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## ESSAY

# After Innovation, Turn to Maintenance

ANDREW L. RUSSELL and LEE VINSEL

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### Introduction

*“It’s funny ’cause it’s true.”*

—Homer J. Simpson

In the fall of 2014 the best-seller lists featured a hot new book with an unlikely cast of characters: pioneers in the history of computing. The book’s author, Walter Isaacson, had established impeccable credentials as a hagiographer with books on Ben Franklin, Albert Einstein, and Steve Jobs. Reviewers showered Isaacson’s new book, *The Innovators*, with praise that was befitting an author of American media royalty (Isaacson was the former managing editor of *Time* and the former chairman and CEO of CNN). *The Innovators* was a born best seller, capturing the era’s enthusiasm for all things digital and new. It even had one of those splashy subtitles, pulled from a genre of subtitles that would enrage dissertation committees: *How a Group of Hackers, Geniuses and Geeks Created the Digital*

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*Revolution*. It seemed like everything about Isaacson's new book was calculated not only to make a lot of money but also to drive academic historians up their ivy-covered walls: a breezy overview of a complicated topic; a slick marketing campaign; and a starring role for one of our era's most tiresome buzzwords, *innovation*.

In other words, everything about the book made it an easy target for a joke. And one came to mind as one of us was plodding through his usual morning routines. Andy imagined that historians of technology should answer Isaacson's book with another one, a book that would stay true to our field's appreciation for contingency, nuance, moral ambiguity, and our thematic touchstones such as gender, labor, users, risk, and regulation. He even came up with a title: *The Maintainers: How a Group of Bureaucrats, Standards Engineers, and Introverts Made Digital Infrastructures That Kind of Work Most of the Time*.<sup>1</sup>

We quickly reframed the joke to include all technologies, not just digital ones, and began playing around with it online in blog posts and on Twitter. The idea of the Maintainers took on a life of its own and resonated with many communities around the globe. It resonated, we think, because it framed technologies in a way that everyone knew to be true but that few people acknowledged—particularly the authors and marketers of best sellers. Moreover, as we will discuss below, the concept valorized important but often unrecognized work that historians of technology were *already* doing. We explored going beyond mere jokes at an exuberant happy hour at SHOT's Albuquerque meeting in 2015. Encouraged by that enthusiasm and ideas from many colleagues, we decided to push forward, writing an essay for *Aeon* magazine, starting a network of scholars and professionals, holding conferences at Stevens Institute of Technology in 2016 and 2017, and communicating via social media, interviews, blog posts, essays, op-eds, and podcasts.

We were astonished to see a joke become a movement. The movement grew, and continues to grow, for a variety of reasons that we did not anticipate. First, the broad theme of maintenance pulls out and pulls together many themes within our field, alive in work that our colleagues were already doing. Second, talking about maintenance brings our subfield into conversation with an endless variety of disciplines and practices, such as anthropology, economics, engineering, and business. Third, maintenance is a topic that appeals to audiences outside of academia: people love to read about it and talk about it, probably because they can easily see how important maintenance is for their own lives. Fourth, maintenance seems to be perpetually in the headlines in our age of train derailments, hurricanes, and infrastructure breakdown.

In this essay we want to focus on the different ways that maintenance

1. For a scholarly appraisal of *The Innovators*, see G. Pascal Zachary's review in the *IEEE Annals of the History of Computing*.

can function as the core of an agenda for interpretation, reinterpretation, and new research for historians of technology. It is an attempt to consolidate some of the things we have observed and learned, to ask readers to tell us about what we have missed, and to make the case that a turn to maintenance can generate compelling new ways to think about technology and its histories.

Although the dichotomy between innovators and maintainers was essential for starting our work in this area, it is in many ways a false dichotomy. Maintenance is a rich subject on its own, and one does not need to bash innovation or innovation-speak in order to establish the profound importance of maintenance and maintainers. Moreover, the more closely we examine maintenance practices and routines, the more we see that creativity—and even innovation—is an essential characteristic. In other words, some maintainers can be innovative, and new technologies can play important roles in maintenance regimes.

Our title, “After Innovation,” has a double meaning that we should make explicit. The first refers to the process of technological development and use, where invention and innovation are early phases. Yet even the briefest of reflections suggests that daily life with technology usually is far removed from the cutting edges of invention and innovation. Accordingly, when we emphasize maintenance we stand alongside historians who define technology as something broader than innovation. We stand among those who study momentum and path dependence, use and users, repair and breakdown, and the decline and senescence of “old” technologies and technological systems—those things that may be swept away in the Schumpeterian gale of creative destruction.<sup>2</sup> The second meaning of our title refers to historiography and is meant to provoke and encourage a change in topical emphasis in our field. We live in a culture obsessed with novelty, and, as we describe below, this obsession has left a noticeable impact on the dissertations, papers, grant proposals, and books that historians of technology write. We believe it is time to detach from our era’s obsession with “innovation-speak,” and this essay will suggest avenues forward for historians writing after (our) innovation (obsession).

