationales, they also indicated the difficulties built into his dream of equality for interspecies communication. For a bona fide "penetration" to occur, nothing less than an articulate exchange of interspecies intimacies would really do, and until that moment arrived, on the human end his research team could only keep faith in the hope that their project was possible:

> If and when dolphins and we do establish communication on a highly abstract level, the proof will become obvious and incontestable. In this book I give some of the details of this developing picture and give the reasons why we, the ones who work with them, must rely for some time on our faith in their intelligence. *This faith is in the working hypothesis that both we and they are intelligent enough to break the interspecies communication barrier between these very different minds.* (84; emphasis in the original)

Lilly's supersonic metaphor of the "interspecies communication barrier" offered an inappropriately material or physical image for the immaterial operational closures of the autopoietic systems that would have to be successfully coupled (not "broken" or "penetrated") to yield the expanded social system that would result from an actual episode of interspecies communication. But what this metaphor did capture is the pathos of "penetration" when the object to be opened up is not precisely palpable—is not a brain, but a mind.

Let us pause to recall that Lilly began his scientific career as a neurophysiologist developing penetrative techniques for behavioral research on mammalian brains, culminating in papers of the later 1950s such as “Learning Elicited by Electrical Stimulation of Subcortical Regions in the Unanesthetized Monkey,” and “Learning Motivated by Subcortical Stimulation: The ‘Start’ and ‘Stop’ Patterns of Behavior.” As communication researcher John Shiga explains: “In these experiments, Lilly inserted electrodes into various regions of a monkey’s brain, sent electric current through the electrode, and recorded the animal’s behavior and its neurological activity. The implanted electrodes enabled Lilly to map neural networks and to link sensory events, muscle movements and other behaviors to patterns of activity in those networks.”[6] The goal, then, to “scientifically penetrate into the area of at least one nonhuman mind” marks a transition from neurophysiological materiality to psychological intangibility. This metaphysical trend is uttered through a metaphorical statement, heavily laden with material-physiological connotations, not for the actual piercing of a material sheath or organic membrane but for the effective elaboration of a virtual communication medium by which to couple two different species in “complete” communication at a fully abstract level of meaning construction.

Projection

In Lilly’s efforts to craft not only theories but also experimental protocols for “complete communication” with dolphins, one difficulty was to establish the requisite controls against an observer’s misconstruing a random instance of cetacean phonation as a humanly meaningful abstract utterance. For human beings generally as well, “this problem of projection blocks a large fraction of true communication” (3). Projection short-circuits a proper understanding of what others are thinking or meaning to convey when they make a communicative offer. However, the paradox built into Lilly’s experimental situation can be said to take this form: unless you’ve already succeeded in communicating, you can’t even know the status of your attempts. Or again, without communication having already been established, how is one to ask the dolphin to confirm if one has understood it correctly the first time? Yet it would seem that in relation to interspecies communication, the problem of projection cannot be circumvented, it can only be controlled for by a trial-and-error protocol maintained at the human end until the moment arrives when the dolphin itself begins to assist in the correction process:

> We use the following *working hypotheses* in our communication research with dolphins: The airborne whistles and the airborne

[6] Shiga, “Of Other Networks.”

> clicks are attempts to communicate with us as they do with one another, i.e., attempts to induce us to use their mode of communication. . . . Their humanoid sounds in air are their approximations to our communication sounds as distorted by their hearing and by their phonation apparatus. . . . *With the humanoid sounds, dolphins are attempting to communicate with us in our mode of communication.* (83; emphases in the original)

In his *Theory of Society*, Luhmann draws out the immanent improbability of any communication whatsoever. He notes that the extreme contingency of communicative success "is hardly ever posed so drastically" as one finds in his treatment of the topic: "the fact that a system of society actually exists and reproduces communication through communication . . . is extremely improbable. Only communication makes itself probable. . . . If the individual components of communication [information, utterance, understanding] are in themselves improbable, their synthesis is all the more so" (1:113-14). Applying Luhmann's theoretical descriptions to Lilly's project, the higher improbability of interspecies communication would also follow from the higher incommensurability of alien *psychic* systems, the radical difference of which would tend to deter the formation of any medium of meaning to which a hybrid, interspecies social system could couple itself such that human and dolphin individuals could arrive at commensurate understandings of communicative offers. And here again is a formulation of the Catch-22 or logical quandary in which Lilly's project is caught: only interspecies communication could make interspecies communication probable. In the human instance, the communications produced by social systems have had eons to evolve in coevolutionary step with neurological and psychic systems. Can the formation of an interspecies social system really be jumpstarted in a few weeks or years, especially when one species is landborne and the other aquatic? Talk about the improbability of communication! Lilly's immanently improbable effort can proceed only on the prayers (since while any conclusive evidence for these assumptions may be "developing," it has not yet arrived) that the nonhuman beings to be communicated with are comparably communicative within their own societal forms, and moreover, that interspecies communication is not just possible but *desired* on both sides of the potential exchange. In other words, to gain any traction at all, Lilly must force the issue. His project must be built on the projection of its desired outcome:

> We must keep the working hypothesis in mind that "they are highly intelligent and are just as interested in communicating with us as we are with them.". . . If we use any other hypothesis, we have no success whatsoever in dealing communicatively with them. This hypothesis seems to be necessary and even overriding

> to accomplish the kinds of communication we are accomplishing and attempting to expand. The proof, the incontrovertible truth, that they are interested in this communication is developing slowly and carefully in our laboratory. (83)

And in any event, as Lilly goes on to assert, the mechanism behind the problem of projection—the psychic generation of mental models—is also at the root of cognition altogether. In line with the cybernetic vogue of the 1960s, Lilly endows that central mechanism with a fully mechanistic description. Complementing his implicitly cybernetic focus on communication, Lilly introduces an explicit computational analogue for the mammalian brain. Like a computer programmed to simulate a real-world process, that brain generates models for the mind to use, and at times, misuse. Addressing the matter of projection, he asks "How do we do this wishful, false realizing? Our relatively large minds (brains) act as computers that can make models inside themselves of other human minds and their activities" (3). Now, social systems theory would redescribe the matter of projection in a post-computational manner, as a normal problem set of observation and attribution for operationally closed meaning systems. Projection is a momentary or prolonged negation of internal or self-reference in favor of an uncorroborated external or hetero-referential attribution. Moreover, in first-order observation, self-reference is blocked as a matter of course.[7] That is, psychic events arise altogether as internal or systemic selections that the mind can check for referential consistency only by participating in society and thus enabling others to form and communicate second-order observations as corrective or affirmative responses to one's own utterances.

Returning to Lilly's psychic cybernetics, we are informed that only specific areas of the brain are "hard wired" for specific tasks, while much of it is "general purpose": this readiness for variable programming "is the saving grace which allows one individual to communicate with another. . . . The important common power is the ability of this brain to assume the tasks of making models of creatures and persons in its surrounds. This is the fundamental property which allows communication to take place" (7). Lilly bases this theorization of communication upon a loosely specified ability of the brain to "take on" the commonality of communication's semiotic medium—language: "We can develop and share a language among uniquely different individuals because each of those individuals can take on enough of the commonality of language within his own brain to allow communication" (7). And yet the commonality of language immediately runs up against the privacy of thought: "But we must never forget that the thinking processes of the individual are still uniquely his or hers. Only

[7] See Niklas Luhmann, *Theory of Society, Volume 1*, trans. Rhodes Barrett (Stanford: Stanford University Press, 2012), 49.

certain aspects are common and shared" (7). Which aspects? Well, language. Lilly does the best he can with the psycholinguistics he has at hand, but his theory cannot break out of the mere circularity of these formulations. Still, his intuition for the closure of consciousness is properly presented. Lilly rightly insists on the impossibility of penetrating to the possession of a fellow human's thoughts: "We may have the illusion of penetrating completely into the mental life of another human being through language, but this is impossible. Each of us is so uniquely different and so uniquely himself that we cannot yet so penetrate" (7). And these considerations of the limits of human knowledge are then to be pointed toward the problem of the absolutely alien mind of the dolphin.

As we have already noted, the theoretical penetration of the mind of the dolphin Lilly introduced in his preface does not mean any material or spiritual seizure of its contents but rather, simply but decisively, the establishment of a relation of communication. Any mind is black-boxed, self-possessed of an inviolable mental privacy whose only inlets and outlets depend upon events of communicative reception and utterance. It is in this context that Lilly obliquely introduces into his dolphin discourse the deep background of his experimentation with the isolation tank.[8]

> No one wants to be insulated and isolated for long from his fellow human beings. In experiments in which I have isolated volunteer subjects and in experiences in which others have isolated themselves, it is shown that the major need that develops in the isolation experience is transactions with others, i.e., communication. This need can be temporarily satisfied by hallucinating and talking to the "projected" persons in the solitudinous surroundings. (8)

With this allusion to the isolation tank, the topic of projection recurs in his text not as a pathology of communication but rather as a sort of involuntary protective reflex, an affective-ideational immune response. The isolation tank provides a literal materialization of the operational closure of the psychic system, momentarily structurally decoupled from any possibility of "true" communication. When you are in the tank, no one can hear you communicate. And so, hallucinatory projection provides an emergency solution to the terrors of extreme isolation by intuiting companionship to counter the momentary impossibility of communication. In Lilly's cybernetic idiom, and especially as induced by immersion within an isolation tank, hallucinations are particular projective phenomena that compute internal models of outer things and then insert

[8] For a detailed and thoughtful overview of this topic, with reference to a recent revival of its scientific application, see Langlitz, "Tripping in Solitude."

them into a larger model of the mind's external environment. The mind in artificial isolation invents and populates its own world, similar to or different than the world outside the tank, but in any event without recourse to the usual consistency checks of actual communication.

Self-Reference

If Lilly himself were to be the first human explorer to make contact across the species boundary to the mind of the dolphin, he could not at the same time stand outside the circuit of communication he hoped to achieve. In his current experimental sphere of sentient encounter between large-brained mammals, any traditional methodological move to remove himself from the stage of his experimental theater would create "paradoxes. Man himself must be included. The scientist himself must be in his system" (28). Lilly's statement anticipates the self-referential turn that second-order cybernetics will soon generalize to all occasions of observation. But by acknowledging the experimenter's presence within the system to be observed, he is not so much escaping from paradox as presciently engaging with the basal paradox of observing systems as that will be codified in second-order systems theory.[9] From the positivist point of view of normal science, of course, Lilly draws paradox to himself just by entering the circle of his own experiment and so collapsing any stance of objective detachment. Nonetheless, Lilly remained fastidious in maintaining an awareness of methodological distinction between hetero- and self-reference, in this instance, between "fact and theory": "In my work as a generalist, I use the model of the physicists and their separation rule. I separate the fact and theory rigorously in my own mind. In addition, experimenter and the parts of himself functioning in the system under investigation are separated as far as is practical" (29). Nonetheless, in order to perform this notional separation he can only step once more into the circle of paradox, holding together in his own person the unity of the distinction between self- and hetero-observation.

Lilly's observational paradox is only compounded in this text written for a general audience by his desire both to share and to guard the revelatory experiences that are backstage-managing the self-referential renovations to his scientific practice:

> If one succeeds in having a religious revelation, the significance is steeped in a perspective so vast as to generate an awe from which

[9] See Niklas Luhmann, "The Paradox of Observing Systems," in *Theories of Distinction: Redescribing the Descriptions of Modernity*, ed. William Rasch (Stanford: Stanford University Press, 2002), 73-93.

> he cannot recover. . . . Such experiences are not yet admitted to the halls of conventional science. A major difficulty is that unless another person has had such experience, he cannot share the wonder and the awe of one's own inner experiences. . . . The truth of what one presents is not subject to the usual tests of evidence as devised in the courts and the sciences. (35-36)

Although unspoken as yet in this text, Lilly labors here to contain his LSD experiences, begun in 1964, within the proprieties of standard objective discourse. Communication of this sort is another problem constituted by the closure of individual experience, especially for those private experiences that permanently alter one's relation to the world. Understanding of the revelatory information that he could utter greatly depends on the mental and experiential preparation of its recipient. In this manner the problematics of interspecies and intraspecies communication intersect.

One rhetorical strategy Lilly develops in this text for rendering impersonal information about himself is his recourse, however strained, to a third-person stance. Another such strategy—concurrently undergoing full development in *Programming and Metaprogramming in the Human Biocomputer*—is the coupling of that expository voice to an idiom and conceptual allegory steeped in cybernetics. Channeling his personal experiences and theoretical stances through the affectless tones of classical computerese nicely induces a scientistic flattening of the delivery. For instance:

> In this theoretical view which we are generating, theories are analogous to computer metaprograms. One's own brain is analogous to a huge computer larger than any built today. The theories (programs and metaprograms) stored in one's self operate the way a stored program in a modern computer operates. The stored program gives the orders for the data acquisition, the computations to be done, the logic to be used, the models to employ, the new models to be constructed, the end use of the results, and the outputs to be chosen to carry out the end uses. Thus, to test a given theory, one "programs" himself with the as-complete-as-possible theory and joins the system under investigation as a participant-computer operating "on line." (92)

The self-referential element returns in the self-programming of the "scientist in the system" as a "participant computer" running a theoretical metaprogram to be put to the experimental test in real time. If one discounts the earnest intentions at play in this edgy science, Lilly might as well be composing a posthuman strain of performance art. Let us call it *experimental performance science*, in which, in this cybernetic milieu, the experimenter self-fashions himself not just as a participant observer but as a computational device coupled into the system to be observed, open to on-line learning and real-time reprogramming and, as prophylaxis against projection, impervious to emotional distraction: "*one streamlines himself for the program.* If one is going to be a participant computer, he must get rid of excess emotional baggage. Excessive guilt has to be eliminated. Personal blind spots and tender pain-shame areas must be changed or erased. The model of the computer itself which one is striving for contains no personal blocks against finding the truth no matter where it lies" (95).

Redefining Information

Chapter 4 of *The Mind of the Dolphin* is titled "Communication Is between Minds." The crucial distinction implied by this statement is that communication is not merely between *brains*. It is not simply a matter of sequential sensory-neurological transmissions and receptions. The threshold of mind arrives with the higher-order computations that allow for metaprogramming and general-purpose modeling. The definition of communication now receiving explicit statement works backward from this distinction of mind:

> Definition: *Communication* is *the exchange of information between two or more minds.* (99)

Nonetheless, as the term "exchange" indicates, Lilly's scheme of communication comes out of an informatic matrix still wedded to a data-transmission model. Lilly provides a diagram directly adapting the famous diagram of a communication system in Warren Weaver's introduction to his and Claude Shannon's *Mathematical Theory of Communication*.[10] Nonetheless, key differences emerge from their comparison. The interest for us will be in the ways that Lilly, for one, finesses classical information theory in order to open up a conceptual residence for *mind* (an entity seldom elicited in standard informatic discourse), and for another, provides some preliminary sketches for a constructivist epistemology.

[10] Warren Weaver, "Recent Contributions to the Mathematical Theory of Communication," in Warren Weaver and Claude Shannon, *The Mathematical Theory of Communication* (Urbana: University of Illinois Press, 1949), 3-28.

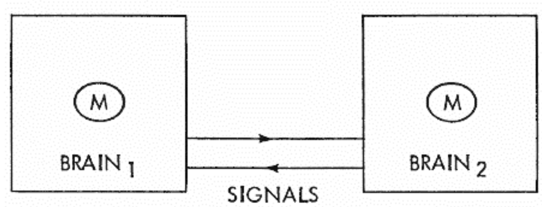

Figure 1 – John Lilly's Schema of the Definition of Communication in *The Mind of the Dolphin*

Regarding his schema of communication, Lilly explains: "This diagram shows a mind (M) on the left in the circle contained in brain 1 (the square) transmitting signals to mind (M) in the circle on the right contained within brain 2, the square. In turn, mind 2 is sending signals to mind 1" (102). Compare Warren Weaver's diagram of information transmission:

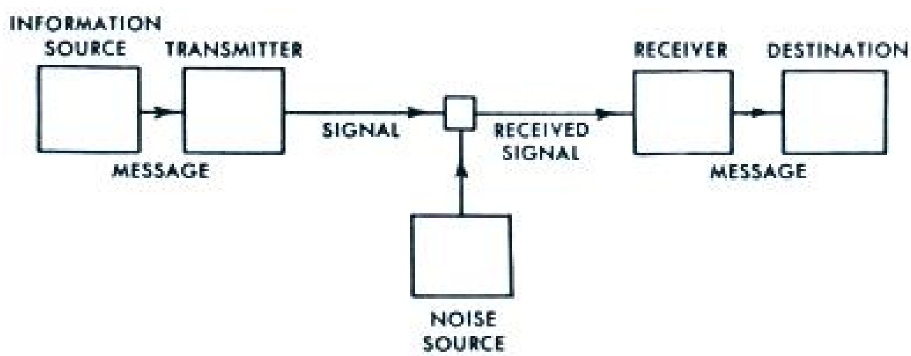

Figure 2 – Warren Weaver's diagram of information transmission from *The Mathematical Theory of Communication*

Information theory per se is oriented to technological systems. Weaver's diagram is modeled on a telephone system and focuses on signal conversion, signal load, and signal loss, for which depiction a one-way transmission suffices. Lilly's diagram is ostensibly oriented to embodied minds and depicts a minimal social system—in Luhmann's idiom, an interaction system. At the same time, his brain-mind composites are also, at least in the heuristics of his theory, *biocomputers*, and this psychophysiology comes forward in a strongly cybernetic frame. Thus Lilly's diagram can be unfolded toward Shannon and Weaver's technological scheme by momentarily positing the mind in brain 1 as the information source, the mind in brain 2 as the destination, and brains 1 and 2 as the neurological aspects of signal transmission and reception respectively. However, as Lilly operates his diagram, the key turn is this: "The information is not generated from these signals until the signals are received, computed, and turned into the information by each of the minds in turn. This is the essential core of our definition of communication" (102-3).

Purveying a common equivocation in communication theory, what Lilly here terms *information* is more precisely the *meanings* constructed by either mind as a result of their social "exchange." Since he is still working in a first-order informatic idiom, Lilly deploys an equivalent distinction between "signal" and "information." However, in importing the brain-mind couple into the informatic diagram, and in drawing a circle around mind relative to the brain, Lilly's scheme adumbrates a constructivist or second-order distinction between information and meaning. Perhaps I am projecting what I want to find, but it seems to me that by introducing *mind* into his scheme and so "placing new boundaries on information theory" (105), Lilly's biocomputational model posits a strong anticipation of the operational boundaries to be codified in Luhmann's metabiotic appropriation of autopoiesis for the production of consciousness and communication in psychic and social systems:

> The *information* does not exist as information until it is within the higher levels of abstraction of each of the minds and computed as such. . . . Information is the result of a long series of computations based on *data signal inputs, data signal transmissions to the brain substance,* and *recomputations of these data.* . . . The schema of the definition shows that one must differentiate very carefully between "signals" and "information." In this view, a set of signals . . . is not information; *it becomes so only if and when it enters, is computed, and changes the contents of a mind*. . . . In other words, our boundary for information is at a level of discourse of *Cogito ergo sum*, "I think (or I know), therefore I am." *Information is that which I know now, coming from outside me, and coming from the storage inside me, allowing for delays in computation and in transmission.* . . . The mind of the observer-participant is where the information is constructed, by and through his own programs, his own rules of perception, his own cognitive and logical processes, his own metaprogram of priorities among programs. (103-4; emphases in the original)

The Signal-Noise Ratio

With the inscription of the "observer-participant" into the interactive construction of meaningful information for communicative exchange between minds, Lilly now elicits the component of informatic noise left over from the Warren Weaver diagram of information flow. But unlike their simple addition of a noise source to signal transmission, Lilly imports and distributes information theory's signal/noise ratio across his scheme of communication: "the signal/noise ratio is a definable entity only when each of two minds agrees on the definition of what is 'signal' and what is 'noise'" (105).[11] However, having underscored that communication demands social agreement on how to distinguish meaningful forms from the randomness of their medium, Lilly now focuses on the individual mind's self-generation of meaning forms, and his train of exposition arrives once more at the station of physical isolation inducing psychic projection as a source of mental formations. Given a prolonged contemplation of a noisy process, one may begin to "'make signals out of the noise' by introducing systematic changes into the noise. In profound physical isolation, this process can be shown most dramatically. *Our minds project a pattern onto the noise*. . . . Basically, investigators who are looking into their own minds (under special conditions) may mistake the sources of 'new' information within their own minds as if those sources were outside the head. This process in psychology is called 'projection'" (105-6).

In the context of the research protocols for the scientific practices under discussion in *The Mind of the Dolphin*, once again, projection is basically a problem, not simply insofar as it may corrupt the experiential data being collected and examined, but also insofar as one may be tempted to contemplate a hypothesis that hallucinated messages are in fact offers of communication arriving through unknown, immaterial channels. Here in some of the weirdest passages of this text, Lilly darkly intimates, although in the mode of rational negation, that communication with dolphins could conceivably occur—especially if all efforts at normal symbolic exchange yield a null result—through a paranormal or telepathic medium:

> If one is watching "noise" at the logical level, he can sometimes "hear messages," as if he were being spoken to by other persons and these persons were telling him some important message…

[11] Lilly's exposition of noise makes his equation between meaning and information explicit: "In the standard theory, 'noise' . . . is a form of energy in which no part can be taken, no matter how chosen, as conveying any meaning whatsoever. Physical noise is that set of signals which, when received by a mind, generates no new information in that mind" (105).

