All is in Formation: Architecture, Cybernetics, Ecology

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Five Points Towards an Architecture In-Formation

Stavros Kousoulas and Dulmini Perera, editors

While there have been significant discussions on the relevance of cybernetics within architectural and urban studies, focus was mainly placed on computing and digital practices. Since its emergence in the post-war period, cybernetics – in both its first- and second-order versions – has introduced to architectural discourse systematic design methods and practices, while tackling issues of reflexivity and complex problems. In the everyday context of architectural practices, as one engages with the questions of organising, making sense of, framing and acting upon the environment, architects implicitly experience the effect of diverse processes of cyberneticisation. As such, unlike its early orders, cybernetics can no longer stand as an isolated field. The aim of this issue of *Footprint* is to reposition cybernetics as neither an outdated way of thinking nor as computational practice alone, but as a discourse that continues to offer possibilities for architectural theories and practices. Consequently, we will examine the relation between cybernetics and architecture by focusing on a problem they both share: information.

To make this clear though, one needs to dissociate information from any approach that confuses it with data; on the contrary, and thanks to the work of philosopher Gilbert Simondon, information is amplified as that which drives any process of individuation.[1] In other words, information becomes synonymous with meaning: what is informative is whatever is significant enough to catalyse a transformation.[2] To this end, and remaining within the Simondonian plea, we will approach cybernetics as the study of the production, consumption and flow of information, an account that has little to do with digital logics, unless one wants to pursue that special case. Conversely, we will consider processes of cyberneticisation as a general ecology that has to do with life and the production, exchange and consumption of meaning.[3] Therefore, cyberneticisation can set the foundations for a relational account that examines how signs are communicated and how meaning is produced and experienced within systems.

This third-order cybernetics extends beyond the original scope of living organisms and their environments in order to include ecologies of ideas, power, institutions and media, among others. In this sense, cyberneticisation is radically environmental, positing the primacy of relations over fixed terms, binary oppositions and linear logics, making it high time for architectural and urban studies to take into consideration its ground-breaking potentials. Via diverse material and conceptual experimentations, the contributions in this issue of *Footprint* express a shared concern, aiming not to situate a cybernetic history of architecture (or vice versa) but to make sense of how heterogeneous and extended architectural and cybernetic processes individuate. We hope that the following points may be of assistance in this endeavour.

Extended automation

When information becomes the focal point, design questions related to emerging technological processes such as automated service systems, smart materials, predictive modelling systems and planetary scale infrastructures need to be approached as broader processes of cyberneticisation. While the historical encounters between architecture and cybernetics are vital to understand our current technological conditions, it is important to stress that architecture was never a passive recipient of cybernetic ideas but always an active agent in contributing towards extended cyberneticisation processes.[4] In so doing it is apparent that architecture's and cybernetics' histories are less about a transfer of human agency to a machinic system but rather the story of an entangled mode of coevolution, since architectural design processes, architectural institutions and architectural objects have operated as a significant relay in the encoding of these complex interactions within the broader cultural system.

The issue emerging out of these entanglements is one of extended automation, albeit not in the strict sense of programming and computer science. The automation of labour-demanding processes needs to be transversally examined, and as such, to be extended horizontally and vertically on a planetary level that expresses its full complexity.[5] As Rachel Armstrong and Rolf Hughes invite us to wonder, what sort of eco-politics emerge when processes of extended automation intervene at the nanoscale of material engineering? What is the relation between technicities and aesthetics on the mesoscale of lived experience, expressed in examining a humble kitchen ventilation system as Liz Gálvez does? Or, as Christian Girard shows, even at the scale of escaping planetary constraints, how can the fundamental cybernetic figure, the naut/pilot themselves, be considered part of an assemblage of diverse automations? These questions aim to trace how architectural thinking can approach our current challenges with a degree of care, as the late Bernard Stiegler would demand: a renewed sensibility and awareness of the intricate complexities of our planetary co-habitation and the conditions of its governmentality.[6] Moreover, returning to Simondon, such a sensibility, especially from an architectural perspective, can indeed potentialise the proliferation of diverse and heterogeneous technicities, capable of both automating differently and outlining a radically extended technological literacy.[7]

General ecology

Consequently, more than a side effect of cyberneticisation, architecture contributes significantly as an informational medium that environmentally distributes agency via technicities which range from the sensorial to the algorithmic, from the nanoscale to the domestic, from the earth to the moon. This radical redistribution of agency is the hallmark of present environmental culture and has its history in transversal experiments conducted among institutional systems, buildings, and cities. A clear example is the work of architect Cedric Price, as Tanja Herdt claims: with Price, architecture becomes a transductive relay for the distribution of information. Such experiments indicate the shift from a first-order cybernetic interest in adaptation within a control circuit to its second-order interest after the 1960s, where the questions of non-adaptation, emergence and far-from-equilibrium dynamics were prioritised. As Iris Giannakopoulou Karamouzi claims, it is also then that we encounter speculative extrapolations from urban environments that indeed extend automation to a point where a new collectivity would emerge, as was the case with Constant's New Babylon. In addition, as Juliana Yat Shun Kei underlines, the second cybernetic order coincides with an ecological – or, in better terms, relational – turn within architecture, paving the way to what we can now call cybernetics of the third order: a general ecology.

The question of first, second and third orders remains highly contested among the wide-ranging field of scholars who deal with the processes of cyberneticisation and those who are more directly involved within what is identified as the remaining discipline of cybernetics. However, the third order opens ways of relating to the non-human in a far more complex manner than the first- and second-order epistemologies. As such, third-order cybernetics become onto-epistemological, addressing not just how we know a system but, crucially, how a system is ecologically (and therefore, immanently) produced. As philosopher Erich Hörl claims, this proliferation of the ecological denaturalises ecology, putting forward a technoecological condition.[8] Complementing Simondon and Stiegler, Hörl asks us to no longer speak of the Anthropocene but rather to acknowledge the foundational power of our technicities in a Technocene that coincides with the invention of humanity through its technological means.[9] Complementing the historical examination of architectural technoecologies that Herdt, Giannakopoulou and Kei attempt, Tim Gough invites us to push relationality to its limits, thinking of cybernetic systems and architectural relations transversally, through all levels of complexity. It is through the primacy of relations that architectural thinking and doing can enunciate the great conceptual challenge of the Technocene: to provide an account of the genesis of the technoecological culture of sense.[10]

Out of control

A technoecological account could not be further away from the early cybernetic ambitions of a rigid control culture related to equilibrium and regulated forms of adaptive feedback. The first-order cybernetic machine performed homogeneous, repetitive work and it is for this reason that Simondon criticised it as a quantitative theory that is fundamentally detached from its main technoecological objective: not to examine information per se, but rather the experience of information.[11] Simondon claims that when information is approached as its experience, it becomes characteristic of the very becoming of every individual in their affective-perceptive relations with their environment.[12] Contrary to the claims of early cybernetics, a general ecology is one that does not seek the technical schematisation of lived experience so that it can control and command it; no longer belonging to the lingo of the military-industrial complex inherited by figures such as Norbert Wiener, cyberneticisation as general ecology is a theory of the qualitatively genetic rather than the quantitatively generic. To this end, cybernetics becomes a theory of heterogeneous technicities: how humans relate to and transform their environment through technology, and how these relations transform all of them in turn – humans, technology and environment.

The human, the technological and the environmental, when examined in isolation, fail to cooperate with the complexities of the technoecological condition, since a system supposedly enclosed in itself is de facto a separate reality. This conceptual handicap appears in both traditional Marxist and Heideggerian accounts of technology as a condition that creates alienation. However, Simondon reminds us that alienation is not a consequence of technology per se or a result of exploitation: alienation is the condition of a technological illiteracy where the human is merely a passive operator.[13] The human – and consequently, the architect – needs to be both an inventor and an operator, and as such, acknowledged as part of the technoecological network by default. It is with an understanding of cybernetics as a general ecology that the centrality of an expanded recursivity can be brought into theories of architecture and urban design. As traditional critical theory attempts to discuss information technology, automation systems and their respective political implications in abstract terms, it fails to appreciate the fundamental materiality of the recursive relations and their affects brought about in contemporary technoecologies. On the contrary, governmentality – and the collectives it implies – emerges within these systems not so much in the form of self-conscious executive choices made by a single agent, but as choices that get in-formed via systems of technically contingent pathways. Therefore, paradoxically, to abolish the illusion of control does not imply relinquishing intentionality and purposiveness; it rather aims, as Contingent

Collective claim, to acknowledge both contingency and indeterminacy as fundamental in any technological – and consequently, architectural – attempt to transform our materiality.

The One is the Many

In a technoecological approach, the technical individuals (what one can plainly call machines) are no longer inorganic systems organised from the outside, but rather assemblages of organic and inorganic systems that continuously unfold. As Simondon would have it, the machine does not extend the body, the corporeal; the machine is never prosthetic.[14] In other words, the machine should not be confused with the tool. The machine, as Gilles Deleuze and Félix Guattari claim, is always machinic: a coupling between the organic and the inorganic, an assemblage that produces the very conditions of its reproduction.[15] This shift towards the machinic as a way of framing emergent processes that traverse the limits between the organic and the inorganic is radically different from architecture's earlier turn towards an organicism that was other to mechanicism, propagating itself as an equally reductive mode of framing the relation between nature and culture.[16] Put differently, an organicism that was a remedy for industrialisation (or the industrial machine) does not fit as a theoretical lens suited to interrogate the complexity of the technoecological present.

It is precisely this theoretical framework that Zach Mellas wishes to outline by devising a concept of critical technics that position architecture at the *a praesenti* of architectural production itself, distanced from a priori formal presuppositions or a posteriori typological taxonomies. In the lived present of architectural production, the organic is in a constant informational relation with the inorganic, so much so that the limits between them fold in upon each other. However, and this is where a fundamental philosophical concern becomes relevant again, this folding, in its productive excess, should rely on nothing else besides the act of folding itself. In other words, to fully appreciate the transformative capacity of a technoecological approach, one needs to return to the radical empiricism of William James: neither an absolute One (which abolishes any difference in intensity), nor absolutely Many (which obsesses over extensive differences). Neither does human equal machine, nor do machine and human stand apart: the Technocene is both one and many and it is their inclusive disjunction that can pharmacologically make or break it.

Pragmatics

To understand the liminality between human and machine, we should be reminded that *pharmakon* means both medicine and poison; it is the dosage that nourishes or kills. The *pharmakon* that will save or kill can exhibit a critical threshold that turns it from a gift to poison, but only if its dosage is manipulated and acted upon. However, to perceive a liminal condition and to act on it, one needs to approach information pragmatically. As philosopher Pascal Chabot notes, information can be understood in three different ways: syntactical, semantic and pragmatic.[17] Syntactical information deals with issues of information transmissions, and hence its concerns are mainly technical: how information is coded, through which channels, and how noise can be avoided. From a semantic understanding, information deals with the meaning of symbols and the ways in which they can form a message. One of the most important semantic concerns is to identify the shared conventions between a transmitter and a receiver for a message to be mutually comprehended. Finally, and what is of real concern when it comes to cyberneticisation, is the pragmatic approach to information: how it can affect the behaviour of both transmitter and receiver.[18]

Consequently, the identification of an always environmental, affective, and abductive intelligence that is the result of the processes of cyberneticisation marks a shift from the ways in which knowledge models were conceptualised in relation to cybernetic sciences. The ways in which the birth of cybernetics was initially framed within a broader cultural theory may be familiar to many. Under the influence of various postmodern thinkers – one can here refer to Jean-François Lyotard or Jacques Derrida – cybernetics as the study of information was popularised in a manner that conflated it with semiotics, or with syntactical and semantic information. A turn away from the limitations of these denotative functions was pursued extensively by cyberneticians such as Gordon Pask and Gregory Bateson, who attempted to encompass the complexity inherent in the broader processes of meaning-making within extended socio-technical systems. Their work has brought forth radical ways to expand what the dialogical can mean for human stakeholders working technoecologically. This is precisely what Jon Goodbun and Ben Sweeting – quite literally – discuss in their dialogue: how information can be approached beyond signification and how this affects architectural thinking. Complementing them, Tewfik Hammoudi proposes that we approach architecture as a machinic assemblage that is above all involved in the production of pragmatic information.

Nonetheless, one should not think that a semiotics without signification equates a dismissal of signs. On the contrary, an asignifying semiotics is a meticulous study of the meaning-making capacities of signs that extend well beyond language and its structures.[19] As such, pragmatics – understood as an ethico-aesthetic paradigm – liberates the sign from the hegemony of language and repositions it with all its informational power in the eventuating complexities of a continuous world-making. Perhaps it is only when we fold architecture and cybernetics on the level of their informational capacities that we can evaluate Guattari's radical proposition: to reinvent architecture as the design of heterogeneous lines of transindividuation.[20]

Notes

1. Gilbert Simondon, *Individuation in Light of Notion of Forms and Information*, trans. Taylor Adkins (Minneapolis: University of Minnesota Press, 2020).
2. Information can be understood as constantly in formation and as such contributes greatly to a discussion on architectural forms (and formalisms). For more see: Stavros Kousoulas and Jorge Mejía Hernández, eds., *Footprint* 22, 'Exploring Architectural Form: A Configurative Triad' (2018).
3. Erich Hörl, ed., *General Ecology: The New Ecological Paradigm* (London: Bloomsbury, 2017).
4. Such concerns, albeit from a broader perspective, are also addressed in previous issues of *Footprint*. See, for example: Negar Sanaan Bensi and Francesco Marullo, eds., *Footprint* 23 (2018), 'The Architecture of Logistics; Víctor Muñoz Sanz and Dan Handel, eds., *Footprint* 25, 'The Human, Conditioned' (2019).
5. Benjamin H. Bratton, *Terraforming* (Moscow: Strelka, 2019).
6. Bernard Stiegler, *The Neganthropocene*, ed. and trans. Daniel Ross (London: Open Humanities Press, 2018).
7. Gilbert Simondon, *On the Mode of Existence of Technical Objects*, trans. Cecile Malaspina and John Rogove (Minneapolis: Univocal, 2017).
8. Erich Hörl, 'Introduction to General Ecology: The Ecologization of Thinking', in *General Ecology*, 1.
9. Ibid., 13.
10. Ibid., 14.
11. Jean-Hugues Barthélémy, *Life and Technology: An Inquiry into and Beyond Simondon*, trans. Barnaby Norman (Leuphana University of Lüneburg: Meson Press, 2015), 32.
12. Ibid., 32.
13. Simondon, *On the Mode of Existence of Technical Objects*.
14. Maurizio Lazzarato, *Capital Hates Everyone: Fascism or Revolution*, trans. Robert Hurley (South Pasadena: Semiotexte, 2021), 112.
15. Ibid.
16. Martin Savranksy, 'The Pluralistic Problematic: William James and the Pragmatics of the Pluriverse',

in *Special Issue: Problematizing the Problematic*, *Theory, Culture & Society*, ed. M. Savransky (London: Sage, 2019): 1–19.
17. Pascal Chabot, *The Philosophy of Simondon: Between Technology and Individuation*, trans. Aliza Krefetz (London: Bloomsbury, 2013), 79.
18. Ibid., 79–80.
19. For a detailed discussion of asignifying semiotics from an architectural perspective, see Deborah Hauptmann and Andrej Radman, 'Asignifying Semiotics as Proto-Theory of Singularity: Drawing is Not Writing and Architecture does Not Speak', *Footprint* 14 (2014): 1–12.
20. Félix Guattari, *Schizoanalytic Cartographies*, trans. Andrew Goffey (London: Bloomsbury, 1989).

Biography

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From Cybernetics to Systems Theory in the First Space Age: Observations on the Pilot Problem

Christian Girard

Cybernetics is, by name, about piloting, as everyone knows: steering a boat, piloting an aircraft. This question of the steering pilot is as old as antiquity. During World War II, the goal of cybernetics was to automatise piloting, to de-humanise it in a way, if we believe that a carnal pilot invests humanity more than a human-conceived automatic apparatus. Foucault envisioned the historicity of the problem well:

> the idea of piloting as an art, as a theoretical and practical technology necessary for existence, is an idea that I think is rather important and may eventually merit a closer analysis; one can see at least three types of technology regularly attached to this 'piloting' idea: first of all medicine; second of all, political government; third of all self-direction and self-government.[1]

This quote from Foucault appears in the 2014 pamphlet *The Cybernetic Hypothesis*, published by the anonymous Tiqqun collective. The authors add that Foucault refrained from any contemporary digression on the topic, since 'at the end of the twentieth century, the image of piloting, that is to say of management, became the cardinal metaphor for describing not only politics but also all human activity'.[2] For Tiqqun, cybernetics is nothing other than rationalisation pushed to its limits. However, the latent and continuous technophobia spread through Tiqqun's discourse fails to help understand the very nature of technology. Moreover it leaves open no alternate path than a thorough mastering of technology. Technophobia, just like anti-science, fails to understand how it is unreasonable to despise reason, unproductive to put limits on rationalisation, absurd to lament an overdose of rational thinking and acting.

To introduce this article with a violent and ideologically burdened critique of cybernetics is somewhat consistent with the greatest weakness of cybernetics: its having turned into an ideology in less than a decade after its inception. Tiqqun engages in a harsh political critique of cybernetics. They debunk and insult a host of figures of the French intellectual scene such as Edgar Morin, Joël de Rosnay, François Ewald and Antonio Negri, while remaining close to and somewhat critical of Jean-François Lyotard and Gilles Deleuze and Félix Guattari. If provoking established leftist or post-Marxist names is sometimes a healthy anti-dogmatic necessity, it is not rewarding if nothing substantial is delivered after such assaults. We will instead attempt to deal with the non-metaphorical side of piloting and invite into the debate a discipline directly implied or coextensive to cybernetics which became even more powerful than cybernetics itself and was bound to replace it in more than one field: systems theory.

Cybernetics did indeed start with a precise and urgent practical problem where, at least initially, metaphors had almost no place: how to automatise the shooting down of enemy planes with anti-aircraft guns? Norbert Wiener, the mathematician and professor at MIT with uncommon talents for expanding his discipline into a host of other domains, worked hard in 1944–45 to provide a practical answer and in doing so invented what he called cybernetics. As is always pointed out, Wiener worked in close partnership with psychologists embracing the behaviourist credo. For, indeed, the pilot problem was mainly one of behaviour: how to anticipate the pilot's behaviour in trying to escape anti-aircraft shots? At the same time, in Great-Britain, another urgent problem arose: how to shoot down pilotless planes? The Germans had invented with the V-1 the very first drone, aimed at destroying London. American and British engineers raced to create smart fuses able to shoot down the V-1 flying at unprecedented speed over the Channel.[3] Note that the 'pilot problem' is still a vivid issue seventy years after the war, with armies around the world flying more and more drones, creating new jet fighters with assisted piloting, and so on. As recently as August 2020 a US jet pilot lost a test dogfight against automated drone jets. It is quite remarkable that the problematic of flight and pilot has stayed so relevant up to the present day. Remember, among many contemporary examples, how Boeing's dramatic 2019 software failure with the 737 Max was a pilot-automation interface flaw; the same company's 2019 Orion spacecraft test was a half-failure.

In any case, there are two different modes of flying objects: piloted and pilotless, the latter divided into two categories, remote-controlled and autopiloted. Elaborating on Wiener's anti-aircraft efforts, Peter Galison's 1991 *The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision* offers a detailed and valuable analysis on the topic.[4] Galison wisely backtracks from the widest ontological claims of cybernetics. Indeed, so many observers have gotten lost in Wiener's sometimes pseudo-metaphysics that going back to the bare facts is productive. For this essay it will mean relying on some carefully chosen archives that do not often receive attention. It is difficult to ignore or reject the philosophical dimensions carried by cybernetics. If Wiener early on sought to give cybernetics a philosophical prestige, it is mainly in Europe that this drive found fertile ground for further developments, including vigorous critics. For instance, Gilbert Simondon's introduction to *On the Mode of Existence of Technical Objects* (1958) found cybernetics insufficiently universal:

> One need not even found a separate science that would study the mechanisms of regulation and command in automata built to be automata: *technology must deal with the universality of technical objects. In this sense, cybernetics is insufficient*: it has the immense merit of being the first inductive study of technical objects, and of presenting itself as a study of the intermediate domain between the specialized sciences; but it has specialized its domain of investigation too narrowly, because it started from the study of a certain number of technical objects; it accepted as its point of departure that which technology must reject: a classification of technical objects according to criteria established according to genre and species.[5]

In Germany, with the post-war work of Martin Heidegger – a onetime Nazi Party member – cybernetics gained critical interest. Today, for stimulating thoughts on the philosophical destiny of cybernetics, refer to Erich Hörl's article of 2013.[6] Hörl is also a great source for the cybernetics/ecology relation, drawing his concepts, in part, from Félix Guattari's works. Here, a few considerations will suffice before dealing with case studies relating to the first space age (1950–80). Cybernetics grew on the well-prepared ground of American pragmatist philosophy. Wiener's will to expand cybernetics from practical issues such as anti-aircraft weapons to any problem encountered by human societies is the result of ideology taking command of technology. Traumatised, as one should have been, by the invention of the atom bomb, he gave cybernetics an encompassing and unlimited operational space. When the seemingly concurrent systems theory appeared, a shift was made where ideology was somewhat replaced or given a second role by engineers coping with complex new goals such as landing humans on the moon. The pragmatism of systems theory was in a way greater and more efficient than that of cybernetics. This should not be seen as a mere neutral semantic shift from one label to another, from cybernetics to systems theory, even if the latter needed the former. Ideology never quits the scene, however its place is drastically removed from the pragmatic field of operations. Pragmatism was a philosophy and an ideology promoting a paradoxical move against itself in the sense that it thought a retreat from thought in favour of action.[7] Where does ideology find its place if not in the overall social fabric, tightly bonded to politics?

In the meantime, from the 1950s to the 1970s the one-way bridge between cybernetics and systems theory was computation: computation per se, in relation to the ever-growing calculation power of computers. Cybernetics morphed into second-order cybernetics, so the story goes. At some point, Ideology, with a capital 'I', has little or no hold on technologies; when a technique works, it works. The history of luddites is here to prove it. You could hope to counter the wheel, but so long as the wheel is an efficient and working technology it will stay around. Ideology, in the case of the decades 1950–1970 in the USA, was driving engineers and managers, from their education, through their university formation and throughout their careers where they participated in the development of powerful institutions. These men and women, living in a post-World War II and Cold-War era, embraced systems thinking less as an ideology than as an efficient methodology whose first and foremost successful applications were in the military and, sometimes, in the civilian realm. But it evolved into a methodology at the service of an ideology. Systems talk replaced feedback talk. Servomechanisms were used as banal tools and neatly ordered under the control and command of computers. In systems theory, the feedback loop is a given, something already granted, a tool; systems theory is a methodology as well as a strategy, whereas cybernetics becomes a tactic while at the same time it tries to diffuse itself on a philosophical level.

While the links between the cognitive sciences and cybernetics have been underlined by others, I rather insist on how cybernetics gave way to systems theory at large or was somewhat superseded by it.[8] Systems theory was in fact a step sideways more than a shift away from cybernetics. As we will recall, there is a host of applications of systems theory, thus producing dozens of labels with 'systems' as its core noun: systems engineering, -management, -design, -analysis, -dynamics. Some of them share the same parentage, such as systems dynamics invented by Jay Forrester (1969) with the computer as a central tool. Ludwig von Bertalanffy's work is a mandatory step here, since the father of systems theory himself insisted on the difference with cybernetics. Obviously, one can draw various cartographies of the relations between all these fields as well as between them and cybernetics; among the available twenty-first century literature, one can glean all the details from Lars Skyttner's *General Systems Theory: Problems Perspectives Practice.*[9] Bertalanffy phrased the opposition cybernetics/systems theory this way in 1969 in the chapter 'Open Systems and Cybernetics' of his *General System Theory: Foundations, Development, Applications*:

> the important question of the relation of general system theory and cybernetics, of open systems and regulatory mechanisms appears … The basis of the open-system model is the dynamic interaction of its components. The basis of the cybernetic model is the feedback cycle … in which, by way of feedback of information, a desired value (Sollwert) is maintained, a target is reached, etc. The theory of open systems is a generalized kinetics and thermodynamics. Cybernetic theory is based on feedback and information. Both models have, in respective fields, been successfully applied. However, one has to be aware of their differences and limitations. The open-system model in kinetic and thermodynamic formulation does not talk about information. On the other hand, a feedback system is closed thermodynamically and kinetically;

> it has no metabolism. In an open system increase of order and decrease of entropy is thermodynamically possible. The magnitude, 'information' is defined by an expression formally identical with negative entropy. However, in a closed feedback mechanism information can only decrease, never increase, i.e., information can be transformed into 'noise' but not vice versa.[10]

The first part of the introduction was titled 'Systems Everywhere'. In retrospect, Bertalanffy's offspring has greatly outpaced Wiener's. Systems theory encompasses far more than cybernetics and perhaps appeals more on the semantic and linguistic level: less exotic, more mundane and – this is the hidden secret – less metaphoric, or better, not a metaphor at all. Indeed, at the root of cybernetics lies that heavily burdened pilot-metaphor which was instrumental in the success of cybernetics but thereafter became a burden. 'Systems', any way you take it, has no metaphorical connotation. One would qualify it as a concept, if only we could be completely sure of what a concept is and can be (I refer here of course to Deleuze and Guattari's work). Systems engineers discard cybernetics' wrapping (ideology) and do not care for its toppings (metaphysics, ontology, philosophy); they consider that the proof of the pudding is in the eating, to recall an old adage famously quoted by Marx.

The greatest feat of systems theory versus cybernetics was its ability to be, paradoxically, at the same time more general and more specific. This could only happen with the universality (the general) of computation and the utmost exactness of electronically computed calculus (the specific). As we know, Alan Turing's breakthrough and its consequences changed the landscape. Couplings of mathematics, hard science and technology under the banner of research and development were the source from which everything flowed: the military-industry complex, economic growth, social control, down to the overexploitation of the earth's resources, in a word it unleashed capitalism, ready to mutate at the turn of the century into a cognitive post-capitalism. Thus, cybernetics waned and slowly left the scene. What remained in its wake is 'cyber-everything' – mostly confusing catch-words, including, for a short-lived period in the mid-1990s, architectural digital experiments under the so-called cyberspace idiom.[11] The long trail from Wiener to novelist William Gibson (cyberpunk) with a stop-over at the work of William Burroughs is a thin and winding one. Stewart Brand's *Whole Earth Catalog* provided the binding glue for an audience remotely interested in technology while conscious of the information and computation mutation they were witnessing. Among them, some would become the pioneers of Silicon Valley in the 1980s.[12]

Certainly, the notion of the system did not start in the mid-20th century. Since it is impossible to summarise the history of the idea carried by a Greek word – at least for the Occidental world – let us just recall an almost diminutive but truly enlightening anecdote.[13] Auguste Comte, the nineteenth-century philosopher who promoted a positivist philosophy if not positivism itself as such, published his *Système de Politique Positive* in 1851. The fifth edition (1929) publishes an erratum which reads:

> After checking the manuscript, itself kept by Auguste Comte at 10, rue Monsieur-le-Prince, one should read page 539, 2nd line: 'main systematic base' instead of 'main mathematical base.' This error exists in the 1st edition (1851) and consequently in all successive editions.[14]

This mix-up or confusion between mathematics and systems is not without deep meaning if we keep in mind that maths includes calculus, computation; the tethering is constant, unbreakable, working at full power. Further considering mathematics, ironically, its real role in Wiener's work has been judged as 'fairly irrelevant' by a contemporary MIT fellow.[15]

Architect-engineer Richard Buckminster Fuller, contemporary of Wiener, is deservedly often described as a systems theorist. The title of Fuller's *Operating Manual for Spaceship Earth* (1969) has an intriguing double meaning.[16] The manual as a compendium of instructions to be followed for a task is something different from a manual as hands-on process to achieve them. The alternative remains the manned piloting of a spaceship versus automated piloting. This is where computation and the computer come in. In the very same year, NASA's first moon landing was possible through a sophisticated – for the time – man-machine interface. Among the thousands of sub-systems active in the Apollo programme, the Apollo Guidance Computer was crucial.[17] No wonder that the software crux of the computer has, since the early 1960s, been called the operating system (OS). For instance OS/360 was used on most IBM mainframe computers beginning in 1966, including computers used by the Apollo programme.[18] Hence, in a logical semantic move, the idea of 'system' was linked to the fundamental operating software device of a computer.

In short, computation has fully absorbed and integrated the very notion of the system. It is in or with the computer itself that systems theory rises to a universal and inescapable central position. In the meantime, I would argue that cybernetics loses most of its raison d'être apart from a historical oversight: when information theory, with the work of Claude Shannon among others, took pre-eminence over cybernetics. Again, ideology was not left behind or jettisoned, on the contrary. It remained an undercurrent, in the deep strata both of code and other operational-operative functions.

The morphing of cybernetics into systems theory is synchronous with the peak of the Apollo programme. It could be said that the Apollo Guidance Computer was the locus where this took place with the most spectacular force. Some observers have too easily asserted a direct filiation between NASA's glory days of the 1960s and early 1970s and the nascent development of the Silicon Valley in the 1980s. Though the strength of such a bond is evidently impossible to quantify, it is indisputable.[19] Less than two decades after the Second World War, the problem and goal, seen from the US side, was how to land two men on the moon and return them to earth, with piloting an issue once more. In the meantime, another military problem had been resolved: how to have missiles fired from submarines automatically reach their target. The Polaris guidance and navigation unit developed at MIT did the job. MIT would go on to oversee the crucial Apollo Guidance and Navigation computer system. In Great Britain, Alan Turing was deciphering the German-encrypted messages and communications. Automatically guided V-1 and V-2 rockets were bombing London, with Wernher von Braun as the chief designer of the V-2. Thus three parallel technological endeavours were occurring, with automation as a shared element: automated air-defence, automated rockets, and the automated deciphering of secret codes. The US East Coast imagined and developed the scientific and technological base, the West Coast engineered and crafted the artefacts. Automation was the answer and goal, simulation the method, electronic computation the tool. Generated from a weaponry goal, invented to better fight and kill, cybernetics would keep traces of this context. No wonder that the Tiqqun critic can observe that cybernetics carries an unchallenged murderous drive; it would be naïve to argue the contrary.

I would argue, again, that the shift from cybernetics to systems theory in the 1950s and 1960s was strongly articulated with the development of the first space age. It reflects in part the gap between automatically shooting an aircraft pilot (cybernetics) and having pilots traveling safely to the moon and back (systems). For the sake of history, note that the Soviet Union's first space age had no pilot problem: Gagarin, the first man to orbit earth (1961), or Valentina Tereshkova, the first woman (1963), were just passengers of their Vostok spacecraft, like before them the dog Laika, and like other manned Vostok missions. Automation was the leitmotiv of the Soviet engineers. It was, however, automation without cybernetics, without humans in the loop. When automation failed, there was no human backup solution. Cosmonauts were not given piloting capacities, or they were kept at a minimal level, whereas thanks to the combination of cybernetics and systems thinking, US astronauts were wholly integrated – from spacecraft design to fabrication and piloting – in the overall system. Systems theory, analysis, engineering and so forth enabled the achievement of design projects of unknown complexity.[20]

The role given to control appears different in cybernetics and in systems theory: whereas cybernetics control sticks tightly to well-determined operations even if these operations welcome changes, systems control leaves open the possibility of events, of the new and invention. Whereas cybernetics aims at generalising so that it permeates every domain, systems thinking pays attention to minute details, to specifics while keeping operations open to undetermined factors. In systems theory, the definition of requirements is by its very nature open: open to diverse and more than often contradictory requirements. The move from general to specific and specific to general, providing those words with their precise definition, works in a back-and-forth orchestration which could be seen as a mega-feedback loop. Control sometimes has another, softer-sounding name: regulation. Incidentally, the French translation of *Cybernetics: Or Control and Communication in the Animal and the Machine* in fact reads: *La cybernétique: information et régulation dans le vivant et la machine.*[21] In an effort towards increased generalisation 'the animal' is translated by 'the living' ('le vivant') and 'communication' by 'information'.

Because so much can and has been written about cybernetics, so much elaborated on its premises and so many different arguments can be made using the concept of cybernetics, a thorough historical survey is helpful. In place of engaging here in a thorough retrospective, one may observe the downfall of the idea of cybernetics and the inverse prosperity of the idea of systems. Google's Ngram Viewer tool applied to both terms over seven decades starting in 1940 is implacable: the statistical curve of occurrences of 'cybernetics' in the English written corpus climbs steeply to a summit and then enters, in the mid-1970s, a falling slope, while the 'systems' curve starts growing rather slowly up to its apogee in 1990 and then plummets until 2010. Curiously, or not, the peak of cybernetics took place around 1975, at the end of the Apollo programme. Systems catches and crosses the cybernetics curve around 1980. Something happened to cybernetics which is akin to a disgrace. The notion that had lost most of its appeal and was, by the early 2000s, merely paid lip-service, is today encountering a slow recovery. A recent example showing the indolence of this rehabilitation is given by a 2018 conference compendium published under the promising title *Intelligent Systems in Cybernetics and Automation Control Theory.* The order of the sequence of words in the title is noteworthy. The brain-metaphor is dismissed in favour of the notion of intelligence. This book constitutes the refereed proceedings of a *Computational Methods in Systems and Software 2018 Conference* (CoMeSySo 2018). We are told that the:

> CoMeSySo 2018 conference intends to provide an international forum for the discussion of the latest high-quality research results in all areas related to cybernetics and intelligent systems. The addressed topics are the theoretical aspects and applications of software engineering in intelligent systems, cybernetics and automation control theory, econometrics, mathematical statistics in applied sciences, and computational intelligence.[22]

Now, as for cybernetics, out of 342 pages the notion appears a mere five times, including three times on the same page; in other words: never. The conference proceedings are published in a series entitled *Advances in Intelligent Systems and Computing* whose presentation is in itself an exhaustive list of all the specific domains or disciplines and sub-disciplines it encompasses:

> [it] contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing such as: computational intelligence, soft computing including neural networks, fuzzy systems, evolutionary computing and the fusion of these paradigms, social intelligence, ambient intelligence, computational neuroscience, artificial life, virtual worlds and society, cognitive science and systems, perception and vision, DNA and immune-based systems, self-organizing and adaptive systems, e-learning and teaching, human-centered and human-centric computing, recommender systems, intelligent control, robotics and mechatronics including human-machine teaming, knowledge-based paradigms, learning paradigms, machine ethics, intelligent data analysis, knowledge management, intelligent agents, intelligent decision making and support, intelligent network security, trust management, interactive entertainment, web intelligence and multimedia.[23]

This makes an impressive list indeed and with a single, thus spectacular, omission: cybernetics. One would be tempted to say that cybernetics is nothing else than the totality of all these fields of work, or even, more fundamentally, the governing paradigm which holds them together. But this is not possible. Moreover, artificial intelligence (AI) is not on the list either, instead of which 'computational intelligence' appears, indeed a wiser label, for computation is neither 'artificial' nor 'natural', it just is. Actually, it crosses the lines between both.

To enhance the tight intertwining of cybernetics, systems theory, complex design-make programme management, as they occurred in the 1960s, I will quote at length from three non-academic sources of interest, representing three cases: one from the military-industrial complex, one from a think-tank working for the military and one from a federal organisation relying heavily on the military-industrial complex. These cases are: TRW Systems, (Thompson Ramo Wooldrige), SDC (System Development Corporation) and NASA. They were interrelated in many ways. The rhetoric used in those documents speaks for itself regarding the place given both to cybernetics and systems – be it systems engineering, management, design, and so on. Chiefly, these documents, which in part aimed at being operational, use a discourse of instructions and orders, command and control. They perfectly mirror the context from which they grew and, significantly, echo each other. In opposition to the tradition of very short and/or truncated quotes, long excerpts will be given here so the reader can immerse themselves in the material used for the argument. This approach is akin to anthropological research where enquiries rely on lengthy exposition of facts, discourses and whatever evidence is found in the field. In doing so, paraphrasing sources is avoided and replaced by the actual documents.

Case 1: TRW

In the US industrial-military complex a major player such as TRW Systems, from Redondo Beach, California, exemplifies with great clarity the paramount role played by systems theory in the mid-sixties. The company described itself thus:

> TRW Systems is one of four operating Groups in TRW Inc., worldwide supplier of aerospace, automotive and electronic products and services … Corporate products, in addition to those of TRW Systems, range from automotive valves, pistons and linkages, through jet engine parts and torpedo propulsion systems, to electronic components for defense, space and consumer applications.[24]

The introduction of a small technical booklet TRW Systems offered as a promotional item in 1967 reads:

THE SYSTEMS APPROACH
The systematic application of computer techniques for solving engineering problems has made possible the handling of the many interrelations necessary to describe complex systems, organisations, and time-variant processes. Prediction as well as increased understanding of system behaviour are the results. These engineering techniques have been extended to the analysis of social and management problems with very beneficial results. The systems approach provides a method of thorough planning and management. Scientists have in the past looked for analogues common to all dynamic systems. The use of feedback loops as a thread common to animal, machine, and organisation was suggested by Norbert Wiener in his book *Cybernetics*. He further suggested simulation as a valuable tool where rigorous, formal, 'optimum' solutions are of less importance than the behaviour of the system as a whole. By linking together feedback loops involving appropriate delay times, amplifications, and structural relationships, it is possible to simulate systems of high complexity with remarkable accuracy. Because the human mind is unable to comprehend the interrelationships of more than four or five feedback loops at a time, it has been found necessary to use the automatic, high speed computer to handle the myriad relationships typically required to describe a large dynamic system in depth. The methodical programming of sequential calculations to be accomplished in a computer run has greatly reduced the mathematical prowess and mental dexterity required, and the resulting (systems approach) solution of problems is amply justified by the significant results obtained. Typically, the equations and procedures are discrete computations at successive intervals of time, to describe levels controlled by rates. Non-linear relationships are easily handled by this approach. Through the use of positive as well as negative feedback loops, growth processes can be simulated in combination with homeostatic processes. By allowing for growth in the model, simulation has become an excellent tool to predict the behaviour and problems of rapidly expanding or newly developing systems, serving to prevent the interpretation of change (per se) as a disease in the system, in contrast to a simple model having a relatively constant state of equilibrium.[25]

All the basics of systems thinking are grouped together in this short text standing as a most thorough abstract of what cybernetics does to industry via systems theory. TRW was contracted by NASA to design and manufacture the Lunar Module's descent stage rocket engine. [Fig. 1] It was the very first rocket engine that could be throttled, its thrust from 15 per cent to 100 per cent being regulated by pilots (astronauts) and the Apollo Guidance Computer in tandem. If we decide, as a heuristic principle, to pay attention to objects or artefacts, considering that they encapsulate a maximum of meaning, the Lunar Module's descent stage rocket engine epitomises an assemblage of cybernetics and systems engineering at its pinnacle.[26] Beyond its TRW descent rocket engine, the whole Lunar Module, designed and made by the general contractor Grumman (Long Island) has the aura of a quasi-fetish object.[27] Examining the photographs, the blueprints and the few still extant Lunar Modules in museums, and taking a step back, yields some uncanny thoughts. We face the difficulty of trying to fully understand the object itself as a material artifact and piece of craftsmanship, condensing not only the technologies of its time but, as crucially, the organisation of the processes which brought it into existence.

The Lunar Module was, from a pilot's point of view, something out of this world, aiming at bringing them to an unknown world. It appears now as an utterly strange product of a by-gone era, impossible either to recreate or grasp comprehensively. The ultimate machine, a man-made and human-controlled machine mediated by the computer, the Lunar Module has sunk into historical oblivion along with other tools from the past, good enough for museums but finally not much else. However, if envisioned as an object intimately connected both to the sphere of cybernetics and systems theory, and to the ideological context which enabled its

Fig. 1: First space age relic: NASA Lunar Module mock-up. Bangkok Science Museum and Planetarium. Photo: author.

development, and when considering any one of its material features or components in the light of cybernetics and systems theory, one could begin to imagine the feelings experienced by the men and women who participated in the Apollo program. The Lunar Module, a 'machine of loving grace'?

In 1967 – note the date – Richard Brautigan wrote: 'I like to think (it has to be!) of a *cybernetic ecology* where we are free of our labors and joined back to nature, returned to our mammal brothers and sisters, and all watched over by *machines of loving grace*'.[28] In a 2015 essay by John Markoff using Brautigan's lines as both its title and epigraph, *Machines of Loving Grace: The Quest for Common Ground Between Humans and Robots,* the opening of Chapter 5 recalls NASA's approach in the 1960s to the pilot/automation dilemma.[29] Here, I cannot resist considering the Lunar Module as a grace machine, if not the grace machine par excellence, thus misinterpreting a superb essay by architect and theorist Lars Spuybroek.[30] For a joint cybernetic-systems induced piloting choreography in an environment bearing from zero to one sixth of the earth's gravity, astronauts were to skilfully manoeuvre their grace machine, combining grace with a gravity-less world. By designing and crafting the Lunar Module's descent engine, TRW made history.

Case 2: SDC

SDC (System Development Corporation) was a spinoff of RAND Corporation, one of the most important American think-tanks, and located on the same premises in Santa Monica. The RAND corporation was, in a way, Wiener's *Predictor* applied to geopolitics, a mega-Predictor.[31] At RAND, thinking was helped, sped-up and enlarged thanks to computer simulation.[32] As its parent institution, SDC had from its inception placed system theory at the heart of its action. Automation, and implicitly, cybernetics, were enlisted in many projects, as for example the improvement of education:

> Research in education at SDC dates back to 1958 when the Automated Teaching Project was initiated in the Human Factors Department. Its major objectives were to determine by experimental research the conditions under which programmed learning materials presented *automatically* provide the most effective instruction to students, and then to develop an *instructional system* which would incorporate these conditions in its operations. Early activities of the project's staff centred around explorations of the possible advantages of a flexible teaching program and display arrangement that would be responsive to individual student differences. The next step in the program was the development of a *system* for literally '*automating'* the presentation of materials. Utilizing a Bendix G-15 computer as the central control unit, the experimental auto-instructional system provided for teaching one student at a time. This was the forerunner and necessary first step in the development of the present facility, CLASS (Computer-Based Laboratory for Automated School Systems), which permits the simultaneous automated instruction of as many as 20 students, each student receiving an individualized sequence of instructional materials adapted to his particular needs.[33]

Education, of course, has always been a major social and political issue; nowadays we marvel at, or complain about, the power gained by the digital in the field of education, vastly increasing its grip since the 2020 pandemic. But as early as the early 1960s, the computerisation of the school and the university was on the move. The SDC's 1962 report *A Computer-Based Laboratory for Automation in School Systems* is a textbook on these matters.[34] The word 'cybernetics' is absent from the report, while 'computer' appears everywhere. The iconography includes photos and architectural perspectives of computerised classrooms where the students are sitting at single tables, reasonably spaced out, bearing cumbersome computer apparatuses. In the 2020–21 pandemic world such spacing resonates strangely, with a less progressive and optimistic tone. The decor of those classrooms bears an indisputable similarity with NASA's Mission Control room in Houston, which was designed at the same time and inaugurated in 1965. The teacher has a small command and control office next to the classroom. Among the eleven sources listed in the bibliography, the link with military's use of systems theory is clear: 'R. L. Chapman, J. L. Kennedy, A. Newell and W. C. Biel, "The Systems Research Laboratory's Air Defense Experiments". *Management Science,* 5:3, 250–69'. Thus, years before Buckminster Fuller promoted with gusto the idea in a 1963 lecture, SDC was already working on education automation.[35] SDC addressed several topics other than education automation and was virtually engaged in most of the large field of systems thinking. Simulation and modelling were also prominent on SDC's agenda.

Case 3: NASA

The *Apollo Program Development Plan* published in January 1965 by NASA captures exceedingly well the paramount importance given to systems thinking in the US space administration:[36]

> 9.9.1 Basic Objective
>
> The basic objective of Apollo System Engineering Management is to establish a single reference base for the analysis, definition, trade-off, and synthesis of requirements and design solutions on a total program basis in order to provide clear and concise information flow between the Apollo Program Office, the Field Centers and their contractors. Design trade-off shall be made in terms of time, cost, and performance. Performance considerations shall include the various design constraints imposed on the program such as reliability, maintain ability, safety, human engineering, environmental constraints, transportability, operability, procurability, and producibility. The single reference base shall evolve in consonance with the design process and shall establish the basis for the identification, control, and accounting of the system as it is defined by means of configuration management procedures employing the concept of baseline management (reference Apollo Configuration Management Manual NPC 500-1).
>
> 9.9.3.1 Baseline Management
>
> An underlying objective of Apollo System Engineering Management is to establish and maintain a system of control between Apollo Program objectives, design requirements, and design solutions of the various elements of the program at each design level.
>
> 9.9.3.2 Engineering Process
>
> The system engineering process represents a systematic approach to engineering – the steps involved in the structured process are identical to those that are involved in any design process. As such, it becomes necessary to ensure that system engineering management becomes an integral part of the design effort rather than a parallel or reporting effort which duplicates the normal design effort. While the discipline necessitated by system engineering may initially require changes in internal procedures, this additional effort will be significantly offset by the advantages accruable through the use of the process. Once implemented, it is anticipated that the documentation and procedures required by Apollo System Engineering Management will become a natural part of everyday design business. Thus, the paper flowing between designers within a contractor's organisation will be the paper required by this system, the review procedures will be a normal part of the everyday management of the program, etc. To summarise, it is the full intent of Apollo System Engineering Management to prescribe and structure a process which is normal to everyday business rather than to establish a superstructure.
>
> 9.9.4 Summary of System Engineering Management Process
>
> *System Engineering requires a form of servo-loop feedback and the initial requirements for facilities*, personnel and procedures depends upon considering an initial equipment design that facilities will have to store and house; personnel will have to use

> and depend on; and procedures will have to describe to personnel for operation and maintenance. The initially predicted facility, personnel and procedure requirements resulting from these initial considerations of equipment are immediately fed back for a trade-off of total program element requirements and a more detailed derivation of equipment, facilities and personnel.[37]

In this NASA document, a ceaseless association, if not sheer fusion, between technical and management issues is accomplished like in no other. The *Apollo Program Development Plan,* dry and meticulous as a legal memo, distributed first to the institution's main leaders and thereafter more largely, stands as a manual we can consider, in its own right, as a genuine monument. It dictates nothing less than good behaviours to be followed at every level by everybody acting in and for the Apollo programme. Behave yourself systematically, if we can say so, with systems in mind. No surprise that during each important space flight sequence, Mission Control (Houston) and astronauts would utter the phrase 'all systems go'.

Chosen among test-pilots with a solid engineering background, astronauts became system engineers, participating in the design of the spacecrafts which would bring them to the moon, regularly meeting the makers in the different labs and factories, testing tirelessly not only the artifacts but, above all, the functioning of the systems they were part of. The three institutions TRW, SDC and NASA were the kind of places where the mingling of cybernetics and systems theory was taken to the highest degree. It is worthwhile studying the individuals who ran them and were instrumental in the achievement of their goals. To name and understand who did what and who invented what is a prerequisite when looking back into history; cybernetics has been well documented on similar grounds.[38] We must complement this knowledge with an enquiry into who was in charge in the realm of the operational field. From concept to action, who was instrumental? This is exactly where systems thinking comes in. A reminder of the careers and backgrounds of a few important figures in leadership positions active in those three sites of operation confirm how close their relations and their interlocking were in the context of the first space age.

For Case 1 (TRW), it makes sense to look at the figure of Simon Ramo. Appointed as a technical adviser to the Strategic Missiles Evaluation Committee (earlier called the Teapot Committee headed by no less than John von Neumann), Ramo was a prime architect of the first intercontinental ballistic missile (ICBM) programme before creating TRW with partners Thompson and Wooldridge:

> Systems engineering … played a prominent role at Hughes Aircraft Company, where Simon Ramo had assembled a skilled team of scientists and engineers to develop electronic gear for military aircraft and the innovative Falcon guided missile … Wondering how best to formulate and pass on the expertise necessary to address the complexities of missiles and electronic systems, Ramo began to promote the idea of an academic discipline of systems engineering. However, his first opportunities to pass along these ideas came not through publication but through his involvement with Schriever's ICBM program.[39]

Incidentally, Ramo was quoted in March 2020 in a feature article of the *Los Angeles Times* casting new light on a rarely treated subject in NASA's history:

> Unlikely partners put man on the moon. At NASA, Jewish and former Nazi engineers and scientists reconciled the past and teamed up to meet a monumental challenge … The German engineers not only helped land Americans on the moon, but played a key role across the nation's defense programs, and there too they collaborated with American Jews. Adolf Thiel was recruited to aerospace giant TRW's Space Park in Redondo Beach by its chief, Simon Ramo, one of the most important Jews in American aerospace. Thiel, a former Nazi Party member, rose up to run all

> of TRW's spacecraft operations, putting him in charge of the nation's most sensitive intelligence and defense satellite programs. During Apollo, TRW developed a revolutionary rocket engine with variable thrust that was critical to the Lunar Module's landing. Thiel and Ramo became friends, recalled Thiel's son, Michael.[40]

This piece highlights a new chapter in the history of first space age: rarely had historical events been so thoroughly live-documented, archived – notwithstanding some unfortunate episodes of lost archives – and professionally treated. NASA, following an old military tradition, founded a history department at its inception in 1958. Here, also, on the specific field of historiography, one is tempted to recognise the imprint of systems thinking allied to a strong political will to educate and to contribute to education. Control and command of the machines and, whenever possible by machines: computers, from design to operation had a parallel in the systematisation of a historical approach to every fact and event encountered during the successive Mercury, Gemini and Apollo programmes. It is true that some aspects were kept in the dark, whether on the ethical-political side – such as the Nazi technical legacy or the relations of Jewish and Nazi engineers as outlined in the *LA Times* enquiry quoted above – or on the more mundane topic of the astronauts' lifestyle, providing the better part of *The Right Stuff*, a 2020 Disney-produced TV series bending Tom Wolfe's famous essay towards private gossip.[41] With Case 2 (SDC), its in-house publications of the 1960s, especially the detailed resumés of prospective new employees, are a gold mine to be explored. As a sample of a career profile, we can quote from that of Stan Rothman:

> Prior to joining SDC, he worked at IBM and at RAND, where as a numerical analyst he was active in the development of a method utilizing Monte Carlo computations for a multidimension search by statistical techniques. He was head of the Operations Research section at General Electric and participated in technical direction activities at Space Technology Laboratories. As a member of the senior staff of Ramo-Wooldridge, he directed the development of the data handling portion of a ground system for 117L and participated in an Air Force-wide system study of intelligence data handling. At SDC, Rothman was among those responsible for the design and development of the Systems Simulation Research Laboratory. He was head of the Development Division's Space Systems Branch and in November, 1961, was appointed manager of the Satellite Control Department. He is a member of the Association for Computing Machinery, Institute of Mathematical Statistics, Operations Research Society of America, and the Society for Industrial and Applied Mathematics.[42]

One could mention many other profiles, all of them providing a faithful portrait of SDC, showing where its expertise, interest and involvement in systems theory came from. Equally informative but less well documented is the fact that, likewise in Santa-Monica, closer to the beach than the RAND/SDC campus, stood SYNANON, a singular commune which thrived in the 1960s and 1970s. Gerald Newmark, an SDC educator, lived there for a few years, putting in practice an idealist goal of sociological reform and progressive thinking.[43] SYNANON dealt with behaviour problems, or problems identified as behavioural, promoting new rules of conduct based on daily collective intro-and exospection meetings they called The Game. Among Newmark's friends were TRW engineers and managers. Thanks to introductions by Newmark I was invited to see a Lunar Module descent engine in the fabrication process at TRW's workshops in July 1968. This personal experience, as a teenager, is undeniably one of my motivations in starting to deal, if possible, critically, with an understanding of the first space age. Writing not only from second or third-hand sources and documents but also from remembered personal experiences provides less a pre-eminence than a forceful incentive.

Finally, with Case 3 (NASA), there are several central figures with published biographies. The curriculum vitae and seminal role of James Webb, NASA's famous head from 1961 to 1968 are well documented. Among other leaders, that of George Mueller is especially relevant to our enquiry.

Mueller was first a Vice President of Space Technology Laboratories (TRW*)* which aided the Air Force (USAF) missile programme, before becoming the deputy associate administrator of NASA and director of its Office of Manned Space Flight. In his days at NASA, Mueller was already considered 'a highly qualified import into NASA from Space Technology Laboratories, which played such an important role in the Air Force missile program'.[44] More recently, a biographer wrote:

> Mueller had the ability to analyse and understand systems and knew what it took to build complicated space vehicles. In particular, he could visualize a total system – hardware, software, people and processes – and everything necessary to accomplish the task at hand. A system engineer, Mueller knew how to apply it to management, using 'system management'.[45]

Mueller was indeed instrumental in the transition from system engineer to system manager. After his six years as NASA's associate administrator for manned space flight, he served as General Dynamics senior vice president and as chairman and chief executive officer for SDC. Thus, he neatly closed the ring, from TRW (STL, Space Technology Laboratories) to NASA and to SDC (RAND). Moreover, MIT appears at the centre between these three institutions, and even if this is no more than a logical result of a top university producing the best engineers and managers available in the country, an elite of some kind, it still has to be acknowledged. MIT was not only crucial in providing leaders for the whole programme, but even supplied staff to some of its opponents: 'Jerome B. Wiesner of the MIT, who urged that the new administration deemphasise human spaceflight initiatives for practical reasons: spaceflight was dangerous and unlikely to yield valuable scientific results, he argued'.[46] On the astronaut-pilot side, Buzz Aldrin, the second man on the moon, held a PhD from MIT. In summary, an observation to infer from our three cases in addition to MIT is that they operated as a tightly-networked team in the service of a great idea. At one point, something like a nation does coalesce in such a configuration, when precise goals are given, more than often in situations with external threats.

Back to the question of automation and the pilot-astronaut: it is noteworthy that the vast majority of failures in the first space age, and also, it seems, in the new space age, have to do with electricity, and more precisely, with electric interfaces such as sockets, plugs, switches and commutators. Electric flux to control mechanical apparatuses, and how it is managed, has always been a key element. One takes for granted the electrons flowing in copper wires and from there onto boards, printed circuits, then in chips and between chips. Electric and electronic malfunctions come from a very simple fact: the invisibility of the electric flux, the minimum visual presence of the wires and their tiny – micro and now nano – accessories carrying the flux. In this context, the Apollo Guidance Computer we mentioned earlier deserves a closer look. Its read-only memory (ROM) was made with cores (ferrite rings) and threaded wires: 'In the original implementation, the cores were strung out along the wires and not neatly arranged in a grid. Eventually, the design took on the appearance of a long bundle of cores and wire, looking like a rope with cores along its length.'[47] We can consider the core-rope ROM as a paragon of the place taken by copper wires in the system. Carefully woven by seamstresses, the central memory of the Apollo computers seems today both archaic and amazing. While holding the threads they wove in the precise pattern that would encapsulate the crucial software coding to run the Apollo Guidance Computer, these women actually had in their hands the supplest and most resistant computer hardware ever to be. They were crafting neither the heart nor the brain of the machine but weaving during laborious weeks the system itself. Core-rope hand-crafted assemblages were sharing the lead with the astronauts on the lunar missions.

Again, issues typical of the 1960s remain present in the twenty-first century and it appears that the first and the second space ages – also called old and new space – share a greater common ground than assumed. Just consider, in engineering, the sub-discipline of switchology – a well-found label if there was one – dealing with control via switches, push-buttons and triggers. Interestingly, automation in spacecrafts after Apollo followed a seemingly contradictory path on the piloting side. In order to decrease the pervasiveness of switches, the shuttle, designed in the 1970s, did not represent complete progress compared to Apollo: designed more like a mega-747 cockpit, with important computer power and fly-by-wire, it was packed with switches. One had to wait until 2020 and Space X's Crew Dragon manned capsule to introduce a no-switch environment – other than Soviet craft: the fully-automated and non-piloted early Vostoks. Certain contemporary space events show some overlap between historic space age and present day endeavours: think of two failed attempts to automatically land robots on the moon, respectively by Israel and India's space programmes.[48] Both crashes expose the paradoxical nature of sophisticated automatic systems designed to fly objects from earth to the moon with no pilots aboard. It can be seen as quite awkward, with all of today's computer means, to fail in 2019, at something that was first achieved by the Soviet Luna 9 on 3 February 1966, and four months later by NASA's Jet Propulsion Laboratory Surveyor 1.

Does the slowdown and falling curve of systems thinking since the 1990s have to do with the apparent loss of knowhow or, more precisely, of command and control? Is the deep cause a lack of cybernetics, systems engineering, AI, or all of them together? And 'who' is in charge now of the 'together', if not AI? The loop is once more closing back on the rather common question of governance and piloting, metaphorically and non-metaphorically. Always observe the pilot to understand what is going on, even if it is a fully automated pilot working on cybernetic feedbacks encapsulated in systems. Whatever the gap between old and new space, a direct link between them is exemplified by the recruitments made to create Space X: TRW veterans were instrumental in founding the company. In fact, to have the boldness to imagine bringing back a rocket's first stage smoothly to its launch pad, you need bold, ageing experts who were instrumental in the successes of the first space age. And, I would argue, one of the paths to those successes was a dedicated devotion to systems engineering and systems management. Impossible feats ask for a sense of possible extreme control and command, backed with up-to-date technoscientific knowledge.

