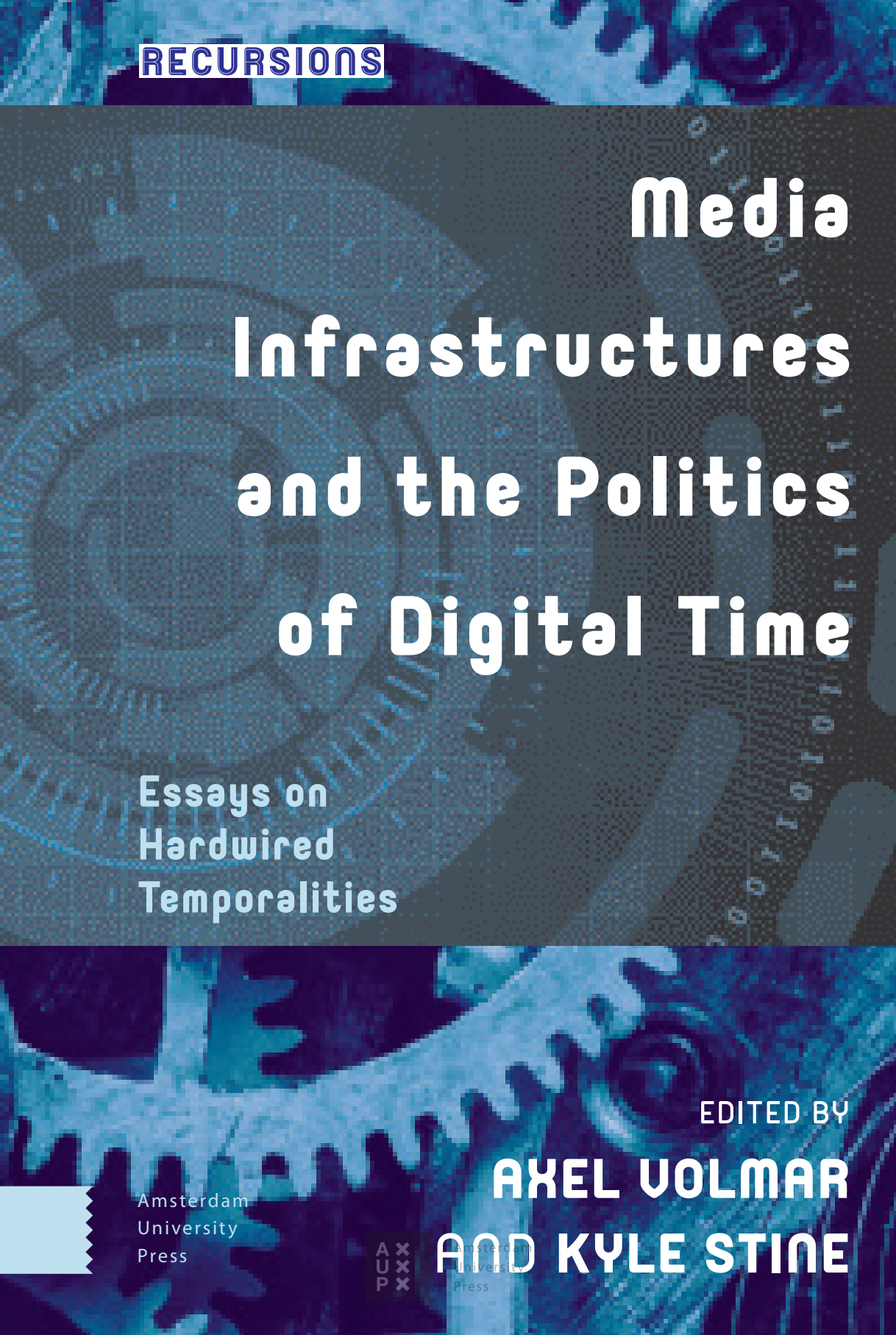
RECURSIONS
Media Infrastructures and the Politics of Digital Time
Essays on Hardwired Temporalities
EDITED BY
AXEL VOLMAR AND KYLE STINE
Amsterdam University Press
AUP
Amsterdam University Press

Media Infrastructures and
the Politics of Digital Time

Amsterdam
University
Press

The book series RECURSIONS: THEORIES OF MEDIA, MATERIALITY, AND CULTURAL TECHNIQUES provides a platform for cuttingedge research in the field of media culture studies with a particular focus on the cultural impact of media technology and the materialities of communication. The series aims to be an internationally significant and exciting opening into emerging ideas in media theory ranging from media materialism and hardware-oriented studies to ecology, the post-human, the study of cultural techniques, and recent contributions to media archaeology. The series revolves around key themes:

– The material underpinning of media theory
– New advances in media archaeology and media philosophy
– Studies in cultural techniques

These themes resonate with some of the most interesting debates in international media studies, where non-representational thought, the technicity of knowledge formations and new materialities expressed through biological and technological developments are changing the vocabularies of cultural theory. The series is also interested in the mediatic conditions of such theoretical ideas and developing them as media theory.

Amsterdam University Press

Media Infrastructures and the Politics of Digital Time

Essays on Hardwired Temporalities

Edited by
Axel Volmar and Kyle Stine

Amsterdam University Press

Gefördert durch die Deutsche Forschungsgemeinschaft (DFG) – Projektnummer 262513311 – SFB 1187. Funded by the German Research Foundation (DFG) – Project-ID 262513311 – SFB 1187.

Funded through a Social Sciences & Humanities Research Council of Canada (SSHRC) Connection Grant, file number 611-2015-0336.

Cover illustration: Pete Linforth (Pixabay), Pavlofox (Pixabay).
Cover idea: Julia Eckel

Cover design: Suzan Beijer
Lay-out: Crius Group, Hulshout

ISBN 978 94 6372 742 6
e-ISBN 978 90 4855 075 3
DOI 10.5117/9789463727426
NUR 757 | 811

Amsterdam University Press

Table of Contents

Part III Lifetimes

Part IV Futures

Acknowledgments

This collection stems from two conversations started at McGill University in Montréal, Canada, in 2015 and the University of Siegen, in Siegen, Germany, in 2018. We express our gratitude to the Social Sciences and Humanities Research Council of Canada (SSHRC), which generously funded the project through a Connection Grant, as well as the Andrew W. Mellon Foundation, the Dean of Arts Development Fund of the Faculty of Arts at McGill University, and McGill's Post-Graduate Students' Society (PGSS). We extend special thanks to Jonathan Sterne for his support. Additionally, we thank Errol Salamon, Maryse Ouellet, Anastasia Howe Bukowski, and Megan Mericle for logistics and organizing; Caitlin Loney for designing our website, posters, and flyers; and Kathleen Holden for administering the awards funds in the Faculty of Arts. We also owe thanks to the Collaborative Research Center "Media of Cooperation" at the University of Siegen, funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), and to Jenny Berkholz and Anja Höse. Finally, we would like to extent special thanks to the German Research Foundation for making this volume freely available via Open Access.

Amsterdam
University
Press

Infrastructures of Time: An Introduction to Hardwired Temporalities

Kyle Stine and Axel Volmar

Abstract

The introductory essay to the volume proposes a framework for understanding the transformative and disruptive effects of digital time. It argues for a multiscalar approach to the layers of temporality active in current media infrastructures, which coordinate different magnitudes of time from the microtemporal to the *longue durée*. Situating the phenomenon of digital time within a trajectory of increasing materialization of temporal relations, it provides a historical account of the becoming concrete in technology of what were once relations between people and objects.

Keywords: media theory, digital time, infrastructures, materiality, temporality

All machines, whether mechanical, electronic, or symbolic, are in a crucial sense time machines. They pattern the movement of mechanisms, the flow of electrons, or the operations of symbols to meet temporal demands such as synchronism, succession, repetition, and pace. Media technologies thus constitute not only *material* infrastructures, as has been a watchword in recent media theory, but also *temporal* infrastructures, architectures, and systems—materialities designed in and as time. An aspect of this patterning of time that has received heightened scholarly attention is the ubiquitous experience of technological and cultural acceleration. Temporal speed-up has in fact emerged as a defining characteristic in accounts of modernity, as Peter Conrad expresses in saying, "Modernity is about the acceleration of time."[1] Recent works, from critical theory to the sociology of time, have

Volmar, A. and K. Stine (eds.), *Media Infrastructures and the Politics of Digital Time: Essays on Hardwired Temporalities*. Amsterdam: Amsterdam University Press, 2021
DOI 10.5117/9789463727426_INTRO

emphasized this in terms of a cultural doctrine of accelerationism.[2] However, focusing on the temporal aspects of media culture reveals not only an acceleration of life and communication systems but also complex temporal relations within technologies, between technologies, and between human time and technological time.