> Fundamentally, then, we must eliminate, insofar as our brains and minds and their scientific investigation are concerned, a hypothesis which says that the noise coming from inside one's own mind and brain can be "signals caused by direct mental influence of other minds without the interposition of the usual modes and media of communication." (106)

Lilly continues for a number of pages in this vein of the logical dismissal of as well as denial of evidence for uncanny communication, ostensibly to underscore the comprehensive reach of his theorizations and rigor of his experimental procedures. He arrives at a declaration of practical agnosticism: "My own position about religion is the same as my position about ESP ["extra-sensory perception"] and thought transference. Until I have empirical, down-to-earth, hard-nosed information thrust upon me, I will maintain a position of not knowing; such thinking also belongs in the area of the unknown" (110).

Nonetheless, at this point in the text a reader could still wonder why Lilly wants to take his discussion on a long detour into such outlandish matters. *The Mind of the Dolphin* does not really answer that question, although a bit later, in chapter 5, the essential clue is given when Lilly provides a short work-up of the parallel research project that has been moving in and out of focus between the lines of this text. Now shifting into a first-person narration, he remarks that "after many exposures to the physical isolation under ideal physical conditions, I was able to overcome self-created mental discomfort to a certain extent. I learned a lesson about our minds as follows: Our huge computers are, to a certain extent, self-metaprogramming and self-programming" (121). Right here Lilly provided a footnote to an early version of the second book-length text he completed in 1967. This was the obligatory final research report composed at the conclusion of his five-year Career Award from the National Institutes of Mental Health (NIMH), which award had been largely financing the CRI since 1962. In Lilly's footnote, the title is given as *The Human Biocomputer: Programming and Metaprogramming* (*Theory and Experiments with LSD-25*).[12]

An extended consideration of this major intertext must wait for another occasion. Instead, by way of conclusion for the moment, I will move directly to a section of *Programming and Metaprogramming* that overlaps some key topics we have been tracking through the discourse of communication in *The Mind of the Dolphin*. In particular, we will look at some passages from chapter 8, "Basic Effects of LSD-25 on the Biocomputer: *Noise* as the Basic Energy for Projection

[12] Lilly addresses this work's "curious history" in his 1972 foreword to the second edition of *Programming and Metaprogramming in the Human Biocomputer: Theory and Experiments* (New York: Bantam, 1974), v. I will quote the text from this 1974 edition.

Techniques." The wording of the title indicates the crux of the difference between the two treatments. In the dolphin book, invested in the maintenance of a baseline of normal scientificity, projection is presented primarily if not entirely as a source of aberration in the data collected, a problem factor to be controlled. But what Lilly discovered and subsequently explored in the isolation work was that, depending on the kind of experiment one had in mind, projection need not be controlled *for* but simply itself controlled as a research *technique*. All the more so under the radical suggestibility induced by LSD, projection offered a phenomenological resource that could itself be "programmed" and so tested experimentally for the purpose of sounding the limits of possible belief.

In the following passages from *Programming and Metaprogramming*, Lilly adverts to the signal/noise ratio, but with some major differences. Whereas in the dolphin book, the noise source was located "in the external world . . . by either looking at a very noisy visually presented process or by listening to a very noisy acoustically presented process" (105), in the biocomputer text, the noise source is fully internalized. It is in fact the form of the contribution LSD makes, an amplification of "the *noise level of the mind itself*" (82):

> In the analysis of the effects of LSD-25 on the human mind, a reasonable hypothesis states that the effect of these substances on the human computer is to introduce *white noise* (in the sense of randomly varying energy containing no signals of itself) in specific systems in the computer. . . . The major operative principle seems to be that **the human computer operates in such a way as to make signals out of noise** and thus **to create information out of random energies where there was no signal**; this is the "projection principle"; noise is creatively used in non-noise models. (80-82; emphasis in the original).

Later on the same page Lilly introduces a long passage from a 1962 paper by Heinz von Foerster, "Bio-Logic," in order to cite the latter's argument for the hypothesis that some percentage "'of all operations in the brain are afflicted with an intrinsic noise figure which has to be taken care of in one way or another'" (83).[13] But let us also jump forward for a moment to von Foerster's justly famous 1974 paper "On Constructing a Reality," to sample what may be its own reciprocating of Lilly's attention. A section on "Computation" ends with the observation that "In 'biological computers' the programs may themselves be computed on. This leads to the concepts of 'metaprograms,' 'meta-

[13] Lilly cites from Heinz von Foerster, "Bio-Logic," in *Biological Prototypes and Synthetic Systems*, volume 1, eds. Eugene E. Bernard and Morley R. Kare (New York: Plenum Press, 1962), 1-12.

metaprograms,' and so on. This, of course, is the consequence of the inherent recursive organization of these systems" (224). The following section on "Closure" formulates a "postulate of cognitive homeostasis" that reads like a straightforward generalization of the bio-computational principle underlying the statements Lilly's text placed in bold font above. Von Foerster writes: "The nervous system is organized (or organizes itself) so that it computes a stable reality" (225).

The postulate of cognitive homeostasis would of course hold, as much as may be possible, under relatively extreme conditions such as LSD's amplification of the white noise perceived by the mind amidst any other signals. And so, as Lilly lists off the basic effects of LSD-25 on the biocomputer, "One can thus 'explain' the apparent speed-up of subjective time; the enhancement of colors and detail in perceptions of the real world; the production of illusions; . . . the projection of emotional expression onto other real persons; the synesthesia of music to visual projections; the feeling of 'oneness with the universe'; apparent ESP effects; communications from 'beings other than humans'" (80). While caution over seduction by misconstrued projections remains, in *Programming and Metaprogramming* the projection process itself becomes an openly and open-endedly self-experimental technique, a voluntary search for the limits of mental experience that the adept metaprogrammer of one's own biocomputer (brain) can induce: "One can . . . detect the *noise level of the mind itself* and use it for cognitional projections rather than sense-organ-data projections" (82).

Put another way, projection is a problem only if the goal being sought is communication in an interaction system, such as that constellated by the interspecies effort. In the end, communication research with dolphins ran aground against its own improbability, not to mention Lilly's increasingly precipitous loss of institutional support as the outlandish aspects of his dolphin work came to loom larger than its initial promise and appealing pathos.[14] Once Lilly turned the "projection principle" from a side-effect into a primary technique for self-experimentation on the limits of belief, the matter of communication was no longer the object of the science but simply the process of its symbolically-mediated presentation beyond the self. If Lilly's proactive treatment of "cognitional projections" upon the noise of the mind directly anticipated some aspects of von Foerster's mature contribution to the discourse of systems theory, the epistemological constructivism of second-order cybernetics, it did so in an activist mode of psychic exploration, a mode that the necessary protocols of communication research could only hinder and impede. Ever the intellectual sophisticate, von Foerster successfully moderated and streamlined the more outré

[14] For copious detail on this score, see Burnett, *Sounding of the Whale*, chapter 6.

elements of his friend Lilly's psychonautical adventures, extracting their gist and making it eventually into a resource for social systems theory's autopoietic coupling of the discourses of consciousness and communication.

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Clean by Nature. Lively Surfaces and the Holistic-Systemic Heritage of Contemporary Bionik.

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Abstract

This paper addresses questions regarding the prospering field of *Bionik* in Germany. Its starting point is the wide spread assumption that universal functional principles exist in nature and that these 'solutions' can be transferred into technological objects. Accordingly, advocates of *Bionik* herald the advent of a better world with more sustainable and efficient products of engineering. The so-called 'functional surfaces' occupy a special place within this contemporary version of biomimesis. Shark-skin-inspired swim suits, self-cleaning façade paints with lotus effect or drag reducing Dolphin-Skins for aircraft-wings are expected to improve the quality of life for everyone. It seems that skin and shell of living systems return as revenants to our technological world and live their afterlives as *lively surfaces* of everyday objects.

This paper argues however, that understanding this attention to 'natural engineering solutions' in contemporary Bionik, one needs to focus on a different kind of afterlife. For baring the historic-epistemological roots allows fathoming direct connections to two widely influential historical concepts within the history of science in the 20th century: *Biotechnik*, a very popular bio-philosophical concept from the Weimar Republic of the 1920s and *Bionics,* an in many ways similar endeavor that emerged during the second wave of Cybernetics in the USA from around 1960. Both historical concepts share a certain proximity to a distinct holistic-systemic style of thinking that emerged during the 20th century and still resonates with the movement of *Bionik* in contemporary Germany.

Based on the example of the lotus effect, I want to address three aspects of the afterlife of this holistic-systemic heritage in contemporary *Bionik*. First, the assumption that the best engineering solutions can be found in nature conceals the specific discursive and non-discursive complexity that forms the basis of all technological objects. Second, the holistic-systemic heritage of *Bionik* directly correlates with its epistemological bias towards visual evidence and its enthusiasm for 'functional surfaces'. Third, the rhetoric of Bionik paradoxically oscillates between a counter-modern demotion of human creativity and autonomy and a fascination for modern scientific instruments and practices.

Keywords

Biotechnik, Biotechnics, Cybernetics, Bionics, Bionik, Biological Computing, lotus effect, Numarete, Raoul Francé, Jack Steele, Heinz von Foerster, Wilhelm Barthlott

Cover Page Footnote

Translated from German by Clemens Ackermann. I would like to thank Thomas Brandstetter for calling my attention to Raoul Francé's biotechnics in the first place and helping me with its historical contextualization

1. Paint and Dashed Hopes

After having received countless personal inquiries from his customers and as a consequence of numerous debates with his colleagues, master painter Martin Kempf from Alzenau in Lower Franconia deemed it necessary to address a question on the website of his company in May 2003 that had worried his guild for some time past:

> It rarely ever happened that something as mundane as exterior paint would let the feelings of experts run as high, as it was the case with the promotionally effective introduction of the Lotusan paint. The industry appears to be divided into proponents and critics. On closer inspection, it is evident that the proponents are part of the faction that would make money off of this paint, and that the critics must be apportioned to the faction that unfortunately cannot offer a comparable product […] and thus see their hopes dashed. What is actually so special about this paint? And about the so-called lotus effect?[1]

A brief look at the advertising brochure for the exterior paint LOTUSAN by Sto AG[2] renders the worries of the competitors easily comprehensible and the question of the painter—"what is so special about this paint"[3]—appears more than aptly put (Figure 1). As a last consequence, Sto promises nothing less than the fact that buildings coated with LOTUSAN will never require another coat of paint. For the first time, it was allegedly successful to…

> …transfer the natural self-cleaning Lotus-Effect® of the lotus plant to exterior paint and plastering… Because, similar to the leaf

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[1] Master Painter Kempf. "Der Lotus-Effekt an der Fassade – Dichtung oder Wahrheit?" Accessed March 29, 2014. http://www.maler-kempf.de/html/thema_lotusan.html ["Es ist selten vorgekommen, dass so etwas Banales wie eine Fassadenfarbe die Emotionen der Fachwelt so hochkochen [lässt], wie die werbewirksame Einführung der Lotusan Fassadenfarbe. Die Branche [scheint] gespalten in Verfechter und Kritiker. Bei näherem Hinschauen [kann] man erkennen, dass die Verfechter zu dem Lager zählen, die mit dieser Farbe Geld verdienen, und die Kritiker dem Lager zuzurechnen [sind], die leider kein Vergleichsprodukt anbieten [können] […] und nun ihre Felle davon schwimmen [sehen]. Was ist eigentlich dran an dieser Farbe? Und an dem sogenannten Lotus-Effekt?"].

[2] Sto AG is an internationally leading manufacturer of paint, lacquer, and coating from Baden-Württemberg.

[3] Ibid. ["was dran sei"].

of the lotus plant, the paint and plastering with Lotus-Effect® have a highly water-repellent surface with a special microstructure. Dirt particles cannot adhere to this surface—as soon as it rains, they will be entrained by the rain dripping off. The result: ideal protection of the façade and the veneer remains dry and beautiful.[4]

Figure 1 – Advertisment for Sto AG's "intelligent color" LOTUSAN (http://www.lotusan.de)

Regardless of the highly controversial query among experts, whether LOTUSAN actually delivers on the manufacturer's promise, it is especially interesting regarding the question of surfaces that the maker calls its product a "trendsetter-product"[5] of a branch of engineering research, which is tremendously popular in Germany since the mid 1990s; namely, *Bionik*. According to the manufacturer, the lotus effect is a prime example for a successful transfer of a "millennia-old invention of nature" to technological applications.[6] And, since—according to their

4 "StoLotusan. Fassadenbeschichtungen mit Lotus-Effect", advertising brochure of Sto Ges. m.b.h. 2005. ["natürlichen selbstreinigenden Lotus-Effect® der Lotuspflanze auf Fassadenfarbe und Fassadenputz zu übertragen… Denn ähnlich wie beim Lotusblatt besitzen auch Farbe und Putz mit Lotus-Effect® eine hoch wasserabweisende Oberfläche mit spezieller Mikrostruktur. Schmutzpartikel können auf dieser Oberfläche nicht anhaften – sobald es regnet, werden sie von den abperlenden Regentropfen mitgerissen. Das Ergebnis: Ein optimaler Fassadenschutz und die Fassade bleibt trocken und schön"].

5 Ibid. ["Schrittmacherprodukt"]

6 Ibid. ["jahrtausendalten Erfindung der Natur"]

claim—nature has often long before us discovered the most ecological and economical solutions for a specific technical problem due to "the experience of millennia",[7] one can now not only offer better, but also more sustainable exterior paint. In their advertising endeavors, the marketing department of Sto can rely on an enormous, yet constantly growing linguistic and no less visually stunning apparatus of marketing propaganda concerning *Bionik* that encompasses pretty much everything that the toolkit of contemporary business communication has to offer; viz. reaching from professional publications,[8] nonfiction and textbooks[9] to elaborately produced movies and documentaries[10] all the way to experimentation sets and board games.[11]

The so-called 'functional surfaces' occupy a special place within the binomial frenzy of enthusiasm. Be it low-friction shark skin for swim suits, anti-glare compound eyes for cell-phone displays, gecko soles with nano-hair for superglue, or the aforementioned lotus leafs for exterior paint: it seems that skin and shell of living systems return as revenants to our technological world and live their afterlives as *lively surfaces* of everyday objects.[12]

In the following, I will thus reflect upon the question of what exactly *lives on* in these products of contemporary *Bionik*. While at first glance the obvious answer would probably be, that the superiority of these artifacts can be explained

[7] Ibid. ["Erfahrung von tausenden von Jahren"]

[8] Recent scientific publications include: Werner Nachtigall, *Bau-Bionik. Natur – Analogien – Technik* (Berlin: Springer 2013); Yoseph Bar-Cohen, *Biomimetics: nature-based innovation* (Boca Raton: CRC Press 2012); W. Nachtigall, *Bionik als Wissenschaft. Erkennen – Abstrahieren – Umsetzen* (Berlin: Springer 2010).

[9] Claus-Peter Lieckfeld, *Der Natur auf der Spur : Bionik - Herausforderung und Chance* (Waldbröl: Pro Futura/World Wildlife Fund 2012); Robert Allen and Andrea Kamphuis, *Das kugelsichere Federkleid: wie die Natur uns Technologie lehrt* (Heidelberg: Spektrum/Akademie 2011); Thea Lautenschläger, *Bionik – Experimente für die Schule: spannende Entdeckungen aus der Natur* (Berlin: Duden 2011).

[10] For example: *Bionik – Das Genie der Natur,* DVD 150 min., directed by Alfred Vendl and Steve Nicholls (ORF Universum: Vienna 2006).

[11] For example: *KOSMOS 633035 – Lotusblume Experimentierkasten*, experimentation set (Stuttgart: KOSMOS 2013) and *Bionik. Natur macht erfinderisch*, board game (Ravensburg: Ravensburger Spieleverlag 2000).

[12] By referring to these contemporary products of Bionik as 'lively' artifacts, I want to hint at the fact that they are not simply lifelike objects, understood as neutral copies of natural prototypes, but in fact independent epistemic agents that appear to be alive by showing some form of biological 'behavior'. I will go into more detail about this aspect of liveliness at a later point in this article.

by the fact that natural principles are being transferred to (and thus *live on* in) these devices, I want to focus on a different kind of afterlife. For baring the historic-epistemological roots allows fathoming direct connections to two widely influential historical concepts within the history of science in the 20th century: *Biotechnik*, a very popular bio-philosophical concept from the Weimar Republic of the 1920s and *Bionics,* a in many regards similar endeavor that emerged during the second wave of Cybernetics in the USA from around 1960. While holding a significant place in the wider context of a more general history of Biotechnology,[13] both historical concepts share a certain proximity to a distinct holistic-systemic style of thinking that emerged during the 20th century and still resonates with the movement of *Bionik* in contemporary Germany.[14]

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[13] As Robert Bud has shown, the general concept of 'biotechnology' understood as a combination of biology and engineering developed a rich and highly complex history in the course of the 20th century. The range of its changing connotations is very broad, many different ideologies and areas of application have gathered under its banner over the course of time. The most prominent trajectory of meaning within the history of this concept undoubtedly refers to the idea of using biological organisms for the benefit of men, ranging from such diverse (and historically contextualized) fields of application as agriculture, medicine, hygiene or eugenics to contemporary genetic engineering. In this paper however, I want to focus on the notion of 'biotechnics', as the attempt to emulate nature by technological means in order to create 'environmentally friendly' technological products in accordance with nature. Cf. Robert Bud, *The Uses of Life. A History of Biotechnology*, (Cambridge, Mass.: Cambridge University Press 1993).

[14] Historically speaking, 'holism' and 'systems theory' are evidently not the same thing. The term 'holism' was coined by the South African statesman and philosopher Jan Smuts in 1926, who was drawing on late 19th century biology and the popular Aristotelean idea that nature forms 'wholes' that are greater than the sum of its parts due to the implementation of a vital principle that is absent in inanimate things (Cf. Jan Smuts, *Holism and Evolution* (London: Macmillan 1927), 88). The introduction of a general 'systems theory' after WWII is usually ascribed to the Austrian biophysicist Ludwig von Bertalanffy, who wanted to overcome the prewar opposition of mechanism and vitalism by taking a new approach to understanding the 'organizational principles' that distinguish 'living systems' from other objects (Cf. Ludwig von Bertalanffy, *Problems of Life: An Evaluation of Modern and Scientific Thought* (New York: Harper 1952 [1949]). However, both concepts share an anti-reductionist and anti-mechanist worldview that focuses on the organization of a system's parts as well as on the interaction of the whole systems with its respective environment. The so-called Second Wave of Cybernetics during the 1960s in particular drew heavily on both holistic and systemic rhetoric to explain living systems.

Subsequently, I want to show by means of the example of the lotus effect, that this holistic-systemic way of thought directly correlates with the biomimetic enthusiasm regarding surfaces. As interface between living systems and their respective environments, surfaces initially prompt thought concerning *every biotechnical endeavor* by way of the problem of natural universally valid operating principles. However, an epistemology operating on the surface—as it is the case with the example of the lotus effect from contemporary *Bionik*—can never be looked at independently of the media technologies that make epistemic things out of epidermal ones.

2. Poppy Seed Capsules and Salt Shaker

Initially, I want to consider the sober assessment that technological artifacts can be the product of a cultural technique, which purposefully imitates natural forms and functions. This mimetic demand has first been formulated as a philosophical program at the beginning of the twentieth century. Along these lines, Vienna born botanist Raoul Francé indicated, by employing the term *Biotechnik* as early as around 1920, not only the similarities between nature and technology, but he also demanded mimesis to be the highest goal of technical work.[15] Francé developed this concept in multiple monographs and numerous essays.[16] For example his

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[15] Cf. Raoul H. Francé, *Die technischen Leistungen der Pflanze*, (Leipzig: Veit & Comp. 1919) & Raoul H. Francé, *Die Pflanze als Erfinder* (Stuttgart: Franckh'sche Verlagshandlung 1920).

[16] His real name being Rudolf Franze, Raoul Francé was born in Vienna on May 20, 1874. He studied analytic chemistry and microtechnology as autodidact. At the age of 16, he was the youngest member of the royal Hungarian society of the natural sciences, where he would work as vicarious editor from 1893 to 1898. Starting in 1897, Francé studied medicine for eight semesters and became a student of the Hungarian protozoa scholar Geza Entz. During this time, he accomplished 14 botanical research trips. In 1898 he was appointed vice director of the institute for the protection of plants at the agricultural academy in Hungarian-Altenburg. Here, he published his first work on natural philosophy. Subsequently, Francé was prompted to come to Munich in 1902. In 1906, Francé founded the Deutsche Mikrologische Gesellschaft and the appertaining institute, which he presided over as director. He was the editor of the societies' journal and co-founder of „Mikrokosmos" (1907). He presided over further series as editor, such as "Jahrbuch für Mikroskopiker" und die "Mikrologische Bibliothek." Also in 1906 Francé initiated the eight-volume encyclopedia *Das Leben der Pflanze* by writing the first four volumes himself (1906-1910). Alluding to the highly popular zoological reference book *Brehms Tierleben*, first published by Alfred Brehm in the 1860s, Francé's monumental work was advertised as 'Pflanzen-Brehm' by its publisher

short essay *The Plant as Inventor*, in which he describes the primal scene that allegedly lead him to the principle of biotechnics.[17]

According to Francé, he one day had to face a problem whilst conducting experiments in his laboratory in Munich. He had to evenly spread soil samples on the surface of his bench, in order to examine the microorganisms contained within them. Having tried multiple every day objects with unsatisfactory results, he had the "incidental idea […] to ask, how nature attends to dissemination."[18] He was considering specific plants and fungi, which are dependent on evenly spreading their seeds or spores; in the dried seed capsules of the poppy seed plant, he eventually found what he was looking for: "I immediately realized that nature had found a solution to my problem. All I had to do was mimic nature and I was relieved of my troubles."[19] Following the model of the dried capsules, Francé eventually applied for a patent for a new "shaker/scatterer for the household and for medical purposes." (Figure 2)[20]

Based on this primal scene, Francé subsequently developed a universal biotechnic philosophy, according to which every mechanism in the world has its necessary technical form and that this form is furthermore always already realized in nature. The crucial point with Francé is thus the substitution of men's creative effort with the originative power of nature. Or, as he put it himself: "I am […] not interested in being considered an inventor, because I am merely a wretched copyist of nature."[21] At the heart of his philosophy lies the conviction that the entire world is governed by a principle of economy, which Francé calls "the law

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Kosmos, R. H. Francé et al, *Das Leben der Pflanze* (Stuttgart: Kosmos 1906-1913). Today Francé is mostly known for coining the biological term 'edaphon', cf. René Roth, "The foundation of Bionics," *Perspectives in biology and medicine* 26 (1983): 238.

