Challenging Collections

APPROACHES TO THE HERITAGE OF
RECENT SCIENCE AND TECHNOLOGY

Edited by Alison Boyle and Johannes-Geert Hagmann

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Contents

Reflection

Conceptualizing Contemporary Collecting

Networks of Collecting

Dialogue and Diversity

Alternative Approaches

Insights and Experiments

Series Preface

Science and technology have been defining elements of the modern era. They have entered into our lives in large and small ways—through broad understandings of the universe and in the tools and objects that make up the texture of everyday life. They have been preeminent activities for organizing expertise and specialized knowledge, in defining power and progress, and in shaping the development of nations and our relations with others across the planet. In 1996, the Smithsonian Institution, the London Science Museum, and the Deutsches Museum formed Artefacts to emphasize the distinctive role that museums—through their collection, display, and, especially, study of objects—can play in understanding this rich and significant history.

Artefacts has two primary aims: to take seriously the material aspects of science and technology through understanding the creation and use of objects historically and to link this research agenda to the exhibition and educational activities of the world community of museums concerned with the intimate connections among material culture, the history of science and technology, and the transnational. The effort gradually has gained footing: Artefacts holds an annual conference and has expanded its formal organization to include fourteen cosponsors (listed on this volume's copyright page). This expanded community, composed primarily of European and North American museums, provides opportunity for more robust professional conversation and broadens the range of local and national historical experiences of science and technology represented in Artefacts. Not least, Artefacts has created a fruitful interplay between scholarly research and museum practice. Aided by its Advisory Editorial Board, it publishes this book series, which, in conjunction with annual meetings, has helped stimulate a broader turn toward material-based research in scholarship and its use in museum collecting and exhibitions.

The Artefacts community believes that historical objects of science and technology can and should play a major role in helping the public understand science and technology: the ingenuity associated with these activities, their conceptual underpinnings, their social roles, and their local and global connotations. We welcome other museums and academic partners to join our effort.

Martin Collins
National Air and Space Museum, Smithsonian Institution
Series Managing Editor

Introduction

"Research not communicated is research not done," warned Anne Glover, then chief scientific adviser to the president of the European Commission, in 2014.[1] We might extend this to say that scientific research not preserved in some form may in future never have been done so far as the historical record is concerned. Likewise, museological research and practice not shared is not fully or usefully done: thus, the rationale behind the Artefacts consortium and its annual meetings is to provide a forum for communication for people from a range of disciplines concerned with the material culture of science and technology.

In 2011, Artefacts XVI at Museum Boerhaave in Leiden addressed the theme of "Conceptualizing, Collecting and Presenting Recent Science and Technology." Building on the research presented at the meeting, this volume will focus on the question of collecting post–World War II scientific and technological heritage and the equally challenging question of how such artifacts can be displayed and interpreted for diverse publics.

However, this volume also has another aim, as indicated by the ambiguity of the title *Challenging Collections*. In addition to examples of practice and the inevitable detail associated with these, we have invited prominent historians and curators to reflect on the nature of recent scientific and technological heritage and to challenge the role of museum collections in the twenty-first century.

Challenges of Contemporary Collecting

The interpretation of contemporary scientific and technological heritage is a challenging subject for curators and scholars for a number of reasons, for example:

1. *Mass and Scale.* During the twentieth century, notably from World War II onward, scientific and technological research saw a dramatic increase in the use of resources, in particular in the dimensions of human labor and financial effort. As a consequence, the number and size of equipment, prototypes, samples, and setups have significantly grown also, and a curator attempting to formulate well-thought-through rationales for the preservation of cultural memory may be overwhelmed by the extent of the task.

2. *Delocalization.* The places of research activity today can be difficult to identify and discern. The mobility of both thinkers and their equipment, moving rapidly between different spaces and working in international and interdisciplinary networks, leads to a multiplication of contexts that need to be studied, discerned, and museologically interpreted, often a change

from the locally or nationally specific contexts in which artifact-based collections were first conceived.

3. *Uniformity-Immateriality-Opacity.* By their very nature, many artifacts of science and technology from the past 60 years pose a challenge to preservation, study, and interpretation. Specialization, miniaturization, mass production, the use of new materials, and the omnipresence of electronics have led, among other factors, to highly complex and professionalized equipment for research that is both modular and opaque in appearance. The frequent exchange and reusage of components, sometimes called cannibalization of research equipment, adds to the difficulty of identifying particular artifacts worthy of preservation.

While bearing these factors in mind, we should be cautious to avoid thinking that today's artifacts mark a uniquely difficult juncture for the collector or scholar. As Jim Bennett reminds us, the material record is only ever a partial one: we must be conscious that any collection of artifacts represents what was collected, rather than what was actually there.[2] Meanwhile, Jeff Hughes has argued that the challenge of working on recent history is not methodological so much as political—there is *always* too much source material no matter what period you are working on, and it is the historian's job to manage the scope.[3]

As Hughes notes, the particular challenge of working on recent material is usually not artifacts, but people—the actors who own the artifacts, documents, or memories and who often have their own cherished histories to be negotiated by the scholar.[4] This can be particularly pressing when an artifact is not only collected but exhibited. Public exposure is a valuable commodity, and as Joseph Tatarewicz attests, the prestigious spaces of museums can be highly contested; the often-congealed histories of artifacts can lead to disagreements between contemporary actors over how they should be interpreted.[5] Actors in the museum world inhabit what has been termed an "ecosystem of collecting," with the curator often acting as intermediary in a network of "tastemakers" (including artifact makers, collectors, educators, and media) and as the interpreter of artifacts for the public.[6]

The Changing Role of Collections

In this volume we aim to reflect on not only the nature of scientific and technological artifacts post World War II but also the nature of today's "museum ecosystem" as it has emerged over this period. Museums are no longer primarily repositories that preserve and classify material culture. They must balance a number of functions, not always mutually compatible: exhibition, preservation, research, and education. Collections can be regarded as important material resources for historians of science and technology who in recent decades have moved on from telling narratives of progress to exploring science and technology in a wider cultural, social, and political context. Meanwhile, over this period the nature of museums' relationships with their public has shifted from one of unquestioned authority to a partner in dialogue: visitors' needs are now considered foremost in exhibition interpretation, and the public may even have a say in shaping collections.

Although many science and technology museums were originally envisaged with an educational remit and the artifacts they contained became historic with the passage of time, in recent decades curators and collectors have been increasingly informed by the emergence of academic disciplines of science and technology studies, and the history of science, technology, and medicine.[7] Thus, an artifact's current pedagogical value and future historical value must both be taken into account at the time of collecting; as Bruce Altshuler argues, "contemporary works valorized by entering museum collections—and, to a lesser extent, by being exhibited in museums—are in a sense projected into the future, identified as playing a role in an anticipated history."[8]

In this context, we have invited historian of science and technology Dominique Pestre to provide a reflection on the present state of the sciences. Tracing the changing nature and circulation of modern science and its products over the past 200 years, he notes how science has been situated between different politics, markets, and publics. He challenges us to move away from idealized narratives of science to consider its blind spots and the downsides of progress and to foreground ordinary human experience. Although science and technology will continue to be at the core of knowledge, we should be careful to appraise novelty critically, to reflect on our present experience within the broader narrative of modern science. He argues against developing overly generic or strict criteria for understanding twentieth- and twenty-first-century science and technology; instead, we must facilitate an ongoing dialogue, acknowledging that dissent and diverging opinions are a normal facet of how we make sense of the world.

In our experience, colleagues from different disciplines concerned with the material culture of science and technology have already made progress toward addressing Pestre's challenges; however, as is common for work in progress, much of the dissemination of this work has been of the nature of informal conferences and reports within particular professional disciplines, and there have been few broadly scoped accounts of the state of the field.[9] This volume seeks to gather a range of accounts from around the world, showing a variety of activities and approaches in conception and execution of collecting practice. Reflecting this variety, the volume contains a range of styles, from theoretically grounded arguments to practical reports to personal perspectives.

Conceptualizing Contemporary Collecting

In building collections that help us make sense of the world, the framework of the historian must be combined with the material knowledge, experience, and sometimes sheer instinct of the curator. In the volume's first section, we have asked leading curator-historians to reflect on what historiographically informed collecting practices might look like when concerned with contemporary material culture.

John Durant argues that museums are uniquely positioned to tell rich and meaningful stories about the place of science and technology in late twentieth- and early twenty-first-century society as a contribution to a "thick description" approach: several of the artifacts he describes

have negligible economic or aesthetic value but pack a powerful emotional punch. Martin Collins suggests that collections of science and technology need to be shaped with consideration of the historiography of the period as an ex post approach, providing the example of the spaceflight collections of the National Air and Space Museum, Washington, D.C. Robert Bud argues that the inherently ahistorical category of "contemporary collecting" can be analyzed historically, exploring its various manifestations over the twentieth century in the Science Museum, London. Henry Lowood's chapter charts the growth of new kinds of artifacts and collections responding to an increasingly digital world, which within most museums still remains an area for pioneers.

Networks of Collecting

The rest of the volume is concerned with case studies illustrating aspects of contemporary collecting in practice. Our next section explores how today's global science and technology are being reflected in collecting practices on the national and regional scales; on these scales various political and economic trends inevitably influence how artifacts are chosen for collection and display. As Jia-Ou Song and Dagmar Schäfer show, science and technology collections in China are currently growing in light of a policy-driven boom in contemporary science museums and their social value in building local and national identities. In contrast, France's now well-established national program prioritizes preservation over museum collecting, leaving it to future generations to decide what is valuable: Catherine Cuenca and Serge Chambaud report on the creation of decentralized repositories safeguarding artifacts of science and technology.

Dialogue and Diversity

We then zoom in on case studies from institutions around the world, showing how today's collectors are negotiating with a range of people and practicalities and developing their own particular solutions. The very different collections of Jennifer Landry and Rosie Cook and of Anna Adamek, encompassing specialized chemistry instruments and everyday kitchen technologies, contain artifacts of strong emotional value to their original owners and users; both have been shaped in recent years by also taking into account the value judgements of various museum audiences and foregrounding personal stories. Sometimes the historical value of artifacts may be fairly readily agreed on by interested parties, but the logistics of preservation are more complex and often locally specific. Finn Harald Sandberg and Kristin Ø. Gjerde describe the creation of digital repositories documenting Norway's oil platforms, whereas Teresa Anderson and Tim O'Brien outline the challenges of balancing the preservation of historically important radio telescopes against their value as working scientific instruments.

Alternative Approaches

Our next two contributors, from within museums and without, offer some alternative perspectives on recent collecting practices. Olov Amelin questions whether explicitly stated rationales, including those present in contributions to this volume, are desirable at all, offering

insights from non-method-oriented practices at the Nobel Museum. Karen A. Rader describes the growth of an anticollection science center movement inspired by the Exploratorium, challenging the primacy of artifacts—and also asking us to rethink what we mean by *artifact* by considering whether interactive exhibits might constitute valuable material records in their own right.