Take a smartphone, for example. A host of services are at one's fingertips: rides available for pickup at an exact address, rooms ready to be reserved and digital keys accessed without interaction with any person, goods connected to whole systems of order delivery through automated warehouses and same-day transportation, and entertainment media set to stream on the go. Such ease of access can give the impression of instantaneity and immediacy, of time compressed to the zero degree. There are no lapses in programming, such as when television stations of old shut down for the night, and no closed signs to be flipped on shop doors.[3] Yet obvious from experience is that these conveniences are also subject to service interruptions, scheduled maintenance, system lag, and downtime, not to mention rush hours and peak pricing. Behind and beneath our real-time interactions with on-demand media and services is a temporal geography as uneven as our social and political geographies, in which slowness and waiting are produced and distributed alongside every advance in convenience and speed.

Recent research in media and cultural studies has attended closely to the widening gap in lived experiences of time across different social geographies. Emily Keightley in this regard urges media scholars "to move beyond a one-dimensional characterization in which speed and immediacy monopolize accounts of how time is encountered and lived" and instead address the "social temporalities of mediated experience."[4] Sarah Sharma shows in her ethnography of business travelers that the experience of living "fast," as promoted throughout self-help literature on time management, represents a luxury that draws on an entire service industry of workers made to calibrate their bodies to the demands of global capitalism.[5] In the words of Markus Krajewski, modern service workers, or "servers," to express the comparison between people and technologies that are ordered to stand by, have always been consigned to "idle time," or waiting for a bell, command, or instruction that positions them in relation to the time they serve.[6] In the essays collected in this volume, we follow these studies by understanding time in its unequal distribution across our social and political world, while emphasizing its particular relation to the problem of technological acceleration, the stark departure of technological time from lived human time, and in this way couple the themes of social inequality and accelerationism in the analysis of time.

The scale of this inquiry cannot be addressed solely at the level of the individual medium or technology, in that the defining characteristic of digital time is that it coordinates multiple layers of technological time within a comprehensive system. The analytical figure of digital time is for this reason the infrastructure. On the one hand, infrastructures embody temporal relations between technologies, as maintained through standards and protocols; on the other hand, they coordinate relations between technologies and human beings, who serve as interlocutors, care givers, proxies, and delegates. So while digital technologies construct an uneven geography that accelerates life for some and impedes life for others, they also profoundly transform and reorder temporal regimes and practices in other ways that require critical attention.

A central argument of the volume is that the concerns of digital time and contemporary media infrastructures exceed any one field of inquiry, requiring cross-disciplinary perspective. Our objective is to account for devices and processes whose spheres of action range from the microtemporal to the geological, addressing for the time domain what studies have noted for the spatial domain of international logistics, whose vectors range from the flows of microscopic circuits to the paths of orbiting satellites.[7] We pursue this goal through a broadly inclusive range of media and infrastructure studies, with perspectives from science and technology studies, cultural studies, and the philosophy of time, while acknowledging the need for future collaborations between the humanities, sciences, and engineering. The volume in this way serves as a meeting ground between disciplines and begins a cross-disciplinary conversation that will become increasingly relevant and necessary as infrastructural systems extend yet further into the social and political systems of everyday life.

The contributors study two aspects of the infrastructuring of time: the *infrastructures of temporality*, namely the means of ordering time through technologies and practices ranging from calendars to computers; and the *temporalities of infrastructure*, or the specific, often incompatible temporal orders of different technical milieu in media, science, business, and government. As our title suggests, the central metaphor of our inquiry, drawing on the predominant mode in which temporalities are inscribed and effectuated today, is the hardwiring and rewiring of temporal orders, calling attention to how stabilized temporalities, erected in infrastructures, exert pressures of conformity and standardization on the temporalities of lived experience and among different temporal infrastructures. *Hardwired temporalities* refers to all the ways that time patterns become fixed in materialities: these can occur through unplanned flows of habituation whose constancy eventually

sculpts a definable space, just as flowing water carves out a river bed that endures even while remaining open to redirection; but they can also be formed by more obdurate temporal governance, the imposition of temporal patterns by top-down command. *Temporal regimes* refers to the guiding principles of ordering time in a given locality and epoch. The overriding temporal regime today is the imperative speedup of global capitalism, but smaller scale temporal orders exist within this larger regime, such as the orders of religious time and leisure time. Because networks so define social space, we speak of hardwiring and rewiring temporal relations, rather than using the more amorphous phrasing of temporal flows. Reorganization of temporal patterns in infrastructures is not liquid—it cannot take just any shape—but is nevertheless flexible and open to reconfiguration. Moreover, these patterns coordinate different spheres of action. The temporal orders of our digital culture involve infrastructural formations across multiple temporal scales, from the microtemporal domains of manipulating, processing, and transmitting information, through the temporal orders on the meso scale of everyday life and lived temporalities, to the macrotemporal scales of cosmological and geological deep time.

The collection speaks to and consolidates insights among three important directions in media studies today, making contributions in this way also to three broad pursuits in recent humanities and social science research. The current social and political unrest in the neoliberal economies, following an intensified concentration of wealth enabled by disruptive new technologies, has prompted a turn toward material culture and a deeper consideration of the technical specificities of the networks, devices, and programs used in our daily lives. This turn toward the nonhuman and emphasis on new materialisms for rethinking the relationship between human societies and technological networks has significantly broadened the scope of inquiry and deepened the scales of time considered.[8] However, it also risks a certain spatializing bent. Jane Bennett points to one aspect of this bias when she notes the tendency in object-oriented ontology to disregard the relations between objects, in response to which she suggests a way of thinking objects and their relations together.[9] We argue that time is precisely the dimension that is lost in an approach to objects that brackets out relations, and it is necessary to develop approaches to materiality that analyze time, which is fundamentally relational.

Our inquiry comes at the question of digital temporality from two directions. The first of these we have discussed in addressing the social experience of time and its multiplicity, what we can characterize, for the sake of comparison, as a culturally focused approach. However, we follow the insights of science and technology studies to understand that no technical

system or device is value neutral. Any divergence between the temporal patterns of human life and those of networked technologies is likely to exacerbate inequalities already perpetuated by systemic discrimination. The last two years have seen important interventions in the areas of technological and algorithmic bias, whose insights point to ways scholars might further interrogate the uneven distribution of time. The attention economy's effort to maximize engagement is an explicit program to monopolize people's time.[10] When biased algorithms filter results in discriminatory ways, as Safiya Umoja Noble has shown, they not only misrepresent people and concepts; they also misdirect people and consume their time.[11] Charlton McIlwain and Ruha Benjamin have pointed out how technological systems that present as neutral means of problem-solving are cut through with racial biases. Early computer systems, as McIlwain demonstrates, were explicitly intended to aid police countermeasures against the Civil Rights Movement and were further embedded in the carceral apparatus of the War on Drugs.[12] Benjamin has extended this insight in the deepest way to show that, even beyond the point-of-the-sword biases of facial-recognition software and search tools that predict ethnicity according to people's names, technological systems entrench racial hierarchies throughout their design in myriad ways that are inescapable in their effects.[13] The continual march of innovation, which hardwires and rewires power relations, deserves further attention in analyses of time, a framework to which the essays in this volume seek to contribute.

Complementary to the perspective on lived time is an approach that draws insights from German media theory,[14] media archaeology,[15] and studies of microtemporalities,[16] with their attention to the design and inner workings of the technologies themselves, to extend an analysis of time beyond representational media, such as literature and film,[17] to the nonrepresentational media and programs that enable them, often invisibly. Following Wolfgang Ernst, we understand that media studies must become "time-critical."[18] Being sensitive to the time-criticality of media technologies means being attentive to temporal actions that are in a certain way "critical factors" for the successful execution of a process.[19] This includes real-time applications, whose operations exist below the threshold of human perception, and more generally the synchronization and coordination of different co-operative speeds and time windows. The volume is thus informed by and speaks to the current German discourse on understanding media less as means of representation and transmission than as fundamental "conditions of cooperation," a conversation closely connected to the "practice turn" in media theory.[20]

Lastly, the volume benefits from and contributes to the growing interest in infrastructures.[21] We take our cue from Susan Leigh Star and Geoffrey

Bowker's notion of "infrastructuring" as an active, ongoing process and from Lauren Berlant's recent broadening and refinement of the concept of infrastructure to mean "the movement or patterning of social form."[22] Berlant's choice of the word "patterning," in its active, gerundial sense, as opposed to the more static connotations of "pattern" and "form," lays emphasis on infrastructures as temporal processes of becoming. Social patterns, however fixed they may seem, are only ever the circuit for movements and temporal flows. Keller Easterling has shown how infrastructure space, even when not "mediated" in the common sense by sensors and media technologies, is an information technology where the mere mobilization of form, in grids and containers, is "an operating system for shaping the city."[23] We might argue, in a similar way, that infrastructure time, the rhythm and patterning of temporal order, is the very basis of information, which never stands still but must be processed and transmitted. Indeed, recent developments in network technologies and smart sensors, we argue, have created a need to reexamine infrastructures particularly in terms of their patterning of time. "To be modern," as Paul Edwards puts it, "is to live within and by means of infrastructures."[24] To be digital—or to be in an algorithmic, networked culture—is to live within and by means of infrastructures that are themselves monitored, maintained, and controlled by deeper data infrastructures. The infrastructures of modernity, such as roads, bridges, communication lines, and financial systems, have long been equipped with cybernetic feedback infrastructures that monitor their operations, make corrections, and, when needed, marshal workers to repair them.[25] The temporalities of their operation and aging are now bound up in the computational time of digital networks and, as such, submitted to the control and surveillance of these networks. Yet at the same time, these newer infrastructures rely on the older infrastructures of water, energy, and human transit, as a nervous system relies on a circulatory system. Infrastructures in this way are coordinating and synchronizing features of multiscalar action, which, as we have mentioned, embody relations between technologies and people, and are thus appropriate figures for thinking about materiality, microtemporalities, and the social geography of time together.