[17] When using the term 'biotechnics' to translate the German term 'Biotechnik', I am following American historian and sociologist Lewis Mumford who learned about Francé's *Biotechnik* through his correspondence with the British Biologist Pattrick Geddes and introduced the term '(bio)technics' to the American discourse through the publication of his book *Technics and Civilization* in 1934, Bud, *Biotechnology*, 69.

[18] Francé, *Pflanze als Erfinder*, 5-8. ["der beiläufige Einfall ... zu fragen, wie denn die Natur das Ausstreuen besorge."]

[19] Ibid. ["Sofort sah ich ein, dass die Natur eine Lösung meines Problems gefunden (hatte). Ich brauchte sie nur nachzuahmen und war dann jeder Sorge enthoben."]

[20] Ibid. ["Streuer für Haushalt und mediz. Zwecke."]

[21] Francé, *Pflanze als Erfinder*, 5-8 ["Ich habe ... gar kein Interesse daran, als Erfinder zu gelten, denn ich bin nur ein elender Kopist der Natur."].

of least resistance and the economy of efficiency."[22] The consequence of these laws is that every mechanism "has its necessary technical form." For example: "Everything that is sought to drill or to penetrate something, has to have the form of a screw."[23] Francé even goes a step further and claims that there are no more than seven fundamental technical forms, namely, "crystal form, sphere, surface, column and brace, screw and cone" from which "all mechanisms of the world process are derived": "Nature has not brought forth anything else and the human mind may create whatever it wants, it will always only arrive at combinations and variations of these seven fundamental forms."[24] For Francé, this universal basic kit of the world is the reason, why there cannot be any form of a man-made device that would not be deducible from nature.

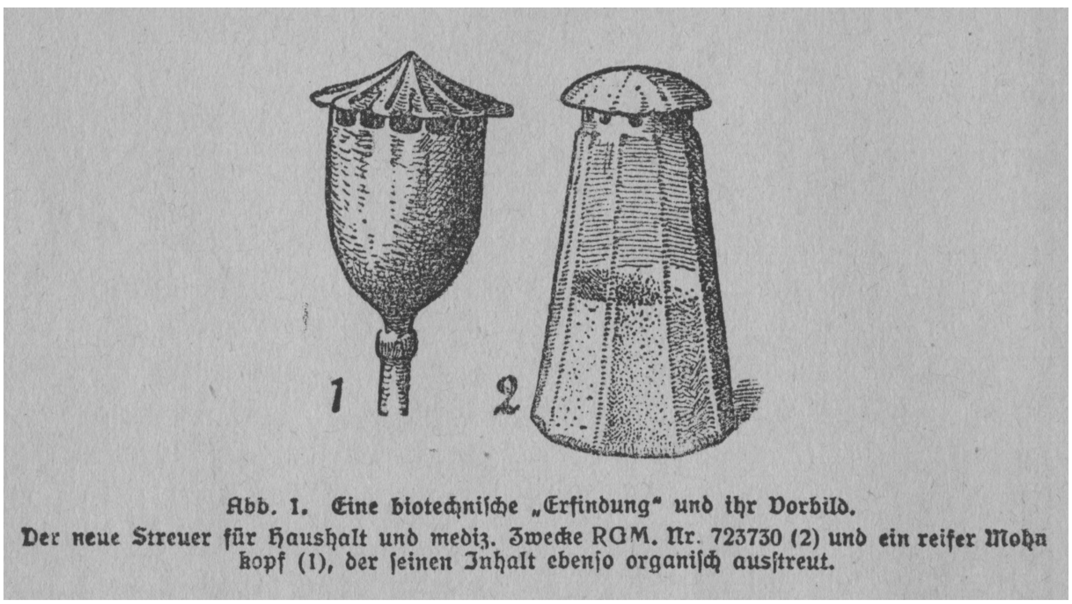

Figure 2 – Poppy Seed and Salt Shaker (Francé, *Pflanze als Erfinder* 1920, 8).

[22] Ibid., 25. ["Gesetz des geringsten Widerstandes und der Ökonomie der Leistung."].
[23] Ibid., 17. ["Alles, was bohren, durch etwas dringen soll, muss die Form der Schraube haben."]
[24] Ibid., 18. ["...Kristallform, Kugel, Fläche, Stab und Band, Schraube und Kegel ... sämtliche Prozesse des Weltprozesses ... Die Natur hat nichts anderes hervorgebracht, und der Menschengeist mag schaffen, was er will, er kommt immer nur zu Kombinationen und Varianten dieser sieben Grundformen..."]

One quickly recognizes two epistemological problems with Francé's cosmology: initially, there is a contradiction between his supposition of a universalistic principle of economy and the simultaneous call to the engineer to mimic it: why does man as part of nature not automatically choose the most economical technical solutions? The reason for this contradiction is that, despite Francé's argument for the existence of a harmonious and 'whole' cosmos, his idea of copying nature by technological means in fact presupposes a clear cut distinction between nature and culture, or to quote Katherine Hayles: "The flip side of drawing analogies is constructing boundaries. Analogy as a figure draws its force from the boundaries it leapfrogs across."[25] Secondly, there is the problem regarding the retroactive character of *biotechnics*: the starting point is always the culturally formatted search for solutions of technical problems (for example the task of evenly spreading samples of soil on a laboratory bench) and not the invention of a nature.

At this point however, I cannot extensively discuss the context of the history of science in which Francé developed his—in many respects problematic––biotechnic philosophy. It may suffice to draw attention to the fact that his approach can be classed with a whole range of popular holistic approaches from that time, which, contrary to other approaches—such as Marx or Cassirer—do *not* argue the case for autonomy of modern technic with respect to nature,[26] but instead strive for an integration of technic into a harmonically organized 'cosmos.'[27] Confronted with the disastrous ramifications of World War I, an increasing desire for "a new technology for a new age" among European intellectuals emerged. Having witnessed the catastrophic destructions caused by modern machinery and industry, an integration of biology with engineering promised to "integrate the contemporary ideal of manufacturing with visions of humanity and its environment, and a faith in the privileged view of life".[28] However, inspired by vitalist Biologists such as Hans Driesch and Lamarckian

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[25] Hayles, Katherine, *How we became posthuman: virtual bodies in cybernetics, literature, and informatics* (Chicago: University of Chicago Press 1999), 93.

[26] Marx discusses the emancipation from "organic limits." ["organischen Schranke"] Karl Marx, *Das Kapital. Erster Band* (Wien: Globus 1982), 394. Cassirer undertakes a clear separation of magical and technical worldview in his essay „Form und Technik." Ernst Cassirer, "Form und Technik", in: idem. *Symbol, Technik, Sprache* (Hamburg: Meiner 1995), 39-91: 74.

[27] In this regard Francé's Biotechnik is a typical example of what Ann Harrington labeled a 'reenchanted science', Anne Harrington, *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler* (Princeton: Princeton University Press 1999).

[28] Bud, *Biotechnology*, 51-52.

concepts of evolution, figures like Francé's must also be seen as representatives of what Jeffrey Herf has coined "reactionary modernism" in Weimar Germany; a romantic enthusiasm for technology that was accompanied by a rejection of humanist and liberal concepts.[29] Subsequently, this holistic legacy had a wide influence on all recoinings and reformulations of the biomimetic idea up until today.[30] Even the *lively surfaces* of contemporary *Bionik* such as sharkskin and self-cleaning façades ultimately also imply a counter-modern demotion of human creativity and autonomy.

Of at least equally great interest for the question of surfaces is however the fact that Francé has framed his biotechnical principle employing a rhetoric of visual evidence and immediacy. According to this, inventions of the flora could be recognized with the naked eye. And it is surely no coincidence that to this day, bionic analogies are legitimized via a mirror-imaged juxtaposition of model and copy. Nature, according to Francé, complies with the universal forms of functions "unto the very edge of visibility."[31] And yet, the fact that *Biotechnik* was the product of a fundamental shift of just this edge was not borne in mind. Because, different from what Francé's anecdote of the poppy seed shaker suggests, he developed his biotechnic philosophy of universal forms not during copious walks in the woods, but whilst sitting at the microscope, with pen and drawing paper ready at hand. Figure 3 for example shows drawings of flagellates, i.e. monads with flagella, which, according to Francé, found the "ideal solution to the problem of swimming."[32]

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[29] Jeffrey Herf, *Reactionary Modernism. Technology, Culture and Politics in Weimar and the 3rd Reich* (Cambridge: Cambridge University Press 1985).

[30] Oddly enough, among the wide readership of Francés writings was the Hungarian painter, photographer and professor in the *Bauhaus School* László Moholy-Nagy. His famous *form follows function*-principle was greatly influenced by Francés cosmology, cf. Inge Baxmann, "Der labile Mensch als Kulturideal. Wahrnehmungsutopien der Moderne," in *Electric Laokoon. Zeichen und Medien, Von der Lochkarte zur Grammatologie*, ed. Michael Franz et al. (Berlin: Akademie 2007), 97-117: 110-112.

[31] Francé, *Pflanze als Erfinder* 1920, S. 14. ["bis zur letzten Grenze des Sichtbaren."]

[32] Ibid. ["optimale Lösung des Schwimmproblems"]

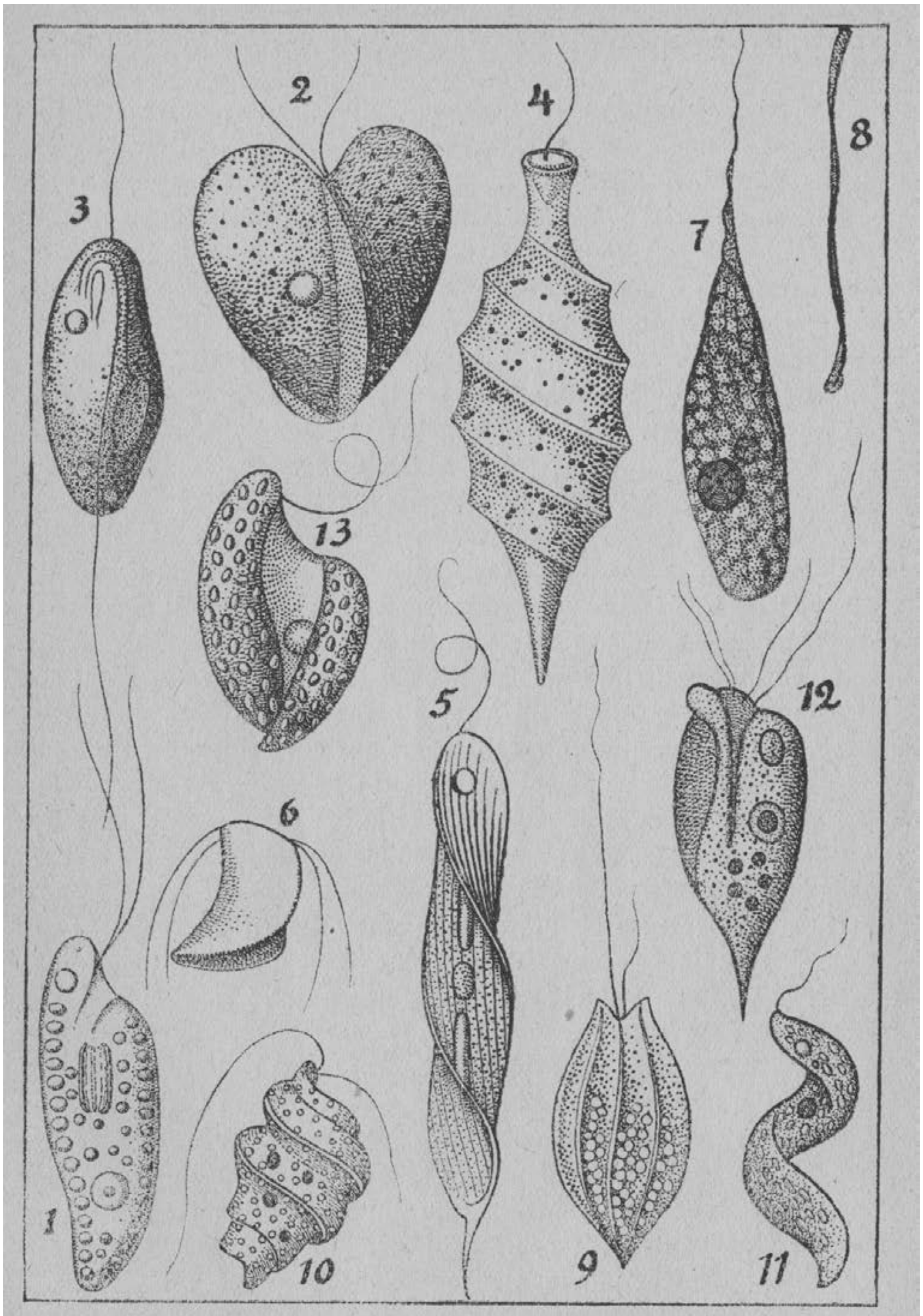

Abb. 9. Flagellatenformen. (Erklärung nebenstehend.)

Figure 3 – Flagellates drawn by Raoul Francé (Francé, *Pflanze als Erfinder* 1920, 27).

And indeed, as founder of the *German Micrological Society* and as editor of the *Yearbook for Microscopists* he found himself amidst that light microscopical wave of enthusiasm, which reached the mainstream of German speaking botanists around 1900.[33] The irony in Francé's work thus lies in the fact, that the *conditio sine qua non* of his biomimetic endeavor, was in fact a media technology that does *not* easily qualify as a biomimetic artifact. Being the product of age-long craftsmanship, purposeful experimentation and geometrical understanding, the microscope must rather be interpreted as a prime example for the discursive and non-discursive complexity that forms the basis of all technological objects.[34] That however, calling upon Kittler, the "unknown creature Hardware" walks abroad behind the back of biotechnics remains—as we shall see—a blind spot of all biomimetic ambitions.[35]

3. Frog Eyes and Biological Computer

The European holistic concept of a biologically informed technology reached the US discourse as early as in the late 1930s. Especially the idea to combine conventional engineering education with a base training in biology and medicine became increasingly popular and led to the establishment of several institutions offering a variety training and research programs.[36] In the light of this

[33] In his biography Francé mentions that, as a young man, with he tried great effort to build his first own microscope, following the descriptions of the 17th century Dutch scientist Antonie Philips Leeuwenhoek. He reports that he succeeded at building a rudimentery device that would allow him to observe the "dwellers of the swamp water ... at the size of bugs" but that he was also afraid the self-built microscope might eventually "spoil his eyes", R.R. Francé, *Der Weg zu mir. Lebenserinnerungen erster Teil*, (Leipzig: Kröner 1927), 64. ["…groß wie die Käfer krochen und huschten die sonst punktgroßen Bewohner des Sumpfwassers vor meinen entzückten Augen dahin, die man sich nun viele Stunden lang verdarb"]

[34] Note that this statement does of course not contradict Jutta Schickore's assumption of an "entwined history of microscope and the eye" from the early 19th century, understood as a *discursive* and *epistemological* entanglement of microscopy, sensory physiology and the formation of what Schickore calls "second order concerns", J. Schickore, *The Microscope and the Eye. A History of Reflections*, 1740-1870 (Chicago: University of Chicago Press 2007), 1-13.

[35] Friedrich Kittler, "Hardware. Das unbekannte Wesen", in *Medien, Computer, Realität. Wirklichkeitsvorstellungen und neue Medien*, ed. S. Krämer (Frankfurt a. M.: Suhrkamp 1998), 119-132. ["unbekannte Wesen Hardware"]

[36] The *MIT* established a combined training and research program called "biological engineering" in 1936, which was pushed forward by its Vice President and Dean of

development the idea of biotechnics was rediscovered around 1960 by the protagonists of the second wave of American cybernetics and reformulated as *Bionics*. This undertaking surely has to be initially assessed as an attempt to revive the still not successfully institutionalized universal science that was some fifteen years earlier driven forth by the now discontent protagonists of the *Macy Conferences*.[37] Other than that, the fusion of Norbert Wiener's theory of feedback as universally valid principle in the world of animals and machines alike with the old biomimetic paradigm appears to be reasonable, indeed. Ultimately, cybernetics also wants to harmonize the fragmented and specialized branches of science based on the proposition of abstract circuits and procedures. And, although there are no examples from the projects of *Bionics* research from around 1960 that would directly correlate with the initially mentioned lively surfaces, it can be established that boundaries—understood as the differentiation of a living system and its environment—are epistemically especially productive within the new field. "Functional relations", in the sense of a cause-effect relationship between form and function in Francés cosmology, were indeed put back as opposed to the problematization of modes of behavior.[38] Then again, the discourse about homeostasis, self-organization and pattern recognition moves system-boundaries and with it surfaces to the center of attention.

But one thing at a time: From 1960 to 1966, the US-Air Force research division organized four big *Bionics*-Symposia.[39] At the first meeting, the chairman of the conference, Jack Steele, explained the goal of *Bionics* as follows:

> Apparently we are going to design devices and systems, which to

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MIT School of Engineering Vannevar Bush. The University of California established a new engineering school in 1944 that offered a special program in "biotechnology", outlined by the head of the new school L.M.K. Boelter who envisioned "engineering as an unified whole", Bud, *Biotechnology*, 86-92.

[37] Ronald Kline, *Cybernetics in Crisis: Reviving and Reinventing a Postwar interdiscipline in the United States*, unpublished manuscript.

[38] Norbert Wiener, Julian Bigelow and Arturo Rosenblueth, "Behaviour, Purpose and Teleology", *Philosophy of Science* 10 (1943): 18-24. ["Funktionale Relationen"]

[39] The presented papers were published in four volumes: Joan Robinette (ed.), *Bionics Symposium. Living Prototypes. The Key To New Technology* (Dayton: WADD Technical Report 60-600 1960); Eugene E. Bernard (ed.), *Biological Prototypes and Synthetic Systems. Volume 1: Proceedings of the Second Annual Bionics Symposium*, (New York: Plenum Press 1962); Anonymous (ed.), *Bionics Symposium 1963. Contributed Paper preprints* (Ohio: WADD Technical Reports 1963); Hans Oestreicher and Darrel Moore, Darrel (ed.), *Bionics Symposium 1966: Cybernetic Problems in Bionics* (New York: Gordon and Brech Science Publishers 1966).

> the naive observer might appear to be alive. They will employ processes and techniques and accomplish functions, which hitherto have existed only in living systems.[40]

Composed of the Greek syllable "βίον" (= life form) and the English adjective ending "ic", the neologism "Bionics" was thought to signify a new universal science and finally to guide the way toward a transdisciplinary unification of biology, mathematics and engineering.[41] On the side of the military, such unification was expected to *first of all* enable a direct and productive incorporation of biology into the scientific-academic-military complex and *secondly*, to engender new 'biological' approaches to mastering the growingly complex military technologies.[42] According to Jack Steele's assessment in his closing remarks, it is crucial—in addition to the education of young engineers in the new field—to have "gadgets" available as soon as possible, which could demonstrate the potential of the new science by presenting simple solutions. As accepted products of *Bionics*, such "gadgets" were thought to generate a high degree of acceptance and support.[43]

One attendant of the first symposium was the Austrian Heinz von Foerster. The physicist had the intention to adopt the model of biological-mathematic

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[40] Jack E. Steele, "How Do We Get There?", in Robinette, *Living Prototypes*, 487-490: 487.

[41] Chris Hables Gray, "An Interview with Jack E. Steele", *The Cyborg handbook, ed. by idem* (New York: Routledge 1995), 61-69: 62.

[42] At the Symposium John E. Keto from the *Wright Air Development Division* identified two major areas of technological problems that the Air Force was currently facing and for which the new science of Bionics was expected to offer better solutions. The first area belonged to the field of information, where Keto saw "tremendous data processing problems" caused by "highly complex weapon systems" and an "extremely close coupling of man and machine". By outlining the second area of potential application Keto referred to the efficiency in nature: "Military equipment and weapon systems are plagued with major problems of size, weight and operative power requirements. These pressures increase on an exponential scale … Bionics has a tremendous potential payoff in this area when you appreciate the extreme compactness, very low comparative weight and power requirements of living prototypes", John E. Keto, "Bionics. New Frontiers of Technology through Fusion of the Bio and Physio Disciplines", Robinette, *Bionics Symposium* 1960, 7-12.