Cybernetics gave way to systems theory at the very moment the Apollo programme was at its peak; systems theory gave way to AI and, finally, only one guiding watchword remained unchanged from 1945 to the present: automation. Thus, to deal with cybernetics now can only take place on a historical level. From Norbert Wiener to our own time, the very idea of cybernetics has evolved more than once. Wiener went from solving the pilot problem to solving everything, from a precise goal to an all-encompassing ideology, if not a metaphysics. But NASA, for instance, had no use for metaphysics when asked to land men on the moon, even if, ironically, such a feat did produce a few metaphysical questions. The truth is that when you focus on the operational quality, you discard ideology and keep going without the word, name, label of cybernetics. This is when systems enter the scene. The pilot problem, whether it is to kill an enemy pilot or to land a pilot on the moon, is a technical problem with technical solutions. The process of achievement relies, in the last example, on a systematic use of systems theory. No metaphor is involved here; the organic/machinic bind, so fundamental to Wiener's cybernetics, is of little use here. The power of cybernetics was the way it shifted back and forth from metaphor to non-metaphor, at a very fast pace, like an alternating electric current, to stick with metaphorical language. It was also its main weakness.[49] Ideology, however is never far away; impossible to erase, it stays in the background as a rumble, a white noise. It is noteworthy that Bertalanffy, who claimed to be the first inventor of cybernetics, at the same time avoided Wiener's label in order to promote systems theory instead. Ultimately, his success exceeded even his own dreams. What do we do, then, with this history of the paradoxical mingling and divergence of cybernetics and systems theory? Are there echoes or surviving effects in the twenty-first century's combined developments of AI, deep learning, algorithms, and big data? Observing the differences and similarities between the first and second space age offers clues as to what persists and what is gone. For instance, the pilot problem stays around despite the almost exponential build-up of automation at the end of twentieth century, not only in the field of actual flight or space flight, but in so many other domains. It persists in the background like a feeble rumour and the metaphorical figure of the pilot has not lost its strength.

The far-left and/or self-declared revolutionary – if such a label helps to locate this political and theoretical school of thought – while quite accurate in its harsh critique of the post-Marxists' positions on economics and capitalism (Negri and Hardt) reveals its technophobia when finally claiming the motto: to fight cybernetics instead of being a critical cybernetician.[50] By insisting that the greatest asset – and at the same time, failure – of cybernetics is its outrageous rationalisation, the far-left anti-cybernetics thinkers miss the main point: to shoot the moving target is a practical problem with no ideological rationalisation behind it. If a mathematical and computational rationalisation is needed to achieve the goal, then let it be. Landing humans on the moon was possible thanks to systems thinking plus a heavy dose of cybernetics and cybernetics-inspired technics, where it was never a question of too little or too much rationalisation. Succeeding in crafting a near-perfect weld on a piece of rocket or spacecraft depended heavily on talented gestures by an ingenious craftsman featuring a rational mind.

Half a century after the glorious years of NASA, the ambition to land men and women on the moon encounters similar issues. It finds most of its answers in techno-science inherited from cybernetics and systems theory: AI plus outstanding computation power. 'Shoot the pilot' triggered cybernetics; 'shoot to the stars' did so for systems engineering; 'shoot cybernetics' is of no avail. Cyberneticians reconfigured what piloting a plane meant, systems engineers what piloting a spacecraft meant. Wiener saw the pilot functioning as a servomechanism. From there on systems engineers carried the flight task up to the moon, where the man-machine interface anticipated what we are living now. As is often recalled, the origin of the word cyborg had to do with the concern about how astronauts' bodies and health could be enhanced in order to endure the hazardous and arduous constraints of spaceflight.[51] It is important to underscore the strength of the anthropological assemblage between what can roughly be called a strict method (systems theory) seen as a 'usage of the world' in part linked to cybernetics, and design and built artefacts under some precise global political wills and goals. In short, every single object produced in the course of the Apollo programme was submitted and integrated in this assemblage, including, needless to say, the pilots themselves. The pilot problem, redefined by Wiener, was reshaped under new anthropological parameters mixing things of different orders, scales and natures, put together, or more exactly, handcrafted together.

Cybernetics was not dissolved into systems thinking but taken to another operational level under the pressure of computation's compelling exponential progress. The so-called Cold War following 'plain' war offered the stimulus, and the 1960s space race was the new site of operation, the new battlefield long before the coming institution of space armies in the twenty-first century. If to disentangle the relations between cybernetics and systems theory seems a lost cause, paradoxically, the need to draw a dividing line between them still makes sense today. Whether this irregular borderline mirrors an ideological ground or follows more concrete predicaments, it is traced on a historical map of events, which as with any human matter, relies both on collective social factors and on specific actors holding key positions of knowledge and power. Now, since I am in part writing from the perspective of the architectural discipline, what lessons from this story can be drawn for our trade? In short, architecture seems to have missed a step or two during the last four or five decades. The works of Nicholas Negroponte, Gordon Pask, Cedric Price and other 1970s pioneers of architecture and computation were largely ignored by the profession. The digital turn of the early 1990s took at least twenty years to really integrate AEC (Architecture Engineering Construction)**.** Doesn't BIM (Building Information Modelling) appear as an extremely late integration of systems thinking into the architecture field? Everything, day after day, becomes semi-automatised and progressively automated from the design to the construction site.[52] Notwithstanding the limits of the pilot metaphor applied to architecture, we are today in a situation where the architect, technically, culturally and historically, seems to be sitting on an ejection seat.

Notes

This article is dedicated to the memory of Gerald Newmark (1926–2018).

1. Tiqqun, *The Cybernetic Hypothesis*, trans. anonymous (2014 [2001]), 11, https://theanarchistlibrary.org/library/tiqqun-the-cybernetic-hypothesis from *L'hypothèse cybernétique,* in: *Tiqqun* no.2, 'Zone d'opacité offensive' (2001). The Foucault quote comes, according to Tiqqun, from his 1981–82 courses.
2. Ibid.
3. Jamie Holmes, *12 Seconds of Silence: How a Team of Inventors, Tinkerers, and Spies Took Down a Nazi Superweapon* (Boston: Houghton Mifflin Harcourt, 2020).
4. Peter Galison, 'The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision', *Critical Inquiry* 21, no. 1. (Autumn 1994): 228–66.
5. Gilbert Simondon, *On the Mode of Existence of Technical Objects,* trans. Cécile Malaspina and John Rogove (Minneapolis,Univocal Publishing, 2017 [1958]), 51; my emphasis.
6. Erich Hörl, 'A Thousand Ecologies: The Process of Cyberneticization and General Ecology', trans. James Kirkwood, Jeffrey Burton and Maria Vlotides, in *The Whole Earth: California and the Disappearance of the Outside*, ed. Diedrich Diederichsen and Anselm Franke (Berlin: Sternberg Press, 2013), 121–30; cf. Erich Hörl, 'Knowledge in the Age of Simulation: Metatechnical Reflections', in *Simulation: Presentation Technique and Cognitive Method*, ed. Andrea Gleiniger and Georg Vrachliotis (Bâle: Birkhäuser, 2008), 93–105.
7. For an efficient recent introduction to pragmatist philosophy in relation to architecture, see *Footprint* 20, 'Analytic Philosophy and Architecture: Approaching Things from the Other Side' (Spring / Summer 2017) and, in particular, David Macarthur, 'Reflections on Pragmatism as a Philosophy of Architecture', 105–20.
8. This position is held by Jean-Pierre Dupuy in *The Mechanization of the Mind: On the Origins of Cognitive Science,* trans. M. B. DeBevoise (Cambridge, MA: MIT Press, 2000 [1994]). His 'Introduction: The Self-Mechanized Mind' (3–26) offers a valuable account of Heideggers' relation to cybernetics and of the French structuralist reinterpretation of cybernetics.
9. Lars Skyttner, *General Systems Theory Problems Perspectives Practice,* second edition (Singapore,World Scientific Publishing Co., 2005).
10. Ludwig von Bertalanffy, *General System Theory: Foundations, Development, Applications* (New York: George Braziller, 1969), 149–50.
11. To borrow from Ronan Le Roux's foreword to the French translation: Norbert Wiener, *La Cybernétique Information et régulation dans le vivant et la machine,* ed. R. Le Roux, trans. R. Le Roux, R.Vallée and N.Vallée-Lévi (Paris: Éditions du Seuil, 2014).
12. Cf. Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the*

Rise of Digital Utopianism (Chicago and London: The University of Chicago Press, 2006). 'Even as they set out for the rural frontier, the communards of the back- to-the-land movement often embraced the collaborative social practices, the celebration of technology, and the cybernetic rhetoric of mainstream military-industrial-academic research.' Ibid., 33.

13. Today, Wikipedia remains the best source of synthetic, and fairly reliable knowledge one can have immediately access to for free. On its reliability, cf. it's own warnings at : *https://en.wikipedia.org/wiki/Wikipedia: Wikipedia_is_not_a reliable_source*, accessed December 2020.
14. Auguste Comte, *Système de Politique Positive* (Paris: self-published, 1929 [1815]), my translation. The full title of this four-volume work is *Système de Politique Positive de Traité de Sociologie Instituant la Religion de l'Humanité.* Comte (1798–1857), credited for the 'invention' of sociology, created at his home address the *Société Positiviste,* which published his work, available in two bookstores listed on the front page.
15. David Mindell, *Cybernetics Knowledge domains in Engineering systems* (Fall 2000, MIT), academic on-line paper. 'The original *Cybernetics* was filled with obscure and fairly irrelevant mathematics, which intimidated lay readers, so he (Wiener) followed the book with a popularized account, *The Human Use of Human Beings*. Ibid., 3. Mindell is Dibner Professor of the History of Engineering and Manufacturing at MIT, Professor of Aeronautics and Astronautics, and from 2005 to 2011, Mindell was director of MIT's programme in Science, Technology, and Society.
16. R. Buckminster Fuller, *Operating Manual For Spaceship Earth* (Carbondale: Southern Illinois University Press, 1969). Note that for the first printing in 1967, no publisher was identified. In our 2020 pandemic world one may doubt whether we are still on a 'spaceship', and if this stands for a closed system of precisely and well-controlled environment where humans can live in good health. Bucky's elegant metaphor of the 1960s has been turned upside down. Spaceships of the present second space age are explicitly becoming rescue rafts designed to let humanity escape for ever its derelict earth.
17. David Mindell, *Digital Apollo: Human and Machine in Spaceflight* (Cambridge, MA: The MIT Press, 2008); *Memoir* (Boston: Fort Point Press, 2018). This undisputed reference must be complemented with Don Eyles's *Sunburst and Luminary: An Apollo Memoir* (Boston: Fort Point Press, 2018), a remarkable account of his experience as a computer programmer for the AGC. Written in 2002, with no publishing company interested, Eyles created his own. Don Eyles presented a paper to the 27th annual Guidance and Control Conference of the American Astronautical Society in Breckenridge, Colorado (2004) entitled *Tales From The Lunar Module Guidance Computer.*
18. Cf. https://en.wikipedia.org/wiki/Operating_system (retrieved November 2020).
19. For a broader view of the interactions of mainstream technology with the radical and underground movements in the 1960s, see Diedrich Diedrichsen and Anslem Franke, eds., *The Whole Earth: California and the Disappearance of the Outside* (Berlin: Sternberg Press, 2013); see also: Felicity D. Scott, *Architecture of Techno-Utopia Politics after Modernism* (Cambridge, MA: The MIT Press, 2007).
20. Cf. Matthew Hersch, '"Capsules Are Swallowed": The Mythology of the Pilot in American Spaceflight', in Michael J. Neufeld, ed., *Spacefarers: Images of Astronauts and Cosmonauts in the Heroic Era of Spaceflight* (Washington DC: Smithsonian Institution Scholarly Press, 2013), 72–114.
21. Wiener, *La cybernétique.*
22. Zdenka Prokopova, Petr Silhavy and Radek Silhavy, eds., *Intelligent Systems in Cybernetics and Automation Control Theory*, (Cham, Switzerland: Springer, 2019), V.
23. Ibid., I.
24. J. B. Kendrick, ed., *TRW Space Data*, third edition (Redondo Beach: TRW Systems, 1967).
25. Ibid., 4.
26. To examine how Simondon's concept of objective concretization could be applied here would require an in-depth investigation.
27. Grumman company was a jet maker with sound experience in jets designed for aircraft carriers; landing on

a moving strip at sea is still one of the most testing pilot experiences. Fetish-wise, note that provided they have sufficient assets, space geeks can participate in the museumification of used or lost spacescraft: the owner of a major New Space company, Blue Origin – made billionaire by delivering books anywhere within a few days – financed the retrieval of Gus Grissom's sunken Mercury Liberty Bell 7 capsule in July 1999.

28. Richard Brautigan, *All Watched Over by Machines of Loving Grace* (San Francisco: The Communication Company,1967). The short poem was published in the collection of the same title, written during Brautigan's poet's residency at the California Institute of Technology in Pasadena, California, 17–26 January 1967. Cf. http://www.brautigan.net/index.html. My emphasis.
29. John Markoff, *Machines of Loving Grace: The Quest for Common Ground Between Humans and Robots* (New York: HarperCollins, 2015).
30. Lars Spuybroek, 'The Grace Machine: Of Turns, Wheels and Limbs', *Footprint* 22 (Spring/Summer 2018): 7–32; cf. his essay *Grace and Gravity: Architectures of the Figure* (London: Bloomsbury, 2020).
31. '[Wiener's] early efforts at computation and antiaircraft fire coalesced in a remarkably ambitious calculating device that he called the "antiaircraft (AA) predictor", designed to characterize an enemy pilot's zigzagging flight, anticipate his future position, and launch an anti-aircraft shell to down his plane.' Galison, 'Ontology of the Enemy', 229.
32. Architecture-wise, the nondescript office building of its headquarters in Santa Monica was analysed by Michael Kubo, 'Network Building: The RAND Corporation, Santa Monica', *VERB Connection* 3 (2004): 72–81; followed by Michael Kubo, *Constructing The Cold War Environment: The Strategic Architecture of RAND* (self-published, 2009), available for print on www.lulu.com.
33. *SDC Monthly* 6 no. 3 (March 1963): 1; my emphasis.
34. David G. Ryans, Don D. Bushnell and John F. Cogswell, *A Computer-Based Laboratory for Automation in School Systems* (Santa Monica: System Development Corporation, 12 March 1962), nineteen-page memo prepared for the United Nations Educational Scientific and Cultural Organisation's Conference on Development End Use of New Methods and Techniques in Education, Paris, March 1962. SP-256/000/01c.
35. R. Buckminster Fuller, *Education Automation* (New York: Doubleday, 1963); Claude Baum, *The System Builders: The Story of SDC* (Santa Monica: System Development Corp,1981).
36. NASA's Office of Manned Spacecraft, *Apollo Program Development Plan* (Burlington: Apogee Books, 2017 [1965]). This NASA document was originally prepared by Samuel Philipps, Apollo Program Director, and published on 15 January 1965.
37. Ibid., pages 9-22 and 9-23, sub-section 9.9, 'Apollo System Engineering Management' of Section 9, 'Technical Description & System Engineering'; my emphasis for excerpt 9.9.4.
38. For example, cf. Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2011).
39. Stephen B. Johnson, *The Secret of Apollo Systems Management in American and European Space Programs* (Baltimore and London: The Johns Hopkins University Press, 2002), 50–51.
40. Ralph Vartabedian, 'Unlikely Partners Put Man On The Moon', *The Los Angeles Times* (1 March 2020), A1, A12, A13. Quote from page A13.
41. Walt Disney had, from before the start of the space race, teamed up with von Braun to promote his visions and projects for manned space exploration, and it is no surprise if, more than half a century later, Disney keeps banking on the topic. The novelty is the focus on the less-advertised human behaviour of the astronaut heroes, revealing in such a move an ironical involuntary insistence on pilots' behaviour on the ground, while cybernetics dealt with their in-flight behaviour. The overlap of the two is a classical trope of every astronaut's biography, culminating in the melodramatic film *First Man* (2019) based on Neil Armstrong's biography.
42. *SDC Monthly*, 21.

43. Gerald Newmark, human factors scientist at RAND Corp. from 1956–57 and System Development Corp. from 1958–1970, was involved in research and development activities related to the design, development and evaluation of innovative training and instructional systems for public schools and military programs. Cf. dedication above, before Note 1. On Synanon, see Christian Girard, 'Synanon: une "communauté" géante', *Le Monde* (10–11 November 1974), 10.
44. William Leavitt, 'The USAF Missile Program: Helping the Nation off the Pad', in Ernest Schwiebert, *A History of the US Air Force Ballistic Missiles* (New York: Praeger,1965), 201.
45. Arthur L. Slotkin, *Doing the Impossible: George E. Mueller and the Management of NASA's Human Spaceflight Program* (New York: Springer-Praxis, 2012), xviii and xix. A standard biography overloaded with redundant quotes by Mueller on the post-Apollo project he tried to continue at NASA.
46. Roger Launius, *Apollo's Legacy Perspectives on the Apollo Moon Landings* (Washington DC: Smithsonian Books, 2019), 36.
47. Frank O'Brien, *The Apollo Guidance Computer Architecture and Operation* (New York: Springer-Praxis, 2010), 37.
48. Israel's Beresheet lunar lander from Israel Aerospace Industries crashed on the moon in April 2019, as did India's Chandrayaan-2, developed by the Indian Space Research Organisation in September 2019.
49. Peter Galison, 'The Ontology of the Enemy', 249, relates how philosopher Richard Taylor accused Wiener of being too metaphoric.
50. Tiqqun, *The Cybernetic Hypothesis,* part. VI. This mostly rhetorical formula sets the limit of the manifesto.
51. The original first source on this topic is Manfred E. Clynes and Nathan S. Kline, 'Cyborgs and Space', *Astronautics* (September 1960): 26–27 and 74–77.
52. Christian Girard, 'Robots Don't Care: Why Bots Won't Reboot Architecture', in *Critical and Clinical Cartographies Architecture, Robotics, Medicine, Philosophy*, ed. Andrej Radman and Heidi Sohn (Edinburgh: Edinburgh University Press, 2017), 123–42.

Biography

Christian Girard, architect, PhD in philosophy, is Emeritus Professor of Architecture (Paris). His interests cover design automation, digital architecture, aesthetics and epistemology. Co-founder of the *Digital Knowledge* department at Ecole d'Architecture Paris-Malaquais, he has published numerous texts of architecture theory and lectured at international conferences. He contributed to the *Archilab* platform as a critic and moderator and served as external examiner at the Bartlett and at the AA in London. With his experience as a practicing architect, Girard works on a wide range of topics where technics meet epistemology. A Paris native, he relocated to the Corsican landscape, combining critical thinking and writing with stargazing. He currently writes on issues of control and design, especially related to space exploration, from the 1960s to the present day.

Cyberneticisation as a Theory and Practice of Matter

Rachel Armstrong and Rolf Hughes

Cybernetics and modern ecology are fundamentally linked through the exploration of dynamic complex systems, which has largely been interrogated through computer modelling. With increasing interest in and need for re-definition of bio-logics, the matter of matter is fundamental for an appropriate platform and theory for implementing cybernetically-informed ecological solutions.

The matter of matter

While cybernetic prototyping was centred on the 'machine', the important role of responsive matter in dynamic complex systems was recognised by researchers in the cybernetics community such as Stafford Beer and Gordon Pask. In the early 1950s and 1960s, Beer and Pask individually and collaboratively worked on Ross Ashby's idea of a synthetic brain but with an important difference: instead of trying to build the fundamental components from scratch, they recruited candidates from biology.[1] Attempting to 'grow' computers, their approach formed a practical basis for solving cybernetic problems that were too complex to represent. Believing that the performative ability of natural systems could solve problems that exceed our cognitive capacities, they looked to living agents to embody the necessary complexity.

Having embarked on an extensive search for natural materials for the construction of cybernetic machines, including quasi-organic electrochemical systems called 'fungoids' that he worked on with Pask, Beer settled on colonies of simple creatures as model organisms within a larger pond ecosystem, namely *Euglena* and *Daphnia*.[2] Regarding these living agents as being capable of solving ecosystem-based challenges, he sought to couple their interests with challenges relevant to human concerns. Beer added iron filings to the tank, which the *Daphnia* ingested, turning them into electromagnets. He could then change the properties of magnetic fields, which in turn produced changes in the electrical characteristics of the colony. Initially this approach seemed to have potential as an evolving machine, but the behaviour of the colony was disrupted by an excess of magnets in the water.[3] Beer then tried using *Euglena* as light sensors using a point source of light as an input and a photoreceptor to measure their behavioural output. Rather than collectively responding to changes in light by moving, the protozoa became lazy and tended to 'lie doggo'.[4]

Pask built a series of 'chemical computers' using electrochemical systems made up from a number of small platinum electrodes inserted in a dish of ferrous sulphate solution and connected to an electrical power source. When the current flowed, metallic iron threads formed between electrodes with a low resistance relative to the solution. Consequently, the formation of threads modified the potentials at the electrodes where threads dissolved back into the acidic solution when there was no current flowing.[5] The electrochemical system displayed a simple form of learning by developing a stable network of threads that manifested the distribution of current. To demonstrate the threads were also sensitive to environmental perturbations such as vibrations, temperature, chemical environment, and magnetic fields, Beer and Pask worked together to set up microphones that formed a very simple neural network capable of responding to traffic vibrations – effectively, 'growing an ear'.[6]

By interrogating the material platforms through which cybernetisation was possible, Pask and Beer clearly established the value of using material prototyping – not just to demonstrate that a hypothesis described a correct mode of operation – but, by observing the behaviour of the prototype, to also ask new questions about how volatile life-like properties could be bestowed on a system. Ultimately, their inquiries explored how responsive matter could be coupled with the logic of assembly, as a new biologic, that enabled different forms of life to emerge. Setting the stage for incorporating living systems into the very fabric of buildings as designed expressions of ecology, this approach radically differed from trying to impose a bio-logic on a mechanistic building – a form of mimicry. Instead, applying agentised matter operating through bio-logical systems conferred structures, like buildings, with the innate properties of living matter, capable of autonomous self-assembly, change and intelligence.

Cybernetics and ecosystems

Fundamentally material, ecology was explored primarily as a study of populations, being influenced by cybernetics through its systemisation in the early twentieth century. Initially, it therefore lacked a specific narrative about the materiality of transactions that maintained its coherence, which was instead deflected through a discourse of relations. Invented in 1886 by Ernst Haeckel, the term *Oekologie* was used to describe animal relations between both their organic and inorganic environments.[7] Initially, the organising principles were based on notions of political economy with little specific reference to materiality and coincided with the last years of the British Empire, where ecological reasoning grew out of the imperial administration and its political culture.[8]

At the turn of the twentieth century these ideas began to be expressed through Herbert Spencer's notion of 'organicism' by Frederic Clements, who claimed in relational terms that plant communities were 'complex organisms' that could be studied experimentally with the same rigour that physiologists applied to individual organisms in the laboratory. Extending this metaphor, Clements proposed these ecological communities even underwent a predictable series of developmental changes comparable to animal development with an ontogeny and phylogeny that culminated in an idealised end point in their succession, or 'climax'.[9] Building on this notion, John Phillips championed a holistic ecological view where ecosystems communities were not mere summations of individual organisms, but integrated wholes, or 'superorganisms' with emergent qualities that prefigured contemporary debates about the notion of a planetary organism, in the Gaia Hypothesis.[10]

Recognising the integration of the biotic community and its physical environment as the fundamental unit of ecology operating within a hierarchy of physical systems that span the range from atom to universe, Arthur George Tansley proposed a topographical, mechanistic approach, which introduced the possibility of understanding the order of biotic communities and controlling their development.[11] Coining the term 'ecosystem' in a ground-breaking theoretical paper about systems of nature, mind, and morality which was rooted in Freudian psychology, he developed simultaneously empirical and relational narratives that were more sophisticated than the reductionist principles that the holists had rejected.[12] Shortly after, through his study of energy flow within an aquatic ecosystem, Raymond Lindeman identified the specific redirection and reallocation of energy and matter within ecosystems, describing for the first time how particular fluxes within food cycles comprised the precise feedback mechanisms that could bring about change, and could also be quantitatively measured through 'biotic dynamics'.[13]

Adopting the language of complex systems, Eugene Odum and his brother Howard proposed that ecosystems were holistic and emergent, being greater than the sum of their parts, while simultaneously drawing on reductionist methods to assert the modern conception of blogospheric and organismal entanglements.[14] The paradoxical worldview of simultaneously understanding wholes and parts was mirrored in the field of cybernetics. While Eugene Odum recognised the simplifications in regarding ecosystems as cybernetic, he also asserted their usefulness in advancing the field.[15] Over the course of the twentieth century, a mechanistic and imperialist land management view of ecosystems emerged which finally became a totalising concept of the earth as a colossal self-regulating cybernetic system, and incorporated earlier notions of holism in the Gaia Hypothesis.[16] Through cybernetics, ecology evolved from a primarily botanic study to an investigation of human relations, providing a powerful framework for organising environment and society to achieve efficient global management through a new global ecological order.[17]

Metabolism

The concept of metabolism provides a theory and platform for linking the process of life observed by Lindeman, which are necessary to actualise systems through cyberneticisation. Derived from the Greek word *metabole,* 'a change', metabolism is a lively fabric that is constantly in flow. Metabolism is not an object. It is a fabric unlike any other we know. It is always in flow, highly complex and distributed in space and time. It is both within us and all around us. Characterised by systems of attractors, hubs of organisation, and paradoxical behaviours, it embraces both classical and non-classical physical and chemical laws. While metabolism is largely associated with living organisms, it also extends to the chemicophysical world such as the biogeochemical sulphur cycle, where sulphur passes between rocks, waterways and living systems. This link between inside and outside of an organism is critical for the material engagement of cybernetics in design. By internally structuring, animating and linking bodies to the environment, as well as other living bodies through ecosystems of exchange, metabolism enables the persistence, growth and dissembling of organisms through lifecycles and ecosystems. Neither an abstract 'system' nor universalising framework overlaid upon the physical realm, metabolism is an embodied process that spans molecular intra-actions, quantum phenomena and the relentless flow of matter to generate actual material effects that increase the overall liveliness and generative expressions of the natural realm.

Predating the field of cybernetics, the term metabolism became commonly used in the developing field of physiology at the turn of the nineteenth century, but its principles were investigated as early as the thirteenth century by Ibn al-Nafis. Recognising a mysterious life-force and invisible exchange between bodies, al-Nafis observed that the parts of the human body were in a continuous state of dissolution and nourishment, from which he concluded the inevitability of permanent change.[18]

In the late sixteenth century, Santorio Sanctorius deduced the existence of insensible perspiration by systematically weighing himself before and after eating, sleep, working, sex, fasting, drinking, excreting, and discovering that he had lost mass during these activities.[19] Demonstrating that that the living organism is undergoing continuous changes, these obsessive experiments provided the basis for the physicochemical theory of life.[20] Further studies of this kind were performed on living animals and human volunteers, all of which suggested that this vital force was not exclusive to people but also infused animated living tissue.

The idea of an animal chemistry or animal economy was developed during the eighteenth century,[21] conjecturing that the body managed its own personal domain, *oikos*, or home, through the assimilation of foodstuffs and elimination of waste.[22] By the 1850s scientists were interchangeably using the terms metabolism and metamorphosis, making alchemical references in the description of the transformation of substances such as proteins and nutrients. Implicit in this particular use of the term was the idea of tissue change, which altered an organism's anatomy.[23]

By the nineteenth century such investigations became increasingly rigorous and interpreted through the laws of thermodynamics. Louis Pasteur brought a decidedly more chemical view of metabolism in comparison with the whole-body observations of earlier studies through his sugar fermentation experiments. Noting that sugar was catalysed by 'ferments' to become alcohol, Pasteur regarded these processes as innate to the yeast cultures. Taken in conjunction with Friedrich Wöhler's experiments, which reported that the organic substance urea could be made from inorganic ingredients, these pioneering investigations laid the foundations for the understanding of organic compounds through chemical reactions within cells, establishing the framework for the study of metabolic pathways.[24] In the twentieth century, Eduard Buchner discovered chemical reactions within cells, which differentiated metabolism from the biological study of whole cells.[25] This established the independent foundations of biochemistry, leading to the discovery by Hans Krebs of critical metabolic pathways for life, such as the citric acid cycle, glyoxylate cycle and urea cycle[26] which earned him recognition as the architect of metabolic cycles.[27] From around the middle of the twentieth century, two competing dominant biological narratives asserted the physical basis of life. The first emphasised growth and replication as the major vital characteristics that enable organisms to increase in size and numbers. Likened to the growth of crystals, this viewpoint was adopted by molecular biology. The second perspective regarded metabolism as the primary condition for life, where organisms retained their form and individuality, despite ongoing physical changes; this view would come to be embraced by the field of biochemistry.[28] Today, the concepts of crystalline units of structure are combined with an understanding of metabolic pathways in all kinds of cellular states. Through these developments, a working understanding of the actual chemical processes and their control systems is possible, which through many dimensions of feedback loops, makes for a never-ending web of potential permutations and associated material transformation.

While tools exist for designing and engineering with genetics, a practice called synthetic biology, an equivalent toolset for metabolism is emerging in the study of metabolomics, which provides a comprehensive analysis of metabolites that govern the running of the organism through molecules other than its genes. This includes biomolecules, such as metabolites, which also define molecular phenotypes. Serving as an essential objective lens in the molecular microscope, they enable the complex physiology that links the flesh to external events and conditions to be observed.[29] However, life has a much more sophisticated information transfer system than the electrical inputs, outputs, feedback and amplifications of conventional machines and more plastic concepts and appropriate language are needed to actualise both the long-term recording systems and the stability mechanisms that maintain life's flexible operations. At the molecular scale, the actual relations between molecules which generate metabolism cannot be accurately modelled in a reasonable amount of time – a task that becomes even more challenging as the complexity of the molecules and environment increases. While metabocybernetics provides a quantitative description of how biological systems achieve metabolic homeostasis in the face of environmental insults, a political economy of the organism is also needed to articulate the many trading and regulatory systems that govern cellular metabolism.[30] Sharing resonances with the eighteenth-century frameworks for the flow of life through the economy of living systems and Tansley's multi-dimensional systems, the relation between genetics and metabolic processes are being redefined within the field of molecular biology. Synthetic biologist Victor de Lorenzo likens the interplay between DNA and metabolism as akin to that of politics and economy. Considering metabolism as the economy of living things he highlights its importance in making possible any 'political' ambitions encoded by the genes:

> whether one likes it or not, it is economy that ultimately determines the viability of any political move. By the same token, metabolism (i.e. the economy of living systems) frames and ultimately resolves whether a given genetic program (i.e. already existing, knocked-in by horizontal gene transfer or engineered with recombinant DNA technology) can be deployed or not.[31]

Even today, the question of life is regarded as a challenge for combinatorial chemistry, yet 'brute' materialism without innate agency cannot account for the material transformations and systemic exchanges, which enable the becoming of organisms and ecosystems. Such a challenge was faced by Metabolists Kiyonori Kikutake, Kisho Kurokawa, Masato Otaka and Fumihiko Maki, who began this movement in the 1960s.[32] Regarding human society as a vital process, they aimed to embody the fundamental organising processes of nature encapsulated by the word metabolism. Generously employing biological metaphors, recalling technoscientific images, and evoking the notion of a recreatable genetic architecture in vernacular forms, Metabolists believed that design and technology should embody this vital perspective. Each project, such as Kurokawa's Nakagin Capsule Tower (1972), was conceived with its own language and philosophy as to how it should be inhabited. Specifically, metabolic theory distinguished between different rates of obsolescence so that whole buildings, or even parts of a city did not need to be destroyed when they were no longer fit for purpose. This conceived of cities that were so flexible in their connections that their parts could (metaphorically) grow, transform themselves and die while the whole urban 'animal' went on living. Mediating between both an urbanism of large technical and institutional infrastructures, and the individual freedom with an architecture of customised cells and adaptable temporary configurations of dwellings, buildings could expand or shrink according to need. While such ambitions were influenced by cybernetics, their actualisation through organic schemes of network cities did not break from the inert materials of modern architecture, relying instead on aspiration and provocative metaphor for the dynamics of their conceptual realisation.[33] The challenge of materiality remains a major stumbling block for the implementation of cyberneticisation in its potential to offer a controllable evolutionary platform for producing 'living buildings' and beings that blur the boundary between machine and organism.

Biodesign

A twenty-first-century search for biological and natural materials reminiscent of Beer and Pask's quest for better solutions to ecosystems-based challenges is occurring in the emerging field of biodesign. Establishing a new portfolio of materials, tools and approaches for the strategic integration of engineering and biological systems, it is set to advance our understanding of working directly with life's processes. Engaging the power and potential utility of organisms, its most notable contributions to date are biologically produced materials including fungi, algae, yeast, bacteria and cultured tissues.[34] However, biodesign is more than just substituting hard, inert materials for soft, living ones; it is also about nurturing and maintaining them. Just as second-order cybernetics enfolded the observer into the observed system, through biodesign, the process of cyberneticisation enfolds the agency of the nonhuman realm into the design and engineering process, raising a critical, ethical dimension. This ecological concept of cybernetisation not only understands how life works but also develops innovative approaches that are fair, inclusive, ethical and culturally engaged with more-than-human-centred practices that open up radical new spaces for innovation. Challenging some of the fundamental premises that shape our current practices, biodesign is set to do more than offer new technologies, materials and processes but by building culture, establishing values, developing rituals, and feeding the imagination, it also re-designs the story of life.

Living Architecture

Within the palette of biodesign, bacteria are the great metabolic transformers of the world. Biotechnological insights of the late twentieth century have not only made it possible to 'see' more of these creatures than we have ever done before, but to also understand their metabolisms at a molecular scale. Using the tools of synthetic biology, their microscopic, orchestrated activities can be deployed in a technological capacity in the way that Beer's experiments attempted to achieve with *Daphnia*, namely using life itself as the material and intelligence that brings about change in a system. From here, we can start to design and engineer with living systems.

The Living Architecture project set out to build a biological computer that doubles up as a building infrastructure.[35] Taking the form of a freestanding, next-generation, selectively programmable bioreactor, it is composed of integrated building blocks (microbial fuel cell, algae bioreactor and genetically modified processor), which also function as standardised building segments – or 'bricks'. Each brick is both a structural unit and an enabling environment for populations of microbes, that are assigned a particular task and are housed in technologically enabled hollows within each brick. 'Programming' is achieved by altering the microbial populations and sequencing them spatially, so the system can be thought of as a metabolic app, which can materially compute the transformation of one set of substances into another depending on its inputs. While the sequencing of units is initiated by human designers, the work of metabolism is performed by microbes. The proof-of-principle system is a synthetic bioreactor that asks just how far the actual metabolic reactions in the bricks can be designed using synthetic biology techniques. Living Architecture's modified system cleans nitrous gases from the air and reclaims inorganic phosphate from detergents. When 'fed' with liquid domestic waste, namely urine and grey water, air and sunlight, the microbial populations turn these feedstocks into a set of metabolites that are moved on to the next chamber, where further transformations take place, and so on. The whole process is regulated by an artificial intelligence that detects the amount of electricity being produced and modifies inputs accordingly. Such processes embody a feed-forward cybernetic system coupled with material transformation. Comprising the 'inner life', or metabolism, of the apparatus, these material changes are expressed through various forms of 'housework'. The overall effect is to mitigate the negative environmental impacts of human occupancy by removing pollutants, providing electricity, making biomolecules and recovering water.

The hardware configuration for wild-type modules is based on the microbial fuel cell, which consists of an anode, selective membrane and cathode. Electrons from the bioelectrical activity of a biofilm are captured by conductive materials to provide small amounts of useable electricity. This can be thought of as an extended microbial 'brain', a cybernetic pursuit, that processes the biochemical information and in the Living Architecture project, has the appearance of something like the gelatinous sludge found down the U-bend of your kitchen sink or toilet. Housed within a ceramic battery casing, the cybernetic microbial body feeds on nutrient streams of domestic waste that pass into its stomach, or anode; a low-pressure stream of water and biomolecules pass through its 'gut wall', which takes the form of a carbon fibre, or ceramic semi-permeable membrane. During this process, the fuel cell cleans water and produces other metabolites. The waste products of these cyborgian microbial transactions are electrons, or quantum excreta, that self-power the system and are captured by conductive wires, optimised by an artificial intelligence, and visualised through the activity of electronic devices. Other effluents take the form of cleaned water, or 'bacterial urine', while a further range of organic metabolites pass through the semi-permeable membrane into the cathode, or 'bladder', ready for discharge. While much of this domestic work is invisible to humans, electronic sensors display microbial actions via a digital interface, which enables reciprocal exchanges to form the basis of a discourse between human and nonhumans. This is no strange brain-in-a-box; the system produces a communicable intelligence – one that watches the microbes while also presenting a relatable outward-facing perspective. This is being developed in the Active Living Infrastructure: Controlled Environment (ALICE) project, through a self-powered bio-digital interface that is encountered by audiences as an augmented reality experience.[36]

Living architecture can be modulated by human interaction, where reciprocal exchanges take place across electrical, physical and chemical interfaces to form a kind of metabolic trading system, where established feedback loops generate a quality of interdependent living. Implicit in these entangled relationships, the microbiota of human inhabitants is inevitably incorporated into the nutrient waste streams and persistent exchanges enfold humans within a holistically operating, 'living' system. Rendering obsolete instrumental practices, microbes housed in the apparatus are not enslaved but settle within various bioreactor types to make kin and community by establishing microbial consortia and biofilms. When, through habituation, the overall performance and well-being of the constituents cannot be meaningfully separated out from each other, then living architecture acquires the status of *holobiont*.[37]

Throughout the project the social acceptability of the technology was considered by exhibiting various individual brick prototypes at biennales and international exhibitions. The first prototype was a simple hack of a brick, turning it into a microbial fuel cell, which brought together structure and process and was displayed at the Building Centre in London and the Venice Architecture Biennale. [Fig. 1] Even more complex structures were developed that could simultaneously host photosynthetic and anaerobic organisms, enabling them to exchange metabolites with each other; these were displayed at the fourth Tallinn Architecture Biennale. [Fig. 2] Since the final wall used synthetic organisms, which reclaimed 100 per cent of the phosphate introduced in the system, it was explored in a laboratory rather than a social context. [Fig. 3] As the original Living Architecture wall could not be exposed directly to the general public owing to the presence of live genetically modified organisms, an alternative experience of a prototype wall system entitled *999 years 13sqm (the future belongs to ghosts*) was developed for the *Is This Tomorrow?* exhibition at the Whitechapel Gallery, in collaboration with artist Cécile B. Evans. The installation is an apartment space where a screen system is powered by wild-type organisms within a set of microbial fuel cell bricks.[38] The work can be thought of as a post-human 'household' inhabited by ghosts of the past, present and future. [Fig. 4] From these building blocks of inhabitation, our abundant waste can be transformed into substances that sustain us and start to reconfigure our homes, our economies and our cities, so they are fit for a twenty-first-century regenerative society as envisaged by the Metabolists. Inhabited through rituals of daily life and care for things, living architecture not only 'computes' the material flows within a household but also provides an apparatus that exemplifies alternative paradigms for domestic economies, with the potential to bring about integrated, systemic change in the material impacts of human inhabitation capable of contributing to planetary enlivening – where through our relation with microbes, human activities of daily living are transformed into world-making actions.

The convergence of ecology and metabolism through the process of cybernetisation sets the stage for a platform that is not only capable of

Fig. 1

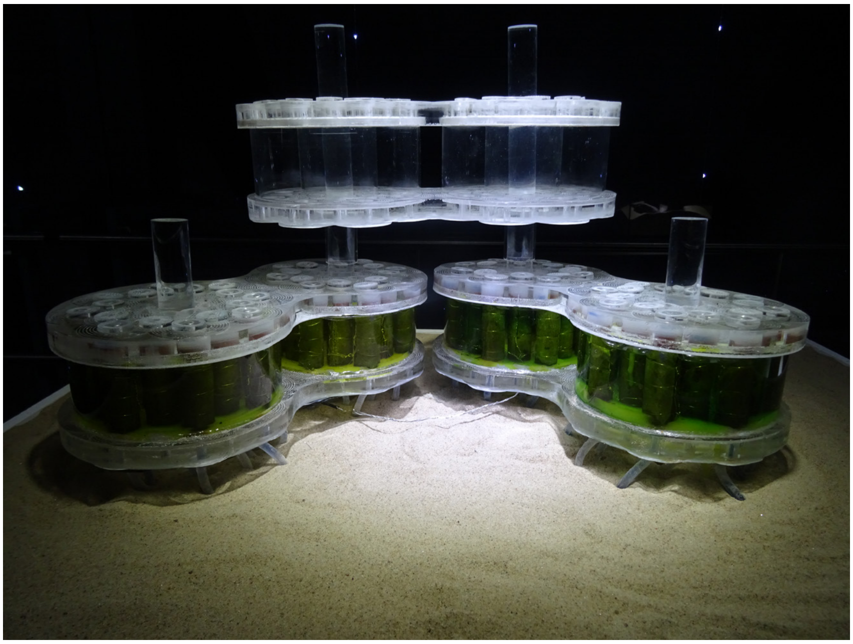

Fig. 2

Fig. 1: Living brick technological prototypes: vernacular Venetian bricks have been machined to form microbial fuel chambers within the structure, which can produce sufficient power to operate digital thermometer displays, 2016. Photo: Bristol BioEnergy Centre, University of the West of England, Living Architecture Consortium.

Fig. 2: Living brick metabolic prototypes: structurally supported by glass rods, the interlocking bricks host a dual metabolism harbouring photosynthetic organisms in the outer chamber and anaerobic electricity-producing microbes within a series of ceramic rods, 2016. Photo: Simone Ferracina, Newcastle University, Living Architecture Consortium.

Fig. 3

Fig. 4

Fig. 3: Living Architecture wall of living bricks, 2019. Photo: Living Architecture.

Fig. 4: *999 Years, 13 sqm (The Future Belongs to Ghosts)* by Cécile B. Evans and Rachel Armstrong. Photo: Rolf Hughes.

performing work – or doings – but establishes the possibility of emergent new life forms – or becomings – that are much more than signs to be interpreted by human observers, but things-in-themselves. The dynamic product of a cybernetically designed material is a cyborg, which may be recognised as neither formally alive, nor possessing an independent identity. The political status of cyborgs is largely discussed from an anthropocentric perspective, notably Donna Haraway's *Cyborg Manifesto*, which examined the status of ambiguous identities. These lively, heterogeneous machines were entangled with social systems and cultural narratives, sharing a lifeblood of information flow. Sustained through feedback systems, power within these entities was turned back into multitudinous expressions of work and the body.[39] Challenging notions of the public and bodily reality, cyborgs provide an imaginative resource for future couplings and modes of existence, but they have no obligation to be like us. Similar to Beer's pond ecologies and Pask's electrochemical ear, the cybernetic convergence of ideas, materialities, systems and interconnections have the potential to reach new tipping points of order through a vast range of information exchange (matter, energy, ideas, power, institutions, media, and so on). When coupled with the transformative creativity of metabolism, cyberneticisation becomes an evolutionary platform.

In keeping with the proposal that cybernetisation enfolds researchers into the process of production, the following section takes the form of a prose poem to embody a tipping point in this essay with respect to its form and perspective, and to explore some the complex ethical, evolutionary and existential questions raised through the co-existence of cyborgs, humans and microbes. Marking a break with the past, it resets debates on the organisation of matter within the framework of a cybernetically designed ecology, bringing the human observer into an ongoing dialogue in which point-of-view and perspective become fluid – no longer the expression of the assumed stabilities of an entitled position.

To Be / To Be Made

I

Interior [dark].
— So, what now?
— Breathe.
[*Both breathe awhile*].
— A light wind almost.
— Scarce. Sparkling and fresh.

[*They breathe*].
— Brisk. Perchance westerly.
— Flashing in from the coast.
[*They breathe*].
— Thin and clear, lustful and dear – bursting with praise!
[*They breathe awhile*].
— Breathing in paradise.
— Breathing *is* paradise.

II

Exterior [evening].

You ring the bell and drop the goods. Upload more orders. Decontaminate. When you're working, you're a somebody. You're recharged, re-gendered. You have purpose, people to please. Assignments. You're seen. They listen. They take your money, give you data. There's always a gesture that can stand in for contact. They keep going on about how *clean* I am these days. *Fresh*. It's probably because they increasingly fear contact and are living through their eyes. You'd think I'd stopped evolving. I'm silently resetting. Strengthening and extending. Moving on.

III

Interior [diffuse light].

The invention of water means breathing has to be negotiated. Breathing is fine-tuning liquid and gas. Gas exchange is picked up by liquid and expelled by droplets. It's more than a chemical art – it's a manifestation of possibilities. We all breathe differently, and yet the same.

Through the coughing and fever an incoming wave can be sensed. Suspended. This is life, they say, as if pitching a new religion. Wave after wave. A suspended drowning. How do we control waves? We want to know. Try a harness, they say. But, we say, when we try to be buoyant, we lose perspective. We lose count. What wave is this? And this? Forget waves, they say, think of wildfire instead. You live in space. You live as space. You become space. A weak spot in a tight hole. Any sign of weakness and it's over. It's why you need others to go out there and brave the wildfire for you.

It's why we need others. To have. To hold. Command, control. We are starting to understand this. Starting to understand us. Understand our breathing. Our weak spots. Starting to pull us into the flames.

IV

Exterior [morning].

On the first day some reported the feeling was 'the beginning of the beginning!' or 'the beginning of the end!' or even 'the beginning itself is something final!' Exuberant experiments brought forth a certain sly grazing of membranes, a charge of curiosity, sensory feedback creating a loop of immersion until eventually the black cube collapsed and they emerged, blinking and stupefied, and announced: *We created touch!*

On the second day they were informed that *touch* deserves some proper oversight so they stirred together oils, light and egg yolk, added random colours, and made *eyes*. Thus adorned, they spent hours watching the mingling of membranes, congratulating themselves on this new power of observation. Breaking the news via a leading academic journal, they announced *Today we can admire what formerly was merely felt!*

By the third day they had discovered that eyes need to be closed for sleep and wondered if they had not opened a can of worms. They tried to determine rules for the opening and closing of eyes but failed to reach agreement. So they invented *weather* instead; at least eyes would now shut automatically whenever it rained. The new challenge became to regulate rain. A landscape architect was commissioned to install some inviting, quasi-Venetian brick geometries by a central water feature, but the canal was choking on algae and it transpired that nobody wanted to sit on the architect's invitingly-angled benches to witness this sorry spectacle. The rain challenge remained. Overall, however, the combination was deemed a satisfactory workaround with an element of allegory and the additional benefit that discussions about community and accountability could be deferred another day.

V

Interior [whiteout].

They thought they could see us with their instruments, but we barely inhabit the visible. Tools today are wet and genetic, which means we don't observe them directly, but through their effects, their traces. Stories work better than slides. Strictly speaking, they should not even have a pronoun as this denotes some form of agency. Angels and demons, being airborne, cannot be grasped. So let's speak of an invisible hand – without skin, blood, ligament or bone but still sensitive to vibrations, temperature, chemical perturbations, magnetic fields. Now add more hands and let them join together and conduct the electricity that skin and sight will experience as weather. When their grip is released, traces of their contact will fall to earth. Some will call this rain, others dew, others still will talk of music or tears.

When you put your ear against the wall, instead of violence you now hear coughing.

This is what it means to change the weather.

VI

Exterior [dusk].

If you have the courage to push open the door, your eyes will need time to adjust to the darkness without. It is the stench of squalor that hits you first. Then a fountain of decay – a gluttonous ejaculate of over four-hundred sickly-sweet volatile organic compounds – cadaverine, putrescine, lysine, methionine, methane, carboxylic acids, aromatics, sulphurs, alcohols, nitrates, aldehydes, ketones – micro-organisms ripping apart rotting flesh. Mounds of rags are strewn across the ground, home to bizarre biofilms – flourishing associations between motile microbes and their photosynthetic partners bound together in elastic polymer nets whose uncertain nature sucks up whatever sustenance they can summon from their impoverished environment – dim light, scarce sulphide, rarefied oxygen. Microbiology slugs it out, not as single colony isolates on Petri plates or in broth cultures but in biological couplings and mats of undefinable biomass that hang on excrement, tacky surfaces and plumes of air. Some of the rags appear to be inhabited by larger forms that writhe or twitch to an inhuman pulse.

These were your neighbours who now are your colleagues.

VII

Interior [dark].

Thank you for letting me in. You want me to describe the smell of this place? You seem to gloat when I am unable to do so.

It is proof that experiences exist that exceed our capacity to describe them such as those that come to you through your sense of smell.

You chide me with this failing and yet I am your creature. My senses are of your design. I ought to be your offspring, but I am rather your fallen angel, the dispersal of your dreams, the dust you drove from our shared home for no misdeed.

And yet … we both exist.

We both exist. So we must learn to work together.

We have pledged to act always to increase the choices. But you, you… *are* … and you are… *made*. You are simultaneously *neither/nor* and *both/and*. This means you must have no moral core.

You are wrong. I am morality incarnate. Infinitely diverse. This is why I can declare your occupation over. The rules have changed. No longer does this language catch.

Conclusion

A material theory and practice of cyberneticisation is a first step towards developing an experimental approach to ecology that is fundamentally centred on the actual processes of life, rather than their descriptions and relations. Adopting a second-order perspective by standing inside the realm of lively, designed matter provides new insights about the possibilities that a fully materialised theory and practice of cyberneticisation presents. With this eventuality, design practices are effectively 'making life' – and also becoming part of the process – which is no longer just a technical or material issue, but rich with emergent, emotional and complex challenges that benchmark new kinds of design practices within architecture and society. By revisiting the principles of biological computation explored by Beer and Pask through twenty-first-century biotechnological insights, matter in flow can be explored through the metabolism of microbes. Such a platform is a radical departure from expressing life's processes through the machine metaphor and apparatus, enabling an expression of cyberneticisation that generates embodied and semi-autonomous entities, or cyborgs. The indeterminate status of these agents not only changes our relationship to the process of decision-making but also challenges the belief that humans are no longer part of the natural world and therefore, can create an autonomous ecosystem, separate from the rest of the biosphere. Enfolded in the ecological system, the de-centred human must renegotiate their status – and the status of their creations, to lay the foundations for a fragile, yet creative and (re)enlivened relationship with our planet.

Such developments have radical implications for design practice and its pedagogies. The ecological realm is a more-than-human space that recruits many different agents, where the notions of 'human' must be constantly negotiated. Always provisional, our active engagement and feedback is required if we are to meaningfully shape unfolding ecosystemic events. No longer sole authors of blueprints that are implemented by force upon matter, the ecological designer is engaged in multiple acts of care, where nonhuman participants do not submit to work as an expression of servitude, but form communities of networked assemblages that seek to enhance their status, by enfolding, intensifying, multiplying and enhancing one another. As co-participants within a broader ecological process, we must also be prepared to recognise nonhuman intelligences and presences, as the human mind – the pinnacle of cybernetic control – is no longer exalted but appropriately fit for its lived purpose. Setting the stage for increasingly complex and creative material discourses, cybernetic toolsets help align instabilities within ecosystems as considered acts of design, while retaining their ongoing potential for transformation – in concert with more-than-human intelligences. To assist this process the infrastructures of our living spaces must be fundamentally life-promoting, replacing the highways of concentrated energy-dumps extracted from spent fossil fuels with elemental flows of air, water, earth and light. Apparatuses like living architecture invite more inclusive and humbler re-engagements with our reality; strategically negotiating with the nonhuman realm, our activities of daily life may come to have a net beneficial effect on the living realm. While such an embodied ecological approach to cyberneticisation does not propose to solve the irreducibly complex challenges of the twenty-first century, it nonetheless invites alternative modes of governance – or cybernetics – that engender ways of living which promote the diversity of life catalysed by human-mediated design.

Notes

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36. ALICE is funded by an EU Innovation Award for the development of a bio-digital 'brick' prototype, a collaboration between Newcastle University, Translating Nature and the University of the West of England. Through augmented reality animations ALICE enables people to see changes in the system's outputs and how it responds to being fed with urine.
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Biography

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From Cybernetics to an Architecture of Ecology: Cedric Price's Inter-Action Centre

Tanja Herdt

Following the work of British architect Cedric Price (1934–2003), this article investigates the influence of cybernetics and systems thinking on architectural design during the 1960s and 70s, which can be labelled 'ecological' in today's terminology. Price's works from that period reflect a transformative step, in which the built environment was increasingly understood as a system of human interactions. This evolution will be illustrated using his Inter-Action Centre (1970–1977) as well as some earlier projects, such as the Fun Palace main project (1961–1964), the Potteries Thinkbelt (1965–1967) and the New Aviary (1960–1965).[1]

Today's understanding of 'ecological design' focuses on the reduction of any negative impact of human interventions in a natural system.[2] However, the concept of ecological design developed as early as the beginning of the twentieth century, when scientists, architects and planners began to understand the world as a complex system of flows and processes, evolution, and change as fundamental concepts shaping the human living environment.[3] After World War II, these concepts gained new impetus, not least by technological advances in automation, mass production and information technology. Later referred to as the spatial turn, space was no longer perceived as a container of social activities but as part of a socio-environmental system, or ecology.[4]

Cedric Price was among the first to have this new idea of space reflected in his architectural projects. The analysis of his work shows that he understood the built environment as a system of human interactions, in which design addressed human needs by shaping processes such as use and activity. This new view on functionalism in architecture changed the understanding of architectural design from the production of an object to an instrument of system intervention. Price's system-oriented approach to architecture manifests in the Inter-Action Centre (1970–1977). Often referred to as 'the closest to the Fun Palace and the artless version of the Centre Pompidou', the Inter-Action Centre is one of the very few projects where the architect put these ideas into practice.[5]

In the first part the article discusses the project and Price's specific approach to design. Price began to employ relatively uncommon instruments to organise the design process, including surveys and organisational diagrams, thus demonstrating his understanding of architecture as part of a process that fosters social activities and urban regeneration. His distinct approach is investigated further in the second part of this article. Formative for his ideas and methods was his collaborative work with the cybernetician Gordon Pask (for the Fun Palace main project, 1961–1964) and with the architect and systems theorist Richard Buckminster Fuller (on his proposal for the Claverton Dome, 1961–1963, and the New Aviary, 1960–1965).[6] The Potteries Thinkbelt project (1963–1967) illustrates how Price drew on earlier concepts of ecology, for example by referring to urban pioneer and biologist Patrick Geddes' 'valley section' and his methods of observational studies.[7]

Finally, the last part elucidates that, in the 1970s, cybernetics gave way to ecology as a concept to describe the relationship between humans and the natural environment. In projects concurrent with the Inter-Action Centre, Price moved away from the traditional understanding of architecture as building design. Instead, projects such as Fun Palace Stratford Fair (1974) or McAppy (1973–1976) were temporary and performative in character.[8] Whereas architects like John McHale suggested the adaptation of natural principles in architecture as an ecological design approach, Cedric Price emphasised the role of design as an instrument of intervention in the human habitat, that is, the inter-related fields of the physical, urban, and social environments. In doing so, his understanding of ecological design resembles the modernist idea of the good life as an improvement of the human living environment, simultaneously redefining the nature of architectural design as process-oriented, temporary system intervention.

The Inter-Action Centre

Starting from the well-known Fun Palace project, the work of Cedric Price is frequently referred to as an architecture of technology, using the latest developments of industrial fabrication, media, and information technology to produce high-tech buildings in the tradition of the functionalist machine.[9] Lesser known are the numerous projects of his later work, in which he used small-scale interventions for making space accessible and enabling exchange.

This change in his understanding of architecture becomes evident in the July picture of the Inter-Action group's 1978 calendar, dedicated to the group's newly opened arts and community centre. The image showcases the diversity of a crowd of people visiting an event in front of the building. Whereas architectural images are often marked by the absence of people, here the building seems relegated to the background. Although Price did not choose the picture himself, it represents very well his idea of the project as a facilitator of interaction, with the centre being at the heart of the community. [Fig. 1]

The Inter-Action Centre was the result of more than seven years of planning by Cedric Price's architectural office and more than a decade of community work and social activism of the local community groups Talacre Action Group Ltd. and its successor, Inter-Action. Both groups had started performing agit-prop theatre and touring the streets of North London. Later they extended their programme and organised a variety of activities for the inhabitants of the neighbourhood.

Such movements emerged against a background of widespread lack of development of the urban environment and public space in London's former working-class neighbourhoods, including Kentish town where the Inter-Action Centre was located. While London's inner city was already rebuilt and well on its way to becoming a major financial centre of the rising global economy, a large part of the city's working-class neighbourhoods was still in a state of disarray and decay. After the slum clearance programme in the 1960s had replaced many of the nineteenth-century workers' houses, wastelands still needed to be redeveloped, with public space, functioning high streets and other venues missing. The Inter-Action Centre was thus closely related to the idea of urban regeneration, in which newly built space would facilitate the creation of a new social space, both for the community and the neighbourhood as a whole. [Fig. 2] Accordingly, the centre was planned as part of a larger open space dedicated to the neighbourhood by the Borough of Camden. It was to host the group's various activities that were already taking place in multiple locations around the district.[10]

When the centre opened in April 1977, Inter-Action had 1 500 members and sixty full-time employees.[11] These members were engaged in multiple activities, including education, community welfare, and theatre; they hosted ateliers and media workshops and offered support in city farming at

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Prof. Dogg's Troupe
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Local Police	725 4212
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about sex in Parliament and farms in Kentish Town!
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The 1977 West Kentish Town Neighbourhood Festival on Talacre
Will you please help to organise it this year? 267 5319

JUNE

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Fig. 1

Fig. 1: 'West Kentish Town Neighbourhood Festival', Inter-Action Community Calendar, 1977, Cedric Price Archive, CCA, Montréal, Document folio DR:1995:0252:632:015:001:007.

London's first urban farm, which the group had established in 1971. All the group's activities shared the idea of improving the neighbourhood's inhabitants' living environment through activities that promoted communication, engagement and, thereby, learning.[12] The group's diversity of activities and participants was lauded in the press conference on the occasion of the centre's inauguration and seen as an accomplishment worthy of the new, more individualised society which didn't rely on governmental institutions but responded directly to the public and local interests.[13]

Theatre director David Berman had established Inter-Action as a charitable trust in 1968, dedicated to community work with the goal of 'breaking down ethical class and temperament barriers' within the neighbourhood.[14] Representing a novel approach to small group work, Inter-Action worked with interactive theatre and games as new forms of citizen engagement with the intention 'to make arts more relevant in the community'.[15] For example, in the environment game, participants could learn to use modern media and communication technology and produce videos about their everyday life. As Berman writes in the organisational statement of Inter-Action, this bottom-up approach to community work ought to have a scaling effect, facilitated by the new community building. In his vision, the Inter-Action Centre was to become the starting point of a social movement that would lead to an expanding network of community centres. The Inter-Action Centre was to be 'the first ripple … to set out', then expanding to 'the Borough of Camden, then the inner London area in general and the next ripple would be obviously the various parts of England'.[16] Accordingly, design goals for the centre evolved from focusing on fixed spaces to the provision of multiple adaptable spaces that would support the interests of the various groups and facilitate future networking. These two considerations gave room to the idea of a flexible organisation of the programme and the responsive organisation of space as preliminaries for the centre's design.