Technologies as Consolidated Temporalities

A guiding thread in this regard involves the processes by which technical systems *consolidate temporality*, in the most literal sense of their gathering together disparate temporal processes and making them solid in physical

infrastructures. Scholars of the social construction of science and technology teach us that even nonrepresentational technologies, which cultural analysis long overlooked in favor of media and artistic works, embody social values and relations of power. In Bruno Latour's apt phrasing, technologies are "full of people": they concretize human expertise and function to advance human goals.[26] Just the same, technologies are full of time. Karl Marx described one aspect of this when he argued that the value of the commodity consists in "congealed labor-time."[27] Yet even beyond the actions necessary for their immediate manufacture, technologies embed multiple histories and spheres of temporal action. Michel Serres calls technologies "polychronic" to express the multiple pleats of time that fold together "the obsolete, the contemporary, and the futuristic":

> Consider a late-model car. It is a disparate aggregate of scientific and technical solutions dating from different periods. One can date it component by component: this part was invented at the turn of the century, another, ten years ago, and Carnot's cycle is almost two hundred years old. Not to mention that the wheel dates back to neolithic times. The ensemble is only contemporary by assemblage, by its design, its finish, sometimes only by the slickness of the advertising surrounding it.[28]

Comprising parts of different vintage, technologies also operate on multiple scales of temporality. To use Serres's example, a modern car going at 60 miles per hour is likely to have wheels rotating at around 800 revolutions per minute, an engine firing at 2,000 revolutions per minute, and a microprocessor calculating at 2 GHz, or 120 billion cycles per minute. Meanwhile, the driver must maintain a safe reaction time, at best 0.7 seconds, and endure the length of travel, sometimes numbering several hours, interrupted by cyclical human events such as stopping off for food or at a rest area. Human-scale actions and technological actions, as this example suggests, are divergent along many paths, guided by their own temporal logics, but they are importantly coordinated and synchronized by means of cultural techniques of time patterning.[29] The frame for thinking this coordination must come from temporal infrastructures, which by design integrate and mediate these various human and nonhuman temporalities, drawing together the micro, meso, and macro domains, and thereby enable systematization and diverse forms of cooperation.[30]

Not only do temporal practices and processes tend to consolidate into temporal infrastructures; they also reciprocally interact as hardwired infrastructures with new kinds of pliable and adaptable systems, both

above and below: above, in the flexible software systems designed to operate using new circuit generations and the various social practices centered on new communication technologies; and below, in the flexible economies and manufacturing processes at the base of fabricating these technologies. This dialectic between rigidness and flexibility, structure and versatility, predictability and unpredictability, as Serres notes, lies at the very heart of temporality. It is for this reason that the Latin ***tempus*** gives us not only the structured "temporality" of the clock but also the intemperate fluctuations of "temperature," the wild swings of "temperament," and the fierce unpredictability of "tempests":

> The French language in its wisdom uses the same word for weather and time, *le temps*. At a profound level they are the same thing. Meteorological weather, predictable and unpredictable, will no doubt someday be explainable by complicated notions of fluctuations, strange attractors. Someday we will perhaps understand that historical time is even more complicated.[31]

John Durham Peters elaborates these etymological connections in broad perspective:

> In Latin, *tempus* means weather and time, giving English such words as *temporal* and *tempest*, and French *le temps* and Spanish *el tiempo*, both of which mean both time and weather; the Spanish *al tiempo* means both "in season" (of fruits) or "at room temperature" (of drinks). Terms such as *temperature*, *tempering*, *tempo*, and *temperament* show shared semantic fields across heat, harmony, rhythm, and mood.[32]

Time, in this sense, is moody and multiplicitous, varied and in flux. The goal of infrastructuring time, founded on time technologies and cultural techniques of time management, is to tame these moody fluctuations and to submit them to ordering—to hardwire them into lasting temporal regimes or cultures.

By the same token, the term "hardwired" relates equally to embedded systems and more flexible practices involved in rewiring temporal orders. To use an example, computer components in the 1960s, whose electrical layout would soon be characterized as hardwired, were at the time compared favorably "soft" against the fixed-program analyzers of yesteryear. The first recorded instance of the then-hyphenated "hard-wired" documents this usage, when a contributor to the journal *Nuclear Instruments and Methods*

in 1965, comparing the two generations of computers, wrote: "Another trend is the use of small computers instead of hard-wired analyzers."[33] In this way, the conceptual ground of hardwiring is, in a deconstructive turn, precisely the opposite of being fixed and immutable. Technical consolidation is instead the product of a new kind of adaptive industry, a flexible economy founded on the production of a new component, the integrated circuit, capable of being hardwired and rewired across product generations. Moore's Law, formulated in the same year of 1965 to describe the regular doubling of circuit complexity from one fixed pattern to another, has since turned into a self-fulfilling prophecy, a stable temporality that serves to predict future technological progress. In a system of planned obsolescence, hardwired components come to enable the periodic "rewiring" of the systems they run.[34]

The hardwiring of space, as seen in the doubling of component density on microchips, thus structures time in new ways as well, setting industry on a regular course of introducing new product generations and creating a new density of temporal intervals, or actions that can occur in a given period of time, with increased processing speeds. It would not be a stretch to say that these computational components and their infrastructuralization into larger networks invented a new sphere of time in the same way that James Carey saw the telegraph as instituting a new regime of time a century before. In its ability to send messages faster than physical commodities, according to Carey, the telegraph rendered obsolete the system of arbitrage—the practice of buying low in one market and selling high in another—and redirected financial speculation into commodity futures. "In a certain sense," Carey writes, "the telegraph invented the future as a new zone of uncertainty and a new region of practical action."[35] That is, the telegraph initiated a new domain of time by hard wires. Judy Wajcman stresses the continued material pressures of such wires with the example of a recently laid fiber-optic cable between Chicago and New York: "While previous cables between the two cities had been laid along railway lines, the new cable takes the shortest route possible, even drilling through the Allegheny Mountains. It shaves 1.3 milliseconds off the transmission time of the earlier cables."[36] Likewise, contemporary developments in big data, artificial intelligence, and machine learning can be regarded as a result of the "wires" that have gone into the microprocessors and networked environments that enable algorithms to operate over global information networks within ever smaller temporal intervals.[37]

Historically, temporal practices have tended to consolidate into technical objects and from objects into structures and infrastructures. The more organized the materialities, the more structured the temporalities.

Our project thus seeks to reassess material infrastructures as *stabilized structured temporalities*, forms of patterned time sustained over given periods of history in formations of technologies, practices, and conventions that affect people's actions and experiences and are themselves subject to constant "rewiring." The two terms that organize our thinking on the topic, "hardwired" and "temporalities," in this way name a dynamic interaction between infrastructured temporalities and their continual interactions with more pliable, flexible, mortal, human systems.

A Chronology

Temporality, as seen throughout history but especially in an age of global digital networks, is palimpsestic. Concretized within temporal infrastructures and embedded in our experiences of temporality are multiple historical regimes successively layered and combined. A modern smartphone, for instance, which is subject to the timing of a processor clock and various network synchronization protocols below the level of human awareness, also remediates earlier temporal interfaces through apps such as calendars, clocks, and stopwatches. To take but one example, Chinese, Hebrew, and Islamic calendars are standard options on smartphones alongside the western Gregorian calendar, while apps are available for Persian and Tibetan calendars, among others, and even more remote historical calendars such as the Maya calendar. Indeed, the applications of timekeeping in new media are practically limitless. While not dismissing this multitude of applications and their complex interactions, it is possible to outline four overarching *temporal regimes*, or historical hegemonic temporal logics, that inhere in modern technologies and continue to structure temporal techniques and experiences, namely, calendar time, clock time, capitalist time, and technological microtime.

We understand these temporal logics to have emerged from multiple locally installed and trans-locally networked temporal orders rather than from any single authoritative center. After all, even a regime as centrally administered as medieval Christian time was not commanded by a single source of timekeeping but was instead made possible by a multitude of individual clocks and clock towers in every Christian settlement, involving procedures for displaying the time, as for instance by the chiming of bells, and people tasked with caring for the clocks and regularly setting the time. Likewise, the concept of capitalist time, which introduced the virtue of optimization, emerged from a proliferation of town bells and factory time

clocks, not from a single timekeeper, and in this way resulted in ever new "rewirings" of procedures of production, organization, and cooperation.