Insights and Experiments

Our final section offers a new addition to the usual Artefacts volume format. Bearing in mind the work-in-progress nature of our topic, we interviewed professionals from different disciplines about their present experiences in the field; their frank insights show the dynamic nature of working with recent artifacts. James Hyslop offers insights into a world largely neglected by contemporary museum studies: the commodification and circulation of recently made scientific artifacts in the private collectors' market. Osamu Kamei describes research-based efforts to document Japan's industrial and technological heritage, citing case studies of research in progress. Universities play a very special role in contemporary heritage efforts as they are particularly close to the spaces of the production of knowledge and artifacts. Roland Wittje reflects on his engagement with collection in university environments over more than a decade. Finally, Thomas Söderqvist offers a personal view as historian of contemporary science and technology turned curator advocating relinquishing the narrative-oriented approach common in many museums in favor of strategies driven by the artifacts themselves.

These interviews, and the contributions throughout the volume, demonstrate the variety and divergence of opinions and approaches in making sense of recent science and technology through material artifacts. We envisage *Challenging Collections* as part of an ever-evolving dialogue among communities of collectors and scholars seeking to keep pace with the changing landscapes of science and technology and of museology and historiography. We believe it is important to continually reflect on our active roles in creating values through the preservation and research of material culture and to share our experiences of developing intellectual frameworks for collecting. In the words of Howard N. Fox, "Among museums, or within encyclopaedic museums, contemporary collections might position themselves in the spirit of Wunderkammer, more as laboratories and sites of discovery than places of sacred trust intended to preserve the received culture. A healthy curiosity is in order. Contemporary curators, like scientists and contemporary artists, should not resist experimentation; it's part of the job."[10]

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Notes

1. Anne Glover, "Science and Decision Making" (plenary paper presented at Science Centre World Summit, Mechelen, Belgium, 17 March 2014), http://www.scws2014.org/wp-content/uploads/2014/08/Science-and-decision-making.pdf (accessed 22 December 2015).

2. As cited in D. H. DeVorkin, "Space Artifacts: Are They Historical Evidence?," in *Critical Issues in the History of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington, D.C.: National Aeronautics and Space Administration, 2006), 573–600.

3. Jeff Hughes, "Whigs, Prigs and Politics: Problems in the Historiography of Contemporary Science," in *The Historiography of Contemporary Science and Technology*, ed. Thomas Söderqvist, Studies in the History of Science, Technology, and Medicine 4 (Amsterdam: Harwood Academic, 1997), 19–37.

4. Hughes, "Whigs, Prigs and Politics," 19–37.

5. Joseph N. Tatarewicz, "Writing the History of Space Science and Technology: Multiple Audiences with Divergent Goals and Standards," in *The Historiography of Contemporary Science and Technology*, ed. Thomas Söderqvist, Studies in the History of Science, Technology, and Medicine 4 (Amsterdam: Harwood Academic, 1997), 71–91.

6. For example, Anders Petterson, "Value, Risk and the Contemporary Art Ecosystem," in *Risk and Uncertainty in the Art World*, ed. Anna M. Dempster (London: Bloomsbury, 2014), 67–86.

7. Jim Bennett, "Museums and the History of Science: Practitioner's Postscript," *Isis* 96, no. 4 (2005): 602–608, doi:10.1086/isis.2005.96.issue-4.

8. Bruce Altshuler, "Collecting the New: A Historical Introduction," in *Collecting the New: Museums and Contemporary Art*, ed. Bruce Altshuler (Princeton, NJ: Princeton University Press, 2005), 2.

9. For a recent overview of existing initiatives and methods, see, e.g., Marta C. Lourenço and Lydia Wilson, "Scientific Heritage: Reflections on Its Nature and New Approaches to Preservation, Study and Access," *Studies in the History and Philosophy of Science* 44, no. 4 (2013): 744–753.

10. Howard N. Fox, "The Right to Be Wrong," in *Collecting the New: Museums and Contemporary Art*, ed. Bruce Altshuler (Princeton, NJ: Princeton University Press, 2005), 27.

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Lourenço, Marta C., and Lydia Wilson. "Scientific Heritage: Reflections on Its Nature and New Approaches to Preservation, Study and Access." *Studies in the History and Philosophy of Science* 44, no. 4 (2013): 744–753.

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Reflection

The Sciences between Technical Demiurgy, Economic Matters of Fact, and Political Regulations

Historical Overview, Current Situation, and Normative Principles

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Editors' note. Decisions about the preservation of artifacts of recent scientific heritage involve value judgements as to which artifacts are characteristic of science in the present era. Although a critical historical appraisal might benefit from the distance of time, decisions as to which artifacts to retain must often be taken swiftly and potentially in the absence of consensus. To consider how such decisions might be made more effectively through a historically informed long view, we invited Dominique Pestre to provide an overview of the sciences—and their actors, locations, and products—over the modern period. Here, he offers a perspective from science and technology studies as to how we, as both consumers and collectors of today's science, might approach our choices.— A.B., J.-G.H.

Academic works currently abound on the links between knowledge, technologies and science, society, politics, and democratic regulations. The phenomenon started to take shape in the early 1980s when science studies began to deal explicitly with the relationship between scientific knowledge, social worlds, and politics when Latour published "Give Me a Laboratory and I Will

Raise the World," Shapin and Schaffer published Leviathan and the Air-Pump, and Haraway published "A Cyborg Manifesto."[1] At the same time, an intellectual movement drawing on the work of Robert Mumford, Herbert Marcuse, and others had continued to flourish around critical analyses of technologies.[2]

In the interests of simplicity, I would suggest that today, in both academia and the public domain, two main narratives underpin science-in-society studies. The first contends that society's *trust* in science has disappeared. There are two opposing variations on this theme. The first, which is more common in the political, economic, and scientific spheres, contends that we are experiencing a historical regression in terms of rationality, universalism, and Enlightenment values, that the social realm has become irrational. The symmetrical version, which is at the core of science and technology studies, claims that society has cast off the tutelage that previously shackled it, that a new civil society has succeeded in grasping its autonomy and developing its own forms and technologies of knowledge.[3] Obviously, these two interpretations give rise to diametrically opposed politics—top-down technophilia versus bottom-up participatory politics—a point that is, of course, of central importance. On the other hand, neither version seriously challenges the veracity of the point of departure—that science and techniques have been easily "trusted" *in the past.*

The second theme currently in vogue today claims that we have emerged from the insouciant modernity inherited from the eighteenth century to become conscious (as good postmodernists or "amodernists") of the ravages we have caused to our environment.[4] We are now supposed to seriously consider the consequences of our technoindustrial development and have entered an era in which "risk societies" have realized that they cannot but also be "reflexive societies."[5] Again, these narratives about precaution and reflexivity raise the question of the relevance of what is stated. My first contention is that these narratives make up a simplistic image of the past—an image largely false, as historians have documented[6]—probably to display our *own* excellence (*we are* reflexive) and avoid taking seriously into account the (positive and negative) effects of the solutions advocated in the last two centuries. They also let us believe that our precautionary attitudes are grounded in fact—*we are* beyond crude modernity—an assumption that, when looking at all curves defining what is usually called the Anthropocene, is more than debatable.[7]

These approaches have two other (and perhaps more important) weaknesses: They tend to frame the problem as mainly a matter of relationships between two entities (science and society) occurring mainly in one context, the public space, which is far too simple to be of interest. In posing the problem this way, these approaches forget actors (states, international finance, industrial products) and social spaces that are most decisive: the way products and technoscientific offerings are deployed, for example, how they circulate, the role that markets play; the fact that top-down forms of government (set up by states, business, or media) always sidetrack the public space and interfere with dialogical orders; the fact that the public sphere is compartmentalized, made of many spaces and opinions, that the Habermassian notion is far too ideal to be taken at face value; and also the fact that many regulations have been deployed over the last two centuries

and it might be useful to look at their efficiency/inefficiency. And although certain regulations are implemented through dialogical spaces, others are conceived and enforced independently via market regulations, positive law, contracts, and ethical norms.[8] If our purpose is to point out the contradictions and synergies with which we are confronted and to consider the principles that could underpin a normatively assumed attitude, it is essential that we radically complexify our analytical tools.

To do so and show the immense variety of logics, actors, and contexts we have to consider, a historical detour might prove worthwhile. I will thus start by looking at key historical moments, around 1800, around 1900, and around 2000, and try to show changes and continuities. I will then comment on the relationships between contemporary technoscience, expertise, and civil society and on the multiplicity of social spaces in which assessments are made and decisions taken. Finally, I will become normative and propose some principles for the future—principles that might also be of interest for exhibition and museums curators. Not being an expert in this field, however, I will not enter detailed, concrete consequences, but I have no doubt readers of this volume could and will do it.[9]

"Modern Science" between Economics and a New Social Order: Circa 1800

We could say that knowledge (and knowledge production) underwent major changes between the sixteenth and eighteenth centuries, that new practices and social spaces, which we now label scientific, emerged.[10] Agreeing on exactly what that meant, what happened and was then "invented," however, is not so simple. For some, there was a scientific revolution geared on a philosophical shift—a move to Platonism.[11] *Mathematization* is another key word for that change, meaning that natural philosophers now limited their ambitions by plotting only numerical relations between measurable entities. Others saw the change, and I do not take into account medicine or natural history, as stemming from the deployment of instrumented laboratory experiment as a primary source of knowledge—the generalization of *experimentum* to the detriment of shared *experiential*.[12] Other historians claim that the crux of the matter lay in the juncture between the universe of practical mathematics and natural philosophy, in the link to the mechanical and technical arts, to machines.[13] For others the central element was the emergence of new social spaces for knowledge production (from Italian courts to academies and military institutions) that progressively superseded universities, placed new constraints on the producers of knowledge, and gave rise to different types of approaches and knowledge (Figure 1).[14]

One way to (partially) summarize this is to say that this new set of practices relies on a certain disposition via-à-vis its object, on an operational, instrumental, and pragmatic way of looking at and analyzing the world. What was deployed was a modus operandi that offered a practical way of mastering objects and phenomena, an approach that could easily lead to the deployment of technologies—a means, to use the Cartesian expression, of enabling man to become lord and

1.
A General Display of the Arts and Sciences, Sebastian LeClerc, 1798 engraving. © Science Museum / Science & Society Picture Library.

master of nature. In the process, nature was objectified, considered stable and regular, subject to (eternal) laws, just like the world created by the Christian God at the end of the Middle Ages, replete with its own immutable life, a world in which this God no longer intervened directly except under very special conditions.[15]

You will note, extending Latour, that this image is built on a dual cleavage: between *active* and *passive*, subject and object, culture and nature, between human (and mostly masculine) actors and a nature without any agency that they conveniently dissect. But the cleavage is also between *transcendence* and *immanence*, truth and contingency, knowledge and action in the world. Or, to talk like Descola, a major French anthropologist, we could say that a new "naturalist cosmology" was given shape, a new way to connect humans' inner and outer realities and human realities with other beings, entities, and worlds.[16]

People often admit that, particularly since the second half of the eighteenth century, other changes took place, this time comprising political and economic, philosophical, and legal transformations.[17] What lay behind these developments is complex. From a political perspective we can point to the secularization of European political power beginning in the sixteenth century, what Marcel Gauchet, borrowing from Max Weber, has labeled the disenchantment of the world—the fact that God was progressively removed from legitimate justifications of public life. This was accompanied, in the eighteenth century, by new modes of producing goods (think of coal, power engines, and the mechanization of textile production) and by a new unfurling market economy,

booming consumption in the cities, and the circulation of products proposing new lifestyles to an ever-greater number of people.[18]

Legal and ownership rights were also overhauled at this time, and a new concept of patent was developed in America and France in the early 1790s.[19] The new patent relied on the idea of radical newness; it purported to harness the initiative of all in the name of common technical progress, declared that ownership rights were universal, and brought them to life through written and graphical representations. The patent "deterritorialized" the process of invention, as Biagioli says, removed privilege as a political form, and sidelined the physical presentation of objects as a basis of proof. As a result, new kinds of collections emerged: patent collections. They were made public via printed documents of all sorts and were often paralleled by collections of material models and machines (Figure 2).

