ROUTLEDGE

The Routledge Companion to Media Technology and Obsolescence

Edited by Mark J. P. Wolf

THE ROUTLEDGE COMPANION TO MEDIA TECHNOLOGY AND OBSOLESCENCE

While so many books on technology look at new advances and digital technologies, *The Routledge Companion to Media Technology and Obsolescence* looks back at analog technologies that are disappearing, considering their demise and what it says about media history, pop culture, and the nature of nostalgia. From card catalogs and typewriters to stock tickers and cathode-ray tubes, contributors examine the legacy of analog technologies, including those, like vinyl records, that may be experiencing a resurgency. Each essay includes a brief history of the technology leading up to its peak, an analysis of the reasons for its decline, and a discussion of its influence on newer technologies.

Contributors: Meredith A. Bak, Paul Benzon, Peer D. Bode, M. M. Chandler, Jason Curtis, Anne C. Deger, Joshua Greenberg, David Hochfelder, Peter M. Hopp, Matthew Kirschenbaum, Peter Krapp, Lori Landay, Gary Locklair, Stephen Mamber, Ken S. McAllister, Amanda McQueen, Sheila C. Murphy, Richard Osborne, John Reid Perkins-Buzo, Richard Polt, Judd Ethan Ruggill, Paige Sarlin, Matt Soar, Braxton Soderman, Brent Strang, Michael Thomasson, Robert S. Wahl, Mark J. P. Wolf, Josh Zimmerman

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Abstracting Reality: Art, Communication, and Cognition in the Digital Age (2000), *The Medium of the Video Game* (2001), *Virtual Morality: Morals, Ethics, and New Media* (2003), *The Video Game Theory Reader* (2003), *The Video Game Explosion: A History from PONG to PlayStation and Beyond* (2007), *The Video Game Theory Reader 2* (2008), *Myst and Riven: The World of the D'ni* (2011), *Before the Crash: Early Video Game History* (2012), the two-volume *Encyclopedia of Video Games: The Culture, Technology, and Art of Gaming* (2012), *Building Imaginary Worlds: The Theory and History of Subcreation* (2012), *The Routledge Companion to Video Game Studies* (2014), *LEGO Studies: Examining the Building Blocks of a Transmedial Phenomenon* (2014), *Video Games Around the World* (2015), the four-volume *Video Games and Gaming Cultures* (2016), *Revisiting Imaginary Worlds: A Subcreation Studies Anthology* (2017), *Video Games FAQ* (2017), *The World of Mister Rogers' Neighborhood* (2017), *The Routledge Companion to Imaginary Worlds* (2017), and two novels for which his agent is looking for a publisher. He is also founder and coeditor of the Landmark Video Game book series from University of Michigan Press, the founder and editor of the Imaginary Worlds book series from Routledge, and the founder of the Video Game Studies Scholarly Interest Group and the Transmedia Studies Special Interest Group within the Society of Cinema and Media Studies. He has been invited to speak in North America, South America, Europe, Asia, and Second Life; has had work published in journals including *Compar(a)ison*, *Convergence*, *Film Quarterly*, *Games and Culture*, *New Review of Film and Television Studies*, *Projections*, and *The Velvet Light Trap*; is on the advisory boards of Videotopia, the International Arcade Museum Library, and the *International Journal of Gaming and Computer-Mediated Simulations*; and is on several editorial boards including those of *Games and Culture* and *The Journal of E-media Studies*. He lives in Wisconsin with his wife Diane and his sons Michael, Christian, and Francis. [mark.wolf@cuw.edu]

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PREFACE

Snow, on the television screen, after the end of the broadcast day. The radiant glow of projected Kodachrome imagery on a silver lenticular screen. The high-speed *clickety-clack* of a 16mm film projector, or the *tack-tack-tack* of typewriter keys hitting the page. The smell of warm Bakelite and the humming fan of an Airequipt slide projector operating. The looping, scratchy crackle of a record player needle after the record has ended. The fresh scent of newly printed purple mimeograph ink. The whirring crunch of a disk drive searching for data. The cacophonic ambience of a video game arcade. The buzzing, beeping, and dinging tones of a modem receiving data. All of these sensations, and many more, are now largely things of the past; memories and nostalgic recollections that my generation might be the last to have experienced as a part of normal daily life. Digital technology, for all its advantages, will never be able to accurately reproduce the sights, sounds, smells, and feel of yesterday's analog technologies.

The idea for this book began in 2015. For Valentine's Day that year, my wife bought us an HDTV television set, to replace the NTSC cathode-ray tube television set that we had had since 2001, which had been a wedding gift. But having the HDTV set sitting in its box in the family room, waiting to replace the CRT, somehow made me realize the nostalgia I had for the old television technology, which was of course the kind I had when I was growing up. I realized it would probably be the last CRT we would ever own, and I became a bit loath to give it up. Ever-thankful for my wife's patience with me, it wasn't until October that we finally switched over to the HDTV, and of course I enjoy the high-resolution imagery and flat screen technology as much as anyone else. The old CRT now sits in the basement, my wife once again patiently waiting for me to get rid of it entirely, as its bulky shape takes up space in the playroom.

My nostalgia for the CRT led me to consider writing about it, along with the disappearance of so many different technologies that I had known in my childhood, an idea that grew into a proposal for an anthology I planned to call *Analog Sunset: On the Impending Demise of Vanishing Media*. Not only did Routledge like the idea for the anthology, they asked me to expand it and turn into *The Routledge Companion to Media Technology and Obsolescence*. This allowed me to add essays on some obsolete digital technologies, a reminder that obsolescence is not limited to analog media; in fact, anyone who fondly remembers using home computers of the 1970s and 1980s will note that digital media artifacts often become obsolete even faster than analog media ones. All these media, however, comprise a technological milieu that has largely passed away.

Analog Sunset

The rapid advancements in technology mean that our children's childhoods and lives will be very different from our own, widening the technological generation gap; but there is

even more at stake here. The technological developments going on all add up to a much larger-scale changeover, which began slowly in the latter half of the 20th century, gradually picking up speed; the change from analog technology to digital technology. This involves not just new technologies but a whole new lifestyle, with a different set of metaphors ordering society, a paradigm shift as great as that separating the industrial age from the agricultural age that preceded it.

As well as evoking a sheen of nostalgia, the term "Analog Sunset" describes the end of the production of technology with analog video inputs and comes from section 2.2.2.1 of the "Advanced Access Content System ("AACS") Adopter Agreement"[1] published in June 2009 by the Advance Access Content System Licensing Administrator LLC (AACS LA). The AACS LA is a consortium organized by IBM, Intel, Microsoft, Panasonic, Sony, Toshiba, The Walt Disney Company, and Warner Bros. to develop the AACS, which they describe as "a specification for managing content stored on the next generation of prerecorded and recorded optical media for consumer use with PCs and CE devices".[2] The AACS was designed for the protection of copyrighted material against illegal copying and distribution, and the consortium determines not only new systems to be used, but also the ending, or "sunset" of older systems and technologies. Thus, while some technologies decline and fall out of use simply because newer or (supposedly) better technologies become available, and especially ones that are cheaper than the technologies they replace, other technologies are deliberately designated as obsolete by the companies and institutions that used to produce and support them.

Of course, the idea of declaring something obsolete for the purpose of selling newer things to consumers goes back to 1924 and the "dynamic obsolescence" of Alfred P. Sloan Jr., head of General Motors (his critics referred to it as "planned obsolescence", and so it has been remembered to this day). Likewise, companies can also retain a tight grip on older technologies that are well-entrenched, rejecting a move to something provably better; consider RCA's ruthless rejection and suppression of Howard Armstrong's FM radio, which RCA saw as a threat to its radio networks and production of AM radios. And sometimes in the marketplace, for a variety of reasons, the best technology does not win out over its inferior competitors; consider the battle between VHS and Beta videotapes, which VHS won. The rise and fall of technologies are complex and overdetermined things, difficult to analyze, and require a great deal of historical context. The essays in this volume admirably take on this challenge, giving an overview of their chosen technologies, and for the sake of some consistency across the essays of the book, contributors were urged to include the following: a description of the technology and its purpose; a brief history of the technology leading up to its peak; an analysis of its decline and descent into obsolescence, and the reasons for its decline or demise; its influence on the technology that is replacing it; discussion of the tradeoffs involved in replacing it, what was gained, and more importantly, what might be lost due to the transition; and finally, the transformation of the dying technology into a luxury item, cult object, collectible, object of nostalgia, or curiosity; the continuing legacy that the technology leaves behind.

Types of Obsolescence

The essays are organized chronologically, according to their subject's time of appearance. This was done not only because earlier technologies often influence the form of later ones, but also because many technologies never completely die out; for example, a quick search on the Internet reveals that people are still making Daguerreotypes today, even though the

technology nearly died out after 1860, when better photographic techniques became available. Thus, we can demarcate several different types or stages of obsolescence. The first is when a technology is no longer the dominant one of its kind, when it has functionally been replaced by something which is hailed as better (whether or not it might actually be so); for example, when LCD and LED screen technologies brought an end to the dominance of the cathode-ray tube, or when Windows 95 replaced MS-DOS-based Windows 3.1, or when the confusingly-named Xbox One replaced the Xbox 360. Such shifts are usually the result of new or improved technologies, coupled with corporate production and marketing, requiring consumers to buy in and adopt to a great enough degree that the dominant technology changes.

The second type of obsolescence is when a technology is no longer mass-produced for everyday consumers; it is no longer just a less-popular choice in the marketplace, but something that is considered unprofitable to continue to produce or for stores to carry at all. Some technologies have enough of a niche that they might not reach the second stage for some time, even after reaching the first; AM radio, for example, lost its dominance to FM, but still remains a viable medium. But many technologies lose their viability along with their dominance, find themselves unable to compete, and thus go out of production. At this point, a technology becomes difficult to find for those still using it; one might have to resort to buying used items, or find unsold inventories still lingering in back storerooms. Such a stage of obsolescence might come as a surprise, especially if it does so rapidly, turning what was once a commonly found object into a rare item.

This can lead to the third stage, when a technology's rarity, or even nostalgia for the technology, make it collectible, and people begin competing for the acquisition of what remains of it. Occasionally, if there is interest in the technology beyond just being a collectible, it might even spark a niche market, becoming a specialty or even luxury item; no longer mass-produced, it will likely be more expensive than when it was dominant, but there will be a small audience still willing to pay for it. Such resurgences can be minimal (as in the Daguerreotype example given earlier), or might be surprising widespread, like the comeback made by vinyl records in recent years.

Finally, the last stage of obsolescence is when a technology almost completely disappears, leaving only stories about it, and perhaps a few extant artifacts (naturally, if a technology *completely* vanished without any trace, we would no longer even know about it). At this point, such a technology is truly a collectible or museum piece, valued only for its rarity, and perhaps used very little in order to keep its condition intact. In the most extreme cases, a lost technology might only have left us a few puzzling remains, allowing speculation as to what it might have been, like the gears of the mysterious Antikythera mechanism of which we have only a few remains from the ancient world. Despite greater interest in preservation and museums, some technologies, even more recent ones, still have managed to slip into extreme obscurity and rarity.