An obvious way of understanding these four temporal orders, which historically succeed one another, is in their progressive refinement of counting time. Each method of measuring time, which is also characteristic of a historical epoch, sharpens the unit of measurement, while the epochs themselves shorten. Calendar time, incipient with the invention of writing, patterns longer intervals such as days and years, while Christian clock time, beginning in the twelfth century, enables the standardization of human practices within the span of a day through the divisions of hours. Beginning in modernity, capitalist time, especially gaining momentum in the nineteenth century, with its inherent logics of efficiency and acceleration, increasingly focuses on the shorter measures of minutes and seconds, building upon which technological microtime more finely divides temporal measure below human sense thresholds. Temporal units and the span of innovation in this way historically tighten. However, the command of time, always directed toward the future, has progressively expanded, as evidenced by contemporary megaprojects, including the decade-long construction of CERN's Large Hadron Collider and the nearly two-decade construction of the Three Gorges Dam in China, which beyond taking a long time to build, consumed billions of dollars of labor time, relying on various specialized workforces.[38] In a similar fashion, the historical record available in each temporal regime has also expanded, evidenced nowhere more conspicuously than in the introduction of deep geological time in the eighteenth century, but also apparent in the heightened resolution of historical data. In this sense, it is not enough to consider only the units of temporal control and the length of future time under the command of the present; we must also acknowledge the new scales of temporal complexity within shorter intervals. Just as a computer performs more actions in a second than is possible using conscious calculation, a megaproject facilitates and coordinates more actions in the span of a week or year than was possible in previous projects in previous eras. Put simply, technological time today is denser and more vivid than past times; it contains more action moments and has a much higher resolution. Within these denser frames of planning and action must be coordinated the many temporal measures of the actors involved, whether human or nonhuman, which operate across these four temporalities.

In what follows, we attempt to delaminate these various layers of temporal governance to better understand their historical sources and how they interact, combine, over-pattern, and stabilize in durable infrastructures.

Calendar Time

Since the early beginnings of so-called "civilization," the life of the vast majority of people has been and still is governed not only by the natural temporal rhythms of seasons and cycles of day and night but also by temporal regimes, i.e., orders of patterned time sustained by technologies and practices of timekeeping and temporal organization. John Durham Peters, for instance, reminds us of the fundamental significance of the calendar as a cultural technique of social order and governance that, through the science of astronomy and the politics of calendar making, provided a means of predicting and determining recurring events, from yearly floods, as in Mesopotamia and Egypt, to holy days.[39] From their earliest uses to the present day, calendars have served to track the succession of days by dividing the year into arbitrary intervals of months and weeks. Their temporal divisions allow for repetition and ritual and hence the coordination of social, economic, and religious life into structured temporal schemes, both past and future. Alongside the political and military control of space, or territory, as Harold Innis argued in *Empire and Communications*, the cultural control of time based on common cosmological, religious, or philosophical narratives and materialized into different time media has played an equally important role in securing the endurance of cultural-political entities.[40]

A direct line extends from our present computational timekeeping technologies back to the calendars of earlier empires. In an influential essay on time and human language, Émile Benveniste explains that the calendar owes its existence to a baseline computation.[41] Paul Ricoeur explains Benveniste's insight especially clearly: "the features common to every calendar 'proceed' from the determination of the zero point of some computation."[42] In this sense, the calendar can be viewed as an early form of computing whose logistical functions issue from three basic conditions: the establishment of an axial moment, e.g., in the common era of occidental civilization marked by the birth of Christ; the determination of whether an event occurred before or after the axis; and the measurement of intervals, such as days, weeks, months, and years. The calendar, as Ricoeur puts it elegantly, thus "cosmologizes lived time and humanizes cosmic time"[43]; it is the first technique to organize these different spheres of temporality and serve as a bridge between them.

Calendars, as tools of temporal social organization, are the first techniques to introduce what Benveniste calls "chronic time," a term he uses to encapsulate both calendar and clock time for their ability to join together interior subjective duration and exterior physical time within a coordinating

grid that locates personal experience within cosmic rhythms.[44] Out of this logistical construction arises a seeming paradox in that chronic time, which Benveniste says is the only time we generally encounter in our day-to-day lives, does not move; it is instead arrested and, to repeat Hamlet's lament, "out of joint" with our inner experience of time, which constantly slips away: "It might thus seem natural that the structure of chronic time should be characterized by permanence and fixity. Yet, at the same time, it must be realized that these characteristics result from the fact that the temporal organization of chronic time is actually *intemporal*. This is not a paradox."[45] Chronic time is a rigid atemporality, and only for this reason can it situate passing events in relation to one another. To use the language of our title, chronic time is the hardwired a priori of our more flexible everyday experiences of and interactions with irreversible time. An insight that we can draw from Benveniste is that just as the calendar presents a grid of temporal reference for calculating events, today's computer systems and infrastructures extend this intemporal grid to new levels of complexity and acceleration and thereby enable not only new modes of calculative governance but also new variabilities in lived temporality.

Clock Time

In his foundational work in the history of technology, Lewis Mumford (1934) demonstrates how the unified time of monastic life in the Middle Ages precipitated the development of the mechanical clock and influenced the subsequent temporal coordination of people and technologies that enabled both the Scientific and Industrial Revolutions, a development that leads him to argue: "The clock, not the steam-engine, is the key-machine of the modern industrial age."[46] Alongside the calendar, which forges cultural unity on the basis of common holidays and other social events throughout the year, the clock enables within this initial computation of calendar time more fine-grained coordinations of human activities and forms of cooperation throughout the day and week, particularly the organization and control of human labor.

Historically, the prime points of time reference were not calculated abstractions but physical, often cyclical, work-based particularities. The rising and setting of the sun marked the passage of days, the wilting of flowers and spoiling of foods influenced cycles of work and gathering, the passage of winters measured age, and the recurrence of ten moons promised that an expecting mother would soon give birth. Noting among other regularities of human life, such as "the beating of the pulse" and "the

breathing of the lungs," Mumford cites practices of agrarian subsistence: "The shepherd measures from the time the ewes lambed; the farmer measures back to the day of sowing or forward to the harvest."[47] James Henry Breasted, writing in 1935, noted how the lives of his contemporaries gained temporal meaning by reference to seasonal fluctuations: "Among certain Swedish peasants even at the present day a birthday may fall at the 'rye harvest' or at the 'potato harvest.'"[48] From similar examples of celestial and earthly timekeeping, Peters (2015) has argued that the movements of the skies and earth themselves constitute "elemental media."[49]

It would be a mistake, however, to suggest that the onset of regimented clock time did away with these corporeal and more sensible temporal measures. In his commanding work on the history of timekeeping, Eviatar Zerubavel cites a striking example of time formulation without recourse to calendar or clock from the opening of Kurt Vonnegut's *Cat's Cradle*: "When I was a younger man—two wives ago, 250000 cigarettes ago, 3000 quarts of booze ago."[50] Drawing on more functional examples, he reminds us that even today it continues to be more appropriate "to designate the life expectancy of tires and running shoes in terms of mileage—or that of children's beds in terms of the child's weight—than in terms of years of use."[51] What has changed though is that these time references take on new meaning in an era when, as Mumford argues, "The modern industrial regime could do without coal and iron and steam easier than it could do without the clock."[52] For, now, all of these more variable temporal measures are caught within the mesh of modern clock-based time.

The wresting of time away from personalized reference points has been crucial in establishing intersubjective social realities. Time-counting devices, from water clocks to later mechanical clocks, in situating individual actions within a common social frame, have allowed for the organization of work, the establishment of cultural identity through repetition, and the incorporation of these identities and processes into larger cultural configurations such as corporations and nations. The monastery, according to Mumford, was the first instrument for calculating this form of social time:

> Within the walls of the monastery was sanctuary: under the rule of the order surprise and doubt and caprice and irregularity were put at bay. Opposed to the erratic fluctuations and pulsations of the worldly life was the iron discipline of the rule. Benedict added a seventh period to the devotions of the day, and in the seventh century, by a bull of Pope Sabinianus, it was decreed that the bells of the monastery be rung seven times in the twenty-four hours. These punctuation marks in the day were

> known as the canonical hours, and some means of keeping count of them and ensuring their regular repetition became necessary.[53]

In a similar way, modern technical systems and infrastructures should be thought of as instruments for calculating and managing time. As profound as was the clock's impact on social organization was its effect on mechanical processes. For Mumford, the clock set "the regular collective beat and rhythm" of a technical system by wedding together these regular mechanical actions with the synchronized movements of people. More than a mere counting device, it was also "a new kind of power-machine, in which the source of power and the transmission were of such a nature as to ensure the even flow of energy throughout the works and to make possible regular production and a standardized product."[54] Timekeeping was, then, from the beginning, a means of not only coordinating human actions but also regulating and operating machinery. The clock's qualities of standardization, automatic action, precise gearing, accuracy, and reversibility allowed it to divide time and conquer it. Even more significant, by taking on these characteristics of space, time could be added, saved, and controlled, laying the conditions for capitalist time.