All these transformations helped recast the economic and political ontologies promoted by the American and French Revolutions: the notion of individual contracting parties, the values of universalism or freedom, the notion of representation as both a political and a technical tool. They contributed to the emergence of these autonomous individuals that composed "bourgeois civil society," to quote Habermas, who believed they had total mastery over both themselves and their environment and who nurtured public debate and intended to govern themselves freely. In the process, what came to be later defined as traditional lifestyles—quite diverse forms of life, different relationships with nature, and complex bases of ownership—was eradicated in favor of simpler, dichotomous, instrumental, and more "efficient" forms.[20]

There is no doubt that changes both in knowledge and knowledge production and in the social, political, and economic worlds interfered and have shared histories and values, as suggested by Hessen in his famous text of 1931, by Merton in his thesis of 1938 that linked English puritanism with the emergence of modern science, and by Funkenstein when he characterized the new science as a "secular theology."[21] The shared values included, at least rhetorically, an overt rejection of acts of authority, a declared stance of modesty and equality (in dealing with facts, in front of the law as in political terms), a duty to have recourse to Reason in arguments (be they philosophical, political, or scientific), and the use of rational forms of debate as *the* means of settling disagreements.

From a more political and eschatological perspective, both changes—even if we had never considered them separate—also shared a new sense of history, a sense of progress, and a Promethean, demiurgical approach.[22] From Condorcet to the liberal thinkers, a new vision of society and knowledge emerged as part of an inexorable, common process of transformation. The quasi-exclusive link of the new science to the sovereign thus broke down, and it was turned into a full-fledged actor in both the economic and the public dialogical spheres.[23]

We should also stress, however, that there was a *contradictory* and *conflictual* relationship between these new forms of scientific knowledge (and their associated technical developments) and the political and dialogical order for two main reasons. First, that new kind of knowledge, which was backed by economic and administrative elites mobilized to promote their nation's strength in the international competition, regularly claimed to be of superior, more proven value
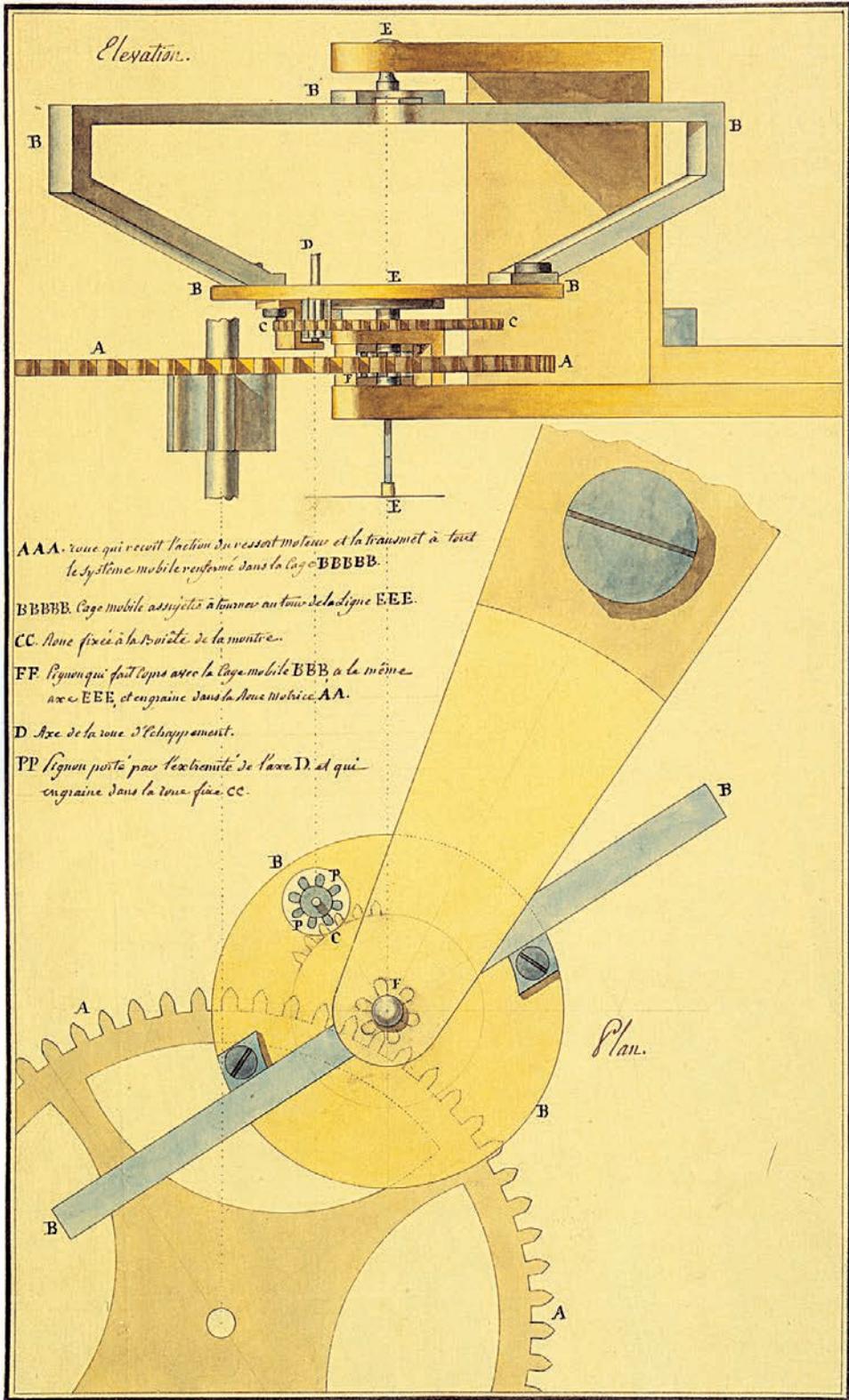
2.
The 1801 patent application by Abraham-Louis Breguet for a tourbillon mechanism. Image courtesy Breguet.
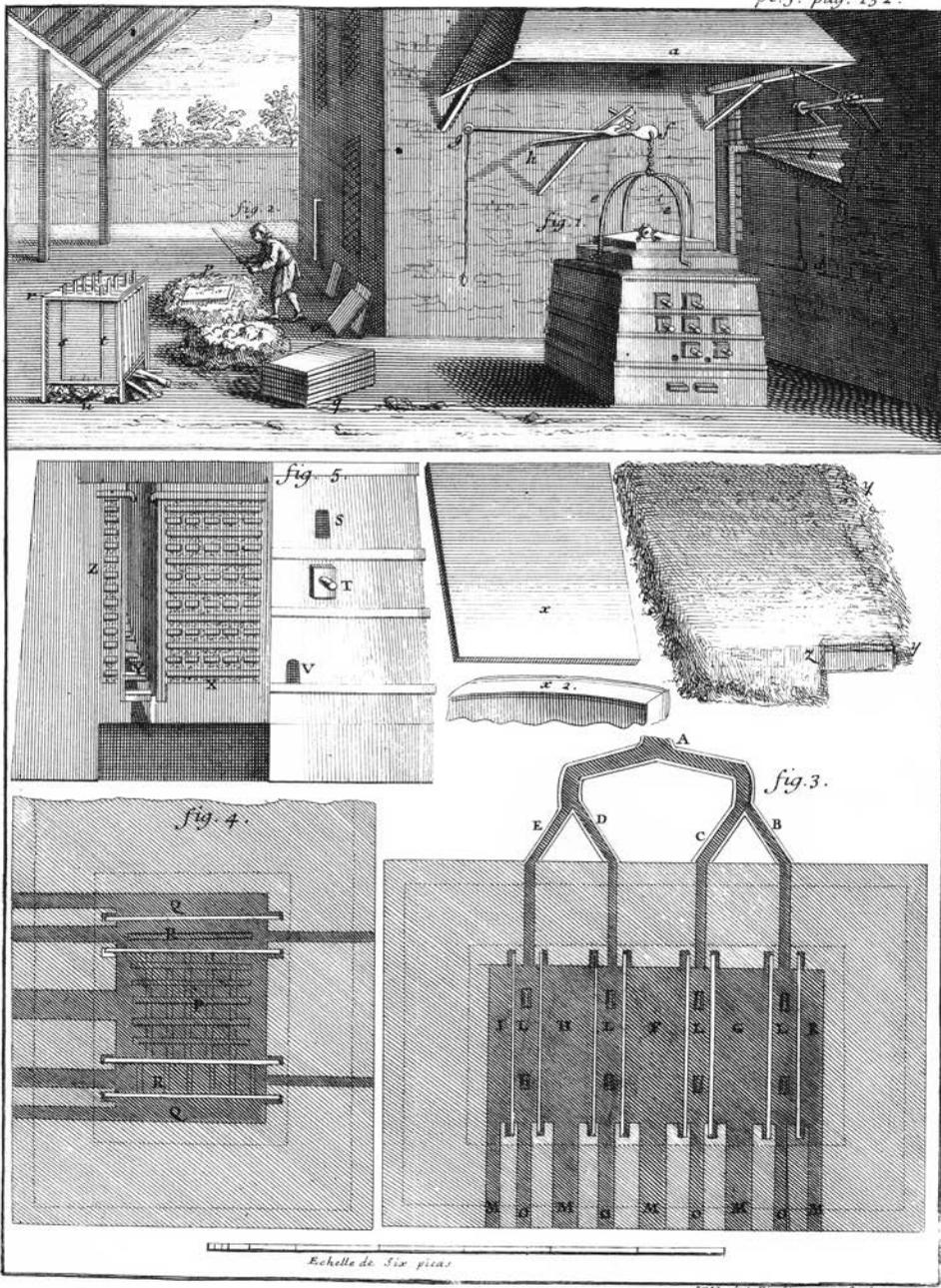
3.
Cement-steel works, René Antoine Ferchault de Réaumur, 1722. Photo: Deutsches Museum Archives.

and as such not really open to debate.[24] Second, that new form of knowledge was not merely bookish. It developed in such a manner (from an instrumental and operational perspective, as I have said) that it could easily be deployed through all types of machines and processes. It had notably a propensity to become embodied in industrial plants and in products entering social worlds via markets (Figure 3).