But there is still much technological history to be brought to light, and I have had the pleasure of working with many of the finest scholars writing about declining and obsolete technologies, whose research and writings have certainly broadened and enriched my own knowledge of the field. Together, the essays in this volume reveal a number of themes and issues regarding technology, such as how technologies become obsolete and the many factors contributing to their demise; shifts in the way technologies are used and how this affects their longevity; how technology, culture, and society mutually shape each other; how the status of vanishing technology changes what we think of it; and why certain technologies become objects of nostalgia and enjoy comebacks, while other technologies do not.

As mentioned above, the essays are arranged chronologically according to each technology's appearance, and each tracks a technology's growth and decline, and its cultural legacy which continues today.

Following the essays is a Timeline of Obsolescence, which charts the disappearance of a number of technologies over the last hundred years or so. Seeing all these dates, many of which mark the discontinuations and departures of technologies, makes one realize just how quickly the world is changing, and also that such changes are accelerating, a feeling that many of the individual essays also convey.

Naturally, a single volume can give only a sampling of the many topics and ideas through which media technology, even obsolete media, can be considered and studied.[3] Hopefully readers will find the *Companion* useful and interesting, as well as a point of departure for further research, and perhaps even an influence on how we think of new and emerging technologies, and the place they should have in society and culture.

Notes

1 See AACS LA, "Advanced Access Content System ('AACS') Adopter Agreement", June 2009, available at www.aacsla.com/license/AACS_Adopter_Agrmt_090605.pdf.
2 According to the AACS website overview, available at www.aacsla.com/what/overview.
3 For example, I would have loved to include essays on hand-cranked motion picture cameras, cassette tapes, dial telephones, 8mm and super-8 film formats, specific brands of early home computers, and other obsolete media technologies.

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A *Companion* like this is possible with the contributions of readers and scholars whose interest and desire bring about the study of media technology and obsolescence. Therefore, great thanks go out to all of the contributors to this volume, who graciously agreed to join in this endeavor: Meredith A. Bak, Paul Benzon, Peer D. Bode, M. M. Chandler, Jason Curtis, Anne C. Deger, Joshua Greenberg, David Hochfelder, Peter M. Hopp, Matthew Kirschenbaum, Peter Krapp, Lori Landay, Gary Locklair, Stephen Mamber, Ken S. McAllister, Amanda McQueen, Sheila C. Murphy, Richard Osborne, John Reid Perkins-Buzo, Richard Polt, Judd Ethan Ruggill, Paige Sarlin, Matt Soar, Braxton Soderman, Brent Strang, Michael Thomasson, Robert S. Wahl, and Josh Zimmerman. Thanks also to all those who gave suggestions for this volume; to Erica Wetter and Routledge Press for accepting the book, asking to turn it into a *Routledge Companion* (the third one that I have edited), and supporting it along the way; and to all those who will use it in the classroom and elsewhere. Finally, I also must thank my wife Diane Wolf and sons Michael, Christian, and Francis who were patient with the time taken to work on this book. And, as always, thanks be to God.

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PAPER SLIPS

The Long Reign of the Index Card and Card Catalog

Peter Krapp

Before fading toward obsolescence, the index card and card catalog had developed into an influential technology of knowledge management and discovery: a mere clutch of paper scraps deployed to great effect not only in libraries but in academic research and in offices, for business and creative pursuits alike, permitting storage, processing, and transmission of data in discrete, mobile, uniform chunks that can be rearranged according to various principles.

Yet, is this range of applications for index cards completely obsolete? Certainly the index card as an informative object has faded in importance, and while you can still find purveyors of normed index cards among stationery or school and business supplies, it is a safe assumption that librarians, office managers, and writers no longer rely much on index cards, despite the fact that the card catalog long reigned supreme in those information environments. Few students today cram vocabulary, for instance, or formulae with index cards, yet a certain type of hipster will proudly own a piece of furniture originally designed for a library card catalog. However, while the object as such might have faded, arguably the affordances of a card index have not. Few among us maintain our own system of cross-references among browser bookmarks, recipe collections, metadata for CDs ripped to our gadgets, or any other sort of data collection, yet most of us have grown accustomed to associative indexing, from Amazon's reading suggestions based on your past browsing to streaming music service recommendations.

Certainly under the conditions of hypertext, as manifested across networked computers, the storing, processing, and transmitting of data (business data, library data, audio recording metadata, etc.) allows for a kind of serendipitous discovery of correlations and cross-references that were one strength of index cards, as valued by generations of writers, artists, and academics. One might say the card index lives on in a number of related formats: from hypercard stacks as introduced by Apple—maintained from 1987 to 2004 as a multimedia programming environment, for CD-ROM interactive content and games like *Myst* (1993)—to the generalized footnote we now call hypertext, and even to the ubiquitous slide decks, be they collated in PowerPoint or Keynote or Prezi. Each of these media exhibits features of what made index cards a success for centuries.

From Library Catalogs to Accounting and Business

> A scholar is only a librarian's way of creating another scholar.
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> —Daniel Dennett[1]

Establishing origins is, so often, hazardous terrain. A British historian of science, Staffan Mueller-Wille at the Centre for Medical History at the University of Exeter, recently claimed that Swedish natural scientist Carl Linnaeus (1707–1778), the father of modern taxonomy, had "invented" the card index to manage his information storage and retrieval. Working with paper slips that could be shuffled, updated, and sorted according to different criteria, Linnaeus certainly helped change the understanding of the natural world, away from linear filiation models and toward networks of characteristics that could be mapped.[2] Despite such claims, one can find index card systems that predate Linnaeus.

At the end of the 17th century, a comparison of techniques for excerpting led the German lawyer and librarian Vincent Placcius (1642–1699) to develop a "learned box" to enable the relational manipulation of notes.[3] German polymath Gottfried Wilhelm Leibniz (1646–1716) was able to buy such a piece of furniture to accommodate his paper slips in 1676.[4] And in the 16th century, Swiss doctor Conrad Gessner (1516–1565) reflected openly on how to generate and copy excerpts for a register, although then paper slips were usually threaded together.[5] For rhetorical memory, it was preferable not to work with loose sheets, as this could imperil the entire project if their positions were variable.[6] The ability to sort and shift entries in varying correlations was long perceived not as a valued feature of knowledge management, but as a dangerous weakness of excerpting, copying, and note-taking. Although secretaries in 17th-century France or Italy were forbidden to speak of their work in public, their confiscated speech never dampened their drive to express the master-medium dialectic of their employment. As Foucault demonstrates, doctors, like confessors, figured as stenographer of a client's secrets, until the birth of the clinic forced them out of their secretarial role. Discussing the documentary system of surveillance, Foucault points to a "partly official, partly secret hierarchy" in Paris that had been using a card index to manage data on suspects and criminals at least since 1833. In a note, he dryly remarks: "Appearance of the card index and constitution of the human sciences: another invention the historians have celebrated little".[7] Soon, card catalogs were used not just in a learned scholar's study but in libraries and in business.

Upon taking office, librarians often complained about the lack of order in the stacks and catalogs, and went about reorganizing shelves and finding aids. Document mobility requires addressing and recombination both of what is cataloged and of catalogs themselves. The Viennese Imperial Library established a card catalog (around 300,000 paper slips in 205 boxes) of its holdings in 1780, featuring instructions for the cataloger, along with a flowchart for dividing indexing labors. As Krajewski tells it, however, it was an accidental reinvention at the Harvard College Library in 1817 that brought the card catalog to the New World. Instead of tackling the overwhelming task of cataloging all stock, William Croswell cut up the partially bound catalogs compiled by his predecessors, allowing him to prepare a complete card index for over 20,000 volumes in less than six months.[8] But before the card index could also reign in office management, technical questions had to be settled.

In many places, the search for a normed paper slip size was conveniently settled: playing cards were in use for indexing at least since the French Revolution. On May 15, 1791, the French government decreed that a list of nationalized holdings was needed to make them accessible to the public. Librarians working for aristocrats and clergy resisted, since they had reason to fear that after an index went to Paris, the items themselves would soon follow. Thus, new instructions were issued to aides who would take stock where intractable librarians procrastinated. Regardless of local cataloging, they were to copy each item's identifying information on a numbered playing card. The operation netted the commission 1.2 million cards, soon used to add 300,000 volumes to the national library.[9]

By the time energetic reformer Melvil Dewey returned from Europe to his roots in the United States (having played a lot of cards on the transatlantic voyage), the country was ready for the standardization by Dewey's business, Library Bureau. Patenting the card index and furnishing drawers that held 1,000 slips in two rows, he succeeded in getting the American Library Association to bless his index card format in 1877. Within a few years, the business found more demand from offices rather than libraries.[10] By 1896, Library Bureau supported census data in several countries, in major contracts with the Hollerith Tabulating Machine Company (renamed IBM as of 1924). Before punched cards took over, the humble paper slip economy made inroads in government and business offices around the globe.

Elsewhere, this method for a flexible knowledge repository was soon adapted and adopted by historians, writers, lawyers, and philosophers. And while the memory crutch and administrative kludge long goes unacknowledged, soon one sees card index techniques openly credited: while John Locke had published a description of his card index in 1686 anonymously, by 1796 Jean Paul could publish a novel called *The Life of Quintus Fixlein, pulled from 15 card indexes*. Whatever occurred to Leibniz while reading or even on his walks, he scribbled onto slips for which he had a special cabinet constructed.[11] As contemporaries of Hegel describe in detail, he systematically hoarded ideas and excerpts on note cards, and carried them with himself from his school days, when he started at age 15, to his death.[12] A similar system was described by Charles Darwin:

> I keep from thirty to forty large portfolios, in cabinets with labeled shelves, into which I can at once put a detached reference or memorandum. I have bought many books and at their ends I make an index of all the facts that concern my work. Before beginning on any subject I look to all the short indexes and make a general and classified index, and by taking the one or more proper portfolios I have all the information collected during my life ready for use.[13]

One can find index cards at play all the way into the 20th century, for instance in Walter Benjamin's unfinished *Arcades Project* (1983/2002). Pioneering social scientist Beatrice Webb reported in her autobiography, *My Apprenticeship* (1980), of her attempts to persuade Oxbridge graduates that her index cards were "an indispensable instrument in the technique of sociological enquiry", and C. Wright Mills notes that what he called cross-classification was crucial in keeping index cards.[14] And indeed, all the way into the 20th century, the playing card remains one model for how to interact with paper slips to generate new knowledge.