Capitalist Time

Until recently, the temporal orders of calendar and clock have been subject to a politics of time, struggles within societies based on conflicting interests between the state, economic and religious actors, and individuals over matters such as the recognition of holy days and the designation of work times. The convergence of meanings on May 1 in cultures of the northern hemisphere helps to illustrate these conflicting politics of time. First celebrated in response to the astronomical event of spring, the day was a seasonal festival of the return of the warm season. After being adopted by the international workers movement to commemorate the Chicago Haymarket massacre in the late-nineteenth century, the day became a further palimpsest when, during the First Red Scare in the early 1920s, it became a reactionary, unofficial holiday dubbed "Americanization Day" that the US Congress would later inscribe into law as Loyalty Day during the Second Red Scare in the 1950s. Concerns about the temporal politics of paid labor continue unabated today in negotiations over how many hours per day and per week employees should work, how much vacation time should be allowed, how many sick days employers and health insurers should pay for, how overtime should be compensated, and how the post-work life of

retirement should be managed. These struggles are largely crystallized in agreements, contracts, laws, and other forms that set more or less specific conventions for the patterning of human everyday life.[55]

In this regard, E. P. Thompson argued that the decisive change paving the way for modern capitalism was the shift from task-oriented labor to time-oriented labor.[56] Labor focused on tasks such as fishing and harvesting crops is embedded in the rhythms of the natural world, such as the rising and falling of tides and the passage of the seasons, and thus ritually connected to universal time. Such labor, rather than being set to the employer time clock, is characterized by "alternate bouts of intense labor and of idleness."[57] The continuation of this labor pattern in the creative economy today leads one to wonder, as Thompson himself wondered in the 1960s, whether "it is not a 'natural' human work-rhythm."[58] But possessing one's natural time is largely at odds with capitalist economics. By uprooting time from one's personal experience, it becomes abstract and controllable, and in this way, as Thompson explains, time becomes money: "Those who are employed experience a distinction between their employer's time and their 'own' time. And the employer must use the time of his labour, and see it is not wasted: not the task but the value of time when reduced to money is dominant. Time is now currency: it is not passed but spent."[59] When time-oriented labor becomes *counted time*, it makes work time accountable and evaluable, with the historical side-effect that it renders forms of labor that are not compensated monetarily, such as household and care work, traditionally (and even today) largely performed by women, invisible.[60] This alliance between money and time, as Peters notes, rests on their being paradigm cases of "logistical media," or those media that "establish the zero points of orientation."[61]

In establishing a grid of temporal structure capable of containing and coordinating diverse practices in time, the calendar and clock have functioned to lift time out of the necessity of particular reference and produced what French historian Paul Ricoeur calls "anonymous time."[62] Anonymous time, for Ricoeur, is a mediating temporality between phenomenological experience and worldly time; it functions to situate and compare subjective and objective temporalities, giving temporal place both to inner experience and external events. Reading Alfred Schütz's influential phenomenological account of intersubjectivity, Ricoeur argues that the division of social time into anonymous categories of "contemporaries, predecessors, and successors" initiates a temporal logic that forms a bridge between "lived time and universal time."[63] The succession of generations, socially experienced as the "replacement of the dead by the living,"[64] constitutes a third time between

inner subjective reality and the physical time of the world, out of which time becomes a matter of roles. People in their radical singularity can never replace one another in their phenomenological experience of time, a point that Martin Heidegger emphasizes in calling phenomenological time one's "ownmost possibility,"[65] but they can step into vacated stations. This ability to assume specific temporal roles, first established in the psychological relationship of contemporaries, predecessors, and successors, is accelerated in the temporal coordination of industrial labor through the clock's division of work processes into replaceable tasks. Network temporalities today greatly expand these logistical functions and their anonymizing proclivities, as can be seen in ride-sharing services such as Lyft and Uber that, even as they track individual riders and drivers, treat them as anonymous data points to be algorithmically paired.

Indeed, anonymous time is crucial to timesharing companies, such as Lyft, Uber, and Airbnb, which automate both monetary transactions and clock and calendar time. Rides and rooms are not exchangeable with one another totally but are instead exchangeable by categories, anonymously. The driver is not treated as a singular, irreplaceable being but instead as a class of car, a set of reviews, an anonymous anchor for a constellation of ratings. Similarly, an Airbnb rental location is generalized, departicularized, made anonymous, and submitted instead to ratings, reviews, and other data points. Anonymous time is in this way constructed out of the unique possibility of precise addressability. Although such anonymity seems merely coincident with temporal organization, it proceeds from time management in a very radical way. Its freedom to accept multiple diverse phenomenological actors is founded on an exacting system of computed temporality.

Technological Microtime

Over the last two centuries, time media have increasingly come to operate on microtemporal levels. In this process, temporal infrastructures have come to more finely divide calendar and clock time, operationalize them, and establish the structuring grids necessary for a new density of action moments. For while calendrical moments, such as years, months, and days, are efficacious in calculating events such as the rise and fall of empires, the beginning and end of wars, or the course of a lifetime, they are inadequate for calculating the clock time of hours, minutes, and seconds. More minute and finely tuned temporalities require still more refined technologies of temporal measure, such as Jimena Canales has explored in the nineteenth century's invention of the "tenth of a second."[66] Instruments such as

chronoscopes, myographs, and photographic cameras, which operated beneath the temporal thresholds of human perception and reaction, carried remarkable epistemological significance.[67]

In their attempts to study the processes of sense perception, nineteenth-century experimental physiologists turned equipment such as telegraphs into instruments for measuring the microtemporal dynamics of muscle activity and the transmission of nerve impulses within living organisms. Hermann von Helmholtz' measurements of the velocity of nerve impulses and Matthäus Hipp's reaction time experiments, for example, gave rise to a new understanding of reality as being radically constituted by the conditions of temporal perception.[68] Such physiologists realized that the temporal experience of living things is determined by their respective temporal thresholds of perception and reaction, and thus the quality of temporal perception came to be understood as a function of quantitative values. Accordingly, the temporal category of the "present" was to be understood as determined by its appropriate sphere of action, the decisions that calculate its order of magnitude in the interplay between reaction times, transmission times, and processing times. Microtemporal actions and technological speed-up would thus be seen as yielding less quantitative than qualitative and thus aesthetic effects.

In 1860, the Baltic German entomologist Karl Ernst von Baer captured this relation eloquently in a series of thought experiments by demonstrating the relativity of temporal perception depending on the number of "moments" a perceiving subject is able to distinguish in a given interval. For instance, he stated that a human being taking in 1,000 instead of the usual ~10 moments per second would perceive a waterfall as a quasi-stable object, comparable to how we perceive the growth of plants, while events such as gunshots would appear as traceable movements (similar to the perception of cinematic slow-motion). On the other extreme, a subject with just one moment per day or even per month would perceive the sun not as a slowly moving object but, due to the extreme time-lapse, as a glowing ring, just like people would normally perceive a piece of coal fixed to a string swirling around in a circular fashion. Emerging from the same temporal regime of microtime, cinematography produced out of the temporal succession of photographs the illusion of visual movement.[69] Notably, von Baer framed his ideas more than a decade before the famous chronophotographic experiments by Eadweard Muybridge and Étienne-Jules Marey, which precipitated motion pictures and demonstrated the synthesizing effects of microtemporal technologies. Since these experiments in the nineteenth century, the sciences of astronomy, psychology, and microphysics, as well as the various media industries of

film, radio, and television, have constructed their own microtemporal infrastructures to enable and govern the actions within these domains beyond human sense.