[43] "Some simply consider the task too difficult and all effort wasted. The answer is unceasing education and explanation, and gadgets, simple solutions, soon delivered. Identified as the offspring of bionics they will bring honor and support to their parent and make the greater achievements possible", ibid., 490.

research with a soldering iron in hand, for his newly founded *Biological Computer Laboratory* at the University of Illinois at Urbana Champaign.[44] Foerster understood *Bionics* to be the logical continuation and extension of the encompassing and unifying aspirations of cybernetics:

> Bionics extends a great invitation to all who are willing not to stop at the investigation of a particular function or its realization, but to go on and to seek the universal significance of these functions in living or artificial organisms.[45]

And, with the experience of five years of Bionic practice at his BCL at Illinois, he described the future perspective of the new field as follows:

> Bionics characterizes an activity – or a point of view – which insists that attempts to synthesize biomorphic functions such as habituation, adaption, perception, recognition, cognition, recall, learning abstraction, conceptualization, association, induction, ideation, appetition, awareness, consciousness, self-repair, self-reproduction, growth, evolution, self-organization, etc., etc., will not only aid the analytic studies of these functions in living organisms, but also will eventually provide us with operational definitions of these terms.[46]

Foerster conceived of this interplay of analysis and synthesis as a cybernetic control loop (Figure 4). The observation and analysis of a biological organism, the "living prototype," would thus allow for a formalization of universally valid principles that could be recorded on the technical level in the course of the construction of artificial systems. Finally, a comparison of an artificial and an organic system would in turn augment the biological analysis and thus deepen the understanding of fundamental operating principles, and so on.[47]

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[44] Albert Müller, "A Brief History of the BCL. Heinz von Foerster and the Biological Computer Laboratory", in *An Unfinished Revolution? Heinz von Foerster and the Biological Computer Laboratory BCL 1958-1976*, ed. by idem and Karl Müller, (Wien: echoraum 2007), 279-302.

[45] H. v. Foerster, "Preface: Bionics", in: Robinette, *Bionics Symposium,* 1-3.

[46] H. v. Foerster, "Bionics Principles: A summary", in: *NATO Advisory Group for Aerospace Research and Development*, edited by R.A. Williams, 1-11. Bionics Lecture Series XX Vol.1, Paris 1965.

[47] "Comparison with the living prototype may either reveal the significance of certain organizational features in the prototype – i.e., aid in the analysis of living organisms –

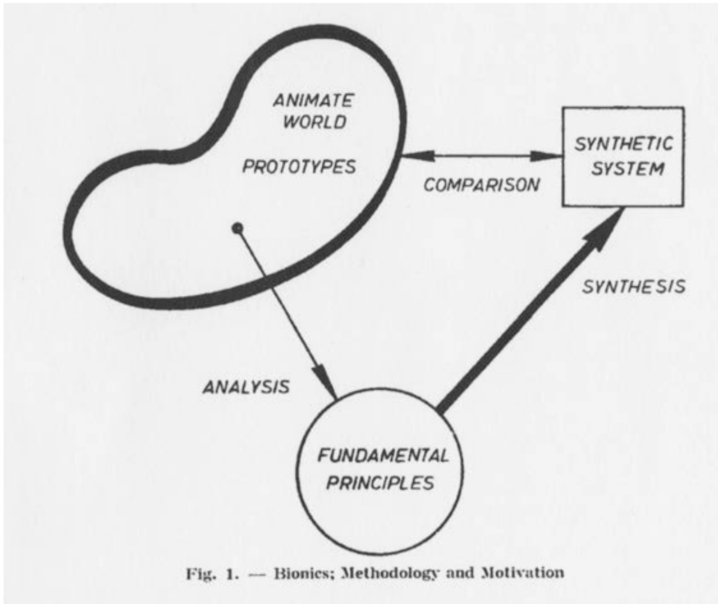

Figure 4 – Methodological Circle of Bionics (Foerster, *Bionic Principles* 1965, 2)

It is initially noticeable that the epistemologically relevant natural processes were entirely different for Foerster than they were for Raoul Francé; i.e. perception, cognition and learning, instead of spreading, screwing or cranking. And, since the military-academic-industrial complex of the 1960s would rather request information-processing systems such as radar- and computer-technologies, the research practice at the BCL would deal with *lively surfaces* very different form sharkskin and gecko feet: the *NumaRete* for example, an artificial cognition machine modeled after the retina of a frog, was thought to reproduce the 'natural' phenomenon of pattern recognition. The basis of the machine's construction plan came from the neurophysiological frog experiments by Humberto Maturana and Jerome Lettvin, who, in the late 1950s, published an essay with the central claim that for vertebrates a lateral connectivity of neurons in the retina already prompts an intelligent pre-interpretation and computation of visual stimuli before they reach the brain.[48] The frog-machine *NumaRete*, which was constructed at the BCL, would—as Foerster tirelessly pointed out—adopt the 'natural algorithm' of the faunal retina and operated according to the same, simple 'fundamental

or detect redundancies in either artifact or organism whose presence may be justified by considerations that are beyond the original task", ibid., 2.

[48] Jerome Lettvin et al, "What the Frog's Eye Tells the Frog's Brain", in: *Proceedings of the Institute of Radio Engineers* 47 (1959), 1940-1951.

principle' of retinal connectivity. Just as the frog-eye from the experiment could recognize small, agile points ('flies') and large shadows ('birds') immediately, *NumaRete* could display the number of objects sitting on its artificial retina, thus baffling the visitors on a regular basis because of this seemingly intelligent capacity (Figure 5).

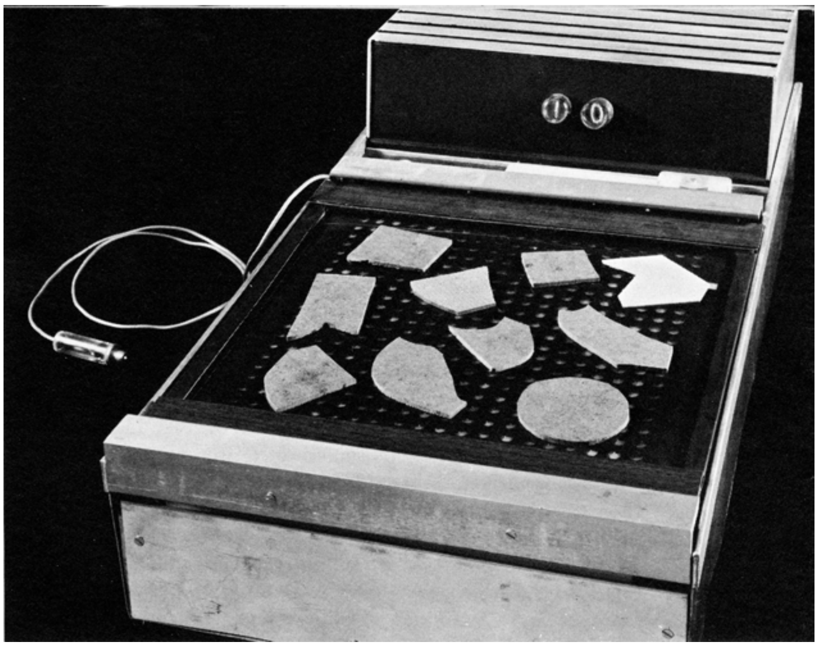

Figure 5 – *NumaRete*, an artificial retina by Paul Weston (Halacy, *Bionics* 1965, 113)

Drawing on the example of BCL's machine models,[49] I want to briefly mention two more fundamental characteristics shared by all products of *Bionics*: First, despite the holistic rhetoric regarding an immediate access to principles of natural form and function, bionic machines are screwed and soldered together by engineers, they are *constructions*. In order for the prototypes to credibly attest to the fundamental research paradigm, *Bionics*-Engineers have to improvise, explore alternative options or adapt or translate their knowledge of biology to the task at hand. Instead of simply following the 'blueprints of nature,' they always operate in an uncertain space of possibilities between improvisation and compromise, and they can only implement those solutions that are feasible regarding the

[49] For a more detailed discussion of the *NumaRete* see Jan Mueggenburg, "Lebende Prototypen und lebhafte Artefakte: Die (Un-)Gewissheiten der Bionik", *Ilinx. Berliner Beiträge zur Kulturwissenschaft* 2 (2011), 1-20.

availability of tools and materials.[50] Secondly, Bionic artifacts are in fact *lively artifacts* in the sense that they always develop their own certain epistemic dynamic beyond their characteristic as mimetic objects. Accordingly, what is meant by *lively* is the effect that creates itself mainly aesthetically and aims towards the mediation of appearance and animacy. This effect of liveliness is a function of the knowledge of the subject interacting with these artifacts. Based on this ability to create bafflement, curiosity or enthusiasm with the interacting observer, lively artifacts seem to be visual arguments *in favor of* efficiency, elegance or of the sustainability of biotechnical solutions. I.e., they stabilize the discursive formation of which they are a product and further develop it by actively advancing the process of generating discourse.[51]

4. Cacti and the self-cleaning effect

In the late 1960s funding for Cybernetics as a universal meta-discipline in the US declined, when its former military and foundational supporters started to lose interest in research under the Cybernetics label. While a few societies that were founded during this crisis continue to spread some elements of the Cybernetic heritage up until today (most prominently the *American Society of Cybernetics* and the *Society for General Systems Research*),[52] members of the second generation of cybernetic researchers such as Foerster ultimately failed to successfully institutionalize their discipline in the long term.[53] Alongside this development enthusiasm for *Bionics* in the US also started to fade away and the biomimetic approach was absorbed in specialized fields such as *Biomechatronics* or *Biomedical Engineering*.

In contrast to the decline of Cybernetics in the US, *Kybernetik* became a highly fashionable science in the Federal Republic of Germany in the 1960s and

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[50] In retrospect, Paul Weston, the maker of the NumaRete, compared his device to a Rube Goldberg-Machine, an overengineered machine that performs a comparably simple task, cf. Jan Mueggenburg, "Kybernetik in Urbana: Ein Gespräch zwischen Paul Weston, Jan Mueggenburg und James Andrew Hutchinson", *Österreichische Zeitschrift für Geschichtswissenschaft*, 4 (2008), 126-139, 129.

[51] For the concept of *lively artifacts* see Jan Mueggenburg, "Lively Artifacts", Feedback (Open Humanities Press 2013), accessed March 31, 2014. http://openhumanitiespress.org/feedback/science-technology/lively-artifacts/

[52] Kline, *Cybernetics in Crisis*, 20-28.

[53] A. Müller, "The End of the Biological Computer Laboratory", in: id./Müller, *Unfinished Revolution,* 303-321.

early 1970s.[54] It was far more successful in establishing professorships, research institutes and collaborative research centers than its American mother-discipline ever was. Although it is important to note that Kybernetik in Germany has its own idiosyncratic and in parts independent genealogy, protagonists of this new boom around the 1970s adopted many of the research topics from their American colleagues. When by the end of the 1960s a search commenced in order to find a concept that would *firstly* pool the many, from an economical perspective less successful cybernetic initiatives and that would *secondly* grant further subsidies, *Bionik* was selected as an umbrella term: “Its explicit proximity to practical application permitted to expect the very economical innovative strength that cybernetics could have never offered.”[55] The federal ministry for scientific research consequently initiated a large-scale development program called *Bionik* in 1969 that involved multiple institutions and that resulted in the foundation of societies, journals, and expert committees for a German *Bionik*. The implementation of the worldwide first chair for *Bionik und Evolutionstechnik* at the TU Berlin (Ingo Rechenberg, Engineer) and a course of study for “*Bionik* and technical biology” at the University of the Saarland (Werner Nachtigall, Biologist) followed. It is noticeable in this regard that the attempts to justify the old idea of biotechnics on the basis of evolutionary theory grew stronger. That is that ‘natural selection’ cannot only be interpreted as the further development and the emergence of new species, but also as a continuous process of optimization of technical developments and improvements. The tentative climax of the *Bionik*-movement in Germany was the implementation of the *Bionik*-network of excellence BIOKON in 2001, initially funded by the German Federal Ministry for Education and Research (BMBF) and by the German Research Foundation (DFG) since 2006. According to its website the network aggregates more than 70 academic and nonacademic national and international facilities and represents university institutes as well as private corporations. Much like its holistic-systemic predecessors it continues to nurture the hope for “sustainable and resource-conserving technologies” to this day and aims to harmonize nature, men, technology and economics (Figure 6).[56]

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[54] Philipp Aumann, *Mode und Methode: die Kybernetik in der Bundesrepublik Deutschland* (Göttingen: Wallstein 2009), 307-314.

[55] Ibid., 307. [“Ihre explizite Anwendungsnähe ließ jene wirtschaftliche Innovationskraft erwarten, die die Kybernetik nie hatte liefern können.”]

[56] BIOKON – Network for the Future, last accessed June 13 2014, http://www.biokon.de/en/.

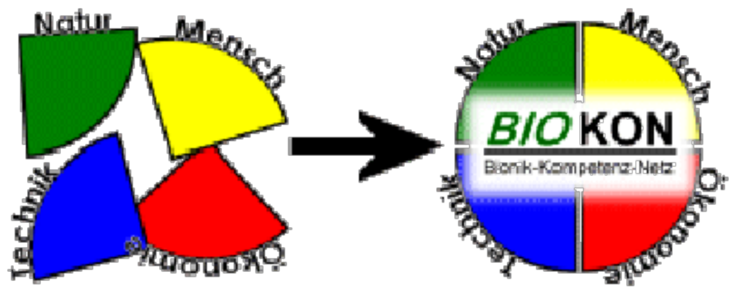

Figure 6 – Illustration from the BIOKON-Website (www.biokon.de)

Although *Bionik* was thus successfully institutionalized, and although it could revert to widely spread personal networks and generous subsidies from economy and politics, researchers in the field still tend to present their products as the result of individual discoveries. With regards to Francé's poppy seed shaker, the tale of the lotus effect for example, sounds all too familiar: It does not begin with a widespread bionic research program, but with a sole botanist and his microscope.

Wilhelm Barthlott's taking notice of the self-cleaning effect of certain phyto-surfaces in 1977 was not the result of a large-scale search, but it happened by proxy of taxonomy and systematics.[57] Barthlott was one of the first botanists, who intensively devoted himself to the scanning electron microscope (SEM) and who wanted to fathom the limits of his discipline in the nanometer-scope of the visible. As early as in his dissertation in 1972, Barthlott tried to resolve questions of taxonomy and phylogenetics by means of the new technologies in his area of expertise—viz. epiphytic cacti—by comparing and relating to each other the microscopically enlarged fine structures of their surfaces. "The scanning electron microscope," Barthlott later remembers, "revealed an almost inexhaustible and a difficult to imagine multitude of complex structures to the biologists."[58] Five years later, Barthlott chaired a project financed by the DFG, in which his method was thought to be applied to other representatives from the subsection of

[57] Wilhelm Barthlott, Nesta Ehler, *Raster-Elektronen-Mikroskopie der Epidermisoberflächen von Spermatophyten* (Wiesbaden: Steiner 1977).

[58] Zdenek Cerman, Wilhelm Barthlott and Jürgen Nieder, *Erfindungen der Natur – Was wir von Pflanzen und Tieren lernen können* (Reinbek: Rowohlt 2005), 36. ["... die Raster-Elektronenmikroskopie offenbarte den Biologen eine schier unerschöpfliche und kaum vorstellbare Vielfalt komplexer Strukturen."]

spermatophytes. A central role was assigned to "surface sculptures" of the epidermal cuticle; that thin wax film, which abuts the external wall of the epidermal cell (Fig. 7).[59]

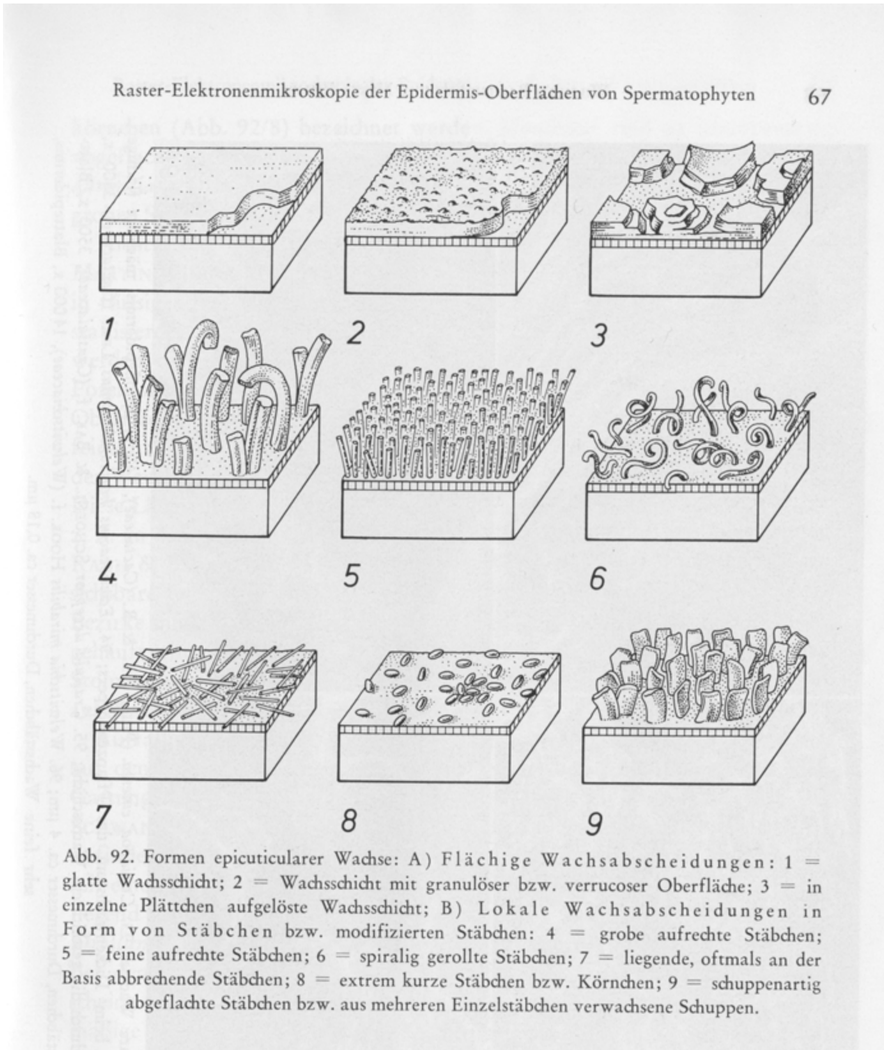

Figure 7 – Epicuticular Wax Structures (Barthlott, Epidermis-Oberflächen 1977, 67)

[59] Barthlott, *Raster-Elektronen-Mikroskopie der Epidermisoberflächen*, 1977, 35-71. ["Oberflächenskulpturen"]

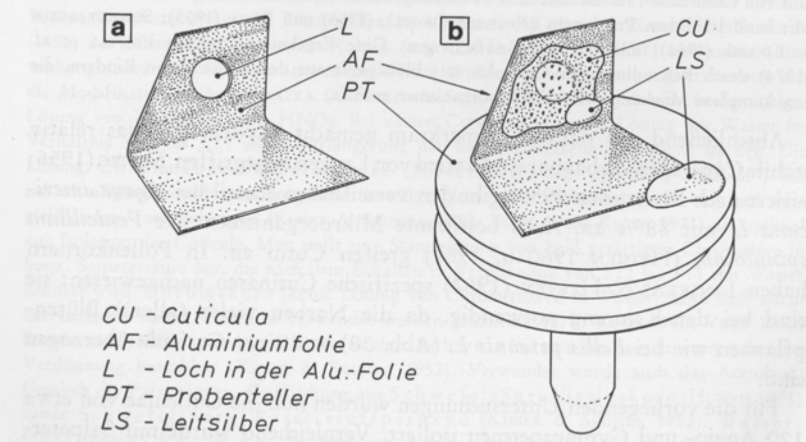

Abb. 5. Methode zum Aufziehen der isolierten Cuticula auf eine Aluminium-Lochblende.

(380)

Figure 8 – Prep. of Epidermic Samples (Barthlott, *Epidermis-Oberflächen* 1977, 18)

A first step of the elaborate preparation proceedings of epidermic samples for the SEM consisted now in cleaning the samples in an ultrasonic bath (Figure 8). And in doing so, as Barthlott reported in retrospect, he realized that some of them had apparently completed this task ‘themselves.’ Those were particularly such epidermic samples that featured especially complex folding patterns on their surface, that had highly hydrophobic surfaces based on their chemical composition and that furthermore exhibited especially complex epicuticular wax structures, such as rod cells, platelets, or granules. This combination, in conjunction with the water surface tension, lead to the ‘self-cleaning effect’ that was first named as such during the analysis in 1977. Epidermic surfaces of this kind did not only exhibit an especially low degree of “wettability”, but were also highly “unsoilable”.[60] Due to the epicuticular wax structures the contact area (and thus adhesion forces) between the epidermis and water droplets is significantly reduced so that the droplets do not spread out, but move along the surface as virtually perfect spheres even if the surface’s angle of slope is very small. If on its way across the surface, a water droplet encounters particles of dirt, the adhesion force between the particle and the droplet is higher than that between the particle and the surface and the particle simply ‘rolls off’ the leaf adhering to the droplet (Fig. 9).

[60] [“Benetzbarkeit … unbeschmutzbar”].

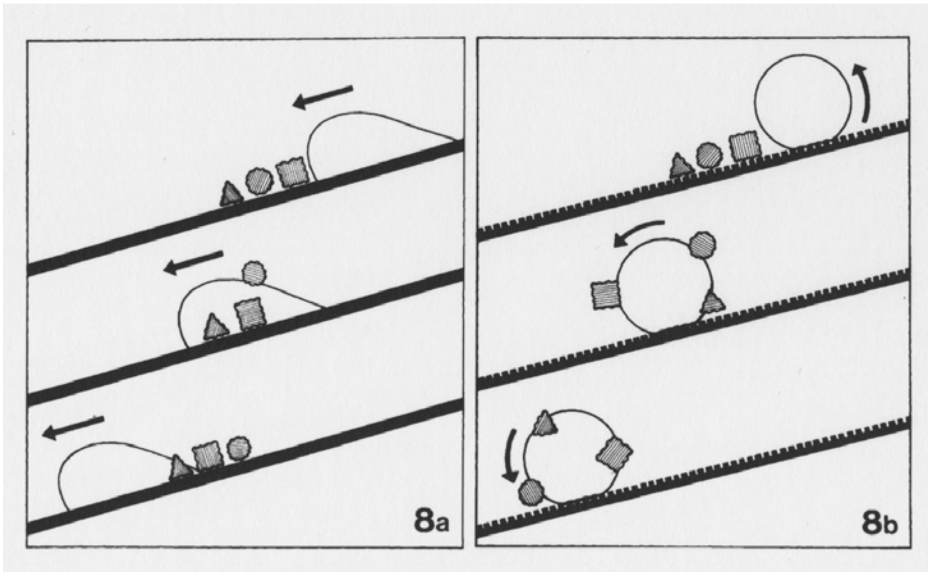

Figure 9 – "Diagram summarizing the connection between roughening and self-cleaning" (Barthlott/Neinhuis, *Sacred Lotus* 1997, 6).