These products (machines or chemicals) redefined material and social worlds. They shifted the equilibria between persons and groups, revamped relations with nature, and threatened existing forms of life. They triggered refusals and requests for protection since they poured into society without debate, without public opinion being given a say, at the moment they were dramatically affecting people's environments and lives. The promotion of *sciences* and *techniques*, terms that started to be used interchangeably by both their proponents and detractors in the nineteenth century, thus often ran headlong into the promotion of the dialogical order.

In this sense, contrary to well-worn theories in vogue from the French Third Republic through to interwar and Cold War America,[25] there is no organic link, no osmotic relationship, no relation of congruence between modern science and democracy. As a corollary, there is no antinomy between science and Nazism or Communism. Science can easily become a potentially inhuman institution of authority—history is littered with examples. Science offers and has always offered its services to key institutions of power, regardless of their nature.[26] In more theoretical terms, the point is easier to grasp if we stop idealizing science and learn to consider the diverse sciences and technologies in their banal and ordinary human, social, industrial, economic, and political embodiments.

Therefore, from the early 1800s, the links between these diverse entities that I provisionally labeled new knowledge, sciences, techniques, society, institutions, production, markets, states, regulations, and democratic forms are all present. These links are complex and structured around points of convergence, as well as conflicts that may be systemic and that remain more than ever at the heart of today's great issues.

Industrial Modernity, War, and Nation States: Circa 1900

Fast-forward 100 years and the links between science, technology, production, and politics are much closer.[27] In the last third of the nineteenth century, science began to occupy a key position in economic construction, nation building, and war. Laboratory sciences (physics or chemistry as practiced by German university professors, for example, in links with new companies) came to be more directly relevant to economic development (take submarine telegraphy, organic chemistry, and radio), to defense policy (consider the stabilizing platform for navy fire), and to population management (think of eugenics). Teaching laboratory science became the norm in Cambridge, Berlin, and Paris, products for mass consumption exploded, and states began to pour money into universities and technical schools and create bodies to encourage research (such as the Kaiser-Wilhelm-Gesellschaft). The state, scientists, and industrialists banded together to set up national research institutes and metrological centers to facilitate mass production. The first and most well-known example of such a metrological center was the Physikalisch-Technische Reichsanstalt set up in Berlin in 1887 by the three major figures in politics, economy, and sciences: Bismarck, Siemens, and Helmholtz. In short, as Edgerton put it, the sciences were then "nationalized,"

meaning that they became intimately bound up with technology, industry, economy, and state in the national frame.[28]

This integration of the sciences into the very heart of nation building arose from the new technical potential offered by "pure sciences" (a key expression in late nineteenth century). But that was not enough. It also resulted from the management requirements of the large technical systems that were fanning out: gas lighting, railroads, electrical systems, intensive agriculture.[29] It found decisive resources in new managerial techniques (think of Taylorism), in the skills of workers, and in the know-hows embodied in small, science-intensive companies (such as Zeiss in optics). Thence, also, there was the invention of a whole new world to handle potential technoindustrial hazards (by experts, government departments, legal proceedings, etc.) and the waves of enthusiastic or alarmist declarations surrounding modernization.[30] In a nutshell, this period experienced the emergence of an already intensely reflexive world torn between placing its trust in progress and development and an awareness of the risks to which it was left exposed by these new scientific, technical, and industrial developments.

Amid this process of increasing technification and scientization that has flourished since the end of the nineteenth century (and that reached a high point during the Cold War), science and the state entered into a hitherto unprecedented degree of symbiosis. More precisely, science became the state's alter ego, its double, a value and a means of proclaiming a common neutrality.[31] This relationship did not prevent a more individualistic, as well as a more egalitarian and more caring, political society from being forged.[32]

Because science tended to consider itself as being at the heart of the industrial revolution and because it highlighted the direction of social progress (think of Durkheimian sociology), it became a point of reference. Of course, states used it when it suited them—just like industrialists—but science, which milked this situation both for its funding and its symbolic importance, became a central *institution of authority,* a powerful and directive institution at the core of the new political and economic order. And that was translated into the creation of many new institutions like international exhibitions, collections, and museums displaying the wonders of science and industry.

In mid-nineteenth-century literature, it is often the engineer who personifies this type of all-knowing science that guides industrial and social progress. To illustrate my point, let us revisit Jules Verne's classic novel *The Mysterious Island*.[33] Many will remember that it tells the story of a small group of runaways who wash up on what they believe to be a desert island and of the material means by which they develop agriculture and industry on their colony (Figure 4). But it is more than just an account of how a small group succeed in recreating industrial civilization out of nothing but sheer will, ingenuity, and scientific principles. It is also an evocation of the *ideal polity* that should prevail in a technoscientific and industrial age where a scientist-engineer like Cyrus Smith was the only man capable of rising to the occasion. And this colony marches on, unhindered by any reverses. Technology is never found to be wanting and never produces any side effects. The five inhabitants of the island (six with Master Jup, the ape captured and sent to

Des mannequins effrayants suffirent à les écarter. (Page 276).
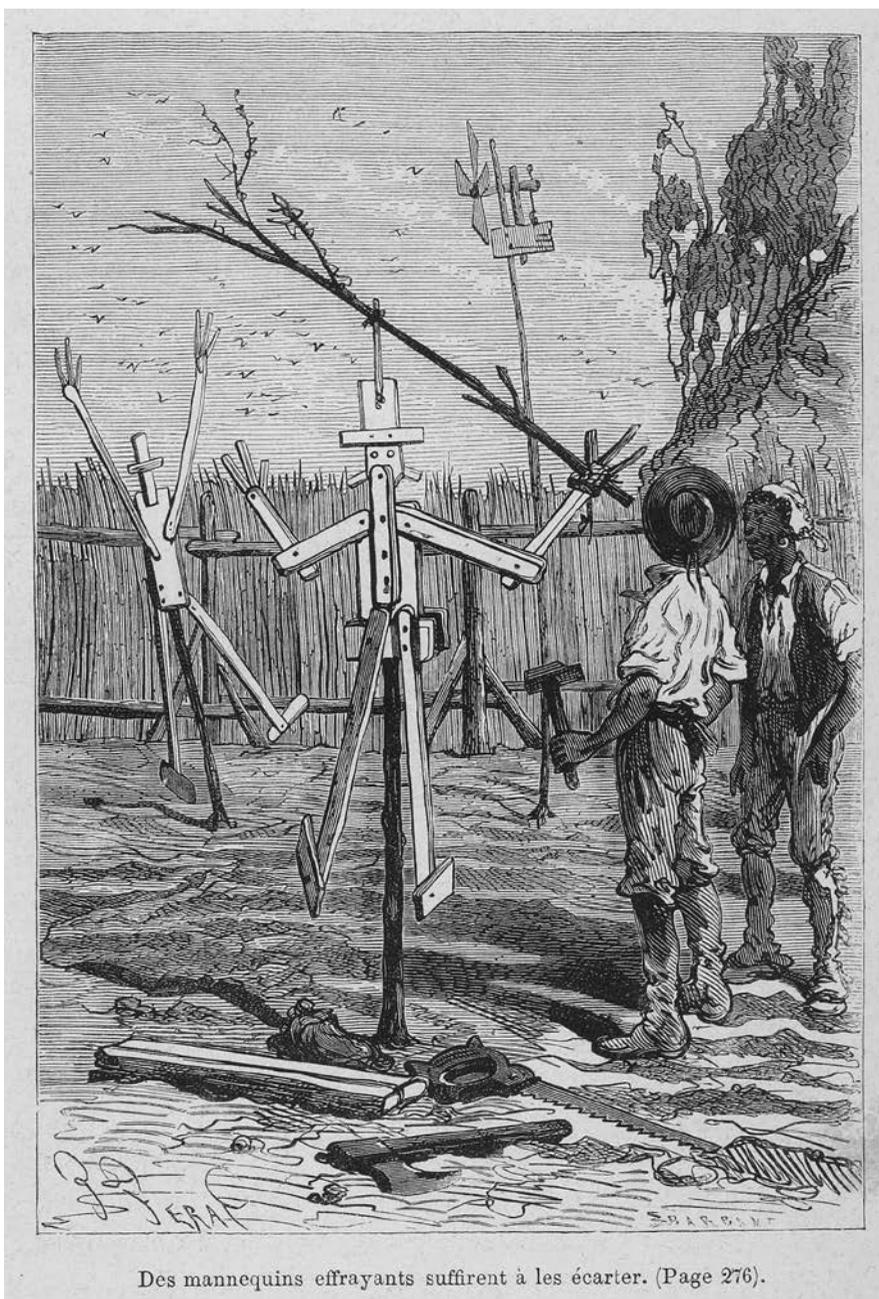
4.
A Jules-Descartes Férat illustration from Jules Verne's *Mysterious Island*, p. 280, 1875. Courtesy of Bibliothèque Nationale de France.

Nab, the black servant of Cyrus Smith, to help in the kitchen!) benefit equally from the progress, the battle for control of nature is waged without respite, and there is no need for any exchanges or discussions. Because progress is inherently good, because it relates to science and is thus synonymous with fraternity and the unity of the group, there is no need to debate and choose. There is, in short, no need for a political space.

My point here is simple: Jules Verne's image is at the same time most true and a normatively dangerous proposition that does not provide an understanding of real problems. It is an interesting image because it reflects a massive reality: the determining influence of engineers and scientists in social dynamics, the systemic autonomy of technoindustrial worlds, and the fact that they easily bypass any dialogical order. It is a dangerous image, however, since it masks many things and lets us believe that solutions reside in the fusion of science and the political (in the person of Smith). It forgets that progress without negative consequences is most rare and does not envisage that ordinary (or affected) people could also be sources of interesting knowledge. Of course, science and industry offer increasingly sophisticated products that were stored in museums to show our ingenuity or warn against their environmental, sanitary, or social effects. But technoscience and industry are often blind to the consequences of their actions, and people consider that they are entitled to react and talk, something that is an inexorable trend in the democratic makeup of our societies that I believe we need to nurture.