From the Scholarly to the Literary Card Index

> Only a historian of playing cards might find this relevant.
>
> —Jean-Baptiste Labiche[15]

Despite a respectable lineage, the card catalog mostly remained an anonymous, furtive factor in text generation, acknowledged merely as a memory crutch. Since the enlightened scholar is expected not just to reproduce knowledge but to produce innovative thought (not just as a recombination of good quotations, but opening new arguments and lines of investigation), knowledge management is a private matter, with rare exceptions. The question remains whether there is indeed a departure from the "neolithic mind" anthropologist Claude Lévi-Strauss glosses over in an interview, when he admits that his own memory "is a self-destructive thief" counter-balanced only by his extensive use of a card index:

> I get by when I work by accumulating notes—a bit about everything, ideas captured on the fly, summaries of what I have read, references, quotations . . . And when I want to start a project, I pull a packet of notes out of their pigeonhole and deal them out like a deck of cards. This kind of operation, where chance plays a role, helps me revive my failing memory.[16]

In his subversion of the rigorous constraints of memorial order by dint of chance and play, Lévi-Strauss seems to allow that his notes might either restore memory, or else restore the possibility of contingency which gives thinking a chance under the conditions of modernity. That hypertext may instantiate such an epistemology of chance and play on-screen is therefore no innovation; the encoding and deciphering practices of computer-linked textuality merely recapture what had been possible already with the means of note cards or playing cards.

Ludwig Wittgenstein's papers, dispersed between Britain, Norway, Austria, and elsewhere, presented the executors of his estate with a conundrum when they found a box labeled ZETTEL ("paper slips"), containing 717 loose fragments, the earliest dating from 1929, the latest from 1948 (the bulk was dictated between 1945 and 1948). Were they excess material, occasional ideas, sources and excerpts? Should the typescripts and hand-written notes be published, destroyed, classified? Posthumous version control proved to be arduous. Not presuming to reconstruct what Wittgenstein had "meant" to say in unfinished notes, the editors ordered and published what they deemed significant from this card index. A typescript of 768 pages (labeled simply *The Big Typescript*) dated from 1933 had been in the estate since 1951, but only in 1967 were the "Zettel" recognized from which it was compiled. Cut-and-paste was integral: "Usually he continued to work with the typescripts. A method which he often used was to cut up the typed text into fragments ('Zettel') and to rearrange the order of the remarks".[17]

Another important 20th-century thinker to rely on index cards was pioneering media theorist Harold Innis.[18] The executors of his estate published a tome called *The Idea File* (1980), composed of 18 inches of index cards, plus five inches of reference cards. Innis had a selection of hand-written index cards typed up and numbered, 1 through 339. It is unclear if these ruminations on television and art, communication and trade, secrecy and money, literature and the oral tradition, archives and history were intended to constitute a book project; the decision to publish the cards balances the putative will to posterity of an author, and the potential embarrassment of incomplete work. Clearly Innis intended to work synchronically rather than diachronically, to focus less on logical connections than on analogies, to practice pattern recognition—and the associative links of a card index lend themselves perfectly to this kind of project.

Similar features can be discerned in the silicon sociology of Niklas Luhmann's recombinant excerpts.[19] His card index cost him more time, he claimed, than writing his many books: little surprise that they demonstrate systematic redundancy.[20] Shortly after Luhmann's death in 1998, a dictionary and a glossary facilitated access to his thought, and an interactive database, marketed as "Luhmann on your computer", was offered on disk. A provocative question is whether from the depths of such a memory bank, further texts could be generated. Users of the Luhmann CD-ROM might try their hand at emulating his arguments within the recursive parameters of his systems theory.[21] A different approach to Luhmann's associative indexing is explored in another collaborative database tool, called nic-las in homage to the late sociologist ("nowledge integrating communication-based labeling and access system"), and billed as a "software prototype of an *autopoietic* knowledge landscape for social systems".[22] Intriguingly, deleted elements end up, for a while, in a digital unconscious: they remain searchable, and can return in unforeseen ways. The system distinguishes

between a Freudian and a Deleuzian unconscious; while the former pushes some deleted objects back onto the documentation surface, the latter generates a random selection of deleted and undeleted objects in the form of new virtual index cards.

With this transition to multimedia software imitating the card index, we arrive at the surmise that hypercard systems and hypertext online obey the index card logic of associative links. George Landow and other adopters of this convergence hypothesis claim that French cultural theorist Roland Barthes anticipated this.[23] Be it Proust, the daily newspaper, or the television screen—to Barthes, it was all text, so in the age of the Internet, it was going to be Barthes who always already anticipated its structures and strictures.[24] Barthes' writing lends itself to this, because he often read in a manner that generated, despite all categorical, classificatory zest, a déjà vu effect.[25] In *S/Z* (1970), Barthes goes so far as to claim that, faced with the impure communication or "intentional cacophony" that is literature, one must accept "the freedom of reading the text as if it had already been read"—and asserts that faced with the plural text, there is no such thing as forgetting its meaning: one truly reads only in such quasi-forgetting.[26] No surprise that distinctions Barthes made in 1960 between writerly and readerly texts return in 1968, and his semiological definition of text crops up in publications from 1963 through 1976. "Though most of Barthes' now 'canonical' formulations on textuality occur in the period from 1968 to 1975, the issues that pushed him toward it were organizing his writing much earlier," observed John Mowitt, "in essence adumbrating the move that directed his attention to the work's status".[27] Mowitt notices how "articulation", Barthes' term in "The Structuralist Activity" of 1963, "reappears eight years later in the Preface to *Sade/Fourier/Loyola*"—and such continuities abound:

> Though I might be accused of stretching the point, it is also worth noting that in order to exemplify the procedural category of "dissection" (articulation's twin) Barthes has recourse in this essay to the sonoric distinction between s and z—precisely the distinction that Barthes later exploited in his most ambitious demonstration of how one might read "textually", namely, *S/Z*.[28]

Faced with such textual echo, Mowitt concludes "it becomes difficult to dismiss this tangle of associations as merely fortuitous." The reason became widely evident when the *Centre Pompidou* mounted a big exhibition on Barthes: he had worked, daily throughout his intellectual life, with an extensive card index. In an interview, Barthes described his method:

> I'm content to read the text in question, in a rather fetishistic way writing down certain passages, moments, even words which have the power to move me. As I go along, I use my cards to write down quotations, or ideas which come to me, and they do, curiously, already in the rhythm of a sentence, so that from that moment on, things are already taking on an existence as writing.[29]

From 1942 to his death, Barthes amassed 12,250 index cards, constantly rewritten and reordered. "There is a kind of censorship," he said, "which considers this topic taboo, under the pretext that it would be futile for a writer to talk about his writing, his daily schedule, or his desk". But as Barthes confessed:

> I have my index-card system, and the slips have an equally strict format: one quarter the size of my usual sheet of paper. At least that's how they were until the day standards were readjusted within the framework of European unification.

But Barthes found solace about his mental health in this unwelcome change: "Luckily, I'm not completely obsessive. Otherwise, I would have had to redo all my cards from the time I first started writing."[30] Once his papers became accessible to manuscript researchers, the scope of his card index could be studied. Written in pencil or blue ink, cards show quotes, observations, or diagrams; words or phrases are underlined, crossed out, or corrected. In the left or right top corner, he would note the date and page numbers of publications where he used the information on the card (e.g., a fiche on "acting out" refers to *S/Z* pages 71–72). Many cards show more than one use—including the passages noted by Mowitt.[31] Underlining or circling a word indicates it is taken up on another card (some cards list up to three such links). Outing his card catalog as co-author of his texts was "an anti-mythological action", he said: "it contributes to the overturning of that old myth which continues to present language as an instant of thought, inwardness, passion, or whatever." The editors of the exhibition catalog concluded that Barthes' *fiches* are not the carcass of an unfinished project, despite his sudden death in 1980.[32] The last course Barthes taught, however, was called *La préparation du roman*, preparing the novel. Spread over two years, it simulates exercises leading up to a novel; soon after the last class, Barthes died from injuries sustained in a traffic accident. On the one hand, his death might have prevented him from actually writing his novel; on the other hand, the entire seminar, now published as a notebook, marks the novel as a lost object from the start. A postscript to his *Lover's Discourse: Fragments* (1977) was going to discuss his card index and method of writing, as found only later among his papers.[33]

Tension between academic and literary production also propels a Swiss novel published posthumously in 2016, in a hybrid edition (in print and online) by the Swiss Literary Archives, presenting the textual genesis of a complex project. Hermann Burger's *Lokalbericht* is a playful book written between 1970 and 1972.[34] The typescript of 177 pages had rested in the archives in part because of its provocative format—it is construed as the mutual contamination of two expansive decks of index cards, one working toward an academic dissertation and the other toward a quasi-autobiographical novel by a doctoral candidate. Their mixing up and cross-fertilization (page 45f.) is owed to a purported challenge tossed off by the protagonist's thesis advisor, who joked about the career potential of an interpretation of a novel that does not yet exist—an invented time, place, and plot, an unknown author, an extended index card catalog on some 600 fragmentary pages somewhere between impressionism and expressionism, and *voilà*—the makings of a chair in new discoveries in literature. But realizing that creative ideas of this sort are all too rare in academia, the protagonist decides to explore this fantasy, and sets out to construe such a house of index cards, without completely abandoning his expected thesis on street names and places in the works of Günter Grass. Thus this card index novel starts with an imaginary letter to the advisor, along with the inevitable response the protagonist expects he would receive. In a historical context that sees Swiss literary figures and critics debate whether regional focus in writing is a limitation or a strength, a weakness or an intentional fountain of creative inspiration, the ridicule heaped on a dry-as-dust dissertation about place names and streets is only one elaboration of this debate, as Burger, throughout his career as a writer, emphasized the poetic potential of the local.[35]

The archival publication of the novel (in around 550 pieces) documents not only how Burger developed his verbal acrobatics, but also how, having been an advanced graduate student of literature at the University of Zurich for quite a while, he parodied and criticized academic prose in his work. The framing meta-fiction of a researcher struggling with two writing projects is an aspect of the novel that lends itself particularly well to a hyper-textual presentation.[36] That digital edition, prepared by the Swiss Literary Archive in collaboration with Cologne Center for eHumanities, not only presents high-resolution images of

the fragmentary typescript, but also documents the text-genesis with a range of variants and corrections Burger made, as well as an edited digital text version without any micro-genetic variances. Commingling traits of various genres, including but not limited to the *nouveau roman*, campus novel, ironic *Bildungsroman*, city novel, *roman a clef*, and picaresque novel, *Lokalbericht* is, above all, a meta-novel: a novel about writing and about the stakes of the 20th-century novel, with detailed reflections about production processes and conditions for crafting the narrative. When the protagonist interrupts his "local report" to intersperse letters to the reader or to characters in the book, he provides details not only about locations, place names, views, and other circumstances, but also, in one memorable passage, about the two typewriters he uses: ostensibly one for the dissertation and one for the novel, but soon they enter into other levels of competition. Describing them as a sporty red convertible and a classy grey-green sedan, a stylish Ferrari and a comfortable cruiser, he speculates about the best use of their different typefaces, and begins to worry about their rivalry. Soon he feels he needs to write about one on the other and vice versa—the well-damped luxury of the Hermes Media describes the thrill of the Olivetti Valentino (*sic*), the white letters on black keys here, black letters on off-white keys there, and so on (pages 21–26). The same recursive structure is observed in the two growing card indices that mutually contaminate each other, one aiming at a novel, one at a dissertation:

> Who pulls the hollow tooth within which the paper scrap with the story of the hollow tooth is hidden? Once there was an old man who had a hollow tooth. In that tooth there was a box, and in the box, a piece of paper that said: once there was an old man.
>
> (page 207)

Much the same mockery is directed at the academic and critical figures that are part of the framing narrative; Kleinert the professor and Neidthammer the literary agent are the beginning and the end of the literary frame, and both figures are barely veiled representations of real people (the Zurich academic Emil Staiger, who was in fact Hermann Burger's doctoral advisor, and the local literary critic Anton Krättli whom Burger had known since 1963). Indeed, the critic has the last word, advising the protagonist not to write the projected novel but to let the manuscript age a year, two years, ten years—the book closes with the critic's advice not to finish and publish that very book (page 228). And the more the protagonist accidentally mixes his notes for the novel into the notes for the dissertation and vice versa, the more obvious it becomes that the incompletion of the novel is a mere simulation, while the completion of a dissertation recedes into the distance with the increasing poetic use of the academic ideas about contemporary novels (page 101). Beyond this rivalry, however, the project becomes legible as an archival fiction, and archive novel, which the reader puzzles together from the index card notations that form a montage of varied textual and fictional or metafictional levels. Unsurprisingly, one finds references to other novels that rely explicitly on index cards, for instance Arno Schmidt's notorious *Zettel's Traum* (1970).