The emergence of microtemporal technologies has correspondingly given rise to another form of temporal politics, to what we refer to as the politics of microtime. In order for technologies capable of recording, transmitting, and reproducing sounds and images to become *media*, they need to be articulated to one another and organized into larger social and economic systems.[70] Consequently, the political contestations of microtime are waged over temporal machine standards and media formats, such as motion picture frame rates, audio playback speeds, television line numbers, screen refresh rates, and compression standards for both audio and video, all of which pattern time on scales below the temporal resolutions of human perception and cognition and yet perform the necessary work of rendering human and nonhuman actions compatible.[71] Another example might be the 60 Hz standard of the North American power grid, which allows different technologies and devices to make use of the same resource and participate in the same industry. In this way, temporal standards serve as what Susan Leigh Star and James Griesemer call "boundary objects," or artifacts that enable and govern modes of cooperation between heterogeneous technologies and social worlds.[72]

The necessity of coordinating human and nonhuman time can be seen most fundamentally in the different ways traditional clock time and microtime are counted. Time systems that have a direct human interface, such as the calendar and clock, tend to use reference points that align with human experience and the necessities of human reckoning, while those time systems below the thresholds of human perception operate on the metric system. The Russian and French Revolutions attempted to institute nonreligious calendar systems that largely failed because of their lack of intuitive connection with the celestial rhythms of people's lives. The explanation is relatively simple. While the metric system is excellent for mathematical calculation, it is much less amenable to effortless counting and subdividing by human minds unequipped with paper and pencil. Sexagesimal (based on 60) and duodecimal (based on 12) systems on the other hand use superior composite numbers, with hours in a day being split into two duodecimal halves divisible by 2, 3, 4, and 6, and sexagesimal minutes and seconds adding divisors of 5 and 10, making them easily calculable at a glance. It is on the basis of time systems having no necessary human interface, however, that we owe much of contemporary technology. The industrialized acceleration of digital switching over the last five decades

has not only transformed computers from machines of calculation and data processing into media, in the traditional sense of audiovisual technologies, but also rendered them increasingly as decision makers and thus autonomous nonhuman actors in the temporal flow of the real world. On the operational level, most general-purpose digital computers are based on technologies of short-term memory as opposed to long-term storage, a temporal logic Wendy Chun has termed the "enduring ephemeral,"[73] which describes random-access operations of reading, writing, and deleting information that must be performed with considerable speed. The processual necessity to refresh, which forms the temporal basis of computing from computer memory and hard drives to bitmapped graphics and databases, makes possible an endless process of reading and rewriting.[74]

The time-criticality of computers, their ability to act in real-time or in the temporal flow of the world, is further predicated on technological reconciliations between external time windows and internal processing time. The principles and technologies of "timeliness," reliant as they are on the exponential growth of processing power captured in Moore's Law, are crucial to understanding digital temporalities, whether at play in the hardware of computers or in the interactions of networks. Indeed, technological speedup forms the very basis of "smart machines" and other forms of artificial intelligence applications. The range of qualitative tasks and actions that an algorithm can perform, such as listening, speaking, playing chess, detecting faces, or driving a car, largely depends on the number of calculations that can be made in a given critical time window. Time is still money, but in light of today's digital capitalism, characterized by big data analysis, algorithmic trading, and the mining of cryptocurrencies, it is especially the investments in microtime and the massive exploitation of data processing infrastructures that foster the contemporary imaginaries of value extraction. Given that digital devices increasingly engage as nonhuman actors and decision-makers in the real world, we need to consider the temporalities on which their "smartness" stands.

The focus of this volume is on this unique extension of technological microtime enabled by the universal medium of computation, which we refer to as *digitally networked time*. Digital time is marked by its universality and thus its ability to be extended into new domains of communication and action. It is the baseline possibility of temporal coordination between networked technologies that possess their own unique temporal orders. Like the internet itself, this temporal network is distributed and layered; it makes few restrictions on the types of time that can exist and enables programs and apps to institute independent interfaces of time.

Layout of the Volume

The book is divided into four thematic sections, beginning with the holistic concerns of media philosophy and passing into topical considerations of temporal regimes on the micro, meso, and macro scale. The papers of the first section, "Media Philosophies of Time Patterning," investigate the specific ability of media to suspend the course of time and how they pattern time to make interventions, as nonhuman actors, in the present, past, and future, on the level of both technical phenomena and human decision-making. John Durham Peters takes up Kittler's view of technical media as means of "suspending irreversibility" and argues that this capacity for reversibility "is the necessary condition of repeatability, transmission, and data storage." In an essay that builds on arguments from his book *The Marvelous Clouds*, Peters ponders the phenomenological ironies of time's irreversibility, which exists, like music, in a constant dynamism of disappearing. Thus he reopens the question of media ontology as crucially a question of time. Gabriele Schabacher takes a media-theoretical approach to the question of care in analyzing the energies and labor practices necessary to maintain technological infrastructures, introducing a typology of four infrastructural care practices: repair, maintenance, abandonment, and repurposing. Yuk Hui, drawing on the phenomenology of Edmund Husserl and Martin Heidegger, as well as their more recent take-up by Bernard Stiegler, seeks to understand the unique new futurity coming into visibility with the rise of predictive technologies. He argues, provocatively, that a new category of temporal experience is currently taking hold, what he calls *tertiary protention*, or a future that issues not from one's own subjective projection but instead from a socially and technologically constructed projection imposed from without in the form of artificial intelligence. Wolfgang Ernst concludes the section by placing recent developments within a deeper set of time-critical operations involved in media infrastructures, focusing on "the basic layer of bit processing on the Internet." Delving into the operative dimensions of media infrastructures, Ernst directs attention to the microtemporal processes that are their *sine qua non*, using the example of the "Ping" signal as a time-critical signal of internet logistics.

Following from Kittler's determination of technical media as technologies that operate below thresholds of human sensory perception and cognition, the papers of the second section, on "Microtime," focus on media technologies that move beyond even the physiological and cognitive requirements for displaying textual and audiovisual information to alter and manipulate data in these inaccessible intervals. Isabell Otto shows in her analysis of current debates about abolishing the leap second that digitally networked

media reveal "the fundamental relativity of each regularity of time." Taking as a starting point the video diary app Leap Second as a concrete example of the plurality of time experience, she argues for an understanding of the multiplicity of time measurements. The leap second makes a further appearance in Geoffrey Bowker's chapter "Life at the Femtosecond." Going back to Charles Babbage, Bowker roots the computer industry's drive for technological acceleration in the simple fact, as stated by Babbage, that although machinery cannot be built into unlimited space, it can run through unlimited time. Thus having not world enough, but time, computers traffic in speed. Addressing operations taking place at the femtosecond, or the very limits of technological microtime, Bowker asserts that, although they fall well below human perception, they are nevertheless "real in their consequences." Florian Sprenger focuses in on a particular area where the density of machinic action that can be performed in the blink of an eye has created extraordinary new levels of complexity, tracing the logic of microtemporal interventions in Tesla's advanced driver-assistance systems. These automated driving systems, by necessity, make decisions about future events that escape human sense. As Sprenger puts it, "the autonomous car brakes before the incident." It calculates time and speed to predict possible futures, such as a collision, opening up important questions about the politics of machine decision in these inaccessible intervals. Andrew R. Johnston, in his contribution on Google's DeepMind project, notes that these new levels of complexity come at a price. Researchers in machine learning are increasingly confronted with the problem of rendering the computational technologies they work with accessible. In particular, the efforts by Google's researchers toward accessibility have landed on the need for visualization, turning to video games from the Atari 2600 system, such as *Qbert* and *Space Invaders*, as ways of providing visual feedback for machine-learning test runs. Moreover, the focus on test runs in the development of machine learning systems reveals contemporary shifts in software engineering where programmers enter into new relations of care and coaching with increasingly autonomous algorithms.

Where the second section focuses on material changes and technical objects, the third, "Lifetimes," turns a lens toward the lived experiences of human beings as they interact with and work to maintain network infrastructures. Nicole Starosielski returns to the cable systems and network infrastructures that formed the basis of her book *The Undersea Network* to address the embodied experiences of the infrastructure operators who maintain these systems. Two crucial new concepts emerge out of this analysis: the idea that speed is always *grounded speed* in the sense that it

relies on the temporal rhythms and safe passages of human bodies, and the problem of *temporal irruptions* that occur when the ground disrupts system speed. Through these, Starosielski directs our attention to the everyday experiences and politics that underlie digital networks, the often-omitted "soft temporalities" of hardwired infrastructures. In a related investigation, Marisa Leavitt Cohn argues that the overall emphasis in recent years on the materiality of software has neglected "the temporal dimension of this materiality—how software ages, decays, obsolesces." Drawing on her ethnographic work with engineers and software developers on a long-term space project, Cohn examines how aging software becomes unmistakable in its materiality and how it is feminized and pathologized for being material. Software shows up as an "unruly body of code" in its passage through different iterations, prompting a reckoning with its material history. In this sense, the felt materiality of code is a product of time, revealing the ideological forces that treated it as immaterial in the first place. In this way, Starosielski and Cohn also connect back to Schabacher's consideration of human laborers as caregivers for nonhuman actors. James Hodge considers how the temporal dynamics specific to network platforms open themselves up to entertainment, both anxiety inducing and fun. Three online artifacts come under Hodge's watchful eye and incisive analysis: Brian Eaton's artwork the *Memento Mori Clock,* the "This Is Fine" meme, and a YouTube video entitled *I Put Wii Music over a Final Destination Death Scene.* Through these artifacts, Hodge considers how media creators and viewers reclaim the demanding, machinic temporalities of contemporary infrastructures, which through digital preemption both short-circuit anticipation and proliferate experiences of anxiety, to make them humanly meaningful again. Concluding the section, Sumanth Gopinath traces the emergence of the digital wristwatch in the 1970s to show how designers used sound—in the form of "beeps"—to connect these devices to the human sense realm, an industry practice that has continued into the era of cell phones and smartphones.