New Sciences, New Liberalism, and New Civil Society: The Present Day

Far from disappearing, the key tensions that I have evoked have taken, over the last decades, a new dimension and assumed a sharper focus for a number of reasons. First, there has been an extraordinary development in both the range of potential uses and offerings in the technosciences. Second, the negative (side) effects of our technological development, alongside the undisputable benefits, seem to have changed in scale (think of climate change). Third, after a century of more temperate political development, a newly emboldened economic liberalism has altered the balance put into place one century earlier between individual and collective rights. Fourth, "society"—consumers, producers, citizens—is demanding its rights and freedoms in an increasingly forthright manner. I would now like to clarify these developments and identify the most salient aspects of the issues with which we are confronted at present.[34]

First, the technoscientific sphere is no longer dominated by the same kind of knowledge, the same "disciplines," the same epistemologies or values. From the nineteenth century up to the Cold War, it was the physical laboratory–based sciences and associated engineering that influenced and guided technical and political choices and left their material footprint on society; it was these sciences, especially basic physics, as was said in the 1950s, that left the most lasting symbolic mark and fashioned the norms of "proper knowledge": think of Popper, who conceives of the sciences and their dynamics via only relativity and quantum mechanics. Since the late 1970s, these physical sciences have been transplanted by other laboratory-based technosciences in both the popular imagination and in reality: the life sciences, biotech, and nanosciences, which are capable of reconstituting and optimizing biological material and remaking both humankind and nature.

These sciences are eminently pragmatic and focused on technological action and production, on patentability and the creation of start-ups: indeed, they might be considered primarily

technical (and commercial) and scientific thereafter;[35] they lie at the heart of new market practices, new ways of exercising ownership, and new ways of recomposing individual bodies and the social sphere. They do not play as central a role in war as the physical sciences, but as Rabinow and Rose have pointed out, they have given rise to brand new forms of biopolitics that are controlled to a much greater extent by individuals than by states.[36]

Scientific practices have also been recast by the deployment of new IT tools, databanks, models, and simulations. New fields of science have grown up around the Earth system and its equilibria, around climate and biodiversity protection, around risk management and ecological engineering issues. It is important here to appreciate the sheer newness of this kind of work in comparison with what contributed to the historical glory of the sciences up to the 1970s. Their epistemologies are different—think of the notion of scenario, which is so central in those fields; they tie together human action and nature, they build a knowledge that is at the same time descriptive and prescriptive, and they make it, *from inside* I would say, a tool of government.

The social implications that are locked away in biotechnologies, simulations, and Earth sciences are greater than those of the preceding physics-based technologies. Just think of human cloning, which cannot fail to become a burning issue in the near future and is set to polarize society to a far greater extent than the physical sciences ever did. They also require the use of less binary criteria, criteria that are more complex and difficult to manipulate than in the previous phase—take the notions of precaution and sustainability or the problems in performing 30-year evaluation forecasts of the effectiveness of climate change adaptation measures.

The second aspect is the fact that science and technologies have been affected by the new moral and economic order that has emerged over the past few decades. Productive regulations have been transformed, and power in the economic sphere has generally shifted from industrial managers to shareholders and financial actors. The geopolitical order, for its part, has partly shifted from a system regulated by nation-states in Westphalian equilibrium to global systems regulated in many different governance spaces by actors with varying degrees of democratic legitimacy: large corporations, the World Bank and the World Trade Organization, all manner of agencies, a plethora of nongovernmental organizations, and, of course, some major nation-states like China and the United States.[37]

Through the emergence of these new global and/or environmental questions and forums, as well as the emergence of neoliberal forms of government using *benchmarks* to mold people and guide the action of *stakeholders* in a "pastoral tradition,"[38] politics, as it had been defined since the emergence of mass democracies, has been redefined and, to a certain extent, marginalized.[39] Finally, the entire geopolitical ensemble appears to be in a constant flux with no obvious focal point and prone to all manner of upheaval. This situation is the very opposite of the predictability that prevailed during the Cold War: the status quo was looked on as permanent, as a guarantor of our continued survival. The upshot of these changes is an increasing feeling of uncertainty and all-pervasive risk, a situation on which Ulrich Beck based his celebrated book.[40] This shift to a regime that can be qualified as global and dominated by financial actors has finally been

accompanied by increasingly fraught labor and social relations, which also account for the over-riding impression of uncertainty among the most distressed sections of society.

It has also been accompanied by a transformation of what it means to produce knowledge, particularly in universities. First, a whole host of new interests in research now exist: venture capital and pension funds, the Nasdaq capital market, start-ups, and commercial lawyers have all become crucial, alongside central government and armed forces, which obviously continue to be of key importance. They all now combine to mold the forms that research takes and define what is studied and what is forgotten. Industrial research, on the other hand, has broken free from the territorial constraints that continue to affect universities and populations, and decisions as to where research is to be located are now taken at global level in light of current opportunities.

In large corporations, there have also been major changes in the nature of innovation work. The design of generic products and product lines have now replaced R & D as the cornerstone of innovation in a whole host of domains, and research can now be *outsourced*, to use the current jargon. Intellectual property rules were overhauled in the 1980s under the impetus of the U.S. government and the U.S. Patent Office (originally around GMO products), and this change has led to a greater compartmentalization of knowledge and to new forms of monopoly and a litigation culture. So a new political and moral economy of knowledge has taken root at the heart of what is often referred to by the catchall, ectoplasmic terms "knowledge-based economy."[41]

Last, individuals themselves and social bodies have experienced root-and-branch changes. These are apparent in shifting subjectivities, in attitudes and lifestyles, and in the relationship to authority, notably institutional and scientific authority, including that of science museums. We could say that our societies have become flatter, more diverse, less structured, guided by a multiplicity of principles and values. We could say that personal trajectories and references are more varied, that there is a wider range of possibilities for self-definition and self-realization and, ultimately, a decline in the power of traditional institutions such as the school or the family.[42]

Contemporary Technoscience, Expertise, and Multiplicity of Social Spaces for Assessment

As regards attitudes to science and technology, these developments have given rise to changes in social certitudes. Although it was never complete in the first place, belief in beneficial, controllable technoscientific progress has frittered away. Chronologically, the key turning point was the radical opening up of the nuclear debate in the United States during the 1960s and the fact that arguments between experts about the intrinsic complications of the technology entered the public domain.[43] The decisions of experts working behind closed doors are now being contested with increasing frequency. These developments have been accelerated by the pace of technological change (from GMOs to tailored biotechnical products), global health and environmental crises

(with higher media exposure), and the opacity of the new governance regime and its dissolution of responsibilities.

Alternative forms for producing knowledge and debating have thus multiplied and possibly mutated around technoindustrial development. The issues are less considered local affairs, for example, contrary to what dominated in the nineteenth century vis-à-vis chemical pollution.[44] Environmental questions are now considered a battle for the survival of humankind and the planet, a global combat. The environment is now of concern to all. It has become a separate issue that is no longer derived from the social question and has even supplanted the latter in terms of values and preoccupations. If we start with the simple contention that social and political debates are structured by three questions—economic development, social justice, and environment—we may say that the relative weight of the last two has changed in inverse proportions between 1860–1960 and 1960–2010 and that this shift in priorities is a salient feature of the current situation.

Militant activism in relation to technoscientific development is now largely in the hands of NGOs and patient associations. Since the 1960s, these groups have begun to intervene more directly to question the appropriateness of scientific or political choices. Many associations have their own research institutes that openly challenge official certifications.[45] They undertake campaigns to promote measures and controls themselves. Far more legal proceedings are also being instigated than before (even if they have always existed), and all manner of "consensus conferences" are organized, usually top-down forums that aim to organize and avert the population.[46]

Such behaviors are not simply due to the negative impacts of technoindustrial practices. They also arise from the emergence of new tools and new ways of producing and disseminating knowledge. Just as the heightened sense of liberty in the late eighteenth century had to do with the rapid increase in the number of printed works in circulation,[47] the exponential increase in Internet use appears to be of capital importance today. Particularly for younger people, the web promotes alternative forms of learning, working, and expressing oneself. It gives rise to other ways of defining relevant information and promotes alternative practices for assessing it. Because it is radically polycentric, it easily short-circuits hierarchical channels and undermines the authority of scientific spaces, including, of course, science and technology museums.[48]

In most scientific and technological circles, the tendency remains to not really take these realities on board and treat them as anomalies to be remedied by further doses of sciences. The reaction is similar among most European politicians and in economic milieux where the actors are petrified by the GMO affair, which they see as an unfounded mass outbreak of technophobia that needs to be dealt with through more effective communication.

This simplification is, of course, a failure to come to grips with new challenges. The idea that this phenomenon is a fleeting one has long been disproven. It also seems that it is less science or knowledge per se that is being singled out than regulations, the way crises and responsibility are handled. It is oversimplistic to see this as a new irrationalism. Indeed, what is at issue is precisely the contrary, the very success of the industrial technosciences and the passions they arouse. And in this respect, most reactions are eminently *reasonable*.[49]

More precisely, these passions and attitudes are often double-edged. On the one hand, when collective welfare is at stake, greater caution is being urged, for example, around public health (the Vioxx scandal), the environment (nuclear waste management), religious convictions or ethics (cloning, stem cell research), and ownership (freeware). But there is also a greater belief in progress and eager adoption of technoscientific offerings when individual users themselves retain control over the inherent risk involved: think of self-enhancement, for example.

In concluding this section, I think it appropriate to stress one final point: the historically obvious fact that (pre)caution mainly stemmed from the refusals of the negative (and initially often unnoticed) side effects of progress. Contrary to what industrial managers, company engineers, politicians, and risk experts would have us believe, it was mainly the post hoc *contestation* that drove safety committees, government departments, manufacturers, and courts to adopt stricter standards. This resistance started 200 years ago, and it has been the decisive factor in making technological and industrial behavior safer in environmental and health terms.[50] It is thus crucial to listen to society when it expresses its concerns: because it reflects a myriad of preoccupations and values, the social body, in all its multiplicity, is the most effective whistleblower.

A Few Pointers for Reflection and Action

So what is the best way forward? I did promise to develop a few kinds of normative ideas. For a start, I guess we first have to recognize that the world is an inherently complicated and contradictory place in terms of interests, ideals, and preoccupations and that there can be no simple prescription. Any belief in the happy marriage between reason, science, and society has evaporated—if it ever existed—and that should be at the heart of any of our thinking.