## Maintenance in Historiography

Since SHOT’s founding, the history of technology has been dominated by studies of invention, innovation, and the creation of the new, as John Staudenmaier made clear in *Technology’s Storytellers*. Understandably so:

2. Eric Schatzberg, “*Technik Comes to America*”; Thomas Parke Hughes, “*Technological Momentum in History*”; David Edgerton, *Shock of the Old*; Jonathan Cooper-smith, *Faxed*; Jérôme Denis and David Pontille, “*Material Ordering and the Care of Things*”; Steven J. Jackson, “*Rethinking Repair*”; Nelly EJ Oudshoorn and Trevor Pinch, *How Users Matter*.

after all, history is the study of change over time, so one might argue that the study of not-change over time is outside the definition of what historians do. One of SHOT's giants, Thomas Hughes, wrote about the creation of large technological systems but gave far less attention to their maintenance and conservation. The Social Construction of Technology (SCOT), an approach that dominated technology studies for a generation, also primarily examined the creation of the new. As recently as 2009, Wiebe Bijker, a founder of SCOT, titled an essay, "How Is Technology Made? That Is the Question!" Moreover, as David Edgerton and others have pointed out, research on "users" has emphasized user innovation, or the introduction of novelty, rather than focusing on the far more common act of simply using technologies. Simply put, the history of technology has focused predominantly on the earliest stages of technological life cycles and, for that reason, has missed most human life and activity with and in material reality. In the words of Carroll Pursell's *White Heat*, the history of technology has emphasized "the design of technology over its production, and its production over consumption, with maintenance hardly considered at all."<sup>3</sup>

The historical study of maintenance and repair is not new, however. At least since John G. Burke published "Bursting Boilers and the Federal Power" in *Technology and Culture* in 1966, the necessity of maintaining technologies has been a minor subtheme in the history of technology, though it has often been marginal and subterranean. Poor design caused many boiler disasters in the nineteenth century, but Burke noted that others resulted from "problems connected with boiler operation and maintenance," and laws, like the Steamboat Act of 1852, came to shape these practices.<sup>4</sup> Burke's essay could have opened a new avenue of inquiry, yet few followed in his footsteps. Maintenance featured prominently in Ruth Schwartz Cowan's influential *More Work for Mother*, even though the book was innovation-centric in its examination of the industrialization of the home through new technologies, like the washing machine and the vacuum. Yet Cowan upended expectations by focusing on women's housework, which was centrally the labor of maintenance and upkeep.<sup>5</sup> Cowan's work played a vital role in bringing feminist perspectives into the history of technology. She was a pioneer among many women in the field whose work has analyzed maintenance—probably more commonly than their male peers.<sup>6</sup>

3. Carroll W. Pursell, *White Heat*, 33.

4. John G. Burke, "Bursting Boilers and the Federal Power," 4.

5. It's important to be careful with our terms. Gardening and cooking are forms of production. They bring new things into the world, though they always require forms of maintenance, like clean pots and dishes, for instance. Most other forms of domestic labor, like cleaning, laundering, and darning socks, fit our definition of maintenance: they are focused on maintaining social and material orders.

6. Gail Cooper, *Air-Conditioning America*; Arwen Mohun, *Steam Laundries*; Amy Slaton, *Reinforced Concrete and the Modernization of America*; Ann Greene, *Horses at*

Kevin Borg's work on auto mechanics and chauffeurs represented perhaps the first self-conscious studies of maintenance and repair in the history of technology. Borg demonstrated that the social position and authority of auto mechanics and chauffeurs were not static but changed a great deal over time. The desirability of automobile ownership and use for wealthy patrons around 1900 enabled chauffeurs, nearly all of whom were mechanics as well as drivers, to "enhance their social power." The rich depended on mechanics' expertise. This increase in status did not last, however. Powerful individuals soon passed laws to limit the discretion and autonomy of chauffeurs, who were once again put in their place. In the late twentieth century, new rules and regulations "turned the auto mechanic's occupation into a very closely monitored occupation."<sup>7</sup>

The British historian David Edgerton, who has outlined an ambitious vision for a history of "maintenance, repair, and remodeling," has provided the most capacious view and exploration of the topic. Edgerton sees these activities as part of a broader concept he calls technology-in-use, which stands in stark contrast to the innovation-focused accounts that dominate our field. Edgerton's arguments about maintenance have inspired us and should continue to form the foundation for future inquiry: maintenance has always been essential to industrial capitalism and makes up a large portion of economic activity as well as professional engineering work; maintenance and repair are "the most widespread forms of technical expertise"; mass production and consumer culture prompt individuals to buy new stuff rather than fix old things; maintenance and repair take radically different shapes in different geographical areas; and maintenance and repair are often moments of transformation and, sometimes, innovation. Yet, despite his provocative and well-reasoned arguments, Edgerton's work has not yet significantly altered practice within the history of technology. He has expressed some disappointment that the community could not recognize or face his challenge, or at least that it did not translate these insights into new practices of topic selection and archival reading.<sup>8</sup>

Why, then, do histories of maintenance and repair continue to rise to the surface only to fall again into the depths? Why does the history of technology perpetually return to the question of how new things come into the world? Why does the focus on ordinary work and technology-in-use remain a minor voice? Many factors are likely at play, since contemporary historians of technology share some implicit cultural beliefs as well as

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Work; and Susan Strasser, who has published several books related to the topic, including *Waste and Want* and *Never Done*. We have theories for why women have been so central to developing this literature, but the theories are speculative at best and would take the essay too far afield.