Although Barthlott made his discovery of the self cleaning-effect as early as in the late 1970s, it took him ten more years before he started to think about potential applications. From 1988 on he talked to "well-respected and globally operating companies from the chemical sector", trying to convince them of the advantages the self cleaning-mechanism has against conventional methods of keeping modern surfaces clean.[61] When the industry showed little interest at first, Barthlott and his team reacted with a couple of measures: First of all, they decided to give their brainchild a new name: Whereas in the 1970s Barthlott had observed the self cleaning-effect in different kinds of cacti and plants (for example in cabbage and broccoli), he and his assistants picked the Lotus flower *Nelumbo nucifera* as their front- and figureplant to advertise what they now called the *Lotus Effect*®. Not only did the leaves of the lotus flower "afford and impressive demonstration of the effect",[62] its meaning "as a symbol for purity in Asian religions" made it the ideal choice.[63] As a next step Barthlott and his team—"even if we were

[61] Zdenek, Barthlott and Nieder, *Erfindungen der Natur,* 52. ["Renommierte und weltweit agierende Firmen aus dem chemischen Bereich"]

[62] W. Barthlott and C. Neinhuis, "Purity of the sacred lotus, or escape from contamination in biological surfaces", *Planta* 202 (1997), 1-8, 1.

[63] Zdenek, Barthlott and Nieder, *Erfindungen der Natur,* 33. ["… ein Symbol der Reinheit in asiatischen Regionen"]

Botanists"—started to build prototypes of self cleaning-surface on their own, had their 'invention' patented in Europe in 1996 and even registered the trade mark of the *Lotus Effect*®.[64] As Barthlott remembers, it was the "patent and the self developed prototypes" that finally caught the industry's attention and led to approximately 20 contracts of collaborations and a number of products; among them: Sto AG's LOTUSAN paint.[65]

5. Past Lives and Future Technologies

In his short essay on the so called telegraph plant *Desmodium gyrans*, media historian Stefan Rieger dealt with the phantasm of communicating plants and asserted, following Heidegger: "When the plant acquires a voice, a communication model speaks."[66] What Rieger means is that functionality in nature can only come into the picture in light of contemporary cultural techniques and theories. With this in mind, I want to conclude by contemplating on the question 'Who cleans a self-cleaning building?'—Or, in other words: 'What lives on in *lively surfaces*?'

Following an (admittedly bold) combination of all three perspectives of *Biotechnik*, *Bionics* and *Bionik*, the answer would probably be that in the course of evolution 'nature' has endowed certain types of plants with a 'functional' epidermis that employs an ideal solution to the problem of avoiding unwanted fungi or bacteria. The engineer can 'see' and eventually 'understand' the principle underlying this biological solution and 'transfer' it to the realm of technology. From this perspective the self-cleaning building as technological object would in fact be cleaning itself by applying this principle to the task of 'cleaning surfaces'. Consequently, to speak of an afterlife of biological systems in technological objects would be misleading. What lives in both *bios* and *techné,* according to this view, are *universal* principles that undermine the distinction between nature and technology and rather bear the implication of a whole and harmonious cosmos. The real question would then of course be, why the in*ter*vention of the engineer is necessary at all, or, to give this thought a sharper turn, why can *deficient solutions* to technological problems exist in the first place?

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64 Wilhelm Barthlott. 1996. Self-cleaning surfaces of objects and process for producing same. WO1996004123 A1, filed July 25, 1995, and issued February 15, 1996.

65 Ibid., 54. ["Erst die Patente und unsere selbst entwickelten Prototypen weckten schließlich auch das Interesse der Industrie"]

66 Stefan Rieger and Benjamin Bühler, *Das Wuchern der Pflanzen. Ein Florilegium des Wissen* (Frankfurt a.M.: Suhrkamp 2009), 67. ["Wenn die Pflanze spricht, dann spricht ein Kommunikationsmodell."]

However, as we have seen, biomimetic artifacts do accommodate afterlives of a very different kind. *First of all* the products of *Biotechnik*, *Bionics*, and *Bionik* involve cultural techniques such as the use of microscopes, drawing, writing and calculating. Thus, specific discursive and non-discursive factors determine what is being interpreted as 'lifelike' or 'inspired by nature' at a certain place and point of time. What lives on in *lively artifacts* is thus not the result of a clean and simple transfer from nature to technology, but rather perpetually undergoes complex processes of *translation*.

Second, all three historical manifestation of the biomimetic postulate seem to carry an epistemological bias towards visual evidence and persuasiveness. The analogy between the 'natural' and the technological solution is usually presented as a comprehensive and compelling argument, just like the juxtaposition of Francé's saltshaker next to the poppy seed capsules. In fact it can be said that *lively artifacts* are generally build for an audience, the impression of their liveliness being a function of the knowledge of the subjects observing or—for example in the case of the *NumaRete*—interacting with the artifact. It is precisely this bias towards visuality and persuasiveness that makes 'natural surfaces' like skins, coats or soles such an attractive starting point for biomimetic theory and practice.

Third, what lives on in *lively surfaces* is a *longue durée* of holistic and systemic thinking. Even if the proponents of contemporary *Bionik* occasionally name their historic predecessors such as Francé, they usually characterize them as exceptional and singular prophets while the ideological and pragmatic contexts of earlier attempts to promote the biomimetic approach are mostly neglected. On the contrary, each historical recurrence of the biomimetic postulate is presented as something new and revolutionary. As a sharp critique of modern technology and society it invokes the idea of an alternative way of harmonizing 'nature' and technology by reducing the human factor in the process of creating technological objects. However, as we have seen *Biotechnik*, *Bionics* and *Bionik* are in fact far from being actually non-modern sciences or practices. They rely on modern cultural techniques, involve human decisions and compromises and are embedded in the discursive networks of their times. In this regard, it rather seems that their proponents use the rhetoric of system theory and holism to *cleanse* their products from the 'aberrations' of modernity. Thus, what actually cleans a self-cleaning building can be called the paradoxical desire to escape modernity by modern means.

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Hear After: Matters of Life and Death in David Tudor's Electronic Music

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Abstract
In David Tudor's electronic music, home-brew modular devices were carefully connected together to form complex feedback networks wherein all components—including the composer/performer himself—could only partially 'influence' one another. Once activated, the very instability of mismatched connections between the components triggered a cascade of signals and signal modulations, so that the work "composed itself," and took "a life of its own." Due to this self-producing, perpetuating nature of his works, Tudor insisted on what he called "the view from inside," focusing more on the internal observation of his devices and sound than in materials external to the immanence of performance. When Tudor passed away in 1996, it became apparent that the sheer lack of resources outside the work—scores, instructions, recordings, texts—had made many of his music impossible to perform in his absence. The works that took a life of their own could not survive their composer's death partially because of his utter reliance on them to do their work. By connecting often mismatched resources obtained from extended research on Tudor, this paper presents modular observations that seem to offer certain perspectives on the issue of life and death surrounding Tudor's music. A comparison with developments in systems theory, most notably autopoiesis, outlines a mechanism for the endless life of sounds that compose themselves. Moving out of this theoretical reflection, a fieldwork report of an ongoing attempt to 'revive' some of Tudor's works is offered. This report demonstrates the observer shifting from one 'inside' to another—from an electronic circuitry inside a particular device, to a network composed of several devices, and further into the activation of a composite instrument. Meandering away from the archives, the composer's "view from inside" of his electronic devices is set side by side with recent insights of object-oriented ontology. A certain portion of this observation then feeds itself back to the perspective of autopoiesis, while others proceed to extract a distinct notion of 'life' out of object-orientation, this time in programming: an indeterminate 'waiting' time inherent in each 'object' that cannot be computed within a singular universal time. This latency embedded in objects that await activation correlates to the trajectory of the observer who is always in a transit from one 'inside' to another, finding different objects on each level of observation, and for whom, therefore, the delineation between life and death is always indeterminate. This view provides further explanation to the operative mechanism of Tudor's music, wherein mismatched components sought to activate and influence one another, constituting an 'electronic ecology' endowed with a life of its own, but filled with partial deaths. The paper thus observes ultimately a parallel between the composer's trajectory within his performances and that within his life, while attempting to reenact the complex nature of these said trajectories through the meandering manner of its own delivery.

Keywords
Electronic Music, Autopoiesis, Cybernetics, Object-Oriented Ontology

Cover Page Footnote
I am grateful to Ron Kuivila from Wesleyan University and Nancy Perloff from Getty Research Institute for kindly having accommodated my visits to their respective institutions.

Either one is alive or one is dead.

Niklas Luhmann

What is death for the beholder? What is death for the dying?

Humberto Maturana

1

The composer David Tudor passed away on August 13, 1996. Following his death, it quickly became apparent that a large part of his electronic music was gone with him. There were several works that he had passed on to other people—including *Rainforest IV* that members of 'Composers Inside Electronics' had been performing since the inception of the group following a summer workshop that Tudor led in 1973; or a later series of works employing the Neural Network synthesizer (*Neural Network Plus* and *Neural Synthesis*) that Tudor's then-assistant John D.S. Adams had learned from the composer just before his death. But the majority of Tudor's idiosyncratic compositions seemed utterly impossible to perform in the absence of the composer, who was their primary, and most times the only, performer. The evident obstacle was the sheer scarcity or utter lack of all the vicarious, primarily textual, materials that usually stand in as more stable proxies for the ephemerality of sounds—scores, instructions, descriptions, interviews, articles, and recordings. It was as if Tudor had deliberately restrained the production of materials external to his music. There were objects—a large number of instruments made by the composer and other people—but they remained esoteric (particularly to musicologists) and mostly inoperative. The only way to proceed seemed to carefully connect the limited and often mismatched resources together to form a chain of observation.

Tudor had turned himself into a composer of electronic music in the mid-1960s, after almost two decades of a remarkable career as the most virtuosic pianist of post-war experimental and avant-garde music. He worked closely with prominent composers at the time, such as Pierre Boulez, Karlheinz Stockhausen, Christian Wolff, and most notably, John Cage. Tudor as a performer was reticent, being inside the works of other eloquent composers who were more than happy to do the talking. But even after he started composing, Tudor refrained from writing or talking about his works. This ostensible quietness is often described as pertaining to the composer's nature by people who knew him: "It was very much David's nature; other people would talk about doing stuff, but David would do the stuff."[1] Nevertheless, in the few occasions where he did talk about his works, Tudor also talked about why they needed no talking about them. In *Bandoneon!* (1966), his first substantial effort as a composer, Tudor used the instrument in the title, both as a sound source and as an interface to activate the distribution and modulation of sounds, switching of loudspeakers and lighting, as well as the projection of visual images by Lowell Cross. The program note claimed that the work, "when activated, (…) composes itself out of its own composite instrumental nature."[2] For *Rainforest* (1968-76), Tudor set out to build "an orchestra of loudspeakers, each speaker being as unique as any musical instrument,"[3] by attaching audio transducers onto various physical objects. The composer thought this "was a nice piece because it would teach itself."[4] It was as if these works, left to their own devices, took care of themselves, rendering all external language unnecessary and irrelevant. Or, in Tudor's own concise explanation: "it is they who are doing it."[5] Tudor's unwillingness to talk or write about his works was in this way partially conditioned by the very nature of the same works.

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To describe in a generic manner, the nature of Tudor's music was based on modular electronic devices connected in chains to form complex feedback networks. Once activated, a signal would be distributed throughout the network, passing through various gain stages, filters, and modulators, before being fed back to repeat the process over and over again. The multiple channels of signals would be transduced and output from loudspeakers at different points of the network. These loudspeakers were often distributed across the space to particularize the perception of sound at a given location. The output sounds could then be fed back once more into the electronic circuitry either through microphones (acoustic feedback), or via Tudor the performer who would decide on his next maneuver based on what entered his ears. Not that accurate control was possible, for

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1 Phil Edelstein, Interview by author, Long Island, NY, November 19, 2011.

2 David Tudor, "Program Notes for Nine 'Evenings (1966)," Los Angeles: David Tudor Papers, Getty Research Institute, Box 3.

3 David Tudor and John David Fullemann, "'…performing is very much like cooking: putting it all together, raising the temperature' (May 31, 1984, Stockholm)," http://davidtudor.org/Articles/fullemann.html (April 1, 2014).

4 David Tudor and Matt Rogalsky, "Interview with David Tudor by Matt Rogalsky (March 28, 1995, Tomkins Cove, NY)," http://davidtudor.org/Articles/rogalsky_inter2.html (April 1, 2014).

5 David Tudor, "Note (circa 1975?)", Los Angeles: David Tudor Papers, Getty Research Institute, Box 19.

indeterminacy permeated Tudor's system on multiple levels. The sheer complexity of the circuitry based on parallel channels of feedback exceeded the capacity of the human performer to fully predict or control its behavior. As Tudor recounted, referring to his realization of Cage's *Variations II* (1960), in which he implemented electronic amplification to his piano constructing one of the earliest examples of an instrumental system based on complex feedback—"you could only hope to influence the instrument."[6]

A similar relationship based on indeterminacy also existed between the components themselves. Tudor often neglected the usual practice in the building of modular synthesizers to match the voltage or impedance between devices to ensure the clarity of signals.[7] Instead, he deliberately mismatched his components to obtain additional layers of noise/signal, describing the resulting relationship among components with the same verb he used to address the relationship between himself and them: "with a synthesizer you match up each component with the next one, so that each input can handle the previous output. I found out that if the components don't match, then the one component is able to *influence* the next, so that signals are created at many points within the circuit"[8] [emphasis added]. The whole network was thus carefully put together so that all components—including the human performer—could partially 'influence' one another, without any taking over universal control. Once activated, the very instability of partial connections within the feedback network incited oscillations of diverse character, triggering a cascade of signals and signal modulations.[9] The

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[6] Ray Wilding-White, "David Tudor: 10 selected realizations of graphic scores and related performances (1973)," Los Angeles: David Tudor Papers, Getty Research Institute, Box 19.

[7] "Every time I've had to use the synthesizer, or a synthesizer component, I had something outboard to it that then would change the way it operates. It's mostly because all the considerations of the voltage, you know, where voltage needs to correspond to what the output signal level is—that's all coordinated. And if you manage to uncoordinated that, then you are in a completely different position" (David Tudor, "Workshop with students at Mobius, Boston, September 29, 1985," Los Angeles: David Tudor Papers, Getty Research Institute, Box2A, C75).

[8] David Tudor, "From Piano to Electronics," *Music and Musicians* 20 (August 1972): 26.

[9] For a more detailed and specific account of how Tudor's compositions operate, see Ron Kuivila's description of *Untitled: Homage to Toshi Ichiyanagi* (1972) (Kuivila, "Open Sources: Words, Circuits and the Notation-Realization Relation in the Music of David Tudor," *Leonardo Music Journal*, Vol. 14 (2004): 17-23). Upon a closer observation, Tudor's trajectory also reveals a certain shift in the nature of his works around the mid-1970s. His initial exploration into the electronic generation and modulation of sounds through feedback with no external input resulted in a proliferation of devices, which presented two problems: the sheer controllability of the composite instrument (the

composition, in other words, composed itself from within.

What is heard as music to the human ear is the sonic expression of these multiple components 'influencing' (or, hoping to influence) each other, both in space, and within the circuitry. And following the composer's own wording—as when he explained how with the instrumental loudspeakers of *Rainforest*, "the objects should teach you what *it* wants to hear"[10] [emphasis added]—the action on the receiving end of this chain of influences could be portrayed as 'listening,' or 'hearing.'[11] In Tudor's music, the human listener listens to components

degree of influence, so to speak), and its portability for tours with the Cunningham Company. As Tudor recalled, "I came to a situation where my hands were completely tied to the performance trying to do the generation," but on top of that, "I couldn't take four suitcases of equipment" (Tudor, "Workshop with students at Mobius, Boston, September 29, 1985"). The composer's solution to this double predicament was simple yet effective. He recorded the output of sound generation, and in performances used this recording as source material to be processed through a much more simplified circuitry. But this tactic had a significant side effect: it triggered Tudor to shift his focus from sound generation to modulation of pre-recorded sound sources. From the late 1970s, Tudor's music leaned towards the use of pre-recorded sound materials that went through multiple, parallel modulating channels—consisting mostly of noise gates, pitch shifters, various filters, and so on—which were then output from multiple speakers. Despite this change of focus narrated by the composer himself, it is my view that Tudor's general approach remained basically coherent. Just as the initiating signal that triggers the process of oscillation in a no-input setting cannot be determined in advance, nor it matters what its nature is, the properties of sound material to be processed was secondary to the processing itself: "it wasn't important which take it [sound source] was, it wasn't important where the take started, it just meant you had to have something to generate the process" (Tudor, ibid.). Whether external input was used or not, Tudor's focus was always on the behavior of the overall network of his components (moreover, the use of pre-recorded sound material had already appeared in *Pepsibird* and *Anima Pepsi* from 1970).

10 David Tudor and Matt Rogalsky, "Interview with David Tudor by Matt Rogalsky (March 28, 1995, Tomkins Cove, NY)," http://davidtudor.org/Articles/rogalsky_inter2.html (April 1, 2014).

11 The use of the verb 'listening' to address the workings of electronic devices has a long history in electronic music, and was already in use among some of Tudor's collaborators as can be seen in Gordon Mumma's wording that appears later in this paper. For a general survey of (more recent) musical systems that 'listen,' see for instance: Robert Rowe, *Interactive Music Systems: Machine Listening and Composing* (Cambridge, MA: MIT Press, 1993). As demonstrated in Rowe's title, the crucial point in the application of this verb to non-human devices is in its strict coupling with the ability to *respond* to what is 'listened,' in a complex, nonsingular (indeterminate) manner, and hence to 'interact' with the human performer accordingly. This acknowledgement of 'listening' via the observation of consequent response, or more

influencing and listening to each other—"it is they who are doing it." And when they did what they did, Tudor saw them as springing to life: "there is a point where a certain sound-world or a certain color conception can appear, an electronic set up that's hooked together with a certain idea. And all of a sudden you realize that it has a life of its own."[12] Similar observation employing the same wordings was even adopted by other composers to account for Tudor's music: "With David Tudor," Cage stated in 1987, "the components, the circuitry is the music, and it comes alive when it is performed."[13]

This attribution of 'life' to Tudor's music had one peculiar consequence: his performances were notoriously never-ending. For how could something that springs to life and composes itself once activated, end? Whenever Tudor performed with the Merce Cunningham Dance Company, which he regularly did throughout his career, it was customary for him to abruptly halt the music when the choreography reached its end. Matt Rogalsky recounts another anecdote demonstrating that finishing was not Tudor's concern: "at a Mills College concert in the late 1960s, (…) Tudor is said to have been cautiously questioned as his performance showed no signs of coming to a conclusion, while the hour was growing late: his response was to stand up and abruptly turn off the sound, with the comment 'I still had lots to do'."[14] It was this seeming indifference towards endings that took an ironic turn after 1996. The dedication to the immanence of performed life correlated to a certain disregard for the time and materiality outside the living present. The works that took a life of their own and knew no end in performances thus seemed to accompany the fate of their creator—who was also

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accurately, via the perception of a nonlinear relation between input and output, connects to the tendency of programmers to observe subjectivity and affect in programming objects through their indeterminate 'waiting,' that will be discussed in section 9. It also extends, therefore, to the use of 'listening' based on 'cues' in the works of Christian Wolff, as described in footnote 42. The only non-electronic piece in the repertoire of 'Composers Inside Electronics' was Wolff 's *Changing the System* (1972), which Phil Edelstein from the group described as "a school for listening" necessary for performing Tudor's *Rainforest*: "that was the training ground, to a certain extent. And you know, David was never quite explicit about that as Pauline (Oliveros), or Christian was, but it was there, you had to be able to do it" (Phil Edelstein, Interview by author, Long Island, NY, November 19, 2011).

[12] David Tudor and Teddy Hultberg, "'I smile when the sound is singing through the space': An Interview with David Tudor by Teddy Hultberg (May 17-18, 1988, Dusseldorf)," http://davidtudor.org/Articles/hultberg.html (April 1, 2014).

[13] John Cage and Bruce Duffie, "Composer John Cage: A Conversation with Bruce Duffie (June 21, 1987)," http://www.bruceduffie.com/cage.html (April 1, 2014).

[14] Matt Rogalsky, "'Nature' as an Organising Principle," *Organised Sound* 15-2 (2010): 134.

the single component within the system responsible for initiating its activation—when *his* life came to an end.