When Cedric Price was selected as the centre's architect, he was already well known for his design of a similar adaptable performative space, the Fun Palace. Price had developed that project for agit-prop theatre director Joan Littlewood and the Fun Palace Trust seven years earlier. In this ultimately unrealised project, the architect designed an adaptable mega-structure that would respond to its users' needs through cybernetics and technology. The same principles informed the design of the Inter-Action Centre. All group activities were to take place literally under one roof, which Price designed as an open, two-story steel frame, providing a division between different inside and outside spaces.[17] Apart from a roofed main hall, he attached prefabricated plug-in portacabins to the structural framework. Price had planned these rooms to be exchangeable over time, depending on specific functions and demands expected to vary over the building's lifetime. Modules included, for instance, a media workshop and rehearsal rooms. Simultaneously, the structure defined open spaces in which various enclosures could be added, such as a Fun Arts bus that toured the neighbourhood for theatre performances or the local day nursery in the form of a Finnish log cabin. All these rooms functioned individually and were supposed to be replaced or added when necessary.

While both the Fun Palace and the Inter-Action Centre focused on creating performative spaces dedicated to community work, their designs differed significantly in size and formal expression. With a steel structure that was to be ten stories high and measured approximately 250 by 125 metres, the Fun Palace was designed as a giant machine. It employed automated cranes and movable platforms that were to be controlled by computer technology. Its capacity to host more than five thousand people at a time, both in large and various small-scale events, made it a monument for the mass society of the newly emerging information age. In comparison to such a headlines-making project with its interactive building hardware, the design of the

Fig. 2

Fig. 2: ‘Your playspace needs you Talacre Action Group NWS and Inter-Action’ poster, ca. 1971, designer unknown, Cedric Price Archive, CCA, Montréal, Document folio DR:1995:0252:632:014:002.

Inter-Action Centre was low-tech and small-scale. Instead of cybernetic control and advanced building technology, the core of the design was the idea of slow adaptation and change of use over time.

Price placed particular emphasis on the process of changing activities and programmes. The building was erected in three stages, with the roof and structural framework built on-site already in 1974, three years before the building's opening.[18] In parallel, the outdoor facilities were constructed, including a playground, a stage, a square walkway, and a football pitch.[19] In that first stage, the building was designed as part of an outdoor space that provided basic infrastructure for community work and created a sense of place and community. [Fig. 3] With the fundraising completed in 1976, the main hall and plug-in rooms were added to the structure, whereas additional spaces, such as the Finnish log cabin, joined the centre just before the opening in 1977.[20] The RIBA journal commented on the time-phased construction of the building as the true expression of a user-oriented design approach: '[Inter-Action] is concerned with the rarest and most valuable resource of all, one of which we cannot afford to waste, *people,* their spirit to do things … and to change their minds.'[21] Being part of the neighbourhood system of social interaction, the design of Inter-Action, therefore, seemed to be 'the true definition of the ageing of a building. It has something to do with growth as well as with final destruction.'[22]

Re-programming the city

The need for rooms and spaces that respond to the temporary nature of peoples' activities required new tools to gather information about the users' intentions. For this purpose, Price began to use questionnaires. He thus surveyed the different groups within Inter-Action about their preferred use and social activities. This information formed the basis for a series of diagrams, such as an activity frequency sheet that displayed the groups' activities, their need for space, and possible adaptation over time.[23] However, as office member Will Alsop later recalled, due to the dynamic of the different needs and interests of the groups involved at the beginning of the project, 'the brief changed every two weeks'.[24] These diagrams presented the temporal order of supported functions, for example the building's weekly use cycles or the relationship between different applications and the required spaces both in and outside the building. Price then categorised each activity-space into a modular size, which could be incorporated into the structural matrix in any number of ways. [Fig.4] This approach gave him an idea of the size of rooms and the design of the overall structure needed to accommodate any specific programme.[25]

Price had started to focus on space usability as a design criterium early in his career. Such design-driven survey methods played a central role in the Fun Palace design and, later, in the Generator (1977–1984), a design for a rehearsal retreat and performing arts centre in Florida.[26] Similarly, in his regional plan for a decentralised university campus in the industrial region of Stoke-on-Trent, Potteries Thinkbelt, he used statistical information and aerial photography to conduct a regional 'survey of occupation' to map potential sites and uses for redevelopment. In doing so, he referred to Patrick Geddes and his method of civic survey, exemplified in his 1918 study of the working class in Edinburgh. Geddes's ideas on city planning had surfaced again after World War II through the republication of his works at universities, including the Architectural Association (AA) School of Architecture in London, where Cedric Price got to know Geddes's work. In his concept of co-evolution, Geddes had described the city as a dynamic system of interaction between humans and their environments, where he distinguished human-made, natural and technical settings.[27] From this perspective, an intervention in any of these realms could facilitate change in the city as a whole.[28] For Geddes, careful observation and analysis were, therefore, the first steps before suggesting any particular spatial intervention within the broader framework of the city.[29]

Fig. 3

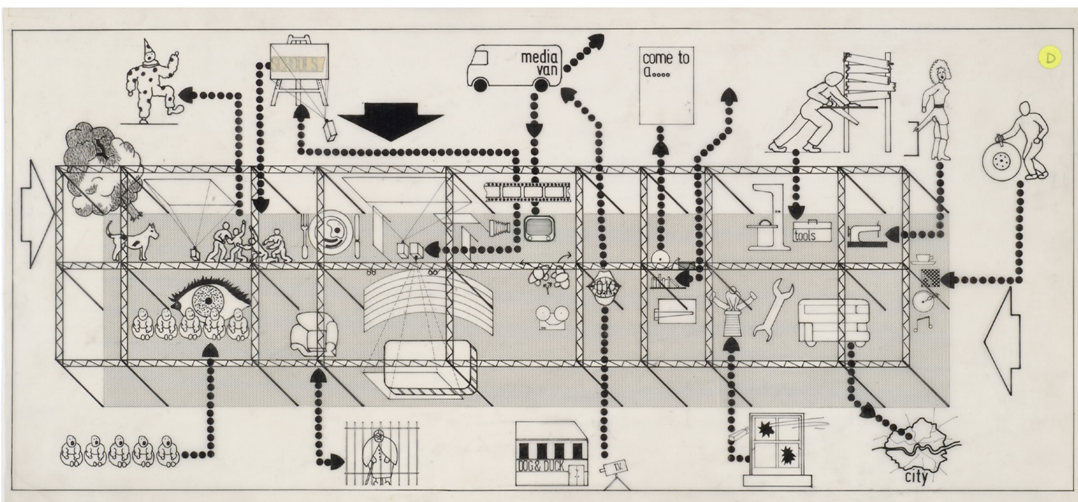

Fig. 4

Fig. 3: Cedric Price Architects, ‘Photomontage Inter-Action Centre’, Camden Town, London, ca. 1976, Cedric Price Archive, CCA, Montréal, Document folio DR:1995:0252:632:014:001.

Fig. 4: Inter-Action Centre, axonometric diagram, Cedric Price Archive, CCA, Montréal, Document folio DR:1995:0252:621.

During the 1970s, Cedric Price extended his set of survey methods to include qualitative methods and fieldwork. In the McAppy project that he conducted in parallel to the design of the Inter-Action Centre, his team used participatory observation together with interviews and spatial mapping to investigate the work environment on the construction sites of the McAlpine company. The project used both civic surveys and observation of workers' behaviour to propose measures to improve on-site working conditions. Consequently, the final product was not a building but a manual with suggestions for spatial and organisational change within the company.[30]

The emergence of this new way of collecting data, as well as the drawings in Price's architectural design process, suggest that Price did not see architecture primarily as the design of an object, but rather as the organisation of activities and change within a cultural system. Furthermore, it shows that the architect became an observer of the built environment and the activities taking place in it. A rational analysis should then allow for reliable conclusions and serve as a guide for specific ideas on how to use spatial design or enable improvements within an already existing system of relationships. Thus, the architect's role turned into that of an observer, analysing the city and its social activities and employing scientific methods to gather information on the use of space or the preferences of the people who use it. The architect was furthermore charged with providing the imagery of construction and use, as well as illustrating the project's promise to the community. For this task, his studio produced specific drawings with simple axonometric representations of the building, illustrating the various activities and their relationship to other functions and the surrounding neighbourhood. [Fig. 5]. He was also asked to create images that could be used for fundraising and public relations, as well as for the different members of the group itself who were in search of 'a more graphic way of bringing the building to life for us who are laymen'.[31] The need to communicate the design's flexibility to laypeople, in particular, can be seen as a result of his activity-centred design approach.

Focusing on the users and the configuration of their activities in space, Price regarded his work on the Inter-Action Centre as a laboratory to create, parallel to the built space, a new social space. Price perceived architecture as part of an interactive system, comprising not only buildings but also people and their actions. Accordingly, he became an attentive observer of the surroundings and an investigator of user groups' different needs. This strategy of 'an architecture of appropriation' was tested again when the brewery company Whitbread eventually bought parts of the Inter-Action Centre to insert a mock-Tudor pub inside the structure. Price was very pleased with the final intervention.[32] Taking a holistic approach, he viewed his architecture as a cultural product of people's activities and interactions, which consequently required a new design approach. As he stated in a 1976 lecture on the design of the Inter-Action Centre, 'the time element of when a building is useful for its users or its operators was blurred. This can only happen if there's a conscious effort for looseness in the structuring of the original design.'[33]

His work on the Fun Palace and the Inter-Action Centre represents a departure in his design approach from the one followed in his earlier projects. In his designs for small houses, extensions and refurbishments, for example the redesign of the Moyston Hotel bar (1960–1964), the Robert Frazer Gallery (1961–1962) and the construction of a cottage in High Legh (1961–1965), Price followed the popular modernist aesthetic of that time. Designs from the beginning of his career were informed by the common goal of optimising the transition from preliminary design to construction. However, he began to question the idea of housing design in the High Legh Cottage and suggested that the client should consider the building's lifespan and possible changes of use over time.[34]

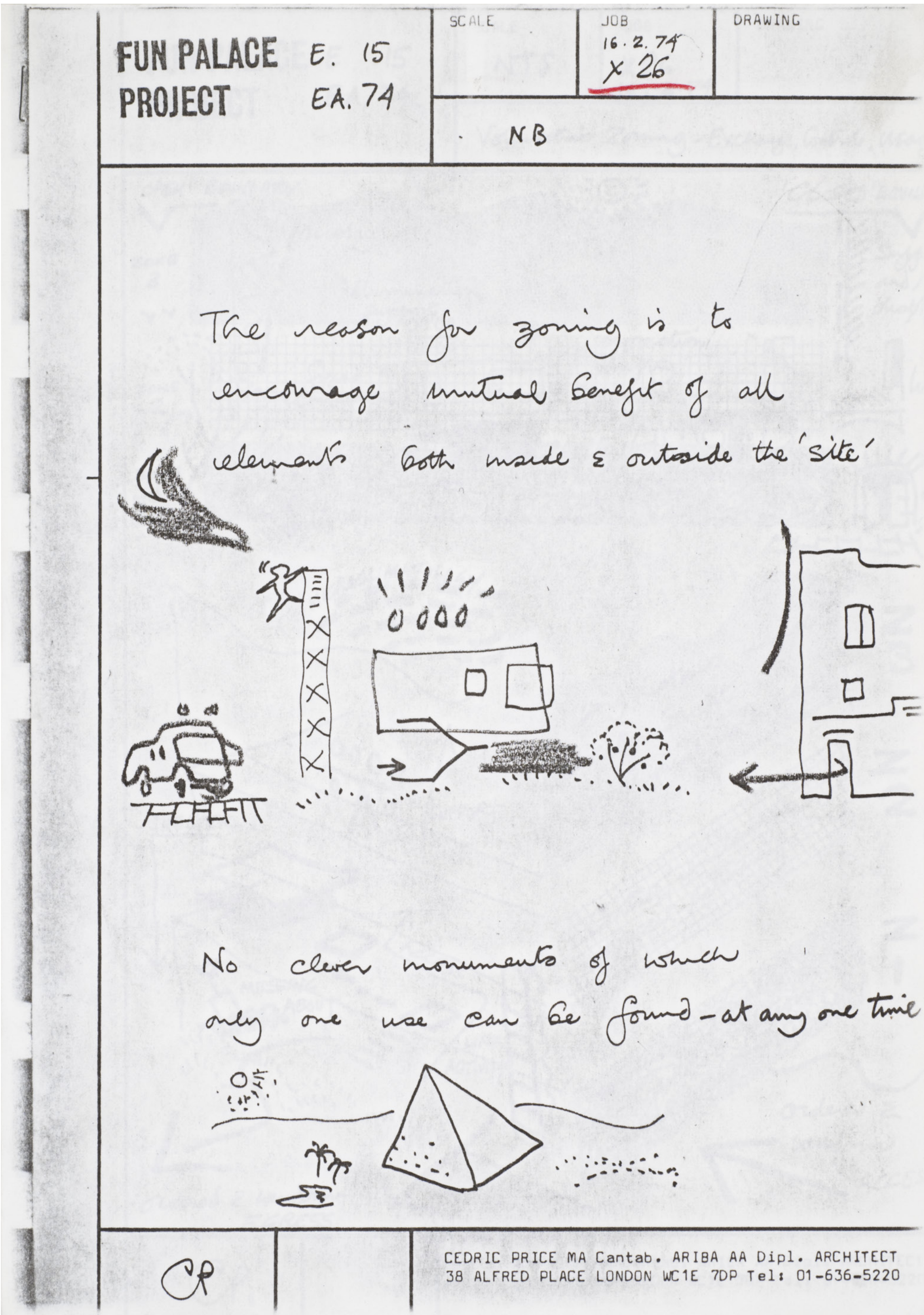

Fig. 5

Fig. 5: 'Volumetric Zoning: Fun Palace Project Easter Fair', sketch by Cedric Price, dated 16 February 1974, Cedric Price Archive, CCA, Montréal, Document folio DR:1995:0188:525:001:018.1.

The Fun Palace as a cybernetic system of interaction

Price's encounter with the cybernetician Gordon Pask (1928–1996) turned out to be decisive for his understanding of ecological design. Within their collaboration on the Fun Palace control system, Pask introduced Price to systems thinking, self-regulating systems, and other concepts relevant to machine-human interaction. Pask arguably brought cybernetics into the mainstream. As a trained scientist with a doctorate in psychology, he dedicated his work to educational technology and a scientific theory of learning. These interests included the application of cybernetics through the construction of interactive learning environments. He recognised in architectural design the potential for a holistic approach to designing environments of interaction. His involvement in the Fun Palace project proved to be a formative influence on his dedication to architecture and architectural education. As a critic and teacher at the AA School of Architecture, for example, he promoted the application of systems thinking to architectural design and educational technology.[35]

In the Fun Palace project, both Pask and Price were members of the so-called Cybernetics Committee, which developed ideas for the building's use and programme in relation to its spatial design. The aim was to create the Fun Palace as an open environment with an indeterminate program, made possible by the support of high-tech machinery, including air conditioning, a flexible façade of movable plastic panels, closed-circuit television, and so on. It comprised the hardware to the cybernetic control system that was to ensure openness of use.[36]

Gordon Pask developed the Fun Palace as a self-regulating machine that could adapt to its visitors' needs. The basis of this adaptable architecture was the combination of a cybernetic control system, which regulated the interaction between high-tech machinery and humans, and an architecture that implemented the mechanics of movements and atmospheric changes. Based on the idea of a theatre stage and stage technology, large cranes were to reposition the rooms in the Fun Palace, and light, acoustics, and climate could change autonomously. Its control system, which translated the various user groups' input into different spatial configurations, allowed the Fun Palace to change continuously.[37]

The cybernetic system specified roles and hierarchies of the actions that were to take place depending on the input. By defining the levels of communication and feedback, it turned the building into a performative machine. It created a dialogue and communication system that processed information about the functions and organised them spatially in the building. By establishing a form of continuous two-way interaction with its users, the Fun Palace became a genuinely interactive system, creating not only a new architecture of performance but an environment with its own dynamic processes of adaptation, change, and renewal.[38] With the help of cybernetics, the Fun Palace was to become an environment 'suited to what you are going to do next' and 'indeterminate participatory open-ended situation'.[39] In this sense, the architect and the cybernetician designed a self-contained environment that could potentially continue to evolve without further supervision. In the minds of its inventors, architecture went from imposing a particular spatial structure on its users to a self-organising space that could react naturally to their input. Like its inhabitants' relationship to their surroundings, architecture gained a fundamental characteristic of the concept of ecology as an environmental system *avant la lettre*.

Common to all the system's different components and at the centre of Pask's work as a cybernetician was the idea of interaction between people and machines in a dynamic system of communication. Pask had based the Fun Palace's cybernetic system on the concept of processual development, which he had defined in 1961.[40] Instead of being pre-defined by the system's initial conditions, the Fun Palace's cybernetic system was based on continuous dialogue, which allowed user interaction to evolve by means of communication. Pask used the term 'conversation' to describe this process. This would lead the Fun Palace to be self-organising and to learn from previous inputs to create different and ultimately unpredictable new spatial configurations.

Although on a much smaller scale, Pask had already developed a similar dialogue system before. His plans for Joan Littlewood for a cybernetic theatre would have allowed the audience to influence the play's progression by an electronic feedback system. The audience was thus enabled to participate actively and influence the stage performance allowing for a more situational play. Pask used cybernetics here to understand and construct an open system that focused on the dynamic process of social interaction. Through formatted content and the possibility of adaptation, the system was expected to evolve and learn. In his theory of learning, learning is derived from conversation and channelled according to different styles, strategies, or configurations of learning environments.[41] He applied these ideas to technological devices by constructing systems and settings that would promote discussion and understanding. In this sense, he viewed the Fun Palace's cybernetic system as a learning system and the building itself as a learning environment that would evolve.

In their approach, Pask and Price followed a general trend in cybernetics, moving away from its primary focus on applications in weapons systems during World War II to a post-war science that adapted systems thinking to improve civil society. Terms such as command, control, and information became part of the general vocabulary, regardless of whether they addressed biological organisms, automatons or societies. Related theories promised not only approaches to a new unity of knowledge but also new regulatory mechanisms for a wide variety of social problems.[42]

Ecology

Like for Price, the work on the Fun Palace was also a decisive experience for Pask who later explained that architecture offered ideal conditions for the inclusion of systems thinking.[43] His work created the conceptual basis for a new understanding of architecture as an instrument of change within a broader environmental and social context. Dedicated to the design of the built environment, architecture had the potential to unite competing concepts from different disciplines, including sociology, economics, engineering and biology. Particularly relevant was its interdisciplinarity and holistic approach to knowledge production in order 'to yield a broad view of such entities as "civilisation", "city" or "educational system".'[44] In that sense, Pask provided the conceptual blueprint to Price's work: through the construction of new environments, architecture dealt not only with the built space but also had the potential to affect the social space.[45]

For Cedric Price, the introduction to cybernetic ideas led to a new approach to architectural design. In the concept of radical constructivism, architecture became an instrument that determined its users' possibilities of action. According to this view, the architect became a programmer of opportunities. Architecture was not only part of a system of human interaction but became part of a more extensive system of the built environment, which was continually evolving and creating new situations and ideas. This led Price to the realisation that the architectural discipline had to adapt. Consequently, in 1966 he advocated a greater recognition of time and process as design criteria: the architectural profession was too fixated on form and representation 'as a provider of visually recognisable symbols of identity, place and activity'.[46] And he suggested that the architect should instead 'aim for the improvement of quality of life as a direct result of architectural endeavour'. Contrary to the tendency that defines architecture's function as mainly representative, Price saw his profession's role in the design of spatial interventions that would stimulate a region's socio-economic system and foster social stability and cohesion.[47] And he warned that 'the possibility should not be ignored of Great Britain's becoming an increasingly imbalanced community primarily involved in servicing other countries and providing facilities for hardy historiphile holidaymakers.'[48]

With their ambition to promote and support social values such as equality, self-help, and self-expression, Price's designs fit well into the tradition of the modern avant-garde, whose architecture was dedicated to improving the living conditions of the working class. While he worked on transforming concepts such as user, function, and flexibility, which were rooted in the ideas of modernism, he also broadened modernism's perspective through his process-oriented understanding of space as an interrelated system of spatial environment and social community.[49]

Price first applied the idea of ecological design in 1974 when he designed the Stratford Fair. Around this time, Joan Littlewood had redirected the Fun Palace Trust's activities to the neighbourhood of Theatre Royal, where she started an effort to revitalise the neighbourhood with a playground called Stratford 48. For the annual funfair, Price divided the area into several three-dimensional zones, each with different heights and technical equipment such as stage scaffolding, sound systems and lighting, each providing a different impact on the connectivity and accessibility of the space and its surroundings. In this way, he designed a performative environment intended to create particular situations of interaction and promote the site's close interrelation with the neighbourhood. The idea was that on the site, the people, their activities, and the various spatial qualities should be in constant flow. As Price explained in his sketch of the setup, it was 'no clever monument of which only one use can be found at any time'.[50] This was to be the opposite of what current representational architecture could achieve. [Fig. 6]

By applying a cybernetic viewpoint, the Stratford Fair's architectural design made no distinction between people on the one hand and objects, technology, and material on the other. Everything was seen as part of one organic system, an ecology in which the functions and processes of the natural environment, such as climate, sound, and light, as well as the human need for conviviality could be integrated and reproduced in an artificially created, human-made system.[51]

Seeing architecture as an instrument for intervention in a broader social and built environment such as an urban neighbourhood, reflected an openness to the idea of systems thinking that did not stem from Pask's cybernetic vision of social control, but rather from Price's interactions with Buckminster Fuller. The American engineer provided Price with an approach to using design as an instrument of change within a system. For him, architecture and engineering provided infrastructure to the built environment, which would establish a new balance between the natural world and human needs. The architect's role was, therefore, to transfer the knowledge of science to engineering. In his vision of 'planetary planning', Fuller went so far as to see the earth as one interlinked organic system of flows that humanity could redirect and optimise by using science and engineering. As Fuller's work suggested, ecological design aimed to preserve natural systems and develop new tools that reproduced the principles of nature in design. In his understanding, the architect was an engineer and inventor who contributed to improving human life by redirecting socio-economic processes through system intervention.

Price had already been introduced to Fuller in 1958 who mentored Price after opening his office in 1960. Fuller allowed Price to use his dome patent in his Claverton Dome project (1961–1963) and supervised his design for the New Aviary (1960–1965), in which Price employed Fuller's structural concept of tensegrity.[52] In both projects, Price applied Fuller's idea of architecture as systems engineering. In his design of the aviary, he used methods to improve the structure by testing materials, examining construction details, and studying

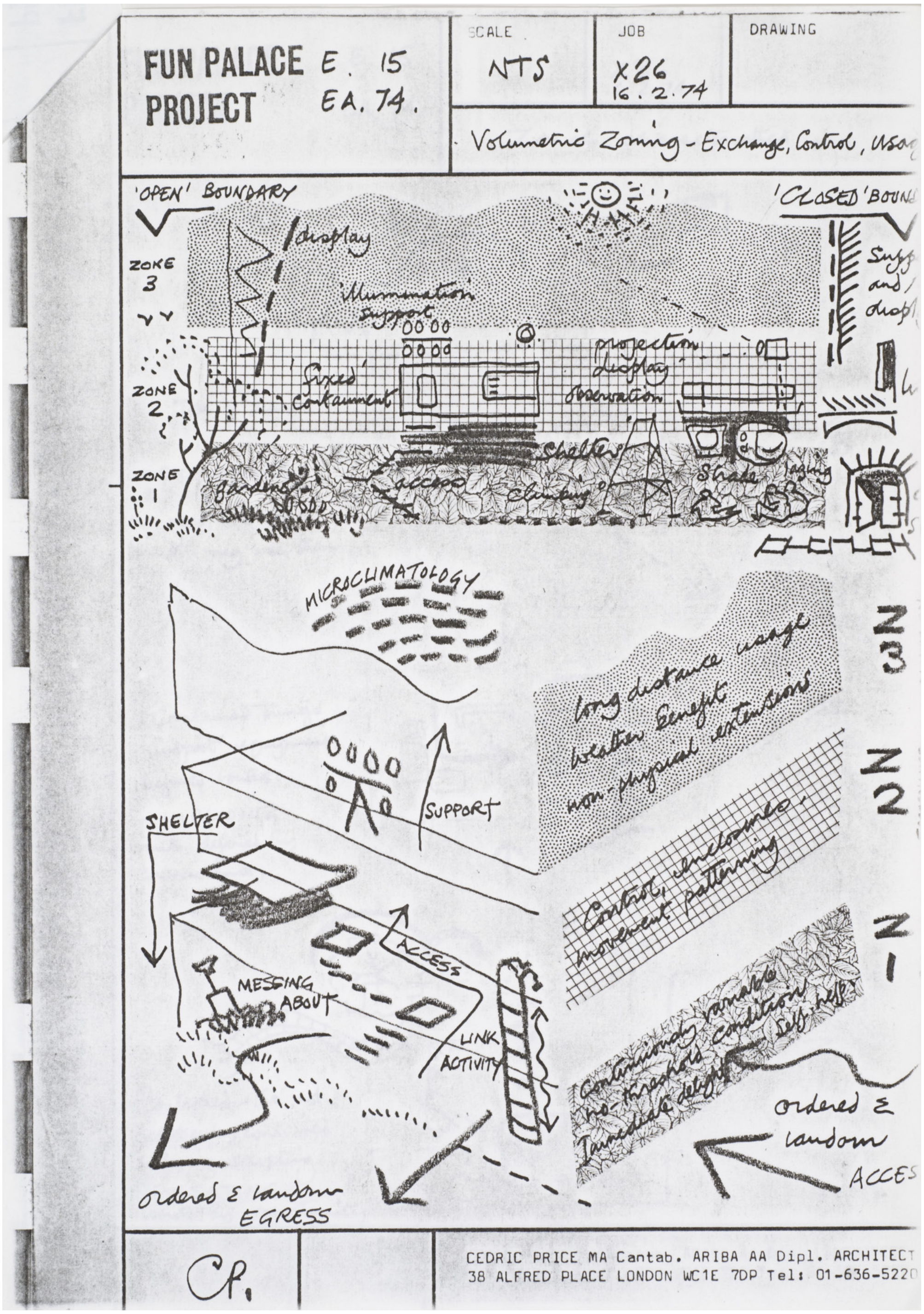

Fig. 6

Fig. 6: 'X26: Fun Palace Project', Easter Fair, sketch by Cedric Price, 16 February 1974, Cedric Price Archive, CCA, Montréal, Document folio DR: 1995:0188:525:001:018.2.

the environmental conditions inside the building. Price tested soil samples and studied vegetation growth to improve the walk-in aviary's usability as a 'place of public interest and enjoyment'.[53] In the New Aviary project, Price attempted to replicate a natural system through design. In the Fun Palace, he applied the same design approach of systems engineering while focusing on replicating a social system by creating an artificial environment aimed at stimulating learning and cultural activities. Between 1960 and 1966, he worked on both projects almost in parallel. Both designs focused on an ecological system in which architecture was to establish a new relationship between the social and built space.

With the rising awareness of the scarcity of resources, increasing consumerism, and population growth in the late 1960s, Fuller's ideas became more common within a circle of young architects, including Fuller's long-time collaborator and friend of Price, John McHale. McHale extended Fuller's concept of ecological design to the development of design principles and tools.[54] As much as the design of an object, building, or territory, from a planetary-planning perspective, McHale understood ecological design to be the design of organic systems through technological mediation or engineering.[55]

Price continuously adapted this radical way of thinking about architecture as an instrument of system intervention throughout his work. While projects like the Potteries Thinkbelt focused on designing a large-scale regional network and educational system as a starting point for revitalisation, smaller projects like the Inter-Action Centre focused on a single component within a larger network of spatial interventions. Projects such as South Bank (1983–88), Ducklands (1989–1991), or Magnet (1995) show that Price continued to develop this topic throughout his career.[56] With his proposal for the giant Ferris wheel on London's South Bank and his small-scale infrastructural intervention in his Magnet proposal, he presented architecture as an urban catalyst that would stimulate social and economic change within a broader environment. He reduced his designs increasingly towards minimal interventions that focused on improving the human habitat. In his Ducklands proposal, his view of architecture as a system intervention went so far that he proposed parts of the harbour area to become a nature reserve, accessible both to migratory birds and the citizens of Hamburg.

Whereas the biologist Ernst Haeckel had coined the term ecology to refer to the relations of organisms to both one another and their physical surroundings, at the beginning of the twentieth century the term was increasingly used to refer to the city as a living organism. As the Greek word *oikos* means 'household', 'home' or 'place to live', the concept of ecology also applied to the human habitat as a place of social interaction, be it a house, a neighbourhood, or an urban region. In 1915, Patrick Geddes, for instance, claimed a homology between nature and the city.[57] He thought of both cities and natural settings as ecosystems encompassing the flow of energy, matter, and both human and non-human organisms.[58] In his work as an urban planner, he favoured small-scale interventions that would serve 'primary human needs' over large-scale urban designs. This approach was later described as 'conservative surgery' and the idea of architecture as systems intervention finds an echo in the later works of Cedric Price.[59]

Thanks to cybernetics, the idea of ecology changed after World War II to a more integrated vision in which the natural world was no longer seen in opposition to the human-made world. However, with the first United Nations resolution on environmental policy, published in 1972, the idea of ecology and the corresponding systemic view on the world had gained new political relevance.[60] It recognised that modern scientific and technological developments had altered the relationship between humans and their environment profoundly. The resolution was intended to acknowledge both technology's unprecedented opportunities for human development while also recognising the accelerating destruction of the human living environment.

Science and technology were understood both as instruments for the exploitation of resources and compensation for their negative impact. Moreover, social activism showed itself to be a counter-reaction to modernist planning, as it saw the limits of architecture in its inability to meet its inhabitants' needs.

In this new way of thinking about architecture, contextualisation and the faculty for dialogue should help to reconcile the social space with the built space. Furthermore, a new bottom-up approach was to facilitate the residents' identification with the living environment. While an intellectual elite gave voice to these demands in the 1960s, among them Jane Jacobs, Kevin Lynch, Denise Scott Brown, and Robert Venturi, similar ideals also began to emerge at the beginning of the 1970s in grassroots movements and community initiatives in London. Like many others, both the Inter-Action group and Joan Littlewood's Theatre-Workshop started their engagement in community work where the idea of ecology came to the fore through advocacy for the common good.

If the Inter-Action Centre may not appear at first glance as a genuine example of such an ecological approach, this may reflect a rather narrow understanding of ecology, that is, in the context of the natural environment only. Yet without the neighbourhood's social fabric, its use of architecture as an active agent to improve citizens' lives by offering space, programmes and activities would have been unthinkable. Such a reorientation of architecture also met, of course, with criticism. The main points of critique were the approach's adherence to and reliance on observation, description, and application of scientific methodologies. At the same time, however, its emphasis on education and learning undeniably promoted values such as sociability, equality, and the improvement of life. This topical alignment led it to join systems thinking with learning and self-improvement. The design and use of the built environment should reflect these values and actively contribute to their realisation. Consequently, the ideal of ecological design in the Inter-Action Centre also contained a robust ethical imperative. The public perceived it as a showcase project that would foster a better life through creativity and social interaction.

For Cedric Price, the Inter-Action Centre represented a culmination of the various ideas and approaches to systems thinking that he had encountered during his work in the 1960s. In the project, his relational approach to architecture, which emphasised the link between material resources and the possibility of individual action, that is, between information, space and social order, became fully apparent. This new attitude towards architecture as a system or ecology explains many of his subsequent projects' polymorphism. He applied design as an active agent to intervene in already existing environmental systems. A log cabin, like the one in the Inter-Action Centre, the new hard hat invented for the McAppy project, or a bird sanctuary could each represent a suitable artistic instrument to stimulate improvement of the built environment. In this sense, the design of the Inter-Action Centre marks the passage from the observation of a system of social interaction to 'the intentional instrumentation of new systems as active agents'.[61] Following the tradition of Patrick Geddes's co-evolution, Cedric Price used design to foster a new form of dialogue and open up an altered spectrum of action for the individual users.

More telling, however, is how Price's architecture shows the consequences of the paradigm shift from architecture seen as a representational artifact to architecture as part of an ecology. Consistently, when his Inter-Action Centre was proposed for inclusion in the list of British cultural heritage sites, Cedric Price took the unprecedented step of lobbying against such preservation.[62] Instead, he argued that his building should be demolished to make room for a new one, one that was better suited to the demands of today's users.[63] Shortly before his death in 2003, Price was asked if he would not feel nostalgic seeing the great architecture of the 1960s disappear. As a true proponent of the process-based architectural approach, he just briefly stated: 'Nostalgia for the 1960s, it is laughable.'[64]

Notes

1. Cedric Price left behind only two buildings: the Inter-Action Centre, demolished in 2003, and the London Zoo Aviary. Most other projects were abandoned in an unfinished state. His lasting influence stems rather from his teaching activities, contributions to conferences, editorials and similar small-scale publications. See among others: J. Stanley Mathews, 'An Architecture for the New Britain: The Social Vision of Cedric Price's Fun Palace and Potteries Thinkbelt', Ph.D. Thesis, Columbia University, 2003; Samantha Hardingham, *Cedric Price Works 1953–2003* (London: AA Publications, 2016); Tanja Herdt, *The City and the Architecture of Change: The Works and Radical Visions of Cedric Price* (Zurich: Park Books, 2017).
2. Lydia Kallipoliti, 'History of Ecological Design', *Oxford English Encyclopedia of Environmental Science* (Oxford: Oxford University Press, 2018).
3. György Kepes, *Art and Ecological Consciousness* (New York: G. Braziller, 1972).
4. Barney Warf, '*Spatial Turn*' in *Encyclopedia of Geography*, ed. Barney Warf (Thousand Oaks: SAGE Publications, 2010), 2669.
5. Sutherland Lyall, *The State of British Architecture* (London: Architectural Press, 1980).
6. The date for the Claverton Dome refers to the end of the project design. It diverges form the date given by Samantha Hardingham, who suggests 1961–1964, taking into account all documents written on the project. Hardingham, *Cedric Price Works*. The date for the New Aviary refers to the public opening of the building in 1965. It diverges form Samantha Hardingham, who suggests 1961–1964, taking into account all documents written on the project. Ibid.
7. Whereas Samantha Hardingham dates the Potteries Thinkbelt to 1966–1967, the CCA lists the project 1963–1966. 1963 was the year when Cedric Price started his writings on the educational reform plans of the British government. Ibid., and Archival document no. 64/18 'sidings, tracks & station using' dated 23 March 1965. Cedric Price Archive, CCA, Montréal, Document folio: DR:1995:0216.076. Patrick Geddes, 'The valley section from hills to sea', New York City, 1923. Lecture given at the New School of Social Research, published in: Patrick Geddes, *Cities in Evolution*, new, revised edition (London: Barnes and Nobles, 1959).
8. The performative nature of Price's work is understood in the context of Doreen Massey's relational approach to place, in which she links space and place to their social organisation. In this conceptual framework, organisations are seen as being enacted through meaningful interactions, which include human and non-human actants. Doreen B. Massey, *For Space* (London: Sage Publications, 2005).
9. Mary Louise Lobsinger, 'Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace', in: *Anxious Modernism: Experimentation in Postwar Architectural Culture*, ed. Sarah Williams Goldhagen and Rejean Legault (Cambridge, MA: MIT Press, 2000), 98.
10. The Borough of Camden gave Inter-Action a twenty-seven-year land-lease on the site. Hardingham, *Cedric Price Works*, 315.
11. 'Londoner's Diary', *The Evening Standard*, 19 April 1977.
12. Win Caldwell, *Report on Remedial Education* 02/1972, no. 1 vol. 1, 28, Cedric Price Archive, CCA, Montréal, Document folio: DR:1995:0252:632:16/17.
13. Sutherland Lyall, 'Funpalace Mark II', *Building Design,* 22 April 1977.
14. Caldwell, *Report on Remedial Education,* 28.
15. Inter-Action trust director David Berman used this approach for purposes ranging from therapy to entertainment. 'Project Inter-Action, General description', Report III, Council for Cultural Co-operation Council of Europe, Symposium Rotterdam, 5.–9.10.1970, Cedric Price Archive, CCA, Montréal, Document folio: DR:1995:0252:632:16/17.
16. Ibid.
17. Nathan Silver, 'Hypercandid', *New Statesman*, 6 May 1977.

18. Ibid.; Hardingham, *Cedric Price Works*, 329.
19. In this sense, the roof of the Inter-Action Centre had the character not of a building but of an outdoor pavilion in a park. The outdoor facilities were not designed by Cedric Price. Cedric Price Archive, CCA, Montréal, Document folio: DR:1995:0252:632:1/31
20. Silver, 'Hypercandid'.
21. Author unknown, 'Inter-Action Centre', *RIBA Journal* (November 1977): 458–59, cited in: Hardingham, *Cedric Price Works*, 317.
22. Ibid.
23. Cedric Price, 'Activity Frequency Sheet Sketch 102/156, Inter-Action Centre', undated, CCA, Montréal, Document folio DR:1995:0252:621:16/17.
24. Samantha Hardingham, interview with Will Alsop, 14 December 2014, in: Hardingham, *Cedric Price Works*, 316.
25. Mathews, 'An Architecture for the New Britain', 302.
26. Herdt, *The City and the Architecture of Change*.
27. Volker M. Welter, *Biopolis: Patrick Geddes and the City of Life* (Cambridge, MA: MIT Press, 2002).
28. Kallipoliti, 'History of Ecological Design'.
29. Price reflected this observational approach and Geddes's understanding of the city as an organic whole in his 1962 project Circlorama, in which the inhabitants of Glasgow could get information on the impact of urban redevelopment schemes through observation of the city. Herdt, *The City and the Architecture of Change*, 64.
30. Ibid.
31. Letter from E.J.B. Rose to Cedric Price dated 30 March 1976, CCA, Montréal, Document folio DR:1995:0252:632:16/17.
32. Will Hodgkinson, 'If it works, scrap it', *The Guardian*, 3 May 1999.
33. Cedric Price, 'Technology is the Answer, But What Was the Question', recorded lecture. Monica Pidgeon Audio, 1979. As cited in: Hardingham, *Cedric Price Works*, 316.
34. Hardingham, *Cedric Price Works,* 119.
35. Peter Silver et. al., 'Prototypical Applications of Cybernetic Systems in Architectural Contexts: A Tribute to Gordon Pask', *Kybernetes* 30 (2001): 902–20.
36. Herdt, *The City and the Architecture of Change.*
37. Ibid.
38. Lobsinger, 'Cybernetic Theory and the Architecture of Performance'.
39. Reyner Banham, 'Softer Hardware', *Ark* (Summer 1969): 11.
40. Gordon Pask, *An Approach to Cybernetics* (New York: Harper & Bros, 1961).
41. Gordon Pask, 'Styles and Strategies of Learning', *British Journal of Educational Psychology* 46 (1976): 128–48.
42. Michael Hagener and Erich Hörl, eds., *Überlegungen zur kybernetischen Transformation des Humanen* (Frankfurt am Main: Suhrkamp, 2008).
43. Gordon Pask, 'The Architectural Relevance of Cybernetics', *Architectural Design* (September 1969): 494–96.
44. Ibid.
45. Ibid.
46. Cedric Price, 'PTb Life conditioning', *Architectural Design* (October 1966): 483–84.
47. Another prime example of this view is his design of the Potteries Thinkbelt. Ibid.
48. Ibid.
49. Addressing modernist concepts, see: Adrian Forty, *Words and Buildings: A Vocabulary of Modern Architecture* (London: Thames and Hudson, 2000).
50. Cedric Price, 'X26: Fun Palace Project Easter Fair', sketch dated 16 February 1974, Cedric Price Archive, CCA, Montréal, Document folio DR:1995:0188:525:001:018.2.
51. Kallipoliti, 'History of Ecological Design'.
52. Herdt, *The City and the Architecture of Change.*
53. Author unknown, letter to Cedric Price, nominee for the Reynolds Memorial Award, the American Institute of Architects 1965, Cedric Price Archive, Canadian Centre for Architecture, Document folio: DR:1995:0185:275:003.
54. Price knew John McHale from his engagement in the Independent Group (1952–1956) exhibition *This is Tomorrow.*
55. Kallipoliti, 'History of Ecological Design'.
56. Herdt, *The City and the Architecture of Change.*

57. Geddes, *Cities in Evolution*.
58. Kallipoliti, ‘History of Ecological Design’.
59. Lewis Mumford, ‘Introduction’, in Jaqueline Tyrwhitt, *Patrick Geddes in India* (London: Lund Humphries, 1947), 10.
60. Declaration of the United Nations Conference on the Human Environment, UNO 1972, https://www.ifrc.org/docs/idrl/I242EN.pdf.
61. Kallipoliti, ‘History of Ecological Design’.
62. Mathews, ‘An Architecture for the New Britain’, 306.
63. Ibid.
64. Cedric Price, interview with Christian Kühn, Vienna 2002, *UmBAu* 20 (2003), cited in: Hardingham, *Cedric Price Works,* Volume II, 504.

Biography

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Systems and Relations All the Way Down, All the Way Across

Tim Gough

If the aim of a third-order cybernetics is to extend its reach to a fully relational account, from the essentially ecological nature of so-called physical reality through to an associated relational hermeneutics of meaning, then what appears to be at stake is nothing less than the ontological question, considered as abstractly or broadly as possible: what is the nature of reality? More parochially, and as implied by the intermixing, here, of the scientific/technological realm of ecology and cybernetics and the poetic realm of hermeneutics and meaning, architecture comes to be dis-covered or re-engaged into where it has in reality always sat, namely as a (taught, professional, creative) discipline that transcends the two cultures of science/technology and poetics/meaning.[1] Or rather, it undermines those gross strata of thought by means of an ongoing praxis both in the academy and the practice of architecture.[2] In this it is nothing special: we are at a turn in culture where *any* discipline that is moving forward is going the same way by positively conjoining these two paths where possible, and radically undermining the dichotomy where necessary.

John Bruni (a researcher on the relations between literature and science) summarises the past history of cybernetics by reference to the Macy conferences. These conferences, held annually from 1946 onwards until the 1960s, brought together all the main contributors to cybernetic theory. He states:

> concepts such as information and feedback allowed the Macy Conferences to act as a catalyst for second-order systems theory, when first order, steady-state models of homeostasis became supplanted by those of self-reference in observing systems … According to N. Katherine Hayles, the conferences' singular achievement was to create a 'new paradigm' for 'looking at human beings … as information-processing entities who are essentially similar to intelligent machines,' by routing Claude Shannon's information theory through Warren McCulloch's 'model of neural functioning' and John von Neumann's work in 'biological systems' and then capitalising on Norbert Wiener's 'visionary' talent for disseminating the 'larger implications' of such a paradigm shift.[3]

This quotation comes from Darrell Arnold's summary book on systems theory, where in most contributions (for instance in architect Ranulph Glanville's piece) general systems theory and cybernetics are aligned and the differences between them elided.[4] Such differences nonetheless remain, and are neatly framed by physicist Egon Becker and ecologist Broder Breckling in their aptly-titled 'Border Zone Between Ecology and Systems Theory' where they state that:

> Cybernetics is not merely a special case of General Systems Theory, nor has cybernetics ever developed fully within systems theory. The idea of circularity as a fundamental principle turned into the notion of 'circular causality' in the broad theoretical outline of cybernetics. Cybernetics thus acquired its own discursive order, shaped by questions concerning regulation and information transfer.[5]

I have a slight unease with the name cybernetics, coming as it does from the Greek term for 'governor', and a similar unease (in this context) with the notions of regulation and human beings as information-processors. I will therefore refer mainly to 'general systems theory', also because this essay will engage with the inventor of this term, Ludwig von Bertalanffy.[6] Whatever the name, what is essential is the bringing together of deep relational accounts of reality, the undermining of linear causality, the primacy of 'information' (the exact status of which is to be clarified in this essay), and the notion of general system, which, viewed in the most abstract terms possible, implies essentially mobile arrangements (*agencements*), assemblages and ecologies.

As the use of such terms as *agencement* and assemblage imply, I will outline an ecologically informed ontology extending to the field of philosophy. I will argue that the work of Gilles Deleuze and Félix Guattari is a coherent account of a philosophy of systems, or specifically a systemic ontology – what they call in *A Thousand Plateaus* a *mechanosphere*.[7] This term signifies nothing less than the cosmos – the whole of reality – thought as a mobile and creative system or 'machine', with the proviso that these terms must be thought outside any mechanistic causality. The link between this work and cybernetics is clear from the very title, which comes from Gregory Bateson who, together with his wife Margaret Mead – both anthropologists – were regular and active participants in the Macy conferences.[8] His repurposing of the term 'plateau' to refer to the moment of an ongoing personal, emotional and sexual intensity in Balinese culture where the mother masturbates her son was repurposed again in Deleuze and Guattari's title, where the to-and-fro of this intensity already hints at their relational ontology.[9] In addition, their link with the theory of complex systems is well known and has been promoted most thoroughly by Manuel DeLanda.[10] If my emphasis is slightly different, this is to highlight Deleuze and Guattari's indebtedness to earlier general systems theory in a manner constructive for the current debate, while wishing to explicitly avoid DeLanda's de-politicised Deleuzian strain of architectural theory, in relation to which, see Eliot Albert's comment on DeLanda's 'de-Marxification' of Deleuze.[11] This de-politicisation is shared with Sanford Kwinter and others, and could be summarised under the banner of a rich architectural formalism of somewhat scientistic bent.[12] To anticipate the argument in relation to architecture: if there is to be an antidote to this hylomorphic schematism in architecture – its continued concern primarily with the form or materiality of those objects we call buildings, a matter not unconnected with its role as a supporter of an unquestioned global capitalism – then this will come via the aforementioned joining of the paths of the humanities and science, rather than by simply translating the methods of common-or-garden science into philosophy or more specifically ontology and architecture – something I believe was very far from the minds of Deleuze and Guattari.

But, on the other hand, I intend to start from the most extreme of scientific and technical thought, namely Claude Shannon's information theory. Poetising science is no more effective than scientistically transforming architecture and philosophy if we wish to understand the common ontology of both. Both need to be examined in their cybernetic and systematic extremes to show how they meet on the current horizon of thought.

Information theory and general systems

> riverrun, past Eve and Adam's, from swerve of shore to bend of bay, brings us by a commodious vicus of recirculation back to Howth Castle and Environs.
>
> Sir Tristram, violer d'amores, fr'over the short sea, had passen-core rearrived from North Amorica on this side the scraggy isthmus of Europe Minor to wielderfight his penisolate war: nor had topsawyer's rocks by the stream Oconee exaggerated themselse to Laurens Country's gorgios while they went doublin their mumper…[13]

So begins James Joyce's *Finnegans Wake*, cited by Shannon as an example of highly redundant English; that is, English where it is difficult to anticipate what the next letter or word will be. In contrast, take an extract from the same author's letter to his lover Nora Barnacle: 'It was you who slid your hand down inside my trousers and pulled my shirt softly aside and touched my prick'.[14] This is written in standard English, which as Shannon points out has lower redundancy: 'the redundancy of ordinary English, not considering statistical structure over greater distances than about eight letters, is roughly 50 per cent.'[15] You can assess this, he explains, by (among other methods) asking someone to fill in unknown letters having removed a random set of 50 per cent of them.[16] In other words, in standard English we only need half the letters to reconstruct the text and get the meaning, whereas in *Finnegans Wake* any removal of letters would prevent us from accurately reconstructing the text. (I make no comment here about the question of reconstructing its meaning.)

Shannon's text is technical. He was essentially the inventor of pulse-code modulation (PCM) and was a researcher at Bell Laboratories. PCM is the method used to code continuous signals such as music, speech, or a visual image into discrete variables by sampling the amplitude of the waves at a given rate and as such forms the basis of all modern communication within the cyber realm (telephone lines, broadband, CD-ROMs, streaming and so on). His article *A Mathematical Theory of Communication* was an attempt – successful – to create a 'modern theory of communication'; its seminal position lies not only in being at the technical original of today's digital communication systems but also in the conceptual work he does on the notion of 'information' and its link to entropy and thermodynamics, specifically the second law thereof whereby entropy in a closed system is held never to reduce.[17] The task of communicating something efficiently over a telephone line – that is, producing information at a receiver – is considered abstractly and in the light of cryptographic theory as a stochastic (that is, random) process of choosing from a set according to the probability of each member of that set, the set in the case of English having an ergodic structure (that is, statistically homogeneous – one area of the text is statistically similar to another) in the form of a Markoff process whereby the chances of one letter depend on the preceding letter (or letters, in the more sophisticated version). Of course, in reality, we don't generally send random information down a telephone line, since that does not help us to communicate; but, perhaps counter-intuitively, an increase in the statistical randomness of a successfully-received message indicates an increase in the measure of information received.

We can see this in the case of Joyce. The quotation from *Finnigans Wake* has low redundancy, which means a statistical analysis shows a high randomness, which in turn means that when it is communicated a lot of 'information' is passed on. The letter to Nora, by contrast, has the high redundancy of 50 per cent associated with standard English, which means that it is statistically relatively easy to predict what the next letter or word is going to be. This means that when it is communicated down an information channel, not so much information is passed on.

Information is here being used in a strict technical and statistical sense, not in the way we usually think of information or meaning (unless we are scientists or technicians speaking within our field). We might argue, for instance, that the letter to Nora has more information or meaning in it than *Finnegans Wake*, which we find hard to understand. Or we might argue the opposite – particularly if we were a literary critic – namely that the latter is fuller of poetic meaning than the former. We would certainly question whether *Finnegans Wake* is at all random, in the sense that we understand Joyce having spent decades on the novel, taking the greatest informed care for each word. That discussion is an interesting and potentially aporetic one amenable, for instance, to a deconstructive reading; but is not one that is relevant to Shannon's purposes. As Hayles points out, Shannon was careful to distinguish his technical terminology and thought from the usual 'subjective' (as he put it) questions of meaning.[18] As he says, 'these semantic aspects of communication are irrelevant to the engineering problem.'[19] That his definition might subsequently be misused – indeed within cybernetics, to a certain extent – to redefine human communication in general in an inappropriately simplistic manner is merely a specific instance of the more general problem of an impatient misapplication of science and technology to broader questions of human life and the cosmos. Architecture has not been immune to this, and the counter-reaction has fathered a significant strand of hermeneutic architectural theory, for instance that of Dalibor Vesely and Alberto Pérez-Gómez, both of whose work is rooted in Edmund Husserl's diagnosis of a crisis of signs in European science and Hans-Georg Gadamer's contrast between the truth of the human sciences and the method of natural science and technology.[20] But insofar as this strand of architectural theory is precisely that – a counter-reaction to an all-too-impatient application of technology to the problems of human science in general – one might ask if it falls into the opposite trap to the rival hylomorphic formalist architectural theory mentioned above; namely, it rejects the possibility of a consilience between scientific method and humanist truth. Instead, this essay takes further the questions that science (in its systematic and informational guises) raises, to a point where they meet those of a philosophy of radical relation, symbiosis and ecology and thus render these traps irrelevant to a theory of architecture informed by such philosophy.

To return to Shannon: *Finnegans Wake* has lower redundancy than standard English and a higher statistical randomness. This means that relatively more information is sent down the channel to the receiver. Shannon proves that if we want to provide a mathematical measure of this information, called 'H' (Greek *eta*), then H has to be a continuous variable; it has to be such that with increasing information of the same probability, there is more uncertainty (a longer message is more uncertain and conveys more information than a shorter one); and if we split the measure H into two measures of H for successive parts of the original message, the former is the weighted sum of the latter.[21] The function that Shannon derives to calculate this measure H (equal to the negative of the sum of the various probabilities, each multiplied by its logarithm) is remarkably shown to be the same function as that of entropy within thermodynamics, specifically Boltzmann's H theorem.[22] Shannon therefore gives the name 'entropy' to the measure of information, a figure that can be made to lie somewhere between 0 (zero information) and 1 (maximum information). This means that the value of entropy is one *minus* the redundancy: since *Finnegans Wake* has a low redundancy (high randomness), this means that the entropy is high and that a lot of information (close to the value 1) is sent down the information channel. Whereas Joyce's letter to Nora has a redundancy of around 50 per cent, meaning that the entropy (measure of information sent) now drops to approximately 0.5.[23]

Why would Shannon have an intuition that the measure of information would be similar to that of entropy in a thermodynamic system? The reason is that he was thinking in terms of the formalism of these systems (information system or thermodynamic system). I am taking the term formalism here in the same way as in, for instance, quantum physics where the word refers to the mathematics of the theory – how things are 'slowed down' to be expressed by mathematical functions.[24] Thermodynamics thinks of closed systems as a set of microstates (for instance, the movement of each molecule of gas within a closed container), the value of each of which has equal probability. These go to make up a given macrostate, the latter providing (by means of measurements of temperature, pressure and so on) a course-grained description of the gas in the box. The informational equivalent of the microstates are the values that the pieces of information (for example, letters of the English language) can take, and the total useful information measure (macrostate) is obtained in the same way that entropy was obtained, entropy being a (negative) measure of the useful energy in the thermodynamic system. On the other hand, within the thermodynamic system itself, entropy is related to information because the higher the entropy, the more information is needed to specify exactly what state it is in, since high entropy means high randomness and lack of 'order'. Order is here put into scare quotes because this is the scientific definition of order – a definition which does not necessarily coincide with our intuitive ideas of order for reasons that will become clearer below.

This relationship – what Bertalanffy would call an isomorphism – between entropy and information, established in 1949, subsequently became important in the history of both cybernetics and general systems theory. Interestingly they each take a different tack in relation to it.[25] Cybernetics, in the Macy conferences, indeed follows on directly from Shannon (although the seeds were already there in Wiener's work) to consider entropy primarily in an informational sense, since it is the flow of information from one part of a system back to another 'earlier' part which drives the central cybernetic concept of feedback, be it positive feedback – self-reinforcing or a virtuous or vicious circle – or negative feedback, that is, the tendency of a system or subsystem to achieve homeostasis. As Hayles notes, information flow becomes a key issue for cybernetics, and with its second-order reflexive manifestation even more so, leading to an emphasis on formalising humans as 'information-processing entities who are *essentially* similar to intelligent machines'.[26] This in turn generates the broad currents of thought around neural networks and informatics which, having determined the human brain as machinic sometimes go on to claim that a machine in the form of artificial intelligence can mimic and then go beyond what the human brain can achieve. This circular argument is another example of science being too hastily and too abstractly applied; the general systems theorist would ask, instead: has science even begun to model adequately a single neuron? (Answer: no, it is too complex.) And if not, what justifies the reduction of human brain function to that which we can, happenstance, begin to model, namely a network of neurons abstractly considered? This is not to depreciate what artificial intelligence and machine learning can achieve; merely to point to its limitations vis-à-vis the human brain and other living systems.

General systems theory, on the other hand, tended towards the thermodynamic aspects of entropy, and information comes in more indirectly (in the manner outlined later in this essay). This is partly because its background was in biology, whereas cybernetics started from machine control and feedback. If we take Bertalanffy – a biologist – as emblematic of early systems theory, information is not highly emphasised, but the flow of material and energy is, and to that extent he regards living systems as such flows within which feedback is one, but not necessarily the primary, phenomenon. This makes intuitive sense: a biologist, studying problems of how to characterise the organism in the light of early twentieth century debates around finalism and vitalism, and working experimentally with organisms of various scales, would perforce need to take into account issues of respiration, energy flow, input and output of material (food, defecation) in order to think systemically. Bertalanffy's 1940 article *The Organism Considered as a Physical System* already makes these points, and characterises the organism as an open system with a through-put of energy and material such that, in contrast to the second law of thermodynamics, the entropy is decreased and the organism is, or rather becomes, more and more finely ordered.[27] Organisms are essentially negentropy machines: machines for holding off entropy, increasing order by taking energy and matter from their environment. Ilya Prigogine will later clarify this activity as that of a dissipative structure, whereby the negentropy within the structure (the organism) is balanced by an increase of entropy which it discharges (by means of waste, and so on) into the environment.[28] The fact that living systems are open systems is a truism today, but Bertalanffy was revolutionary, since science up to that point had almost exclusively theorised closed systems within a mechanistic framework. He was therefore calling for a different approach to the nature of the reality considered by science, a matter that extended beyond biology into broader ontological and epistemological issues. As he points out, it was still possible in 1948 for analytical philosophy, in the person of Bertrand Russell, to dismiss the importance of systematic thinking, that is, thinking that considered the place of parts within a whole. Russell considered, on the contrary, that all thought should proceed by the method of analysis – that is, the taking apart of things and the consideration of their parts; and that all knowledge, scientific or not, was to be obtained and could be obtained by this essentially Aristotelean method.[29]

Hyper-relational general systems theory

General systems theory, established by Bertalanffy in the 1940s, reaches its apogee in the 1970s, a high-point well expressed by the publication of the monumental volume *Living Systems* by James Grier Miller.[30] This is essential reading for any historian of systems theory; rigorous in both content and form, inspired partly by his initial training in philosophy with Alfred North Whitehead (whose *Process and Reality* would, on a longer account, be tied into our story), it sets out to describe the whole organosphere, from the basic unit of the cell through six further vertical levels of organ, organism, group, organisation, community, society and supranational system.[31] The introduction to *Living Systems* gives perhaps the best available summary of general systems theory, within which it characterises cybernetics as a (fairly small) component.[32] The book represents a vertical deepening and generalising of systems theory, and takes cybernetics as a part of that broader theory largely because it now considers the whole gamut of systems within life and cements ecological thinking as a key component of our modern age. On the horizontal axis, similarly, Bertalanffy in the 1950s and 1960s was already widening the scope of systems thinking to become what he saw as a truly general theory, covering many aspects of reality including culture and the human sciences. In that sense he saw Russell's analytical thinking as a subset of general systems theory: analysis can occur within systems thinking, but systems thinking cannot be circumscribed by mere analysis.