We probably also need to recognize the nontransient nature of the three major historical sources of friction I evoked: between market-based innovation and dynamics and the desire to deal with problems through dialogue and democratic means, between technoindustrial progress and the negative or uncertain social and environmental impacts, and between self-realization and individualism and the necessity for common legislation. To paraphrase Paul Ricoeur, democracy is not a political regime free from contradiction or conflict but one in which solutions are open and partly negotiable. Conflict in democracies is neither an accident nor a misfortune; it is an expression of the *scientifically* nondecidable aspect of the public good. Even though it sounds laudable, the idea of global consensual governance cannot but remain a myth. Political discussion is, out of necessity, without logical conclusion, says Ricoeur, although it is not without decision.[51]

This complexity should not hold us back even if it should make us quite prudent. I would like to put four proposals forward. First, we should recognize the reality and the vital necessity in normative terms of the variety of human values, the variety of the ways in which we make sense of the world, and also the variety and complementarity of forms of knowledge. I propose that, in every context, notably in science museums, we actively show this radical diversity, this *biodiversity of knowledge and values,* that we fight for an acknowledgement that dissensus and diverging opinions are normal. To be sure, consensus-building initiatives cannot be negative, but

diversity and differences, not unanimity, lie at the heart of scientific and political life. Diversity also facilitates more effective problem detection and helps provide a better fit with unknown situations. The sciences will undoubtedly continue to constitute the inner core of knowledge, and technological innovation will undoubtedly continue to be a central resource for the world. But they (we) will have to (re)learn modesty in a way that they (we) have never had to before and to be wary of the hubris that frequently characterizes their (our) relationship to novelty—something scientists, people in the humanities, and curators should constantly keep in mind.

This first suggestion leads on to a second: realizing that there are always many things that we, and science in particular, do not know.[52] This involves learning not to cut ourselves off and not to be over confident in our own conclusions, a common fault among scientific intellectuals. It involves carefully examining the blind spots in the technologies, theories, and artifacts that we advocate or display, blind spots more often highlighted by those who bear the brunt of the downside of progress, by those who refuse certain forms of development or dream of other futures and for whom we should open means of expression.[53]

However, we are not here simply talking about some ecumenical love-in, which is precisely why things are complicated. We need to bear in mind that power relationships and vested interests cannot but interfere with, and instrumentalize, any dialogue. Indeed, this has been theorized since the late 1980s by consulting firms offering their services to corporations and political parties.[54] We also know that the quality of arguments matters, even if nobody occupies God's position and could decide what is valid and what should be simply discarded. No doubt a big-tent approach to debating, exhibiting, and deliberating is a positive move. It hangs on a thread, however; it needs to be constantly nurtured given its vulnerability in the face of ordinary power relationships and the unequal strength of arguments, and there is *no general recipe* to succeed when presenting or analyzing these situations. As such, revitalizing the forms of counter democracy that challenge the *doxa* and monitor failings is a sound policy. And it is normal to insist that post hoc surveillance and whistleblowing are just as vital as the definition of proper decision-making processes in instituting the political order that our hi-tech and liberal societies need. Trying to open decision-making processes to have them include as many people as possible is essential. Because that process will never be perfect, however, it is just as important to have in parallel independent, multiple (and post hoc) forms of assessment by as many people as possible and to ensure that public visibility is given to these dissident findings.

Therefore, beyond the sometimes facile calls for "good governance" for one and all to safeguard the common good, we need to (re)learn choice, or, more precisely, *the necessity and difficulty of choice*.[55] We have to explicitly accept that deciding cannot but be painful because we are rarely in win-win situations and because choosing means having to allocate the impending negative consequences to certain people and not to others. For example, a successful adaptation to climate change cannot have no cost or fail to impact our lifestyle,[56] unless we do not really take the question seriously and, carrying progress to its logical conclusion, behave as if science will always come up with a solution that will absolve us of any duty to adapt.

In sum, we need to (re)learn how to keep a dialogue going and to realize that choices are often painful, that decisions are never perfect, that they must be checked and commented upon ex post facto by as many people as possible, and we also need to be inventive in detecting forthcoming problems. It is not enough to simply enumerate procedural arrangements to be deployed, something science and technology studies scholars have stressed perhaps too much: we also need to pinpoint the weighty, all-important issues and come up with matching, imaginative, *substantial* solutions. Let me evoke two examples to illustrate what I have in mind.

First, what kind of relationship do we have, or would we like to have, with illness, death, and our dream of eternal youth and immortality as it is crystal clear that healthcare expenditure is increasing faster than our revenues, that it is simply unsustainable in the short to medium term?[57] Second, what is our collective vision of global commons (air, water, biodiversity, or knowledge), and how can we (re)qualify these commodities from a legal perspective as it is patently obvious that many of our current problems cannot be solved without including these global commons in the equation? There is, on these questions, no shortage of historical examples from which to draw in the quest to (re)learn more effective and collective modus vivendi.

* * *

I will stop there in full awareness of the brevity of my remarks, as well as the simplicity and levity of some of my arguments. I simply hope to have engaged the reader's attention at least part of the time and to have partially convinced him or her that many of these questions are still wide open.

Notes

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14. M. Wintroub, "Court Society," in *Reader's Guide to the History of Science*, ed. A. Hessenbruch (London: Fitzroy Dearborn, 2000), 154–157. Of course the Euro-centered vision I propose here does not exhaust what should be said. For a reading at world level see, D. Pestre, "Savoirs et sciences de la Renaissance à nos jours. Une lecture de longue durée," in *Histoire des sciences et des saviors*, vol. 3, ed. D. Pestre (Paris: Seuil, 2015), 461–485.

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27. For that whole section, see Pestre, *Science, argent et politique*; *A contre-science*.

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Conceptualizing Contemporary Collecting

A Tape Measure and a "T" Stop

Or, Why Museums of Science and Technology Should Collect More Contemporary Artifacts

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A Tape Measure

In January 2011, the MIT Museum unveiled the largest single exhibition that it has ever attempted. Spread across three sites (the MIT Museum itself, the Compton Gallery located in Massachusetts Institute of Technology's [MIT] main buildings, and the Maihaugen Gallery in the Institute's Archives and Special Collections) and occupying a total of around 7,500 square feet, the *MIT 150 Exhibition* brought together 150 artifacts chosen for their collective ability to evoke the spirit of the Massachusetts Institute of Technology on the occasion of its 150th anniversary.

This was no ordinary array of artifacts. For one thing, it comprised an almost bewildering variety of materials, from archival documents recording the founding of the institute, through all manner of scientific, technological, engineering, art, and design objects, to a number of positively quirky items, including the remains of an old piano, dropped from the roof of MIT's Baker House five-story dormitory on "drop day" (get it?), the last day of the 2010 spring semester on which students were entitled to drop a class. For another, it was the result of an 18-month crowdsourcing experiment, in which members of the extended MIT community were invited to nominate artifacts for inclusion in the exhibition. With nearly 900 nominations for just 150 slots, a considerable amount of curatorial discretion was inevitably involved in the final selection;

nevertheless, to a significant degree the exhibition was the product of collective intelligence (for example, the Baker House Piano Drop was the clear winner in an online popularity contest among all the nominated artifacts, and after that there was never any doubt that it would be included in the show).

The *MIT 150 Exhibition* was a three-dimensional institutional autobiography. From the outset, the aim was to capture the culture of the place, not through a mere chronology of events, but through an assembly of what exhibition curator Debbie Douglas, following the lead of our MIT colleague Sherry Turkle, chose to call "evocative objects."[1] And evocative they certainly were. For although the show was presented as an array of artifacts, it felt like nothing quite so much as a collection of stories about every imaginable aspect of MIT life, past and present. Some of these stories were personal vignettes, whereas others were nationally or internationally significant events, but what they all had in common was that they were anchored in—I feel compelled to say, they were animated by—a collection of inanimate, unspeaking objects.

Take, for example, what was surely the humblest of all the artifacts to find its way into the exhibition: a perfectly ordinary tape measure, of the sort that can be found in millions of homes across America (Figure 1). What distinguished this artefact (which is now in the collections of the MIT Museum) was certainly not its nature, which was thoroughly prosaic, but rather its provenance. For this particular tape measure was purchased by biology professor Nancy

1.
Nancy Hopkins's tape measure. Michael Cardinali, photographer, courtesy MIT Museum.

Hopkins in the late 1990s to help her substantiate a charge of gender discrimination in the institute. In a place famed for its reliance on quantitative evidence, where even the buildings are numbered, Hopkins's straightforward documentation of the amounts of floor space allocated for research by male and female faculty members had an immediate impact. Following the release of an MIT faculty study chaired by Hopkins herself, MIT president Charles Vest admitted publicly that the institute was essentially guilty as charged; and this bold admission triggered real changes at MIT and in American research universities more broadly.[2] At a memorial service for Vest in March 2014, his administration's engagement with the issue of gender discrimination was cited repeatedly as one among a handful of signature accomplishments of his 14-year tenure as president of MIT.

If a tape measure can be an evocative object, then anything can be an evocative object. We know this from personal experience, of course, for example, when we look back on objects that had an unusual impact on us or when we hang on to personal possessions that we could well do without because of their "sentimental value," and we know it, too, from more overtly public actions, such as when communities decide to create time capsules as ways of communicating with the future.[3] What objects will make the best emblems and tokens of a particular time and place, as judged by generations yet to be born? The answer, it seems, is anything and everything from a bus ticket and timetable to a department store catalog and a spool of thread. Time capsules have been dubbed "dormant museums," and the difficulties associated with deciding what to put in them provide clues to the challenges faced by real museums and professional curators over the question, what to collect?[4]

Criteria for the acquisition of new artifacts into museum collections are notoriously tricky to define in terms other than the seemingly platitudinous. My own museum, for example, provides the following by way of first-order acquisition criteria:

Relevance: the object must support the Museum's mission and fit within its stated collecting goals.
Use: the object must have the capacity for use in exhibitions and/or for research and scholarly purposes.
Condition: the object must be in reasonable condition and must not require significant expense for treatment in order to make it relevant or useful unless such funds are provided.[5]

In fairness to my colleagues, I should acknowledge that the collections document from which I've just quoted continues with more specific statements about key collecting areas, but in truth, many collecting museums have formal acquisition policies that are easy to caricature as elaborations on the basic maxim that "we want what we want (and can afford)." This does not necessarily imply that such museums don't know their business; on the contrary, it may mean only that in practice they need to rely more on connoisseurship and professional curatorial judgment than on general criteria and formal rules.

This reliance on connoisseurship and judgment is what we would expect if, in part at least, objects are valued by museums for their capacity to evoke particular times, places, and circumstances, if, indeed, objects are sought after as carriers and containers of significant stories. A tape measure is a tape measure, after all, unless and until it is judged to be a token of important debates about the role of women in science in the late twentieth century. Equally, a broken piano is a broken piano, unless and until it is interpreted as the physical embodiment of a longstanding culture of "hacking" among students at MIT.[6] An object in a museum is never a purely objective or natural thing; rather, it is always a cultural thing—a thing by virtue of its being embedded in particular worlds of personal, artistic, historical, scientific, etc., experience—and such embedding is not obviously or easily reducible to the formulaic application of general principles.[7]

This point applies differently to different types of museum objects: to art objects of all sorts, which have been made precisely in order to be sensed and appreciated; to historical artifacts, which may have been made with any number of other purposes in mind; and even to "natural" or "found" objects, such as the rocks, fossils, plants, and animals that make up the bulk of the collections in museums of natural history worldwide. One way or another, however, the point always applies. Inevitably, the very acts of acquiring, naming, classifying, describing, arranging, and displaying collected objects serve to invest these objects with meaning by making them dramatis personae in stories of presumed significance. Such investment is not something that can be avoided; rather, it is something that should be embraced and exploited—in the best sense of the word—for the benefit of researchers, students, and museum visitors.