3

Almost two decades have passed since the composer's death. When the current observer looks back from his viewpoint outside the immanence of Tudor's performances, the idea of creating compositions that compose themselves through chains of feedback conceived circa mid-1960s appears comparable to contemporary developments in cybernetics or systems theory in general. Tudor spoke nothing about it of course, and none of his notes show any interest in this regard. Discourses of cybernetics therefore seem to have laid *outside* the composer's concern. But they were certainly in the environment, and Gordon Mumma, a colleague musician from the Cunningham Company who worked on several projects with Tudor and built him several instruments, was well aware of the parallel. 'Influenced' by cybernetics, Mumma coined the term 'cybersonic' to address his self-built instruments from which he composed music that operated on feedback principles. For instance, in *Hornpipe* (1967), a cybersonic console attached to the hornist "listens (with microphone)" [15] and analyzes the resonances of the performance space from the sounds of the horn, creating an electronic analog of the same resonant characteristics. This "map of [the space's] resonant spectrum"[16] is later sent out from the loudspeakers once a certain threshold has been attained within the circuitry. Mumma described this process as a three-fold interplay between the human performer, the cybersonic console, and the 'personality' of the auditorium.

But both Tudor and Mumma went beyond the naïve premises of cybernetics. For at the core of their systems were factors of noise and indeterminacy that distorted any intention for regulated control of its operation. Sound was generated and modulated via the very failure of cybernetic control. The human composer-performer was accordingly seen not as a privileged observer who oversees the entirety of the composition but as a local component within the system; and machines, contrary to the cybernetic perspective, were no longer regarded as mere 'servo-mechanisms.' "If we admit of [sic] musical performance as social intercourse," Mumma wrote in his 'Notes on Cybersonics' in 1970, "then we may include the varieties of artificial intelligence in our musical ensembles: not merely for their sophistication and speed, but also for the contribution of their personalities. We may treat the artificial intelligence not as a

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[15] Gordon Mumma, "Notes on Cybersonics: Artificial Intelligence in Live Musical Performance," Los Angeles: David Tudor Papers, Getty Research Institute, Box 38.
[16] Mumma, ibid.

slave, but as a collaborative equal in a democratic musical society."[17] This egalitarian view on machines and humans inside a musical system resembles not cybernetics, but 'cybernetics of cybernetics' that Heinz von Foerster and others were articulating circa 1970.[18] Contemplating on the role of the observer who inevitably enters and affects the operation of the system itself, von Foerster formulated the cybernetics of 'observing systems' as opposed to that of 'observed systems.' But the attribution of 'personalities' to electronic components (as well as the concert space), adds a further twist to this second-order cybernetics, by distributing the capacity for distinct observation (and listening) to all the components of the system. Not only the observer is included within the system, but his position is no longer stable nor singular since the other components return their gaze to him.

4

The difference between the observations of the observer and the system itself was theorized by one idiosyncratic theory of living systems that was developed in close relation to second-order cybernetics by Chilean neurophysicist and biologist Humberto Maturana and his former student Francisco Varela in the early 1970s: Autopoiesis. A simple observation formed the basis of their approach to living systems: there is always a gap between what an observer says about a system and the constitutive organization of the system itself. When this difference is thoroughly pursued, many characteristics endowed to living systems in previous theories are revealed to exist only inside the perspective of the observer and his domain of description. From here, Maturana and Varela made a radical move to dispense altogether with the perspective of an exterior observer. The list of things they excluded from the organization of living systems runs long: teleology, function, development, time, and even the notion of input and output of systems. When seen from its own standpoint, the operation of a living system is a closed network of processes of production (transformation) of components that produces the components that continuously regenerate the network of process that produced them—once activated, it might be added. Maturana and Varela stick to the forefront edge of the production process, describing happenstances only as they emerge and letting them go without retaining them in time: "the organism always behaves in the present."[19] The actual, physical components, along with the static,

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[17] Mumma, ibid.

[18] See for instance: Heinz von Foerster, et al. eds, *Cybernetics of Cybernetics* (Urbana, IL: University of Illinois, Biological Computer Laboratory, 1974).

[19] Humberto Maturana and Francisco Varela, *Autopoiesis and Cognition: The Realization of the Living* (Dordrecht, Holland: D. Reidel Publishing Company, 1980), 24.

spatial relations between them—which autopoiesis calls ‘structures’—are mere products of the process of production, and not the other way around. Maturana and Varela claimed that this notion of autopoiesis was the necessary and sufficient to characterize living systems.[20] It was not only that living systems are autopoietic, but any system that is autopoietic, is living.

Only a small adjustment is necessary and sufficient to describe Tudor’s compositions that compose themselves as autopoietic systems, and thus as living: to regard not his instruments, but the sound/signal they produce through their listening processes, as components of the system. For the instruments, after all, are already composed and composited before the concert. What becomes spontaneously composed in performance is a processual network of generation, transformation, and perception of sound/signals that produces the sound/signals that continuously regenerate the same network. The perpetual life of listened sounds and sound listening forms a topological closure that can neither be reduced to the architectural space where the concert is held, nor to the physical configuration of instruments.

Contrary to Maturana and Varela’s attempt to exclude any trace of an external observer in accounting for systems, however, the existence of an autopoietic system depends largely on what the observer defines as the ‘component’ of a system. Rather than being an accurate description of living systems, the autopoietical approach is primarily a heuristic device. That is to say, the observer’s choice for what to describe as an autopoietic system is a choice, and therefore never neutral. The gain of connecting autopoiesis to Tudor’s music (or more accurately, to the account of his music) is not so much in what it enables, but in what it fails to explain. Maturana had begun his introduction to the book *Autopoiesis* with a poem that the biologist wrote when he was a first year medical student. The poem—which the author admits is “not a very good one”—starts by posing two questions: “What is death for the beholder?/What is death for the dying?” It ends with a single proposition: “And life without death is only emptiness.”[21] But the theory he developed as a scientist did not reflect his concerns as poet. Death is the ultimate outside of the autopoietic closure, strictly correlated to external observation. As far as system itself was concerned, it would simply live permanently until it did not. Life without death is a tautology and thus empty (of meaning), indeed: “Since the relations of production of components are given only as processes, if the processes stop, the relations of production vanish.”[22] Next to this issue of death (the impossibility thereof) was another, similarly ordinary phenomena that autopoiesis just could not describe: the

[20] Maturana and Varela, ibid., 82.
[21] Maturana and Varela, ibid., xi.
[22] Maturana and Varela, ibid., 79.

multiplicity of autopoietic systems that gather together to form an aggregate system. Maturana and Varela spent more than a decade trying to explain how an operationally closed living system which knows no outside or inside could find its other, and conjoin to form another system like itself without losing its autopoietic nature.[23]

The external observer can clearly see how these two conundrums of autopoiesis are coupled. For death and multiplicity are both phenomena that can only be observed from a view outside a given, singular living system. The multiplicity of systems is the multiplicity of exteriority from where an observer can account for their deaths. The autopoietic account of Tudor's music thus fails to describe the difficult yet inevitable ending of performances, as well as the difference between one work and another. For Tudor's music did reach a halt every evening and the composer always composed a new work. The question is never quite as simple as whether a system is autopoietic and thus living. The question is rather which system is to be described as autopoietic, when, and why. And the particularities of the answer necessarily pertain to an observer who is free to make that choice because he is free from the choices themselves.

5

In 1976, Tudor wrote a short manifesto-like text entitled "The View from Inside," for the program note of his concert with 'Composers Inside Electronics':

> Electronic components & circuitry, observed as individual & unique rather than as servomechanisms, more & more reveal their personalities, directly related to the particular musician involved with them. The deeper this process of observation, the more the components seem to require & suggest their own musical ideas, arriving at that point of discovery, always incredible, where music is revealed from 'inside,' rather than from 'outside.'[24]

The words which describe electronic components as non-subservient and the gaze that sees their personalities, accord well to Mumma's 'Notes on Cybernetics.' But

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[23] Niklas Luhmann solved this puzzle by simply regarding the social system as an entirely different autopoietic system whose components were not humans, but communication. Humans were not components of society, but rather formed its "environment." See for instance: Niklas Luhmann, "The Autopoiesis of Social Systems," in *Sociocybernetic Paradoxes: Observation, Control and Evolution of Self-Steering Systems*, eds. F. Geyer and J. Van d. Zeuwen (London: Sage, 1986), 172-92.

[24] David Tudor, "The View from Inside (1976)," Los Angeles: David Tudor Papers, Getty Research Institute, Box 19, Folder 11.

the topological trope here addresses the depth of observational process of circuitry, and not the immersion into sounds with a life of their own. This view from inside, in other words, is the view of the 'composer' who delves into his components to discover a new music through his observation, and gives a name to a particular musical idea to distinguish it from another. In this way, he produces a unity of 'composition' that cannot be reduced to the instantiations of its performed life. And as a composer he will indeed produce many of them throughout his life.

The earlier description of the nature of Tudor's composite instruments was generic. It was intended as such to form a correlative to the level of observation that saw the interminable life of sounds. But there is an 'inside,' located outside of the autopoietic process of production. And Tudor's observation of 'life' oscillated between these two insides. "There's always a certain point where the work that you do to realize these musical ideas, all of a sudden it has a life of its own, and that's the point where I decide that it's my musical composition. When it's living for itself then I feel, 'Okay, I can sign my name to that.'"[25] In a peculiar manner, the composer obtained a work that belonged to him at the very moment it left his hands. Then, relieved of his duty, the composer would become a performer within his composition that now lives for itself: "when the process is really living, I can set to work and not really worry about it"[26] But before this life is fully composed, the observer encounters components quite other than autopoietic sounds within Tudor's 'view from inside': electronic objects.

6

There are two primary archives for Tudor's materials. One is the David Tudor Papers at the Getty Research Institute (GRI) in Los Angeles, storing 177.5 linear feet of his paper documents which include sketches, schematics, notes, diagrams, letters, magazine cutouts, photographs, articles, recipes (Tudor was a virtuosic cook of Indian food), realization scores from his pianist days, as well as recordings from tapes that Tudor owned. The other is the World Instrument Collection at Wesleyan University which has assembled more than 500 of Tudor's electronic instruments and equipments.[27] These are a mixture of devices,

[25] David Tudor and Bruce Duffie, "Presenting David Tudor: A Conversation with Bruce Duffie (April 7, 1986, Chicago)," http://www.bruceduffie.com/tudor3.html (April 1, 2014).

[26] Tudor and Duffie, ibid.

[27] There was a significant amount of instruments at the basement of Merce Cunningham Dance Company, but these have been surveyed and transferred to Wesleyan in April 2012. The Cunningham Dance Company also holds a substantial amount of

many made by Tudor himself, some by others (including Gordon Mumma, John Fullemann, and John Driscoll), along with a large number of commercial equipments (mostly guitar pedals that the composer heavily used from the late-1970s onwards). Going back and forth between California and Connecticut, I have been conducting research with aims to 'revive' some of Tudor's works.[28] Inside each archive, one must switch back and forth materials on at least three levels to discern the operative mechanism of each composition: A) the individual instruments, B) the composite instrument formed by connecting multiple instruments, and C) the performance of it all. Different materials exist on each scale of observation, the details of which I am relegating to footnotes here.[29]

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documentation of their works over the years which include many of Tudor's compositions.

[28] This project, which began as a personal endeavor, is now coupled with a larger project led by John Driscoll from 'Composers Inside Electronics.' My investigation on the *Weatherings* material was initiated under this context, especially through exchanges with Phil Edelstein. I thank Driscoll and Edelstein for their generous support and encouragement on my research. I have chosen to limit my description to my own trajectory and findings in this paper, however, since the group project is quite diverse and still at its preliminary stages for me to give a generic account from my individual perspective.

[29] Some of important categories of documentation in the archives are as follows:

Rogalsky's List: As for the instruments at Wesleyan, there is a comprehensive list of devices that Matt Rogalsky painstakingly put together in 1999. The state of preservation differs greatly from one instrument to another: some are utterly dysfunctional, other still operative. Many of the custom-built devices remain unknown as to their function. Rogalsky's essential document compiles, whenever possible, the presumed function, designer, related composition, date, and a description for each device. It also includes a note on the sounds that came out when it was activated (though often times with no results, or just noise). For several relatively simple instruments, Rogalsky also wrote down their interior circuitry. Inside the Getty archives, a vast number of sketches for miscellaneous schematics exist, along with cutouts of articles from popular electronics magazines. My research has identified many of these as corresponding to the Wesleyan instruments.

Diagrams: Since the late 1960s when he started composing his own works, and throughout the next decade, Tudor created neat block diagrams for the connection of components. The difficulty with these diagrams is twofold. First, the components are marked by idiosyncratic symbols or with equally enigmatic acronyms. Secondly, the composer was known to constantly change his components from one performance to another, even when performing the 'same' piece. So not only the accurate identification of each component is questionable, the notion of identity is in itself an issue. But these two issues might be complementary: the level of abstraction attained by the unconventional symbols in the diagram is in a way a practical method to notate the variety of actual, physical components that can fill in that particular function. The true omission of these

Rather than giving a general description of the materials, I choose to offer a 'field report' drafted from the localized perspective moving inside the archives, with a focus on a singular piece.

Instigated by exchanges with John Driscoll and Phil Edelstein from 'Composers Inside Electronics,' I delve into the materials of *Weatherings,* a work from 1979, which accompanied Cunningham company's dance *Exchange*. A diagram showing the configuration of components is contained in the 'Weatherings' folder of the Getty archives (Box 3, Folder 38). [Figure 1]

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diagrams actually lies elsewhere: it does not depict the placement of loudspeakers which was crucial for Tudor's works, nor any other details concerning the implementation of the work within the physical space.

Matrix Maps: For most of the pieces after the 1980s, Tudor seemed to have abandoned the diagrams. Instead he made a list of inputs and outputs to the matrix switcher. D'Arcy Gray has addressed these lists as "Matrix Maps" (D'Arcy Gray, "David Tudor in the Late 1980s: Understanding a Secret Voice, " *Leonardo Music Journal* 14-1, (2004): 41-48). Matrix switcher allowed Tudor to control and rapidly shift the connection of any input to any output, and was used as the kernel of almost all of his compositions from this period. Matrix Maps are more specific in their information, but therefore less definitive, and do not convey the sense of relatively fixed configuration as the diagrams do.

Sound Sources: Tudor alternated between works of no-input—in which components chained into a feedback network would operate as a giant oscillator, triggering sounds from inside its circuitry—, and works that used recorded sound sources, which were input to the chain of components for various modulation. There is actually no distinction between these two types of works when the entirety of the performance is seen as a system and the performer as one of its component. For then, what he does, including the playing back of a taped sound source, pertains to the internal operations of the system. In other words, the existence of input and output is correlated to the scale of observation, and what is observed as composition. But for the observer trying to revive Tudor's pieces, the identification of sound sources is absolutely necessary. In many cases this can only be achieved by a close listening to available recordings of performances. In some rare occasions, one can find a list of tapes that Tudor wrote down for a particular performance. The specific maneuvers Tudor conducted to 'influence' the other components and to keep the sounds going during the performance is very difficult to discern. There are only a couple of notes describing what he did at what time during a particular performance can be found—presumably written out after the concert, listening to a tape recording. In all other cases, the trajectory of a performance can only be followed through a comparative listening to the various recordings.

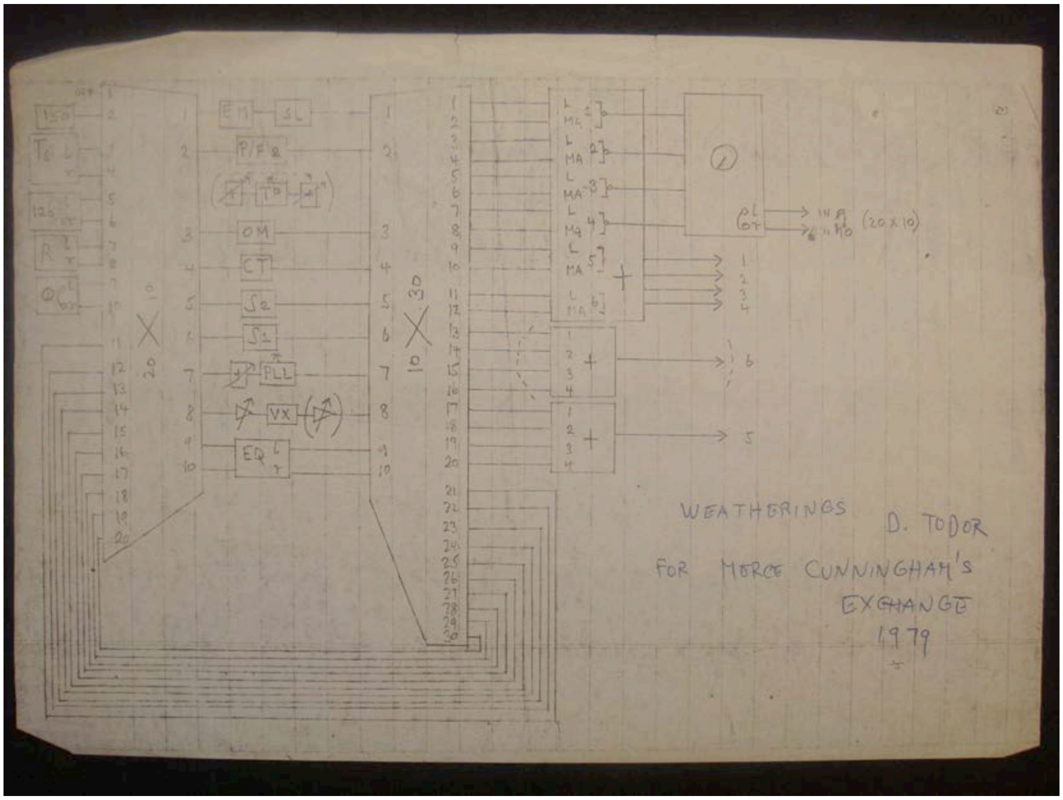
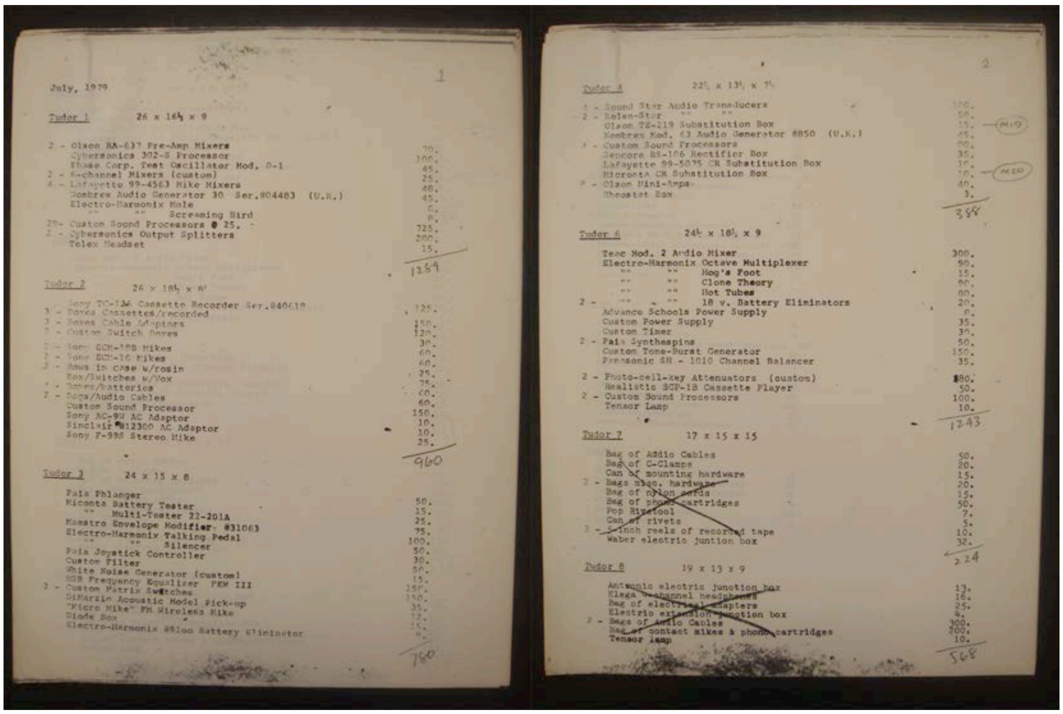


Figure 1 - Weatherings (1979), Diagram (Box 3, Folder 38)

The Getty Research Institute, Los Angeles (940039)

The components, consisting mostly of commercial devices, are laid out around two matrix switchers—one with 20 inputs and 10 outputs, and the other with 10 inputs and 30 outputs. Matrices allowed Tudor to control and rapidly shift the connection of any input to any output in performances, and were used as kernels of almost all of his compositions from this period. There are 4 tape recorders going into the inputs 2 to 8 of the first matrix switcher, and 10 devices inserted in between the two matrix switchers. 10 outputs from the second matrix feed back into the input of the first, while the rest goes into 6 loudspeakers through 3 mixers. 4 outputs from one mixer are panned and routed back into the first matrix switcher. The 10 modulating devices between the two matrices are marked by acronyms. Some are easy to discern (such as “EQ” for an equalizer), others are enigmatic. In order to identify the less obvious components, I go through an inventory of Tudor’s equipments dated ‘July 1979,’ found in another part of the archive (Box 30), presumably drafted for custom declaration when the composer toured with the Cunningham company. [Figure 2] By comparing the names of components listed in this document with the acronyms, I am able to decipher most of them ("EM" = Maestro Envelope Modifier, "SL" = Electro-Harmonix Silencer, "TP" = Electro-Harmonix Talking Pedal, "OM" = Electro-Harmonix Octave Multiplexer, "CT" = Electro-Harmonix Clone Theory, "S1" and "S2" = Paia Synthespins, "PLL" = Phased-Locked Loop).