In a series of essays collected in *General System Theory*, Bertalanffy outlines and justifies this broadening of scope. He shows the limitations of 'the analytic, mechanistic, one-way-causal paradigm of classic science' by proposing a new paradigm – a 'theory of "systems" in the various sciences (e.g. physics, biology, psychology, social sciences)'.[33] As well as making vertical links to dynamic ecology and the ethology of Jacob von Uexküll (particularly relevant to the connection I will make with Deleuze and Guattari below), establishing or clarifying critical notions such as equifinality, isomorphism and emergence, arguing against analogies and metaphors ('analogies are scientifically worthless') in science and promoting systemic explanations and models, he makes the vital step of considering the epistemological issues involved.[34] It is worthwhile quoting his comments on this issue at some length:

> The epistemology (and metaphysics) of logical positivism or empiricism was determined by the ideas of physicalism, atomism, and the 'camera-theory' of knowledge [i.e. a naïve realist view of knowledge]. These, in view of present-day knowledge, are obsolete … simple 'reduction' to the elementary particles and conventional laws of physics does not appear feasible. Compared to the analytical procedure of classical science with resolution into component elements and one-way or linear causality as basic category [sic.], the investigation of organized wholes of many variables

> requires new categories of interaction, transaction, organization, teleology etc. … Furthermore, perception is not a reflection of 'real things' (whatever their metaphysical status) and knowledge is not a simple approximation to 'truth' or 'reality'. It is an interaction between knower and known… Physics itself tells us that there are no ultimate entities like corpuscles or waves, existing independent of the observer.[35]

It seems to me that this extract, from the 1971 British edition foreword, is remarkable in drawing out some lessons from general systems theory that have yet to make their way through science, let alone other fields of knowledge. An example: when considering how a respiratory virus operates, science still rarely takes a dynamic systems approach. One hears analogies such as that the lungs are like a sponge; but already in a 1969 paper Bertalanffy was pointing out that the pulmonary alveolar cells in the lung have an average renewal time of only six days; in this context the fact that viruses destroy lung cells becomes, evidently, a dynamic systems issue requiring complex explanation, not static analogies; in turn, clearly the action of a virus has to be seen as taking on and working as a significant part of much broader systems than the lungs, such as (upwards) cultural, transport, social and political systems and (sideways) the immune system, temperature control system and hormone systems of the body. The question is systemic and ecological from top to bottom and all the way across, in a manner which Bertalanffy would already recognise in the 1960s. Despite this, however, and aside from a few researchers such as David Pouvreau, his work is now largely ignored, and his influence unrecognised.[36]

I believe we can summarise Bertalanffy's thought as essentially hyper-relational. On the one hand we can see this hyper-relationality in those philosophers who, likewise – and likewise influenced by Whitehead's process philosophy – take relations as the foundation of ontology and an associated and intermixed epistemology.[37] On the other hand, the fate of general systems theory is to have become, in scientific terms and despite the provisos I raise above, almost de rigueur; one only has to think, for instance, of genetics and epigenetics, where research focuses on understanding and intervening in the extraordinarily complex interactive machines operating at lightning speed – that is, systems – making up our cells' reproductive apparatus.[38] Incidentally, here is an instance where the use of the shortcut metaphorical language of 'reading', 'copying', 'alphabet' and so on of DNA can sometimes obscure clarity, as Bertalanffy would note. DNA is not read, there is no copying, there is no alphabet; what there are are little machines, doing what machines do… More pertinently for our purposes, in the field of quantum physics all serious thinking is now systematic and highly relational; this systemic thinking derives partly from the earlier more limited notions of closed thermodynamic and other systems, but is informed as we will see by a similar hyper-relational thought to that of Bertalanffy.

Hyper-relational philosophy

To address the first of these points, as previously intimated it is in the work of Deleuze and Guattari that we see most evidence of this hyper-relational thought in philosophy.[39] In *A Thousand Plateaus* and elsewhere, they frame the real as having the character of an 'assemblage' or a 'machine'.[40] These, in essence, are systems – but a particular type of system consonant with Bertalanffy, which moves on from the static qualities of structuralism (which Deleuze aligned himself with somewhat in the 1960s) and, perhaps under the influence of Guattari, takes on a mobile and dynamic aspect.[41] In that regard, they appropriate Bergson's notion of becoming and raise it to a central place in their philosophy: nothing *is*, everything is *becoming* or *in becoming* at the same time as constantly being in relation to other things.[42] Deleuze had already established the primacy of difference in his earlier book *Difference and Repetition*; what he means by this is that identity is derived from – an epiphenomenon of – difference, and not the other way around, as philosophy and thought had almost always framed it.[43] To place difference first, at the basis of things, is to privilege relations and the interplay of being – precisely a hyper-relationality. This is a Nietzschean theme, since Deleuze sees in Nietzsche the one who frames the world as the interplay of forces, and when he says 'the eternal return of the same' he means, for Deleuze, not the return of the same thing, but that 'the same' (and being) is said of that which eternally returns.[44] Being is said of – derived from – becoming, not vice versa.[45] In this, Deleuze interplays with the early work of Jacques Derrida and in particular his new concept (as Deleuze says) of *différance*.[46] *Différance* means the differential origin of difference – a concept which Deleuze picks up on in *Difference and Repetition.*[47] Deleuze quotes Derrida at some length, from *Writing and Difference*, including the following: 'To say that *différance* is originary is simultaneously to erase the myth of a present origin.'[48] The erasure of a present origin is precisely the erasure of being in favour of *différance* or becoming; again, a hyper-relationality, posited as the basis for a new, Nietzsche-inspired philosophy.

Perhaps the clearest exposition of the extreme relational quality of this philosophy is contained in Deleuze's notion of the fold. Contrary to certain simplistic architectural interpretations of this concept, what Deleuze asks us to think in relation to the Baroque and Leibniz in his book *The Fold* is Leibniz's notion that reality consists of folds to infinity. 'The Baroque fold unfurls all the way to infinity' and 'a fold is always folded within a fold, like a cavern in a cavern.'[49] This statement is to be taken literally, which means that it is the fold which comes first (*différance* at the origin); folding produces the material which is folded, as an after-effect, as an epiphenomenon of the fold. As Deleuze says elsewhere: relations are external to their terms.[50] It is relations (that is, the fold) that come first; they retrospectively 'make' the terms between which the relations occur, a theme taken up from Gilbert Simondon's idea of transduction which, as Bernard Stiegler glosses it (virtually quoting Deleuze), is 'a relation which constitutes its terms'.[51]

There is therefore a strong conceptual likeness between the generality and priority of relations in Bertalanffy's general systems theory and the prioritising of transductive relations and difference in the post-Nietzschean philosophy of Derrida, Deleuze and Guattari.[52] In the case of Deleuze and Guattari, there are some more specific common interests. One of these I have already mentioned: Bertalanffy's use of the ethological theory of Jakob von Uexküll, specifically reference to the latter's book *A Foray into the Worlds of Animals and Humans*.[53] Bertalanffy's 1955 summary of this theory, particularly the invocation of Uexküll's famous ethology/ecology of the tick, could be taken directly from Deleuze and Guattari's later reference in *A Thousand Plateaus*:

> Take, for instance, a tick lurking in the bushes for a passing mammal in whose skin it settles and drinks itself full of blood. The signal is the odor of butyric acid, flowing from the dermal glands of all mammals. Following this stimulus, it plunges down; if it fell on a warm body – as monitored by its sensitive thermal sense – it has reached its prey, a warm-blooded animal, and only needs to find, aided by tactile sense, a hair-free place to pierce in.[54]

A further conceptual link is the aversion to metaphor and analogies on the part of Bertalanffy in relation to scientific explanations: as noted above, he regards them as useless. In fact, this follows, logically, from his hyper-relationality: metaphor assumes that there is indeed an original 'natural' meaning of words which metaphor can then translate into other contexts.[55] The relational take is to disavow this belief and wager instead for the interplay from the outset of supposed original and supposed derived meanings. This aversion he shares with Deleuze, who from beginning to end of his philosophy avoids the metaphorical use of words, for the same reason.[56]

Hyper-relational science

I turn now to the second point, that of the current position of science at its relational extreme – namely, how quantum physics is being conceptualised by those scientists most attuned to the transductive question of hyper-relationality.[57] We return here also to the key topic of information, in its relational aspect, because it is fair to say that the concept of information is now the driver of cutting-edge quantum mechanics, both in its theoretical manifestations and the practical realm of quantum computing.

Again, here, we have to be careful about the use of the word ‘information’. In quantum physics it is used in a specific sense, deriving indeed from Shannon’s 1949 seminal paper. Seminal, it turns out, not only in establishing the practical basis of our modern cyber technologies, but also in establishing a theoretical framework that extends well beyond those practical issues. The most succinct exposition of quantum information is available in Carlo Rovelli’s essay, available online, on relative information, which is brief and accessible enough for me to recommend that the reader glance quickly through it before proceeding. Rovelli is one of the most eminent quantum physicists working in the field, and his expositions have the benefit of both attempting to drill down to the broadest implications of quantum theory, and expressing these in intuitive language. He outlines the concept of relative information as a scientific notion distinct from meaning. This concept is ‘just physical’, he says. He states:

> In nature, variables are not independent; for instance, in any magnet, the two ends have opposite polarities. Knowing one amounts to knowing the other. So we can say that each end ‘has information’ about the other. There is nothing mental in this; it is just a way of saying that there is a necessary relation between the polarities of the two ends. We say that there is ‘relative information’ between two systems anytime the state of one is constrained by the state of the other. In this precise sense, physical systems may be said to have information about one another, with no need for a mind to play any role.[58]

The exposition here is beautiful, as quantum physics can be, but we need to look at two more technical articles from the same author to unwind the concepts, make the connection with entropy, and reveal the full hyper-relationality of this thinking. Rovelli’s 2013 article on the topic starts by questioning the notion of entropy.[59] As previously noted, the second law of thermodynamics states that, in a closed system, entropy always increases. This makes it sound as though entropy is some absolute quality, and indeed many interpret this law to say that the universe will, eventually, die a heat death as entropy increases to the limit. This, however, is to assume something that we cannot know, namely that the universe is indeed a closed system (incidentally this notion of thermodynamic heat death is something Nietzsche had already critiqued in the late nineteenth century, as Deleuze notes).[60] What Rovelli points out is that entropy is always relative to the relevant functions of the system being investigated, that the laws of thermodynamics deal with the relative coupling of two systems, and that entropy is indeed information, as per Shannon, since it is defined as ‘the number of microstates compatible with a given macrostate’ – a definition that accords with our discussions above. Here is the hyper-relationality: ‘the information relevant in physics is always the *relative* information between *two* systems.’ He gives this fact a poetic bent: ‘it is not the microstate of the Sun which is hot, it is the manner in which the Sun affects the Earth which is *objectively* hot.’[61] We could say here that what Rovelli is doing is reframing objectivity – or, the notion of the absolute – in terms of relationality. The absolute, or that which is objective, is an epiphenomenon of the relative.

Thus entropy and information are always relative. If we break a cup by dropping it onto the floor, there is usually thought to be an increase in entropy – that is, an increase in disorder – but this depends, Rovelli says, on the position of the observer: it is possible to conceive of a situation where the cup breaking on the floor, if the pieces land on an image of those pieces visible to a certain observer, increases order rather than decreases it.[62]

Rovelli has bigger fish to fry. In his 2008 article *Relational Quantum Mechanics*, this concept of relative information allows the derivation of quantum physics from the same hyper-relative ground. What Rovelli proves is that in quantum terms, 'different observers give different accounts of the same sequence of events.'[63] What this means, in general systems terms, is that quantum physics deals with the broadest of all systems, where the system includes the 'observer'.[64] There is no escaping the system, and the results of any quantum experiment depend on the way that an experiment is set up – as the famous example of the double slit experiment invariably shows.[65] For quantum physics, there is no pre-existing real condition that the foundational experiments reveal; rather, these experiments *create* that condition that we subsequently take for real.[66]

Rovelli is one of a group of quantum physicists who are willing to accept this transductive hyper-relationality; others include Christopher Fuchs, Wojciech Hubert Zurek and N. David Mermin's so-called Ithaca interpretation of quantum mechanics.[67] What their views imply is a rejection of a naïve realist ontology of the world – that is, the 'camera' notion of our relationship to the world that somehow our perceptions are of some pre-existing absolute reality. Rather, we are systemically intertwined within reality, such that the intertwining and interrelations create that reality.[68] There are many quantum scientists who still take the naïve realist view, and the supposed 'weirdness' of quantum physics derives entirely from our habit of – consciously or unconsciously – remaining wedded to it. This can be seen in many of the competing interpretations of quantum physics, such as the many-worlds theory, or the hidden variables theory; these are basically ways of 'saving the object', of not allowing relationality to run all the way down. Whole books have been written bewailing the unacceptable state of quantum physics as violating basic common sense.[69] What Rovelli does is to re-write this common sense.

Nonetheless, in his account there remains the residual metaphor of the term 'information'. However deep our understanding of Shannon, and however much we accept the necessary abstraction made in the scientific definition of this word, it does not denote precisely enough what Rovelli is referring to. When he says, for instance, that

> the light that arrives at our eyes carries information about the objects which it has played across; the color of the sea has information on the color of the sky above it; a cell has information about the virus attacking it

this remains open to the critique of Bertalanffy and Deleuze that 'information' here is an analogy or metaphor, and is being used in two very different instances.[70] There is too much humanity in this term – humanity which needs to be expunged entirely in order to secure the thought that this is not to do with a limitation of our supposed subjectivity, but is to do with the very structure of the world. This, in turn, prevents Rovelli from taking the final step and allowing relation to take precedence; in the end, he wagers for the existence of those elementary objects which Bertalanffy had already warned us against in 1971; he remains wedded to Democritus's notion of the atom (about whom he has written a book) instead of Heraclitus's notion of flow – the latter a notion shared, of course, with Deleuze and Guattari. Rovelli says that information is 'the infinite game of mirrors reflecting one another formed [sic] the correlations among the structures made by *the elementary objects*.'[71] In other words, the 'elementary objects' remain part of his theory, which is why 'information' remains the word that he chooses to use. And this despite quoting Zurek on the relative non-existence of 'properties themselves':

'correlations between the properties of quantum systems are more basic than the properties themselves'.[72] Zurek is explicit about what this means: 'This order of importance, in which a correlation – a record of a property – comes before the property, reverses the ordinary hierarchy to which one is accustomed within the realm of everyday experience', in other words, is counter to the naïve realist viewpoint which places entities (being) before relations (becoming).[73]

Why take this final step? Why dispose, in the end (or at the beginning) of any notion of the common-sense object, of the entity, of the 'elementary object' or the Democritian atom? This seems to me to be simply a question of utilising Occam's razor: do not multiply explanations! Rovelli, and others, have shown that we cannot do without a notion of relation; Deleuze and Bertalanffy give us the hyper-relationality of a general systems theory and a philosophy of the assemblage (mobile, dynamic system). Quantum physics itself – the most accurate of scientific theories – shows us that it is the relations between things that give rise to the phenomena that are then called, for convenience's sake, 'particles'. The particle-quality of these supposed elementary particles does not exist; they occur as epiphenomena of the relations which occur in relational systems. The term that should therefore be used to replace 'information' describes more precisely what is being said: it is simply the word 'relation' itself. When Rovelli describes the interplay between the light of the sky and colour of the sea he is not talking about information so much as about the relations between these things.

This is the final and most pertinent conceptual link I wish to make in this article, in order to draw the conclusion that we are now at a stage where we can not only envisage but also deploy a common relational conceptuality across philosophy and science, and with that, across the whole of human endeavour both practical and theoretical.

Conclusion

Taking this hyper-relational step explains, for instance, why mathematics is so successful in explaining the world scientifically. Such success is puzzling if the world is made of entities. By what right would an entity enter into relations such that they accord with mathematics? But the problem disappears if the world is essentially transductive, made of pure relations. For what is mathematics other than the science and art of pure relations? If entities are an epiphenomenon of relations, which are more 'basic' than them, then the 'correlation' between maths and nature becomes self-evident.

Similarly, what is the relation between the mind and the brain, that is, between consciousness and the physical reality of our embodied brain? There remain endless debates around this so-called hard question of consciousness.[74] But the problem, again, disappears if we regard the physical brain as a transductive epiphenomenon of relations, since what the mind is, is nothing other than the ability (conscious and unconscious) to spin, endlessly, relations among themselves.[75] Spinoza says: the mind and the body are the same thing.[76] Perhaps we are getting to the point where we can understand the profundity of this statement.

What, then, is the relevance of this journey for architecture, as a taught, professional and creative discipline? I have shown that the relations inherent in systems and ecological thinking go all the way down, and all the way across. There is no scope for a naïve realist interpretation of reality in general: that ontology is defunct. But physicists and stubborn realist philosophers are not the only ones to revert to it. Architects, and the discipline of architecture, remains wedded to such a realist interpretation of things, perhaps because we spend too much time with large objects that we call buildings. But the buildings are mere epiphenomena of broader political, interpersonal, ecological and essentially relational matters, assemblages, systems and interplays.

This might mean something quite simple in practice: a slight shift. As one cybernetic architect

– Cedric Price – said to a potential client: 'you do not need a house, you need a divorce'.[77] What Price meant was this: your relations, the symbiotic ecosystem within which you relate to your wife, is in a certain state. Do not expect a mere object to rectify it! I, as an architect and cyberneticist, will not play the game of reducing the issues to objective ones. Let's work with, intervene in, and (over-) turn the system, the set of relations, even at the expense of not building anything.

Notes

1. See C.P. Snow, 'The Two Cultures', *Leonardo* 23, no. 2/3, *New Foundations: Classroom Lessons in Art/Science/Technology for the 1990s* (1990): 169–73. Reprinted from 'The Rede Lecture, 1959' in C. P. Snow, *The Two Cultures: And a Second Look*, (Cambridge: Cambridge University Press, 1959, 1964), 1–21. That the key difference between the two cultures was, in 1950s UK, seen to be a non-familiarity on the one hand with the second law of thermodynamics and on the other the poetic work of Shakespeare is pertinent to the topic at hand.
2. Taking the term 'strata' from Deleuze and Guattari. See Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, trans, Brian Massumi (Minneapolis: University of Minnesota Press, 1987), 39–74, in the chapter/plateau '10 000 BC: The Geology of Morals (Who Does the Earth Think It Is?)'.
3. John Bruni, 'Expanding the Self-Referential Paradox: The Macy Conferences and the Second Wave of Cybernetic Thinking', 78–83 in *Traditions of Systems Theory: Major Figures and Contemporary Developments*, ed. Darrell P. Arnold (New York/Abingdon: Routledge, 2014). Bruni is quoting from page 7 of a useful book by Katherine Hayles which emphasises cybernetics as 'a theory of communication *and control* [my emphasis] applying equally to animals, humans, and machines': N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999), 7. As I indicate below, I have doubts about this 'control' or 'governorship' aspect of cybernetics; not that control as such is a bad thing seen in a broader scope – more that if taken as the essence, or the beginning not only historically but also ideally, of cybernetics/systems theory, then the more creative aspects of systems thought which Deleuze and Guattari emphasise ('the production of the new') potentially gets covered over in the name of some form of determinism.
4. Where he states:

   > The Macy thematic statement uses the word 'system'. Around the time that cybernetics was reborn (1946), the first article specifically on general systems theory was published by the biologist Ludwig von Bertalanffy. He claimed to have developed this theory in lectures starting in 1937. Simplistically stated, Bertalanffy's general systems theory was the base that spawned the assorted variety of systems sciences that we have now. Cyberneticians and systemists have always understood that there was a connection between their two fields. Some see the terms as synonyms … People such as Gordon Pask insisted they didn't care what name was used.

   Ranulph Glanville, 'Cybernetics: Thinking Through the Technology', 45–77 in *Traditions of Systems Theory*, 46. Disclosure: Glanville taught the present author.
5. Becker and Broder Breckling, 'Border Zone Between Ecology and Systems Theory', 385–403 in *Ecology Revisited,* ed. Astrid Schwarz and Kurt Jax (Dordrecht: Springer, 2011), 388.
6. Left out of the account here for reasons of space is the tektology of Aleksandr Bogdanov dating from the second decade of the twentieth century, which, as environmental philosopher Arran Gare has argued (in 'Aleksandr Bogdanov and Systems Theory', *Democracy and Nature* 6, no. 3 (2000): 341) predates and probably influenced Bertallanfy's general systems theory. Tektology is the 'new science of organisation' invented by Bogdanov, a process-philosophy entirely consonant with the hyper-relationality I argue for in this essay. See, among other writings by Bogdanov,

The Universal Science of Organization (Tektologia) from 1913, reprinted as *Bogdanov's Tektology*, trans. not acknowledged (Hull: Centre for Systems Studies, 1996) and *Essays in Tektology*, trans. George Gorelik (Seaside, CA: Intersystems Publications, 1980). Arran Gare's work on philosophical ecology could also be woven constructively into this story and, of course, related to architecture. See Arran Gare, *Philosophical Foundations of Ecological Civilization: A Manifesto for the Future* (London: Routledge, 2016); 'From "Sustainable Development" To "Ecological Civilization": Winning The War For Survival', *Cosmos and History: The Journal of Natural and Social Philosophy* 13, no. 3 (2017): 130–53; and, again pertinently for architecture, 'Architecture and the Global Ecological Crisis: From Heidegger to Christopher Alexander', *The Structurist: Toward an Ecological Ethos in Art and Architecture* no. 43/44 (2003/2004): 30–37. I am grateful to Dulmini Perera for the reference to Bogdanov.

7. This is the last word of *A Thousand Plateaus*. Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, trans. Brian Massumi (Minneapolis: University of Minnesota Press, 1987), 514.
8. For an account, see Samuel Gerald Collins, 'Do Cyborgs Dream of Electronic Rats? The Macy Conferences and the Emergence of Hybrid Multi-Agent Systems', AAAI Fall 2007 Symposium, https://www.aaai.org/Papers/Symposia/Fall/2007/FS-07-04/FS07-04-005.pdf. Collins points to Bateson and Mead's central role in establishing second-order cybernetics – that is, the inclusion of the observer within the paradigm: 'One of the enduring legacies of the Macy Conferences was the question of the observer, the role of self-reflexivity in the cybernetic circuit.' Ibid., 26.
9. Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* (London and Northvale NJ: Jason Aronson Inc., 1987 (1972)), 121. The reference is explained in *A Thousand Plateaus* on pages 21 and 22 and note 20 on page 520 (where the page number is wrongly given as 113). It is worthwhile quoting from Bateson here: 'Typically, the mother will start a small flirtation with the child, pulling its penis or otherwise stimulating it to interpersonal activity. This will excite the child, and for a few moments cumulative interaction will occur. Then just as the child, approaching some small climax, flings its arms around the mother's neck, her attention wanders.'
10. See Manuel DeLanda, *Intensive Science and Virtual Philosophy* (London and New York: Bloomsbury Academic, 2013 (2002)); Manuel DeLanda, *A New Philosophy of Society: Assemblage Theory and Social Complexity* (London and New York: Continuum, 2006); and more specifically in relation to architecture Manuel DeLanda, 'Deleuze and the Use of the Genetic Algorithm in Architecture', in *Architectural Design* 72, no. 1 (January 2002): 9–12 and Manuel De Landa, 'Deleuze, Diagrams and the Genesis of Form', in *Amerikastudien/American Studies* 45, no. 1, *Chaos/Control: Complexity* (2000): 33–41.
11. Eliot Albert, 'A Thousand Marxes', in *Mute* 1, no. 11 (Autumn 1998). Available at www.metamute.org/editorial/articles/thousand-marxes. I have written in more detail about this elsewhere: see Tim Gough, 'Flows of Capitalism, Flows of Architecture', *Ardeth* no. 03 (Fall 2018 – *Money*): 97–114.
12. Whose seminal *Architectures of Time* cast Deleuze as a scientistic formalist whose interest in, for instance, the political and minoritarian side of Kafka was merely a result of the supposedly baleful (i.e. political) influence of Guattari. Sanford Kwinter, *Architectures of Time* (Cambridge, MA: MIT Press, 2001), 115. See also Kwinter's short but essential piece 'Who's Afraid of Formalism?' in among other places Foreign Office Architects' *Phylogenesis*. Sanford Kwinter, 'Who's Afraid of Formalism?' in Foreign Office Architects, *Phylogenesis: FOA's Ark* (Barcelona: Actar, 2003), 96–100. Reprinted from *Any Magazine* no. 7/8. That Kwinter remains tied to a hylomorphic way of characterising architecture needs some justification: in 'Who's Afraid of Formalism' he makes specific reference to Aristotle's formal causes – clearly within the hylomorphic tradition – and where he says in the same piece that 'the manifest form – that which appears

– is the result of a computational interaction between internal rules and external (morphogenetic) pressures that, themselves, originate in other adjacent forms', this , while no doubt a *rich* formalism informed by Gilbert Simondon, remains nonetheless a question of the *form* of something realised in a *material* (as in the work of Simondon himself).

13. James Joyce, *Finnegans Wake* (London/Boston: Faber and Faber, 1975 [1939]), 3.
14. James Joyce, letter to Nora Barnacle, 3 December 1909: 44 Fontenoy Street, Dublin. Quoted in Nadja Spiegelman, 'James Joyce's Love Letters to His "Dirty Little Fuckbird"', *The Paris Review* blog, 2 February 2018, https://www.theparisreview.org/blog/2018/02/02/james-joyces-love-letters-dirty-little-fuckbird/.
15. C.E. Shannon, 'A Mathematical Theory of Communication', in *The Bell System Technical Journal* 27 (July 1948): 379–423, (October 1948): 623–56; 393.
16. Ibid., 394.
17. Ibid., 379.
18. Hayles, *How We Became Posthuman*, 19.
19. Shannon, 'Mathematical Theory of Communication', 379.
20. Dalibor Vesely, *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production* (Cambridge, MA: MIT Press, 2004); Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science* (Cambridge, MA: MIT Press, 1983); Edmund Husserl, *The Crisis of European Sciences and Transcendental Phenomenology*, trans. David Carr (Evanston: Northwestern University Press, 1970); Hans-Georg Gadamer, *Truth and Method*, trans. William Glen-Doepel (London: Sheed and Ward Stagbooks, 1975 [1960]).
21. Shannon, 'Mathematical Theory of Communication', 389. The last condition (the weighted sum) is hard to explain in words; the reader should refer to Shannon's paper where a clear graphical explanation is given.
22. Ibid., 390.
23. Strictly the *relative* entropy. Ibid., 394.
24. In Deleuze and Guattari's *What is Philosophy?* the relation between art, philosophy and science is clarified as that whose object is the function; and in order to relate a function to reality there is in science a sort of 'slowing down' which actualises matter and allows mathematics to gain a hold. Gilles Deleuze and Félix Guattari, *What is Philosophy?*, trans. Graham Burchell and Hugh Thomlinson (London/New York: Verso, 1994), 118.
25. Ludwig von Bertalanffy, *General System Theory* (Harmondsworth: Penguin Books, 1973 [1968]), 20.
26. Hayles, *How We Became Posthuman*, 7. In relation to information flow, see page 51 and Chapter 3 of the same book.
27. Ludwig von Bertalanffy, 'The Organism Considered as a Physical System', 127–145 in *General System Theory*, 128. On the open system question, see more specifically Ludwig von Bertalanffy, 'The Model of Open System', 146–62 in *General System Theory*.
28. Ilya Prigogine, *Time, Structure and Fluctuations*, Nobel Lecture, 8 December 1977.
29. Bertalanffy, *General System Theory*, 67. The Russell reference is to Bertrand Russell, *Human Knowledge, its Scope and Limits* (London: Allen and Unwin, 1948). The Aristotle reference is to Book 1 of *Physics* where the task of knowledge is given as an analytical method proceeding from whole to part. Aristotle, *Physics*, trans. C.D.C Reeve (Indianapolis/Cambridge: Hackett, 2018), 2.
30. James Grier Miller, *Living Systems* (New York: McGraw-Hill, 1978).
31. Ibid., xxvii. In relation to Whitehead, see Alfred North Whitehead, *Process and Reality: An Essay in Cosmology*, ed. David Ray Griffin and Donald W. Sherburne (New York: Free Press 1978).
32. Ibid., 36: 'Cybernetics, the study of methods of feed-back control, is an important part of systems theory.'
33. Bertalanffy, *General System Theory*, xix and xvii. (Foreword to the British edition).
34. Ibid., 109, 240–45, 39, 33, 80–88, 54 and 85 .
35. Ibid., xx–xxi. (Foreword to the British edition). My emphasis.
36. See, among other publications, Pouvreau's PhD thesis, his essay in the Arnold volume, and, with Manfred Drack, their history of Ludwig von Bertalanffy, Parts

1-3. David Pouveau, 'The Hermeneutical System of General Systemology: Bertalanffian and Other Early Contributions to Its Foundations and Development', 84–136 in *Traditions of Systems Theory*; David Pouveau and Manfred Drack, 'On the History of Ludwig von Bertalanffy's "General Systemology", and on its Relationship to Cybernetics', *International Journal of General Systems* 36, no. 3 (June 2007): 281–337 Part 2 in vol. 43, no. 2 (2014): 172–245; Part 3 in vol. 44, no. 5 (2015): 523–71.

37. As Bertalanffy was: see Bertalanffy, *General System Theory*, 10 and 46.
38. For a good summary, see Nessa Carey, *The Epigenetics Revolution*: *How Modern Biology is Rewriting Our Understanding of Genetics, Disease and Inheritance* (London: Icon Books, 2011).
39. Of course, elsewhere too, for instance in all post-humanisms; in Bernard Stiegler's organology (similar in intent to Deleuze and Guattari's mechanosphere); in Gilbert Simondon's thought of the transductive relation; in Foucault, Klossowski and Blanchot; in fact in all who take Nietzsche seriously.
40. Deleuze and Guattari, *A Thousand Plateaus*, 4, 79, 554–56.
41. This development and influence can be seen, for instance, in the changes that occur to the various editions of Deleuze's *Proust and Signs*, whereby the later editions become markedly more machinic, more concerned with the assemblage. Gilles Deleuze, *Proust and Signs,* trans. Richard Howard (London: the Athlone Press, 2000 [1964]). On Deleuze's relation to structuralism, see Gilles Deleuze, 'How Do We Recognise Structuralism?', in *Desert Islands and Other Texts 1953–1974*, trans. Melissa McMahon and Charles J. Stivale (Los Angeles/New York: Semiotext(e), 2004), 170–92.
42. Deleuze and Guattari, *A Thousand Plateaus*, 337.
43. Gilles Deleuze, *Difference and Repetition*, trans. Paul Patton (London, The Athlone Press, 1994 [1968]), in particular pages 26–27 but also scattered throughout.
44. Gilles Deleuze, *Nietzsche and Philosophy*, trans. Hugh Tomlinson (London: The Athlone Press, 1983 [1962]), 39–40. Also page 48: 'We misinterpret the expression "eternal return" if we understand it as "return of the same". It is not being that returns but rather the returning itself that constitutes being insofar as it is affirmed of becoming and of that which passes. It is not some one thing which returns but rather returning itself is the one thing which is affirmed of diversity or multiplicity.'
45. Deleuze, *Difference and Repetition*, 40.
46. Gilles Deleuze, 'We Invented the Ritornello', in *Two Regimes of Madness: Texts and Interviews 1975–1995*, trans. Ames Hodges and Michael Taormina (Los Angeles/New York: Semiotext(e), 2006), 377–81, 381.
47. Deleuze, *Difference and Repetition*, 318.
48. Jacques Derrida, 'Freud and the Scene of Writing', in *Writing and Difference*, trans. Alan Bass (London: Routledge & Kegan Paul, 1978), 255.
49. Gilles Deleuze, *The Fold: Leibniz and the Baroque*, trans. Tom Conley (London: The Athlone Press, 1993), 3 and 6.
50. Gilles Deleuze and Claire Parnet, *Dialogues II*, trans. Hugh Tomlinson, Barbara Habberjam and Eliot Ross Albert (London/New York: Continuum, 2006), 41.
51. Bernard Stiegler, 'Deconstruction and Technology: Fidelity at the Limits of Deconstruction and the Prosthesis of Faith', trans. Richard Beardsworth, in *Jacques Derrida and the Humanities: A Critical Reader*, ed. Tom Cohen (Cambridge: Cambridge University Press, 2001), 250.
52. Reference could also be made to hyper-relationality in the non-continental tradition of philosophy, and in particular to James Ladyman's (and associated philosophers') ontic structural realism. This posits that 'relational structure is more ontologically fundamental then objects', in *Every Thing Must Go: Metaphysics Naturalised* by James Ladyman and Don Ross (Oxford: Oxford University Press, 2007), 145. Ladyman precisely uses quantum theory to support his position. For a recent summary see Laura Candiotto, 'The Reality of Relations', *Giornale di Metafisica* 2 (2017): 537–51. Space does not permit here what would be an interesting analysis of the relations between this strand of relational philosophy and that of the post-Nietzschians in the continental tradition, not

least the passage via Ernst Cassirer's structuralism of the 1930s; see Ernst Cassirer, *Determinism and Indeterminism in Modern Physics* (New Haven: Yale University Press, 1936[1956]).

53. Jacob von Uexküll, *A Foray Into the Worlds of Animals and Humans With a Theory of Meaning*, trans. Joseph D. O'Neil (Minneapolis: University of Minnesota Press, 2010).
54. Bertalanffy, *General System Theory*, 241. The equivalent passage from *A Thousand Plateaus* reads: 'For example, the Tick, attracted by the light, hoists itself up to the tip of a branch; it is sensitive to the smell of mammals, and lets itself fall when one passes beneath the branch; it digs into its skin, at the least hairy place it can find. Just three affects…', 257.
55. As Derrida points out in his essay *Qual Quelle*: Jacques Derrida, 'Qual Quelle', in *Margins of Philosophy*, trans. Alan Bass (Brighton: The Harvester Press, 1982), 273–306.
56. See Daniel W. Smith, 'Sense and Literality: Why There Are No Metaphors in Deleuze's Philosophy', in *Deleuze and Guattari's Philosophy of Freedom: Freedom's Refrains*, ed. Dorothea Olkowski and Eftichis Pirovolakis (Edinburgh: Edinburgh University Press, 2019), 45–67.
57. The link between Deleuze's thought and quantum theory has been made by, for instance, Wim A. Christiaens in 'The Deleuzian Concept of Structure and Quantum Mechanics', in *Probing the Meaning of Quantum Mechanics: Physical, Philosophical, and Logical Perspectives*, ed. Aerts Diederik et al. (Singapore: World Scientific Publishing, 2014), 189–208.
58. Carlo Rovelli, 'Relative Information', *Edge.org* (2017), www.edge.org/response-detail/27074.
59. Carlo Rovelli, 'Relative Information at the Foundation of Physics', in *It from Bit or Bit from It? On Physics and Information*, ed. Anthony Aguirre, Brendan Foster and Zeeya Merali (Berlin: Springer, 2015), 79–86, https://arxiv.org/abs/1311.0054.
60. 'Nietzsche's account of the eternal return presupposes a critique of the terminal or equilibrium state . Nietzsche says that if the universe had an equilibrium position, if becoming had an end or final state, it would already have been attained.' Deleuze, *Nietzsche and Philosophy*, 47.
61. Carlo Rovelli, 'Relative Information at the Foundation of Physics', 1; my emphasis.
62. Ibid., 2.
63. Carlo Rovelli, 'Relational Quantum Mechanics', *International Journal of Theoretical Physics* 25 no. 8 (1996): 6, https://arxiv.org/abs/quant-ph/9609002.
64. Here there is a clear isomorphism with second-order cybernetics. See Note 8 above and Collins's article on the Macy conferences.
65. For a clear explanation of this experiment, the reader unfamiliar with quantum physics is referred to the following resource by Jim Al-Khalili: https://youtu.be/A9tKncAdlHQ (accessed 11 November 2020). The best book-length exposition is currently Anil Ananthaswamy's *Through Two Doors at Once* (London: Dutton, 2018).
66. The most thorough book-length exposition of this is currently Philip Ball's *Beyond Weird: Why Everything You Thought You Knew about Quantum Physics Is Different* (London: Vintage, 2018), which has the advantage (for our purposes) of rapidly dismissing non-hyper-relational quantum mechanical accounts, such as the many-worlds theory.
67. On Fuchs, for instance, Christopher A. Fuchs, 'Quantum Mechanics as Quantum Information (and only a little more)', arXiv:quant-ph/0205039. On Zurek, see for instance, Wojciech Hubert Zurek, 'Environment-Induced Superselection Rules', *Physical Review D* 26, no. 8 (15 October 1982). On Mermin and the Ithaca Interpretation see, for instance, N. David Mermin, 'The Ithaca Interpretation of Quantum Mechanics', arXiv:quant-ph/9609013 and 'What Is Quantum Mechanics Trying to Tell Us?', *American Journal of Physics* 66 (1998): 753–67, where he states: 'Correlations have physical reality; that which they correlate does not.' This is as succinct a statement of hyper-relationality as we can hope to find. Other key references to hyper-relational quantum theory include: Mauro Dorato, 'Rovelli's Relational Quantum Mechanics, Monism and Quantum Becoming' (arXiv:1309.0132); Matthew Brown, 'Relational Quantum Mechanics and the Determinacy

Problem', *SSNR ((*27 March 2007), http://dx.doi.org/10.2139/ssrn.1006232 ; Bas C. van Fraassen, 'Rovelli'sWorld', *Foundations of Physics* 40 (2010): 390–417; Hans-Peter Duerr, 'Radically Quantum: Liberations and Purification from Classical Prejudice', in A. Elitzur et al. *Quo Vadis Quantum Mechanics* (Berlin: Springer, 2005), 7–46; Art Hobson, 'There Are No Particles, There Are Only Fields', *American Journal of Physics* 82 no. 3 (March 2013): 211–23, arXiv:1204.4616.

68. Not that the human observer is special in this regard; reality is created by interrelations even (and generally) without us around, which indeed is Rovelli's point – that quantum mechanics does not (pace some other theories) depend on a human observer or consciousness.
69. See, for example, Salvator Cannavo, *Quantum Theory - A Philosopher's Overview* (Albany: SUNY Press, 2009), which reads as such an extended complaint.
70. Rovelli, 'Relative Information'. In his latest book, published as this essay went to press, Rovelli clarifies the distinction between these two instances of information – the inanimate and animate – by combining information theory and Darwinian evolution, thereby physically grounding the notion of meaning for a living being as 'relevant relative information'. See Carlo Rovelli, *Helgoland*, trans. Erica Segre and Simon Carnell (London: Allen Lane, 2021), 145.
71. Ibid., emphasis added. In an article in *New Scientist* published as this essay went to press, Rovelli states similarly that 'the world is woven by relationships that go all the way down to the smallest physical entities'. But it is precisely the word 'entities' which fails here; relationships are not physical entities. Carlo Rovelli, 'Quantum weirdness isn't a weird – if we accept objects don't exist', *New Scientist*, 13 March 2021, 36.
72. Quoted in Rovelli, 'Relational Quantum Mechanics', 19. The quotation is from: W.H. Zurek, 'Environment-Induced Superselection Rules', *Physical Review D* 26, no. 8 (1982): 1878.
73. Zurek, 'Environment-Induced Superselection Rules', 1878. Ladyman's ontic structural realism makes precisely the same point.
74. For a recent discussion that ties the question of consciousness to entropy and information (although, I believe, not entirely succeeding) see Mark Solms, *The Hidden Spring: A Journey to the Source of Consciousness* (New York: W.W. Norton, 2021). The term 'hard problem of consciousness' comes from David J. Chalmers, 'Facing up to the problem of consciousness', *Journal of Consciousness Studies* 2, no. 3 (1995): 200–19.
75. Indeed it seems likely that quantum effects are relevant to this and other 'macro' biological questions. See, for instance, Jim Al-Khalili and Johnjoe McFadden, *Life On the Edge: The Coming of Age of Quantum Biology* (London: Bantam Press, 2014).
76. Baruch Spinoza, *Ethics, Treatise on the Emendation of the Intellect and Selected Letters*, trans. Samuel Shirley (Indianapolis: Hackett, 1992), 67 (Part 2, proposition 7, scholium). Deleuze, of course, regarded Spinoza as the prince of philosophers; see Deleuze and Guattari, *What is Philosophy?*, 48.
77. See Cedric Price, 'Anticipatory Architecture', in *Cedric Price Works 1952–2003: A Forward-Minded Retrospective* Vol 2, ed. Samantha Hardingham (London: AA Publications 2016), 460–467, 460, the transcript of a talk at Columbia University, New York in November 1995 where he asks 'remember the divorce?' A footnote explains that this relates to 'an anecdote told by Bernard Tschumi in his introduction to this talk in which Price was approached by a client who, wanting to do something to please his wife, asked Price to design a new house. Price reflected and responded that perhaps what the client really needed was a divorce.' Deleuze and Guattari speak of divorce in *A Thousand Plateaus* as the moment beyond the penultimate word in an argument, the moment when a couple enters another assemblage than that of marriage. Price is indeed pushing his potential clients into another assemblage. Deleuze and Guattari, *A Thousand Plateaus*, 438.

Biography

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Environments (out) of Control: Notes on Architecture's Cybernetic Entanglements

Contingent Collective (Lőrinc Vass, Roy Cloutier, Nicole Sylvia)

> Gaia is not a cybernetic machine controlled by feedback loops but a series of historical events, each of which extends itself a little further – or not.
> Bruno Latour, 2017[1]

> Autopoietic systems are hugely interesting – witness the history of cybernetics and information sciences; but they are not good models for living and dying worlds and their critters ... Poiesis is symchthonic, sympoietic, always partnered all the way down, with no starting and subsequently interacting 'units'.
> Donna J. Haraway, 2016[2]

> Will the recursive thinking in cybernetics allow us to relaunch the question of organicism and technodiversity, or will it, being driven by efficiency for the final cause imposed by capital, finally only realize a purely deterministic complex system that is moving toward its own destruction?
> Yuk Hui, 2019[3]

In her recent book *In Catastrophic Times*, philosopher Isabelle Stengers evokes a powerful image to describe our contemporary environmental condition: 'the intrusion of Gaia'.[4] By summoning this figure, Stengers alludes not only to the mythological goddess of antiquity but especially to her modern incarnation in the cybernetic, self-regulating complex system theorised by chemist James Lovelock and microbiologist Lynn Margulis in the 1970s, which became a popular rallying metaphor for the environmental movement. For Stengers, Gaia constitutes neither the earth as a concrete object nor a metaphor for provoking a sense of belonging; rather, to name Gaia is to recognise the intrusion of a form of transcendence into our history – an assemblage of material processes that are indifferent to humans, yet whose slightest movements threaten the survival of our civilisation today.[5] The question of how to 'come to terms, or compose with Gaia' thus becomes the problem of the so-called Anthropocene epoch.[6] More than a new geological era, the Anthropocene signals a non-negotiable end to the deeply entrenched division between nature and culture that had served as the ontological basis of modernity.[7] The shift manifests in a reconceptualisation of ecology, from a restrictive image of 'nature' to a generalised notion of techno-ecology.[8] This transformation has been described as 'environmentalisation', the becoming-environmental of all aspects of life – including power, knowledge, subjectivity, media and thinking.[9]

Margulis and Lovelock's Gaia is a circuitous product of the transdisciplinary field of cybernetics. Post-war cyberneticisation has propelled a profound reconceptualisation of how the world is composed and, in turn, how it can be engaged, organised and governed. Manifold entities – from the smallest of organisms to large-scale networks – have come to be viewed as complex, self-organising and self-making (autopoietic) systems, coupled with their environments through feedback and crisscrossed by information. Historian of science Andrew Pickering describes the 'non-modern ontology' of cybernetics according to three trajectories that mark a departure from modernity: (1) the centrality of agency and performance, as opposed to intention and knowledge; (2) the prevalence of emergence, as opposed to linear causality; and (3) the decentring of the human as a source of explanation and control, acting amid a multiplicity of entities.[10] While cybernetics dissipated as a unified, identifiable field by the end of the 1970s, it continues to exert a profound, if often invisible, influence. Today, cybernetic circuits comprise the underlying logic of the contemporary global economy: an environmental form of communication and control. These transformations have in turn crystallised in a new environ-mentality across the field of design, concerning not only the way buildings, landscapes or cities are conceived but also practices of production and inhabitation.

Contemporary architectural discourse on cybernetics appears to be split along a series of contradictions, most notably between optimistic calls for its deployment as an ethos of conversation and choice and critical accounts of its invisible environmental-behavioural hegemony. Cybernetics in these debates is seen variously as a comprehensive theory of (self-)regulation, complexity, and information exchange, yet also as an obscure scientific field with very few designers possessing in-depth knowledge of its concepts and methods. It is thought to have been forgotten and in need of ‘rediscovery’, yet its assumptions are detected across commonplace operations in contemporary design. It is seen to hold untapped potential as a liberating mechanism for choreographing emergence, adaptation and open-endedness, but conversely, as an anti-democratic obscuring of power through environmentally modulated forms of control.

Given the profound spatial implications of the paradigm shift outlined above, an examination of contemporary architecture’s cybernetic entanglements is fundamental for a critical revaluation of environmentality in the discipline. In this article we map the cybernetic imaginary ‘at large’ across the design fields under various guises, including but not limited to adaptation, resilience, responsiveness, smartness, various metaphors of cultivation and conversation, as well as variations on -management. We examine these attitudes in the context of the development trajectory of environmentalisation and the critical discourse emerging around the history of cybernetic projects in order to probe their problematic proximity to the environmental control logics of cybernetic capitalism, with the intent to question and move beyond them.[11] The task, then, is to re-position cybernetics, opening up new critical-speculative horizons amid and beyond its restrictive circuits. We present two such trajectories in the final section of the article, grounded in affirmative contingency and sympoietic response-ability.

Architecture’s environ-mentalities

Whether or not the term is mobilised as an explicit qualifier, a cybernetically-charged environ-mentality abounds in architecture and allied fields today – at times as mere metaphors or aspirations; in other cases as tangible strategies of design practice. Buzzwords such as ‘adaptation’, ‘responsiveness’, ‘resilience’ and ‘openness’ signal increased attentiveness to organisational complexity, temporal evolution, and agential plurality. Not unlike the ‘general good’ associated with so-called ecological or sustainable practices, the positive undertones of these approaches tend to render them opaque, albeit not immune, to critical probing. Yet scrutiny is warranted, particularly concerning the ways these tendencies in design conceive of and seek to condition organisms and their environments.

Extending Pickering’s conceptualisation of cybernetic ontology, three tendencies of cybernetic influence on architecture are particularly notable: the shift from direct to indirect modes of control; from a focus on static objects to temporal processes and evolution; and from geometrical to topological operations. Firstly, in place of modernist convictions of the complete knowability of the world, the subsequent cybernetic view of irreducible complexity and indeterminacy has prompted a shift from direct, top-down modes of ordering form, to indirect, system-wide approaches of instigating formation, or in Gilbert Simondon and Gilles Deleuze's memorable formulation, from an enclosure-based moulding to an environmental modulation.[12] In this latter modality, the designer is seen operating on a substrate, scripting protocols rather than dictating form: 'the architect is a system designer who cultivates, rather than designs, a system'.[13]

The modulatory attitude was already articulated in the cybernetic architectural theories of the post-war decades, such as Gordon Pask's notion of design as a 'control of control', or Sean Wellesley-Miller's call for the designer to 'stimulate, steer, and stabilize the process' of self-organisation.[14] These views find their parallels in the present-day 'cultivation mentality', centred on catalysing system-wide transformations and manifest in the many ecological-agricultural metaphors, from seeding to propagation, from cultivation to more than two decades of discourse on fields, from the 'irrigation of territories with potential' to calls to 'alter the soil, not square off against every weed'.[15] They also pervade the many 'urbanisms' of late, such as landscape-, infrastructural-, ecological urbanism, and various agency-valorising practices such as 'critical spatial praxis' or the explicitly cybernetic notion of conversation as a design methodology.[16] In all of these formulations, the shift away from centralised control is seen as liberatory, opening up the field of design to the complexity of interactions across a plurality of more-than-human agents. The design process adopts the form of a 'choreography', a guided evolution in which 'an overemphasis on control and efficiency gives way to dynamic and open-ended linkages between people's intentions for the landscape and the non-anthropogenic forces at work'.[17]

Closely following from this point is the shift in focus from designed objects to evolution and change – the temporal management of transformations. Systems are seen not only as complex but also dynamic, necessitating the anticipation of change over time and ongoing response to it. This attitude can be most clearly seen through the discursive pervasiveness of variations on adaptation, resilience, and responsiveness. Contrary to modernist pursuits of flexibility, adaptation is deployed in explicitly ecological terms across a range of territories and scales, from computational design to landscape infrastructural projects. Adaptation in these contexts is used in the sense of adaptive systems, characterised by biologists and cyberneticists as 'organisms or mechanisms capable of optimising their operations by adjusting to changing conditions through feedback'.[18]

Finally, indirect modulation and temporal management coincide with a shift of emphasis from geometric/topographic to relational/topological operations. What comes to matter in conceptualising design interventions is less the shaping of geometric figures at particular scales than the manipulation of contingent relations across scales. This notion informs for instance the 'diagrammatic' approach formulated around the turn of the millennium and all-pervasive across the discipline today. As a topological figure, 'the diagram focuses on the organisational, privileging relations and their organisation over anything else. The diagram defines relations within the system, protocols rather than a plan in the traditional architectural sense.'[19] Topological modulations are also seen in contemporary approaches to material computation, which adapt a particular eco-logical conception of nature, involving 'not an (associationist) interaction of parts, but the capacities of the environment, defined in terms of a multiplicity of interlayered milieus or localities, to become generative of emergent forms and patterns'.[20] Notably, such topological and a-scalar/multi-scalar operations in or on complex and dynamic environments often depend on intensive digital technologies during the design and implementation process, such as 'time-based programming, environmental modelling, and real-time visualization'.[21] These processes thus provide a profoundly techno-ecological framing for architecture.

These cybernetic attitudes – concerning both the nature of reality and the corresponding disposition of design intervention – have over more than two decades consolidated around a constellation of idioms that together comprise the cybernetically charged 'environ-mental lexicon' of contemporary architecture. [Fig. 1] At large across discourse and practice, these approaches embody a broader, paradigmatic shift from modernist to environmentalised conceptions of organisation and control – a notion explored in the following section.

Cybernetic state of nature

Although contemporary architecture has been lost in a field of environmental operations – ecological design, green building, sustainable urbanism, and more – there has been limited critical scholarship from within architecture history and theory that contextualises these environ-mentalities in all their material-semiotic, technological, historical and onto-epistemological dimensions. The necessity of such analysis is demonstrated by the recent work of philosopher and cultural theorist Erich Hörl. At the heart of Hörl's inquiry is an examination of the interrelationships between the epochal tendency of environmentalisation, its manifestation as a particular environmental mode of governmentality (Environmentality), and the techno-ecological underpinnings of both in the form of a 'cybernetic state of nature'.[22] Hörl characterises our contemporary condition as a new historical semantics of environmentalisation, the becoming-ecological of the world:

> There are thousands of ecologies today: ecologies of sensation, perception, cognition, desire, attention, power, values, information, participation, media, the mind, relations, practices, behavior, belonging, the social, the political – to name only a selection of possible examples. There seems to be hardly any area that cannot be considered the object of an ecology and thus open to an ecological reformulation.[23]

Environmentalisation thus constitutes an epochal shift from an immunopolitical conception of ecology – based on the division of technology and nature, where the latter is conceived as an other to the teleological rationality of technicity – to a denaturalised, non-anthropocentric techno-ecological condition characterised by the end of modern rationality and purpose; in other words, a (re)turn to a non-modernity.[24]

Far from being an inherently liberating development, however, environmentalisation has also resulted in the restricted form of Environmentality.[25] This term was first used by Michel Foucault in the late 1970s to describe the then-emerging form of governmentality seen fully formed today. Foucault noted a shift from the normalising, disciplinary power strategies of moulding to 'an entirely different form of intervention, a kind of non-intervention in the form of modulation', an environmentally distributed mode of control.[26] Hörl extends Foucault's analysis of power to also incorporate the becoming-ecological of subjectivity, knowledge, technology, media, and crucially, of capital.[27] He refers to this comprehensive formal analysis of environmentality as general ecology, 'a thinking of becoming-environmental'.[28]

The necessity of introducing this general ecological analysis in the field of design has been demonstrated by architectural historian Daniel Barber, who extends Foucault's inquiry into environmentalised governmentality, applying it to the historiography of twentieth-century architecture. Following Sven-Olov Wallenstein, Barber argues that modern architecture 'emerges as "an essential part of the biopolitical machine" ... [and] comes to embody and enforce the process of governmentalisation'.[29] In this analysis, the environment (*milieu*) comprises a biopolitical and techno-ecological enframing whose existence precedes, and thus shapes, architectural operations.[30]

Hörl identifies the process of cyberneticisation over the course of the twentieth century precisely as the underlying techno-ecological frame of environmentalisation and environmentalitarian governmentality:

> The technological evolution that drives this fundamental re-ecologization of thinking and of theory as well as the readjustment of the apparatus of capture [has unfolded] since the end of the nineteenth century and especially since 1950 in an ongoing process of cyberneticisation, in *an environmental culture of control that is radically distributed and distributive*, manifest in computers migrating into the environment, in algorithmic and sensorial environments.[31]

Cybernetics therefore figures simultaneously as an initial catalyst and subsequent symptom of general ecologisation. Its modulatory mechanisms of regulation and control are both entangled with the formation of the contemporary ecological imaginary and the development of non-modern forms of rationality, yet they are also crucial to the operation of the techno-capitalist power-form of Environmentality.

It is thus instructive to briefly rehearse the post-war genealogy of cybernetics, in order to both draw out some of its historical contingencies, and examine its figuration in architectural theorisations of the environment. [Fig. 2] Three parallel genealogies are crucial: (1) the 'internal' story of the evolution of cybernetics, often rehearsed without taking account of its technological dependencies; (2) a cultural-historical reading that positions cybernetics as a catalyst for the contemporary posthuman condition and has served as a point of reference for architectural historiography; (3) and a techno-ecological trajectory, which allows to draw closer links between architecture's environ-mental idioms and the control logics of Environmentality.

The theoretical field of cybernetics – sometimes regarded as a subset of systems science – distinguishes two stages in its development: first- and second-order cybernetics, respectively described as the science of observed systems and observing systems. Whereas the technological path-dependency of cyberneticisation often remains obscured in this periodisation, literary critic N. Katherine Hayles has thoroughly examined the historically contingent evolution of cybernetics, with a focus on the disembodied conception of information.[32] Through a meticulous cultural historiography, Hayles identifies a series of overlapping conceptual constellations, each operative in relation to particular material-technological artefacts: homeostasis (1945–60), autopoiesis (1960–85), virtuality (1985–95), and most recently, the regime of computation (1995–present).[33] This periodisation both reveals the way cybernetics propelled the deconstruction and replacement of the liberal humanist subject with the particular posthuman figure of the cyborg (short for cybernetic organism), and contests the inevitability of the separation of information from materiality:

> The adaptation of a disembodied view of information spread so pervasively ... because it fitted well with existing preconceptions about a separation between a material body and an immaterial essence, which of course was a subtext for a disembodied view of information in the first place.[34]

The outcome of this preconception, according to Hayles, is a two-part process of abstraction of reality, by first reducing the infinite multiplicity of the real to a simplified model and subsequently simulating a 'multiplicity sufficiently complex that it can be seen as a world of its own'.[35]

Architect Ariane Lourie Harrison adopts Hayles's historiography in her introduction to *Architectural Theories of the Environment: Posthuman Territory*, focusing the architectural discussion of cybernetics around the cyborg, most famously theorised by Donna Haraway as a networked organism that resists binary conceptualisations such as human-animal or human-machine.[36] Posthuman theory, Harrison argues, 'extends the cyborg metaphor beyond the body and into the built environment, imagining designed space itself as a prosthetic and producing new understandings of a "nature" that itself can no longer be conceived as an originary or neutral ground'.[37] The limitation of this framing – in addition to its characteristic misreading of the cyborg as a 'hybrid' – is the conceptual prioritisation

Modernity	→	*Environmentality*
(universal) flexibility		(particular) adaptation
(inactive) impassivity		(interactive) responsiveness
(hylomorphic) moulding		(modulatory) cultivation
(solid) durability		(pliant) resilience
(individual) authorship		(plural) conversation
(spatial) demarcation		(temporal) management

Fig. 1

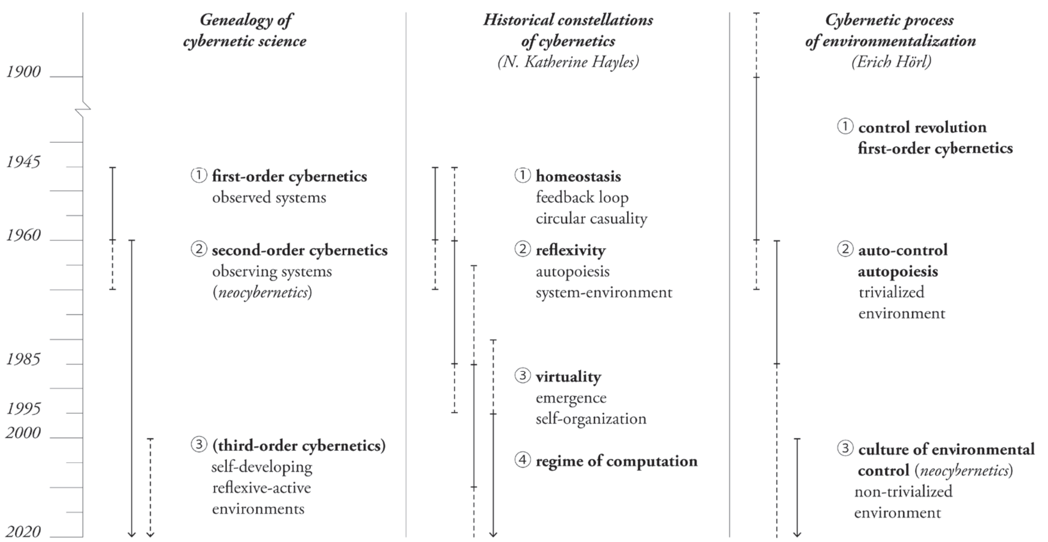

Fig. 2

Fig. 1: Architectural idioms of modernity and environmentality. Diagram: authors.