Voraciously citing, inveterately punning, Schmidt, like Burger, distilled his card index into literary texts, published as complex typescripts, photo-mechanically reproducing his montages without editing. Between 1963 and 1969, Schmidt worked on his 130,000 cards for up to 16 hours per day, producing a text of 1,130 pages, 13 by 17.5-inches in size, and managed to publish it as *Zettel's Traum* the following year. But he sought recognition not only as a creative writer, but also as a theorist of linguistic and stylistic elements of modern prose. According to Schmidt, only diaries constitute a serious attempt at dealing with

internal human processes—they help recollect, just as a photo album does, and Schmidt calculated the graphic dimensions of his textual arrangements so as to assist you in following certain associations and connections. Critics even speak of Schmidt's guidance "luring the reader into identification, into the *déjà vu* conviction that these recollections are his own".[37] Joining impulses from Joyce and Freud, among others, Schmidt documents how literature springs from less than divine sources. *Zettel's Traum* is an extended essay on E. A. Poe; over the course of 24 hours, the four protagonists discuss Poe's works, and Schmidt arranged his text in three parallel columns: the center column contains the action, the left one the Poe discussion, and the right column is made up of comments, footnotes, and auctorial opinions. Page (or card) 914 of this proto-hypertext contains the passage most critics view as the key to this gigantic structure.[38] Each of the four characters in this card index fiction is spaced out on Schmidt's pages in a collective score, and here, the book is allegorized as a quartet of voices—the voluptuous unconscious, the mean super-ego, the observant ego, and a fourth instance—something which, according to Schmidt, happens to men in their fifties, when the sex drive wanes and gives way to what the detached, smiling alter-ego of the author represents. Such unrelenting artifice stands in the way of naive investments in make-believe, auctorial inspiration, or genius.[39]

These textual devices have a long literary history, although it is relatively rare that creative writers make them known. Gerhart Hauptmann "wrote his nocturnal ideas on the wallpaper near his bed", then cut it up to paste it into his daily output.[40] Similar textures are also evident in Michel Butor's *Mobile* (1962), or in Vladimir Nabokov's *Pale Fire* (1962), a self-declared novel that falls into four parts: a preface, a poem, a lengthy annotation, and an index focusing almost exclusively on the notes.[41] In the preface, Nabokov recommends that readers start with the annotations, then return to them after cursorily picking the poem apart; he even goes so far as to suggest taking the book apart in order to cut-and-paste pages together at will, or at least buying a second copy to read them side by side. The poem itself is said to be written on 80 index cards of 14 lines each, as the preface dryly describes.[42] Similar concerns accompanied the posthumous publication of another Nabokov novel, or scraps for one, which is extant on index cards; indeed Nabokov wrote most of his novels, including *Lolita* (1955) and *Pale Fire*, on index cards. His novel *Ada or Ardor: A Family Chronicle* (1969) takes up over 2,000 cards, *The Original of Laura* (2009) consists of 139 transcribed cards.[43] Jules Verne's writing is equally illuminated by the reflective fire of a card index, since the source code for his science fiction was a box of some 20,000 excerpts and notes on scientific journals and books.[44] Raymond Carver taped citations and fragments on three- by five-inch cards to the wall beside his desk; Georges Perec, who had worked as an archivist in a scientific laboratory, likewise yielded to the "temptation towards an individual bureaucracy" and developed a complex filing system, using his index cards for most of his literary publications.[45]

From Individual Collections to Art Installations

> The card index marks the conquest of three-dimensional writing, and so presents an astonishing counterpoint to the three-dimensionality of script in its original form as rune or knot notation.
>
> —Walter Benjamin[46]

By 1969, it had become possible for Lucy Lippard to curate an art exhibit in Seattle titled *557,087* with index cards she had solicited, including from notables such as Eva Hesse and Robert Smithson, arranging black and white photographs and the index cards in glass cases.

Taking its title from the 1960 census figure for Seattle, the show was archived as revolutionary, despite and because of the fact that it did not leave behind paintings and sculptures, but a stack of 4- by 6-inch cards from around 60 artists, among them many names now famous for conceptual art or minimalism. The concept also traveled to Vancouver (where its title became *955,000*) and Buenos Aires (as *2,972,453*) before returning to the Seattle Art Museum.[47]

What art historian Aby Warburg laid out in his *Mnemosyne Atlas*, namely pattern recognition that operates by analogy and associative linking rather than diachronic filiations, finds its purest expression in art installations pivoting on index cards. But is notation on mobile paper slips outdated in the computer age, and reduced to ad-hoc jottings on sticky notes? Arguably, the card index influenced not only knowledge management, but interface design and creative processes.[48] A late example for the former: in 1981, when the Internet consisted of just 256 computers, Bob Kahn—co-designer of the TCP/IP networking protocol—was in charge of issuing Internet addresses, and carried around index cards in his shirt pocket to keep track of newly issued addresses.[49] As for the creative potential: it would appear to reside in part in material resistance on the one hand, and in harnessing chance on the other—as when Brian Eno designed a deck of inspirational cards titled "oblique strategies" (1975), or when Marshall McLuhan sold a deck of playing cards with provocative quotes as a management game called "Distant Early Warning" (1969). One wonders whether despite all the continuities in card index use over the centuries, there are not aspects of the index card catalog that are in peril of disappearing in the transition of valuable traits and affordances of index cards into other formats. Can everything be transcoded? This question motivated the artist David Bunn, who found pencil marks, hand-written corrections, drawings, finger prints, chocolate smears, and other manifestations of what he calls "subliminal messages" in the discarded card catalog of the Los Angeles Central Library. Focusing on these aesthetic communications that the electronic catalog did not preserve, Bunn developed art installations in dogged pursuit of contingent traces.[50] As if offering to make a connection between the aforementioned Roland Barthes exhibit at the Pompidou and David Bunn's art installations a continent away, Christian Marclay also mounted index cards so as to fill the walls of an art gallery, calling it "White Noise".[51]

A famously more conspiratorial example in the art world of the use of index cards involves Mark Lombardi. His drawings, based on his own index card catalog of public sources, trace relationships between powerful financial and political figures, such as oil companies, the Bush family, the Bin Laden family, and various banks. A few weeks after the September 11, 2001 terrorist attacks, an FBI agent called the Whitney Museum of American Art and asked to see a drawing on exhibit there.[52] Lombardi allegedly committed suicide the year before. Using just a pencil and a huge sheet of paper, Lombardi had created an intricate pattern of curves and arcs to illustrate the links between global finance and international terrorism. Meanwhile, a collector made a substantial offer to the show's curator, Robert Hobbs, a professor of art history at Virginia Commonwealth University, for the purchase not of any drawings, but of Lombardi's extensive index card collection.[53] Thus it appears that a poetics of intellectual capital can be embodied in the card index.

Other artists noted that an "index" can also denote repression and censorship. *The File Room* (1994) by Antoni Muntadas is one of the first widely recognized art works on the World Wide Web—a pioneering work of net art inviting online collaboration to document censorship (thefileroom.org). On display at the Randolph Street Gallery of the Chicago Cultural Center as well as online, *The File Room* started in May 1994 with 450 entries on censorship, from Athens in the fifth century BC to Salman Rushdie's *The Satanic Verses* (1988); viewers could ponder Diego Rivera's dispute with the Rockefeller Center over his depiction of Lenin, or TV moderator Ed Sullivan's request to The Doors to change one

line of their lyrics in "Light My Fire". Moreover, the installation invited members of the public not only to browse the card index or website, but also to add entries about current or historical bias regarding religion, ideology, or sexual orientation. Visitors in Chicago and online were able to interact and contribute, emphasizing that an archive of censorship can never be closed or complete. The installation featured a computer on a desk, surrounded by 138 black metal filing cabinets of four drawers each; seven of the 552 cabinet drawers were taken up by computer monitors. *The File Room* offers definitions of censorship, an archive of cases, an interface used to submit additional cases, a bibliography, and a search tool—by date, subject, location, and medium. Today, the National Coalition Against Censorship maintains *Censorpedia* (wiki.ncac.org) as a participatory wiki of censorship from antiquity to the present, building on Muntadas's *File Room*.

Censorship is a thorny topic, as it seeks not only to suppress images, sounds, and words, but also to hide the means of suppressing them. Muntadas called himself an "information analyst".[54] As Edward Shanken writes, the creators of *The File Room* were "concerned about the potential of technology both to support and resist censorship".[55] As with his pioneering contributions to CD-ROM art in the 1990s, Muntadas put some thought into affording interactivity without yielding control over the installation to viewers, balancing access with maintenance, both in the card index and online. Announcing *The File Room* during a residency in September 1993 at the University of Illinois, Muntadas worked with gallery director, Paul Brenner, as project manager and Maria Roussos as hypertext developer for over two years. Drawing on the capabilities of the NCSA Mosaic browser (1993–1997) and starting with definitions before branching out into cases, *The File Room* comprises examples from visual art, music, dance, and literature. Curator Steve Dietz associates Muntadas's art with the "dream of the open work" as inspired by Umberto Eco: "one of the strongest shifts of emphasis in the digital age has been on the production side and on the movement from creating finished works of art to creating systems for the production of art".[56] As Muntadas moved beyond the gallery's index cards onto the Internet, he described the project as "a social sculpture *à la* Joseph Beuys which gains its meaning through a group effort".[57] Institutions taking on net art and web art (such as the ZKM in Karlsruhe, the Walker Art Center in Minneapolis, the Whitney Museum in New York, and the San Francisco Museum of Modern Art) emphasize that this is not merely a different exhibition space, but a different modality for aesthetic communication.[58] Muntadas's *The File Room* is indebted to conceptual works of the Art & Language collective—card stacks such as *Index 01* (1972), eight cabinets of variable dimensions (like columns topped with drawers) and photostats; *Index 2* (1972), consisting of a similar installation and surrounded by a wallpaper of index cards, plus file boxes on a table; and *Index 5* (1973), offering "instructions for reading the index". These installations, pillars of database art, illustrate how information lies dormant until it is accessed through an interface, but also how that same interface might distort information. They illustrate the perennial tension between attempts to erase, suppress, or hide information, and efforts to document historical, geographical, and topical dimensions of creation and censorship. This tension motivates art projects with index cards in the computer age, counting on the material resistance of analog remainders.