The evocative nature of objects is a major—I am inclined to say, it is a principal—reason why museums of science and technology should collect more contemporary scientific artifacts. With the help of such artifacts, our museums will be enabled, now and into the future, to tell an indefinitely large number of meaningful stories about the place of science and technology in late twentieth- and early twenty-first-century society. In a sense, they will be able to do for the larger culture what the *MIT 150 Exhibition* did so convincingly for a single research institute. If, on the other hand, museums of science and technology fail to live up to their professional responsibilities to collect contemporary artifacts, then I fear that they will be obliged, now and into the future, to tell a poorer, more restricted range of stories about the place of science and technology in our society.

In an important sense, the difference between these two sets of possible stories, those that are enabled and enlivened by evocative objects and those that are not, approximates to the difference between what the anthropologist Clifford Geertz famously termed "thick description" and "thin description," where by thick description he meant richly interpretive description (description, as it were, "from the inside") and by thin description he meant merely factual description (description, so to speak, "from the outside").[8] Museum visitors deserve the opportunity to encounter displays that offer thick descriptions of science and technology, descriptions that offer

genuine insights into the character of scientific and technological developments; and in the creation of such displays, contemporary artifacts have a great deal to offer.

This, at least, will be the argument of this chapter. I shall conduct this argument by considering, first, the changing role of objects in American museums over the course of the past 150 years. This consideration will lead to further reflection on what it is about artifacts that makes them so revealing of the character of scientific research and technological innovation. Then I shall describe a recent example from the work of my own museum that illustrates some of the ways in which artifacts can enrich our understanding of recent and contemporary science and technology.

"Do Museums Still Need Objects?"

Museum historian Steven Conn has argued that the first major flowering of American museums in the late nineteenth century coincided with the rise of what he terms an "object-based epistemology," according to which it was possible both to create and to convey knowledge through the proper collection, classification, and arrangement of objects. In the period immediately after the American Civil War, the endeavors of a new generation of leaders were inspired by an ambitious vision of museums as object-based institutions of research and teaching. Although the serried ranks of glass cabinets full of carefully classified artifacts that these leaders assembled came to be viewed much later as the fusty, dusty heirlooms of a hidebound past, Conn helps us to understand that they were originally intended to enable systematic learning up to the very highest levels. Indeed, for a time the nation's great museums vied with the emerging research universities for the title of America's premier institutions of higher education.[9]

Of course, it was not only the rise of the research universities that undermined the credibility of object-based epistemology. For around the turn of the twentieth century it gradually became apparent that even the most complete and carefully organized array of artifacts can afford knowledge and understanding only of certain, rather limited kinds. Such an array may, for example, provide rather effectively for taxonomic and comparative anatomical knowledge, but it is singularly ill suited to many other kinds of understanding. In a more recent work, provocatively entitled *Do Museums Still Need Objects?*, Conn reflects on the fact that through the course of the twentieth century, "the place of objects in museums has shrunk as people have lost faith in the ability of objects alone to tell stories and convey knowledge."[10] The collapse of object-based epistemology after 1900 was influenced by a move on the part of core disciplines (e.g., biology) away from a preoccupation with objects (organisms) and their proper classification (taxonomy) and toward a closer engagement with underlying (physiological, cellular, and molecular) processes and with theory. These were subjects with which cased artifacts alone could scarcely be expected to deal effectively, but for which the research universities were increasingly much better equipped.

These transformations left museums looking for new roles in the twentieth century. Generally speaking, museums of art and history became cultural institutions devoted to interpreting

the multiple worlds of human creativity and meaning making to prevailingly adult audiences, but museums of science and technology took a very different path. In one particularly telling chapter, entitled "Where Have All the Grown-ups Gone?," Conn describes how American museums of science and technology steadily transformed themselves over the course of the twentieth century into places focused squarely on the educational needs of children.[11] The new interpretive techniques they developed, including push-button demonstrations, hands-on interactive exhibits, and multimedia displays, focused increasingly on underlying scientific principles and everyday technological applications, and they had less and less use for original artifacts. Seized with their role as educators of American youth, few new "science museums" created after World War II took seriously any kind of responsibility for the collection and conservation of original artifacts; indeed, some older collecting institutions largely abandoned their curatorial missions.[12]

One important, although unintended, consequence of this flight from original artifacts as the educational raison d'être of science and technology museums has been the failure of the museum world as a whole over the entire postwar period to collect an adequate record of recent and contemporary science and technology.[13] To be sure, a relatively small number of major institutions (e.g., the Deutsches Museum, Munich; the National Museum of American History, Washington, D.C.; and the Science Museum, London) have continued to make important acquisitions of recent material, but even they would be among the first to acknowledge that taken in the round, the collective efforts of museums have failed to keep pace with the breathtaking expansion of research and innovation in many fields since 1945. Although one or two areas—space science and technology, for example, and perhaps computing—have been well collected over recent decades, many others, including many areas of basic science and pretty much the entire burgeoning field of the life sciences and technologies, have not. In part, to be sure, this is a result of the sheer scale of scientific and technological research in the postwar period, which dwarfs the museum sector and is apt to daunt even the most enthusiastic curator, but in part, too, it is a result of a shift in focus among museums of science and technology, away from artifacts and toward newer, thematic displays.

There are many reasons for regretting this collective failure to collect on the part of the world's museums of science and technology. At the most basic level, we are not archiving adequately the material culture of recent and contemporary science and technology, and this matters. There is an elementary fascination with understanding how Galileo Galilei managed to observe new objects in the heavens with the help of his telescope in the early seventeenth century or how Michael Faraday advanced the study of electricity and magnetism in his laboratory at the Royal Institution of London in the early nineteenth century or how Francis Crick and James Watson went about constructing their revolutionary model of DNA at the Cavendish Laboratory in Cambridge in the mid-twentieth century. None of these things can be properly understood without some appreciation of what these researchers actually did; and in each case, what they actually did can only be properly understood by reference to the working materials, the apparatus, instruments, models, etc., with which they did it. Fortunately, in each of these instances we have access

to at least some of the original materials involved, but at the present rate of museum collecting, this is unlikely to be the case in years to come with respect to many of the most important recent and contemporary scientific discoveries.

Objects and the Problem of Tacit Knowledge

At this point, it seems worth stepping back from the details of changing museum practices to consider an important general principle that has been multiply documented by recent work in the field of science and technology studies. Simply put, the principle is this: neither scientific discoveries nor technological innovations are fully and completely captured by the primary written record of research alone. On the contrary, even the most thoroughly written peer-reviewed articles fail to provide a full understanding of how the relevant research was actually undertaken and in what ways the reported results were actually achieved. This failure is not because of idleness, stupidity, or duplicity on the part of researchers but because by its very nature research is a form of professional practice in which at least part of what is happening is based on tacit rather than explicit knowledge.

The concept of tacit knowledge was introduced many years ago by scientist-turned-philosopher Michael Polanyi. In one of his most influential examples, Polanyi wrote the following:

> If I know how to ride a bicycle . . . this does not mean that I can tell how I manage to keep my balance on a bicycle. . . . I may not have the slightest idea of how I do this, or even an entirely wrong or grossly imperfect idea of it, and yet go on cycling . . . merrily. Nor can it be said that I know how to bicycle . . . and yet do not know how to coordinate the complex pattern of muscular acts by which I do my cycling. . . . I both know how to carry out (this performance) as a whole and also know how to carry out the elementary acts which constitute (it), although I cannot tell what these acts are.[14]

In one sense, Polanyi's idea is so obvious that it scarcely seems to require critical reflection. All of us know more than we can tell about virtually everything we do, from how we tie our shoelaces (always supposing that we have any) in the mornings, through how we get to our places of work by public or private transport, to how we negotiate tricky meetings in the workplace and so on and on through the course of our daily lives. For the most part, we can afford to neglect this tacit knowledge: shoe tying can be taught (with some difficulty, as it turns out) to children, although mostly by "show," not "tell"; and for much else, we rely on everyday cultural learning, mentoring, imitation, and all the rest, to help ourselves acquire the myriad of skills that we need in order to survive. Most of these life skills we scarcely bother even to bring into consciousness, for where tacit knowledge is pervasive and (relatively) easily acquired, there is really no need to think about it.

In the case of science and technology, however, the situation is very different. By its nature, scientific knowledge is secured by means of a set of highly specific, often rather esoteric,

performances and procedures. In ways that formal science teaching frequently obscures (or at least neglects), science has always been and remains based on forms of extremely specialized artisanal practice, and artisanal practice is routinely shot through with tacit knowledge (if you doubt this, just try imagining how easy it is to become a joiner, a potter, or a violinist by paying attention to explicit instructions alone). This is why the only sure way to become a scientist is to keep close company with other more experienced scientists, taking guidance from them on what to do and when and how to do it, at least until one has acquired a minimal level of artisanal skill of one's own.

Not only is practice within a community of more experienced practitioners normally essential to becoming a scientist, but keeping one's hand in is normally essential to maintaining one's ability to continue doing experimental science. The reason is, not least, because the artisanal skill base of any area of active science tends to evolve rather quickly as new technologies and techniques come on stream. Many laboratory heads will acknowledge privately that they themselves can no longer actually perform the benchwork that graduate students undertake every day under their supervision because their own skill base—tacit knowledge and all—has long since been overtaken by new developments "on the ground." This acknowledgment doesn't necessarily mean that such leaders are ill equipped to direct research; it simply means that division of labor has occurred to the point where only some people within a well-functioning research team can perform particular tasks.

The tacit nature of much scientific knowledge points strongly to the importance of the material culture of science—of concrete field and laboratory practices and procedures, including the observational and experimental equipment involved, and the protocols on which the use of this equipment depend—for an adequate understanding of how scientific research is actually done.[15] This, in turn, argues for the importance that attaches to the role of museums as collectors and conservators of recent and contemporary scientific and technological artifacts. Without such evocative objects, we risk being confined to a largely text-based and thus (in the worst sense) overly intellectualized view of the scientific enterprise, but with them, we have more of the resources we require in order to be able to tell meaningful stories about the nature and place of science and technology in late twentieth- and twenty-first-century society.

In the next section, I offer by way of illustration of this point a vignette from an area of continuing work in my own museum.

A "T" Stop

Picture the scene:

We're somewhere in the Whitehead Institute/MIT Center for Genome Research, sometime during the second half of 1999. A lot of people, many of them younger but one or two older and more senior looking, are standing around some very complicated looking machinery. They're in a state of nervous expectation, worrying about the difficulties involved in getting

the machinery to work. The voice-over (which belongs to the well-known American science broadcaster Robert Krulwich) informs us that this research group's main competitor, a private company called Celera Genomics, has recently announced its intention to complete a first sequence of the human genome in just two years, way faster than anyone up to this point has ever contemplated. This announcement, we hear, represents a particular crisis for one of the people present, director of the National Human Genome Research Institute and acknowledged head of the Human Genome Project Francis Collins, who has decided to speed up his own massively collaborative public effort, indeed, to cut no less than five years off the original schedule for the project, by mandating the purchase of a whole lot of new equipment.