7. Kevin L. Borg, "The 'Chauffeur Problem'" and *Auto Mechanics*, 8.

8. David Edgerton, "From Innovation to Use," his book, *The Shock of the Old*, and other works.

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explicit incentives. To begin with, our culture is fascinated by invention and the new. Readers enjoy books and films about inventors, but we've yet to see a blockbuster book about maintenance or repair. Moreover, historians of technology have grown up in this culture, which has profoundly shaped their dispositions and affections. That is, many historians are habitually set up to think and write about the emergence of the new rather than the continuation of the old.

A variety of incentives also shape our scholarly choices. Graduate students in the history of technology learn to make their work relevant outside of history, especially if they are seeking jobs in academic units that specialize in business, communication, or STS. In addition, the recent emergence of the Internet, Silicon Valley-based companies, and social media platforms has generated popular demand for explanations of their origins and development, and historians of technology should contribute to public understanding of these phenomena. There are other, more disconcerting causes of these historiographical trends. To the degree that women have been major voices in maintenance studies, the focus on new technologies and, mostly, the men who created them continues a familiar gender bias that afflicts technology and its historians. Capital also plays an influential role. Museums, societies, foundations, and centers dedicated to specific industries, disciplines, professions, and technologies have long been central to SHOT. Moneyed interests often fund these organizations, and for a variety of reasons, these organizations prefer neat narratives, success stories, and inspirational tales. On all these counts, histories of invention and innovation deliver the goods. In summary, to step back and reflect on the continued prevalence of the emergent and innovative is also a way to consider how power shapes our field, and to acknowledge that "relevance" is an important consideration. Simply put, relevant historical scholarship in an age obsessed by innovation must, in some way, consider innovation.

It is exactly this consideration—"relevance"—that leads us to think that our present historical moment is a good time to turn to maintenance. In the United States, for example, it is difficult to escape concerns about "crumbling infrastructure," workers' wages, the feeling that we are experiencing one disaster after another (fires, hurricanes, bridge and dam collapses), and the general sense that our nation and its people are not living up to our own lofty ideals.<sup>9</sup> As a candidate for president, Donald Trump promised to "Make America Great Again"; only months into his chaotic administration, who would dispute the notion that a more decent era is behind us? Moreover, there is increasing public skepticism of the manic hype generated by out-of-touch billionaires in Silicon Valley—those peddlers of algorithms and artificial intelligences that profit from our collective distraction.<sup>10</sup> In this multivalent context, it's easy to see the appeal of a call to take care of the ordinary and the everyday.

9. George Packer, *The Unwinding*.

10. W. Patrick McCray, "Silicon Valley's Bonfire to the Vainglorious."

When we have tried to articulate what the concept of the Maintainers stands for, we say it involves a turn, a switch, not only in regard to the object of study but also in the underlying attitude toward technology. When we focus on invention and innovation, we are neglecting most of human life with things. There is no particular theory that has brought us to this argument; in fact, we do not think that any single theory can cover such a large domain. Even so, many ideas are useful for scholars who feel compelled to “theorize” maintenance as an organizing principle in the history of technology. For example, social theorists who examine habitus, routines, hegemony, and the stability of social structures over time provide routes into thinking about how mundane labor conserves physical orders and the social systems that depend on them.<sup>11</sup> In addition, feminist theories of care ethics and social reproduction provide fresh and insightful ways to think about technology’s role in personal identity and social stratification.<sup>12</sup>

Another way to “theorize” maintenance would be simply to use Thomas Kuhn’s notion of “normal science”—everyday, humdrum routines, how they persist, how they are repaired when they break down, and so on. “Normal science” was the foil, not the hero, of *The Structure of Scientific Revolutions*, but “normalcy” is in many ways evocative of the state that maintenance achieves: neither difference, nor novelty, nor revolution, but rather the distinctive forms of work that go into keeping things the same.

## Maintenance in History

What things persist over time, and why? As noted above, our inclination is not to attack these questions via theory, but rather to knit together stories and anecdotes—microhistories, if you will—into an overarching narrative of maintenance in history. A useful starting point is to dwell on definitions from historians, social scientists, and professionals to determine what, exactly, we mean when we talk about maintenance. We define maintenance as all of the *work* that goes into preserving technical and physical orders. We define technology as broadly as possible: technologies are objects that humans make or transform in order to achieve their goals. And physical orders including everything from machines, to the built environment, to farm fields, including maintaining the borders between fields and “wilderness.” Our discussion here refers only to physical things, and we decided to work with a definition of maintenance that excludes emotional or social activity (such as the maintenance of friendships or one’s own

11. Max Weber, *The Protestant Ethic*; Pierre Bourdieu, “Habitus”; Sidney G. Winter, “Habit, Deliberation, and Action”; Stephen Turner, *Social Theory of Practices*; and John Levi Martin and Ben Merriman, “A Social Aesthetics as a General Cultural Sociology?”

12. Carol Gilligan, *In a Different Voice*; Nel Noddings, *Caring*; Virginia Held, *The Ethics of Care*; Denis and Pontille, “Material Ordering”; Andrew L. Russell and Lee Vinsel, “Making Maintainers.”