Notes

1 Daniel Dennett, *Darwin's Dangerous Idea* (London: Penguin, 1995), 202, alluding to Samuel Butler (who wrote in his *Life and Habit*, 1877, that "a hen is only an egg's way of making another egg").

2 British Society for the History of Science, "Carl Linnaeus Invented the Index Card," *Science Daily* (June 16, 2009), www.sciencedaily.com/releases/2009/06/090616080137.htm. Compare Jonathan

Schiffman, "How the Humble Index Card Foresaw the Internet," Popular Mechanics (February 11, 2016) www.popularmechanics.com/culture/a19379/a-short-history-of-the-index-card/

3 Vincent Placcius, "De scrinio litterato," *De arte excerpendi* (Stockholm and Hamburg, 1689), 121–159.

4 Christoph Gottlieb von Murr, "Von Leibnizens Exzerpirschrank," *Journal zur Kunstgeschichte und allgemeinen Litteratur* (1779), #7, 210–212.

5 Conrad Gessner, *Pandectarum sive partitionum universalium libri XXI* (Zurich 1548); see H. Wellisch, "How to Make an Index—16th Century Style: Conrad Gessner on Indexes and Catalogs," *International Classification* 8 (1981), 10–15.

6 Christoph Meinel, "Enzyklopädie der Welt und Verzettelung des Wissens: Aporien der Empirie bei Joachim Jungius," in Franz Eybl, Wolfgang Harms, Hans-Henrik Krummacher, and Werner Welzig eds. *Enzyklopädien der frühen Neuzeit. Beiträge zu ihrer Erforschung* (Tübingen: Niemeyer, 1995), 162–187.

7 "Apparition de la fiche et constitution des sciences humaines: encore une invention que les historiens célèbrent peu." Michel Foucault, *Surveillir et punir. Naissance de la prison* (Paris: Gallimard, 1975), 287, referring to A. Bonneville, *De la recidive* (Paris, 1844), 92–93.

8 https://hollisarchives.lib.harvard.edu/repositories/4/resources/4004. Compare Markus Krajewski, *Paper Machines: About Cards & Catalogs, 1548–1929* (Cambridge: MIT Press, 2011).

9 Hans Petschar, "Einige Bemerkungen, die sorgfältige Verfertigung eines Bibliothekskatalogs für das allgemeine Lesepublikum betreffend." In Hans Petschar, Ernst Strouhal, and Heimo Zobernig eds., *Der Zettelkatalog. Ein historisches System geistiger Ordnung* (Vienna: Springer, 1999), 17. Compare Heike Gfereis and Ellen Strittmatter, eds., *Zettelkästen. Maschinen der Phantasie* (Marbach: Deutsche Schillergesellschaft, 2013).

10 Wayne Wiegand, *Irrepressible Reformer: A Biography of Melvyl Dewey.* Chicago: American Library Association, 1996.

11 John Locke, "Méthode nouvelle de dresser des Recueils communiquée par l'Auteur," *Bibliothèque Universelle et Historique* (Amsterdam, 1668), vol. 2, 315–340; Jean Paul, *Das Leben des Quintus Fixlein* (Stuttgart: Reclam, 1987) and Jean Paul, "Die Taschenbibliothek," in *Sämtliche Werke* II:3 (Frankfurt: Zweitauseneins, 1996), 772; Ch. G. von Murr, "Von Leibnizens Excerpirschrank," *Journal zur Kunstgeschichte und allgemeinen Litteratur* VII (1779), 211; Markus Krajewski, "Zitatzuträger. Aus der Geschichte der Zettel/Daten/Bank." *Anführen—Vorführen Aufführen. Das Zitat in Literatur und Theorie*, eds. Nils Plath and Volker Pantenburg (Bielefeld: Aisthesis, 2002), 177–195.

12 Johann Jacob Moser, "Einige Vortheile für Cantzley-Verwandte und Gelehrte in Absicht auf Acten-Verzeichnisse, Auszüge und Register," *Lebensgeschichte, von ihm selbst geschrieben* (Frankfurt and Leipzig, 1777), vol. 3; Karl Rosenkranz, *Georg Friedrich Wilhelm Hegels Leben* (Berlin, 1844), 12; Hermann Schmitz, "Hegels Begriff der Erinnerung," *Archiv für Begriffsgeschichte* 9 (1964), 37–44; Friedrich Kittler, *Die Nacht der Substanz* (Bern: Benteli, 1989), 18.

13 Nora Barlow ed., *The Autobiography of Charles Darwin 1809–1882* vol. 1 (London: Collins, 1958), 137.

14 Beatrice Webb, *My Apprenticeship* (Cambridge: Cambridge University Press, 1926), 426–433; C. Wright Mills, *The Sociological Imagination* (London: Penguin, 1970), 217–245.

15 Jean-Baptiste Labiche, *Notices sur les depots littéraires et la révolution bibliographique* (Paris: Parent, 1880), 64; Hellmut Lehmann-Haupt, *Gutenberg and the Master of the Playing Cards* (New Haven, CT: Yale University Press, 1966). There is at least one book structured as a card game: Marc Saporta, *Composition numéro 1*: Roman (Paris: Seuil, 1962); see Reinhold Grimm, "Marc Saporta oder der Roman als Kartenspiel," *Sprache im Technischen Zeitalter* 14 (1965): 1172–1184.

16 Didier Eribon, *Conversations with Claude Lévi-Strauss* (Chicago: University of Chicago Press, 1991), vii–viii; Claude Lévi-Strauss, *Structural Anthropology* (New York: Basic Books, 1963), 129f.

17 Georg Henrik von Wright, "The Wittgenstein Papers," *The Philosophical Review* 78:4 (1969), 483–563, here: 487.

18 Innis Papers, Archives of the University of Toronto, Thomas Fisher Library, Box 8. The cards themselves appear lost, but a typescript based on them was published posthumously: William Christian, *The Idea File of Harold Adams Innis* (Toronto: University of Toronto Press, 1980).

19 Niklas Luhmann, "Kommunikation mit Zettelkästen. Ein Erfahrungsbericht," *Universität als Milieu*, ed. André Kieserling (Bielefeld: Haux, 1993), 53–61. Compare *Evernote* (http://evernote.com) and *Zettelkasten* (www.verzetteln.de/synapsen).

20 Niklas Luhmann, *Archimedes und wir. Interviews.* (Berlin: Merve, 1987), 142–149; William Rasch, "Theory of a Different Order: A Conversation with Katherine Hayles and Niklas Luhmann," *Cultural Critique* 31:2 (autumn 1995), 7–36.

21 Detlev Krause, *Luhmann-Lexikon* (Stuttgart: UTB, 2001); Claudio Baraldi, Giancarlo Corsi, Elena Esposito, *GLU. Glossar zu Niklas Luhmanns Theorie sozialer Systeme* (Frankfurt: Suhrkamp,

1997); Theodor M. Bardmann and Alexander Lambrecht, *Systemtheorie verstehen: Eine multimediale Einführung in systemisches Denken* (Wiesbaden: Westdeutscher Verlag, 1999).

22 Nic-las, 1999–2005, www.nic-las.com (30.11.2005); compare www.iasl.uni-muenchen.de/links/GCA-VI.2e.html

23 George P. Landow, "Hypertext, Metatext, and the Electronic Canon," in Myron C. Tuman ed., *Literacy Online: The Promise (and Peril) of Reading and Writing with Computers* (Pittsburgh: University of Pennsylvania Press, 1992), 67–94.

24 Katherine Hayles, "Information or Noise? Competing Economies in Barthes's S/Z and Shannon's Information Theory," in George Levine ed., *One Culture: Essays in Literature and Science* (Madison: University of Wisconsin Press, 1987), 119–142.

25 This was Paul de Man's attack on Barthes' literary-historical assumptions: "You distort history because you need a historical myth to justify a method which is not yet able to justify itself by its results," in Richard Macksey and Eugenio Donato eds., *The Structuralist Controversy: The Languages of Criticism and the Sciences of Man* (Baltimore: Johns Hopkins University Press, 1972), 150.

26 Roland Barthes, *S/Z* (Paris: Plon, 1970), 9–28, esp. iv, v, ix.

27 John Mowitt, *Text: The Genealogy of an Antidisciplinary Object* (Durham: Duke University Press, 1992), 117.

28 Mowitt, *Text*, 118. See Mowitt, "What is a Text Today?" *PMLA* 117:5 (2002), 1217–1221.

29 "An almost obsessive relation to writing instruments" (interview with Jean-Louis de Rambures of *Le Monde*, September 27, 1973), in Roland Barthes, *The Grain of the Voice* (Berkeley: University of California Press, 1985), 177–182.

30 Barthes, *The Grain of the Voice*, 182. My reading of Barthes' *fichier* has been indexed, as it were, by Rowan Wilken, "The Card Index as Creativity Machine," *Culture Machine* 11 (2010), 7–30.

31 Barthes' note card titled "fiches" reads: "D'origine érudite, la fiche devient le coin vengeur que le désir insère dans la loi compacte du travail. Principe poétique: ce carré savant ira dans le tableau de l'écriture, non dans celui du savoir."

32 "Le fichier n'est pas le livre à venir: il n'y a pas d'oeuvre manquante que quelques milliers de fiches inédites viendraient constituer. Barthes a écrit tout ce qu'il avait à écrire." Nathalie Leger, "Immensément et en detail," *R/B* (Paris: Centre Pompidou/Seuil/IMEC, 2002), 94. Co-editor Marianne Alphant thinks the notes for his last course limn the ichnographic *moi-poisson* book he was working toward: Marianne Alphant, "Presque un roman," *R/B*, 125–128. The executor of Barthes' unpublished papers also believes "these courses revolve around the idea of a possible novel, a novel that death prevented him from writing." Eric Marty, "Interview with Jacques Henric," *Art Press* 285 (December 2002), 51.