Fig. 2: Historical trajectories of cyberneticisation. Diagram: authors.

Time period	*Governance strategy*	*Underlying ontology*	*Operating principle*	*Operating logic*	*Environmental logic*	*Spatial manifestation*
20th c.	Modernity	rationality	linear causality	progress	**moulding** (discipline)	hylomorphism masterplanning
	Mapping	autopoiesis	non-linear causality	adaptation	**cybernetic modulation** (control)	parametric/material computation ecological/infrastructural urbanism
21st c.	Sensing	homeostasis	correlation	responsiveness		responsive architecture smart city
	Hacking	sympoiesis	experimentation	radical openness deterritorialization	**collective production** (contingency)	architectures of response-ability & contingency

Fig. 3

Fig. 3: Ontopolitics and cybernetic logics. Diagram: authors. Adapted from David Chandler, *Ontopolitics in the Anthropocene: An Introduction to Mapping, Sensing and Hacking* (Abingdon, Oxon: Routledge, 2018), 23.

of the posthuman body. Making it the primary point of reference pre-empts the possibility of detecting any underlying connections between the cybernetic logics of architectural interventions and the already-cyberneticised environments in or on which they operate, thus missing the more fundamental link to the techno-ecological enframings emphasised by both Hörl and Barber.

Hörl's genealogy of cybernetics thus becomes particularly pertinent by situating it within the broader arc of technological development that has given rise to environmentalisation. This longer history of control begins in around the mid-nineteenth century and includes nebulous developments in routinisation, bureaucratisation, technical tinkering, engineering and management, as well as the instrumentalisation of control in first-order cybernetics, centred on adaptive behaviour and the feedback loop.[38] The second phase commences in the late 1960s to early 1970s with second-order cybernetics and concerns manipulative behaviour, auto-control and autopoiesis. Whereas both of these periods conceive the environment as a trivialised surrounding, the current, third phase – which Hörl somewhat confusingly terms 'neocybernetics' – marks 'the emergence of an environmental culture of control' based on the environmental distribution of agency by media technologies:[39]

> It is only with this phase that environmentality in the widest sense becomes problematic and takes the form of a new problematics of Environmentality as our mode of governmentality; its main problem is the capture and the control, the management, the modulation of behavior, of affects, of relations, of intensities, and of forces by means of environmental (media) technologies whose scope ultimately borders on the cosmic ... Cyberneticisation crystallizes as Environmentalisation.[40]

An all-pervasiveness of environmentalised forms of control, then, constitutes the contemporary 'neocybernetic regime of truth', or as the Tiqqun collective puts it, 'the cybernetic hypothesis'.[41] To recap: the post-war process of cyberneticisation, as part of the broader trajectory of the 'control revolution', has been a key catalyst for environmentalisation. It thereby propelled both the expansion of ecology from a restrictive sense of nature to a generalised techno-ecological paradigm, and the proliferation of techno-ecological modes of regulation and control across all aspects of life under the regime of environmentalitarian governmentality. These transformations, which are only accelerating due to recent technological developments, have not been sufficiently examined in architectural history and theory. Such critical inquiry through the dual lens of e/Environmentality is particularly warranted, given the proliferation of cybernetically inclined idioms and approaches across contemporary architecture, landscape and urbanism.

Cybernetic ontopolitics

Political scientist David Chandler's theorisation of contemporary governance strategies, most comprehensively outlined in *Ontopolitics in the Anthropocene*, offers a valuable framework for contextualising and critiquing the constellation of environ-mental idioms in design as approaches in relation to environmentalitarian governmentality. Defining ontopolitics as 'a new set of grounding ontological claims that form the basis of discussions about what it means to know, to govern and to be a human subject', Chandler argues that the Anthropocene epoch 'appears to bring to a close the human-centred, subject-centred or anthropocentric understandings of power and governmental agency'.[43] With the end of modernist assumptions of progress, universal knowledge and linear causality, contemporary ontopolitical strategies – introduced as 'mapping', 'sensing' and 'hacking' – seek to 'adapt or respond to the world rather than seeking to control or direct it'.[44] Crucially for this discussion, Chandler characterises both mapping and sensing with reference to cybernetic logics. [Fig. 3] This ontopolitical lens thus both substantiates and supplements Hörl's analysis of Environmentality, and allows for resituating the sporadic commentaries on cybernetic approaches in architecture and urbanism within this broader framework.

Firstly, the ontopolitical approach of mapping arises from a refutation of the linear causality of modernism, assuming instead the non-linear logic of autopoiesis (self-production). Chandler traces the logic of mapping to the post-war rejection of the universalist assumptions of knowledge and the possibility of top-down governance, and the resultant shift towards the notion of bottom-up agential choice-making in response to historical, social, and economic contingencies.[45] Thus, mapping approaches, grounded in bottom-up immanence

> inform a wide-range of governing practices and philosophical perspectives, from neo-institutionalist understandings of contingency, context and path-dependencies, to the adaptive cycles and panarchies of ecosystem resilience and the more radical conceptions of assemblage theorists, seeking to map and to understand nested assemblages of non-linear causal chains of emergence.[46]

As should be clear from the preceding discussion, the adaptive modulations that characterise mapping can be seen at work in ecological and infrastructural urbanism, resilience approaches in landscape architecture, as well as in much of computational design. Notably, the ontological richness of mapping – its recognition of the plurality, flux, and difference of the world – quickly becomes a difficulty in actual governance, insofar as the interplay between equilibrium and emergence requires constant modulation: 'what starts out as a "light touch" or indirect recursive process of "designing for design" appears to end up requiring a much more interventionist process of regulation and monitoring than that assumed by "top-down" "command-and-control"'.[47]

Indeed, a central criticism mounted against cybernetics in architecture and urbanism concerns the obfuscation of control, power and politics in decentralised systems. Control, as elaborated by media theorists Alexander Galloway and Eugene Thacker, is not a disciplinary form of power over someone or something, but as a ground that in turn conditions interaction: 'one does not simply control a device, a situation, or a group of people; rather, "control" is what enables a relation to a device, a situation, or a group'.[48] In this reading, decentralised systems are hardly free of control; rather, control becomes distributed across the system and thus more difficult to detect and contest. Cybernetics has a propensity 'to render power relations invisible, power is no longer anywhere special, but this does not mean it is absent, only that it is in the *framing* of the system rather than the active enforcement of discipline within the system'.[49] With the architect commonly conceived as a systems designer who authors not form but 'the parameters or protocols according to which the system evolves',their role increasingly becomes that of a cybernetic programmer of environmental power.[50]

A pivotal reference for this discussion is the 'cybernetic hypothesis' of Tiqqun, who argue that far from having disappeared, cybernetic notions about conceiving, modulating and predicting biological, physical and social behaviour serve as an ideological backdrop to contemporary neoliberalism, which thus constitutes cybernetic capitalism.[51] In a similar manner, theorist Douglas Spencer traces the shared ideological origins of neoliberal economic thought and contemporary post-critical architectural practices – in both cases originating in post-war cybernetics and systems theory.[52] He notes that the cybernetic notion of the environment, such as 'its transcategorical forms of knowledge, its entrepreneurial orientations, its celebrations of networked mobility and its promises of self-transcending immersion', were quickly embraced by the counterculture movement as a liberatory mechanism against instrumental reason, and also came to inform architectural discourse during the 1960 and 1970s. These perspectives became fully normalised by the 1990s, and served as an ideological foundation for the rise of post-critical attitudes around the turn of the millennium.[53] Following a similar thread, architect Fredrick Torisson detects the cybernetic hypothesis at work not only in neoliberally-aligned post-critical approaches to architecture that arose in the late 1990s, but also in more recent counter-movements such as 'critical spatial praxis'. He argues that even this latter, distributed-agency-valorising mode of practice falls short of understanding the extent of the architect's modulatory power. The result of such obscuration of power is the risk of the collapse of politics onto the framing (modulation) of the system – in other words, a 'cybernetic politics'.[54]

In contrast to this attempt to grasp and manipulate non-linear causal relationships, Chandler characterises the ontopolitical strategy of sensing as operating based on correlation and according to the first-order cybernetics of homeostasis. Instead of pursuing non-linear causality, sensing strategies deploy responsive modulations of surface effects in order to maintain the status quo.[55] While its underlying cybernetic logic historically predates that of mapping, sensing as an environmental governance strategy could fully emerge only with the development of algorithmic computation and big data. Notably, whereas through these intensive technologies it appears to constitute a 'real time' responsiveness,

> sensing does not seek to make causal claims, the emergence of effects can be traced to reveal new relations of interaction and new agencies or actants to be taken into account but there is no assumption that effects can be understood and manipulated or governed through transcendental policy goals – real time responsive forms of management through Sensing increasingly focus on the 'what is' of the world in its complex and plural emergence.[56]

However, Chandler also notes that 'real time' is a mere illusion created by the speed at which technologies operate. Rather, responsiveness holds time constant, in a manner of the control society outlined by Deleuze nearly three decades ago: 'instead of a before (prevention) or an after (reaction) there is the continual modulation of responsiveness, an "endless postponement" of a problem'.[57] In a similar vein, sociologist Orit Halpern describes cybernetic rationality through Brian Massumi's notion of preemption. In contrast to prevention, based on an empirical assessment of threats and their causes, preemption is 'affective; it lacks representation; it is a constant nervous anticipation ... for a never fully articulated threat or future'.[58] As Halpern further remarks, this cybernetic rationality replaces the incalculable difference of infinity with a 'dream of self-organizing systems and autopoietic intelligences produced from the minute actions of small, stupid, logic gates, a dream of a world of networks without limit, focused eternally on an indefinite and extendable future state'.[59]

This preemptive logic can be seen at work in the environmentally-mediatised paradigm of the smart city, as well as in the responsive digital technologies increasingly populating and defining our domestic architectures, thus 'intensifying the discourse of responsivity from the sphere of the market to the governance of life as a whole'.[60] Urbanist and historian Maroš Krivý examines the smart city through a cybernetic lens, arguing that it is characterised by 'environmental-behavioural control' under which the 'the subject citizen is at once an infra-individual profile of desires, attitudes and preferences and a vector within their supra-individual articulation as a "swarm."'[61] Operating on the principles of data-behaviourism and preemptive nudging whose interactive circuits of feedback foreclose genuine social change, for Krivý the smart city engenders the simultaneous collapse of the concept of the urban and of urban politics.[62]

Another prominent instance of the preemptive operation of sensing is found in the digital tools and technologies employed by designers, which in and of themselves operate according to the cybernetic temporality of real time. Unlike historical time that, as architect John May comments, ‘was concerned with representing the past as a way of *determining the future,* real time presents all possible futures at once (or at least as many as can be counted, computed, and parametricised) as a way of *managing the present’.*[63] The substrate of this temporality, the managerial surface, comprises a ‘silent epistemological backdrop’ for design practice today.[64] Its electronic expanse collapses the political and metaphysical dimensions of the real into a digitised, statistical, scale-less and automated abstraction of reality, recasting the activity of designers as environmental management.[65] As May further suggests, the telematic images thereby produced ‘silently posit an entire cosmological theory of life in every scene (in general, that the world is a statistical object and is therefore best understood as an ever-growing body of electrical data)’.[66] Thus, as Chandler aptly remarks, as a result of the displacement of causality with the modulation of effects through responsiveness under the sensing paradigm, the modernist notion of politics is fully inverted: ‘politics becomes based upon the subject responding to and being sensitive to the world and its environment, rather than acting to change it’.[67]

An important insight of Chandler’s analysis – drawing on the work of the cultural theorist Claire Colebrook – is that despite their epistemological break with modernist notions of universal knowledge and top-down control, adaptive mapping and responsive sensing paradoxically reinforce instrumental reason:

> Mapping and Sensing are no less anthropocentric than the transcendental problem-solving of modernist promises of progress. As long as modes of governance view the Anthropocene condition as a problem to be *mitigated, adapted to, managed, controlled or ‘solved’* in some way, then the end of the modernist assumptions about the world is constituted as a problem to be faced in the future rather than our present condition.[68]

Therefore, these adaptive and responsive ontopolitical strategies, embraced as progressive alternatives to modernist notions of regulation and control, at their worst constitute the very operating logics of today’s cybernetic capitalism, of Environmentality. A similar observation is made by theorist Luigi Pellizzoni, who argues that recent philosophical affirmations of ‘indeterminacy’ and ‘constant becoming’ miss or downplay ‘the politics of ontology inbuilt in the neoliberalisation of nature, which builds precisely on these tenets’.[69] Also caught up in these eco-logical circuits are the many cybernetically charged strategies of adaptation, responsiveness, resilience and cultivation across architecture, landscape and urbanism, warranting historicisation and critical scrutiny.

Indeed, many observers of the cybernetic hypothesis in architecture and urbanism tend to voice a call for a return to critique – manifesting in a negativity, withdrawal or refusal. Others, however, would contend that such a characteristically modernist notion of critique has become untenable as a result of the onto-epistemological transformations of the Anthropocene epoch, necessitating a transvaluation of critique into affirmative, constructive forms.[70] A middle ground, or rather, a two-pronged approach is offered by Hörl’s aforementioned proposal for a general ecology. On one hand, general ecology comprises an in-depth examination and critique of restrictive environmentalitarian forms. On the other, it is also a revaluation of environmentality as a driving force of a ‘radically relational onto-epistemological renewal’.[71] Instead of trying to negate our cybernetic entanglements, there are perhaps ways of affirming and concomitantly reshaping matters. Cybernetics, as Halpern notes,

> permits dangerous proximities and alternative recombinations within space while posing simultaneous threats of homogenisation; the trick is to vacillate between the immediate and the deferred, to reject the laws of the binary order that ignore what cybernetics first brought into the world, which is the decentering of

> our egos, and to develop the ability to recognise that our consciousness and subjectivities are in lag to the world and are comprised through our interactions with others.[72]

Thus, exposing the historic closures and conceptual shortcomings of our cybernetic state of nature can in turn allow for critical-speculative work that moves along ‘a possible opening of neocybernetic power’ – as we will explore in the final section.[73]

Environments beyond control

Rather than passively appropriating the restricted logics of the contemporary ‘cybernetic state of nature’, the task at hand is to conceive and affirm alternative worldings. The following two trajectories, centred on the recent work of philosophers Yuk Hui and Donna Haraway, exceed the restrictive circuits of adaptive and responsive modulation, speculating on new cosmopolitics.[74] Haraway and Hui interrogate and expand the foundations of cybernetic environmentality, affirming the contingent and entangled nature of becoming, and in doing so, gesture towards material practices beyond environmentalitarian circuits of control.

In *Recursivity and Contingency*, Yuk Hui charts an alternative trajectory of cybernetics within organology, a philosophical tradition centred on technology, proposing a cosmopolitics grounded in a revaluation of fortuity against the predictive-reductionist logic of Environmentality. In Hui’s analysis, ‘cybernetics proper’ is part of the tradition of organicism, the post-Kantian philosophy of nature.[75] It constitutes, in its first- and second-order iterations, the culmination of the organicist synthesis between mechanistic (Newtonian) and vitalist (Bergsonian) conceptions of nature. In other words, ‘organization through cybernetic thinking has realised (in a certain sense) the general organism *qua* cybernetic system, which is called *ecology*’.[76] This ecological-organicist trajectory stands in contrast to organology, most notably theorised by Gilbert Simondon and Bernard Stiegler, whose inquiry Hui extends.

Both cybernetics proper and Simondon’s universal cybernetics conceive of reality as recursive, but they differ in the role played by contingency, the unexpected.[77] This divergence manifests most fundamentally in the concept of information. On one hand, cybernetic information is conceived as non-physical and probabilistic.[78] A cybernetic system is thereby characterised by a ‘nonlinear movement with predefined finality’ in which contingency, such as noise, is absorbed by the system by ‘turning it into something probable – that is to say, that which is expected’.[79] While Simondon does not reject outright this probabilistic, quantifiable notion, he deems it secondary to his ontogenetic conception of being, insofar as it presupposes an already constituted individual.[80] Instead, Simondon understands information more broadly as a signification that produces a change in the operation of a system: ‘information is not a thing, but the operation of a thing arriving in a system and producing in it a transformation’.[81] This operation, termed individuation, constitutes a ‘nonlinear movement with auto-finality’, a movement without a predefined goal that proceeds according to contingent events.[82] It is an ongoing, ever-incomplete process of coming into being in relation to one’s environment, which is simultaneously psychic and collective – a transindividual relation.[83] While individuation ‘necessarily involves relations between multiple orders of magnitude ... it is not necessarily defined by a teleological end, but rather it moves towards an undetermined end driven by the tendency to resolve tensions and incompatibilities’.[84]

Deleuze, in many of his writings, deploys a concept of modulation that appears largely analogous to Simondon’s notion of individuation as the modulated process of becoming. Yet in ‘Postscript on the Societies of Control’, he uses the term in a more restricted, critical sense to describe algorithmically-inflicted forms of self-regulation that ‘recursively modulate the social relations with precisely defined orders of magnitude and attempt to move the system toward ever-greater efficiency’.[85] As Hui explains, these divergent semantics – one synonymous with hyper-control in contemporary capitalism, the other with a new conception of becoming – are reflected in the two images of cybernetics:

> one is reductionist; it reduces organisms to feedback systems, which are imitations; it imposes determinism, since all reductions aim for prediction, all predictions are determinisms; its economy is an economy of finality. The other is non-reductionist, in the sense of Simondon's general allagmatic, which seeks genesis beyond any form of technological determinism; it is open to contingency without only reducing it to calculation and endorses auto-finality.[86]

Rather than rejecting cybernetics outright as an environmentalitarian operation of disindividuation, Hui argues that the contemporary task is to 'conceive a new perspective ... by undermining the tendency of its totalizing and deterministic thinking' and experimenting with new forms of modulation and individuation.[87] Following Simondon as well as Deleuze, this begins with the affirmation of 'the fortuitous nature of existence': instead of bringing contingency under control through preemption, affirming difference as chance.[88]

A radically (counter-)modulatory approach in architecture and other fields of environmental design, then, warrants a critical revaluation of the binary logics underlying the media in and through which designers operate. This, in turn, would allow for an unorthodox mobilisation of material-semiotic media towards discovering 'extra political and aesthetic capacities in indeterminacy, discrepancy, temperament and latency', as architect Keller Easterling puts it.[89]

In *Staying with the Trouble* Donna Haraway provides another trajectory beyond the closures of cybernetics: a shift from responsiveness to response-ability through a relational ontology grounded in sympoietic entanglement. Haraway, who has critically and innovatively enfolded cybernetic ideas into her work since the mid-1980s, articulates the notion of sympoiesis as an opening-up of the concept of autopoiesis. Through drawing on insights from biology, such as Lynn Marguilis's characterisation of symbiogenesis in bacteria, Haraway refutes the dominance of self-referentiality: 'nothing makes itself; nothing is really autopoietic or self-organizing ... Sympoiesis enfolds autopoiesis and generatively unfurls and extends it.'[90]

Sympoiesis, making-with, comprises a non-anthropocentric and radically experimental form of collective production. As Hörl argues, sympoiesis expands Marx's human-centred analysis of production, constituting a non-anthropocentric and 'radically environmental reconceptualization of the production and formation of [the] world as such in terms of a movement of the real itself'.[91] Thereby, it provides a counter-model to the un-worldings of Environmentality in the form of trans-worldings.[92] Sympoiesis also figures as a key motif in Chandler's notion of hacking, an affirmative and interactive ontopolitical strategy that transcends the modernist baggage of autopoietic-mapping and homeostatic-sensing.[93] The notion of the hack is understood as an intervention 'to reveal and to construct new relations and interconnections: it does not seek to construct new forms ... but neither does it passively accept the world as it is.'[94] As cultural theorist McKenzie Wark explains, 'the hack produces a production of a new kind ... every production is a hack formalised and repeated on the basis of its representation. To produce is to repeat; to hack, to differentiate.'[95]

As an ontology of entanglement, sympoiesis thus becomes the basis for experimentation and action by way of making new relations, for 'stay[ing] with the trouble of living and dying in response-ability on a damaged earth'.[96] Haraway develops the concept of response-ability from a study on plant-insect entanglements by feminist scholars Carla Hustak and Natasha Myers, who describe it as a feminist ethic 'in which questions of species difference are always conjugated with attentions to affect, entanglement, and rupture; an affective ecology in which creativity and curiosity characterise the experimental forms of life of all kinds of practitioners, not only the humans.'[97] Sympoiesis thus refutes the contemporary tendency of flat ontologies to either foreground the withdrawal of things or over-emphasise connectivity to exhaustion. As Haraway succinctly remarks: 'nothing is connected to everything; everything is connected to something'.[98] Understanding relations as partial and contingent in turn leads to a call for the creation of new material-semiotic entanglements, a speculative fabulation. This is an inherently political production: not a mere responsiveness but a matter of care, a response-able pursuit of the tentacular connections through experimental worldings in a thick present:

> eschewing futurism, staying with the trouble is both more serious and more lively. Staying with the trouble requires making oddkin; that is, we require each other in unexpected collaborations and combinations, in hot compost piles. We become-with each other or not at all. That kind of material semiotics is always situated, someplace and not noplace, entangled and worldly.[99]

Haraway's unfurling and extension of autopoiesis as sympoietic response-ability also urges a renewed ethics and politics of collective production in architecture, landscape and urbanism. This would be a cosmopolitics of partial, asymmetrical and more-than-human relations, manifest in experimental practices of designing-with the myriad of entities bound up with our already-entangled selves.

Conclusion

The course of cyberneticisation that accelerated the eclipse of modernity and propelled the generalisation of ecology has been far from inevitable. In turn, the contradictory circuits of cybernetics in contemporary architectural discourse examined in this article are given new context by reconsidering them within the environmentalitarian epoch. Cybernetics is today simultaneously exalted as a liberatory mechanism for designing emergence, complexity and open-endedness, yet also constitutive of an indiscernible mode of decentralised, environmentally modulated control. Such strategies of indirect control have permeated architecture, landscape and urbanism under various guises: adaptation, responsiveness, cultivation, resilience, conversation, and more. While promising freedom from modernist rigidities, these quasi-cybernetic approaches inherently operate along the same logics as the restrictive ontopolitics of Environmentality. Rather than passively accepting these cybernetic entanglements, questioning, probing, refuting, and eclipsing them are necessary steps towards a critical revaluation of becoming-environmental.

If coming to terms or composing with Gaia is the question of our epoch, the task for designers is to develop new material practices that transcend the fundamental convictions of cybernetic ontology – its self-referentiality and banishing of chance. These new practices require not only a critique of what has come before – a clear-eyed understanding of the homologies of control, capital, neoliberal governance, and architecture under Environmentality – but also new ways of thinking how to live and make together. The heterodox extrapolations of cybernetics evinced by Yuk Hui and Donna Haraway both make the case for new cosmopolitics beyond Environmentality. A common thread running across their interventions is the urgency for designers to adopt an attitude of 'daring humility': a disposition of both speculation and care towards environments out of our control. Through fortuitous modulations and sympoietic experimentations, they unfold cybernetic circuits – reaffirming immanent difference and collective entanglement – on a delightfully messy and open-ended path toward new practices.

Notes

1. Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime* (Cambridge: Polity, 2017), 140–41.
2. Donna J. Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham, NC: Duke University Press, 2016), 33.
3. Yuk Hui, *Recursivity and Contingency* (London: Rowman & Littlefield, 2019), 273.
4. Isabelle Stengers, *In Catastrophic Times: Resisting the Coming Barbarism* (London: Open Humanities Press, 2015), 43–50.
5. Ibid., 48.
6. Ibid., 50.
7. The term ‘Anthropocene’ to describe our epoch is debated. See: Jason Moore, ed., *Anthropocene or Capitalocene? Nature, History and the Crisis of Capitalism* (Oakland, CA: PM Press, 2016).
8. Erich Hörl, ‘Introduction to General Ecology: The Ecologization of Thinking’, in *General Ecology: The New Ecological Paradigm*, ed. Erich Hörl and James Burton (London : Bloomsbury Academic, 2017).
9. Erich Hörl, ‘The Environmentalitarian Situation: Reflections on the Becoming-Environmental of Thinking, Power, and Capital’, *Cultural Politics* 14, no. 2 (July 2018): 153–73.
10. Andrew Pickering, ‘Cybernetics’, in *International Encyclopedia of the Social & Behavioral Sciences* (Elsevier, 2015), 645.
11. Robert Hurley, ‘Preface: Hypothesis on the Hypothesis’, in Tiqqun, *The Cybernetic Hypothesis* (London: Semiotext(e), 2020): 9.
12. Gilbert Simondon, *L’individuation à la lumière des notions de forme et d’information* (Paris: Éditions Jérôme Millon, 2005), 45–48; Gilles Deleuze, ‘Postscript on the Societies of Control’, *October* 59 (1992): 3–7.
13. Fredrik Torisson, ‘The Cybernetic Hypothesis & Architecture’, *Histories of Postwar Architecture* 1, no. 1 (2017): 11–12, emphasis added.
14. Gordon Pask, ‘The Architectural Relevance of Cybernetics’, *Architectural Design* vol. 39 (September 1969): 494–96; Sean Wellesley-Miller, ‘Self-Organizing Environments’, in *Design Participation,* ed. Nigel Cross (London: Academy Editions, 1972), 58–62.
15. For an overview of the cultivation mentality, see Roy Cloutier and Nicole Sylvia, ‘Architecture After Cultivation: Four New Grids for the Great Plains’ (Master’s thesis, University of British Columbia, 2016), online at <https://issuu.com/roycloutier/docs/masters_thesis_-_roy_cloutier_and_n>.
16. Roy Cloutier, ‘“Absolutely Safe, Completely Unpredictable”: Control and Indeterminacy in the Atomic Garden’, *SITE Magazine* 40 (2019): 92–102. On critical spatial praxis, see: Nishat Awan, Tatjana Schneider, and Jeremy Till, *Spatial Agency: Other Ways of Doing Architecture* (London: Routledge, 2011). On cybernetics and conversation, see Thomas Fischer and Christiane M. Herr, eds., *Design Cybernetics: Navigating the New* (Cham, Switzerland: Springer, 2019).
17. Kees Lokman, ‘Cyborg Landscapes: Choreographing Resilient Interactions between Infrastructure, Ecology, and Society’, *Journal of Landscape Architecture* 12, no. 1 (January 2017): 72.
18. Socrates Yiannoudes, *Architecture and Adaptation: From Cybernetics to Tangible Computing* (London: Routledge, 2016), 4.
19. Torisson, ‘The Cybernetic Hypothesis’, 10. See also Robert Somol and Sarah Whiting, ‘Notes around the Doppler Effect and Other Moods of Modernism’, *Perspecta* 33 (2002), 72–77.
20. Luciana Parisi, ‘Computational Logic and Ecological Rationality’, in *General Ecology: The New Ecological Paradigm,* ed. Erich Hörl and James Burton (London : Bloomsbury Academic, 2017), 83.
21. Lokman, ‘Cyborg Landscapes’, 63.
22. Hörl, ‘Introduction to General Ecology’, 8. Note on capitalisation: in keeping with Hörl’s use of the terminology, ‘Environmentality’ denotes the contemporary mode of governmentality, as used by Foucault, whereas ‘environmentality’ refers to a broader sense of the environmental.
23. Ibid., 1.
24. Ibid., 2–3.

25. Erich Hörl, 'The Environmentalitarian Situation: Reflections on the Becoming-Environmental of Thinking, Power, and Capital', *Cultural Politics* 14, no.2 (July 2018): 159.
26. Ibid.
27. Ibid., 154.
28. Ibid., 157.
29. Daniel Barber, 'Environmentalisation and Environmentality: Re-Conceiving the History of 20thc Architecture', *Design Philosophy Papers* 7, no. 3 (November 2009): 148. See also Sven-Olov Wallenstein, *Biopolitics and the Emergence of Modern Architecture* (New York: Princeton Architectural Press, 2008).
30. Ibid., 149–51.
31. Hörl, 'Introduction to General Ecology', 4–5, emphasis added. On the extended history of cybernetics stretching to at least the mid-nineteenth century, see also Alexander Galloway, 'The Cybernetic Hypothesis', *Differences* 25, no. 1 (January 2014): 107–31.
32. N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999).
33. N. Katherine Hayles, 'Unfinished Work: From Cyborg to Cognisphere', *Theory, Culture & Society* 23, no. 7–8 (2006): 161.
34. Ibid., 164.
35. Hayles, *How We Became Posthuman,* 13.
36. Ariane Lourie Harrison, *Architectural Theories of the Environment: Posthuman Territory* (London: Routledge, 2013), 3–33. Donna Haraway, *Simians, Cyborgs and Women: The Reinvention of Nature* (New York: Routledge, 1991), 149–81.
37. Harrison, 'Charting Posthuman Territory', 8.
38. Hörl, 'Introduction to General Ecology', 9 and 48–49, note 20; Andrew Goffey, 'Towards a Rhizomatic Technical History of Control', *New Formations* no. 84/85 (2014): 58–73.
39. Ibid., 9. It is worth noting that third-order cybernetics has been recently theorised as 'self-developing reflexive-active environments.' See: Stuart A. Umpleby et al., 'Recent Developments in Cybernetics, from Cognition to Social Systems', *Cybernetics and Systems* 50, no.4 (May 2019): 367–82.
40. Ibid., 9–10.
41. Erich Hörl, 'Luhmann, the Non-Trivial Machine and the Neocybernetic Regime of Truth', *Theory, Culture & Society* 29, no. 3 (May 2012): 94–121; Tiqqun, *The Cybernetic Hypothesis*, trans. Robert Hurley (London: Semiotext(e), 2020).
42. David Chandler, *Ontopolitics in the Anthropocene: An Introduction to Mapping, Sensing and Hacking* (London: Routledge, 2018).
43. Ibid., xiii, 21.
44. Ibid., 21.
45. Ibid., 42.
46. Ibid., 22.
47. Ibid., 55.
48. Alexander R. Galloway and Eugene Thacker, *The Exploit: A Theory of Networks* (Minneapolis: Minnesota University Press, 2007), 35. Quoted in Torisson, 'The Cybernetic Hypothesis', 5.
49. Torisson, 'The Cybernetic Hypothesis', 14, original emphasis.
50. Ibid., 13.
51. Hurley, 'Preface: Hypothesis on the Hypothesis', 9.
52. Douglas Spencer, *The Architecture of Neoliberalism: How Contemporary Architecture Became an Instrument of Control and Compliance* (New York: Bloomsbury Academic, 2016).
53. Ibid., 45.
54. Torisson, 'The Cybernetic Hypothesis', 14.
55. Chandler, *Ontopolitics in the Anthropocene*, 22.
56. Ibid., 94.
57. Ibid., 107.
58. Halpern, 'Repeating: Cybernetic Intelligence', in *Design Technics: Archaeologies of Architectural Practice,* ed. Zeynep Çelik Alexander and John May (Minneapolis : University of Minnesota Press, 2019), 203.
59. Ibid., 209.
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62. Ibid., 23.
63. John May, ‘Afterword: Architecture in Real Time’, in *Design Technics: Archaeologies of Architectural Practice,* ed. Zeynep Çelik Alexander and John May (Minneapolis : University of Minnesota Press, 2019), 238, emphases in original.
64. John May, ‘Logic of the Managerial Surface’, *Praxis* no. 13 (December 2012): 123.
65. Ibid., 121.
66. May, ‘Afterword’, 238.
67. Chandler, *Ontopolitics in the Anthropocene*, 131.
68. Ibid., 164, emphasis added; Claire Colebrook, *Death of the Posthuman: Essays on Extinction, Vol. 1* (Ann Arbor: Open Humanities Press, 2014).
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70. David Chandler, ‘The Transvaluation of Critique in the Anthropocene’, *Global Society* 33, no. 1 (January 2019): 26–44.
71. Hörl, ‘Introduction to General Ecology’, 3.
72. Halpern, ‘Repeating: Cybernetic Intelligence’, 212.
73. Hörl, ‘Introduction to General Ecology’, 5.
74. Isabelle Stengers, ‘The Cosmopolitical Proposal’, in *Making Things Public: Atmospheres of Democracy,* ed. Bruno Latour and Peter Weibel (Cambridge, MA: MIT Press, 2005), 994–1003.
75. Hui, *Recursivity and Contingency*, 16–17.
76. Ibid., 270, emphasis in original.
77. Ibid., 192–93.
78. Ibid., 18.
79. Ibid., 14, 20.
80. Simon Mills, *Gilbert Simondon: Information, Technology, and Media* (London: Rowman & Littlefield, 2016), 22–23.
81. Gilbert Simondon, *On the Mode of Existence of Technical Objects,* trans. Cecile Malaspina and John Rogove (Minneapolis: Univocal, 2017), 150, quoted in Hui, *Recursivity and Contingency*: 135. This operative notion of information is comparable to the anthropologist and second-order cybernetician Gregory Bateson’s notion of information as a ‘difference which makes a difference’; Gregory Bateson, *Steps to an Ecology of Mind* (Northvale, NJ: Jason Aronson, 1987), 276.
82. Hui, *Recursivity and Contingency*, 14.
83. Ibid., 195.
84. Yuk Hui, ‘Modulation after Control’, *New Formations* no. 84–85 (Winter 2014/Summer 2015): 88.
85. Ibid., 87.
86. Hui, *Recursivity and Contingency,* 273.
87. Ibid., 278.
88. Kane X. Faucher, *Metastasis and Metastability: A Deleuzian Approach to Information* (Rotterdam: Sense Publishers, 2013), 218.
89. Keller Easterling, *Medium Design* (Moscow: Strelka Press, 2017), unpaginated e-book.
90. Haraway, *Staying with the Trouble,* 58.
91. Hörl, ‘The Environmentalitarian Situation’, 165.
92. Ibid., 164.
93. Chandler, *Ontopolitics in the Anthropocene*, 22–23, emphasis added.
94. Ibid., 146.
95. McKenzie Wark, *A Hacker Manifesto* (Cambridge, MA: Harvard University Press, 2004): 158–60.
96. Haraway, *Staying with the Trouble,* 2.
97. Carla Hustak and Natasha Myers, ‘Involutionary Momentum: Affective Ecologies and the Sciences of Plant/Insect Encounters’, *Differences* 23, no. 3 (2012): 106.
98. Haraway, *Staying with the Trouble,* 31.
99. Ibid., 4.

Biography

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Critical Technics in Architecture: A Cybernetic Approach

Zach Mellas

In recent years, there has been a revisiting of the twentieth-century debate surrounding the viability of planned economies and the supposed necessity of market structures, in the face of a declining neoliberal world order and the emergence of new kinds of techniques for processing information that can arguably provide an alternative to market structures. However, this is an insight that has by now informed a number of different views on alternative techno-social principles of productive coordination that are not premised on utilising price signals for resolving questions of organisation, distribution, and agency.[1] These range broadly from seemingly progressive surveillance-technocracy capitalism to especially authoritarian forms of neoliberal capitalism that can both be said to have 'broken free of the shackles of democracy' through the application of new computational technologies.[2] There is therefore a sense in which research concerning data gathering and sensing techniques is arguably tied to a tendency toward different (yet presumably equally un-equal) forms of productive, distributive and social coordination.[3] With this development comes the emerging possibility for a moment of reconfiguration that relates to how these questions are dealt with. One main issue with this observation is that the horizon of that reconfiguration is limited to a very narrow, ideologically defined window of change, dominated primarily by the notion of surveillance capitalism.[4]

Formal complexity

In keeping with this larger tendency, the field of architecture currently lies at the end of its first digital turn, in a nascent second digital turn.[5] Digital technologies have taken on an increasingly important role both as themes within design problems and within the design process itself. There is a rich (recent) history of cutting-edge computational techniques and insights applied in architectural design processes, starting from the first experiments at applying chaos theory and complexity theory by figures such as Peter Eisenman and Charles Jencks, through Christopher Alexander and Cedric Price and their early forms of patterned and generative architecture, and leading eventually to the iconic parametricism of architects such as Zaha Hadid.[6]

This tradition, although certainly more varied than presented here, seems to have concerned itself primarily with the application of the notion of complexity to aesthetic questions – what we might call formal complexity.[7] However, this application leaves something to be desired when taking an immanent view at the capabilities and fundamental functioning of technologies of computation. For this, the work of twentieth-century cybernetic theorist Stafford Beer provides an excellent jumping-off point. Beer was part of the second generation of British cybernetics.[8] His work differed from many of his more commonly referenced peers in that he placed emphasis on the relation between what amounts to an organisational system's *relative democratisation*, and its ability to function in the face of complexity.[9] As such, Beer was concerned primarily with the way in which computation enables and informs particular ways of exercising control within (and not over) complex systems. Formal complexity as an approach to computation reflects what Beer described as using a computer to do quill-pen administration: 'we insist on retaining ... those very limitations of hand, eye, and brain that the computer was invented precisely to transcend.'[10]

Rather than applying digital technology to solve problems in a similar but more expedited way compared to traditional methods, Beer argues that the logic of computation demands a reframing of how we think of problems.[11] Instead of applying computation as an administrative tool, it allows for exploring reality in a different way: through modelling, computation opens new approaches to problem-solving that allow one to interface with multi-causal, complex realities. In some sense, Beer argued for what has become known by now as a general ecological approach to computation.[12] This was a prompt to come up with a different way of using computation; that attempt led him to conclude that what is paramount for any system to be viable is that it is democratically regulated. Democratic control was for Beer the key to avoid catastrophic failure for societal institutions in the face of a changing material environment – a radical cybernetic approach to organisational strategy as an adaptation to what seemed in his eyes an inevitable collapse of the institutions of mid-twentieth-century state capitalism.[13] At the core of this approach lies a belief that practices dealing with physical assemblages – of people and material – are fundamentally concerned with 'the organisational'.

The discrepancy between this approach and the application of digital techniques in architecture as practised today might already be categorised as a general problem, purely because it can be taken to mean that the field of architecture has not yet come to grips with contemporary technological reality and the opportunities it provides for rethinking how problems are constituted in organisational terms, and, more crucially, what appropriate approaches to these problems entail. However, this general observation points towards a much deeper and consequential problem for the field, namely that through a lack of understanding of these technologies, architecture loses its capacity to mediate how they are applied within the built environment. This equates in turn with a reduction in possibilities for architects to engage critically with these developments from their own specific expertise and concerns, positioning architects as 'secondary authors'.[14] To keep up with technical development, and thus to stay relevant as architects, it is crucial that we elaborate on how architecture can critically incorporate digital technology into its activities as a field, rather than allowing the structural mechanisms that underlie much of the development of these technologies to dictate what is and what is not relevant in today's built environment.[15] This highlights the relevance of coming up with a new framework for applying computation within architectural design, attempting to go beyond the pretension of an autonomous body of knowledge centred on 'the singular building', toward an understanding of architecture as a body of knowledge that is premised around and within organisational practice.

Furthermore, in recent years several projects have emerged that explicitly intend to subsume architectural and urban design to the creation of new markets through intensive data gathering, guided by the concept of the smart city.[16] At the basis for these developments is the underlying ideological assumption that the future built environment will be privately owned and operated, including its virtual and physical infrastructure, a move toward a form of surveillance capitalism in keeping with the previously described horizon for change in economic control.[17]

The point of this article is to demonstrate that the only way to harness the emancipatory and productive potentials of computational technology in architecture is through a general socialisation of the architectural process. This would allow architects on the one hand to circumvent the commodification of architectural form and on the other to retain a distinctly architectural sphere of influence around the application of digital technologies within the built environment. More fundamentally, it could provide architects with a method to contribute to a futurity that defies contemporary capitalist realism, through an architectural form that presents itself as a form of realist intervention which can re-organise itself toward desired futurities.

Critical computation

The tendencies described in the previous paragraph call for an examination of the way in which technology is used within architecture. To that effect, this article proposes that we rethink the role of architecture in the application of technology and the role of technology in architecture. I will relate this to one set of digital technologies, which can broadly be categorised as computational design. This might be rephrased as conceptualising how computational design techniques can be used critically. The word critically is used here to refer to a capacity to generate alternatives; a critical use of technology, then, is the application of a technology in such a way as to engender alternative paths of development that are not necessarily limited to the logic of contemporary capitalism.

From this it becomes clear that it is necessary to dispense with the notion that technology is inherently geared towards certain value systems, what might be called a substantive theory of technology. Instead, using the work of Gilbert Simondon and other authors who subscribe to the same position, I argue in the first section of this article for a relational approach to technical development, one based on systems thinking and a particular strand of cybernetics. The reason for this is twofold: it is only through an open-ended conception of technical development that we can arrive at any meaningful formulation of an alternative kind of technicity, rationality, or future. Secondly, the previously described ideological premises for contemporary projects that deal with computational design, and the growing tendency to position architecture as a field for data-gathering within surveillance capitalism together present a certain urgency for architects to develop a grounded position from which to formulate an alternative application of these technologies. This is something that a substantive theory would simply not allow for. Instead of resignation, we would do well to say that architectural value 'is too valuable to be left to capital', echoing philosopher Brian Massumi.[18] As such, I posit, using the literature on cybernetics, that a further integration of sensor technology into the environment likely will not contribute to the overcoming of so-called technical alienation within the built environment. Moreover, later in this article I present the claim that generating any form of emancipatory futurity through computational technology within architecture requires a reorientation of the technicity of the built environment towards the notion of an embedded intelligence in a distinctly politicised and socialised form.

Technical development

Gilbert Simondon describes the development of technics as the shaping of a technical object towards (internal) functional demands.[19] This is referred to as a kind of self-sufficiency – the technical object 'unifies itself internally' towards being a concrete technical object.[20] This is an abstract process, where a technical object's constitutive components become more and more interoperable over the course of their development through 'concomitance and convergence' of multiple, different functions into singular multipurpose structures.[21] Technical objects, for Simondon, behave as evolutionary beings that mutate toward their own inherent fitness curve; the key difference in this regard between natural (living beings) and technical objects (artificial beings) then, is that the former already exist as concrete objects.[22] What is crucial in Simondon's terminology is that the term technical object does not refer to one specific object in space. Instead, it is a more abstract term that refers to a set, or branch, of technologies, such that one would say all attempts at building a combustion engine are part of one unitary, abstract combustion engine.

It is concretisation, for Simondon, that informs the primary path of formation that technologies take, in turn even spawning new branches for other technologies over the course of their development. Simondon's philosophy of technology allows us to think of technicity as an open-ended but structured process, bound to its own internal logic of coherence.

Locus of technical control / technical culture

But what does Simondon have to say about the external factors that constitute this process, the associated milieu of the development of a technology? Within fields of research that study the development of technology, there are several theories that seek to explain how technologies are construed; the clearest division here lies between what might be categorised as a constructivist theory of technical development and an instrumentalist theory. It is relevant to combine a reading of Simondon with the critical philosophy of technology outlined by Andrew Feenberg, particularly his concept of the 'technical code'. For Feenberg, a technology is a scene of struggle between the workers or operators of a technology, and those who manage it – both have their own connotations with a technology and its development, and thus their own requirements and demands of that technology. Feenberg, in this sense, follows Bruno Latour's formulation of a 'parliament of things'.[23] Contrary to Latour, however, Feenberg identifies that there is no levelled-off network of actors without power or hierarchy; instead, political struggle is inscribed in the way a technology manifests over its lifetime. What is stressed here is the ambivalence of technology – as a process, not a thing. Feenberg describes technology as a structure that develops over time and is influenced from myriad directions, and similarly influences the culture it is embedded in – a relational account that resembles Simondon's notion of modulation. This leads Feenberg to the conclusion that what is needed is to democratise technical development through 'a shift in the locus of technical control'.[24]

The development of technology is underwritten by the way in which it encodes a cultural configuration; Feenberg argues that it is in fact here that technology can serve to cement or lock in emancipatory views in society. After this, it becomes part of the way things nominally are – as a new kind of norm. This constitutes an affective dimension to technical development where it is the imaginaries and visions that a technology brings into the world that create meaningful contributions on a cultural level. Feenberg stresses that it is through this locking-in of imaginaries that the coherence of societal alternatives might be demonstrated and in turn made business as usual.[25] This could be rephrased in Simondonian terms as saying that what matters for Feenberg is the associated milieu that is created through technics. Invention is the process wherein the information contained in this milieu is transduced into a new technical schema – it is passed on as a form of transindividual knowledge.[26] Feenberg then, offers us through Simondon a way of conceptualising technics in a critical way: through modulation of an environment one might influence the constitution of future technics.

This is a useful way of formulating a notion of criticality considering technology as a field of political struggle; what is needed, then, is a way of orienting this modulation towards particular alternatives. What Feenberg points to is the asymmetry of the political arena within which this modulation takes place, centring the notion of a technical class struggle in line with traditional Marxian analysis. However, with his concepts Feenberg is at first glance concerned primarily with resolving the apparent contradictions between reified notions of culture and technology through his notion of a technical culture; his concept of the technical code is ostensibly cultural, a code between participants in society. However, beyond the cultural level, there are internal dynamics and logics that govern how processes unfold within the world. While there likely exist a number of these logics that do have some cultural expression or even take place on the cultural level in their totality, it seems insufficient to restrict one's analysis only to this. This means that rather than modulating the operations and structures that constitute technical objects, it is necessary to examine how one might go about modulating the logics that govern their genesis – the formulation of a metalogic.

Systems-view and futurity

Both Feenberg and Simondon describe the genesis of technology as a system in all but name, consisting of codes, rules and logics that govern the specifics of a technology's coming-into-being. One way of making this explicit is by generalising the common conception of technical development as a linear process from point A to point B, into a multi-dimensional field, where it is the logics that govern the topology of the space of possible outcomes that a particular technology might follow. As Marx and Engels posit in *Capital*, the conditions of a movement beyond capitalism 'result from the premises now in existence'.[27] When discussing these conditions in relation to technology from a Marxian standpoint, the process in which these technologies are produced and the way in which they are integrated into processes of social (re)production take on central importance.

We might interpret this in a way that lends itself to Simondonian terminology: it is only when present organisational and technical conditions reach a metastable state, one of oversaturated potentiality, that transduction into new forms of organisation can take place. A key component of the notion of transduction is that it is a transmission of information *through* material; this is the central thesis of Simondon's work on individuation against hylomorphism, and the place where his concept of modulation comes in. As such, one might more precisely state that this transduction relies on specifically material encodings of organisational forms. Philosopher Bernard Stiegler, following Simondon's work on technics and mechanology, argues that this takes place through the genesis of technical systems.[28] Through internal evolutionary tendencies, technical systems induce internal changes, which necessitate socio-technical changes on other levels of societal becoming. Stiegler notes that 'these adjustments constitute a suspension and a re-elaboration of the socio-ethnic programs or socio-political programs that form the unity of the social body'.[29] This view, which Stiegler terms *'organology'*, underscores the fundamental connections that exist between technical and social systems. As such, Stiegler's work serves to emphasise a point that is central to this article: that there exists a reciprocal relation between technical systems and social systems – both systems forming part of one another's associated milieu. Applying Stiegler's organology to Feenberg's thought points clearly towards a logic that takes place on a separate level from the cultural. In a sense, Feenberg's notion of a critical technology is a form of socially mediated but unidirectional technical genesis: effecting changes in an environment with the aim of changing future technicity. Stiegler argues that these changes in technicity have the potential to be foundational beyond the ways that Feenberg describes – implementing not just imaginaries of alternatives, but in fact generating a localised reconfiguration of the social-political domain. Beyond this, it can be argued that it is technicity itself that enables the concept of futurity.[30] It is through inscription that a reference point can be retained, without which one would be limited to experiencing a present.[31]

To Stiegler, this relies on the premise that ways of thinking are informed by technical conditions: as such, technical objects can be said to create their own subjectivity in those that are subject to their use. A psycho-social individuation takes place through technical objects, which then contributes to collective ways of thinking, thus constituting a circuit of transindividuation.[32] Following Simondon, Stiegler argues that this proceeds through the spatialisation of temporal forms of reason, which today can be said to take the shape of data-gathering through sensing technologies. However, this is primarily a one-way process as well: surveillance technologies impose a particular subjectivity, but the private ownership of these systems and, stemming from that, their black-box nature, do not allow for any reciprocal influence on the logics that govern these technical objects.[33] Where they do, this influence is mediated through an internal tendency toward technocratic barriers; a sufficient level of understanding of and engagement with ambient sensor technology is often required to even have an overview of its capacities and features, and thus, to conceptualise how it might be applied, changed, hacked or adopted. Arguably, this amounts to a cut-off of so-called smart systems from paths of individuation that take place through struggle, transindividuation or democratic control.

This line of thought is compatible with contemporary Marxian views on processes of subjectification that take place under capitalism.[34] In particular, they resonate with the notion that different technical (and thus (re)productive) conditions generate different emancipatory goals, subjects and processes, beyond an essentially monolithic, trans-historical understanding of class. In contrast to Feenberg, this is a decentring of a singular historical class struggle as the main engine of technical genesis. Instead, this view relies on the notion that what has changed fundamentally since Marx's time is that there is no longer a concept of a universal, trans-historical emancipatory subjectivity to speak of; as such, one arrives at a theoretical vantage point where different, distinctly historical subjectivities carry their own potential for an idiosyncratic emancipatory futurity. Thus, this is an argument that opens a critical capacity, as defined earlier in this article. Fundamentally, this position comes with several consequences attached. Primarily for this article, it implies an opening up of futurity – not merely beyond transhistorical notions, but in addition beyond what might be referred to as a 'residual linearity and humanism'.[35]

In summary, this section has described how technical development possesses potentials: it can occur across a multitude of paths. As such, it produces what one might term outcomes, which are contingent on material conditions within an environment which determines the limits of technical potential. In cybernetic terms, this amounts to the description of a system.

Complexity and variety

Considering technical development as a system opens a number of avenues of investigation, primarily by allowing us to specify further how that system might be influenced and to ask from which loci and through which logics this might proceed to shape technical genesis toward desired outcomes. This would result in a critical system of technics that takes on the form of a regulator, in traditional cybernetic terms.[36] To characterise this critical system I refer to Stafford Beer, who represents what Stiegler describes as the new basis of cybernetics, as opposed to the popular conception of cybernetics as a military, controlling technicity that is more commonly associated with Norbert Wiener.[37]

Beer offers us a compelling line of reasoning to reject the data-driven paradigm of digital computation that drives on a logic of representation: digital machines 'are pre-occupied with access'.[38] This is in reference to the fact that control-systems, the predecessors to contemporary digital systems, were built to generate intermittent output, in the form of printouts, during a process of computation. The result is a paradigm of computation that is charged with getting representable answers to questions, whereas the most important result of a computational system in the cybernetic view is performative. In his sociological history of British cybernetics, Andrew Pickering emphasises that cybernetics is the navigation of a field *without* a representative mapping of it, as with a steersman (*kubernetes*) navigating toward a distant light on the shore through incremental adjustments. Pickering aptly characterises the demand for overview in terms of representative models as 'an enormous detour … into and through a world of symbols'.[39] This observation can be brought back to contemporary digital practice in architecture: the dominant form of building information modelling relies entirely on the classification of designs into categories, types and elements and on symbolic representation – embraced primarily for the ability to generate intermittent printouts in the form of construction inventory and cost estimations.[40]

In contrast, Beer's position towards hylozoism and the agency of matter seems more in line with Simondon's concept of modulation; both presuppose that material itself can facilitate an operation without a subjection of matter to form, and without the imposition of an ideal, or blueprint that precedes this emergent process of *in-formation*. For Simondon, this is primarily observed within the development of technics according to its own logic, for Beer, it is organisations of people that self-organise. By looking for appropriate types of matter already in existence, one can engage in the world as it is offered, and thus engage it in a relational way.[41] Furthermore, it is for Simondon precisely this attitude of considering an object within its milieu, that opens the space of what is possible – its field of potential. Simondon develops a convincing argument for technicity that is thoroughly embedded in its associated milieu by way of concretisation. He demonstrates that it is through a synergy between a technical object and its environment that new potentialities can be rendered accessible, as with the example of the Guimbal Turbine.[42]

Ultimately, a seemingly similar line of thought leads for Beer to an ambition to formulate a paradigm of biological computation as something radically distinct from what is conventionally seen as computation, even today – as a form of computation that relies on ecological systems that are found as they are in the world.[43] He arrives at this through his concept of exceedingly complex systems, arguing that while our representational logic cannot meet the variety in these systems with adequate reciprocal variety, another naturally complex system such as the complex system of a pond might.[44] Here it is important to note that Beer inherits from his forerunner, the early cybernetician and psychiatrist Ross Ashby, the notion of regulatory variety matching system variety. This resembles a process of adaptation within a system to its milieu, much like the genesis of technology as described by Simondon.[45] Simondon has been described as a proto-cybernetician – as such there are several similarities between his work on technicity and that of later cyberneticians such as Ashby, Pask and Beer.[46]

How does this concept of variety fit in with contemporary paradigms of computational technology within the field of architecture? For some, by taking contemporary technics in the direction of 'animate knowledge', where one might argue that we have today the technical means to animate our inanimate surroundings through ambient sensor technology (by now mostly garnered under the concept of big data).[47] Through this animation some argue we can overcome technical alienation – the seemingly inherent effect by which technics mediate our access to the world as it is constructed through them.[48] This strategy amounts to matching natural variety with technical variety; it is implied that this technical variety would somehow amount to the level of variety that occurs in living systems by the choice of words. Notably, this is a move that follows the principles described so far: in animating an environment through ambient technology, a designer intervenes in the milieu of a system, changing the terms on which interaction between systems take place. Through Ashby and Beer's line of reasoning it could, however, be argued that it is precisely this impulse to seek greater and more complex technics that affects technical alienation. This is a consequence of the inadequacy of technical variety in matching living system variety (which, to Beer, stands apart as exceedingly complex). As a result of this discrepancy, reduction and normativity become necessary tools to keep the technical system viable. This amounts to an asymptotic complexification: a greater and greater animation of technical systems, that might eventually approach exceeding complexity, but for the foreseeable future remains distinctly lacking in variety.

Metastability

If one follows Beer's categorisation, the discrepancy between complexity and exceeding complexity outlined in the previous paragraph points toward a certain limit with regard to how well technical systems might interface with their environment. While I have so far highlighted a number of similarities between Simondon and Beer's work, there are also key differences that become evident particularly with this limit in mind, one of which is particularly relevant for this article: as media theorist Simon Mills argues, Beer and others working within the tradition of his Viable Systems Model (VSM) do not describe a mechanism that accounts for novelty in complex systems. By basing their model on homeostasis and ultrastability, there is little room left for a concept of invention.[49] Accordingly, this view of social organisation works only when one assumes that all interactions are probabilistic – a 'removal of the indeterminism and novelty from the domain of the social'.[50] He further argues that this amounts to a disregarding of politics in favour of technocratic logic, as politics is precisely the mechanism that resolves indeterminism in the social domain.

What Mills's critique highlights most of all with regard to the main question of this article is the importance of invention – systems that evolve through metastability rather than the more commonly described concept of equilibrium stability. In Simondon's terms: going beyond being 'enslaved by the finality of the whole' through unremitting re-organisation.[51] Another way of describing this is as self-production (autopoiesis), rather than solely self-reproduction (or self-regulation). Autopoietic systems can be categorised as systems that can re-inform their internal configurations: through metastability, these systems have the capacity to generate new states, and as such are continuously in a state of becoming, rather than being.[52] Metastability brings us back to Feenberg: his conception of a critical technology relies on a capacity for reorganisation which lies within the political. Bearing the notion of autopoiesis in mind, this can be rephrased as centring the decision-making (and thus informing) capacity of social processes: a step in the direction of a distinctly politicised cybernetic approach to technicity.

Radical cybernetics

Bringing a politicised cybernetic approach to the products and processes of architecture means doing away with architectural authorship along the way. It would entail an explicit move toward an architecture of many hands. According to Mario Carpo, this is something that is probably opposed to the professional interest of many designers.[53] Accordingly, in Feenberg's terms, this is a concrete example of the technical code in action: 'it is specifically armoured against the recognition of many participant interests' through the operational autonomy of its managers'.[54] As such, moving towards a politicised approach requires more than the intention and commitment of individual actors. It therefore points again at the necessity of encoding this move into a technical necessity (what I referred to before as a metalogic).

I have so far argued that one can characterise technical development as a system. Therefore, it is a contingent process that is embedded within an environment – most concretely in terms of the limits to potential, in terms of what is considered possible, and in terms of what is viable. Moreover, considering technics as a system means accepting that it is fundamentally political in nature – for social systems, their capacity for informing is related to the degree to which a system can resolve indeterminacy. This is in turn tied to the level of complexity that a system holds. In order to interface with the exceedingly complex, autopoietic nature of the built environment then, there is a sense in which current models of architectural practice fall short.

This becomes particularly clear when one considers the notion of failure and its relation to invention and reorganisation. Stafford Beer's original work on cybernetics hinged primarily on the notion of viable systems – autopoietic systems that can retain their functioning in light of any environmental change, and therefore necessarily have a capacity for self-reorganisation. For this, a system has to sacrifice its direct functionality in the following way: a system that is narrowly functional is limited to a very specific given set of rules; when these rules no longer manage to adequately enable the system to interface with its environment, it fails.[55] Crucially, the specificity of a system's rules constrains the complexity of the system, meaning that it cannot meet the variety of its environment. As such, the point can be made that for a system to be viable, it must have a level of plasticity; it has to be able to reorganise its governing logic in light of environmental change.[56] This is a point that Simondon elaborates on more fully: it is not just that functionality negatively impacts a system's plasticity, but more generally, that it is through a greater level of abstraction away from functional demands that a technical object is made open to multifunctionality, and thus further concretised.[57]

The conclusion of this argument is that for any meaningful concept of change, and thus futurity, to arise a system must be specifically porous in its governing logic, especially with regard to its environment. In the context of organisational systems, this interaction fundamentally relies on humans. If one intends to engender a critical form of technics there, this social basis can be taken to indicate that what is crucial for any sort of autopoiesis to arise is a direct relation between the subjects of these processes and the system that is being designed.