July, 1979 1

Tudor 1	26 x 16½ x 9
2 - Olson RA-637 Pre-Amp Mixers	70.
Cybersonics 302-S Processor	100.
Phase Corp. Test Oscillator Mod. 0-1	45.
2 - 8-channel Mixers (custom)	25.
4 - Lafayette 99-4563 Mike Mixers	48.
Dombrex Audio Generator 30 Ser.#04483 (U.K.)	45.
Electro-Harmonix Mole	6.
" " Screaming Bird	8.
29- Custom Sound Processors @ 25.	725.
2 - Cybersonics Output Splitters	200.
Telex Headset	15.
	1289

Tudor 2	26 x 18½ x 8
Sony TC-126 Cassette Recorder Ser.#40619	125.
3 - Boxes Cassettes/recorded	150.
3 - Boxes Cable Adaptors	120.
2 - Custom Switch Boxes	30.
2 - Sony ECM-188 Mikes	60.
2 - Sony ECM-16 Mikes	60.
2 - Bows in case w/rosin	25.
Box/Switches w/Vox	75.
4 - Boxes/batteries	60.
2 - Bags/Audio Cables	60.
Custom Sound Processor	150.
Sony AC-9W AC Adaptor	10.
Sinclair #12300 AC Adaptor	10.
Sony F-998 Stereo Mike	25.
	960

Tudor 3	24 x 15 x 8
Paia Phlanger	
Miconta Battery Tester	50.
" Multi-Tester 22-201A	15.
Maestro Envelope Modifier #31063	25.
Electro-Harmonix Talking Pedal	75.
" " Silencer	100.
Paia Joystick Controller	50.
Custom Filter	30.
White Noise Generator (custom)	50.
SSR Frequency Equalizer PEW III	15.
2 - Custom Matrix Switches	250.
DiMarzio Acoustic Model Pick-up	150.
"Micro Mike" FM Wireless Mike	35.
Diode Box	12.
Electro-Harmonix #9100 Battery Eliminator	15.
	8.
	780

2

Tudor 4	22½ x 13½ x 7½
4 - Sound Star Audio Transducers	100.
2 - Rolen-Star " "	50.
Olson TE-219 Substitution Box	15.
Kombrex Mod. 63 Audio Generator #850 (U.K.)	45.
4 - Custom Sound Processors	50.
Sencore RS-106 Rectifier Box	35.
Lafayette 99-5075 CR Substitution Box	10.
Micronta CR Substitution Box	10.
8 - Olson Mini-Amps	40.
Rheostat Box	3.
	388

Tudor 6	24½ x 18½ x 9
Teac Mod. 2 Audio Mixer	300.
Electro-Harmonix Octave Multiplexer	90.
" " Hog's Foot	15.
" " Clone Theory	90.
" " Hot Tubes	80.
2 - " " 18 v. Battery Eliminators	20.
Advance Schools Power Supply	8.
Custom Power Supply	35.
Custom Timer	30.
2 - Paia Synthespins	50.
Custom Tone-Burst Generator	150.
Panasonic SH - 1010 Channel Balancer	35.
2 - Photo-cell-key Attenuators (custom)	180.
Realistic SCP-18 Cassette Player	50.
2 - Custom Sound Processors	100.
Tensor Lamp	10.
	1243

Tudor 7	17 x 15 x 15
Bag of Audio Cables	50.
Bag of C-Clamps	20.
Can of mounting hardware	15.
2 - Bags misc. hardware	20.
Bag of nylon cords	15.
Bag of phono cartridges	50.
Pop Rivetool	7.
Can of rivets	5.
2 - 5-inch reels of recorded tape	10.
Waber electric juntion box	32.
	224

Tudor 8	19 x 13 x 9
Antronic electric junction box	13.
Koss 4-channel headphones	16.
Bag of electrical adapters	25.
Electric extension junction box	4.
2 - Bags of Audio Cables	300.
Bag of contact mikes & phono cartridges	200.
Tensor lamp	10.
	568

Figure 2 - Equipment List from July 1979 (Box 30)

The Getty Research Institute, Los Angeles (940039)

At this point, one component remains unidentified: "P/F," which is inserted in between output 2 and input 2 of the two matrices. No device from the inventory seems to correspond to these initials. So I assume it must be one of the "24 custom sound processors." But the search reaches a halt here. Days go by without any advancement. But then, one day, as I go through a completely separate section of the archive (Box 43, folder 6), I notice instruction notes for several components that were used in *Weatherings,* such as 'the Silencer' or 'Clone Theory.' Close to these notes, I find several cutout pages from a 1970s kit manual that contains schematics and board layouts for building a 'Phaser/Flanger'—"P/F." [Figure 3]

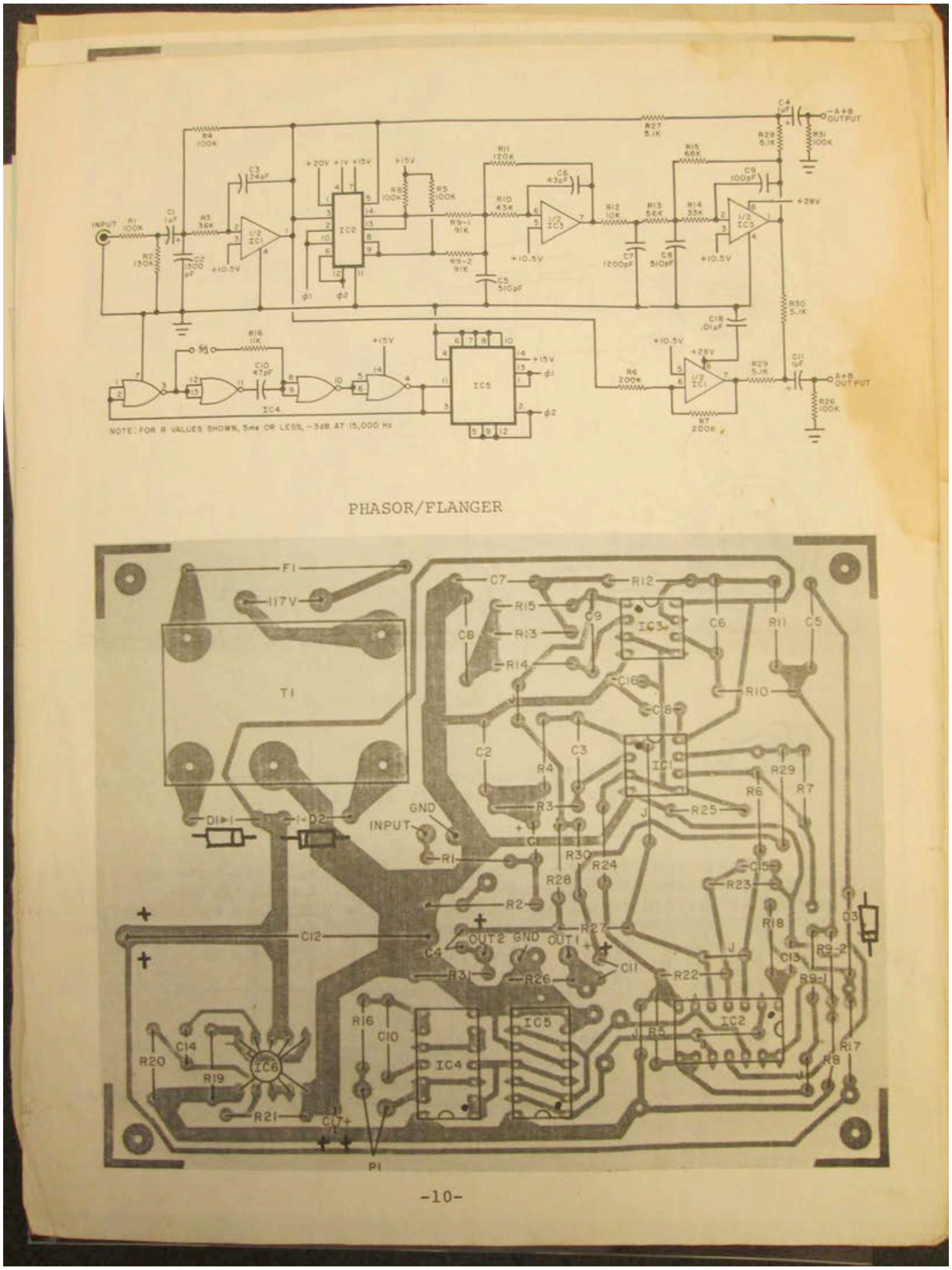


Figure 3 - Phaser/Flanger, Schematics (Box 43, Folder 6)

The Getty Research Institute, Los Angeles (940039)

I then try to identify if there is any device out of all the instruments at Wesleyan that corresponds to this particular 'Phaser/Flanger' circuit. By comparing the board layout with actual circuit [Figure 4], I manage to locate the box: It is the instrument labeled '0039,' which had previously been assumed to be a filter. [Figure 5] In fact, when I check the RCA jack inputs and outputs on the back of the device, I see that they are labeled "P/F OUT -A+B," "P/F IN 1" and so on. [Figure 6] Since a phaser/flanger delays the input signal and mixes it onto the signal itself to produce a sweeping effect, the "D OUT" "D IN" labels stand for the 'delay' function. The peculiar algebra ("OUT A+B") corresponds to another function of the phaser/flanger, which can simulate stereo sound from a mono source, by sending a phased output derived by adding the delayed signal to one channel, and sending another output derived by subtracting the delayed signal to the other. From the way Tudor had written out the algebras, I deduce that the same device must be the component notated as "a-b/a+b" in the diagrams of *Toneburst* (1975) and *Pulsers* (1976-78)—two works immediately preceding *Weatherings.* [Figure 7] In both cases, the "a-b/a+b" box receives one input and outputs two, thus matching the function of simulating stereo from a mono source.

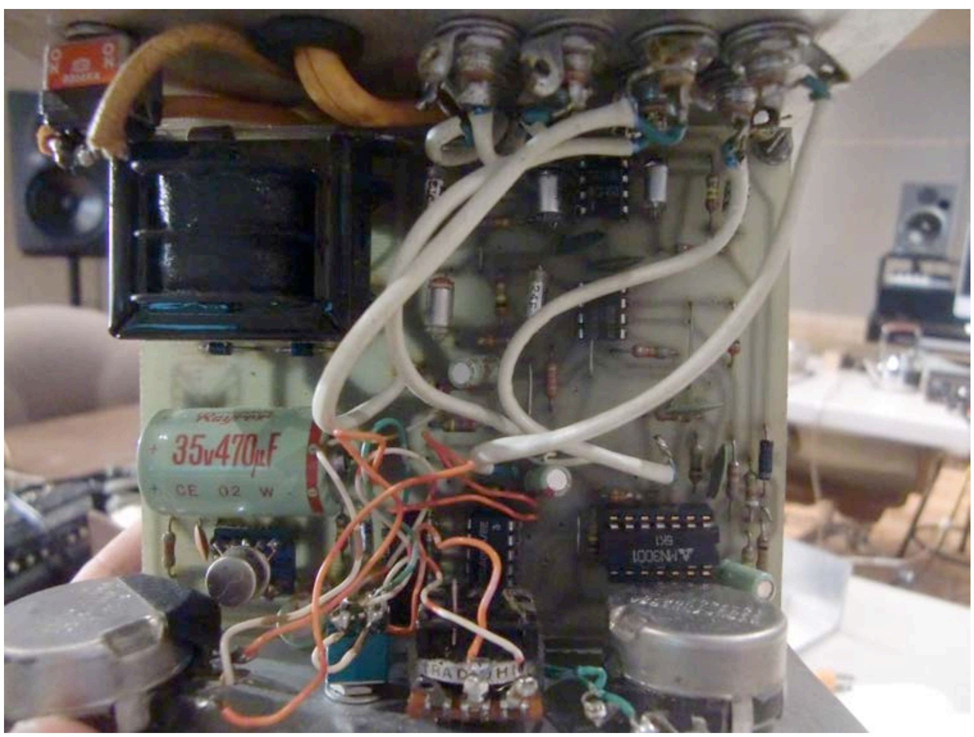


Figure 4 - Phaser/Flanger (Instrument '0039'), Circuit

World Instrument Collection, Wesleyan University

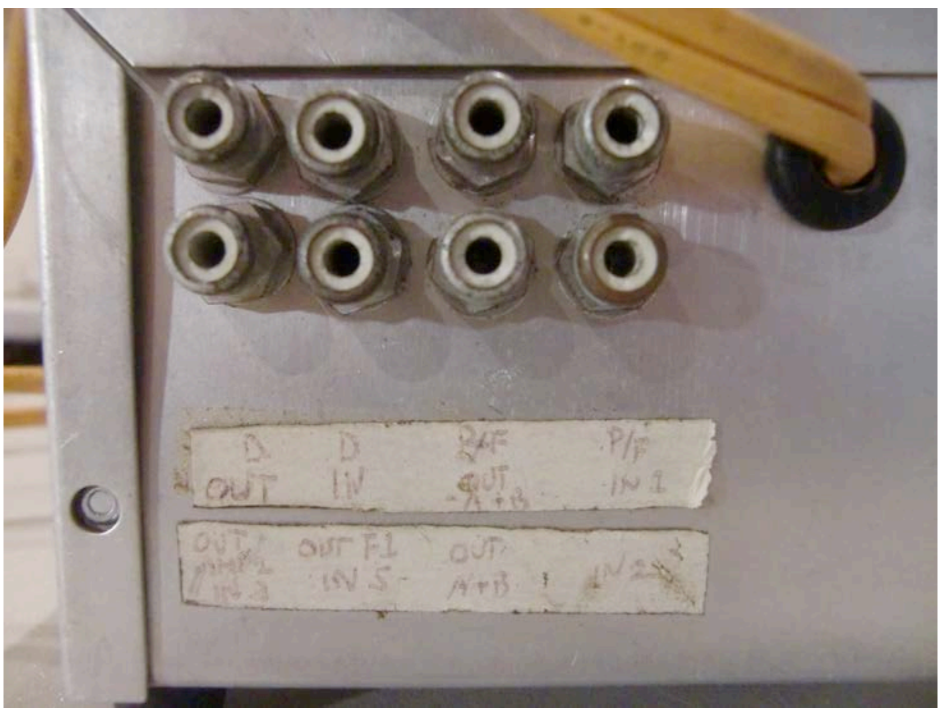


Figure 5 and 6 - Phaser/Flanger, Front and Back

World Instrument Collection, Wesleyan University

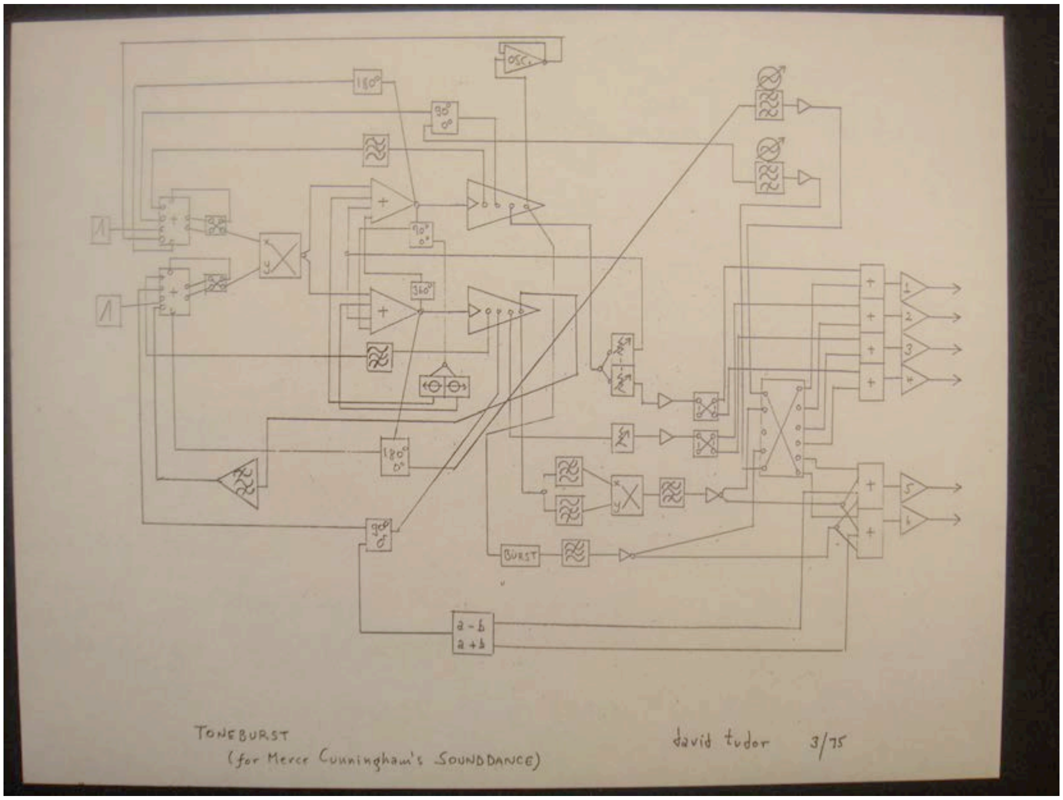


Figure 7 - Toneburst (1975), Diagram (Box 3, Folder 34)

At this point, I have identified all the abbreviations of components in the diagram. But two pieces of information are still lacking to connect my findings to actual performance: the identity of sound sources played from the tape recorders, as well as the temporal outline of performance. As I go through folders in Box 4 at the Getty archive, which assembles unidentified sketches and notes, I come across a list of sound sources (and EQ settings) for *Weatherings* (Folder 11). [Figure 8] The abbreviations of sound sources are not difficult to decipher, and are all included in the recordings stored at GRI: "W. CHG SLO" = Wasp Chewing Slow, "W. CHG N" = Wasp Chewing Normal, "BK" = Brooklyn Kids, "EM" = EEG modulated, "AL. A/F N" = Alpha Amplitude Modulation/Frequency Modulation Normal, "Dd. AL." = Demodulated Alpha, "M, t.t. N." = Mosquito in test tube normal. In another folder nearby (Folder 7), I find a note taken by Tudor while listening to a recording of a *Weatherings* performance. [Figure 9] It lists up timings for the playback of various sound sources, activation of components, and description of events. The corresponding recording might be the performance at Ohio State University on May 6, 1981, also archived at GRI.[30] Several things do align—especially notable are the entry points for 'modulated EEG' (at 5:50), and 'Demodulated Alpha' (which happens not at 9:45 but around 10:08). But the correspondences seem to decrease towards the latter half of the recording, so it may have been from another, similar performance (or the Ohio State University performance could have partially followed this note).[31]

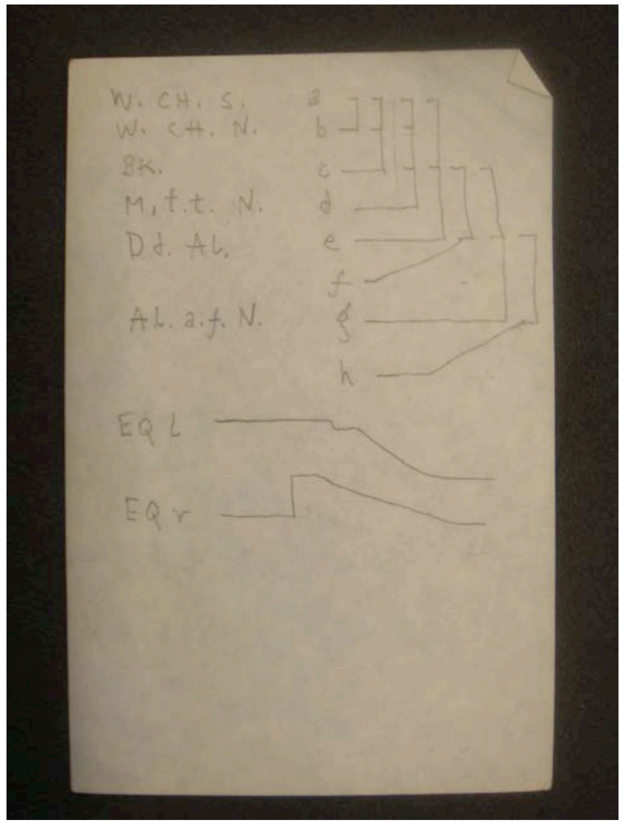


Figure 8 - Weatherings, Tape Sources (Box 4, Folder 11)

[30] David Tudor, "Weatherings, [Ohio State University], 1981 May 6," Los Angeles: David Tudor Papers, Getty Research Institute, Box1A, C12. Digital version available on the GRI website: http://hdl.handle.net/10020/980039_c012 (April 1, 2014).

[31] It was customary for Tudor to not only to vary his performances of a given piece from one concert to another, but also to constantly switch his components. Therefore, the definitive status of a block diagram must always be questioned and examined in comparison to many other diagram sketches, some of which also display intermediary stages from one piece to another.