33 Roland Barthes, "Comment est fait ce livre," *Art Press* 285 (December 2002), 55; Daniel Ferrer, "Genetic Criticism in the Wake of Barthes," in Jean-Michel Rabaté ed., *Writing the Image: After Roland Barthes* (Philadelphia: University of Pennsylvania Press, 1997), 217–227. See Denis Hollier, "Notes (on the Index Card)," *October* 112 (spring 2005), 35–44. *Roland Barthes par Roland Barthes* "manifests the pleasure of auto-commentary and of reflexivity which includes the relation of the author to his manuscript," asserts Anne Herschberg Pierrot, "Les manuscripts de *Roland Barthes par Roland Barthes.* Style et genèse," *Genesis* 19 (2002), 195.

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39 Arno Schmidt, "Der Platz, an dem ich schreibe," *Essays und Aufsätze* vol. 2 (Zurich: Haffmanns Verlag, 1995), 28–31.

40 Günter Kunert, "Zettel," *Akzente* 33:5 (1986), 391–394. Also Francesco Sacchini, *Über die Lektüre, ihren Nutzen und die Vortheile sie gehörig anzuwenden* (Karlsruhe, 1832), 101–102.

41 Vladimir Nabokov, *Pale Fire* (New York: Putnam, 1962).

42 Brian Boyd, *Nabokov's Pale Fire: The Magic of Artistic Discovery* (Princeton: Princeton University Press, 1999); Markus Krajewski, "Ver(b)rannt im Fahlen Feuer. Ein Karteikartenkommentar," *Kunstforum International* 155 (June–July 2001), 288–292.

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44 Vladimir Stibic, *Tools of the Mind* (Amsterdam: Elsevier, 1982), 77; Stibic also mentions Jack London's index cards.
45 Raymond Carver, "On Writing," *Fires: Essays, Poems, Stories* (New York: Vintage, 1968), 22–27. Georges Perec, "Notes Concerning the Objects That Are on My Work-Table," *Species of Places and Other Pieces* (New York: Penguin, 1999), 145 and 152. Perec's novel *Life: A User's Manual* (London: Harvill, 1987) features characters who share his obsession with indexing; see also David Bellos, *Georges Perec: A Life in Words* (London: Harvill, 1999), 207.
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47 Jen Graves, "Dematerialized: A 1969 Exhibition on Index Cards," *The Stranger* (May 3, 2013), and Lucy Lippard, "Curating by Numbers", *Tate Papers No. 12*, www.tate.org.uk/research/publications/tate-papers.
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49 Katie Hafner and Matthew Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon and Schuster, 1996); Janet Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999); Michael Hauben, "Behind the Net: The Untold History of the ARPANET and Computer Science," www.columbia.edu/~rh120/ch106.x07
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54 Slavko Kacunko, *Closed Circuit* (Berlin: Logos, 2004), 305/372; see Antoni Muntadas & Anne-Marie Duguet, *Muntadas: Media Architecture Installations* (Paris: Centre Georges Pompidou, 1999).
55 Edward Shanken, *Art and Electronic Media* (London: Phaidon, 2009), 35.
56 Steve Dietz, "Ten Dreams of Technology," *Leonardo* 35:5 (2002), 509–522, here: 512.
57 Margot Lovejoy, *Digital Currents: Art in the Electronic Age* (London: Routledge, 2004), 248.
58 Steven Wilson, *Information Arts* (Cambridge: MIT, 2002), 563.

2

FROM HERO TO ZERO

The Rise and Fall of the Slide Rule as the Calculating Tool of Choice

Peter M. Hopp

The slide rule, the tool for all mathematical occasions. So it was for some 300 years. Those of us who used one for real at school, college, and at work in pre-calculator days, be it as engineer or academic, automatically reached for one when calculation of any sort requiring multiplication and division and more complex maths such as trigonometrical and exponential functions, was required. Most of us owned at least two slide rules, one 5-inch pocket device and a 10-inch desk model—though our transatlantic cousins were rumored to carry a 10-inch one in a scabbard hooked to their belts! Nothing as "flash" for us stiff-upper-lipped British. We had one in our brief cases. I cannot say I mourned my slide rules' passing when I bought my first calculator, a Sinclair Cambridge in kit form, in the early 1970s. That calculator, despite its idiosyncratic implementation, really was much quicker and more accurate. But was that extra accuracy really necessary? We had certainly got used to "good enough" answers with numbers of significant figures on our trusty slide rules. In any event, the slide rule's demise was not quite as quick as it could have been—I well remember my boss who had given me some horrible mathematical task to do being amazed when I completed the task well ahead of schedule. "How the blazes have you done that?" he asked. I proudly took out my shiny new Sinclair calculator and showed him. "Great heavens!" said he. "Go away and do it properly with a slide rule." Over the next few years the electronic pocket calculator became much more common and financially available and the slide rule was gradually relegated to a desk drawer. Like all new technology we had to learn the foibles of calculators. I can remember an inordinate amount of time being spent at work on an "invention" that was to revolutionize our workplace and make all of our fortunes. This turned into a chimera based on an apparent improvement in performance created by the fact that one divided by three and then multiplied by three again gave an answer 0.9999 on most early calculators! It was only after realizing that the next engineering generation was not as mathematically adept as we were that the loss of the slide rule and its attendant numerical methods became something to be valued. There was further evidence of this when recently a maths teacher relation confessed that she had no idea what a slide rule was or indeed what were log-tables. And what was more to the point, they did not teach such things anymore! Realization of the almost complete disappearance of a legendary and ubiquitous tool is now complete.

Genesis

The slide rule was invented at a period in history when mathematical calculation was becoming more complex, just as the technical world of that time such as astronomy and other

philosophical arts required the ability to perform reliable calculation much more quickly and accurately. The speed of the seminal inventions, their evolution and the further discoveries that allowed a device that we would now recognize to be developed, all followed each other in short order to create the slide rule.

The Reverend William Oughtred (1574–1660) is now universally recognized as the inventor of the slide rule sometime about 1622. Even so, at that time there was a heated argument about who claimed to have invented the device. Richard Delamain(e) (*c.*1600–*c.*1644), another mathematician also involved in the invention of a type of sundial, published his *Grammelogia or The Mathematical Ring* in about 1630. He was declared to be a charlatan and plagiarist, and his claim found to have actually depended on Oughtred's invention. But he was the first to write about slide rules. His claim was probably due to their common mathematical instrument maker Elias Allen. The date of the initial publications relating to Oughtred's slide rules is about 1631, although this date is by no means certain. Oughtred was an old-fashioned believer in understanding the craft of calculating at a time when few could even add reliably, let alone multiply or divide. Users of mathematical "trickery" such as a slide rule to perform calculations were branded "Jongleurs" (jugglers or tricksters, who did not necessarily understand the basics, but worked by rote). Thus it was Oughtred's pupil, William Forster, who persuaded Oughtred to allow Forster to edit on his behalf the first treatise on his slide rules, the *Circles of Proportion and the Horizontal Instrument* (1632), thus recording that Oughtred had invented a slide rule some years previously. This book described a circular slide rule initially made by Elias Allen (1588–1653), a leading mathematical instrument maker of his time, and then by others. At about the same time—and hence the priority debate—Forster published the information on Oughtred's slide rule with an Appendix: *"To the English Gentrie . . . the just Apologie of W. Oughtred against . . . the . . . insinuations of R. Delamain in a pamphlet called Grammelogia or Mathematical Ring, . . ."*. The contents of "*Grammelogia*" were described as a "*patchery and confusion of disjointed stuffe."* Fascinating stuff indeed.

The slide rule is an analog logarithmic device. It takes advantage of the mathematical feature whereby the addition of two logarithms is the equivalent of multiplying the numbers whose logarithm they are. The inverse is also true for division. It is thus also true that multiplying the logarithms by two is equivalent to squaring the numbers and so on. It therefore follows that there had to be further inventions, developments, and transpositions to logarithms before a slide rule as we know it could come into existence.

The seminal invention had to be logarithms themselves. Various efforts at producing a tool that we would now recognize as logarithms were attempted throughout Europe by Burghi and others. However, it is now recognized that it was John Napier, Baron of Murchiston near Edinburgh in Scotland, a true polymath of his period (1550–1617) who in 1614 actually was the inventor of logarithms. We have just recently celebrated, rather quietly, the Quadricentenary of this momentous work. This follows the much more extensive Tercentenary celebrations in Scotland in 1914, illustrating to some extent the demise in importance of logarithms. Napier's initial design of logarithms was not directly usable for a slide rule, nor indeed particularly convenient to use by the average "calculator". The design required translating into a more usable form—the now well-known logarithms to the base 10—by Henry Briggs (1561–1630), Professor of Mathematics at Oxford in about 1617, although most of his work was done at Gresham College. These are the logarithms that generations of school children and mathematicians alike used for calculation through to the present day. Many hundreds of different forms of logarithmic tables, with different systems of presentation and accuracy, were calculated and published in the intervening period. However, it was the four-figure log table which was the most popular and generally used

format. Seven-figure and higher precision tables were available for those requiring greater accuracy, and most laboratories and other major users would have had a set.

The next requirement on the path to the slide rule was for these logarithms to be transposed into a physical form. This form would be either a circular scale for a circular slide rule, or more commonly into a rectilinear form, onto a ruler. The best known of these is from Edmund Gunter (1581–1626), Professor of Astronomy at Gresham College in London, another polymath and prolific inventor who possibly as early as 1621, invented the Gunter Scale. This enabled a precursor to the slide rule, indeed an alternative form of logarithmic calculator—Gunter's rule—to be invented and come into use in its own right before the slide rule itself appeared.

Let us consider these inventions in greater detail. Without doubt, the momentous invention was Napier's logarithms. Interestingly and probably unsurprisingly, in parallel events on the continent we have attempts to develop similar calculating tools, but without the same success. These attempts attested to the recognized need for an improved method of performing sophisticated calculation at this time. We have observed that Napier was a polymath with many different ideas under his consideration. Not least of these was his work on theology, necromancy, and alchemy. He had a particular antipathy to the papacy, evidenced in what many still consider his most important work—ahead of his work on logarithms—his book published in 1593, *A Plaine Discovery of the Whole Revelation of St John* where he predicted the end of the world in 1688 or 1700. His *Mirifici Logarithmorum Canonis Descriptio*, which contained 57 pages of explanatory matter and 90 pages of tables of numbers related to natural logarithms, was published in 1614. This description of his great new invention, logarithms, started the exciting new world of accurate and speedy calculation. Sadly, Napier was to die shortly after his invention of logarithms, and even though the mathematical world largely recognized what a seminal point this was, Napier himself might not have been quite so convinced. In his *Rabdologie*, published posthumously in 1617, he proposed yet another mechanical method of multiplication, this time using a set of rods based on Arabic lattice multiplication—Napier's Bones. It is thus not unreasonable to speculate that perhaps he was not aware of how vital his previous invention of logarithms was, or indeed how useful it would prove to be for future generations of mathematical practitioners. He also produced other calculating tools such as the little known "Promptuary", an extension to his Bones, which was described later in the second edition of his *Rabdologie*.