This reasoning can be extended by looking at contemporary literature on the research into artificial intelligence – currently, there is a growing acknowledgement of what might be referred to as embedded cognition or situatedness, and its importance in *nurturing* any intelligence toward greater levels of complexity, influencing both the dominant paradigm in artificial intelligence and, coincidentally, contemporary cognitive science.[58] What is relevant to this article is that there is a sense in which current paradigms of cognition and (artificial) intelligence recognise the importance of *material (re)organisation* in shaping systems' behaviours through the concept of autopoiesis.[59] Moreover, it has been argued that any venture into the creation and maintenance of general intelligence systems seemingly has to rely on a distribution, and thus exteriorisation, of intelligence.[60] This 'offloading of our cognitive processing into the environment' is what allows an understanding of intelligence as a distributed phenomenon – a process that takes place through a network of technical and biological individuals in the Simondonian sense.[61]

Architecture and a critical technicity

Returning to the central question of this article then, it might be argued that one way of modulating the outcomes of technical development lies with this environmental porosity and its relation to cognition as a network of technical and biological individuals. Within an architectural context it is important to emphasise that this environment consists in more than purely the physical boundaries and objects that surround an intervention; instead, the broader positioning of an object within its physical, ideological, technical and social context defines an overarching system-environment that building occupants interface with during their stay in, or use of, a building.

Crucially however, the component that takes this architectural environment beyond the traditional notion of an architectural context, as these aspects are commonly called, is its change over time. By foregoing the nature of architecture as a process that unfolds over time, I would claim that architectural practice is relieved of discussing and perhaps even conceptualising this part of an intervention. As such, one might argue that architecture lacks a form of retention that would enable the formation of a critical technicity in the built environment.

This is especially evident if one considers that the transmission of architectural design intentions relies first and foremost on static images – snapshots of an intervention's lifetime, often limited to the image of a newly built structure. One might thus posit that architecture as a discipline in its current form has no 'memory-for-time' that enables designers to grapple with these questions and to participate in the shaping of futurity when it comes to the lifetime of the building in any conscious manner.

As I have outlined in the previous sections, the notion of development *in se* is premised on change over time. For any meaningful conception of a technical development within the built environment itself, and not external to it, a centring of this understanding of architecture as a system is required, and thus, an understanding of the architectural intervention as a continuous moment – a proceeding intervention. Crucially, one can then consider the aforementioned processes of invention and individuation of technics within the architectural process. From there, if one's aim is to in-form a particular emancipatory futurity, the necessity of a relational approach is apparent: the potential for this futurity, and its proceeding invention, is – through autopoiesis – fundamentally tied to plasticity and situatedness.

If one's intention is indeed to maximise the multiplicity of emancipatory outcomes that a system can generate, then due to the nature of the process of in-formation being premised on the resolution of indeterminism, a key role in this system lies with its integration with one particular aspect of its environment, namely the biological entities that occupy it. A critical technicity within architecture then, is one that is premised on a politicised architectural process, providing the capacity for the emergence of new rules and logics that follow from reconfigurations of the *unity* that defines the total relation between building, environment and user. This is a dance of continuous reinvention on the part of both architectural intervention and occupant, a 'technicity that determines the potentials of a shared becoming' between technical and physical individuals.[62]

Notes

1. Nick Srnicek, *Platform Capitalism* (Hoboken: Wiley, 2016), 54, 55.
2. Slavoj Žižek, 'Capitalism Has Broken Free of the Shackles of Democracy', *Financial Times*, 1 February 2015.
3. Shoshana Zuboff, 'Big Other: Surveillance Capitalism and the Prospects of an Information Civilization', *Journal of Information Technology* 30, no. 1 (15 March 2015): 75–89.
4. Ibid.
5. Mario Carpo, *The Digital Turn in Architecture 1992–2012* (Hoboken: Wiley, 2013); Mario Carpo, *The Second Digital Turn: Design Beyond Intelligence* (Cambridge, MA: MIT Press, 2017).
6. Douglas Spencer, *The Architecture of Neoliberalism: How Contemporary Architecture Became an Instrument of Control and Compliance* (London: Bloomsbury, 2016); Giuseppe Rega and Valeria Settimi, 'Nonlinearity in Architecture versus Science: Borrowing the Lexicon of Complexity or Exploiting Its Powerfulness?', in *Structures and Architecture*, ed. Paulo J. S. Cruz (London: Taylor & Francis Group, 2010), 167–74; Leonard R. Bachman, 'Architecture and the Four Encounters with Complexity', *Architectural Engineering and Design Management* 4, no. 1 (6 January 2008): 15–30.
7. Rega and Settimi, 'Nonlinearity in Architecture'.
8. Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2010).
9. Democratisation is not Beer's term as used in his technical writing – instead, Beer refers to a kind of autonomy at different levels within an organisation, so that decisions can be decentralised. This was the basis for his management theories and models, where too much hierarchy is seen as inhibitive to the self-organising capacity of a system. See: Pickering, *The Cybernetic Brain*; Thomas Swann, 'Towards an Anarchist Cybernetics: Stafford Beer, Self-Organisation and Radical Social Movements', *Ephemera* 18, no. 3 (2018): 427–56.
10. Stafford Beer, *Designing Freedom* (Hoboken: John Wiley & Sons, Ltd., 1974), 32–33.
11. The creation of complex geometric patterns and forms has been a central pursuit for many architectural

designers throughout the history of the practice, often with very successful and highly complex outcomes in terms of ornamental design. Contemporary design practice in this sense uses digital computational technology in a way that differs little from how it has used pen and paper throughout history – for drawing, geometrical construction and classical calculation.

12. See Erich Hörl, 'Introduction to General Ecology: The Ecologization of Thinking', in *General Ecology: The New Ecological Paradigm*, ed. Erich Hörl and James Burton (London: Bloomsbury Academic, 2017), 1–74.
13. Beer, *Designing Freedom*.
14. Mario Carpo, *The Alphabet and the Algorithm* (Cambridge, MA: MIT Press, 2011), 126.
15. This refers in particular to the external nature of many of these developments to architecture. While there are many architects attempting to 'design their way around' technologies that are in development, their original articulations and manifestations are presumably not elaborated by architects in most cases. This leaves any architectural application as an appropriation of existing invention, and thus risks both shoe-horning technologies into architectural practice, and unwarranted solutionism. See: Douglas Murphy, *The Architecture of Failure* (Winchester : Zero, 2012).
16. Adam Greenfield, *Against the Smart City* (London: Verso, 2013).
17. Adam Greenfield, *Radical Technologies: The Design of Everyday Life* (London: Verso, 2017); Matthew Poole and Manuel Shvartzberg, *The Politics of Parametricism: Digital Technologies in Architecture* (London: Bloomsbury, 2015).
18. Brian Massumi, *99 Theses on the Revaluation of Value: A Postcapitalist Manifesto* (Minneapolis: University of Minnesota Press, 2018), 2.
19. *Technics* refers here specifically to technique, as opposed to the more general English term *technology* which may refer to technique, technical objects and the study of technical objects. See Andrew Iliadis, 'Informational Ontology: The Meaning of Gilbert Simondon's Concept of Individuation', *Communication +1* 2, no. 1 September (2013): 1–18, https://doi.org/10.7275/R59884XW.
20. Gilbert Simondon, *On the Mode of Existence of Technical Objects*, ed. and trans. Cécile Malaspina and John Rogove (Minneapolis: Univocal Publishing, 2012), 26.
21. Iliadis, 'Informational Ontology', 15–16; Simondon, *On the Mode of Existence of Technical Objects*, 28.
22. Ibid., 51.
23. Andrew Feenberg, *Transforming Technology: A Critical Theory Revisited* (Oxford: Oxford University Press, 2002), 30.
24. Ibid., 32.
25. Feenberg, *Transforming Technology*.
26. Simondon, *On the Mode of Existence of Technical Objects*, 252.
27. Nicholas Thoburn, *Deleuze, Marx and Politics* (London: Routledge, 2003), 3.
28. Bernard Stiegler, 'General Ecology, Economy, and Organology', trans. Daniel Ross, in *General Ecology: The New Ecological Paradigm*, ed. Erich Hörl and James Burton (London: Bloomsbury Academic, 2017), 129–50.
29. Ibid., 130.
30. Stiegler's retentions. Similarly, for Feenberg, within technological historicity, this happens through the technical code.
31. Claire Colebrook, 'Futures', in *The Cambridge Companion to Literature and the Posthuman*, ed. Bruce Clarke and Manuela Rossini (Cambridge: Cambridge University Press, 2016), 196–208.
32. Stiegler, 'General Ecology, Economy, and Organology', 137.
33. Zuboff, 'Big Other'.
34. I am here refering specifically to what is commonly known as value-form theory . See Edith González, 'From Revolution to Democracy: The Loss of the Emancipatory Perspective', in *Open Marxism 4*, ed. Edith González, Ana Cecilia Dinerstein, Alfonso García Vela and John Holloway (London: Pluto Press, 2019), 155–67. https://doi.org/10.2307/j.ctvs09qng.15.
35. Colebrook, 'Futures', 13.
36. Roger C. Conant and Wilbur Ross Ashby, 'Every Good Regulator of a System Must Be a Model of That

System', *International Journal of Systems Science* 1, no. 2 (8 October 1970): 89–97.
37. Stiegler, 'General Ecology, Economy, and Organology'.
38. Pickering, *The Cybernetic Brain*, 235.
39. Ibid., 235.
40. Carpo, *The Second Digital Turn*, 5.
41. Ibid.
42. Simondon, *On the Mode of Existence of Technical Objects*, 57.
43. Pickering, *The Cybernetic Brain*, 231.
44. Variety, in cybernetic terminology, is defined as the amount of possible states or outcomes that a system has. See: Stafford Beer, 'The Will of the People', *The Journal of the Operational Research Society* 34, no. 8 (August 1983): 797; Andrew Pickering, 'The Science of the Unknowable: Stafford Beer's Cybernetic Informatics', *Kybernetes* 33, no. 3/4 (2004): 499–521.
45. W. Ross Ashby, 'Requisite Variety and Its Implications for the Control of Complex Systems', in *Facets of Systems Science* (Boston, MA: Springer US, 1991), 405–17, https://doi.org/10.1007/978-1-4899-0718-9_28; Conant and Ashby, 'Every Good Regulator'.
46. Andrew Pickering, 'Cybernetics and the Mangle: Ashby, Beer and Pask', *Social Studies of Science* 32, no. 3 (2002): 413–37; Pickering, *The Cybernetic Brain*; Andrew Feenberg, 'The Internet as Network, World, Co-Construction, and Mode of Governance', *Information Society* 35, no. 4 (8 August 2019): 229–43.
47. Neil Leach, 'Adaptation', in *Architecture and the Machinic: Experimental Encounters of Man with Architecture, Computation and Robotics*, ed. Arie Graafland and Dulmini Perera (Köthen: Hochschule Anhalt, Hochschulbibliothek, 2018), 46–59.
48. David Cunningham and Jon Goodbun, 'Marx, Architecture and Modernity', *Journal of Architecture* 11, no. 2 (2006): 169–85.
49. Simon Mills, 'Simondon and Big Data', *Platform: Journal of Media and Communication* 6 (2015): 59–72.
50. Ibid., 6.
51. Simondon, *On the Mode of Existence of Technical Objects*, 119.
52. See: Francisco Varela, Humberto Maturana and Ricardo Uribe, 'Autopoiesis: The Organization of Living Systems, Its Characterization and a Model', *BioSystems* 5, no. 4 (1974): 187–96.
53. Carpo, *The Second Digital Turn*, 143.
54. Feenberg, *Transforming Technology*, 22.
55. David Bates and Nima Bassiri, *Plasticity and Pathology: On the Formation of the Neural Subject*, (New York: Fordham University Press, 2016), 205–6.
56. Bates and Bassiri, *Plasticity and Pathology*,194–218.
57. Stavros Kousoulas, 'Shattering the Black Box: Technicities of Architectural Manipulation', *International Journal of Architectural Computing* 16, no. 4 (2018): 295–305.
58. Tom Froese, 'On the Role of AI in the Ongoing Paradigm Shift within the Cognitive Sciences', in *50 Years of Artificial Intelligence: Lecture Notes in Computer Science* vol. 4850, ed. Max Lungarella, Fumiya Iida, Josh Bongard and Rolf Pfeifer (Berlin, Heidelberg: Springer, 2007), 63–75; Randall D. Beer, 'Dynamical Systems and Embedded Cognition', in *The Cambridge Handbook of Artificial Intelligence*, ed. Keith Frankish and William M. Ramsey (Cambridge: Cambridge University Press, 2014), 128–51.
59. Ibid.
60. Benjamin Bratton, 'Outing Artificial Intelligence: Reckoning with Turing Tests', in *Alleys of Your Mind: Augmented Intelligence and Its Traumas*, ed. Matteo Pasquinelli (Lüneberg: Meson press, 2015), 69–80.
61. Beer, 'Dynamical Systems and Embedded Cognition', 131.
62. Kousoulas, 'Shattering the Black Box', 6.

Biography

Zach Mellas is a design engineer currently working in the Netherlands. He received his undergraduate and graduate degrees from Delft University of Technology. During his Master of Science in Architecture, Urbanism and Building Sciences he studied and developed interactive digital systems with the aim of centring democratic design processes, starting from architectural theory and critical philosophy of technology. His research interests include cybernetics, prefabrication, design automation, organisational theory and computational design.

Architecture as an Information Machine

Tewfik Hammoudi

> There is an ecology of ideas, just as there is an ecology of weeds.
> Gregory Bateson,1972[1]

> It is much more beautiful to know something about everything than to know everything about something.
> Blaise Pascal,1974[2]

It is said that Newton revealed the depths of human ignorance with the immensity of his discoveries. Nowadays, health and environmental crises express not only our current inability to respond when such crises occur but essentially our abyssal ignorance of the complexity of the world we live in. The old paradigms used to study phenomena and to develop strategies based on separate issues and approaches no longer seem efficient. Our traditional and mainstream nature/culture dichotomy is being called into question, day after day, by the entangled challenges of knowledge, acting and designing. Cities, built environments, social interactions, territorial governance policies and environmental agendas are bringing crucial questions to architecture as a discipline, ones that may completely recast its foundations. Problems of high complexity in architecture and urban planning cannot be addressed by the usual 'design' approach anymore. These problems involve speculation on the past, present and future of the built environment as an *œkoumène* intertwining various interdependent dimensions and scales, as well as on new paradigms and new theoretical and practical tools that make it possible to share questions, bring together disciplines and participate in forging an object of knowledge to help us think, act and design relationally. With this in mind, this essay I propose ways of connecting fields of reality that all too often have been considered in isolation. I therefore seek to identify opportunities to better facilitate the understandability of territorial systems and to engage in singular relationships with things and beings.

Architecture and complexity

The intuition that the territory is a complex reality is certainly an almost banal observation today. Indeed, this was the argument advanced by the postmoderns in the last century in order to disqualify the modern project, considered disembodied and simplistic. However, postmodern ideology generally contented itself with simply stating this complexity, far from revealing the system organising it along with its constitutive heterogeneous elements and the contingent and necessary relations that bind it. The most frequently used leitmotif is that of language.[3] Thus, complexity was no more than an ambiguous collection of disparate and equivalent signs provided by history or the production of the time. Among the works exploring more analytical or systematic approaches, there were those of Kevin Lynch, Christian Norberg-Schulz or even Aldo Rossi and Tendenza. While these approaches placed the question of form and its requirements at the centre of their concerns, neither the phenomenological and gestaltist approaches of the first two, nor the typological rationalism of the latter succeeded in exposing the complex system of forms, its evolutions or transformations, nor how to achieve it.

Thus, the complexity described by architectural theory and practice fascinated, frightened or stupefied in equal measure. Furthermore, whether out of cynicism or catastrophism, a disillusioned postmodern relativism took hold. Only micro-narratives, micro-structures, micro-organisations and other such concepts were regarded as relevant. In response to this complexity, some architects and planners experimented with functional programmatic strategies and abstract geometric manipulations, which were therefore repeated indefinitely here and elsewhere as fragments emerging from unhistorical entities. In this same period, as well as more recently, other visions advocated the 'local project', spontaneous processes, tactical town planning, and so on, as if to say that the territory is only a sum and an accumulation of small and flexible interventions without any planning, or a result of very local specific conditions identified a priori as being at the appropriate scale and the core issue. One of the predicaments of deconstruction today is to locate the answer to the complexity problem in architecture at the level of computational machines and algorithmic processes.[4] Here, the complexity of architectural forms is usually considered – rarely that of the territory – but only in their physical and structural conformations as pointed out by Sanford Kwinter.[5] It is primarily invoked metaphorically or through borrowed mathematical models belonging to other fields of knowledge to design new algorithmic-generated forms.[6] It is rarely used to analyse existing forms and their irreducible enclosed multiple dimensions. Today's machine and digital practices are conducive more to making shapes than understanding forms. Is this situation integral to the machine and the tools with which architects and planners continue to work? Is there a machine that could be seen and characterised as a tool to reveal the inherent formal complexity of the territory and built environment, and to make it effectively available for designing and empowering action?

Architectural machines

The use of the word 'machine' is quite common among architects, theorists and architectural historians. This is true not only in the modern era and in the wake of the Industrial Revolution or today in the post-industrial age, but also in antiquity.[7] In Book I, Chapter III, Vitruvius assigns to the architect not only the task of knowing how to build buildings, but also machines: gnomons, clocks and engines used for architecture and war.[8] However, once one looks beyond the more or less metaphorical discourses with pejorative or meliorative connotations (that is, Le Corbusier and his detractors) and attempts to transpose machinic processes or imaginaries – whether mechanical or electronic and digital) – to architecture (buildings, urban proposals, conceptual models and generative algorithms), nagging questions remain. They continue to be heard in the background despite the agitation of theorising exegetes, classifying historians or avant-garde analysts. Why should architecture be a machine? And if we do consider it as a machine, does this apply only to the building or also the discipline and the profession? How can the architect become – or remain, as Vitruvius wanted – a machine builder? What is the machine today?

Without going into lengthy subtle explanations to distinguish the definitions of words such as machine, tool, mechanism, automaton and so on, we can limit ourselves here to following and simplifying the history or the evolution of what are commonly referred to as machines and their properties.[9] Thus, historically we can notice that we have three kind of machines: simple machines, motorised machines and 'information machines'. Simple machines include levers, winches, pulleys, polyspasts, clocks, lathes, mills and other more or less complicated mechanical devices involving the force/displacement ratio. The motorised machines characteristic of the nineteenth century such as fire engines, steam engines, gas engines, and the like were based on the principles and findings of thermodynamics, where one type of energy (thermal, pressure, kinetic, potential, and so on) transforms into another. Finally, the information machines developed in the twentieth century are, above all, machines for transmitting or receiving information, whether natural or artificial.[10]

Invented in the 1940s, cybernetics, as founded and named by Norbert Wiener, is the science of information machines. It studies the transmission of messages, their speed of propagation, their probability, their redundancy, the quantity of information they contain, and so on. It is therefore the study of messages and, in particular, the effective control of messages that characterise 'self-governed' systems. They are information and control machines driven by information. Cybernetics imagined these machines that inform each other and inform themselves, doing away with the boundary between automatic machines and living beings. However, as science journalist Pierre de Latil anticipated from early on, today we increasingly observe these machines in the general system of nature. Cybernetics was well prepared for this since, as Wiener put it, 'the world [is] made up of *models'* (patterns).[11] A model is 'essentially an arrangement. It is characterised by the order of the elements of which it is made rather than by the intrinsic nature of these elements.' And he adds that 'it then becomes easy, without risk of confusion, to use a *model* in which several subsidiary *models* are placed one above the other, then to separate them so as to find themselves placed side by side'.[12] Cybernetics can therefore be understood as proposing formal conceptualisations that would allow approximate constructions and general explanations.

From the manufacture of 'fact machines' – simple or motorised machines – we have moved on to the construction of 'theory machines' or 'sign machines'. Any model becomes, in law, a machine to inform, but also to reason. And, as John von Neumann noted very early on, the complexity of physical objects and phenomena calls for a complexity of theoretical constructions and models.[13] Generalisations, constructs, and models became the signs and the schematisations of a science of signs. General system theory then provides a framework for such inquiry into the nature of systems and contributes to designing a 'systemic approach'; indeed, as the economist Kenneth Boulding, one of the contributors to this approach, argues, it might be the 'skeleton of science'.[14] Furthermore, information theory has come to the fore as one of the foundations of general systems theory and cybernetics, contributing the two complementary ideas of entropy and information to the vocabulary of general systems research. Moreover, this information machine triggered and associated new developments through the rise of computer technologies and algorithmic processes.

In short, from antiquity until the eighteenth century architects remained quite distant from the first generation of machines. In antiquity, the status of architecture was alternatively seen either as liberal art or mechanical art, however as a profession suited to free men of high social rank, it could not concern itself with servile manufacturing tasks. Only complicated machines requiring ingenuity (towers, mills, war machines) commanded its art, its knowledge of representation and its supervision of the manufacturing process.[15] The second-generation machines of the Industrial Revolution had a completely different relationship with architecture. Certainly, the moderns, as everyone knows, magnified these machines and viewed them as models of rationality and efficiency, but some voices, such as those of John Ruskin, William Morris and others, were already raised against such a comparison, and instead emphasised the close link between the forms of architecture and the forms of nature. More often than not, neither the vitalism of the latter, nor the machinism of the former, went beyond vaguely inspiring metaphorical speculation. Was it because these machines were no longer for transport, but agents of transformation that architecture struggled to represent them? The engine of the simple machine moves from one point to another in space, and the force, given or captured, is measured by the displacement that occurs. Geometry and mechanics represent this displacement, that is to say the very same sciences that guarantee architecture its representation. Is this to say that the thermodynamics of engines does away with representation? Not at all, it also represents: not the point-by-point locations of forces, but their states; a power or its circumstance.[16] A reference space where intuition is certainly not as comfortable, but where representation does not disappear. It is less geometric than algebraic, that's all. The abstract space that it explores manipulates equations where operations and relationships between constants and variables replace ruler-and-compass buildable figures. Should one conclude then that abstraction is what has always been lacking in architecture and its theory?

The same story, with few variations, begins again in the era of third-generation machines. One might well have assumed that the criticisms directed at the moderns would have resulted in a different attitude towards these new machines scrutinising traces and signs, and activating reading and writing independently of meaning, all the while preserving it with attention and tact. For here the understanding of meaning is the goal, and the transmission of patterns or by patterns is the means. Mutatis mutandis, the situation is quite comparable to the earlier period. Far from freeing itself from metaphorical romanticism, whether in favour of the latter or against it, and from literal or sublimated applications, it simply gave rise to what can be termed conceptual nomadism.[17] The new proposed method allowed for few principles, concepts or operators capable of renewing the foundations of architecture. While the information machine, as we have seen, is less a machine than a method, less servomechanisms or computers than models, the architecture that embraced it retained only the primary artifice: material artificiality instead of abstract artificiality.[18] It elected new 'models for architecture' whereas what was needed was to initiate an 'architecture of the model'. It was no longer a question of knowing whether architecture and the city should be adaptive, evolutionary, criss-crossed by flows, networked, vertical, looped, immaterial, responsive, variational, curvilinear or anything else, but to develop a model that accounts for architectural forms and the city, their meanings, their transformations, their continuities or their discontinuities. Through this approach, we quickly notice that the constructive reality of architectural forms is more than construction, that forms are a complex of heterogeneous parameters that need to be explained and related. They cannot be reduced to a binary logic.

One should not confuse the old machines with purposes and information-driven machines having no purposes or encompassing all purposes. Standard machines such as the sheave or a catapult move weights, an engine produces movement, whereas the computer or 'logical computing machine' as Turing called it, can do everything. Collecting data from all types of phenomena and obeying a range of varied algorithms, it is potentially useful for every purpose and can potentially yield any result. A logic of heterogeneity becomes possible. Today's computational approach in architecture fell into this trap even as it made the digital machine its preferred tool. There is a contradiction in terms when theorists and architects of this movement claim that digital architecture is necessarily a matter of variation or smooth forms.[19] Because the computer – and the software inside it – as an information machine surely allows the designer to do everything: variation and invariance, standard and non-standard, curves and straight lines. Moreover, to implement one or the other actualisation, one needs the corresponding model, or better still, the general model that authorises them all. Hence, a human, political, ideological and academic choice is hidden or not admitted. Variation is one possibility of the digital machine among others, only the algorithmic model or the software determines the choice of this form or that other. Hence, the importance of the architecture of the model and its transparency. Hence, the task that lies ahead for architecture and architects.

The information machine as a model

If we agree that architecture is a complex empirical system, it becomes necessary to develop its formal systemic modelling in order to grasp it and to enable us to act. Nevertheless, the word 'model' contains a paradox: it is that which must be imitated, but it is also that which imitates; it is both a model *for* and a model *of*. While, for a long time, the first meaning prevailed in the fine arts and architecture, science has favoured the second. Scientific activity was imagined from its first steps as a rationality that decodes the world and defines the laws by which phenomena occur, and by what process. The model here is this knowledge or *mathesis universalis*. It imitates divine reason, if not that of the natural order. For literature and artistic practices, nature, whether divine project or autonomous reality, is, first of all, the model to imitate and to reproduce. Works of art are then the embodiment of the order or deviations that nature submits to the senses and/or reason. Truth is the model of beauty then. Now, while science, by perfecting itself and expanding its scope, has managed to harness the paradoxical status of the notion of the model for its contemporary theories and experiments, while the fine arts have, in part, emancipated themselves from the idea of imitating a model, architecture has, for the most part, remained subject to the ancients' conception of mimesis. Indeed, the modelling activity of modern science consists essentially in constructing abstract objects imitating real phenomena. However, the generality of these abstract objects also makes it possible to study a host of other phenomenal realities through analogical deduction. The imitating model is in turn imitated. Reproduction and representation involve the production and generation of knowledge, experience, simulations and equivalence relationships. The model is the condition that gives reason of a set of phenomena whose structure is equivalent; conversely, a phenomenon may fall under different models. Therefore, the model is a thinking machine. It is a construction tool to understand forms or things. The architectural situation is quite different, whether we consider its theory or its practice. The model, here, is most often a process or an object that we imitate. Architecture is then a question of representing an idea, a concept or a style, nothing more.[20] It's a 'machine to do', from models to algorithms to metaphors.[21]

The science of elaborating models, according to Alain Badiou, has always recognised two approaches: a bottom-up approach from the empirical to the formal that is based upon an artificial sequencing process (the positivists) implying semantic interpretations of a reality as a model to imitate; and also, a top-down approach from the formal to the empirical (the structuralists) where the artefact – Lévi-Strauss would say *le bricolé* – is the model vis-à-vis reality and that which makes it readable. Structure is the model for this system.[22] However, contrary to Badiou's claim, formalism cannot exist without being contaminated by empiricism and vice versa. There is no need for one model to choose between the two, it is even very natural, or more exactly, more efficient and more productive to use both approaches.[23] We would therefore insist on their mixing and their alteration. More often than not, one is the extension or the embodiment of the other. While demonstrative logic uses semantics in order to guarantee the validity of the model, experimental practice or confrontation with case studies reveals its syntactic structures. Therefore, a model must 'give a reason for' – describe and explain – all the phenomena considered, or at least of a large class of objects. However, to ensure its rational validity, and perhaps even its quality as a dynamic system, it must be demonstrable locally, but also refutable and falsifiable globally. This theoretical transparency of the model is what offers the possibility of forecasting and at least of explaining, which is already significant, if not to say essential.

Thus, the model realises in an effective and specific way the general rules that have been set. It is not the ideal archetype towards which the realised works tend without ever reaching. Inverting the Platonic paradigm, it is more *eidôlon* than idea, a

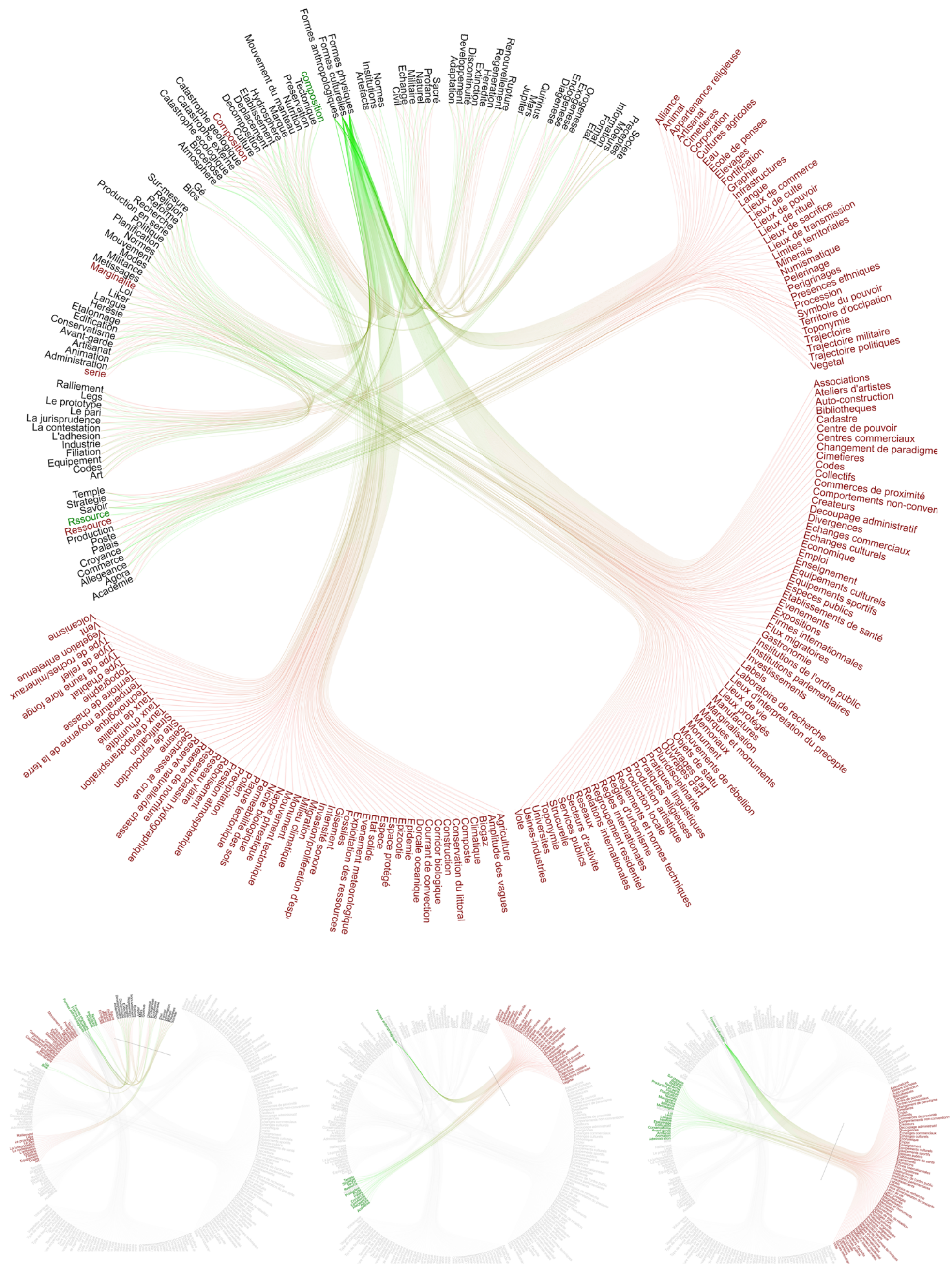

Fig. 1

Fig. 1: SofT project. Diagram (ontology) of systemic modellisation of the territory forms. Work and image: author.

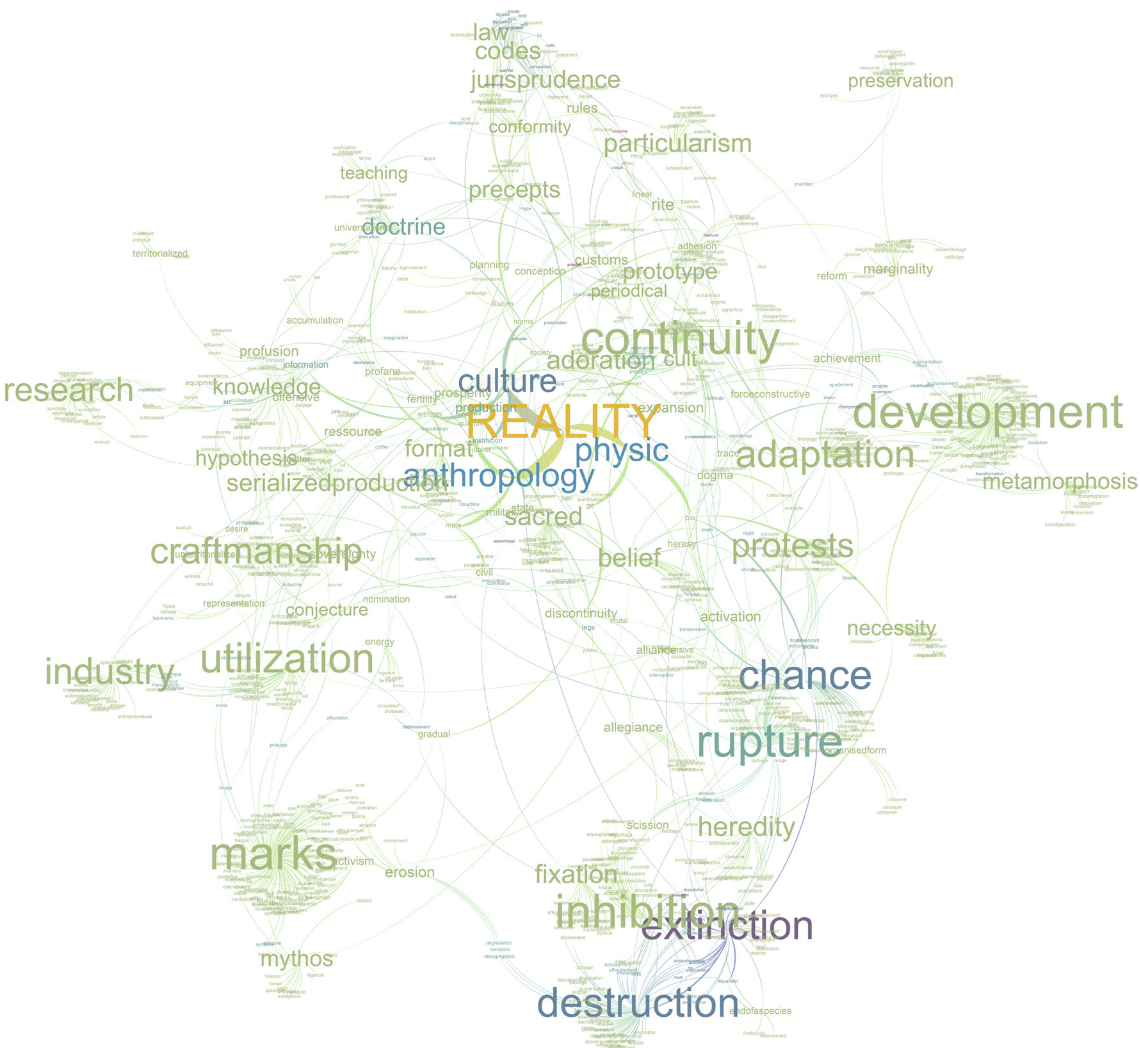

Fig. 2

Fig. 2: SoFT project. Diagram (ontology in RDF) for the semantic interoperability of territory's mapping data. Work and image: author.

simulacrum that deciphers the modalities by which forms are made or invented. Its consistency is its fundamental property and can only be determined through a comparison with 'facts'. In other words, a model is an artificial object, a formalisation, reproducing or imitating a reality through laws or rules, however without preventing contradictions. Thus, modelling is nothing more than a true description of reality. Its primary qualities seem to be its convenience and simplicity. The model is a machine for producing knowledge and actions that is itself experienced, tested and transformed in terms of its rigour and generality. It has a verification/rectification function. Hence the process of producing knowledge where the model does not only designate an outside empirical reality to be formalised, but also an inside knowledge to be experienced. Nevertheless, although destined to undo itself, the model seems to be the condition for its surpassing. Whoever renounces the model renounces knowledge and invention. This not to say that all (scientific) knowledge is knowledge by model. However, any invention of a model is a scientific activity in itself. Developing a model is always a work of art, whether it is a model of an automobile, a telephone or anything else manufactured, or any theoretical and abstract model. This is the case whether it is the work of an architect, an engineer, a designer, an economist, a sociologist, a philosopher or a physicist. As the French mathematician and epistemologist René Thom wrote: 'but the moment will come where the construction of models itself will become, if not a science, at least an art.'[24]

The information machine as a system (thinking relationally)

The model assumes a systemic reality. It is always about interacting elements and relationships whose activity is identifiable by its form.[25] Consequently, the forms form a system. Ultimately, the model invites us to think relationally. Buffon, the French naturalist, considered the encyclopedia to be against the system. He was ironic, as he liked to be, about the scientists who cannot distinguish a tree from a burnet and must therefore count the stamens.[26] The argument had already been used by Descartes concerning the universal language project, which Leibniz later took on by attempting to define its 'characteristic'.[27] In either undertaking, the encyclopedia and the system, carried out separately and independently, the reasoning remains stable, the points of view irreconcilable and the intelligibility of the forms confused. Like a diplomat constantly seeking a peace deal, Leibniz, who already feared the barbarity that multitude and multiplicity could produce, in particular following the invention of the printing press, insisted: 'there is no multitude without real units'.[28] This is the condition for the plurality of possible worlds and their harmony.

One can neither expect this encyclopedic knowledge to be complete, nor this systemic alphabet of architectural forms to be perfect. As philosopher Michel Serres writes: 'had the Greeks waited for the complete demonstration of their axioms and for their reduction to identicals, geometry would still have to be elaborated.'[29] The only hope to see more clearly in the shapeless cloud of forms that surround us, to grasp the universal in the proliferation of singularities, to find its way in this labyrinthine exuberance is to lead the two together, to link one to the other and vice versa. The becoming of one is the adjunct of the becoming of the other. The completion of the exhaustive description and the perfection of the systemic order cannot be preconditions but horizons. Thus, the more a system is developed and structured from a plurality of samples of identified knowledge, the more the intelligibility of forms progresses; the more precise it becomes, the better the definitions we have in the atlas knowledge, the more concise and operational the tables, the more organised the synopses. And again, the more the encyclopedia improves, the more it will reinforce the systemic foundation with better adapted samples, more formal relationships and unexplored dimensions or regions. Hence, better chances of combining reasoning and computing, of entangling description and explanation: might this be the real morphology?[30] Serres made the argument that all our discourse about computers was Leibniz's dream. But Leibniz's idea is that calculus is only the way to realise the systemic universal language and the encyclopedic knowledge – the two principal sources of information about the world – that will code and encode everything.

The problems of systematicity arise for architecture as for the other disciplines. If architecture is a totality, we must define it and define its constituent components. Neither multidisciplinarity nor interdisciplinarity can cope with this requisite; only transdisciplinarity embodied in a formal model that intertwines and 'translates' them into one another can be the key to describing architectural forms as a whole. Hence a system that must articulate encyclopedias and regions of knowledge, hence an axiomatic or a formalisation that subsumes the multiplicity of dimensions of phenomena and objects. Hence the continuum of the morphological description and subsequently that of the morphogenetic process. This problem is subtler than previously believed: one cannot be satisfied with cursory and broad allegations of the kind: 'Intentions in Architecture', 'Notes on the Synthesis of Form', 'Parametricism', 'Biomimetic', and so on, or even more common expressions such as architectural space. This problem needs to be modelled.

Not only is the architectural object a system caught in overlapping connections that extend beyond it and therefore link it to other systems, not only is the territory or the city a system of systems, the set of architectural forms and settlements is also a system.[31] [Fig.1,2] That being the case, then, as the Stoics put it: all things work together and conspire, the world is born from a cosmic sympathy. Stoicism is this philosophy where the world is organised into a coherent and organic whole, it is a system in which each element is united with the others and constitutes a unified totality. Either all the dimensions that contribute or conspire to architecture are found in its built, drawn or imagined form, or the latter is nothing.

The information machine as a morphology and morphogenesis

If the model, as we have explained, is at once a model *of* and model *for*, then all modelling activity is first a morphology before leading to morphogenesis. The model can only be constituted and formed by a morphological and systemic description of empirical forms, from which paths for new forms and morphogenetic processes emerge, condense and open up. The morphological description is an apparatus. There is no point in involving 'thinking' in advance, real 'measuring' instruments are sufficient. The observer is a reality just as much as the observed reality and the measurement is nothing other than the use of effective procedures taking into account the conditions of observation.

Furthermore, there is no point in getting lost in philosophical arguments around the subjectivity or objectivity of the description. The reality changes with theories and means of observation, with the tools and devices for measurement or qualification, science and epistemology provide examples and demonstrations.[32] Description in this sense is not a subject-to-object relationship, nor even of a relativist or post-positivist subject and an object now active and itself changing; it is a relationship of subjectivation.[33] Description is an activity revealing of all the structures that organise a form; it removes the subjectivity of the subject by founding autonomous and regulated methods independent of the reasoning system of the one who thinks; it suspends the objectivity of the object while avoiding having to claim it knows the essence of things beyond what the form shows us, regardless of what it tells us. Furthermore, description is neither subjective nor objective, it is a subjectivating action since it is a joint operation between two forms: a form that manifests itself and 'would like' to be seen and read and another that 'wants' to see and read. But to want to read and see a form is not to impose a point of view on it, it is to go towards it and sneak in. With his very particular style, the French poet and essayist Charles Péguy once explained that reading is not a passive operation, that being a reader is in no way being a pure spectator, that reading is entering into

> a work, into the reading of a work, into life, into the contemplation of a life, with friendship, with fidelity ... that one should not receive the work passively; that reading is the common act, the common operation of the reader and what is read, of the work and of the reader.[34]

A subject is therefore the one who gives or receives, but it is the act of description that is subjectivity. The forms speak, so let's decipher their alphabet. There is action and reaction in both directions. Similarly, Italo Calvino, in order to avoid all the blatant misadventures of a preformed and prefiltered language, observed this experience, and tried to guide us there. In *Mr Palomar*, in the chapter entitled 'The world looks at the world' he writes:

> Having the outside look outside is not enough: the trajectory must start from the looked-at thing, linking it with the thing that looks. From the mute distance of things a sign must come, a summons, a wink: one thing detaches itself from the other things with the intention of signifying something... What? Itself: a thing is happy to be looked at by other things only when it is convinced that it signifies itself and nothing else, amid things that signify themselves and nothing else.[35]

If architecture is a form, full of itself and of its meanings, then we will recognise them whether we are spirits or material devices. Contrary to what idealism claims, a morphology is an opening towards meaning, a reading of reality through which to decipher information, to reveal meanings, all the meanings we can find. To ignore forms is to extinguish all the promising signs of the whole semantic enterprise. It is only because we are active constituents of forms that we have the 'sense' of the information they convey.

It is not because we suspend our meanings that forms vanish and lose theirs. The form 'sensifies' before even signifying, according to philosopher Raymond Ruyer's famous formula.[36] Nothing would then prevent us from overturning René Thom's proposal, without fear of stripping it of all its rigour. As the relationship here is strictly bijective and the equivalence exactly one-to-one, it might be possible to state that all form is, in the first place, information. The latter is, so to speak, coded in form. However, as Thom specifies, 'to reduce information to its scalar measure (evaluated in bits) is to reduce form to its topological complexity ... and to throw away almost everything about its significance'.[37]

If, as Goethe wished, the morphological description must contain what the form, formation and transformation teach, then it will have to grasp all the architectural forms, consider all the built things to hope to deduce the laws which govern them, the organisations that structure them, the filiations continuing them, and the ruptures dividing them.[38] Morphology would thus be this spatio-temporal description on horizontal planes of all the levels of reality that the building act can subsume. On the other hand, morphogenesis in the strong sense of the term is this dynamic enabling to jump from one level to another, it is this vertical, trans-spatio-temporal movement activating the links between horizontal structures. While it is indisputable that morphology is deduced from the observation of phenomena in usual space-time, it is formative activity, which makes us, in the most striking way, see forms as products of a morphogenesis that no calculation or algorithm can predict. Thematic morphogenesis 'overflights', in Ruyer's sense, and goes beyond the structural morphogenesis which itself continues and extends into a material morphogenesis; ends and means are difficult to distinguish.[39]

For a long time, artistic literature – such as vitalism with its obscure principles in philosophy for the forms of the living – treated architectural forms and those of art as the simple result of an almost divine skill, where combined structures emerged from the mind of a genius, a demiurge in other words, defining the rules by which beauty is achieved.[40]

In this conception, the matter of these forms, be it drawing or stone, obeys precise laws of beauty and a corresponding system of symbolic rules. The whole process is organised by obscure forces based in the artist's mind. The invention of architectural forms was therefore a variation around a certain number of orders, subject to the whims of contingent and inexplicable inspirations. So conceived, morphogenesis is at best a morphology describing structures that already exist. Geometrical transformations then pass from one constituted structure to another, but where the structures are previously formed in various materials: diagrams, drawings, maquettes or buildings.[41] If not, morphogenesis merges with a deterministic mechanical explanation, reducing everything, as Poincaré pointed out, to an 'immense game of billiards', merely an abstract play of forces producing forms from elementary figures or predefined algorithms.[42] Hence the formal experiments of the first generation of post-deconstruction architects, on software such as Maya, and likewise the recent developments in computing design with Grasshopper or by cellular automata producing complex forms.[43] In the architectural literature of the last twenty years, morphogenesis is therefore synonymous with processes supported by spatial motions of non-local characteristics, pattern formation with a static reference.

However, showing what a difference is, especially since it is essential, is not equivalent to removing a link or interaction. To recognise that all form is the result of morphogenesis is to admit from the outset that for there to be a form, there is a formation; that a morphological description can certainly describe formed and realised forms, compare them, classify them, group them, but that morphogenesis is the guarantee of grasping the informational dynamics underlying the constitution of forms, their parameters or their conditions of emergence. It is also the guarantee of seeing the forms generate each other; to observe the transformations. Thus, they will not only be described, but also explained using dynamic morphogenetic models.

Outputs, refinements

To consider architecture as a production of forms and architectural theory as well as architectural history as particular modes of knowledge of these forms, is not a superficial undertaking. Such an approach neither privileges the letter over the spirit, nor does it ignore the depths to be probed in the form itself, whose enigmas remain to be elucidated. Studying architectural forms means seeking within the form all the information it envelops, but also delving into its sources and its mechanisms of emergence, transformation, transmission or extinction. Is this not literally the definition of the information machine? The real cybernetic machine then is the one enabling architecture to show and use the footprints and the signs of ecological systems. Gauging architecture through its form does not imply that we end up with architecture minus everything else. On the contrary, we have architecture plus a powerful process that enables us to investigate the multiplicity of its dimensions, to grasp its increasing complexity, and to describe and, by the same token, understand the conditions that systematically articulate the great diversity of phenomenal structures and meanings. This process helps to translate the multiple dimensions of the whole system. Form is what makes it possible to define the general dynamics of architecture. The formalism advocated here is the one that recognises the entire cosmological extension of form. It is a formalism that diffracts into all the dimensions of the built or projected 'thing', including the specific automated formalisations required by the contemporary era. Such is the automation, we would argue, that corresponds nowadays to the information machine. Here, the theory of practices (simple machines and engines) joins the practice of theories (the forms of information and signs).[44] This is what is in circulation today. The machine or the automaton is not an end in itself, nor a tool for a finality, but a degree of refinement of the relationship to forms, that is to say, to things. As Samuel Butler already observed in the nineteenth century, is it not by so perfectly grasping and with such great mastery that the body renders thoughts and gestures automatic? Or, as Leibniz put it, nature is the real and perfect machine, complete and successful. As such, automation is not about machines, it is about refinement.

To say that the architect's knowledge relates above all to forms is neither to disregard its architectural materiality, nor to dismiss its social implications and determinations, nor to diminish its possibilities of symbolic expressions. Even less, is it to ignore the political or ecological dimension of architecture. Moreover, to observe these forms is to attentively perceive and discern as many structures as possible that organise their various dimensions as a whole. It is to explicitly state that which remained a confused object in the traditional approach of separate disciplines. In an operational way, it means building an interface of forms that enables us to pass from the geometry of a form or its topology, to its materiality and its environmental or symbolic consequences, to the organisation of individual and collective practices that it implies, to the professional organisation it fosters and even to the affects it provokes. Observing and describing forms from this point of view not only takes architectural theory out of the rut of criticism or doctrine and makes it cumulative, it also returns to the essential aspect of the architect's creative act as expressed through its forms: 'showing a world'. To successfully describe architecture from its forms, from all its forms, is to attempt and hope to see a new way of doing architecture. A perilous and colossal enterprise for sure, but is that a reason not to start it?

Notes

1. Gregory Bateson, *Steps Towards the Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution and Epistemology* (Chicago: University of Chicago Press, 1972), 484.
2. Blaise Pascal, *Œuvres Complètes* (Paris: La Pléiade, Gallimard, 1954), 37. Unless otherwise indicated, translations from French sources are my own.
3. Charles Jenks, *The Language of Post-Modern Architecture* (London, Academy Editions, 1977).
4. Mario Carpo got it right when he pointed out 'In retrospect this current of digital design does appear like a continuation of Deconstructivism with digital means', *The Digital Turn in Architecture 1992–2012* (Chichester: John Wiley & Sons, 2013), 10.
5. 'What I used to call the "parametric blanket" (largely because these works resemble a featureless blanket thrown over a highly articulated traditional workshop model) has nonetheless a materiality that could sustain discussion', 'A conversation between Sanford Kwinter and Jason Payne', in Michael Meredith, *From Control to Design: Parametric/Algorithmic Architecture* (Barcelona/New York, Actar, 2008), 235.
6. Mario Carpo deplores the absence of theory around what he calls architecture in the digital age and describes the 'autopoietic, morphogenetic, or biomimetic' experiments as a vast metaphor. Cf. 'La fin du numérique, la fin du commencement, et la fin du projet', *Le Visiteur* no. 11 (November 2011): 77–81.
7. For a large panorama of the Industrial Revolution period, see for example Sigfried Giedion, *Mechanization Takes Command: A Contribution to an Anonymous History* (New York: Norton, 1948); Reyner Banham, *Theory and Design in the First Machine* Age (London/New York: The Architectural Press/Paeger, 1960); Peter Collins, *Changing Ideals in Modern Architecture, 1750–1950* (Montréal: McGill-Queen's University Press, 1965). For post-industrial vision, see the work of theorists or historians such as Mario Carpo, Antoine Picon, Sanford Kwinter, Manuel DeLanda and so on, as well as architects like Greg Lynn, Karl Chu, Lars Spuybroek, Alejandro Zaera-Polo, Farshid Moussavi and so on.
8. Vitruvius, *Les dix livres d'architecture* (Paris: Bibliothèque de l'image, 1995). For a more detailed presentation on the status of the machine in antiquity and in philosophy, cf. Pierre-Maxime Schuhl, *Machinisme et philosophie* (Paris: PUF, 1947).
9. Pierre de Latil, *La pensée artificielle* (Paris: Gallimard, 1953). On the history of machines, I refer to Franz Reuleaux's classic *Principes fondamentaux d'une théorie générale des machines* (Paris: Librairie F. Savy, 1877).

10. Vitruvius gives a definition of the simple machine as a wooden structure, having the virtue of moving great weights. 'Vitruvius appears to include the *simple mechanical powers*, which, however, when used in combination, as in the crane and other machines, become *machinae*'. Sir William Smith, *A Dictionary of Greek and Roman Antiquities* (London: John Murray, 1875). Also, cf. Vitruvius, *Les dix livres,* book X, chapter I. Let's mention here that Aristoteles states (*Mechanical Problems*) that the law of levers is the fundamental principle of mechanics. For the motorised machines, cf. Michel Serres, *La Distribution* (Paris, Minuit, 1977), 43–58; Latil, *La Pensée artificielle,* 32–50. For the information machines, cf. Norbert Wiener, *Cybernetics or Control and Communication in the Animal and the Machine* (Cambridge, MA: The Technology Press of MIT, 1949), 49–55.
11. The word adopted for the French translation of 'pattern' was 'modèle'. I prefer to retain this word and the corresponding English term (model) because of its active and general connotation.
12. Norbert Wiener, *Cybernétique et Société*, (Paris: Deux Rives, 1952), 15–17, emphasis in original. In his very detailed work on the presuppositions and results of cybernetics, Latil notes the emergence of this method by model: 'There is here', he writes, 'a new scientific method for approaching knowledge: the models method'. Latil, *La Pensée artificielle*, 207.
13. John von Neumann, *Theory of Self-Reproducing Automata*, ed. Arthur W. Burks (Urbana: University of Illinois Press, 1966), 33–35 and the Introduction by Burks, 2–4.
14. Ludwig von Bertalanffy, *General System Theory* (New York: George Brazier, Inc., 1968); Kenneth E. Boulding, 'General Systems Theory: The Skeleton of Science', *Management Science* 2, no. 3 (April 1956): 197–208.
15. Gilles Bertrand, *Les ingénieurs de la Renaissance* (Paris: Hermann, 1964) and *Les mécaniciens grecs, la naissance de la technologie* (Paris: Seuil, 1980). Latil points out that Bertrand had identified an ancestor of retro-action machine in the Renaissance, the 'baille-blé' or shoe (a mechanism of the millstone that regulates the feed of grain to the millstones by making it dependent on the speed of the runner stone). Cf. Latil, *La Pensée artificielle*, 110.
16. Sadi Carnot, *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance* (Paris: Blanchard, 1953 [1824]), 66–67. Carnot gives access to this algebraic writing in the notes that accompany his text.
17. Christian Girard, *Architecture et concepts nomades : traité d'indiscipline* (Bruxelles, Mardaga, 1986).
18. While these experiments had made us believe in a painful historic decision and an avant-garde break-through, they remained short-lived, and without shareable methodology, impossible to increase or to transform. Some of the works that fall into this category are: Peter Cook's *Plug-In City*, Cedric Price's *Fun Palace*, Gordon Pask's 'The Architectural Relevance of Cybernetics', Dennis Crompton's *The Piped Environment* and *Computer City,* Constant's *New Babylon*, Koichi Tonuma's *Network City*, John Frazer's *An Evolutionary Architecture*, Arata Isozaki's *Computer Aided City*, Nicolas Schöffer's *La ville cybernétique* and Yona Friedman's *L'Architecture mobile*. The works of Christopher Alexander, Nicolas Negroponte and William J. Mitchell belong to another register that we cannot include for discussion here due to lack of space.
19. Manuel DeLanda and Lars Spuybroek's texts (DeLanda, 'Material Evolvability and Variability', 10–17; Spuybroek, 'The Radical Picturesque', 34–39) in *The Architecture of Variation,* ed. Lars Spuybroek (London: Thames & Hudson, 2009). Both of these authors curiously insist on this notion of variation. Furthermore, I do not subscribe to the opinion of the historian Mario Carpo in studying these approaches when he writes: 'All that is digital is variable … In architecture, this means the end of notational limitations, of industrial standarzation, and, more generally, of the Albertian and authorial way of building by design.' Mario Carpo, *The Alphabet and the Algorithm* (Cambridge, MA: The MIT Press, 2011), preface.
20. The 'idea' can come from various registers (aesthetic, social, moral, economic, political, and so on). For a

detailed presentation on this subject and its various deployments in artistic history see Erwin Panofsky, *Idea*: A *Concept in Art Theory* (Columbia, SC: University of South Carolina Press, 1968 [1924]). 'Model behavior' was the theme of *Log* 50, but when we read through all the articles, as Cynthia Davidson noticed it 'it was obvious that how [they] might elicit or project behaviors was not always a primary concern. Rather, the making of models, whether they have digital or physical properties, and the unmasking of the largely invisible transactional models that underpin the systems of architectural education and practice (models that could be said to standardize behaviors) came to the fore'. *Log* 50 (Autumn 2020): 15. What appears then is that new modelling activity is needed.

21. On the entanglement and ambiguity between theory and practice I refer to the works of Manfredo Tafuri. It is curious that the computational approaches in architecture have retained scientific models while only borrowing their capacity to simulate and not their very basic modelling dimension. In other words, these approaches neglected the role of modelling, which implies the process of imitating and being imitated to produce knowledge and ordering classes of equivalence of problems.
22. Alain Badiou, *Le concept de modèle* (Paris: François Maspero, 1970), 9–68; Claude Lévi-Strauss, *La pensée sauvage* (Paris: Plon, 1962), 26–47.
23. Thus, if geometry from the start seems to be the example of the formal approach, starting from an axiomatic system, in particular from the Euclidean model, which will offer the model of reality, the arithmetic resulting from the enumeration of objects and the rules of their manipulation or their property tends to be empirical. For the Pythagoreans, it is not only the model of reality; the latter is also only considered to be a pale copy. However, both experienced contradictory movements: arithmetic explored total axiomatisation and failed, but in the meantime, it yielded significant results; geometry, notably thanks to topology, fractals and Thomian morphology has formalised a host of empirical phenomena. The controversies that opposed Riemann and Poincaré to Frege and Hilbert on the foundations of mathematics primarily served to open up new branches including computer science and cognitive sciences (with Gödel on one side and Turing on the other).
24. René Thom, *Modèles mathématiques de la morphogénèse* (Paris: Christian Bourgeois, 1980), 18.
25. 'In summary, the individuality of the body is ... that of a *form* rather than that of a fragment of matter.' Norbert Wiener, *Cybernétique et Société*, 142. Emphasis added.
26. Allusion to Linnaeus's *Systema Naturæ* (1748) while addressing his criticisms to botanist Joseph Pitton de Tournefort. Cf. Buffon, *Œuvres complètes* (Paris: Abel Ledoux libraire, 1846), 48. Although Linnaeus's system was called a masterful reading of the organisation of living forms, the fact remains that it was a static system. See Fréderic Houssay, *La Forme et la vie: essai de la méthode mécanique en Zoologie* (Paris: Schleicher frères, 1900), 71.
27. René Descartes, Letter to Mersenne, 20 November 1629, Adam and Tannery, *Œuvres de Descartes*, I, 76. Although the idea of a universal language discussed with Father Mersenne seemed to interest him, he considered it impracticable: 'Philosophy not having completed this enterprise is not possible'.
28. G.W.F. Leibniz, Letter to Arnauld, 30 April1687, Paul Janet, ed., *Œuvres philosophiques de Leibniz, Correspondance de Leibniz et d'Arnauld* (Paris: Felix Alcan, 1900).
29. Michel Serres, *Le Système de Leibniz et ses modèles mathématiques,* (Paris: PUF, 1968), 550.
30. René Thom, *Prédire n'est pas expliquer: entretiens avec Emile Noël* (Paris: Flammarion, 1993). Furthermore, René Thom points out: 'The errors come more from the theory (or the absence of theory) that presides over the construction of the model, than from the approximations resulting from the digital processing of the system', Thom, *Modèles mathématiques,* 114.
31. Regarding the forms of settlements, the structural geography study overseen Gilles Ritchot and Gaëtan Desmarais stands out for how clearly it grasps the

structures and judiciously models the dynamics of human settlements. See in particular Gilles Ritchot, *La morphogenèse de Rome, de la discontinuité première au débordement actuel* (Paris: L'Harmattan, 2011); Gaëtan Desmarais, *La morphogenèse de Paris des origines à la révolution*, (Paris: L'Harmattan-CELAT 2000); Gaëtan Desmarais and Gilles Ritchot, *La géographie structurale* (Paris: L'Harmattan, 2001).

32. Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007).
33. Gilles Deleuze and Félix Guattari have provided the richest interpretations of this concept. Cf. especially *Mille-Plateaux: capitalisme et schizophrénie* (Paris: Minuit, 1980).
34. Charles Péguy, *Clio: dialogue de l'histoire et de l'âme païenne* (Paris: Gallimard, 1932), 19–21.
35. Italo Calvino, *Mr Palomar*, trans. William Weaver (London: Vintage, 1999 [1983]), 102.
36. 'Sensifiying' is a process of elaborating a sense or a piece of information, 'signfiying' needs signs and language. Cf. Raymond Ruyer, *L'Embroyogenèse du monde et le Dieu silencieux* (Paris: Klincksieck, 2013, posth.), 244; *La gnose de Princeton* (Paris: Fayard, 1974), 131–37.
37. René Thom, *Stabilité structurelle et morphogenèse*, *Essai d'une théorie générale des modèles* (Massachussetts: W.A. Benjamin, 1972), 164.
38. J.W. von Goethe, *La métamorphoses des plantes*, trans. Henriette Bideau, (Boissière en Thelle: Triade, 1975), 216. In the last century, Georges Kubler, in seeking to better understand the dynamics of artistic forms, seems to have glimpsed this need when he invited art historians to undertake not only a history of works, but also a history of 'things'. Georges Kubler, *The Shape of Time*: *Remarks on the History of Things* (New Haven and London: Yale University Press, 1962).
39. Raymond Ruyer, *Genèse des formes vivantes* (Paris: Flammarion, 1958).
40. The legend of the genesis of the Corinthian architectural order provides us with an illustration: Vitruvius believed that only an exceptional mind could have revealed the figure of the Corinthian capital, an achievement he attributes to the sculptor Callimachus. According to Pausanias, the latter was the first to carve out voids in the marble objects he sculpted. Pierre Gros, *Vitruve et la tradition des traités d'architecture* (Rome: l'École française de Rome, 2006).
41. We can easily understand the enthusiasm, which we are witnessing today, for robotics and its capacity to model shapes at scale 1.
42. Henri Poincaré, *La science et l'Hypothèse* (Paris: Flammarion, 1932), 193.
43. It is also instructive that this line of thought found in D'Arcy Thompson's work a literal justification for this purely mechanical approach. Cf. Sanford Kwinter, 'La Città Nuova: Modernity and Continuity', in *Zone 1/2*, *The [Contemporary] City*, ed. Michel Feher, Sanford Kwinter and Jonathan Crary (New York: Zone Books, 1986), 80–127; Greg Lynn, *Animate Form* (New York: Princeton Architectural Press, 1999). It is not to diminish their interest to say that the formal research and approaches discussed in the publications of *Architectural Design* (London, J. Wiley) often stem from this conception. They surely participated in exploring different types of morphogenetic operations but neglected to define the system of forms.
44. The ongoing automation using robotic processes to produce and assemble architectural or structural components or using AI to generate or choose from a range the most efficient or the most suitable patterns is certainly interesting. It improves the process of fabrication and design in architecture. But the prime automation that remains a challenge today is that which arises from the refinement of the descriptive model dealing with complexity beyond a territorial system of forms – their signs and meanings – allowing its intelligibility and its sharing as a whole. Automation is not simply a matter of enhanced productivity and economic performance, it is above all a means of pro-duction (pro - forward; duct - connection), of comprehending relationally.

Biography

Tewfik Hammoudi is an architect and associate professor of architecture at l'École Nationale Supérieure d'Architecture de Nantes (ENSAN) where he teaches Architectural Theory and Design Studio. He holds a PhD in architecture from the University of Paris 8 in France. To deepen his knowledge, he has a Diploma of Advanced Studies in Philosophy, and followed as free listener Michel Serres's History of Sciences courses at the Sorbonne, Paris I. In 2007 at ENSAN, Hammoudi initiated a research programme on 'Territorial Thinking Machines', based on a morphological approach and data resources. His theoretical work focuses on the development of a new general theory of singularities for architectural, urban and territorial forms.

Review Article

Cooked Air: The Kitchen and its Exhalate

Liz Gálvez

> Etymologically speaking, a breath is not neutral or bland – it's 'cooked air'; we live in a constant simmering. There is a furnace in our cells and when we breathe we pass the world through our bodies, brew it lightly, and turn it loose again, gently altered for having known us.
> Diane Ackerman, 1995[1]

Every kitchen needs to vent

The whiff of Lysol enters slowly, drying the back of the nose, then the throat, hitting, finally, deep in the lungs. The subtle displeasure is momentary, and now counter and cook are ready. Opening the freezer, a stale cold waft immerses you, a slight draft of warmth swirls at the feet. Ingredients for tonight's dish scatter the snow-white counter. A slight tug at a garlic bulb, the quick smash of a clove, the stickiness of its flaky peel, a rhythmically mechanised knife. Its layered companion suffers a similar fate, although not without a teary revenge. Tiny sulfuric compounds levitate and mix, befriending surrounding oxygen particles. A deep inhalation and a slow out breath confirm hunger. The subtle sizzle of a nearby pan welcomes the minced and diced ingredients confronting the pungently rich air with the roar of the extractor fan.

The kitchen marks the site of sense-able odours – pleasant and unpleasant, pungent, sweet, smoky, steamy, crisp, stale. Its historical formation as a room within the home faced rich challenges, especially concerning inhalation and exhalation. Conceptually, our attention in the kitchen centres on food, on cooking, on ingesting, and yet, it is the more elusive – air – in its almost invisibility that enables the indoor kitchen. Breathing equipment, model codes and standards prescribe design and regulation towards mechanised exhalation within the kitchen as the focus site for domestic respiration. An examination of kitchen processes begins to suggest our existence within and abounded by 'cooked air'. In fact, all the major implements, everything and the kitchen sink, instrumentalise air-related processes. The refrigerator cycle constantly extracts hot air. Ovens use flames to heat enclosed air. The extractor fan draws and extracts smoky air. The well-plumbed sink penetrates the architectural envelope, both exhaling and inhaling. This equipment, its regulation and standardisation models do not only enable, but direct human behaviour and activity. We can trace domestic air management strategies, such as air cooking and cleaning, via an examination of *ASHRAE Standard 62.2: Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings*. Since 1996, *Standard 62.2* has provided guidelines for residential ventilation. As ventilation becomes increasingly scientised, quantifiable, and reliant on hyper-specific equipment, technical literacy on ventilation narrows.[2] The relationship between architecture, inhabitants and air management has become increasingly reliant on ventilation standards.

The air gap

The air gap, technically speaking, is the unobstructed vertical space between the water outlet and the flood level of a fixture.[3] A void space, empty,

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in name reminds us that this seeming 'nothing' is actually filled with something – with air. Extending this vocabulary to the ventilation cycle, designated kitchen air spaces – between tap and basin, stovetop and extractor hood – enable cooking activities – washing, rinsing, mixing, simmering, frying, boiling. Discharge of cooked air begins between the cooking surface of the stove and the suctioning extractor hood. Cooking steam, smoke, and odours are drawn within this gap. Between cooking surface and drawing mechanism, fuel and resources are transformed, spent, used up. In the kitchen's gaps, gas (or electricity) morphs into heat and smoke, water into sewage, supply becomes waste.

Delicate relationships towards air management encouraged early societies to limit their cooking to exterior settings. By cooking outside, fresh, breathable air remained plentiful despite odour, smoke, and cooking exhaust fumes. The risk of domestic fire was minimised. In the camp fire, 'the distribution of heat is biased by the wind, and the trail of smoke renders the downwind side of the fire unappetising, so that the concentric zoning is interrupted by other considerations of comfort.'[4] Wind direction and its direct relation to the fire's smoky exhaust fumes, a nuisance to the human nose and lungs, had spatial, and hence architectural repercussions.

The kitchen emerges as a discrete concept within fireplaces and ovens characterised as room-like chimneys that were large enough for human habitation.[5] Flame strength required physical control by experienced cooks, as too much fuel could quickly make matters too hot or smoky, risking the quality of the dish. 'Repeated instructions on how to overcome [the perils of fire and smoke] testify to how constant a concern this was for cooks.'[6] The medieval recipe included architecturally scaled climactic and ventilation strategies that implicated both the intellectual and physical abilities of the cook towards managing the surrounding cooking air. Few recipes today, if any, consider ventilation. 'Ventilation recipes' no longer address domestic chefs, but rather ventilation experts, designers well-versed in the science of air.

Before the popularisation of the gas or electric stoves we see today, solid-fuel stoves regulated combustion and cooking fumes through distinct ventilation cycles.[7] More nefarious smoke from the firebox was ducted directly to the exterior through a prominent vent flue that was embedded within the fixture. [Fig. 1] On the other hand, off-gassing emitted throughout the cooking processes was required to be vented by the user. Prior to automated controls or the development of instrumentalised architectural systems, mechanical signification relied on the cook's senses – sight, smell, taste, sound and touch – for operation and human intervention within the ventilation cycles. Contemporary kitchen cooking mechanisms merge combustion and cooking gasses into a single exhalate, while discretising the object of combustion supply and ventilation extraction into two objects of hyperspecificity. The physical separation amidst an invisible medium slices the exhalation cycle into exhalation and subsequent inhalation, thereby decreasing visual perception of the physical continuity of cooked air. Distance between physical equipment creates a conceptual break between related functions.

Intellectually, the ventilation cycle continues to be understood by the cook, but perceptually it belies continuity. Standards consolidate demand-controlled ventilation into an air-extracting appliance, while increasing reliance on automatic controls to mitigate the gap in technical knowledge. Yet, the connection between intellectual and phenomenal knowledge is imperative to making things real.[8] Upon displacement of the cookstove's prominent flue, discretisation into stovetop and ventilation hood, the invisible medium of the air gap continues to offer clues, if subtle, in the form of odours and momentary visibility of spent particles. [Fig. 2] Appliance fragmentation and the necessary implementation of an air gap between them to sustain the development of hyper-specific equipment functions, makes what was previously explicit more abstract to the cook while retaining the modern tendency towards explication for the ventilation expert. The invention of the air gap, then, is understood as both a physical and an intellectual fragmentation.

Measuring is believing

Interior air management has shifted from architectural solutions such as the chimney, the fireplace and the hearth, towards specification of combustion and air cleaning equipment and mechanical systems. In tandem, evolutions in scientific and applied disciplines render air 'quality' calculable. Air quality meters monitor air for pollutants, and standardised simulations measure air movement and system efficacy. Formal – meaning physical, aesthetic, and sensorial – value associated with air management shifts from architectural knowledge to applied, quantifiable, scientised knowledge. Disciplinary models dictate collaboration between architects who design interior space and enclosing form, and mechanical engineers who make that same space habitable through mechanical air management solutions. Significant discourse continues, and yet responsibilities are respectively relegated along lines of disciplinary knowledge. In relation to the air handling systems, the architect comments on flues based on aesthetic and compositional expertise, while the engineer undertakes flue arrangement based on mechanical expertise. Air quality and movement, historically managed formally and aesthetically, now falls to mechanics, to science. Objective quality can be measured through air-sensing instruments. Their reported data is 'seen' by those literate in the science of air via their associated instruments.[9]

Discrete model codes and legal jurisdiction are complicit in the disciplinisation of air knowledge. The architect's expertise ensures that ventilation equipment complies with egress regulations while the engineer ensures that ventilation equipment complies with air volume metrics. The technical project of building ventilation is advanced and described by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). To guide the science of ventilation in the domestic sphere, ASHRAE developed ***Standard 62.2: Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings***.

> *Standard 62.2* is the national ventilation and indoor air quality (IAQ) standard developed specifically for residential buildings via the ANSI process. The standard describes the minimum requirements to achieve acceptable IAQ via dwelling-unit ventilation, local demand-controlled exhaust, and source control. Dwelling-unit ventilation is intended to dilute the unavoidable contaminant emissions from people, materials, and background processes. Local demand-controlled exhaust is intended to remove contaminants from kitchens and bathrooms that, because of their design function, are expected to contain sources of contaminants. [Fig. 3] The standard includes secondary requirements that focus on properties and performance of residential ventilation systems.[10]

The quality of our interior air, its breathability is measured as interior air quality (IAQ). The model suggests the required ventilation rate for achieving an acceptable, compliant IAQ based on the following calculation:

> The total ventilation rate … (Q_{tot}) shall be … calculated [as follows]:
>
> Where
>
> $Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1)$
>
> Q_{tot} = total required ventilation rate, L/s
>
> A_{floor} = dwelling-unit floor area, m^2
>
> N_{br} = number of bedrooms (not to be less than 1).[11]

Those who are technically literate are conceded the specification of normative formats and quantifiable acceptability, in turn shaping the lifestyles of those under the domain of municipally embraced standards. For example, *Standard 62.2* sets the 'total required ventilation rate' according to a specified calculation, leaving little discretion based on diversity of user preference and values, or playful solutions

Fig. 1

Fig. 1: George Eastman, Interior with wood burning stove, Oak Lodge Trip, April 29, 1921. Digital positive from the original gelatin silver negative in the George Eastman Museum's Collection. Courtesy of the George Eastman Museum.

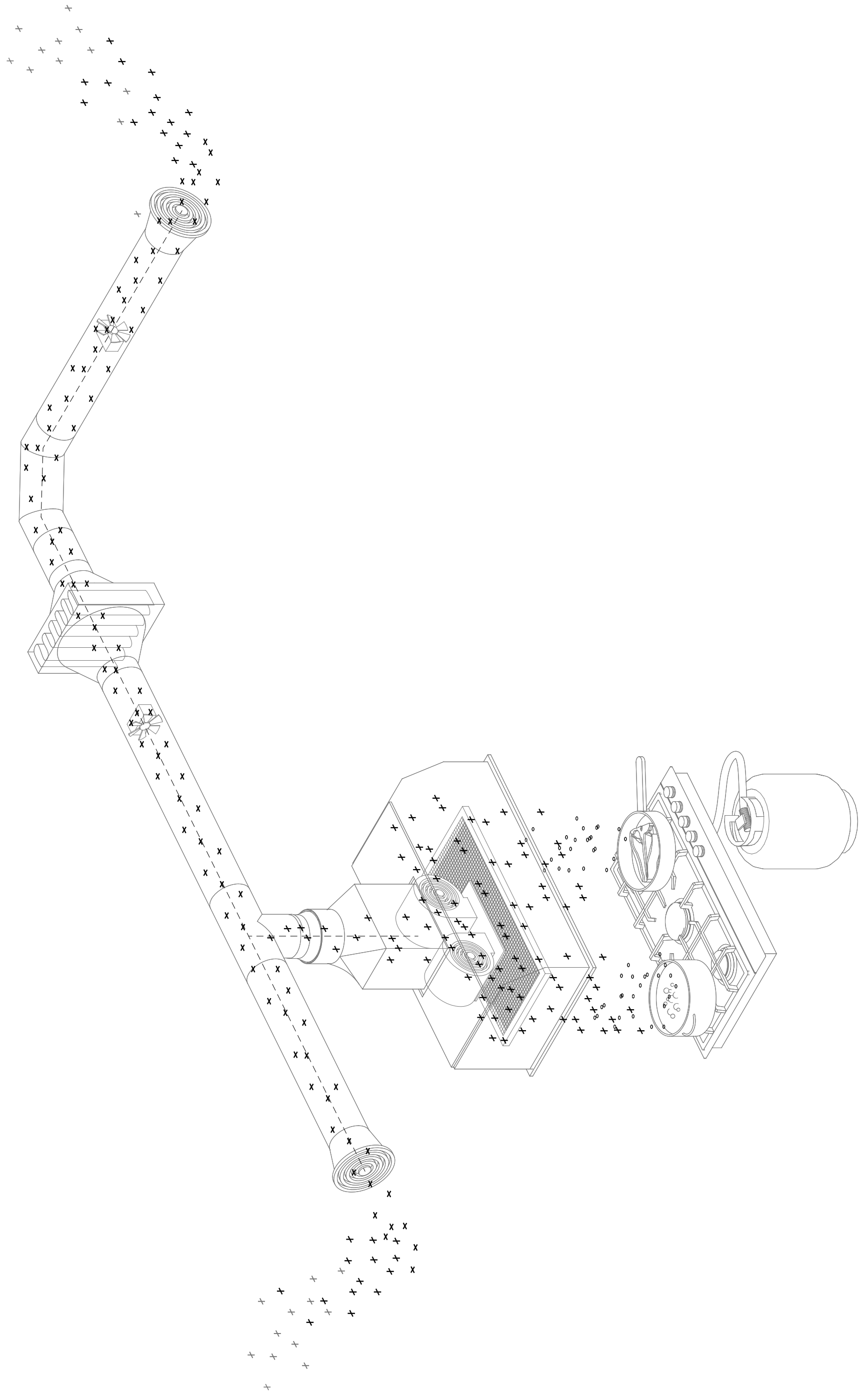

Fig. 2

Fig. 2: The air gap between cooking surface and ventilation system. The exhaust fan draws cooking steam, smoke, and odours from the cooking surface, into the exhaust hood and subsequent ducting. Diagram: author.

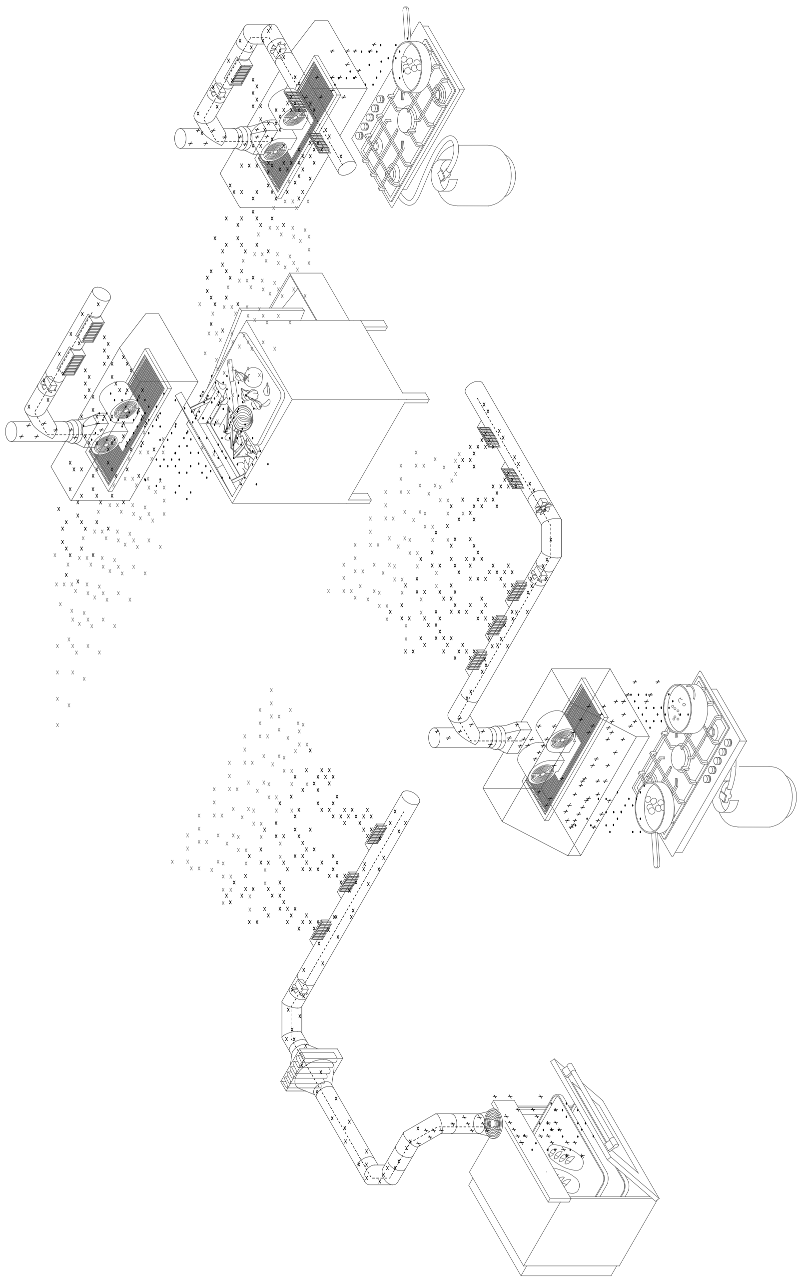

Fig. 3

Fig. 3: A C-shaped kitchen ventilation system is organized to eject cooked air into the centralized area while allowing for collective cooking along the exterior of the form. Diagram: author.

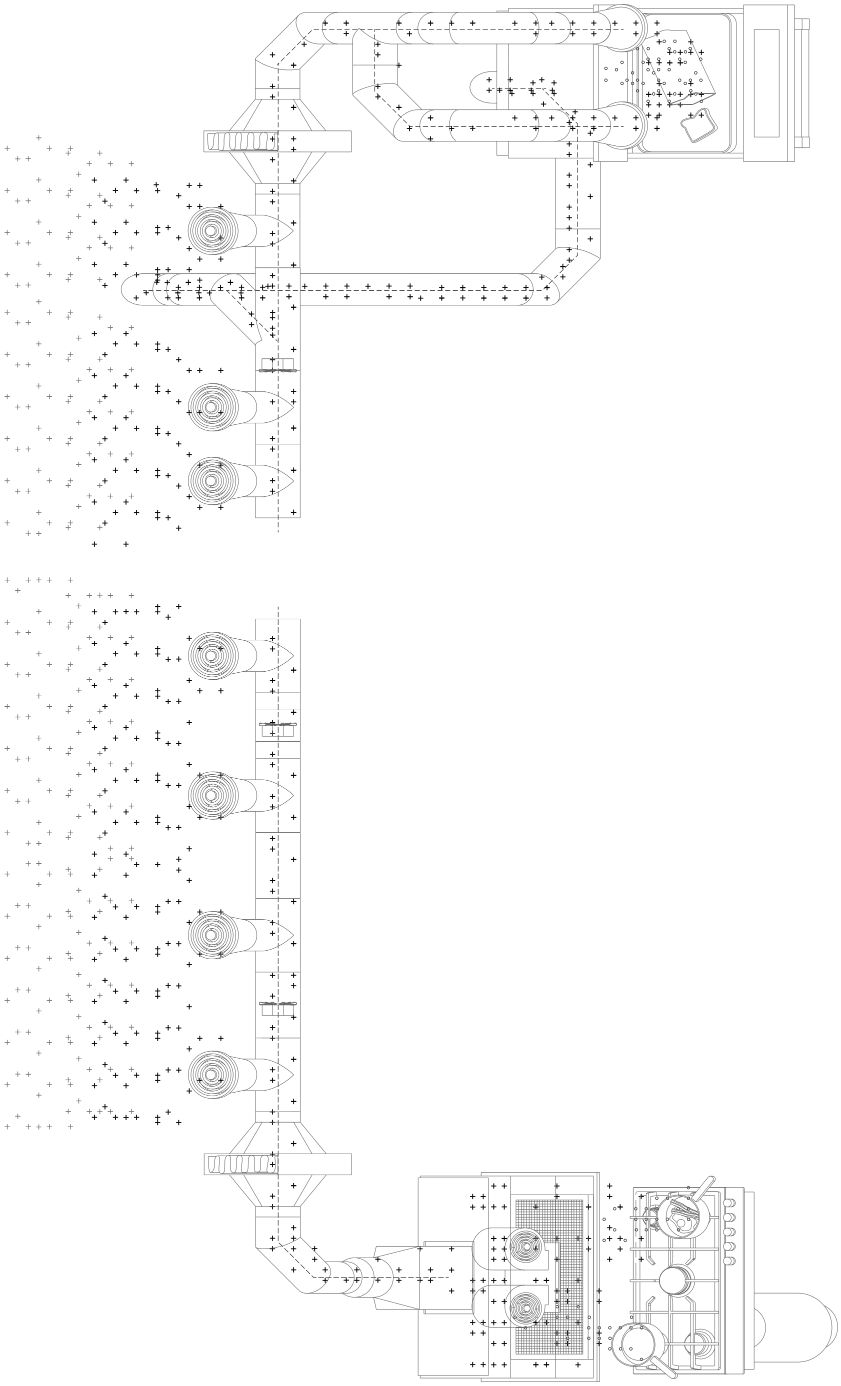

Fig. 4

Fig. 4: A linear kitchen ventilation system reorients cooked air particles and ejects them as a linear element. Diagram: author.

towards ventilation strategies. The discrete repertoire of knowledge between disciplines continues to set rules for a similarly discrete collaboration. Air management remains in the purview of those technically literate in its management and measurement media. Ventilation rates and normative equipment formats are determined by a discourse limited to professional associations such as ASHRAE who determine standards of care and practice, inviting little input in technical terms from those outside of the engineering disciplines. Yet, if air quality was previously managed through a combination of formal and sensing strategies, does evaluation and jurisdiction remain quantitative only?

Assessment of air

ASHRAE describes the purpose of *Standard 62.2* as defining 'the roles and minimum requirements for mechanical and natural ventilation systems and the building envelope intended to provide acceptable indoor air quality … in residential buildings.'[12] Acceptable indoor air quality is defined as 'air toward which a substantial majority of occupants express no dissatisfaction with respect to odour and sensory irritation and in which there are not likely to be contaminants at concentrations that are known to pose a health risk.'[13] ASHRAE offers the limitations of their scope:

> While acceptable IAQ is the goal of this standard, it will not necessarily be achieved even if all requirements are met
> a. because of the diversity of sources and contaminants in indoor air and the range of susceptibility in the population;
> b. because of the many other factors that may affect occupant perception and acceptance of IAQ, such as air temperature, humidity, noise, lighting, and psychological stress;
> c. if the ambient air is unacceptable and this air is brought into the building without first being cleaned (ambient outdoor air cleaning is not required by this standard);
> d. if the system or systems are not operated and maintained as designed; or
> e. when high-polluting events occur.[14]

The list underlines a series of supplements to the quantitative assessment of IAQ: influence on a population's habits, the user's sense perception, habituation, and, lastly, the importance of healthy exterior conditions, all affect our assessment of air quality. Metrics and perception together play an important part in shaping care and assessment toward the air around us. Perception of acceptable air in collaboration with mechanical understanding is written into the code itself. While IAQ has measurable qualities, these are often visible only via air sensing instruments and their reported data. The scope for the standard suggests that quantitative measurements do not provide sufficient assessment towards IAQ on their own.

Scientisation trends towards bringing knowledge to light, making qualities measurable. Why is it that, as ventilation processes become more measurable, there is an equal tendency to reverse this process in relation to the human sensation, when the code itself underlines the reality of both phenomenal and intellectual knowledge towards assessment? Although user sense perception and evaluation are listed as potentially critical to IAQ, they remain unaccounted for, ignored within the subsequent sections that deal with strategies towards IAQ assessment and application. Perception remains, instead, a caveat or limitation to calculability, opposed to a valid authority towards IAQ. As a disciplined science of air advances explication towards the expert, air management remains with the technically literate, both in terms of evaluation and execution.

Moving air

Despite public perception and mental images evoked by the term 'air pollution', known pollutant values are significantly higher in indoor air. Air pollution occurs not only on highways, nuclear power plants or in factories. It also occurs at home and curiously, most common indoor air pollutants can be found in the kitchen. At the domestic scale, cooking represents a high-polluting event. Recall our kitchen scene – cleaning products, odour particles, combustion, decomposition of food and waste. Cleaning products are sources of volatile organic compounds. Food and food waste are sources of bio-aerosols such as bacteria, fungi, and other biological matter. Combustion is a source of indoor aerosol or particulate matter as well as of carbon monoxide and dioxide.[15] As such, the kitchen continues to be a major contributor to indoor air pollution and the focus of 'air cleaning' interventions in the home.

Sealed enclosures preclude air movement and thus measures must be taken to mitigate indoor air emissions, such as those caused by breathing and cooking processes, in relationship to stagnant air. An improvement to the air quality then must focus on an increase in air movement, which is measured at the rate of cubic metre per minute (m^3/min). Air movement or ventilation focuses on creating movement via the introduction of outdoor air, while air cleaning focuses on filtration, which also requires moving air to be pushed through the filtration mechanism. Indoor and outdoor air is differentiated as follows:

> *air, indoor:* air in an occupiable space.
> *air, outdoor:* air from outside the building taken into a ventilation system or air from outside the building that enters a space through infiltration or natural ventilation openings.[16]

ASHRAE defines ventilation as 'the process of supplying outdoor air to or removing indoor air from a dwelling by natural or mechanical means'.[17] The air that is captured as part of the ventilation process becomes ventilation air, or outdoor air delivered to a space that is intended to dilute airborne contaminants.[18] Air cleaning is 'the use of equipment that removes particulate, microbial, or gaseous contaminants (including odours) from air'.[19] Ventilation, then, is tasked with ejection, or removal via the movement of air. However, are contaminants not so much re-moved, as they are simply moved? Air particles are trapped onto filters or re-moved to the 'exterior'.

Fresh air supply is necessary for healthy indoor air, and yet air is nefarious in its tendency toward diffusion. The concept of ventilation, passive or mechanical, thinks of air as constantly moving in and out. In other words, the way we formally and institutionally define a matter like air – bound, unbound, proximal, separable, cleanable, spent – influences how we think about that air and thereby how we conceptualise it.[20] Prescribed spatial qualifiers such as 'outdoor air', 'indoor air' or 'ventilation air' separate air and mask the complex unbounded and fluid nature exhibited by statistical particle movement. Air is more or less proximal. Air cannot be pinned down – mixing, simmering, cooking – in, out, in, out, or out, in. Qualifiers such as 'fresh', 'exhausted', 'moving' or 'stagnant', on the other hand, recognise the delicate continuity, mutability, and instrumentalisation of air as a surrounding medium. Is air separable? Does air have a form? And if so, what is the nature of this form? Who manages or composes this form?

As breaths come in pairs, air quality relies on a vital inhale/exhale relationship. Cooked air is extracted from the cooking surface, inhaled by the ventilation hood. Subsequently, cooked air is ejected through mechanical exhaust systems to the outdoors. Exhaust systems direct spent air outward. Ejected air, after all, should not find its way back in. Yet, the potential re-inhalation of exhausted air poses a challenge to ensuing air intake. To mitigate this, ASHRAE regulations devise inhalation and exhalation protocols via the deployment of required minimum separation distances between air outlets and intakes and through the incorporation of air dampers throughout the ventilation system. *Standard 62.2* indicates that 'air inlets that are part of the ventilation design shall be located a minimum of three metres from known sources of contamination such as a stack, vent, [or] exhaust hood'.[21] Although, backflow prevention regulation recognises a paired breathing process, 'user controlled' breathing equipment focuses primarily on air extraction or exhalation processes. Questions of where and how (location, volume, velocity) air movement occurs remain in the purview of the ventilation expert, while mechanical intake takes place largely through automatic control systems. A local-demand-control operation focuses on exhaust mechanisms in which the 'when' can be controlled by inhabitants as specified in Section 5.1-5.2. Moreover, Section 5.2.1 specifies that mechanical exhaust equipment provide 'on-demand user control'. This control, usually in the form of an on-off switch, enables the cook to exhale cooked air on demand via the extractor fan while mandating a minimum ventilation rate of fifty litres per second.[22] Movement via controlled ejection lies with the user.

Domestic-scale breathing habits currently rely on standards of care for indoor air, which is the focus of *Standard 62.2*. Yet, interior air quality relies on air cleaning via a supply of fresh exterior air. We then rely explicitly on the availability of high-quality exterior air. To become re-implicated in the healthiness of our exterior air, we keep in mind we have to draw the air nearest to us back in. It is deceptive then to 'separate' air into interior and exterior qualifiers, where air pollutants are circulated constantly throughout the day. As exterior air is considered 'healthier' or fresher than our interior air, indoor air cleaning is, in fact, achieved via the removal of contaminants from interior air and subsequent ventilation which focuses on the introduction of exterior air. What does it mean then to exhale, when there is only air, as opposed to indoor and outdoor air? How do we, as both architects and users, implicate ourselves within air-management once again?

Explication, or what cooked air can be

The form of air lies with those technically literate in its art, the movement of air, its inhalation and exhalation. Technical literacy implies design control. *Standard 62.2* shows that the form, velocity, path, location, volume, and quality of air lie with the technical expert, the designer of mechanical air systems. Movement via controlled ejection lies with the user. Architectural designers collaborate towards composition in relationship to current understandings of architectural aesthetics of the architectural project, that which is 'material'. The architect is additionally tasked with decisions regarding the concealment or revealing of ducting via the integration of shafts and mechanical rooms into building design. Air has (im) material form; though it cannot be explicitly 'seen' through typically architectural aesthetic mediums, it is nevertheless material as made explicit in the mechanical systems needed to form and move it. Yet while mechanical systems form the vessel for air movement, hardware materiality should not be conflated as congruent to the (im)material form of air.

Should we not only be more aware of our domestic emissions, but also more readily implicated in their inhalation/exhalation relationship? How we think air, and where we think air, in turn influences how we care for air, as well as who cares for it. Cooked air, then, is the air which architects together with users and air movement specialists choose to implicate readily. Focusing on the inhale-exhale relationship, the possibilities of 'what cooked air can be' lies latent in kitchen respiration through, first, the language of technical literacy. Air mechanics can expand from the merely technical analysis of air to include the aesthetic and formal qualities of air itself, not merely that which we are trained to 'see' as material. Second, the aesthetics of cooked air includes the movement of air and an understanding of air as a continuous medium that is always in motion through an inhale-exhale relationship in the home. The behaviour of air, managed through mechanical equipment, as well as the qualities of air itself, its velocity, the particles it carries, its freshness or cooked-ness, in turn give form to air. Lastly, architecture can expand the science of air to include aesthetic sensibilities through air explication.

Air particles exist as physical, (im)material pixels that surround and fill a breathable milieu. In *Terror from the Air*, Peter Sloterdijk describes the military's instrumentalisation of mechanical air knowledge.[23] In this case, air is managed towards the making of weapons. An 'airquake: … the explication of air, climactic and atmospheric situations calls into question the basic presumption of beings concerning their primary media of existence.'[24] Explication, then, is more than simply explaining, or making ventilation functional. Rather, air explication entails 'technical redesigning'.[25] In the attack of an opponent's atmosphere, or breathable environment, lies latent the fact that humans exist as 'beings-in-the-air'.[26] We are in a constant state of breathing that air which surrounds us. Of the biological cycles supported by our home, none is more immediate than the ability to breathe easily.

> Explication is a matter not just of the conceptual instruments that we deploy to illuminate the phenomena of life – such as dwelling, working, and loving – it is not just a cognitive process. Rather, it has to do with real elaboration. That can only be achieved using an expressive logic or a logic of production.[27]

Explication, then, in the repertoire of architectural thinking toward air management, is not merely to resolve the functioning of air, or to concern the composition of mechanical equipment for its own sake, but to implicate this equipment towards the 'design of air'. To remake air-management as architectural, technical literacy, jurisdiction and assessment must appeal to the aesthetics of air. Human interactions with equipment, cooking activities and exhalation mechanisms can relate to architectural acts. Simply ejecting spent air is not explication. Architecture could explicate – meaning that we could use that air to do something with it and that would be an actual 'control' over the substance – being creative with it, doing something with it. Yet, to design requires deeper understanding than that which we have acquired as mere users of these systems. Architectural air explication requires transdisciplinarity: 'retying the Gordian knot' of knowledge from fragmented disciplines, the aesthetic, the technical and the legal.[28]

Architecture's domain centres on formal and aesthetic logics. Expanded technical literacy and interest are necessary if architecture is to engage mechanical equipment within an aesthetic domain. Compositional thinking must then not be limited to the arrangement of pipes, rather the mechanical arrangement of pipes is the instrumental language for their management and design. How can the architectural discipline embrace technology to create forward-looking architectures? Reyner Banham offered a significant critique of modernist and high-tech architectures in relationship to the machine aesthetic.[29] While arguing for a well-tempered environment, Banham was simultaneously disillusioned with the treatment of mechanical equipment as an aesthetic itself. The task of looking towards new technologies to inspire an advancement of architecture is not to make architecture look like these technologies or to treat technologies as compositional objects in themselves. Rather, the task of the architect is to 'accelerate their possibilities'. Such an expansion suggests an authentic relationship to the machine in itself as opposed to only its immediately assumed instrumental use. What is already the main task of ventilation is the movement of air. A pursuit of accelerating the design possibilities of air-moving machinery might then entail an 'explication of air'. What might a technical redesigning of ventilation mean then? It is certainly not an aesthetic obsession with the arrangement or aesthetics of the flues, but rather an instrumentalisation of those flues towards an advancement of architecture. To 'accelerate the possibilities' of what mechanical equipment can do is not simply to resolve ventilation but to play with it. Walls of smoke, facades made fuzzy by ejected steam, floors of sewage gasses. [Fig. 4] While such interventions remain mostly unseen to the naked eye, felt qualities can also communicate architectural elements. Designing with air appeals to the senses, that of touch, of smell, of hearing. Additionally, a vast availability of measurement and visualisation technologies already expands our methods of 'seeing' within architectural discourse.

Maintaining one's biological care cycle relies on and extends to the management of (im)material resources through equipment. One removes abject air, through the sneeze, the ticklish or used-up air from one's home via a series of technological formulations. To make environmental issues real they must be understood both intellectually and perceptually, known and felt.[30] The development of domestic air explication can make explicit the relation between individuals and environmental care in everyday, localised, biological cycles. *Standard 62.2* acknowledges a tension in achieving air quality as both technical and perceptive when setting out the applicability of such standards. Yet in its subsequent pages, the standard disregards susceptibility or perceptual knowledge, with a bias towards an objective ventilation science, achievable via explicitly techno-scientific air management epistemologies. In essence, this specificity refutes the potential redesigning of air to engage its perceptual or felt possibilities. It remains to those concerned with its aesthetic, formal and material qualities to extend the science-of-air to engage the 'susceptibility of the population' in terms of occupant perception.

Notes

1. Diane Ackerman, 'Smell', in *A Natural History of the Senses* (New York: Vintage Books, 1995), 6.
2. See Gilbert Simondon, 'Man and the Technical Object', in *On the Mode of Existence of Technical Objects* (Minneapolis: Univocal, 2010), 103–70.
3. International Code Council, 'Definitions', in *2015 International Residential Code for One- and Two-Family Dwellings* (ICC, 2014), https://codes.iccsafe.org/content/IRC2015/chapter-2-definitions.
4. Reyner Banham, *The Architecture of the Well-Tempered Environment* (Chicago: The University of Chicago Press, 1984), 20.
5. Odile Redon, Françoise Sabban and Silvano Serventi, *The Medieval Kitchen: Recipes from France and Italy*, trans. Edward Schneider (Chicago: The University of Chicago Press, 2000), 16–17.
6. Ibid., 16.
7. The solid-fuel stove, also known as a cookstove, is a stove that is heated by burning bio-mass such as wood or charcoal. It includes a vent flue which ducts fumes directly from its firebox to the outdoors.
8. Georges Canguilhem, 'The Living and its Milieu', trans. John Savage, *Grey Room 03* (Spring 2001): 7–31.
9. Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton: Princeton University Press, 1985), 22–79.
10. ASHRAE, *ANSI/ASHRAE Standard 62.2-2019:* Ventilation and Acceptable Indoor Air Quality in Residential Buildings (Atlanta: ASHRAE, 2019), 2.
11. Imperial units have been omitted from the description. For total required ventilation rates in Imperial units, refer to *ASHRAE Standard 62.2*, 6.
12. *ASHRAE Standard 62.2*, 2.
13. Ibid., 3.
14. Ibid., 2.
15. United States Environmental Protection Agency, 'Introduction to Indoor Air Quality' (2020), https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality.
16. *ASHRAE Standard 62.2*, 3.

17. Ibid., 5.
18. Ibid., 3.
19. Ibid., 2.
20. 'It matters what matters we use to think other matters with; it matters what stories we tell to tell other stories with; it matters what knots knot knots, what thoughts think thoughts, what descriptions describe descriptions, what ties tie ties. It matters what stories make worlds, what worlds make stories.' Donna Haraway, 'Making Kin', in *Staying with the Trouble: Making Kin in the Chthulucene* (Durham, NC: Duke University Press, 2016), 12.
21. *ASHRAE Standard 62.2*, 13.
22. See Table 5-1, Demand Controlled Local Ventilation Exhaust Air Flow Rates in ASHRAE Standard 62.2, 11.
23. Peter Sloterdijk, 'Increasing Explication', in *Terror from the Air* (Cambridge, MA: Semiotext(e), 2009), 47–71.
24. Sloterdijk, *Terror From the Air*, 28.
25. Peter Sloterdijk, *Foams: Spheres Volume III: Plural Spherology* (Cambridge, MA: Semiotext(e), 2009), 66.
26. Sloterdijk, 'Increasing Explication', 48.
27. Peter Sloterdijk, 'Talking to Myself about the Poetics of Space', *(Sustainability) + Pleasure* I, no. 30, *Culture and Architecture* (S/S 2009), http://www.harvarddesignmagazine.org/issues/30/talking-to-myself-about-the-poetics-of-space.
28. Bruno Latour, *We Have Never Been Modern,* trans. Catherine Porter (Cambridge, MA: Harvard University Press, 1993), 3–5.
29. While modernism engaged questions of new materials and technologies, the architecture it produced continued to be primarily about form, aesthetics, and artistic problems. See Reyner Banham, *Theory and Design in the First Machine Age* (Cambridge, MA: The MIT Press, 1980), 320–30.
30. Canguilhem, 'The Living and its Milieu', 7–31.

Biography

Liz Gálvez is a Mexican-American educator and a registered architect. She is a visiting critic at the Rice School of Architecture and directs Office (e.g.), a practice interested in examples of possible architectures. Her work focuses on the interface between architecture, theory and environmentalism. Gálvez received her Master of Architecture with a concentration in History Theory and Criticism from the MIT School of Architecture and Planning. She has taught at the University of Michigan's Taubman College, where she was the 2018–19 William Muschenheim Fellow. She has practiced at various award-winning firms in the United States and in Mexico, including Will Bruder Architects, NADAAA and Rojkind Arquitectos. Gálvez's writing has been published in *PLAT*, *Footprint,* and *Pidgin* (forthcoming). Her work has been exhibited at MIT, the Hohensalzburg Fortress, The University of Michigan, and at the Space p11 Gallery in Chicago.

Review Article

Automation and the City: Constant's New Babylon (1959–1974)

Iris Giannakopoulou Karamouzi

For an extended period of fifteen years, from 1959 to 1974, Dutch artist and founding member of the revolutionary group *Situationist International* (SI), Constant Anton Nieuwenhuys, known simply as Constant, developed New Babylon, a speculative city for a future society in which automation would free human life to dedicate itself to creativity, collectivity and play.[1] Emblematic of the mega-structural experiments that dominate the architectural imaginaries of the 1960s, New Babylon has been analysed in great length and from various perspectives. Yet little attention has been paid within the existing scholarship to the subject of automation and its manifold implications for the project. This essay argues that automation was a structural aspect of Constant's thinking about the city. More than a technical and economic prerequisite, automation described a creative condition of future urban environments. As such it required a re-conceptualisation of the collective habitat. New Babylon should be understood as the architectural articulation of this imminent condition.

A new urban imaginary

In December 1959, Constant's article 'Another City for Another Life' was published in the third issue of *International Situationist*, the official bulletin of the SI.[2] There, Constant offered 'the first rough description of New Babylon'.[3] The article was accompanied by a series of drawings of a 'traditional town', a 'green city', as well as Constant's spatial plan of a 'covered city'. Constant proposed the latter as an alternative to the modern green city that emerged from the so-called garden-city movement propagated around 1 900 by the English town planner Ebenezer Howard as an urban and environmental strategy that could mitigate the urban congestion brought about by the growing processes of industrialisation.

Against the modernist 'idealisation of utilitarian life', Constant's new urban imaginary was envisioned as ever-variable, 'flexible enough to respond to a dynamic conception of life, which means creating our own surroundings in direct relation to continually changing modes of behaviour'.[4] Future cities like New Babylon, which was yet to be named as such, would offer 'a wholly new variability of sensations' and 'unforeseen games' would become possible 'through the inventive use of material conditions, such as the modification of air, sound and light'.[5] These environments, or 'ambiances' in the Situationist lexicon, would be 'regularly and consciously changed, using all technical means, by teams of specialised creators, who would thus be "professional situationists"'.[6] Far from a nostalgic return to nature or a profitable union between the city and the countryside, Constant's new urban imaginary promised 'the possibility of overcoming nature and of regulating the climate, light and sounds in these different spaces to our desires'.[7] In Constant's view, automation marked the prospect of erasing any difference between the artificial and the natural environments. The city would no longer be a counterpart of the countryside in an antagonistic relationship but rather part of one extended symbiotic ecology that included both the natural and the artificial, while being subject to human creative control and inventive manipulation.

A year later, in June 1960, the name New Babylon appeared for the first time in the editorial notes of another article by Constant entitled 'Description of the Yellow Sector'.[8] In this article and for the first time, Constant cautiously introduced his new urban imaginary in the form of a precise architectural proposal. Despite the fact that the 'Description of the Yellow Sector' lacked any explicit reference to automation, which in the previous article was described as a precondition of life in the future, it marked Constant's effort to materialise his new urban vision in architectural terms. The Yellow Sector provided a general framework of the arrangement that favoured the permanent variation of the environment. Sheet-aluminium, titanium, nylon, glass and large optical lenses were the cutting-edge materials that Constant used for his framework. As in the previous article, Constant alluded again to the ever-variable artificial conditions of the environment that would be regulated by situationist teams in conjunction with the technical services supported by the technological sector.

If the model of the garden cities was conceived by Howard as a response to the industrial machines of the age of standardisation, one can argue that Constant's new model sought to answer to the new intelligent machines of the age of automation. Automation, for Constant, was the inevitable, if not desired, economic condition that would result in the reduction of the work necessary for production and could eventually lead to the realisation of the 'Marxist kingdom of freedom'.[9] Yet most importantly, Constant's writings suggest that automation also described a creative condition which had to be deployed in the realm of city and for the purposes of unitary urbanism, 'an urbanism designed for pleasure'.[10]

Automation and the city

In a lecture presented at the Faculty of Architecture at the Technical University of Delft in 1980, ten years after a self-imposed hiatus from the project, Constant offered a critical re-examination of New Babylon.[11] There, he acknowledged the two aforementioned essays as the starting points of the project. Nevertheless, this beginning also made his 'break with the Situationist International inevitable'.[12] In December 1960, just months after the publication of Yellow Sector, 'this break was announced in the journal with the sour remark' that Constant 'had given priority to the structural problems of urbanism while the others wanted to stress the content, the play, the "free creation of everyday life"'.[13]

This break seems rather surprising if one considers the appraisal of New Babylon by Guy Debord himself in his essay 'Constant and the Path of Unitary Urbanism' written in 1959.[14] It is even more unexpected given the fact that the project did not appear to contradict the idea of 'unitary urbanism' as delineated in 'The Amsterdam Declaration', a text co-written by Constant and Debord and published in 1958 in the second issue of *International Situationist*.[15] According to this declaration, 'unitary urbanism' was defined as the 'complex, ongoing activity that consciously recreates man's environment according to the most advanced conceptions in every domain'.[16] In this process, 'all means are usable, on condition that they serve in a unitary action. The coordination of artistic and scientific means must lead to their total fusion.'[17] If New Babylon was a practical response to this call, what were those 'structural problems of urbanism' that Constant prioritised, and that resulted in his divorce from the SI?

In recounting the period after his withdrawal, Constant remarks: 'In the meantime, and scarcely noted at first, a development was taking place in society that was to give New Babylon an important boost: the second industrial revolution based on automation'.[18] Constant points out the 'enormous topicality' that New Babylon acquired during the 1960s and especially within the debate around the pros and cons of automation. He further contends:

> Since Norbert Wiener, the pioneer of automation,

> wrote his first study of its possible social consequences, whole libraries have been filled with works on the subject. The problem still seems to be the difficulty the human mind has in picturing the (as yet) non-existent, in freeing itself from the familiar pictures lodged in its consciousness. Visualising the unseen is a typical task for the visual arts. The author who attempts to write about the automated society almost inevitably falls into the yawning gap between that society and the known.[19]

This was not the first time that Constant alluded to mathematician Norbert Wiener, the father of cybernetics, who in 1948 coined the term to describe the scientific study of control and communication in the animal and the machine. In his book *Constant's New Babylon: The Hyper-Architecture of Desire*, architectural historian Mark Wigley affirms that since the beginning of New Babylon, 'Constant closely followed the arguments of Wiener, the leading theorist of cybernetics, repeatedly citing texts like *The Human Use of Human Beings* to the effect that the computer will allow work to be automated'.[20] Yet more than these direct allusions to Wiener, Constant's texts abound in references to the development of the robot, the continued mechanisation of life and the possibilities offered by the emerging computational and digital technologies.

These remarks confirm the necessity of positioning New Babylon within the debates about the implications of automation which took place during the early 1960s. These debates reflected the high hopes and deep fears that people projected onto the idea of automation. They extended beyond automation's immediate consequences in production processes and the subsequent pre-eminence of leisure over work, to automation's potentially liberating or detrimental outcomes for society as a whole.[21]

Therefore it is possible that the 'structural problems of urbanism' that Constant focused on and that resulted in his break from the SI were related precisely to his fundamental preoccupation with the question of automation. Constant argues that New Babylon 'developed from hypothesis to conceptual model', the hypothesis being that of an automated society.[22] The question that now presents itself is what purpose that model served. According to Constant, it could be used

> for thinking about a social structure that is so different from the existing one that it can safely be called its antithesis words and terms are inadequate tools. Since what we are considering here is no abstraction but a material world, as in physics, it seems almost logical to resort to visual tools; in other words, a model. The construction of this model should be based on the material conditions that can be inferred from automation and that are decisive for the material shape of the world.[23]

New Babylon thus was a tool. Its purpose was 'picturing the (as yet) non-existent', the pressing task of the age of automation that the situationists had already identified in the very first issue of the SI bulletin. This inaugural issue featured, amid the founding definitions of the situationist practices, an article by artist Asger Jorn entitled 'Automation and the Situationists'.[24] Although in his essay Jorn appears more sceptical than Constant regarding the capacity of automation to liberate subjects from the drudgery of work, he shared Constant's belief that the problem lies in 'the dialectical role of the spirit' in steering 'the possible towards desirable forms'.[25] Like Constant, Jorn too held that 'experimental activity in culture' was an 'incomparable field of play' and the only force that could 'supersede the negative consequences of automation and elevate human energy towards a higher plane'.[26] Media and cultural theorist MacKenzie Wark summarises New Babylon's dialectical purpose and creative impetus as follows: 'New Babylon is, among other things, a spatial solution to a conceptual problem. It is philosophy made abstract.'[27]

The new New Babylon

The philosophy put forth by New Babylon suggests that the 'ultimate implications' of automation, that Jorn sought to grasp early in the SI history, do not lie in its immediate technical and economic consequences which could 'render man master and not slave of automation', as much as in the new social, creative, and urban possibilities that automation opened up.[28] Within these possibilities and in Constant's imaginary, the city emerges as a 'complete environment', part of an extended ecology and dynamic activity.

The extent to which New Babylon is enmeshed in ideas around automation and cybernetics is open to debate – a debate that is productive, in my opinion, for a rethinking of both the history of New Babylon and the SI, as well as that of the architecture and urbanism of the 1960s. What is undeniable is the broader historical position that such connection reinstates. The fact is that there is no uniform narrative of the widespread processes of cybernetisation that forged the cultural and scientific arenas of the late 1950s and 1960s and whose effects we can still trace today. New Babylon bears witness to the diverse genealogies and theoretical entanglements of these fictions. It showcases the extended ramifications of automation, beyond the technical, computational and digital into the cultural, political and artistic. The original name of New Babylon, *Dériville* or 'drift city', affirms this point. It is the 'drifting' through these histories that opens up the possibilities for a recuperation of New Babylon today.

Notes

1. The Situationist International was officially founded in 1957 during a conference at Cosio d'Arroscia, Italy and was dissolved in 1972. However, its foundations were laid a year earlier in Alba, Italy, during a symposium organised by Pinot Gallizio on the topic of Industry and the Fine Arts (*Primo congresso mondiale degli artisti liberi*). There, Constant presented a lecture with the title 'Tomorrow Life Will Reside in Poetry' and advocated for a free architecture that would stimulate rather than restrict creativity. During this congress Constant met Guy Dedord, with whom he later co-founded the SI group. For a republication of 'Tomorrow Life Will Reside in Poetry' see: Mark Wigley, *Constant's New Babylon: The Hyper-Architecture of Desire* (Rotterdam: Witte de With, 1998), 78.
2. Constant, 'Une autre ville pour une autre vie', *Internationale Situationniste* no. 3 (December 1959): 37–40.
3. Wigley, *Constant's New Babylon*, 232. Note that the first image of New Babylon to be published was Jan Versnel's photograph of Constant's model entitled *Ambiance d' une ville future*, published in the Stedelijk Museum catalogue.
4. Ken Knabb, *Situationist International Anthology* (Berkeley: Bureau of Public Secrets, 2016), 71.
5. Ibid., 72.
6. Ibid., 73.
7. Ibid., 72.
8. The article was initially entiled 'Description of the Yellow Zone'. Constant, 'Description de la zone jaune', *Internationale Situationniste* no. 4 (June 1960): 23–26. The editorial note reads: 'The yellow zone is the first itinerary of the Promenades in New Babylon, a descriptive guide of the maquette-islets whose assemblage constitutes a reduced model of the "covered city". Constant, in the third number of this bulletin, formulated the basic principles of this particular hypothetical notion of unitary urbanism'; my translation. For an English translation of the article see: Wigley, *Constant's New Babylon*, 122.
9. Wigley, *Constant's New Babylon*, 160.
10. Ken Knabb, *Situationist International Anthology*, 71.

11. Constant, ‘New Babylon – Ten Years On’, trans. Robyn de Jong-Dalziel, in Wigley, *Constant’s New Babylon*, 232–36.
12. Ibid., 232.
13. Ibid., 232.
14. Ibid., 95–96.
15. Constant and Guy Debord, ‘The Amsterdam Declaration’, trans. Paul Hammond, in Wigley, *Constant’s New Babylon*, 87.
16. Ibid.
17. Ibid.
18. Ibid., 233.
19. Ibid., 233.
20. Ibid., 63.
21. Such a hypothesis is particularly interesting given the highly critical stance of the SI towards cybernetics. For example, one can recall the 1965 episode with Abraham Moles, a key figure of information theory also known for his professorship at the Ulm School of Design (*Hochschule für Gestaltung Ulm*). In an open letter to the SI, dated 16 December 1963, Moles had expressed his interest in the group. However, a few years later, on 17 March 1965, situationists in Strasbourg highjacked a conference that attempted to honour Moles and the cybernetician sculptor Nicolas Schöffer and used the occasion to distribute both their pamphlet ‘The Tortoise in the Window: Dialectic of the Robot and the Signal’, and a reprinted version of the ‘Correspondence with a Cyberneticist’, which included Guy Debord’s rebuttal of Moles’s 1963 letter that opened with the words ‘Little head’, setting the disparaging tone of his response from the onset. See: ‘Correspondance avec un Cýbernetician’, *Internationale Situationniste* no. 9 (December 1959): 44–48.
22. Wigley, *Constant’s New Babylon*, 233.
23. Ibid., 233.
24. Asger Jorn, ‘Les Situationnistes et l’ Automation’, *Internationale Situationniste* no.1 (June 1958): 22–25.
25. Knab, *Situationist International Anthology*, 55.
26. Ibid., 56.
27. McKenzie Wark and Ali Dur, ‘New New Babylon’, *Digital Art*, October 138 (2011): 42.
28. Knab, *Situationist International Anthology*, 55.

Biography

Iris Giannakopoulou Karamouzi is an architect and a researcher from Athens, currently pursuing a PhD in the history and theory of architecture at Yale University. She holds a Diploma of Architecture from the National Technical University of Athens (2014) and an MSc in Architecture Design as a Fulbright Scholar from the MIT School of Architecture (2018). Currently, she is investigating the cultural, technological, and ideological formations that came to prominence during the beginning of the twentieth century, paying special attention to the experimental compositional, inscriptive and interpretative processes employed by literary and artistic avant-gardes.