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morale). Many physical orders are quite intimate, including the labor of “keeping up appearances” of the body, its hair, and clothing. In a paper that he presented at the 2017 Maintainers conference, “Piles of Stuff: Haystacks, Self-Maintenance, and Discipline,” the historian of technology Dan Holbrook observed: “The fundamental thing that is maintained is order. Unordered entities do not need maintenance; indeed, once maintenance (that is, work upon them) happens, they no longer remain unordered.” Put another way, maintenance is a war—maybe *the* war—with entropy.<sup>13</sup>

The dramas of maintenance and upkeep played themselves out in ancient history. Maintenance was fundamental to all societies, including the most basic human settlements, like the stick shelters of the San people of southern Africa.<sup>14</sup> As societies became more complex and accumulated larger and increasing numbers of structures, the amount of maintenance work increased too. Different societies faced this challenge in different ways. Centralized modes of production and maintenance sustained some iconic technological systems in Mesoamerica, India, and China. The art historian Flora S. Clancy notes, “Each Mesoamerican pyramid was rebuilt and/or redesigned many times throughout its active history. It was built with materials that required maintenance and upkeep.”<sup>15</sup> Looking at the other side of the world, Karl Wittfogel’s perennially controversial *Oriental Despotism* also paid great attention to the role of maintenance in “hydraulic empires” in India and China, which he characterized as centralized, extensive, and oppressive bureaucracies that built and maintained the large-scale technological systems of irrigation.<sup>16</sup> The maintenance of water infrastructures remained important for later empires: circa 200 BCE, the senator and historian Cato the Elder prided himself on restoring and maintaining the Roman sewer system. Other extensive systems, such as the thousands of miles of canals surrounding Angkor, were built and maintained by local communities, not by the central authorities of the Angkorian empire.<sup>17</sup> Thus, although writers have traditionally cast ancient megastuctures as testaments to the rise of monumental construction in human cultures, the persistence of these structures memorializes different modes of their maintenance. And, it is next to impossible to know the details of ancient systems that suffered from a lack of maintenance, such as the Easter Island statues created by the Rapa Nui or the Chaco Canyon roads constructed by the Anasazi.

Technological maintenance also went hand in hand with the maintenance and reproduction of social forms. This was as true for societies with

13. Dan Holbrook, “Piles of Stuff.”

14. Elizabeth Marshall Thomas, *The Old Way*.

15. Flora S. Clancy, *Pyramids*, 148.

16. Karl August Wittfogel, *Oriental Despotism*.

17. Roland Fletcher et al., “The Water Management Network of Angkor, Cambodia”; Vernon L. Scarborough, *The Flow of Power*.

megastructures as it was for societies that had particular reverence for special objects. Jewish books—including the Torah, Talmud, and collections of law, such as Shulchan Aruch—specify how holy artifacts and texts should be inspected and maintained, under what conditions they should be repaired, and when they should be ritualistically disposed of through burial. For example, communities are bound by law to inspect *mezuzah*, holy texts that hang outside gates and doorways, twice every seven years. The maintenance of these holy objects highlights that individuals and groups maintain things that they *care* about, that they take interest in, things that demand attention.<sup>18</sup> We can draw similar conclusions from the placement of altars and ancestral shrines in late imperial China, as the anthropologist Francesca Bray has shown. In their careful arrangement of domestic shrines and manipulation of *qi*, neo-Confucian Chinese families could signal their alignment with traditional and ancestral orders—a gesture toward social stability. At the same time, well-placed and well-maintained domestic shrines served as a display of virtue and therefore an implicit claim for social status. Bray’s work, more generally, explores the intersections of gender and technology to show “complex long-term stabilizing effects rather than in dramatic ruptures.”<sup>19</sup> In this sense her work provides a welcome departure from SHOT’s familiar innovation-centric histories, as noted above.

Maintenance presents something of a puzzle for historians: in some cases, maintenance is absent from historical accounts because historians have ignored the maintainers. But in other cases, societies simply did not devote resources to maintenance, even when they understood it was in their own interests to do so. Consider the problem of human waste in the cities that were growing rapidly in the early modern era. One example comes from the streets of Rome, which were overrun by sewage for centuries.<sup>20</sup> Despite their reputation for efficient engineering and bureaucracy, Romans lacked the human and material infrastructure that could dispose of their waste effectively. The fact that this condition persisted for generations indicates an important, more general point: just because a society would like to maintain a certain quality—such as cleanliness—the success of a maintenance regime is by no means assured.

The fundamental importance of maintenance in domestic spheres—and the essential roles of women in such work—is also evident in the history of the American colonies and early republic. These were frontier cultures primarily consisting of farms and small-scale enterprises, where the

18. Marianne Schleicher, “Accounts of a Dying Scroll.”

19. Francesca Bray, *Technology, Gender and History in Imperial China*, 4; see also Bray, *Technology and Gender*; and Bray, “Technics and Civilization in Late Imperial China.”