(940039)

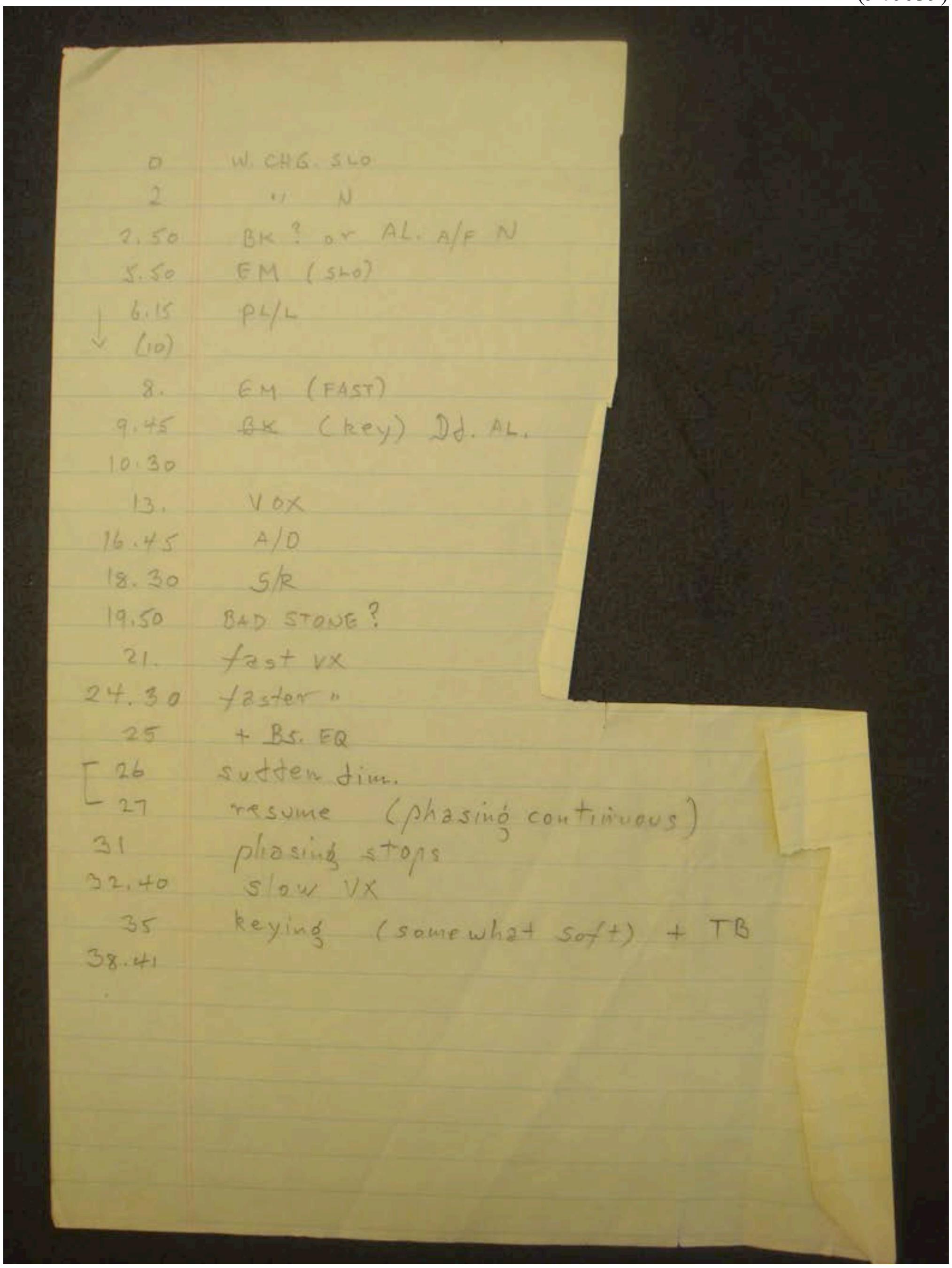


Figure 9 - Weatherings, Time Table (Box 4, Folder 7)

The Getty Research Institute, Los Angeles (940039)

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These meanderings portray a difficulty of sorts. Along with the gaze that moves through different scales of observation, the identification of what an 'object' is constantly shifts. And life and death are matters correlated to this movement.[32] The view from inside a specific device sees a network of electronic components—resistors, transistors, capacitors, transformers, ICs, potentiometers, and so on—some of which might be dead and others living. Observation on this level has its corresponding documentation in the form of schematics, connection diagrams, kit manuals, notes that list up resistor values or IC part numbers. Once outside of the device the observer now sees the network composed by this and other devices. Components are now on the level of devices such as mixers, modulators, oscillators, amplifiers, loud-speakers and so on, that one traces through with the aid of block diagrams, matrix maps, or photographs of Tudor's tabletop settings. Firing up components would constitute yet another domain of interiority.

[32] People often speak of instruments as being either alive or dead, depending on their general popularity or abandonment. Edmond Johnson traced the remarkable revival of the harpsichord starting from around the turn of the twentieth century, carefully analyzing the metaphors of life and death used to portray the fate of an instrument: "Whereas it might seem strange to speak of an instrument as having acquired an 'independent life,' the harpsichord's peculiar history had long attracted similar patterns of speech. As far back as the middle of the nineteenth century the instrument's abandonment was described in terms of death or even extinction, and during its subsequent revival the harpsichord's modern history has been written with terms borrowed liberally from the lexicon of rebirth and resurrection. Indeed, the last two centuries have seen the instrument widely represented, both verbally and pictorially, with figurations that invoke either life or death" (Edmond Johnson, "The Death and Second Life of the Harpsichord," *Journal of Musicology* 30, no. 2 (Spring 2013): 181). The facility of this figure of speech in relation to harpsichords is derived directly from the ease with which an observer can differentiate a harpsichord from other instruments, if not families of instruments, through their mechanism, sound, history, associated music, usage, and/or definition. Harpsichord is not a piano, and it is certainly not the *Goldberg Variations*. But Tudor's work complicates this schema, or rather, exposes its inherent indeterminacy. For in Tudor's music, the notion of 'instrument' can refer to individual devices, or the configuration of devices; as the notion of 'work' may encompass the configuration of instruments, and/or the performance. Moreover, the boundaries between one scale and another are not always clear. Just as several different instruments are chained to create one work, several works may use one specific instrument repeatedly (like the 'Phase/Flanger' which appears in *Toneburst*, *Pulsers* and *Weatherings*). The configuration of components often changed from one performance to another, while remarkably similar assemblies of instruments were given different titles and hence identified as different works.

The trajectory of observation thus decomposes compositions. The boundary between inside and outside is defined by scale and not space. Once the observer is 'inside' an object of a particular scale, the object disappears (or turns into the 'environment') and new objects appear in its interiority. Once 'outside' of it, an object withdraws from contact, concealing an interior not visible from the exterior and thus inexhaustible to observation. The existence of objects on multiple scales, in other words, renders a view from inside (of a certain object) to become, at the same time, a view from outside (of another object). Observation sets scales just to cross them over and turn them indeterminate by its own movement.

8

The strange relationship between the observer and objects thus observed can be connected to recent theoretical endeavors of Graham Harman. The tenet of his so-called Object-Oriented Ontology (OOO) is that objects withdraw from all relations—with humans, as well as other objects. Harman sees this withdrawal as constituting the 'inner life' of objects that is secluded from all external access, and inexhaustible to external observation. All relations between objects and humans, and among objects themselves are thus never direct, and must always be formed through a 'vicarious causation'—mediation by and within a third object. But relations never reach the internal life of an object, and only serve to distort its realities: "We distort when we see, and distort when we use. (…) It is not human consciousness that distorts the reality of things, but relationality *per se*."[33] This ontological schema could perhaps be connected to Tudor's music to explain the role of objects which serve as the infrastructure for the life of sounds that compose themselves. Sounds as well as signals emerge as distortions through the mismatched and indirect relations that components enter into. More accurately, sound/signal is distortion that *is* the relation, and thus constitutes the third object through which components can encounter. And as an object, it also withdraws from the perception of any other object-component. If this withdrawal of sounds from the components is seen as constituting a life of its own, then autopoiesis can happily take over the story from there.

In fact, the philosophy of object orientation reads much like autopoiesis written in reverse. They first of all share the same premise: a strict closure on the side of objects (machines) with inner lives that in no way can be reduced to the description of the observer. From there, they pace in contrary directions. Whereas autopoiesis delves into the closure to depict its operations from within, OOO adheres to the position of the exterior observer. On one side there is only a view

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[33] Graham Harman, "Vicarious Causation," *Collapse* II (London: Urbanomic, 2007): 193.

from inside to account for living systems, and on the other, there is only a view from outside to contemplate objects with inner life. Accordingly, the continuity that is life is defined in extreme positivity (tautology of the view from inside) in autopoiesis, which OOO flips around to a dedicated negativity (irreducibility to the view from outside). Once the basic frame of description is thus set, application follows suit—the condition of interiority and exteriority is generalized. Thus, OOO distributes the status of external observation to all objects, whereas autopoiesis reflects on the act of cognition as a production process that produces its own components. True, the biologists proceed with more caution, since they had started their inquiry by the paradoxical move of abandoning the status of the observer. For the philosopher who never really left his ground, the observer becomes an unexamined premise in the composition of his narrative. Consequently, the sensitivity to the gaze of observation and language of description in autopoeisis becomes coated by an utmost indifference in Harman's philosophy.

This withdrawal *of the observer* leads to an explosion of what the philosopher can account for. Harman's objective is an inquiry into "an ontological feature of objects *in general*,"[34] which is to say, "the basic structural features shared by *all* objects"[35] [emphasis added]. But the generic totality here is more a matter of definition than observation. Admitting that 'marbles' "may not be 'marbles' for anyone but humans or playful kittens," Harman nonetheless provides a peculiar excuse to his generalization: "we need a nickname for the united object that we draw into our games."[36] But if they are not 'marbles' for anyone but humans or kittens, why the presumption that they are "unified objects" at all? The simple answer is because the philosopher *defines* 'objects' as such. Claiming that all objects in general conceal an inner life that cannot be accessed from the outside, does not release them from their correlation with humans—it merely turns the relationship into one that is defined negatively. The general and negative realism of objects is thus consumed under the transparent and determinate authority of the observer and his language of speculation.

The secret withdrawal of the observer in Harman's account is staged explicitly in Maturana and Varela's writing. But as they leave behind the domain of description, they leave it intact. The line between the exteriority of the observer and the interior of the observed system is maintained as forever determinate, providing a space in which the philosopher may later dwell. The view from inside and the view from outside are thus not only contrary, but also complementary. But the position of the observer is neither here nor there. It is not as stable as

[34] Harman, ibid., 205.
[35] Harman, ibid., 204.
[36] Harman, ibid., 205.

object-oriented ontology claims, and not as easily dismissible as autopoiesis desires it to be. Observation stays neither in nor out. It proceeds by decomposing the very boundaries between inside and outside that it composes—decomposing objects into environments, and composing environments into objects. The interiority of observation is this view that traverses and oscillates indeterminately between a view from inside and a view from outside. And the indeterminacy of the observer is that of objects, for observation is the distorted relation between one thing and another. The immanence of life is located neither inside an object nor inside a process, but inside the oscillation between processes and objects. The view from inside, in other words, is a matter of time.

9

Maturana and Varela attempted to dissect the 'influence' of the observer in their description by reducing the time of systems to its minuscule, singular point of operation: the atemporal present. But object orientation offers a contrary path to the same problem (the relativization of the notion of time introduced by the observer) by opening up the time of objects to its maximum diversity and multiplicity. This path was cultivated not so much by the philosopher of our century, but by computer scientists and programmers of the past century working around the same time as Tudor or Maturana and Varela, from whom Harman presumably derived the name of his project ("Of course, philosophy is about opinion and engineering about deeds"[37]).

Object-oriented programming was a revolutionary approach in computer science primarily developed by Alan Kay circa 1970. It replaced the previous top-down programming paradigm with a method of computing that arises from the interaction of closed smaller elements called 'objects' which encapsulated a certain useful structure. Kay imagined each 'object' as being "a recursion of the entire possibilities of the computer."[38] Thus, the difference of scale between the computer as an object and objects within computers is again entwined with the movement of the observation. "In effect, he started out to build a computer language that would enable the programmer to look at the host computer not as a serial instruction follower, but as thousands of independent computers, each one able to command the power of the whole machine."[39]

[37] Alan Kay, "The Early History of Smalltalk," *ACM SIGPLAN Notices*, Vol. 28, No. 3 (March 1993): 71.
[38] Kay, ibid., 71.
[39] Casey Alt, "Objects of Our Affection: How Object Orientation Made Computers a Medium," in *Media Archaeology: Approaches, Applications, and Implications* (Berkeley, CA: University of California Press, 2011), 287.

As the notion of whole became distributed among the various objects, a new conception of time emerged. Instead of the linear universal time that proceeds step by step aligning the program from outside, time now had to be embedded inside each object. As Casey Alt noted, this idea of assigning different times to each object is most apparent in the notion of ‘late-binding.’ In comparison to the method of ‘early binding’ in which all the variable name linkages are determined before the execution of the program, ‘late binding’ leaves the reference linkage of each object undetermined until the run-time of the program. As a result, “late binding allows the object to remain open and ‘wait’ for messages.”[40] This ‘waiting’ creates “an internal, subjective duration specific to each individual object,” which “opens up the ability for programmers to infuse their programming objects with affect.”[41] What accords life to objects here is neither its continuous operation nor its eternal withdrawal. It is the indeterminate duration of ‘waiting’ that cannot be computed within a singular universal time.[42] There is latency inside the object, between the input and output, as there are temporal gaps between objects. Life is conditioned by a state that would be difficult to distinguish from dormancy or death to an observer with no patience.

[40] Alt, ibid., 294.

[41] Alt, ibid., 296.

[42] The operative mechanism of object-oriented programming, as well as the analogy of workers building without a universal plan, have a striking resemblance to the music of Christian Wolff. In his works from the 1960s, Wolff set up an intricate system of cues, wherein the performers' playing of a certain material was conditioned by the perception of a particular sound event. A whole composition, in other words, structured by individual performers waiting for the occurrence of a given particular position and relation. Naturally, the mismatch between what is played and what is heard renders the whole performance indeterminate. It is always possible for a performer to mishear his cue, or the performance to halt because all performers are waiting for each other's sound. Wolff's compositions were closely connected to Tudor. The system of cues, which forces the performer to make decisions in real time, was partially created in order to cope with Tudor's tendency as a pianist to prepare and determine all the details of his performance in advance. Tudor in return singled out the importance of Wolff's music, even after he turned to electronic music: ”Christian Wolff never delineates a universe. He deals with possibilities which one could use if one wanted to. That's what is so beautiful about his pieces, because they don't express a composite view ” (Tudor, ”From Piano to Electronics,” 25). As mentioned earlier, in footnote 11, the only non-electronic piece in the repertoire of ‘Composers Inside Electronics,’ was Wolff ’s *Changing the System* (1972).

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This view of objects in wait not only modifies the general, determinate negativity of object-oriented ontology into a specific, indeterminate mechanism; it also adds a critical twist to the account of autopoiesis. Towards the end of his paper 'Biology of Cognition,' which preceded his collaborative endeavor with Varela by three years (but later included in the same book), Maturana gave an analogy to the difference between the actual operation of living systems and that described by the observer:

> Let us suppose that we want to build two houses. For such a purpose we hire two groups of thirteen workers each. We name one of the workers of the first group as the group leader and give him a book which contains all the plans of the house showing in a standard way the layout of walls, water pipes, electric connections, windows, etc., plus several views in perspective of the finished house. The workers study the plans and under the guidance of the leader construct the house, approximating continuously the final state prescribed by the description. In the second group we do not name a leader, we only arrange the workers in a starting line in the field and give each of them a book, the same book for all, containing only neighborhood instructions. These instructions do not contain words such as house, pipes, or windows, nor do they contain drawings or plans of the house to be constructed; they contain only instructions of what a worker should do in the different positions and in the different relations in which he finds himself as his position and relations change.
>
> Although these books are all identical, the workers read and apply different instructions because they start from different positions and follow different paths of change. The end result in both cases is the same, namely, a house. The workers of the first group construct something whose final appearance they know all the time, while the workers of the second group have no views of what they are building, nor do they need to have obtained them even when they are finished. For the observer both groups are building a house, and he knows it from the start, but the house that the second group builds lies only in his cognitive domain; the house build by the first group, however, is also in the cognitive domain of the workers.[43]

[43] Maturana and Varela, *Autopoiesis and Cognition*, 53-54.

But this analogy distorts autopoiesis' longing for the purity of circular production. For if the thirteen workers, in the absence of a universal program, only follow instructions that are activated when and only when a particular position and relation is attained, then there is nothing to determine in advance how long the building process will take. The particular situation necessary to trigger the next action may not occur for an indefinite amount of time. The workers must then simply wait. The production process might still be in operation, but at a speed too slow that it escapes cognition. Life defined by waiting renders the very distinction between life and death indeterminate. Maturana probably did not consider autopoietic systems that would take years to produce the next production. Although a perfectly logical possibility that is derived from his own analogy, the idea of a living system that only breathes (so to speak) once every decade or every century goes directly against the biologist's tendency to imagine the life of systems from the temporal length and speed of his own life. Autopoiesis did away with the primacy of physical space by accounting for spaces of autopoietic systems via topology. But the same kind of abstraction was never considered for temporality.

11

Artworks are created precisely to wait in the stead of humans who cannot. They are vicars that stand in for our impatience. To use Christopher Wood and Alexander Nagel's formulation, "The work of art 'anachronizes'"[44]—it is always belated, and it constantly lingers. But by dropping out of time and effacing the very notion of contemporaneity, "it points forward to all its future recipients who will activate and reactivate it as a meaningful event." Thus, the life of works in wait is a life that starts as an afterlife.[45]

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[44] Christopher Wood and Alexander Nagel, *Anachronic Rennaissance* (Cambridge, MA: MIT Press, 2010), 13.

[45] It is for this reason that the perspective of media archaeology is pertinent, for instance when Wolfgang Ernst observes that technical media reveal their essence only in their operation, which can be 'activated' at any historical moment as long as they are functional. "There is no 'historical' difference in the functioning of the apparatus now and then. (…) 'Historic' media objects are radically present when they still function, even if their outside world has vanished. Their 'inner world,' is still operative" (Wolfgang Ernst, "Media Archaeography: Method and Machine versus History and Narrative of Media," in *Media Archaeology* (Berkeley, CA: University of California Press, 2011), 241). But the condition of waiting is not unique to technical media as Ernst claims, and the notion of media that he speaks of must be generalized. Even a Greek vase is not merely an archaeological object, but also a technical artifact that awaits activation.

The correlation between the (after)life of works and the possibility of their activation is, however, coupled with the indeterminacy of the observer who is always preoccupied with his own life, always in transit from one inside to another at its own pace—from one life to another, and thus from one death to another. Objects and art works are always partially dead because the observer (human and non-human) cannot wait, or waits for too long. In other words, death is an effect produced by the mismatch of speeds between systems. But so is sound, as noted above. That is why the lethal indeterminacy of observation and objects permeating the afterlife of Tudor's compositions outside the living present of his music, turns out precisely to be what operated *inside* his performances as they sprung into a life of their own. Latencies within, and in between, components and their partial influences upon each other (mutual listening processes) compose the atemporal and perpetually living present of autopoietic sound systems.

Tudor often claimed that the objective of his compositions were to discover the 'nature' of electronic components. The program note for *Untitled*, declared the piece as being "part of a never-ending series of discovered works in which electronic components are found to be natural objects."[46] A similar description was used to address the instrumental loudspeakers of *Rainforest*: "Each output mechanism has its own bias. So I must see what its properties are as a natural phenomenon, and not spend my time making it do something against its nature."[47] Each electronic component, each output mechanism (once composed), has its own nature, an "internal, subjective duration specific to each individual object," that can be 'discovered' (and perhaps 'influenced') through their use. Tudor's composition brings together objects of various natures with different speeds and latencies to form "an electronic ecology."[48] And this was an ecology, like any other ecology—constituted by deaths and processes of decomposition, partial and distributed around the network; difficult to see through, but with plenty to hear.[49]

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[46] David Tudor, "Program notes for Untitled (1972)," Los Angeles: David Tudor Papers, Getty Research Institute, Box 3, Folder 35.

[47] Tudor, "From Piano to Electronics," 26.

[48] "Electronic ecology" was a term often used by Tudor to describe *Rainforest*. See, for instance: David Tudor, "Program notes for Composers Inside Electronics' concert at Fstival d'Automne Paris (1976)" Los Angeles: David Tudor Papers, Getty Research Institute, Box 19, Folder 11.

[49] There is a curious tendency that can be observed among theories of operationally closed systems such as autopoiesis, to resort to metaphors of sound and music to overcome a particular conundrum inherent in their theoretical disposition: namely, the plurality of closures, and the relationship between one closed system and another. The sonic domain, in other words, has continuously been summoned to articulate the mechanisms

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The music that sprung to life once activated also died every night—whether at the discretion of the performer or not. The composer would then simply pack his instruments and take them home, continuing to observe the lives of electronic components in the past and after life of sounds, waiting for them to reveal a new musical idea to him. From one inside to another, and from one life to another, he proceeded. And we have tried to recompose his steps in our observation. For an observer to account properly, albeit always tentatively, for endings, it must move out from the particular inside it finds itself in. We thus end, tentatively, on that note.

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that remain hidden to visible articulations. Leibniz, for instance, employed the concept of 'Echo' in his letters to Bartholomew des Bosses to explain the paradoxical nature of ‘Composite Substance’--an aggregation of supposedly autonomous and singular monads (Gottfried Wilhelm von Leibniz, *The Leibniz-Des Bosses Correspondence*, translated and edited by Brandon C. Look and Donald Rutherford (New Haven, CT: Yale University Press, 2007), 337). Biologist Jakob von Uexküll used the imagery of 'symphony' or 'score' to account for the relationship between numerous ‘Umwelten,’ a self-contained semiotic world that a given species uniquely creates and inhabits (Jakob von Uexküll, “The Theory of Meaning,” *Semiotica* 42, 1 (1982): 25–82). Following this lineage, Niklas Luhmann introduced the term 'resonance' to theorize the mechanism of environmental problem--an issue wherein the behavior of social systems directly affects, and is affected back from, its environment, and thus one that is by nature difficult to articulate through autopoiesis, which regards systems as having no input nor output (Niklas Luhmann, *Ecological Communication*, translated by John Bednarz, Jr. (Cambridge, MA: Polity Press, 1989), 15). The force of these musical and sonic metaphors, however, should not be regarded as demonstrating the sheer transcendence of sound that overcomes the boundaries of systems, but rather as merely indicating the different types of articulation that can be formed via sounds, which may serve to relativize the visual primacy of systems theory.

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