The conversion of Napier's "natural" logarithms to the more useful logarithms to base 10 was something Napier himself had considered but had not attempted due to his ill health. Henry Briggs, who taught Geometry, Astronomy, and Navigation at Oxford, might have been prompted by Gunter to make the first of several four-day journeys to visit Napier in Scotland in 1616 after he had obtained a copy of Napier's *Mirafici*. He went to "congratulate" Napier and to "marvel" at this important invention. What a marvellous picture is painted! Briggs was ultimately charged by Napier with doing the conversion to base 10, for which he is now well known. To some extent, Briggs had a vested interest, as it was astronomical calculations among many others that would initially really benefit from this improved and simplified method of reliable calculation.

Edmund Gunter was another famous English clergyman, mathematician, geometer, and astronomer. Gunter is particularly remembered for his several inventions of Gunter's Chain, Gunter's Quadrant—yet another calculating device—and finally in 1620, the Gunter's Scale. This was another analog device initially invented to calculate logarithmic tangents. Gunter was mentored in mathematics by Briggs and he, too, eventually became Gresham Professor of Astronomy in 1619, a post he held until his death.

William Oughtred was the rector of Albury Church in Surrey, a mathematician and teacher, and the inventor of several important mathematical constructs including the decimal point and "X" for the multiplication sign, as well as inventing the slide rule. It is notable that Oughtred did not take the existing Gunter's scale, but instead used a circular form of the logarithmic scale to invent what was the first slide rule described in his *Circles*, though it is rumored that he had in fact taken two of Gunter's scales and run them adjacent to each other as the first rectilinear slide rule. It is also notable that the first circular slide rule used a single circular logarithmic scale and a pair of opening cursors to traverse the scale and perform the calculations. This is exactly the method many other later designs of circular and pocket-watch slide rules would use some 250 years later. In all probability, this was because it was much simpler to engrave only one set of logarithmic scales rather than the two that would have been necessary if he was to have logarithmic scales moving adjacent to each

Figure 2.1 William Oughtred by Wenceslas Hollar, unknown date, circa 1640 (public domain)

other. Oughtred, our hero as inventor of the slide rule, was a man of some character. He was colorfully described by John Aubrey (1626–1697), a biographer of the day:

> He was a little man, had black haire, and blacke eies (with a great deal of spirit). His head was always working. He would draw lines and diagrams on the dust. . . . he used to lye a bed till eleaven or twelve a clock, with his doublet on . . . studyed late at night, went not to bed till 11 a clock, had his tinder box by him, and on top of his bed-staffe, he had his inke-horne fixed. He slept but little. Sometimes he went not to bed in two or three nights, and would not come downe to meales till he had found out the quaesitum.
>
> (Aubrey, 1693)

He was both a famous teacher whose pupils included Delamain, Christopher Wren, and John Wallis and also a prolific writer. Among many other mathematical works, his *Clavis Mathematicae* (The Key to Mathematics) was an important mathematical work of the day, published in 1631. Just before he died he produced a book on watch-making for his son.

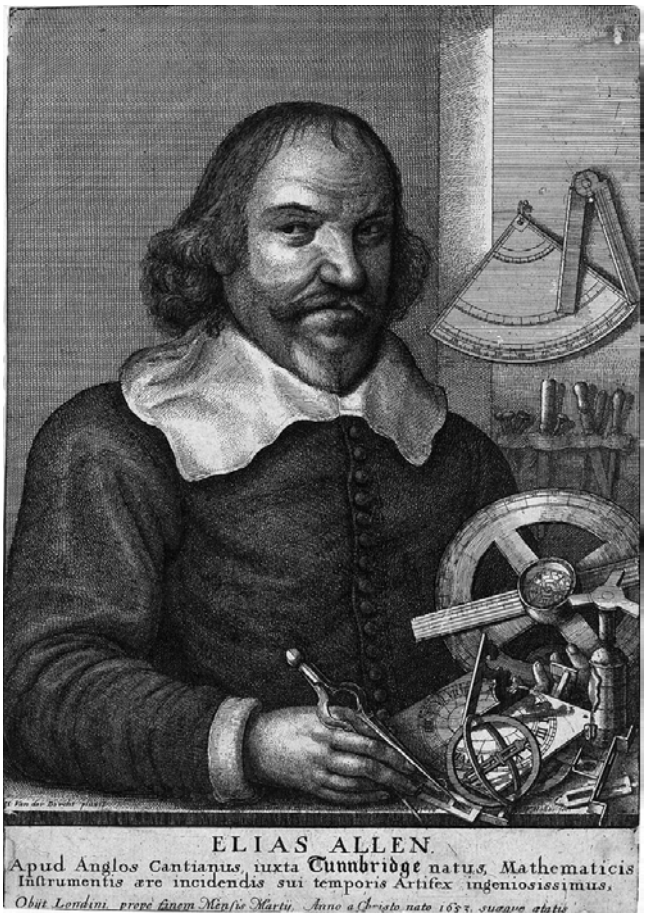

Figure 2.2 Elias Allen, also by Wenceslas Hollar, 1653 (public domain)

He was a truly great mathematician and a real character. Oughtred died after he had been rector of Albury Church for over 50 years and shortly after the restoration of Charles II to the throne.

Elias Allen was the pre-eminent London mathematical instrument maker of the time. He made the first example of "Circles of Proportion" for Oughtred, and subsequently made others. While he was making Oughtred's "Circles . . ." it was likely that Delamain saw them either at Allen's workshop or when he was with Oughtred and rushed to produce his own "Mathematical Ring". A set of these was presented to King Charles I with a claim for a patent on the device, which was never awarded. Florin Cajori (1920) provides a fascinating analysis of the whole saga. We are very fortunate that several examples of Elias Allen and other makers' Circles of Proportion are preserved in museums both in the UK and the USA and thus we are able to appreciate this leap in technology and the beauty and functionality of the instrument makers' art in these devices. No example of the Mathematical Ring is known.

This period of history, the beginning of the "Age of Enlightenment", is interesting in that many new and exciting methods of simplifying calculations were invented and coming into use. We see many earlier designs of calculating equipment such as the several different designs of the Sector already in existence, Gunter's Quadrant and Gunter's scales as well as "logarithms" from Burgi; Prostapharesis, the new logarithms from Napier and so on, all jostling for position and in many cases being further developed for a particular specialization. For example, Gunter's scales were used for navigating, both in the Merchant Navy as well as the Royal Navy, for many years through to the late 19th century. However, despite these minority methods of calculation, the slide rule gradually achieved ascendance in nearly all fields of calculation, both general and specialist. Other tools and devices fell by the wayside.

Evolution

Figure 2.3 An Elias Allen-made Circles of Proportion (circa 1648) from the National Museums of Scotland collection

We are able to follow the initial evolution of the slide rule via many general as well as specialist designs. The very first specialist design was produced by Oughtred himself in about 1633 for the Company of Vintners for gauging. This was a traditional rectilinear slide rule. Another very recognizable rectilinear slide rule due to Robert Bissaker is in the Science Museum and was made in about 1654, showing that interest was widening relatively swiftly. The earliest specialized slide rule to use a format that was subtly different was Henry Coggeshall's (1623–1690) timber contenting slide rules developed from about 1677 through to 1767, almost a century after its invention. This was then followed by Thomas Everard's (about whom very little is known other than he rose from Officer in the Excise in Southampton to Commissioner for Gauging in the Excise) gauging and alcohol and tax calculating designs in about 1683 which became established and continued in use through to the 20th century. Coggeshall's designs were embodied as a slide and logarithmic scales in one arm of a 2-foot, 2-fold measuring rule as already invented some 150 years previously and which would have been used by most artisans and craftsmen working in timber at that time. Everard's designs returned to an ingenious rectilinear design which were built into a different square-form rectilinear rule with slides initially on two sides, but soon expanding onto a third and finally onto all four sides of the square format. These were available in all lengths from 6-inch to 36-inch, allowing considerable accuracy in calculation at the longer lengths. It will be noted that these two major evolutionary designs were remarkably long-lived. All were available probably through to the beginning of World War I.

As other scientific development continued, we find many other special designs produced to achieve a particular result for specific fields. Many special scales came and went, however, some such as the log-log scales invented by Peter Mark Roget (1779–1869) in 1815 were used for different new developments in thermodynamics and other engineering fields. Roget is probably better known for his development of the Thesaurus bearing his name. Log-log scales achieved worldwide acceptance and many variants became standard on many designs of slide rule for general usage. This is yet another example of an idea that was re-invented on more than one occasion—by Thomson in 1881, and yet again by Perry (who patented his version) in 1901, and finally by Boardman in 1933. All these had some "improvements" on Roget's original 1815 idea, over a century earlier. The evolutionary period of the slide rule probably ended with the 18th century, and the final development period began.

Development

The slide rule had arrived and by the mid- to late-18th century had become generally accepted and used across the technological world. Development of the basic ideas continued on several fronts. The rectilinear slide rule was produced in several lengths to give increased accuracy, the most common standard size being the 10-inch desk model. However, the 5-inch pocket model was also produced in huge quantities. There were longer devices, the 20-inch being reasonably common, but somewhat unwieldy. We can identify several specific developments that characterized the advancement of the slide rule into a ubiquitous general calculating tool. We will look at two of these in greater detail. One particular development is the Soho engineering slide rule developed by James Watt (1736–1819) with the assistance of Mathew Bolton in his Soho "manufactory" in Birmingham in about 1790. Soho slide rules were especially recognized for their scale layout, and for their accuracy of scale design and production. The layout with two-cycle logarithmic scales on the top of the stock and on both edges of the slide continued through to the 20th century. This ensured that squares, required in many engineering calculations, were easily calculated by one two-cycle scale

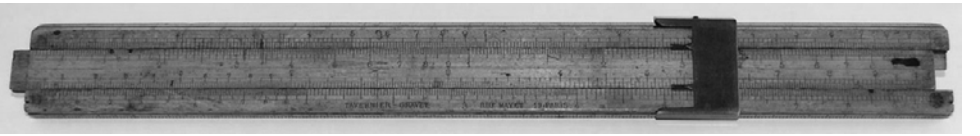

Figure 2.4 Mannheim slide rule made by Taverier-Gravet of Paris, the original manufacturers of such slide rules; circa 1900 (from the author's collection of images)

being adjacent to the single-cycle logarithmic scale on the second edge of the stock. This layout obviated the need for a cursor as the results could be read off directly. Soho rules also featured much sharper scale production with more and finer markings, taking advantage of the recently developed dividing engines and so ensuring increased accuracy.