20. Our discussion here summarizes comments from Pamela Long, who has a forthcoming book on the subject, entitled *Engineering the Eternal City*.

same individuals were producers, users, and maintainers, and much of the work was organized at the household level. In *A Midwife's Tale*, Laurel Thatcher Ulrich describes the midwife Martha Ballard and other women working together to preserve and care for the objects in their lives. Such work took its toll. Ulrich notes that, from 1795 to 1796, Ballard “devoted the emotional center of her diary to laundry.” The intense emotional labor she committed to laundry was matched by her physical labor: laundry was fearsomely difficult work that resulted in aching muscles and sore joints.<sup>21</sup> Ulrich writes that, in Ballard’s universe, the diary note “‘girls washt’ was an important statement, something on the order of ‘got across the river safely,’” a glowing moment where fate spared her aging body from toil and risk. We see the same confluence of production and maintenance in the trades during this period. Local blacksmiths were producers, maintainers, and repairers all. Craftsmen and artisans, like cobblers and gunsmiths, often made their own tools and maintained and repaired nearly all of them. Canal engineers struggled to maintain bridges, railings, locks, and water levels to ensure that their waterways were viable.<sup>22</sup> Papermakers had to ensure that their mills could stand up to challenges from weather, fragile materials, and regular wear and tear on machine parts. In these different forms of activity, there were few traces of the distinctions between makers and maintainers that later became common.<sup>23</sup>

These examples illustrate a feature of maintenance as a central, organizing principle: it emphasizes stability and continuity across history, and thereby undermines and diminishes the “rupture-talk” that is common in some histories of technology.<sup>24</sup> At the same time, there are aspects of the history of maintenance that map to a familiar world-historical change, the transition from an agricultural to industrial mode of production. These changes are most visible in new types of work performed in the name of maintenance and, more clearly, in the changing division of labor and occupational specialization that emerged as part of industrialization. In their varied approaches to maintenance, industrial societies developed distinctive occupations, professions, and patterns of governance—even as they preserved some underlying social dynamics, such as the importance of maintenance in domestic spaces, the division of maintenance labor based on sex and social status, and the diverse approaches (and differing degrees of success) toward the management of maintenance in large technological systems.

Although historians have explored industrialization in the United

21. Laurel Thatcher Ulrich, *A Midwife's Tale*, 218.

22. Wallace Gusler, *The Gunsmith of Williamsburg*; Patrick M. Malone, *Waterpower in Lowell*; Chandra Mukerji, *Impossible Engineering*; Pierre-Claude Reynard, “Unreliable Mills”; Judith A. McGaw, *Early American Technology*; Ann Norton Greene, “Success as ‘Failure.’”

23. Ulrich, *A Midwife's Tale*, 219–20.

24. Gabrielle Hecht, “Rupture-Talk in the Nuclear Age.”

States in great detail, maintenance has been a peripheral theme at best. Consider, for example, two foundational historians of American technology and business, Alfred D. Chandler and Thomas P. Hughes.<sup>25</sup> Amidst all their conceptual and empirical contributions to our understanding of the development and expansion of large organizations, Chandler and Hughes (and their many students) missed the centrality of maintenance to the survival and continued success of these organizations. This is a surprising omission, considering how neatly maintenance fits into their respective frameworks. As individuals and groups constructed businesses, government agencies, and large-scale technical systems, they multiplied the number of things that needed to be constantly maintained for society to function. Addressing maintenance issues was a crucial part of developing the organizational routines that every company, government agency, or other institution needed to survive. Chandler's professional managerial classes may be seen simply as maintainers of corporate order.

Consequently, maintenance was a near-constant topic in the prescriptive literature that arose between the 1870s and 1920s around new technologies. There are vast and underutilized collections of source material that would support maintenance-centered histories of railways, telephones, roads, and other large technological systems that emerged between 1870 and 1930.<sup>26</sup> These sources include documentation from professional and engineering societies that were investigating new, specialized maintenance-focused social roles and job descriptions. For example, the Roadmasters and Maintenance of Way Association of America, a railroad professional group, was established in 1883 when company "maintenance officers [recognized the need] to have the opportunity to meet and discuss their mutual problems."<sup>27</sup> Indeed, one could interpret the professionalization of engineering practice itself as an exercise in maintenance—specifically, the maintenance of expert knowledge through standards and best practices, the organizational tools that typically increased reliability, compatibility, and economies of scale.<sup>28</sup> The professionalization of maintenance also was reflected in the emergence of new job names and positions and the reformation of older ones. Take "janitor," for one example. Going

25. Alfred D. Chandler Jr., *Visible Hand*; Thomas Parke Hughes, *Networks of Power*; David A. Hounshell, "Hughesian History of Technology and Chandlerian Business History."

26. August W. Wright, *America Street Railways*; F. C. Allsop, *Telephones, Their Construction and Fitting*; and Henry Goldsmith, *Modern Road Construction and Maintenance*.

27. Now called the American Railway Engineering and Maintenance-of-Way Association (or AREMA): [www.arena.org/arena\\_mbrr/Predecessor\\_Organizations.aspx](http://www.arena.org/arena_mbrr/Predecessor_Organizations.aspx). We first learned about the existence of this group in Usselman, *Regulating Railroad Innovation*.

28. Bruce Sinclair and James P. Hull, *A Centennial History of the American Society of Mechanical Engineers*; Andrew L. Russell, *Open Standards and the Digital Age*.

back at least to the early eighteenth century, the term originally applied to porters and jacks-of-all-trades who worked for organizations.<sup>29</sup> By the late nineteenth century, the word had taken its current definition: a man or woman who cleaned buildings—and the expansion of corporations and the administrative state created plenty of buildings to clean. Some sources indicate a debate around the status of janitorial work, such as *Standards for Public School Janitorial-Engineering Service*, published in 1926 by Columbia University's Teachers College. The rise of the “janitors” and related occupations, like “repairmen,” indicates the proliferation of maintenance occupations throughout all walks of industrial life and consumer society in the twentieth century.