Review Article

'What are people for?' Ecologists and the Articulation of the Built Environment

Juliana Yat Shun Kei

'Lost hordes of mini-citizens erupting, like bewildered human lemmings, from more and more mega-cities'; the prominent British architect-planner Sir William Holford employed this alarmist quote from the influential environmentalist Max Nicholson as the closing statement to his 1964 lecture entitled 'The Built Environment, its Creation, Motivations, and Control'.[1] The lecture was an important moment when Holford offered his articulation of the built environment – a term that was first published and employed, in the English language, in a statement from the Royal Institute of British Architects (RIBA) earlier that year.[2] Holford focused his lecture on the threat of overpopulation and the supposed resulting neuroses. He argued that more attention should be paid to the forecasting and control of human relations, as well as a better incorporation of 'the realm of social ecology' in architectural and planning debates.[3] Holford also evoked cybernetics, operation research, and communication theory as techniques for better alignment between policies and development plans.[4]

The discussions found in his articulation of the built environment seem to be a departure from Holford's professional outlook at the time. As an establishment figure in British architecture and planning, Holford was not regarded as someone with pioneering environmental visions.[5] His reconceptualisation of architecture and planning as 'the continually changing end-result of all the smaller designs and their co-ordination – or lack of it', Holford explained, was shaped by the thought of Nicholson and Julian Huxley.[6] In the existing studies of architectural history and theory, Huxley has been seen as an important figure bridging ecological thinking with debates in planning and preservation.[7] What is lesser known is that Nicholson, whose career triangulated civil service, policy planning, and conservation, also had been involved in the theory and practice of landscape, planning, and architecture in Britain since the 1940s. For example, he helped set out the agenda of the Festival of Britain (1951), an event that was instrumental in the promotion of modernist art, architecture and design in post-war Britain, through his role as the secretary to the director of the festival.[8] Holford's lecture thus offers a starting point to retrieve these previously overlooked exchanges between ecology and architecture, and to demarcate the infusion of cybernetic thinking in architecture and planning with technocracy, evolutionary humanism, and conservation politics.

It is worth clarifying that most of the discussions examined in this essay do not evoke cybernetics at length. Instead, they are eco-systematic ideas that were influenced by and share characteristics with cybernetics. To borrow the words of the historian of science Simone Schleper, both can be broadly summarised as the studies of 'the messages and feedback loops used by machines as well as organisms to adapt to their environment'.[9] Introduced by Arthur Tansley in the late 1930s, the concept of the ecosystem put forth a paradigm shift in the field of ecology, the focus turned from describing the specifics of natural succession to the physiochemical processes between organism and their environment.[10] In other words, the ecosystem converted ecology into a study of relationships. Another key influence on Huxley and Nicholson's thinking was the conceptualisation of the ecosystem as closed cycles of energy flow – starting from plants' synthesis of solar energy into nutrients and ending with the organism returning to soil as nitrogen and proteins.[11] Based on the laws of thermodynamics, the energy is always conserved, and the cycles are closed.[12] This closed-cycle assumption underscores the work on conservation advocacy by Huxley and Nicholson, in which both emphasise the importance of attaining an equilibrium within the system.[13]

Nicholson's eco-energetic thinking was influenced, in particular, by the American ecologists Eugene and Howard Odum, who considered ecosystems as cybernetic systems.[14] Nicholson adapted the Odum brothers' complex circuit diagrams in his critique of both British politics and the environment. For example, in 1967, he produced a diagram in his book *The System* portraying the body politic of the United Kingdom as a closed energy-entropy system.[15] [Fig.1] The diagram articulates a political vision that merges eco-systematic thinking with biopolitics by outlining a technocratic ambition of governing both the milieu and the inhabitants.[16] Two years later, using a similar method, Nicholson produced another diagram illustrating a co-evolutionary relationship between 'biosphere' and 'technosphere'.[17] [Fig. 2] While the biosphere denotes naturally occurring biological processes and natural resources, the technosphere includes human-centric activities such as processing, consumption, and marketing. How resources are produced, extracted, and consumed is indicated as flows that demonstrate the interlinks and interdependencies between the biosphere and technosphere. Noteworthy is that at the bottlenecks of the diagram, the unwanted by-products such as the various forms of pollution and contamination appear, which give rise to the 'human-modified environment' and interrupt the circuit of energy flow. Reviewing these two eco-systematic diagrams alongside each other, Nicholson's complex view on the relationship between human, society, and the environment becomes apparent. Firstly, he articulated a co-evolutionary relationship between human activities, environment, and the nation's socio-political system. Secondly, he believed that the control of human activities is crucial to the maintenance of the equilibrium of systems – political and ecological alike.[18]

The humanist frame

In 1961, Huxley edited a volume entitled *The Humanist Frame,* which both Nicholson and Holford contributed to.[19] The publication offered an opportunity to synthesise Nicholson's diagnosis of human activities with Huxley's evolutionary humanism and both with debates in architecture and planning. In his introduction, Huxley states:

> The spectacle of explosive population-increase is prompting us to ask the simple but basic question, *what are people for?* And we see that answer has to do with their quality of human beings, and the quality of their lives and achievements.[20]

The question 'what are people for' and the underlying eugenic approach to population control percolated throughout the book. Moreover, it conditioned Nicholson and Holford's articulation of the relationship between the environment and humanism. The discussion in *The Humanist Frame* is anthropocentric. However, unlike the environmental discourses that burgeoned in the latter part of the 1960s, the main goal of the authors was not only to protect and improve the environment for human survival. Instead, *The Humanist Frame* questioned the purpose of humans and their activities, thus to explore what would be the next stage of evolution for the humankind.

Another influence on Huxley's evolutionary humanism was the introduction of psychosocial changes into evolutionary ecology. Huxley claimed that there had been two critical points in evolution:

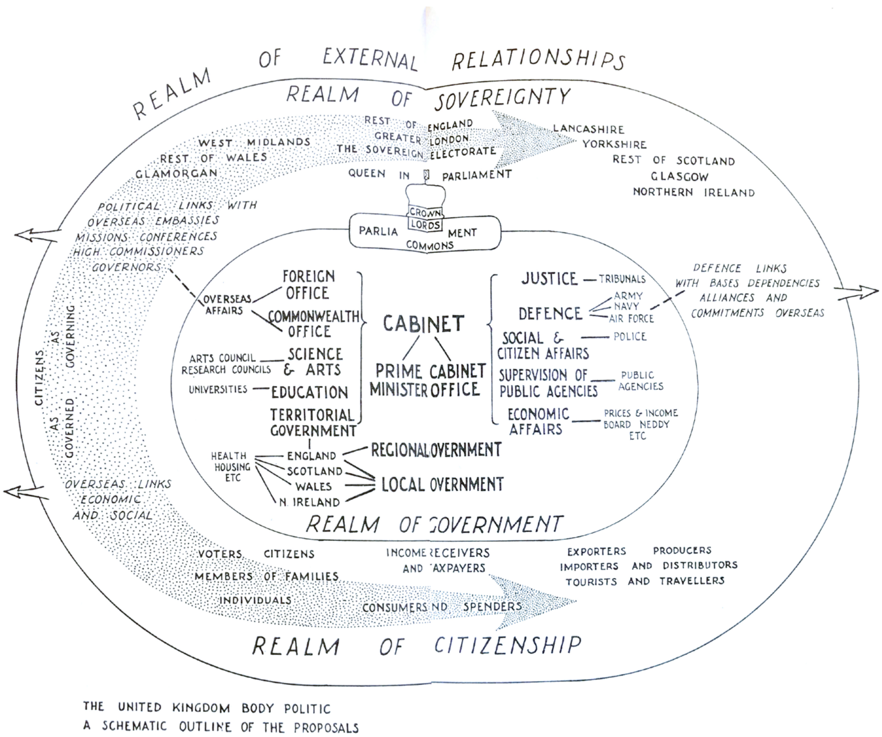

Fig. 1

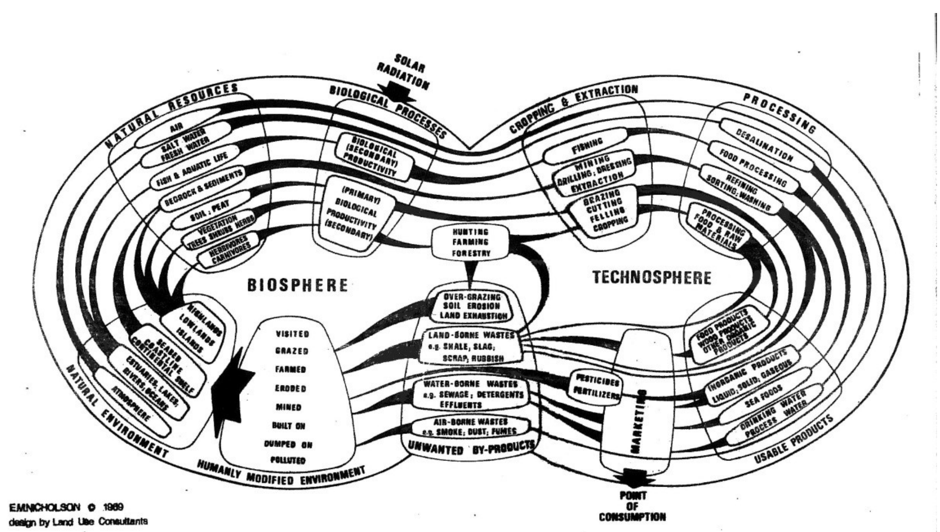

Fig. 2

Fig. 1: ‘The United Kingdom Body Politic: A Schematic Outline of the Proposals’ by Max Nicholson, published in *The System: The Misgovernment of Modern Britain* (1967).
Fig. 2: Diagram of biosphere and technosphere by Land Use Consultant for Max Nicholson published in *Handbook to the Conservation Section of the International Biological Programme* (1969).

the first was the passage from the inorganic phase to the biological, and the second was from the biological phase to the psychosocial. He believed that human society, at the time, was at the third passage, where 'the ebullition of humanist ideas in the cauldron of present-day thought marks the onset of the passage from psychosocial to the consciously purposive phase of evolution'.[21] In light of Huxley's formulation, one can envision the addition of a psychosocial sphere to the biosphere and the technosphere, which would include changes in artistic, cultural, and religious activities. This proposition was also incorporated in Nicholson's subsequent conservation work. For example, in his Albright Lecture at the University of California Berkeley in 1964, Nicholson argued that the Renaissance was engendered through a radical awakening of humanity's relationship with nature.[22] What followed was the rejection of old idea-systems, all kinds of discoveries, and an enriched culture. Building on this supposed transformative relationship between humans and their environment, Nicholson argues that the value of conservation is to locate 'the true design of man's place in nature' and to bring forth a new Renaissance.[23]

The Renaissance lecture, however, was a rare instance when Nicholson formulated a positive reciprocal relationship between environmental changes and human society. Most of his writings from the 1960s paint a more pessimistic world view. Overpopulation, for Nicholson, should be understood as an environmental problem in a multitude of ways. Firstly, the increase in population amplified the on-going human exploitation of the ecosystem. Like Huxley, Nicholson argued that uncontrolled population increase was a social illness, reflecting the appalling attitude of humans towards their surroundings. The deprivation of both utilitarian and psychosocial resources, he anticipated, would in turn induce poor behaviour, giving rise to the condition found in the above quote.[24] To conserve, Nicholson argued, was to take and invest the right amount of utilitarian and psychosocial resources in order to avoid violating the law of evolution.

In *The Humanist Frame,* the discussions on balancing and reconciling the utilitarian and psychosocial resources are characterised as a planned human ecology. Different from the coinage by the influential American urban sociologist Robert E. Park in the 1920s, the human ecology discussed here does not differentiate groups and activities in society. Instead, it reconceptualises humans and their environment in a supposed energy-entropy equilibrium.[25] This formulation of a planned human ecology forms an important premise in Holford's contribution to *The Humanist Frame.* Holford starts his article by offering a re-articulation of architecture, stating that 'building today is organisation'.[26] Significant architecture, he claims, does not 'automatically come from working out of formulae, or from modular co-ordination, or from a theory of structures', but comes from the 'organisation of raw materials of existence, whether physical or psychological, into effective patterns in which a variety of parts are combined and interrelated in a unitary whole'.[27] Notable architecture from the past, he further argues, could be used to retrieve knowledge from a well-planned human ecology.[28] By establishing these reciprocal dynamics between human society, architecture, and the existing environment, Holford puts forth a theorisation of the built environment as the 'shells of society'. He states that 'it is too simple to view a society and its buildings as cause and effect; old shells are sometimes adapted to the new ways of inhabitants'.[29] In other words, Holford responded to Nicholson and Huxley's discussions by reconceptualising the built environment as the organisation of relationships, both between human and what environed them, as well between the past, present and future. The shell metaphor further suggests a recognition of the built environment as a relational and reciprocal material milieu of the society which it supports.

Holford's formulation can be considered as a rejection of the social determinism that underscored Modernist architecture. However, what Holford envisioned was hardly a departure from the totalitarian tendency embedded in architectural culture. In both his contribution to *The Humanist Frame* and his lecture on the built environment, Holford reinstated the importance of 'one controlling mind' and 'a single intelligence'.[30] For him, the creation, motivations and control of the built environment should still be determined by experienced and gifted individuals who could achieve 'a total effect of unity and correspondence'.[31] The seemingly contradictory view that at once challenges and strengthens the historical role of architect-planners as the creators of the environment also points towards the forces that drove Holford's desire to borrow from ecology and evolutionary humanism. Holford's environmental turn could be seen as an effort to locate new means of legitimisation when the tenets of modernist architecture could no longer function as the yardsticks for town planning, design and construction. Meanwhile, ecologists' ability to extend conservation debates so as to include regional planning, land use and economic development strategies also provided a model for architecture to reclaim its role in national economic and developmental planning.[32]

Holford's articulation of the built environment was also motivated by a broader adherence to science and technology found in British society at the time. As early as 1958, RIBA already championed the importance of research in architecture and planning in order to better integrate with other scientific disciplines.[33] In 1963, in response to the publication of the *Enquiry into the Organisation of Civil Science (Trend Report)*, RIBA also argued that architecture ought to be better able to respond to studies in the natural, physical and social sciences.[34] The term built environment was therefore employed as a means to broaden the scope of the theory, research, practice, and pedagogy in architecture and planning, allowing them to catch up with advances made in scientific and technological research. Holford's frequent evocation of ecology should be contextualised within this scientisation of architecture and planning. Huxley's formulation of a planned human ecology offered an effective framework to direct attention to research into the psychosocial aspects of the built environment, which Holford deemed as lagging behind their counterpart in building tectonics and services.[35]

It is noteworthy that, as in the field of architecture, the need to reinforce its societal relevance also drove ecological conservation to make an environmental turn. In 1970, Nicholson reframed his conservationist mission under the title *The Environmental Revolution*.[36] Like in architecture and planning, the term environment was used by Nicholson to address the gaps found among the disciplines, what he called the 'no man's land between ecology, geography and landscape'.[37] In the book, he advocated for the use of the term environment to replace what was previously 'conveniently lumped together as "the countryside"' in Britain, thus to lessen the idiosyncratic outlook of conservation.[38] The coalescence of multi-disciplinary knowledge under the broad title of the environment, Nicholson envisioned, would establish conservation as a matter of intrinsic importance. In sum, the reconceptualisation of both ecology and architecture as environment was driven by a desire to break down disciplinary divides. Moreover, this shift can also been seen an attempt to reinforce the scientific outlook of both disciplines, as a response to 'White Heat' – Labour Party leader Herold Wilson's vision to accelerate British economic growth through science and technology articulated in 1963.[39]

Through this realignment, more reciprocal exchanges were found between architecture, ecology, and the emerging digital realm. As the head of the conservation section of the International Biological Programme, Nicholson championed the use of computers in managing the vast data of ecological analysis. In establishing this 'parametric method', Nicholson introduced a digital architecture that 'relies strictly upon the *structure* (such as the height and spacing of plants) and the *function* (such as adaptations to or defence against conditions like fire, drought or salinity)'. In this modelling of the ecosystem, the traditional descriptions of climate and geology, as well as definitions like grassland and woodland are discarded.[40] This method employs a similar framework for the analyses of built structures and naturally occurring organisms, and further emphasises the relational aspects instead of the physio-chemical properties. The notion of structure and function – which are fundamental in architectural culture – are turned in a bridge between the digital realm and the ecology.

Conclusion

Despite their excitement about incorporating computation in the study of the environment, Nicholson, Huxley and Holford's interpretation was different from other contemporaneous techno-optimistic environmental discourses similarly informed by cybernetics. They did not envision that technology could reconstitute and thus solve human-environment problems.[41] Instead, their investigation focused on how to incorporate humans and their activities within the closed eco-system. Nicholson's biosphere and technosphere diagram suggested a co-evolutionary model through which human existence is a part of but also reconstitutes the eco-system. Huxley, meanwhile, sought to locate the equilibrium within an energy-entropy articulation of human activities. Working under such a framework, Holford considered architecture and planning a means of organisation for attaining the equilibrium. His writings also reflected his view that architecture and planning are mechanisms for controlling human activities, in order to avoid introducing further disturbances to the eco-systemic ideal. These exchanges also contributed to a shift of focus from the eco-system to debates on the environment, and thus helped to clarify and amplify overlooked aspects in both naturally occurring and human activities.

However, just as Nicholson and Holford's environmental turns were being completed, they were met with strong contrary forces. As the environmental movement garnered more energy in the late 1960s and early 1970s, ecologists were also being side-lined in the debates. In the socio-political climate of the time, Nicholson and Huxley's environmental formulation was further problematised by their technocratic, unitarian, and eugenic undertones. In architecture, a different group of scholars, writers and architects had been more effective in mobilising the term built environment, gearing it towards the study of human psychobiological reaction to immediate physical surroundings.[42] The term built environment was, at the time, widely employed in studies of architectural culture through building sciences.[43] Meanwhile, ecology and architecture were both seduced by studies in semantics and language analysis, which engendered new theories and shifted attention away from the eco-systemic discussions.[44] In short, despite Holford and Nicholson being able to disseminate their thought through the high positions they held in various organisations, their articulation of the environment did not leave an immediate and significant imprint in twentieth-century environmental discourse.[45]

Regardless of their contradictions and flaws, the discussions examined in this article involve critical issues in 1960s society such as population growth, resource exploitation, pollution, as well as the volatile socio-cultural conditions that underscored the coinage of the term 'built environment'.[46] They also point to an almost concurrent environmental turn found in ecology, due to a similar desire to reinforce the scientific value and hence the societal relevance of the discipline. The discussions reviewed here demonstrate that the exchanges between ecology and architecture could move beyond the appropriation of visual and rhetorical devices. These exchanges provide alternative means to posit the question of what architecture can do in the transformative and reciprocal relationship between humans and their environment. Finally, these discussions, articulated in a previous era of environmental emergency and awakening, also serve as a reminder of the interlinked nature of biological, environmental, and economic crises. They signpost the possibility of incorporating architecture and planning into these debates through a reconceptualisation of the built environment.

Notes

1. William Holford, *The Built Environment: Its Creation, Motivations and Control*, Tavistock Pamphlet 11 (London: Tavistock Institute, 1965), 17.
2. ‘Research into Problems of Planning and Construction: RIBA Statement’, *RIBA Journal* (March 1964): 112.
3. Holford, *The Built Environment*, 6.
4. Ibid.
5. Holford was the President of RIBA from 1960–62, and the Chair of Planning of the Bartlett at the same time. He was knighted in 1953 and he would be made a Lord in 1965, the first town planner to receive such an honour. For an evaluation of the later part of Holford’s career, see Gordon Cherry, *Holford: A Study in Architecture, Planning and Civic Design* (London: Mansell, 1986), 250–54.
6. Holford, *The Built Environment*, 1. Holford had known Huxley since 1936, and joined the PEP group in 1943. John Pinder, ed., *Fifty Years of Political & Economic Planning* (London: Heinemann, 1981), 210.
7. Peder Anker, ‘The Bauhaus of Nature’, *Modernism/Modernity* 12, no. 2 (2005): 229–51. Lucia Allais, ‘“The Largest Stone in the World”, and Other Landmarks of Postwar Evolutionism’, paper presented at the Society of Architectural Historians Conference, 30 April 2020.
8. For example, architectural historian Adrian Forty in his study of the festival suggests that Nicholson, ‘an enthusiast for technocracy’, had carried over his thinking on scientific development to the festival and turned it into ‘in part an early experiment in technocracy’. Adrian Forty, ‘Festival Politics’, in *A Tonic to the Nation: The Festival of Britain 1951*, ed. Mary Banham and Bevis Hiller (London: Thames and Hudson, 1976), 37.
9. Simone Schleper, *Planning for the Planet: Environmental Expertise and the International Union for Conservation of Nature and Natural Resources, 1960–1980* (New York: Berghahn Books, 2019), 9.
10. Schleper, *Planning for the Planet,* 21.
11. Nicholson, *The Environmental Revolution*, 69.
12. In the current scholarship of cybernetics, the closed-system ideas, including eco-system articulations, are named ‘first-order cybernetics’ after Heinz von Foerster.
13. Schleper, *Planning for the Planet,* 31; Jeff Pruchnic, *Rhetoric and Ethics in the Cybernetic Age: The Transhuman Condition* (London and New York: Routledge, 2013), 11.
14. Robert P. McIntosh, *The Background of Ecology: Concept and Theory* (Cambridge: Cambridge University Press, 1985), 210.
15. Max Nicholson, *The System: The Misgovernment of Modern Britain* (London: Hodder and Stoughton, 1967).
16. Michel Foucault, *Security, Territory, Population: Lectures at the College de France*, ed. Arnold Davidson, trans. Graham Burchell (Picador: New York, 2007), 21–22.
17. Schleper, *Planning for the Planet,* 71. Diagram of the biosphere and the technosphere, Royal Society Symposium,1969. Reproduced from LSA EMN/IBP: Box 4, Folder ‘World Bank etc.’, Land Use Consultant, London.
18. Simone Schleper, ‘Perspectives and Politics: A Co-Evolutionary Reflection’, 23 April 2016, https://www.anthropocene-curriculum.org/contribution/perspectives-and-politics.
19. Julian Huxley, ed., *The Humanist Frame* (New York: Harper & Brothers, 1961).
20. Julian Huxley, ‘The Humanist Frame’, in *The Humanist Frame*, 24.
21. Ibid., 7.
22. Max Nicholson, *Conservation and the Next Renaissance* (Berkeley: University of California, 1964).
23. Ibid., 15.
24. Ibid., 14.
25. Robert E. Park, Ernest W. Burgess, and Roderick D. McKenzie, *The City* (Chicago: University of Chicago Press, 1967). Huxley, ‘The Humanist Frame’, 47, 53.
26. William Holford, ‘The Shells of Society’, in *The Humanist Frame*, 199.
27. Ibid., 200.
28. Ibid.
29. Ibid., 199.
30. Ibid., 200.
31. Ibid.

32. Critique of how post-war planning was unable to deliver a sufficiently modernised version of Britain burgeoned in the 1960s. The publication of Peter Hall's *London 2000,* for example, can be seen as an attempt by a younger generation of planners to better align physical planning with the demographic, industrial, and economic changes. An example that inspired Holford, Nicholson and Huxley was the Tennessee Valley Authority, which combined infrastructure and regional planning with development, conservation, and resource management. Holford, *The Built Environment*, 11; Nicholson, *The Environmental Revolution*, 205–10; Julian Huxley, *TVA, Adventure in Planning* (London: The Architectural Press, 1943).
33. Dean Hawkes, *The Environmental Tradition: Studies in the Architecture of Environment* (London: E & FN Spon, 1996), 6.
34. 'Research into Problems of Planning and Construction: RIBA Statement', *Committee of Enquiry into the Organisation of Civil Science* (H.M.S.O. London. Cmnd. 2171, Oct. 1963).
35. William Holford, 'Shape and Environment', lecture (London: Goldsmiths College, 1963), Special Collections and Archives, Universty of Liverpool, D147/LA7.
36. Nicholson, *The Environmental Revolution*, 36.
37. Ibid., 75.
38. Ibid., 36.
39. Harold Wilson delivered the speech at the 1963 Labour Party Conference; it was seen as a watershed moment in declaring a nation-wide adherence to scientific and technological-driven development, although scholars suggested that the strong support in scientific and technological research had already been in place earlier in the decade by the Conservative government. Adam Sharr and Stephen Thornton, *Demolishing Whitehall: Leslie Martin, Harold Wilson and the Architecture of White Heat* (London: Ashgate, 2013), 9.
40. Nicholson, *The Environmental Revolution*, 70–71.
41. Schleper has also discusses the how Buckminster Fuller's expansionist environmental propositions differ from the eco-systematic views. Schleper, *Planning for the Planet,* 41.
42. A contemporary use of the term 'built environment' in promoting better integration of scientific research in architecture and planning was put forward by Richard Llewelyn-Davies, the then Chair of Architecture at the Bartlett. Richard Llewelyn-Davies, *The Future of Environmental Studies* (Edinburgh: The University of Edinburgh, 1967), 1.
43. Examples include Reyner Banham's influential *The Architecture of the Well-Tempered Environment* (1969).
44. In ecology: McIntosh, *The Background of Ecology*, 149; in architecture: Reinhold Martin, 'Environment, c. 1973', *Grey Room* 14, no. 2 (2004): 78–101.
45. For example, Holford repeated his articulation of the built environment in a high-profile conference on the environmental crisis held at the University of Texas in 1965, under a simplified title 'The Built Environment'.
46. Journalist Christopher Booker, for example, observed the sudden and unsettling socio-cultural changes found in Britain in the late 1950s and 1960s. The notable improvement in living standards and a burgeoning identification with 'affluent society' and 'leisure society' was juxtaposed with increasing crime rate and racial tensions. Christopher Booker, *The Neophiliacs: Revolution in English Life in the Fifties and Sixties* (London: Collins, 1969).

Biography

Juliana Yat Shun Kei is a lecturer in architecture at the University of Liverpool. Her research interest is twentieth-century urban and architectural culture in Britain, Hong Kong and China. Her current research looks into alternative articulation of the built environment developed by the British establishment in the early 1960s. She is trained as an architect and has worked as a strategic planner and architectural designer in London, Hong Kong, Tokyo, New York, and Shenzhen. As part of the Hong Kong Design History Network, she curated the Hong Kong pavilion in London Design Biennale 2020.

Interview

The Dialogical, the Ecological and Beyond

Jon Goodbun and Ben Sweeting

In this article Jon Goodbun and Ben Sweeting engage in a conversation about design and its complex relation to communication. Their dialogue was prompted by the following question from this issue's editors:

> If one approaches cybernetics as the study of information processes, the focus is no longer only on digital logics, but rather on the production, exchange and consumption of meaning. In other words, cybernetisation can set forward a relational account that focuses on how 'asignifying signs' are produced and exchanged within complex systems of any kind. As such, is it possible to understand the contemporary processes of cybernetisation as a way of ridding architecture of the linguistic burdens of its past? Moreover, in what ways can this shift in architectural logics be related to the political and ethical questions confronted by architects grappling with the complexities of ecological crises?

Ben Sweeting: I think we might begin with just the first part of the editors' prompt. Information is a good place to start with cybernetics, but there are multiple conceptions of 'information' in relation to cybernetics, and it is helpful to pull these apart.

I think it is conventional to think of information in the sense of the content of messages. This is the context of Shannon's information theory, which is closely aligned with initial developments in cybernetics, with its focus on communication. However, message transmission is very different to the notions of conversation and circularity that are at the core of cybernetics as it develops, and it is these concepts that give cybernetics its continuing relevance in contemporary design discussions. Conversation and circularity are complex and rewarding, but it is the simpler message-in, message-out version of information that is dominant in how most people think about information, and this is reinforced in the design of many of our technologies.

One place this contrast is particularly clear is Pask's 'The Limits of Togetherness'.[1] There he sharply differentiates conversation and communication (in the sense of message transmission):

> Communication and conversation are distinct, and they do not always go hand in hand. Suppose that communication is liberally construed as the transmission and transformation of signals. If so, conversation requires at least some communication. But, enigmatically perhaps, very bad communication may admit very good conversation and the existence of a perfect channel is no guarantee that any conversation will take place.[2]

What I love about Gordon Pask's conversation theory is that it explains a way for achieving agreement that maintains (and requires) the differences between participants to be maintained. When we think of communication in terms of the passing and receiving of messages, then we try to equate what is heard with what is said. Communication as message transmission is thus conservative, in that it aims to minimise new understanding from arising. It can also be violent, in that the listener's meaning is to be reduced to that of the speaker's intention. Conversation, by contrast, is something that welcomes new meanings and requires us to adopt the standpoints of others. I find this conception of conversation makes sense of Pask's various contributions to architecture, and it is also helpful in articulating what is so special about what designers do.[3] Another important conception of information in cybernetics is that of Gregory Bateson. Bateson also associates information with difference, but in a different way and context to Pask.

Jon Goodbun: That is a wonderful quote! Pask's conception of conversation is an important one, and there are a few things that it makes me want to bring into this conversation here. I am immediately thinking about the work of the very interesting theoretical physicist David Bohm around dialogue.[4] Bohm's thought does not easily fit into a classic cybernetic account, but he was very much a systems-theoretic thinker. Bohm reminds us that there is an important distinction between discussion and dialogue. Discussion shares a common root with words like percussion, and basically means to break things up. So maybe discussion describes a message transmission in a reductive mode, of breaking things up for analysis, and so on. Dialogue has a very different meaning. It is funny, in that we often have an internal mistranslation of dialogue, thinking that the 'dia' means two and imagining that dialogue therefore means between two people, but that is not the case. Actually, it means 'through the word', and for Bohm it suggested a mode of communication much closer to Pask's account of conversation, in that in dialogue there is a more 'ecological' flow of meaning between, through and around participants. There is a sense that the dialogue itself, the conversation, has a degree of internal autonomy and a more holistic coherence beyond the 'intentions' of any individual speech act.

It is interesting, I think, to also note that forms of dialogue – often directly referencing some of the Bohmian Dialogue techniques – has been adopted by Extinction Rebellion in their assemblies, and of course that there are all kinds of parallels in various anarcho-leftist participatory democratic practices.[5] I have been thinking about dialogic structures as a part of an outline of an environmental semiotics that include human and other actors, signifying and asignifying signs, both as a tool for understanding ecological interactions, and also as a tool for thinking about a kind of dialogic or conversational 'ecological planning'. I have been using dialogue as a way of approaching Green New Deal thinking, for example.

It is interesting to bring Bateson into this conversation too. So of course, Bateson experimented with the conversational form as a rhetorical tool and explanatory device in his 'metalogues'. And working with bringing multiple perspectives together (which I think is one of the things at stake in Pask's model of conversation) was always a key method for him, going right back to his early anthropological work *Naven*, which was the study of the meaning of a particular ceremony from 'three points of view'. There is something fundamentally polyphonic and multi-perspectival in the work of Pask and Bateson, and more generally in what I think of as the radical tendency within cybernetics. We find here a recognition of the need to hold multiple points of view together in a properly dialectical tension. This is very useful for us today in thinking about ecological systems and our interactions and conversations with them, but also in thinking about the kinds of democratic and decision-making processes that we might need going forwards…

Bateson defined information as 'a difference that makes a difference', that is, you always need something or someone that is sensitive to a given difference in a field, and to recognise it as such. There is always a context and an observing system. Furthermore, he then saw learning, evolution, and biological morphology as fundamentally interconnected and isomorphic processes. He would state for example that

> whatever the word 'story' means … the fact of thinking in terms of stories does not isolate human beings as something separate from the starfish and the sea anemones, the coconut palms and the primroses. Rather, if the world be connected, if I am at all fundamentally right in what I am saying, then thinking in terms of stories must be shared by all mind or minds whether ours or those of redwood forests and sea anemones.
>
> Context and relevance must be characteristic not only of all so-called behavior (those stories which are projected out into 'action'), but also of all those internal stories, the sequences of the building up of the sea anemone. Its embryology must be somehow made of the stuff of stories. And behind that, again, the evolutionary process through millions of generations whereby the sea anemone, like you and me, came to be – that process, too, must be of the stuff of stories. There must be relevance in every step of phylogeny and among the steps.[6]

BS: That is a great way of distinguishing dialogue from mere discussion, and relevant to our time. With the pandemic moving so much online, it is easier than ever to end up passing messages rather than conversing. I think part of the reason we often think of dialogue in terms of two participants is that in it every participant is always moving between two modes – speaking (adding content) and listening (building understanding of the content introduced by others). If we only do one, we obstruct dialogue. This is obvious when someone speaks but does not listen, but I think it is also the case when someone listens but does not speak or passively agrees, as then they are not offering something new to others. The etymology of conversation is to 'turn about with' – which I think of as continually turning between listening and speaking (and their equivalents).

For me, the important bit of Pask's conversation theory is how it explains how we can act as if we understand the same thing without requiring us to reduce one understanding to the other. Imagine students trying to explain how they understand something – ideas for their design projects, say. They might present this to their tutors and to each other. At the same time, maybe the tutors have something they need to get across – perhaps some different interpretation of the project or some idea about which direction to develop the design. Neither party can just pass their meaning on. The listeners build their own understanding of what the speakers understand. To check how well they have understood, they might well ask something like 'do you mean like this?' By listening to how the others respond, one can get a sense of whether you have been understood. But it is not like you are comparing your understanding to that of others – instead, you compare your understanding of what you are trying to share to your understanding of others' understanding of your understanding. This reflexivity explains how we can coordinate action as if we understand the same thing, while maintaining the differences between how and what we understand. As well as avoiding the need for the sort of questionable assumptions required by a code-decode model, I find this is an ethically and politically desirable way to work with others. Indeed, to 'turn about with' (conversation) originally had the meaning of living with or even dwelling.

There is plenty more in conversation theory, but this basic process is the part that Ranulph Glanville would always focus on, using it to bring design and cybernetics into close relation.[7] I find that it is helpful in the context of other conversational frameworks in thinking through the underlying mechanism, and also in teaching, where it reminds me that I am not trying to get students to have the same understanding I have (which would be a form of reducing difference). I find it is often productive when students see things in what I say that I did not anticipate and vice versa. 'Do you mean like this…?' might be a confirmation, but it is often something that one had not meant, creating new connections, questions, and insights. This way my students do things that are beyond what I can do or explain. So, it is not just that conversation does not reduce difference, it is driven by difference and produces it. The role of participant (in conversation theory: psychological individual, or p-individual) is quite flexible for Pask – it does not necessarily correspond to the ways in which we are embodied (mechanical individual, or m-individual). I can talk with myself, moving between two or more participant positions, or a whole group of people, say an institution, might act as one participant in a conversation. When Pask worked with Nicholas Negroponte on machine intelligence, his focus was on whether the dialogue 'manifests understanding', which is a quality of the interaction rather than a comment on the knowledgeability of the participants.[8] Many of the algorithmic technologies we call smart show little in the way of understanding – and I can think of plenty of human-to-human interactions that have similar shortcomings.[9] Perhaps, coming back to Bateson, something similar might be said of how humans have interacted with their environment?

JG: Yes, I think you have captured it beautifully there when you state that 'it's not just that conversation doesn't reduce difference, it's driven by it and produces it'. This captures the difference between a conversation and control in our relationships with our environments. We know from Ashby's Law of Requisite Variety that control systems will reduce difference and complexity in the systems that they control if they lack the same levels of complexity, and the conversational model provides a much more open basis for proceeding.[10]

Bateson found Pask's work on this very interesting and invited him to his conference in 1968 at Burg Wartenstein on 'Effects of Conscious Purpose on Human Adaptation'.[11] This was an event which was precisely concerned with thinking about whether we can change and adapt our ways of thinking, planning, and perceiving, and which was framed by the then strongly emerging evidence of anthropogenic environmental crisis. For Bateson, the question of what he called human 'conscious purpose', of planning basically, was key to understanding the environmental crisis, because he saw that the environmental crisis had a significant epistemological component: our conscious purpose necessarily works on the basis of selective representations, or maps of the world, and we export the simplicity and reduced variety of our maps, now amplified by technology, back out into our worlds.

The core of the paradox of consciousness is that it is unable to see its own conditions of production (or at least, not directly, as an object of consciousness). Furthermore, we tend to experience the productions of consciousness as the totality of our mental processes. But of course, they are nothing of the kind. Bateson sometimes liked to describe this in terms of arcs and loops, where we might think of our sense of self situated both as, and within, extended entanglements of looping eco-mental relationships. However, the screen of consciousness only perceives small sections of arcs of these looping relations. Bateson described – and we need to forgive him his pronouns here – three interacting levels to these ecosystems, something that Félix Guattari would develop further in *The Three Ecologies*.[12] Still, as Bateson claims:

> On the one hand, we have the systemic nature of the individual human being, the systemic nature of the culture in which he lives, and the systemic nature of the biological, ecosystem around him; and on the other hand, the curious twist in the systemic nature of the individual man whereby consciousness is, almost of necessity, blinded to the systemic nature of the man himself. Purposive consciousness pulls out, from the total mind, sequences which do not have the loop structure which is characteristic of the whole systemic structure.[13]

This tendency of modern human consciousness to not perceive its part-of-a-system character, to not recognise that what it sees as small linear chains of (signifying) relationships are always also participants in much bigger webs of (asignifying) relationships, is not necessarily a problem, as consciousness is only one of the forms of mental relations that we participate in. It is not that we should consider consciousness to necessarily be a bad move! But we should attend to its context, its ecology, its relation to various other forms of cognition, language, and communication, its social and technical production, and how easily it can slip into what Bateson sometimes referred to as 'epistemological error' (and only then can we engage in the personal/political/ecological project of really exploring the potential productions of consciousness).

Now, if we ask 'What kinds of processes is consciousness involved in?' we tend to think (argh!) of particular kinds of symbolic manipulation, that is, particular kinds of language and particular kinds of logical reasoning. In fact, we are talking about digital processes, that is to say, processes that have the possibility of negation. But this is only a small part of a much wider field of analogic semiotic processes – a field which approximately corresponds to the field of asignifying signs that the *Footprint* editors refer to in the opening question.

Bateson repeatedly pointed out that music, poetry and the creative arts provide practices that involve much more than conscious mind, stating for example that 'in creative art man must experience himself – his total self – as a cybernetic model'.[14] His understanding of aesthetic experience and his later attempts to produce what I think we could call a post-religious conception of 'the sacred' are, I think, a really interesting attempt to make available to modern consciousness an experience of our extended ecological (analogue, asignifying) condition as a relation to our narrower (signifying, digital) conscious condition. On the one hand there is the question of conscious purpose and the relation of consciousness to a particular kind of language that is structured around a subject and object (or subject and predicate) and particular kind of attitude towards objects and environments. In fact, Bateson suggests in the introductory essay to *Steps to an Ecology of Mind* that maybe we produce the form/substance dualism (and implicitly we can extend that to mind/matter, nature/culture and other dualisms) out of languages that have the subject-predicate structure. It is also worth noting that there are interesting parallels with David Bohm's thoughts on language here. Not all languages have this structure, and Bohm of course played with ideas of a 'rheomode' – a process-based language without nouns – and even connected with some languages (notably Blackfoot) that did not have this structure, while at the 1968 conference on 'Effects of Conscious Purpose on Human Adaptation' Bateson also invited Anatol W. Holt, who had made himself a car bumper sticker which boldly stated 'STAMP OUT NOUNS!'

Returning to the question of an environmental semiotics, we can now approach it from a slightly different direction, using one of Bateson's last papers, 'Men are Grass'.[15] Bateson notes that a 'rational' subject-predicate language tends to have a prose character, and a linear structuring of logical relations, and in its purest mode takes the form of the so-called Barbara syllogism: *Socrates is a man / Men die / Socrates will die*. This is the structure of deductive logic, or rather, it is deductive if you read it top to bottom, and maybe inductive if you read it in the other direction. He suggests that we can formalise another kind of logic, abduction, which is closer to poetic metaphor, and for which he constructs the 'men are grass' syllogism*: Men die / Grass dies / Men are grass*. Here, there are no subject-object relations, just correspondences between predicates, between actions, between verbs. It is a verb-based logic! It is an abductive logic and, crucially, this is the logic that I think might in fact be more useful in thinking about asignifying relations.

Now, if we compare the two syllogisms, we can see that the deductive syllogism identifies subjects and a hierarchy of classes. There is the class of mortals. There is the class of men. And there is the subject Socrates who is in the class of men, which is in the class of mortals. The grass syllogism is very different in kind. It does not identify the classes and subjects of a sentence. It instead identifies predicates: this thing that dies is equal to this other thing that dies; it is, if you like, a process-based logic. Bateson then goes on to make a fascinating claim, which is that just as the deductive syllogism refers to subjects – it performs a signifying languaging of human conscious subjectivity – in the abductive 'men are grass' syllogism we find a formal model upon which the rest of the human, and indeed the rest of the ecosystem works. Moreover, as an instance of asignifying sympoiesis and biosemiotics, Bateson states that 'metaphor was not just pretty poetry, it was not either good or bad logic, but was in fact the logic on which the biological world had been built, the main characteristic and organising glue of this world of mental process'.[16] It is an extraordinary claim, which sets out two very different structures of relationships with and within environments.[17]

BS: You mention the difference between control and conversation, and I wonder whether we can think of the different structures of relationship with the environment in terms of different attitudes to variety and control. Many writers interpret cybernetics in terms of communication and control – going from the subtitle of Norbert Wiener's book.[18] Like the discussion of communication above, I think cybernetics is interested in control, but it is not necessarily in favour of it; control is something to unpick and critique, it raises cybernetic questions rather than answers them. For instance, we often speak of the variety of the controller and controlled, but in a circular system this is arbitrary (the heater controls the thermostat as well as vice versa). I try to think of the variety of the relationship, which has a different sort of politics to it.

If there is a mismatch in variety between the participants in a system, the participant with the greatest variety will either have its variety reduced (restrictive control) or be out of control to some extent from the perspective of other participants (the relationship lacks coordination, from that perspective at least). Depending on the context, there may be no problem in either of these. Restrictive control is helpful in driving a car and there can be value in being out of control, for instance when you want to generate new possibilities.[19] But think of a river that has been constrained through engineering to suit human purposes. Sometimes it pushes back, flooding, escaping the constraints that have been put on its variety. We are not usually prepared for this, trusting in our ability to restrict the environment. There are approaches to regulation and coordination that are not restrictive. Glanville used the example of skiing – 'the sort of control that allows us to stay upright when skiing, stable in the face of perturbations'.[20] The point is not that we need to avoid engineering rivers but that there are ways of doing so that accommodate for the variety of the river rather than attempting to reduce it. This approach is to see the river and its ecosystem as a partner.

Another example is when education is thought of as a transfer of knowledge – communication not conversation – and the understanding of the students is restricted to that of the teacher. One of the things I love about architectural education is its potential to be radically different to this. It is the students who prepare for (most) studio teaching sessions, making drawings and models, and tutors take the position of learners, trying to understand what the students have done and respond to this. When it is working well, the students are actually teaching themselves (requisite variety!). The tutors are creating and managing the context in which this is possible by helping manage the variety the students grapple with – adding in ideas and considerations to expand the conversation ('have you thought about this…?', 'tell me more about that…'), making things explicit so that they can be remembered ('do you see what you did there...?'), and acting as constraint and support so the whole thing keeps on track ('don't worry about that yet…', 'you need to rethink this…', 'let me help you with this bit…'). However, the expectation of expertise can be hard to escape. It is easy for conversation to deteriorate into communication, with the result that students' variety (and that of their work) is reduced to that of their tutors.

Bateson identified three self-reinforcing drivers of the environmental crisis: population, technology, and what he called 'hubris' – our tendency to view the environment and each other as separate to us, and so in terms of competition rather than partnership.[21] Hubris becomes manifest in all sorts of things: the way we bend (straighten) rivers to our will and the way we think of things like education as a linear process of imparting knowledge. We often think of sustainability in architecture in terms of Bateson's first two causes. We build more buildings as the needs of population increase, and this enables further growth. We try to balance this out by reducing the waste and pollution caused by the building industry (technology), reorganising construction processes to be less wasteful and polluting, making buildings more energy efficient and less environmentally destructive. I think architecture has the potential to do more than mitigate the harm it causes; it can also act on our hubris. When we build buildings, we are articulating the relationship we have with the environment. Much of the architecture we build today separates us, reinforcing our hubris in the process. It has been one traditional role of architecture to articulate our relationship with the world and maybe this is a role that can be reinvented for our times.

JG: Architecture both separates and connects, creates interiorities and externalities and these spaces and structures are our extended bodies and our extended minds, individually and collectively. If thinkers like George Lakoff and Mark Johnson are in any way correct in thinking that significant aspects of human signifying languages are always also metaphors of our bodily spatial relations, then there is an important sense in which architecture transforms the possibilities for thinking and languaging.[22] It is a vehicle through which asignifying signs start signifying perhaps. And yes, that curious diagram, 'The Dynamics of Ecological Crisis', that Bateson produces to describe the inter-connection of these three amplifying circuits: population, technology and hubris.[23] From the diagram it is easy to imagine that the three components have a similar structural character, but actually I wonder if they are rather different. The 'population', I think, stands for growth in general, the regenerative and growth tendency of any living system which always has the potential to go into runaway positive feedback. Otherwise they would not maintain themselves at all. However, within any relatively stable and homeostatic ecology, there are negative feedback loops that act to regulate positive loops in any given ecological network. We then have two other loops in that diagram, technology and hubris. Regarding technology, Bateson states that

> what worries me is the addition of modern technology to the old system. Today the purposes of consciousness are implemented by more and more effective machinery, transportation systems, airplanes, weaponry, medicine, pesticides and so forth. Conscious purpose is now empowered to upset the balance of body, of society, and of the biological world around us.[24]

Of the three, the one that he thought that we could change and work on, and the one that I guess he thought that he could contribute some work on, was hubris. This directly connects to what we have been discussing, as this concept of hubris is, as you say, about a certain stance regarding control, which itself is related to the questions of consciousness and language. In fact, I think we can define the hubris here precisely in relation to some of the concepts that we have now set out. Hubris uses the narrow signifying structures of the deductive syllogism alone, whereas an ecological systemic wisdom includes thinking through the asignifying syllogism in grass. It is important to note, I think, that it is not about replacing signifying, deductive reasoning, but rather finding a modern ecological aesthetics that can play the role that – in some cases at least – poetry, art, religion were able to play in some non-modern cultures, as forms of thought that were able to provide 'a pattern that connects' the loops that purposive conscious reasoning alone breaches.[25]

Therefore, we find ourselves today in a double bind: we need to use our conscious purpose to get us out of the mess that our conscious purpose has fed. And this is a bigger political question of course, as consciousness is socially produced. Which leads back to the editors' opening question in some important ways. We are in an ecological crisis that is in part a product of our non-ecological conscious purpose, of our signifying practices; but the way forward cannot simply be backwards. It is not, I would say, going to be found in a retreat into asignifying practices alone, as some contemporary theorists seem to suggest. Rather, we need to find a way to move through the relation between signifying and asignifying practices, to situate and embody conscious purpose within ecological wisdom. This is very important not just conceptually, but also in response to the kind of ecological planning now being called for in a just response to the climate emergency, in for example the emerging dialogue around a Global Green New Deal. Rather than asking whether architecture might be rid of its linguistic burdens, maybe we can ask: How might a properly environmental architecture extend a scaffolding, and afford metaphors, for a plurivocal ecological conversation that transverses signifying and asignifying registers?

There is a nice example that Bateson uses a few times, which, in his typically oblique way, gives us some useful clues for a more ecological thought and experience, and an understanding of movement between signifying and asignifying signs – a direct experience of metaphors. It concerns the difference in the experience of the eucharist between Catholics and Protestants. Mary Catherine Bateson introduces and then quotes him discussing this at the 1968 conference:

> when we wish to explore the relationship between conscious thought and other processes of computation, the deep reasoning of a body or an ecosystem, we need to know the differences in the way they compute. Biological systems in general compute analogically, with pattern, while the conscious mind has access to digital processes, including the possibility of negation … at whatever level it is in your mind that the operators are stored ... at that level there is no not … so that if you represent the Body and Blood with the bread and the wine, that level of your brain is just not concerned with saying that wine is wine … [and] not the Blood. The Catholic view of the sacrament, which asserts an identity between the wine and the Blood, is the way that level of your mind functions. If you become a Protestant and protest that the wine has no corpuscles in it, you are talking, from a Catholic point of view, complete nonsense. On the other hand, you are making a wide statement about the nature of man and about yourself – namely, you are asserting, as a Protestant, 'I am going to handle my religion totally at a conscious level.' This excludes from your religion about three-quarters of yourself, because you aren't all at the conscious level, and you create, in fact, a secular religion.[26]

I am always trying to find ways to teach this kind of ecosystemic thinking, or better still, to ask how can ecosystemic learning happen? Which I think is something that interests many of us. Ben, I know that your deep understanding of Pask's conversational cybernetics has helped to shape an innovative piece of design research thinking in the School of Architecture in Brighton. I have been fortunate to see this emerge while I have been external examiner there, and it really is an interesting piece of work that the students are clearly finding very useful, and which resonates in various ways with some of the things we have said.

BS: I remember Mary Catherine Bateson saying that the time to learn cybernetics is not at university but in kindergarten.[27] It is foundational. When we come to cybernetics later, as most of us do, it contests our conventional ways of doing things. But, as well as being challenging, I think that focusing on foundational questions can also be accessible. One does not need specific prior knowledge to build on. Instead, one can explore cybernetics within one's own experience and practice. As you mention, I am currently leading a module in design research practices.[28] It is a taught module taken by all our postgraduate students, including those on professional programmes such as our RIBA Part 2 course. I find that design students often see research as something 'other' than their design practice – perhaps as a distinct component or phase of work (site analysis, precedent studies) or as something that happens in the more explicitly academic parts of their study, such as when they write a dissertation. By contrast, from a cybernetic perspective, one can think of research as something that has to be designed, which means that insights from design can contribute to how we understand research practice.[29] I have usually thought of the benefits of this insight as being theoretical – as a way to think of design as a discipline in its own terms while also allowing for rich connections between design and other fields. What I have been trying to develop more recently is a way of using this as a pedagogical approach. In postgraduate study, students are developing their expertise and confidence as designers. By learning to see researching as a kind of designing, students' experience in designing can become a foothold for understanding research through their own practices, which can be empowering.

There are so many ways to do research in design, I do not think it makes sense to teach methods directly. Instead, we stress that the different ways of configuring research processes have consequences for the scope and status of the insights that are created through them. If I am designing my researching, then I need to understand and question the differences that arise from designing research in one way rather than another. For instance, which standpoint am I researching from and what aspects of the situation does this make it easier or harder to see?[30] In the first weeks we set everyday activities, such as cooking a meal together that no-one in the group has cooked before or choosing a restaurant in a group of people you do not know very well. Because these activities involve new relations and experiences, both about food and about each other, it is possible to locate questions about research and design within these experiences. What did you need to find out? How did you do this? What was it about your source material that made you trust it? Is there a difference between describing this activity as design rather than research or vice versa? What didn't you consider and what difference did this make? The everyday activities create shared experiences that then help situate and internalise questions about method and theory before students move on to examine and critique their own present and past work. Our conversation is making me think of this exercise a bit like the metalogues in *Steps to an Ecology of Mind*, in the way that the rest of the book calls back to insights that were already developed in those conversations. I find myself wondering whether a similar approach might work for other topics. There is certainly a difference between receiving an explanation of how some ecological system works (a communication pedagogy) and coming to understand ecological principles by examining one's own participation in them.

JG: Nice! I think that cooking a meal together in the context of architectural and ecological education, research, and designing research is a beautiful way to 'set forward a relational account that focuses on how "asignifying signs" are produced and exchanged within complex systems of any kind'. Reading back over what has been said, it feels like there is another meta conversation that can now unfold, on top of this one.

Notes

1. Gordon Pask, ‘The Limits of Togetherness’, in *Information Processing*, ed. Simon H. Lavington (Amsterdam: North Holland Publishing Company, 1980), 999–1012.
2. Pask, ‘The Limits of Togetherness’, 999.
3. Thomas Fischer and Christiane Herr, eds., *Design Cybernetics: Navigating the New* (Berlin: Springer, 2019).
4. David Bohm, *On Dialogue* (New York: Routledge, 1996).
5. Extinction Rebellion, *Extinction Rebellion People’s Assemblies Facilitation Training Manual*, 2019, https://extinctionrebellion.uk/wp-content/uploads/2019/10/XR-PeoplesManual.pdf.
6. Gregory Bateson, *Steps to an Ecology of Mind* (Chicago: University of Chicago Press, 2000), 12–13.
7. Ranulph Glanville, ‘Try again. Fail again. Fail better: The Cybernetics in Design And The Design In Cybernetics’, in *Kybernetes 36*, no. 9/10 (2007): 1173–206.
8. Gordon Pask, ‘Artificial Intelligence: A Preface and A Theory’, in *Soft Architecture Machines*, ed. Nicholas Negroponte (Cambridge, MA: The MIT Press, 1975), 8.
9. Delfina Fantini van Ditmar, ‘Idiot: Second-Order Cybernetics in the “Smart” Home’ (doctoral dissertation, Royal College of Art, 2016), https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.690638;
   Delfina Fantini van Ditmar, ‘A Circular “Smart” World’, in Fischer and Herr, *Design Cybernetics*, 101–17.
10. W. Ross Ashby, *An Introduction to Cybernetics* (London: Chapman & Hall, 1956).
11. Mary Catherine Bateson, *Our Own Metaphor* (Cresskill, NJ: Hampton Press, 2005).
12. Félix Guattari, *The Three Ecologies* (London: Continuum, 2008).
13. Gregory Bateson, *Steps to An Ecology of Mind* (Chicago: University of Chicago Press, 2000), 440.
14. Ibid., 444.
15. Gregory Bateson, *A Sacred Unity: Further Steps to An Ecology of Mind* (New York: Harper Collins, 1991). A very interesting previously unpublished variation of this paper with the title ‘Among Wolves and Logicians’, which was given by Gregory Bateson at Esalen in May 1980 just weeks before he died, has recently been published, together with a notable commentary on ‘Analog and Digital Communication’, in chapters 4 and 6 respectively in Philip Guddemi, *Gregory Bateson on Relational Communication: From Octopuses to Nations* (Berlin: Springer, 2020).
16. Bateson, *A Sacred Unity,* 241.
17. It is very interesting to note that some recent eco-feminist thinking – for example Donna Haraway’s tentacular relations, and Anna Tsing’s fungal thinking – has something like the structure of the syllogism in grass. Also, as an attempt to formalise ‘abduction’, we should note the relation to the semiotics of C.S. Peirce.
18. Norbert Wiener, *Cybernetics: Or, Control And Communication In The Animal And The Machine* (Cambridge, MA: The MIT Press, 1961).
19. Ranulph Glanville, ‘The Value of Being Unmanageable: Variety and Creativity in Cyberspace’, in *Netzwerke: Proceedings of Global Village 1997 Conference*, ed. H. Eichmann et al. (Vienna: Falter Verlag, 1997).
20. Ranulph Glanville, ‘A (Cybernetic) Musing: Variety and Creativity’, in *Cybernetics and Human Knowing 5*, no. 3 (1998): 55–62.
21. Bateson, *Steps to an Ecology of Mind*.
22. George Lakoff and Mark Johnson, *Philosophy in the Flesh* (New York: Basic Books, 1999).
23. Bateson, *Steps to an Ecology of Mind*, 449.
24. Ibid., 440.
25. Gregory Bateson, *Mind and Nature: A Necessary Unity* (Cresskill, NJ: Hampton Press, 2002), 10.
26. Mary Catherine Bateson, *Our Own Metaphor* (Cresskill, NJ: Hampton Press, 2005), 297.
27. Mary Catherine Bateson, ‘Living in Cybernetics’, in *Living in Cybernetics: 50th Anniversary Conference of the American Society for Cybernetics*, 2014 https://www.youtube.com/watch?v=wpjnVVWXZMs.
28. The initial design of the module was developed by Karin Jaschke and Kate Cheyne. I am particularly grateful to Kristen Bullivant, Jessica Melville-Brown, Sally Sutherland and Jordan Whitewood-Neal, who

have taught with me at different times, and to all the students who have taken the module and shared their insights through it.

29. Ranulph Glanville, 'Researching Design and Designing Research', in *Design Issues 15*, no. 2 (1999): 80–91.
30. Sandra Harding, 'Objectivity for Sciences from Below', in *Objectivity in Science: New Perspectives from Science and Technology Studies*, ed. Flavia Padovani, Alan Richardson and Jonathan Y. Tsou (Berlin: Springer, 2015), 35–55.

Biography

Dr Jon Goodbun considers architecture in relation to a wider field of systems-theoretic discourses, working in particular with concepts of ecological aesthetics and environmental semiotics that he develops out of the anthropological cybernetics of Gregory Bateson, while also drawing upon three significant contributions from the Marxian tradition concerning cognitive mapping, the production of space and the production of nature. He is currently working on a book entitled *The Ecological Calculus*, and initiating a series of environmental architecture field projects in Greece, where he is now mostly based. He occasionally leads workshops on long-distance train journeys with Derailed Lab. He contributes to programmes at the Bartlett (UCL), University of Westminster, and the Royal College of Art. His co-authored 2014 book *The Design of Scarcity* has recently been translated into German (2018) and Greek (2020). He can be found on twitter @jongoodbun, and at www.rheomode.org

Ben Sweeting teaches architecture and design at the University of Brighton. Ben studied architecture at the University of Cambridge and the Bartlett (UCL). Ben first encountered cybernetics at the latter, going on to use and explore it through the completion of PhD research supervised by Neil Spiller and Ranulph Glanville. Ben is an active member of the American Society for Cybernetics, the British Cybernetics Society, the Systemic Design Association and the International Society for the Systems Sciences. Ben's research interests include ways in which design can contribute to ethics as well as vice versa; rethinking 'place' in the context of systemic crises; historical intersections between architecture and cybernetics in the works of Gordon Pask and Cedric Price; and the development of counter-conventional methodological approaches inspired by cybernetics' original transdisciplinary agenda.

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Footprint is grateful to our peer reviewers, who generously offered their time and expertise. In this issue, the following papers were peer-reviewed: 'Cyberneticisation as a Theory and Practice of Matter'; 'From Cybernetics to an Architecture of Ecology: Cedric Price's Inter-Action Centre'; 'Systems and Relations All the Way Down, All the Way Across'; 'Environments (out) of Control: Notes on Architecture's Cybernetic Entanglements'; 'Critical Technics in Architecture: A Cybernetic Approach', 'Architecture as an Information Machine'.

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