Our second example is the cursor. This is also the final item of slide rule equipment needed to make the 20th-century slide rule ubiquitous. The cursor was the device that simplified slide rule use by enabling results found on one set of calculating scales to be transferred to another scale, or different type of scale, and if necessary back again. These pairs of scales could be either on the front and/or the back of the slide rule, and intermediate results did not have to be memorized. It is said that Newton (1643–1727) used the first "cursor"—a hair—to enable squares to be calculated. However, the cursor as we know it with a fine hairline etched on a glass screen, in its movable frame, became the final part of the slide rule design we all know and recognize and was to be omnipresent until the end of its life. The cursor plus the Mannheim scale layout, named after Amédée Manheim, a French Artillery officer (1831–1906), who developed and gave his name to this collection of features, was the final improvement in what became a standard slide rule layout. It appeared in about 1851. There were many further detail changes, but the slide rule was now set. Among other important details we can include the reciprocal scale, now positioned generally in the middle of the slide, a change attributed to Max Rietz, (1872–1956) a German steam engineer who gave his name to the Rietz (or Reitz depending which side of the English Channel was writing) pattern of slide rules which existed from about 1910. We now have the final physical design of slide rule and layout of scales that was instantly recognizable across the technological world and continued to be manufactured worldwide until the demise of the slide rule.

We can identify further design features that contributed to the total *oeuvre* of slide rules. One type that became very popular was the true duplex slide rule with scales on both sides of the stock and/or stator, which were synchronized—that is, the index marks all coincided. There had been duplex and indeed multi-scale rules such as the many designs of alcohol and revenue calculating rules, with two, three, and four slides and sets of scales, but perhaps surprisingly these were never synchronized (the index points of the scales did not all coincide). The first true duplex slide rule was invented in the United States and patented by William Cox in about 1891, and sold by instrument makers Keuffel & Esser in New York. Extreme examples of duplex slide rules with over 30 different scales were developed and manufactured enabling a mighty suite of calculating tools to be accessed by the user. There are also very specialized designs for many and varied uses, as wide ranging as esoteric black body radiation calculations and simple speed–time–distance calculation; with many other even more arcane specializations along the way.

It is also educational to look at the original circular designs and spiral scale designs which started with John Brown and Henry Sutton's designs of 1660 and 1663 and continued in various shapes and sizes through the whole lifespan of the slide rule. There were also several

helical scale designs which had their champions. These all found their adherents and produced very interesting designs which were all manufactured throughout the existence of the slide rule.

Demise

The demise of the slide rule started in about 1970, contemporaneously with the appearance of the first affordable electronic calculators. The demise occurred amazingly quickly. It took place over very few years, with most of the big manufacturers ceasing manufacture of all slide rules after about 1980. The industrial archaeologist would have great difficulty in finding any other device of such importance which disappeared from general use as quickly as the slide rule. The generally accepted reason for this swift demise was the advent of the electronic calculator, followed swiftly by the affordable pocket electronic calculator. Definitions of "affordable" and "pocket" notwithstanding, the appearance of the HP-35 (35 from the number of keys it had) electronic slide rule calculator in 1972 probably signaled the real beginning of the end for slide rules. The HP-35, at $365 in the USA and £365 in the UK, was many times more expensive than even the finest quality slide rule. However, the sheer convenience of being able to press buttons to perform sophisticated calculations—including addition and subtraction—with results to many significant figures, was very appealing. Other designs of small electronic calculator had preceded the HP-35. Bowmar in the USA is generally credited with the very first design, and many other well-known and less well-known makers all produced electronic calculators in an attempt to get a foothold in this new and exciting market. It is interesting and notable that many early designs were marketed as "slide rule calculators" because initially the electronic calculator struggled to find its niche in the calculating firmament, and this marketing trick served to slot the new calculators into a place in the calculating cosmos. As a young electrical engineer at that time there was no way that I could have afforded an HP-35. Their price was equivalent to many weeks' wages and there was not the same appreciation of gadgets or high technology that is a feature of modern day marketing and life. I believe I was typical of my peers at that time and it was the advent of Sir Clive Sinclair's much more affordable—and attainable—calculator technology a very few years later, such as the Sinclair Cambridge in 1973 in its many forms, that finally convinced me to move to a calculator from my trusty slide rule. These Sinclair calculators were also available in even cheaper kit form, and most engineers, electrical as well as mechanical and civil, at that time were well able to put together electronic kits, whether they were for high-fi, amateur radio, calculating, and later for computing. Sinclair's marketing strategy was also brilliant; if it did not work, return it to the company and a working calculator would be returned! This was a quite incredible offer, and was just one of the elements that made them so attractive to buyers. Even so, it was still several years after I bought my first calculator that I finally consigned my slide rule to a peaceful end in my desk drawer—although it was still somehow easier to use a slide rule for quick and dirty calculation, and I still have one on my desk as I write this. There was a down-side; early calculators used batteries at a phenomenal rate. This was a cost not found with a slide rule!

There were numerous ill-fated attempts at extending the life of the slide rule. Perhaps the saddest was the attempt by Faber-Castell in Germany (one of the largest manufacturers of slide rules in the world) of adding an electronic calculator to the reverse of a slide rule. Several such models, with increasingly sophisticated calculators, were produced. How many owners of what was a very expensive slide rule ever used the slide rule in preference to the calculator is not known! It was an understandable development when it is realized that

Faber-Castell, together with other manufacturers, had previously manufactured both 5-inch and 10-inch slide rules with a Pescaline/Troncett adder on the back, called an "Addiator", and these had successfully sold. While this form of adder had been a useful development allowing addition and subtraction, it was definitely redundant to have a sophisticated electronic calculator performing every function that was available on the slide rule—effectively rendering the slide rule obsolete!

The slide rule ethos means that there is now a whole generation, which is fast disappearing, who can remember what a special occasion the purchase of our first slide rule was. This would have followed an extensive and careful selection process with much discussion and deliberation. This culminated in the actual day of purchase—usually preceding another special day or rite of passage—the first day in 6th form, start of National Certificate or Diploma courses, technical college, university, and so on, complete with that shiny new slide rule. The slide rule was not something that was changed for a newer and better example on an almost annual basis as is so much of today's technology. As the saying goes: "A slide rule was for life, not just Xmas!" It was possible that one would buy a better slide rule, better in either or both quality of manufacture or scale selection if it was found that one's first bought was lacking in specific capability or falling to pieces. In general though, the selected slide rule was a one-off purchase for life, an attitude that is totally at variance with today's technological lifecycle. While I now have a multitude of calculators of varying cost and capability, I only ever had one pocket and one desk slide rule. As a collector, I now have over one thousand, but that is as a collector and never as the real-life user that I used to be.

Slide Rule Mathematics

The ubiquity of the slide rule is not immediately obvious until one studies the history of technology across the developing world. When this is done, one finds that every one of the modern wonders of the technological world were developed using a slide rule. A few moments' thought will show that this has to be so—there was no other form of calculator available! Thus all technologists who had to calculate would have had a slide rule, and undeniably they were so ubiquitous that this fact of life is almost never mentioned in autobiographies of the famous designers and engineers. Just a few examples will show what I mean. Sir Frank Whittle inventor of the jet engine was a slide rule user, and James Watt, inventor of the steam engine was a slide rule inventor and user. Many of the Manhattan Project members have been proudly pictured with their slide rules. Authors Robert Heinlein and Arthur C. Clarke were slide rule users, Clarke being christened "Fastest slide rule in Whitehall". Aircraft designers Frederick Handley Page of the UK, Sergei Korolev, "father of the Soviet Space Race", as well as Wernher von Braun his opposite number in the USA, were slide rule users. Architect Frank Lloyd Wright and David Packard of Hewlett Packard fame were users. This is a wide variety of technologists, and there are many others we could also name. How do we know this? They were all proudly photographed with their slide rules. It is an enduring legacy of which we can all be proud. The engineer and technologist were synonymous with a slide rule!

The slide rule by its very design required a familiarity with the order of magnitude of the numbers involved in a calculation. Virtually all books on the slide rule and any training course concentrated for a proportion of their time on the fact that, for example, the "2" on the "C" scale could mean 0.002, 0.02, 0.2, 2, 20, 200, 2,000, etc. Performing the calculation then took place with the final decimal point being placed after an "order of" calculation had been performed. Most of my generation of technologists and mathematicians will look

at a sum written down and mentally work out its order of magnitude. This sum could involve many multiplications and divisions as well as trigonometrical or other functions. Quick mental arithmetic together with an essential knowledge of some common trigonometrical and square function values would enable one to come to this order of magnitude value fairly rapidly and almost automatically. The design of the slide rule with its single-cycle "C" or "D" logarithmic scale used in the majority of calculations was numbered from "1" at the left-hand end of the scale to "10" at the right-hand end. However, depending on the calculation at hand, those numbers could mean any decade one wished, provided one was consistent throughout the calculation and, most importantly, kept track of the decimal point. As mentioned, the slide rule user had already instinctively looked at a calculation and came up with an "order of answer" before carrying out the calculation in detail. The slide rule itself, by the nature of its markings, was only capable of giving two or three significant figures (depending where on the logarithmic scale the answer was found) which meant that users developed a "good enough" approach to the accuracy of that answer. Where greater accuracy was essential, one used either a longer slide rule—20-inch was not unusual, and there were some special monsters designed—or else some alternative extended format such as helical or spiral scales to give a much greater scale length within a workable slide rule size. If all else failed, then one had to resort to 7-figure logarithms or alternatively some form of mechanical or early electronic calculator. I can well remember that while at college we were recommended to attend a course on the use of the Brunsviga mechanical calculator (and indeed, the incredible tearing noise it made when subtracting 1 from 0.9999). Later, I can remember having to "book out" and use the one and only early Facit electronic desk calculator we had on site, complete with its row of glowing "Nixie" number tubes, capable of working to 13 digits. This was required to perform electronic equipment reliability calculations which were impossible on a slide rule and really beyond 7-figure logarithms as well.

The slide rule's inability to be used for addition and subtraction meant that many people who had to work with such numbers—for example, monetary calculations in £. s. d., with its 12 pennies to the shilling, and 20 shillings to the pound—developed a special capability in addition and subtraction. There were many people who were capable of adding a column of figures as fast as the pencil could be run down the column. This was most impressive to witness in action. There were also many mental tricks that were used in simplifying multiplication and division. Certainly all of my peers would have known to the penny what change they expected from a tendered note for any shopping—without having to resort to looking at the till! It is sad that there are films (such as *Apollo 13* (1995)) which show a slide rule apparently being used for addition and subtraction. When ignorance is bliss it is truly folly to be wise!

The modern generation's reliance on the electronic calculator has resulted in a loss of numeracy and facility or comfort with numbers and an over-reliance on spurious accuracy. An example is the asinine statement that one hears where in any conversion, say, from miles to kilometers, the result is regularly stated to three significant figures (at least!). All this is now even further exaggerated when Microsoft's on-screen Personal Computer calculator in the latest versions of Windows can present results to no fewer than 32 significant figures and with a heady four-digit exponent in scientific mode. This inevitably means that conversions are presented with totally unrealistic and unnecessary accuracy, something that the slide rule user would find most unsatisfactory. This is but a part of our loss of understanding of the significance of the numbers being quoted.

The Digital Revolution is no longer part of the "burning heat of technology" and there is a certain irony that the very calculating device that will have produced that revolution is