Later in the twentieth century, many specialties emerged to confront maintenance problems using sophisticated concepts such as asset management, quality control, reliability engineering, and designing for “maintainability.” A variety of public and private organizations continue to publish standards for maintenance of technologies such as nuclear power plants, software, and aircraft.<sup>30</sup> The automation and computerization of maintenance management, along with sophisticated techniques for predictive maintenance, provide fodder for historical debates about the nature of the so-called “digital age” that emerged near the end of the twentieth century. Perhaps future historians will look to maintenance when they try to settle the question: did computerization herald an entirely new third or fourth industrial “revolution,” or did computers merely intensify broader trends that were already established with the onset of industrialization?

The centrality of maintenance for industrial capitalist societies was established in the mid-twentieth century in the field of development economics, where members of rich nations discussed transferring technologies to poorer ones. Stories abounded of Fordson tractors falling to pieces in Soviet farm fields from lack of repair and available parts and other tales of waste for want of maintenance.<sup>31</sup> In *The Strategy of Economic Development* (1958), the development economist Albert O. Hirschman argued that “the lack of proper maintenance” was “one of the most characteristic failings of underdeveloped countries and one that is spread over the whole economic landscape.” Unless societies developed a “maintenance habit” and a “compulsion to maintain,” Hirschman argued, imported innovations would come to naught. In this way, technical maintenance was also a prerogative of the Cold War and larger world of international relations during the period of industrial culture and, ostensibly, a key to economic

29. “Janitor, n.”

30. IEEE's *Maintenance Good Practices for Nuclear Power Plants* (1968); National Bureau of Standards' (now NIST's) *Guideline on Software Maintenance* (ongoing since 1984); the National Fire Protection Association's *Standard on Aircraft Maintenance* (1989).

31. Thomas Parke Hughes, *American Genesis*.

growth and therefore progress.<sup>32</sup> But, as in earlier eras, there was no one best way to maintain. Phil Scranton's new research on industrial management in communist countries in central Europe and Asia demonstrates how maintenance could be managed and justified in many different ways—and not simply reduced to fuel or glue working in the service of economic growth.<sup>33</sup>

We are not encouraging historians to follow Hirschman and assume that maintenance is only a force for social or economic progress. Oppressive societies also have their maintainers. Hegemony too requires maintenance, upkeep, conservation, and mundane work—a basic social fact that is not specific to industrial societies. Caste systems in South Asia, the Jim Crow South, domestic servitude in Tudor England, and South African apartheid were built on infrastructures of exclusion—like segregated neighborhoods and buildings and razor-wired fences—that required constant maintenance and care, including, often, the labor of the oppressed themselves. Maintenance-focused histories need not be histories of progress or reform, and historians looking for underdogs should think twice before assuming the intrinsic goodness of maintenance work and the maintainers. This moral ambiguity generates new analytical possibilities that reach to the very core of historical interpretation as the study of change over time. Histories of maintenance are not necessarily accounts of change; rather, they are often stories of the effort devoted to keeping things the same.

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## Select Themes in Maintenance Histories

Although we find it useful to propose the preceding “grand narrative” of maintenance in history, the bulk of the scholarly work that lies ahead is to consider and investigate select themes in maintenance histories. Some of these themes may fit neatly into an overarching narrative; others may stretch our categories or break the narrative altogether. Many of these themes come from work by our predecessors and peers—some of it published, and some of it still in progress. We highlight historical as well as normative questions, through a brief discussion that is guided by themes that recur in the history and historiography of technology.

### IDENTITY, STATUS, AND TECHNOLOGY

One persistent theme in histories of maintenance is the identity of maintainers. At least in some contexts, maintenance work is performed by people who do not hold positions of wealth or privilege in any given society. To focus on maintainers therefore is to look at the lives and labor of

32. Albert O. Hirschman, *The Strategy of Economic Growth*.

33. Philip Scranton, “Managing Communist Enterprise” as well as “Managing Communist Enterprises,” parts 1 and 2.

women, ethnic and racial minorities, migrants, and laborers whose positions are contingent and vulnerable. A great deal of maintenance takes place within homes and families, where significant responsibilities fall on women and children. Scholars who write about social reproduction within the Marxist-feminist tradition argue that the key to industrial capitalism, labor power, “is actually itself produced and reproduced outside of capitalist production, in a ‘kin-based’ site called the family.”<sup>34</sup> As the sociologists Barbara Laslett and Johanna Brenner summarize it, social reproduction refers to “the activities . . . directly involved in the maintenance of life on a daily basis, and intergenerationally. Among other things, social reproduction includes how food, clothing, and shelter are made available for immediate consumption . . . and the care necessary to maintain existing life and to reproduce the next generation.”<sup>35</sup> The norm that maintenance work is *women’s work* extends into and persists in other settings, such as the “Office Moms” of twenty-first-century corporate cultures.<sup>36</sup>

A maintenance lens also provides opportunities to build on pioneering works in the history of technology that highlight themes of race and ethnicity. For example, historians of technology have described how African Americans and Latinas often filled maintenance and repair roles, from enslaved blacks fixing cotton gins and “colored men” working on airplanes at the Chanute airfield during World War II, to the men and women who ensured the famed reliability of the Bell telephone system through their work as operators and “switchmen.” Ethnographic methods also provide useful complements to historical methods, such as in a recent study of Mexican migrant families whose labor and suffering makes it possible for American consumers to enjoy fresh, high-quality produce.<sup>37</sup>