The final section, "Futures," concerns the ways technologies reach into the future and order new regimes of time, commanding near-term actions and provoking dystopic and utopic visions of their power. Alexander Monea performs a media genealogy of the historical entanglement of vision and attention in the discourse on eye tracking. Connecting this to contemporary developments in eye-tracking technology, he argues that we may soon experience very undesirable new arrangements of the attention economy from digital platforms to smartphone apps where ads are able to stop playing when you look away from the screen. Eva-Maria Nyckel studies Amazon's anticipatory shipping model through an analysis of the company's patent

filings. Nyckel argues that efforts to reduce shipping latencies and better forecast consumer demand have pushed logistical services to use predictive technologies that not only speculate about future events but also serve to build the infrastructure for their arrival. Amazon's anticipatory shipping model confirms that the industry's adherence to the dictum "time is money" is pushing it into developments where "time is media" and where effective media are the future of the medium of money. Andreas Sudmann examines artificial neural networks (ANNs) as predictive systems to illustrate the fundamental importance of analyzing this technology in terms of its temporal dimensions. One aim of his essay is to show how an investigation of the temporal infrastructures of modern ANNs also contributes to a more substantial discussion of their political challenges, such as can be seen in the labor of crowdworkers, hired via platforms like Amazon's Mechanical Turk, for labeling and producing the massive amounts of learning data for ANNs. Concluding the volume with a reading between Kittler's argument that technical media reorder time independently of human input and Stiegler's stance that technically mediated time is central to the experience of human time, Britt Paris looks at how the NSF-funded Named Data Networking (NDN) protocol—a possible successor to the current TCP/IP network protocol—reconciles "social concepts of time with computational and architectural constraints in network design." Paris draws on firsthand interviews with NDN researchers in her examination of how user-facing temporal experiences take second place to the imperative speed-up of information transmission.

Notes

1. Peter Conrad, *Modern Times, Modern Places* (London: Thames & Hudson, 1998), 9.
2. Hartmut Rosa and William E. Scheuerman, eds. *High-Speed Society: Social Acceleration, Power, and Modernity* (Philadelphia: Penn State University Press, 2009); and Hartmut Rosa, *Social Acceleration: A New Theory of Modernity* (New York: Columbia University Press, 2013). It is also worth acknowledging Paul Virilio's longstanding work on technological acceleration. See, e.g., Virilio, *Speed and Politics: An Essay on Dromology*, trans. Mark Polizzotti (New York: Semiotext(e), 1986). For works on accelerationism see Robin Mackay and Armen Avanessian, eds., *#Accelerate: The Accelerationist Reader* (Falmouth, UK: Urbanomic Media, 2014); and Nick Srnicek and Alex Williams, *Inventing the Future: Postcapitalism and a World Without Work* (London: Verso, 2015).

3. See, e.g., Jonathan Crary, *24/7: Late Capitalism and the Ends of Sleep* (New York: Verso, 2013).
4. Emily Keightley, ed. *Time, Media and Modernity* (London: Palgrave Macmillan, 2012), 4, 201.
5. Sarah Sharma, *In the Meantime: Temporality and Cultural Politics* (Durham, NC: Duke University Press, 2014), 20.
6. Markus Krajewski, *The Server: A Media History from the Present to the Baroque* (New Haven, CT: Yale University Press, 2018), 339.
7. See Deborah Cowen, *The Deadly Life of Logistics: Mapping Violence in Global Trade* (Minneapolis: University of Minnesota Press, 2014). Also, for an excellent exposition of the scalar dimensions of media infrastructures, see the introduction to Lisa Parks and Nicole Starosielski, eds., *Signal Traffic. Critical Studies of Media Infrastructures* (Urbana: University of Illinois Press, 2015).
8. See, e.g., Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham, NC: Duke University Press, 2010); Ian Bogost, *Alien Phenomenology, Or, What It's Like to Be a Thing* (Minneapolis: University of Minnesota Press, 2012); Richard Grusin, ed. *The Nonhuman Turn* (Minneapolis: University of Minnesota Press, 2015); Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, MA: Harvard University Press, 1999) and *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2005); and Jussi Parikka, *A Geology of Media* (Minneapolis: The University of Minnesota Press, 2015).
9. Bennett, "Systems and Things: On Vital Materialism and Object-Oriented Ontology," in *The Nonhuman Turn*, 223–239.
10. This is evidenced, for instance, by how contemporary online platforms produce distinct forms of device-specific "realtimeness." See Esther Weltevrede, Anne Helmond, and Carolin Gerlitz, "The Politics of Real-Time: A Device Perspective on Social Media Platforms and Search Engines," *Theory, Culture & Society* 31, no. 6 (2014): 125–150.
11. Noble reveals how search engine results reproduce racist and sexist attitudes from the cultures in which they operate and reinforce those attitudes. See Safiya Umoja Noble, *Algorithms of Oppression: How Search Engines Reinforce Racism* (New York: NYU Press, 2018).
12. McIlwain breaks down his story into two parts, detailing the untold stories of Black entrepreneurs and innovators, who developed "black software" for the personal computing revolution and early years of the internet, and the adverse side of this history where new computing technologies were put to the task of fortifying racial hierarchies. See Charlton D. McIlwain, *Black Software: The Internet and Racial Justice, from the AfroNet to Black Lives Matter* (Oxford: Oxford University Press, 2019).
13. Benjamin covers a wide range of racial biases in technical systems, from campus architectures to online mapping tools, and outlines a set of coding practices to counteract the power of this "New Jim Code." Ruha Benjamin,

Race After Technology: Abolitionist Tools for the New Jim Code (Cambridge, UK: Polity, 2019).

14. See, e.g., Friedrich Kittler, "Real Time Analysis, Time Axis Manipulation," trans. and with an introduction by Geoffrey Winthrop-Young, *Cultural Politics* 13, no. 1 (2017): 1–18.
15. See, e.g., Eva Horn, "Editor's Introduction: There Is No Media," *Grey Room* 29 (2008): 7–13; Erkki Huhtamo and Jussi Parikka, eds., *Media Archaeology: Approaches, Applications, and Implications* (Berkeley: University of California Press, 2011); Parikka, *What Is Media Archaeology?* (London: Polity, 2012).
16. Wendy Hui Kyong Chun, "The Enduring Ephemeral, or the Future Is a Memory," *Critical Inquiry* 35, no. 1 (2008): 148–171; Wolfgang Ernst, *Digital Memory and the Archive*, ed. Jussi Parikka (Minneapolis: University of Minnesota Press, 2013); Mark B. N. Hansen, *Feed-Forward: On the Future of Twenty-First-Century Media* (Chicago: University of Chicago Press, 2015); Adrian Mackenzie, "The Technicity of Time: From 1.00 oscillations/sec to 9,192,631,770 Hz," *Time & Society* 10, no. 2–3 (2001): 235–257; Florian Sprenger, *The Politics of Micro-Decisions: Edward Snowden, Net Neutrality, and the Architectures of the Internet*, trans. Valentine A. Pakis (Lüneburg: Meson Press, 2015); Axel Volmar, ed., *Zeitkritische Medien* (Berlin: Kadmos, 2009).
17. For literature, Paul Ricoeur, *Time and Narrative*, 3 vols., trans. Kathleen Blamey and David Pellauer (Chicago: University of Chicago Press, 1984, 1985, 1988). For film, Gilles Deleuze, *Cinema 2*, trans. Hugh Tomlinson and Robert Galeta (Minneapolis: University of Minnesota Press, 1994); and Mary Ann Doane, *The Emergence of Cinematic Time: Modernity, Contingency, the Archive* (Cambridge, MA: Harvard University Press, 2002).
18. Ernst, *Digital Memory and the Archive*.
19. See Volmar, *Zeitkritische Medien*, 25.
20. See Erhard Schüttpelz, "Infrastructural Media and Public Media," *Media in Action* 1, no. 1 (2017): 13–61; Ulrike Bergermann, Monika Dommann, Erhard Schüttpelz, Jeremy Stolow, and Nadine Taha, eds., *Connect and Divide: The Practice Turn in Media Studies* (Berlin and Zürich: Diaphanes, 2020).
21. Media scholars have shown heightened interest in infrastructure studies in recent years in part because the growing ubiquity of digitally networked platforms, the global distribution of information, and the media ecologies of "smart cities" have shattered the idea of media being single devices or products that can be understood without recognizing the larger systems or environments that enable them. A survey of important texts includes Parks and Starosielski, *Signal Traffic*; John Durham Peters, *The Marvelous Clouds. Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015); and Nicole Starosielski, *The Undersea Network* (Durham, NC: Duke University Press, 2015).
22. Susan Leigh Star and Geoffrey C. Bowker, "How to Infrastructure," in *Handbook of New Media: Social Shaping and Consequences of ICTs*, ed. Leah A. Lievrouw and Sonia Livingstone (London: SAGE Publications,

2002), 151–162; Lauren Berlant, "The Commons: Infrastructures for Troubling Times," *Environment and Planning D: Society and Space* 34, no. 3 (2016): 393.