Histories of technology that focus on maintenance can reframe macroeconomic change at the industrial level as well as microeconomic shifts in status and prestige of particular occupations. From a bird’s-eye view, the economy seems to be made up of old industries maturing and even falling into decline and new industries based on new technologies charging ahead. Yet these patterns—old industries falling behind, new ones charging ahead—become deeply connected with social status systems. Old industries become cultural backwaters: “Innovation districts” and entrepreneurs rise, and “rust belts” and labor unions fall. On an individual scale, it is worth

34. Tithi Bhattacharya, “What Is Social Reproduction Theory?”

35. Barbara Laslett and Johanna Brenner, “Gender and Social Reproduction,” 382; see also Ruth Schwartz Cowan, *More Work for Mother*; Judith A. McGaw, “Why Feminine Technologies Matter,” 26–28.

36. Katherine Rosman, “Office Mom as Corporate Business Strategy”; Adam Grant and Sheryl Sandberg, “Madam C.E.O., Get Me a Coffee”; Tracy Moore, “Women at Work.”

37. Carroll W. Pursell, *Hammer in Their Hands*; Venus Green, *Race on the Line*; Melissa Villa-Nicholas, “The Making of the Invisible Information Worker”; Seth Holmes, *Fresh Fruit, Broken Bodies*.

nothing that the nineteenth-century terms “mechanic” and “electrician” were both markers of middle-class pride and aspiration, but in the twentieth century they came to denote mere “trades,” the occupations of the left behind. The electric power industry experienced a significant “brain drain” in the post–World War II period as young, hot talent chose careers in electronics and computing rather than fields that they perceived as passé—the boring, ho-hum area of electricity generation and distribution. More recently, the maintenance of digital networks also presents promising opportunities for research. Many existing histories of Silicon Valley and the Internet, for example, reflect the innovation-and-entrepreneurship zeitgeist of the eras in which they were written. Scholars are only beginning to explore the “after innovation” stories that demonstrate themes of operation, use, and decline of the digital world. And there remains significant work ahead for scholars to illustrate the immense human costs of celebrated innovation districts like Silicon Valley.<sup>38</sup>

## CAPITALISM

Historical accounts of maintenance can provide new ways to bring the history of technology into closer conversation with histories of capitalism. Maintenance can inform some fundamental questions regarding capitalism’s history, such as: What does it mean to maintain and sustain capitalism? Who are the historical actors who come into our frames when we focus on maintenance, and what types of labor are involved? Wage laborers and salaried manual laborers are obvious candidates—janitors, repairmen, cleaning ladies, mechanics, electricians, plumbers, and the like. But the maintenance lens also supports the notion that the managerial classes scrutinized by Alfred D. Chandler also play crucial roles as maintainers of capitalism. Managers maintain bureaucracies—indeed, armies of white-collar workers do the same. We therefore contend that maintenance is a phenomenon that can spark new conversations and infuse the history of technology across such specializations as labor history, business history, and intellectual history where scholars wrestle with the emergence and persistence of industrial capitalism.<sup>39</sup>

One helpful body of theory and analysis for thinking about maintenance in capitalism is the literature from economics and management studies that emphasizes organizational routines: where they come from, how they

38. Barry Bluestone and Bennett Harrison, *The Deindustrialization of America*; Richard F. Hirsh, *Power Loss*; Nathan Ensmenger, “When Good Software Goes Bad”; Bradley Fidler and Andrew L. Russell, “Infrastructure and Maintenance at the Defense Communications Agency”; Sarah T. Roberts, “Commercial Content Moderation”; John D. Sutter, “Poor Kids of Silicon Valley”; Douglas Rushkoff, *Throwing Rocks at the Google Bus*.

39. This isn’t a new idea, of course; see Philip Scranton, “None-Too-Porous Boundaries.”



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develop, how they change over time, how they succeed or fail.<sup>40</sup> Thinking through this frame raises a related question about what economic incentives and organizational cultures foster maintenance. Some industries, like many (though not all) chemical and refining plants in rich nations, use complicated computerized maintenance management software systems to organize preventive maintenance and vibrational analysis to predict problems. Yet one study of maintenance in building management found that only 2 percent of maintenance was preventive. That is, 98 percent of maintenance in buildings is reactive, or repair-oriented.<sup>41</sup> There is related scholarship on private governance, an old phenomenon that has taken on new significance in a neoliberal age. Governments frequently use *regulations* to mandate, standardize, and oversee maintenance practices. Indeed, many environmental regulations of chemical, petroleum, and other heavy industries involve maintenance standards, and aviation regulatory bodies around the globe order airlines to maintain their planes according to specific criteria. However, decisions that affect the public welfare are increasingly placed in private hands, such as with infrastructure governance and the global adoption of product and safety standards.<sup>42</sup> Private regimes of rule-making can be effective, but public and private organizations alike are known to suffer from short-term thinking that undermines investment in physical assets and devalues spending on maintenance in favor of ribbon-cutting ceremonies and dividends for investors. We expect that future scholarship will explain how the governance of maintenance has changed over time, and the extent to which these changes coincide with the application of science to industrial production, the emergence of the American regulatory state, and global movement toward private regimes of rule-making.

#### ENVIRONMENT, INFRASTRUCTURE, AND DISASTER

A persistent theme and focus within the Maintainers network and conferences is how the presence and absence of maintenance practices affects larger-scale systems, such as the natural environment and infrastructures, as well as what happens when those systems fail in “natural” and human-caused disasters.<sup>43</sup> While few works of landscape history have focused explicitly on maintenance, it is a thread that can be read out of nearly all of them—particularly those that emphasize stewardship and conservation.<sup>44</sup> The creation and maintenance of trails and roads, for instance, is a natural

40. Daniel M. G. Raff and Philip Scranton, *The Emergence of Routines*.

41. Tom Arnold, “Why Aren’t the Wrenches Turning on Preventive Maintenance?”

42. Tim Büthe and Walter Mattli, *The New Global Rulers*; Timothy D. Lytton, *Kosher*. Again, this phenomenon is not new. Jewish law about the maintenance of holy objects can be thought of as regulations, even as technical standards.

43. Dolly Jorgensen, Finn Arne Jorgensen, and Sara B. Pritchard, *New Natures*.

44. W. G. Hoskins, *The Making of the English Landscape*; John R. Stilgoe, *Common Landscape of America*. See also Hilary Sample, *Maintenance Architecture*.

and environmental history that winds its way down to the present from the oldest and simplest human societies.<sup>45</sup> Massive infrastructure projects in the Mekong Delta and Panama Canal, for example, remade landscapes and nature through enormous human effort—and through utter devotion to their maintenance.<sup>46</sup>

There is now a formidable literature on infrastructure within science and technology studies, where maintenance has been an important sub-theme (although not always an explicit focus).<sup>47</sup> Paul N. Edwards, a leading thinker in studies of infrastructure, has written, “Infrastructure is all about maintenance. Maintenance, maintenance, and more maintenance. It doesn’t just get built, like some colossal monument left to stand until natural forces wear it away. It constantly has to be repaired, rebuilt, extended, shrunk, adapted, readapted, continually redefined and reengaged.”<sup>48</sup> A lack of maintenance often plays an essential role in the problems that arise from “natural” and industrial disasters and accidents of all sorts, including the “slow disasters” that threaten modern existence. To put the point simply, infrastructure minus maintenance equals disaster.<sup>49</sup>

## Conclusions

We’ve been thinking, reading, and writing about maintenance for a few years now—ever since we joked about *The Innovators* and *The Maintainers* in late 2014—and we have arrived at a point where most of our conclusions take the form of questions. We feel certain about the vast potential for this topic to stimulate conversations that defy the disciplinary and professional boundaries which we inhabit. We have observed how maintenance is a useful umbrella for gathering work that historians of technology have published, continue to research, and have yet to begin. We have seen how methods and ideas from other fields—ethnography, economics, feminist philosophy, and popular writings about craftsmanship—have infused the small Maintainers community with energy and a sense of purpose. And we are happy to be part of a broader movement that longs to rescue the promise of technology from the grasp of those who are myopic, narcissistic, and profit-hungry.

45. Robert Moor, *On Trails*.

46. Mark H. Rose, Bruce Edsall Seely, and Paul F. Barrett, *The Best Transportation System in the World*; Jo Guldi, *Roads to Power*; David Andrew Biggs, *Quagmire*; Ashley Carse, *Beyond the Big Ditch*.

47. Christopher R. Henke, “The Mechanics of Workplace Order”; Stephen Graham and Nigel Thrift, “Out of Order”; Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out*; Steven J. Jackson, “Rethinking Repair”; Jérôme Denis, Alessandro Mongili, and David Pontille, “Maintenance and Repair in Science and Technology Studies.”

48. Paul N. Edwards et al., “AHR Conversation.”

49. Scott Gabriel Knowles, “Learning from Disaster?”; Knowles, “Maintenance Deferred.”

As we turn to maintenance in our research and scholarship, there are several basic questions that have been useful to keep in mind:

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- Where is maintenance work performed?
- What is being maintained?
- How is maintenance work organized?
- Who are the maintainers?
- Who pays for maintenance?
- Who benefits, and who doesn't?

As historiographers of maintenance, we continue to find several more questions compelling:

- Who are the historians of maintenance, and what meaning did the topic bring to them?
- What draws our focus to singular events, revolutionary behaviors, and spectacular things as opposed to the commonplace, continuity, the mundane?
- What are the incentives for writing histories of innovation and/or maintenance, and what kinds of value do these histories generate?
- How can maintenance connect histories of technology with other specialties and disciplines, such as general history, ethnography, anthropology, sociology, and economics?
- How do we work to ensure that the history of maintenance does not fall into the background once again?

Finally, we have developed a list of questions that can help establish maintenance as a major theme in histories of technology, including:

- How can we quantify the portions of social and economic activities devoted to maintenance?
- What kinds of evidence survive for us to view life from a maintainer's vantage point?
- How did different societies respond to the challenges of maintenance, and how did maintenance feature in societal values and cultural norms?
- Can we identify patterns in the different types of organizations or cultures that are "good at maintenance"?
- Did maintenance workers see themselves as a coherent group, organized around the lines of occupation, social or economic class, sex, race, or ethnicity?
- Are there significant differences between maintenance regimes before industrialization or after computerization?

- When is maintenance a good thing, and when has it been a tool of oppression?

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