23. Keller Easterling, *Extrastatecraft: The Power of Infrastructure Space* (New York: Verso, 2014), 13.
24. Paul N. Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," *Modernity and Technology*, ed. Thomas J. Misa, Philip Brey, and Andrew Feenberg (Cambridge, MA: MIT Press, 2003), 186.
25. For the recent interest in questions of maintenance and repair, see Steven J. Jackson, "Speed, Time, Infrastructure. Temporalities of Breakdown, Maintenance, and Repair," in *The Sociology of Speed*, ed. Judy Wajcman and Nigel Dodd (Oxford: Oxford University Press, 2017), 169–205; and Andrew L. Russell/Lee Vinsel, "After Innovation, Turn to Maintenance," *Technology and Culture* 59, no. 1 (2018): 1–25.
26. Bruno Latour, "The Berlin Key or How to Do Words with Things," in *Matter, Materiality and Modern Culture*, ed. P. M. Graves-Brown (London: Routledge, 2000), 10.
27. Karl Marx, *Capital*, vol. 1, trans. Ben Fowkes (New York: Vintage, 1977 [1867]), 130. Marx writes: "As exchange-values, all commodities are only greater or smaller amounts of *congealed labor-time*."
28. Michel Serres with Bruno Latour, *Conversations on Science, Culture, and Time*, trans. Roxanne Lapidus (Ann Arbor: University of Michigan Press, 1995), 45, 60.
29. For more on cultural techniques of synchronization, see Christian Kassung and Thomas Macho, eds., *Kulturtechniken der Synchronisation*, Kulturtechnik (München: Wilhelm Fink, 2013).
30. Our understanding of technological temporalities as being segmented into micro, meso, and macro scales matches closely the tripartite division of time advanced by Fernand Braudel. However, the differences between our model and Braudel's should also be seen to signal important shifts in human and technological temporalities in a world dominated by networked digital media. See Fernand Braudel, "History and the Social Sciences: The *Longue Durée*," in *On History*, trans. Sarah Matthews (Chicago: University of Chicago Press, 1980 [1958]).
31. Serres, 58.
32. Peters, *Marvelous Clouds*, 244.
33. S. Hultberg, "Some Observations on Systems for Automatic Acquisition and Reduction of Nuclear Data and a Preliminary Report on the Computer System Trask," *Nuclear Instruments and Methods* 34 (1965): 127.
34. Gordon E. Moore, "Cramming More Components onto Integrated Circuits," *Electronics* 19 (April 1965), 114–117.
35. James Carey, "Technology and Ideology: The Case of the Telegraph," in *Communication as Culture: Essays on Media and Society*, rev. ed. (New York: Routledge, 2009), 168.

36. Judy Wajcman, *Pressed for Time: The Acceleration of Life in Digital Capitalism* (Chicago: University of Chicago Press, 2015), 3.
37. Obviously, integrated circuits use "wires" only in a metaphorical sense.
38. Other imaginative efforts include Daniel Hillis' Clock of the Long Now and the performance of John Cage's *As Slow as Possible* over the course of 639 years at a church in Halberstadt, Germany.
39. Peters, *Marvelous Clouds*. See also Thomas Macho, "Zeit und Zahl. Kalender und Zeitrechnung als Kulturtechniken," in *Bild, Schrift, Zahl*, ed. Sybille Krämer and Horst Bredekamp, Kulturtechnik (München: Fink, 2003), 179–92.
40. Harold Innis, *Empire and Communications* (Oxford: Oxford University Press, 1950). See also Innis, *The Bias of Communication* (Toronto: University of Toronto Press, 1951). As Innis showed, "time-binding," or durable, media have played a considerable role in the growth and maintenance of large political and economic bodies such as empires.
41. Émile Benveniste, "Language and Human Experience," *Diogenes* 13, no. 51 (1965): 1–12. Benveniste elaborates three conditions of calendars, namely initiating, directing, and measuring, the first of which involves the calculation of an axial moment: "All calendars share common characteristics which identify the basic conditions which they must fulfill. They take off from an axial moment which provides the zero point of the computation" (5).
42. Paul Ricoeur, *Time and Narrative*, vol. 3. (Chicago: University of Chicago Press, 1988), 107.
43. Ricoeur, 109.
44. Benveniste, 4. A common translation of Benveniste's *temps chronique*, as for instance in the translation of Ricoeur's *Time and Narrative*, Vol. 3, renders the term "chronicle time," and in many ways this translation better captures in English its sense of time as a succession of events. Benveniste himself, however, suggested its translation as "chronic time." Etymologically, the term "chronic" entered late Middle English as a cognate of the French *chronique* and meant simply "of time, concerning time," a meaning reaching back to the Greek *khronikos*, from *kronos*. Nevertheless, its later connotations of disease and addiction might helpfully express the adverse underside of the temporal structure of events.
45. Benveniste, 6.
46. Lewis Mumford, *Technics and Civilization* (New York: Harcourt, Brace & Company, 1934), 14.
47. Mumford, 15.
48. James Henry Breasted, 1935. "The Beginnings of Time-Measurement and the Origins of Our Calendar." *The Scientific Monthly* 41 (1935): 289–304.
49. Peters, *Marvelous Clouds*, 1.
50. Eviatar Zerubavel, "The Standardization of Time: A Sociohistorical Perspective," *American Journal of Sociology* 88, no. 1 (1982): 11. See also his books *Hidden Rhythms: Schedules and Calendars in Social Life* (Berkeley: University of California Press, 1985), *The Seven Day Circle: The History and Meaning*

of the Week (Chicago: University of Chicago Press, 1989), and *Time Maps: Collective Memory and the Social Shape of the Past* (Chicago: University of Chicago Press, 2012).

51. Zerubavel, "Standardization of Time," 3.
52. Mumford, 17–18.
53. Mumford, 13.
54. Mumford, 15.
55. See Rosa, *Social Acceleration*.
56. E. P. Thompson, "Time, Work-Discipline, and Industrial Capitalism," *Past and Present* 38 (1967): 56–97.
57. Thompson, 73.
58. Thompson, 73.
59. Thompson, 61.
60. See Susan Leigh Star and Anselm Strauss, "Layers of Silence, Arenas of Voice: The Ecology of Visible and Invisible Work," *Computer Supported Cooperative Work* (*CSCW*) 8, no. 1–2 (1999): 9–30.
61. John Durham Peters, "Calendar, Clock, Tower," in *Deus in Machina: Religion and Technology in Historical Perspective*, ed. Jeremy Stolow (New York: Fordham University Press, 2013), 42.
62. Ricoeur, 112.
63. Ricoeur, 105.
64. Ricoeur, 109.
65. Martin Heidegger, *Being and Time*, rev. ed., trans. Joan Stambaugh (Albany: SUNY Press), 252.
66. Jimena Canales, *A Tenth of a Second: A History* (Chicago: Chicago: University of Chicago Press, 2009), 3.
67. See also Soraya de Chadarevian, "Graphical Method and Discipline: Self-Recording Instruments in Nineteenth-Century Physiology," *Studies in History and Philosophy of Science* 24, no. 2 (1993): 267–291.
68. See Laura Otis, "The Metaphoric Circuit: Organic and Technological Communication in the Nineteenth Century," *Journal of the History of Ideas* 63, no. 1 (2002): 105–128; Henning Schmidgen, "Of Frogs and Men: The Origins of Psychophysiological Time Experiments, 1850–1865," *Endeavour* 26, no. 4 (2002): 142–148.
69. Karl Ernst von Baer: *Reden gehalten in wissenschaftlichen Versammlungen und kleinere Aufsätze vermischten Inhalts, Erster Theil. Reden* (St. Petersburg: Schmitzdorff, 1864), 237–284. Reprint in Volmar, ed., *Zeitkritische Medien*, 45–59.
70. See Jonathan Sterne, *The Audible Past: Cultural Origins of Sound Reproduction* (Durham, NC: Duke University Press, 2003).
71. See Marek Jancovic, Axel Volmar, and Alexandra Schneider, eds., *Format Matters. Standards, Practices, and Politics in Media Cultures* (Lüneburg: meson press, 2020).
72. Susan Leigh Star and James R. Griesemer, "Institutional Ecology, Translations, and Boundary Objects: Amateurs and Professionals in Berkeley's

Museum of Vertebrate Zoology, 1907–39," *Social Studies of Science* 19, no. 3 (1989): 387–420. See also Elaine K. Yakura, "Charting Time: Timelines as Temporal Boundary Objects," *Academy of Management Journal* 45, no. 5 (2002): 956–970.

73. Chun, "Enduring Ephemeral," 148.
74. See also Ernst, *Digital Memory and the Archive*.

About the Authors

Kyle Stine teaches Film and Media Studies at Johns Hopkins University. His writings on cinema and technology have appeared in *Critical Inquiry*, *Discourse*, *Grey Room*, and the *Journal of Cinema and Media Studies*.

Axel Volmar is a Postdoctoral Fellow at the Collaborative Research Center "Media of Cooperation" at the University of Siegen. He is author of *Klang-Experimente: Die auditive Kultur der Naturwissenschaften 1761–1961* and co-editor of *Format Matters: Standards, Practices, and Politics in Media Cultures* and *Interrogating Datafication: Towards a Praxeology of Data*.