This scene is drawn from a two-hour *Nova* special documentary called "Cracking the Code of Life," which was first broadcast by the American Public Broadcasting Service (PBS) on 17 April 2001.[16] The documentary tells the extraordinary story of the race to complete the sequencing of the human genome, which began in the late 1980s and culminated (in one sense, anyway) in a joint press conference in the White House on 26 June 2000 at which U.S. President Bill Clinton and U.K. Prime Minister Tony Blair (who joined by satellite) congratulated both Francis Collins and Celera Genomics president Craig Venter on their joint completion of a working draft of the sequence of the human genome. What was presented to the world's press as an honorable and amicable tie deceived no one who had had the slightest involvement with the field over the preceding decade, for the race to complete the sequencing of the human genome had been fast, furious, and at times acrimonious; it was a race not only for the prize of being first but also over the disputed question of who should have access to and ownership of human genome sequence data.[17]

"Cracking the Code of Life" portrays rather vividly what was perhaps the single most critical phase of the Human Genome Project, and it portrays it, more than anything else, as a battle with, or even perhaps between, machines—not just any machines, of course, but a succession of new DNA mapping and sequencing machines. To give some flavor of the atmosphere conveyed by the documentary, here is an extended extract from the published transcript:[18]

ROBERT KRULWICH: In the fall of 1999, representatives from the five major labs come to check out Eric Lander's operation. . . . If they want to finish the genome before Craig Venter, these folks have to figure out how to outfit their labs with a lot of new and fancy and unfamiliar equipment. And they've got to do it fast.

LAUREN LINTON: So we'll have to runs [*sic*] some sort of a conduit.

ROBERT KRULWICH: At MIT a different crate is arriving almost daily.

MIT STAFF RESEARCHER ONE: It's like Christmas, everyone unwraps something.

ROBERT KRULWICH: Just like a bad Christmas present, assembly is required. And the instructions are of course not always clear.

MIT STAFF RESEARCHER TWO: Oh, no, the magnet plates stick to each other?

MIT STAFF RESEARCHER THREE: . . .plus or minus three feet.

ERIC LANDER: Since one's on the cutting edge...I guess they always call it "the bleeding edge," right? Nothing really is working as you expect. All the stuff we're doing will be working perfectly as soon as we're ready to junk it.

ROBERT KRULWICH: The MIT crew is particularly excited about their brand new three-hundred-thousand-dollar state-of-the-art DNA purifying machine.

MIT STAFF RESEARCHER FOUR: Why don't you turn it on.

MIT STAFF RESEARCHER THREE: All right, maiden voyage. It didn't ask me for a password. That's good.

MIT STAFF RESEARCHER FOUR: Are you supposed to get the yellow light right away?

ROBERT KRULWICH: I don't think the blinking light is a good sign.

ERIC LANDER: It's sort of like flying a very large plane and repairing it while you're flying. You want to figure out what went wrong. And you also realize that you're spending, oh, tens of thousands of dollars an hour. So you feel under a little pressure to sort of work this out as quickly as you can.

ROBERT KRULWICH: So he calls the customer service line. And of course he's put on hold. So he waits. And he waits. And he waits. Anyway, it turns out that the three-hundred-thousand-dollar machine does have one tiny little valve that's broken, and so it doesn't work.

....

FRANCIS COLLINS: When you try to ramp something up, anything that's the slightest bit kludgy suddenly becomes a major bottleneck.

Here, we are being given glimpses of a group of researchers who are desperately locked into a high-profile race for scientific priority and whose strategy for success is to bank on a series of new mapping and sequencing devices over which, frankly, they do not have full control. As various new machines arrive, they're unpacked, installed, and . . . there are problems. Team members desperately try to figure out what's wrong; sometimes they get help from the manufacturers, and sometimes they don't. Machines are fixed and fudged in any way possible, but there are constant risks, especially with anything that's "kludgy." What's happening, actually, is that researchers are customizing laboratory equipment on the fly in order to make it work not just well but well enough to beat the competition (in this case, Celera Genomics), which probably means better than the manufacturers originally envisaged.

Now, of course, this information is all courtesy of a PBS *Nova* special, which is to say that it's designed for prime-time American TV, so in the end this particular story is told as a heroic folk epic in the time-honored tradition. There's an initial state (let's sequence the human genome, everyone), which is followed by an unwelcome challenge (we're going to blow you out of the water by completing the task in less than half the time, with private money, for private profit), which precipitates a crisis ("these folks have to figure out how to outfit their labs with a lot of new and fancy and unfamiliar equipment"), which is followed by eventual triumph (we made history, and

we got invited to the White House). This familiar frame is neither particularly surprising nor, for present purposes, particularly interesting. What is of greater interest is an alternative, more fine-grained frame: the frame of scientists and their engineering coworkers striving mightily among, against, and with the help of machines.

From one point of view, the Human Genome Project was a technological challenge whose eventual solution lay in more than a decade of dizzyingly fast innovation in mapping and sequencing technologies. Among other things, this challenge drove an iterative process between equipment manufacturers and genomics laboratories, in the course of which each contributed materially to the process of technological innovation. This contribution was never clearer to me than when, in the fall of 2012, I joined my MIT Museum curatorial colleague Debbie Douglas and Chad Nusbaum, codirector of the Genome Sequencing and Analysis program at the Broad Institute of Harvard and MIT, on a visit to a storage facility in Hingham, south of Boston. There, we viewed a large number of historic mapping and sequencing machines that had passed through the Broad Institute (and its immediate predecessor, the Whitehead Institute/MIT Center for Genomic Research) and were now slated for—well, what exactly? Although all of these machines had last seen active service within the past 15 years, all were now entirely obsolete, and although all were in storage, the largest among them, none other than the "brand new three-hundred-thousand-dollar state-of-the-art DNA purifying machine" featured in the 2001 *Nova* documentary, had been moved to one side of the storage warehouse, near the door, awaiting collection for final disposal (i.e., the dumpster).

That day, it was agreed that 10 machines from the Broad Institute's storage facility should be formally acquired by the MIT Museum and transferred for safekeeping to the museum's own off-site storage facility, just a couple of miles from MIT.[19] There, today, sit several generations of successive mapping and sequencing devices. These devices are the very opposite of proverbial black (or gray) boxes. To be sure, they are all based around commercially manufactured products, but they are extensively open, and they show multiple signs of having been customized in various ways by their users. One assembly comprises a Beckman Multimek machine combined with two Perkin Elmer plate stackers (see note 19, items 6–8); another is a small commercial oven, of the sort customarily used for baking pizzas, which has been modified for use in DNA amplification (see note 19, item 5). On closer inspection, many of the machines appear to be nonstandard and, to use Francis Collins's word, extremely "kludgy."

Among these machines are two that appear to be sections (for reasons that will become obvious, let's call them stations) from the very large, production-line-like DNA purifying machine that Collins and his colleagues can be seen struggling with in that NOVA documentary (see note 19, items 1 and 2). During our visit to the Broad Institute's storage warehouse, Nusbaum told us that this machine was sufficiently large and error prone that several techniques had been adopted to make it easier to operate. For one thing, tall masts with traffic lights were set up as error detectors. Whenever one of these masts went orange (or worse, red), the team knew where the next problem was located. Again, since time was of the essence, it was felt to be important to get to a

malfunctioning station as quickly as possible in order to try to fix the problem without delay. So it was decided to give each station a simple, easily memorable name, and what could be simpler or more memorable than the well-known sequence of subway stations along the Massachusetts Bay Transportation Authority (MBTA) system, or "T" system?

The T, the oldest subway system in America, covers the Greater Boston Metropolitan area with a number of different lines, each of which is named after a different color. Cambridge is served by the Red Line, which runs from Braintree and Mattapan south of Boston via Park Street in downtown Boston and on to several stops in Cambridge, including Kendall Square at MIT in east Cambridge and Alewife, the last stop, in west Cambridge. Given the location of the White-head Institute/MIT Center for Genomic Research, just a few hundred yards from the Kendall T stop, it was perhaps natural that the team would choose the names of Red Line T stops by which to recognize the successive stations on their "brand new three-hundred-thousand-dollar state-of-the-art DNA purifying machine." And this, presumably, is why stuck to the side of one of these CCS Packard Sequencing Decks is the word "Park" while stuck to the other one is the even more evocative name "Alewife" (Figures 2 and 3). It must be presumed that were all the components of this sequential analyzer to be reassembled in the correct order, Alewife would be found to be the last and final station stop.

Conclusion

I have argued that there are several fundamental reasons why museums of science and technology should collect more contemporary artifacts. First and foremost, objects are evocative: they are carriers of the cultures that create them and thus are capable of supporting and sustaining stories that serve to embed human endeavors (in this case, scientific and technological endeavors) firmly in their human, real-world contexts. Second, objects embody large amounts of tacit knowledge; that is, they evoke many aspects of scientific and technological research that researchers may know but be unable and/or unwilling to tell.

The intensely competitive, multiply contingent, and relentlessly "kludgy" character of genomics research in the late 1990s and early 2000s is not apparent, even from the most careful perusal of the research papers and reports that were issued by the leading participants in the Human Genome Project. As we have seen, some of these characteristics emerged from the best media accounts of the project, such as the *Nova* special documentary that has been discussed, but such accounts are at best fleeting and evanescent (we may thank PBS for deciding to archive online past *Nova* specials all the way back to the turn of the millennium), and they are mostly driven by other, frequently shorter-term considerations than those that weigh with historians and cultural critics. At any rate, it would be a brave person who would rely on documentary sources even as worthy as those of PBS for their best understanding of the nature and place of science and technology in twenty-first-century society.

The genomics machines that were acquired by the MIT Museum as gifts from the Broad Institute in 2013 have yet to be thoroughly researched. Our partial collection needs to be

2.
Overhead view of CCS Packard Sequencing Decks, with Alewife section to the left and Park to the right. Deborah Douglas, photographer, courtesy MIT Museum.

3.
Close-up of Alewife label. Deborah Douglas, photographer, courtesy MIT Museum.

complemented with additional acquisitions of other material reflective of the breathtaking pace of technical developments in this field through the 1990s and 2000s, and all need to be analyzed in the larger context of the recent history of genomic science and medicine. With the benefit of access to a more complete array of materials, as well as to many of the scientists and engineers who first developed and used them, it will surely be possible to gain deeper insights into the close interplay between equipment manufacturers and the research scientists, engineers, and other technical support staff who customized and used these machines to drive genomics forward with such speed, from the early days right up to the present. One thing only is certain: there will be rich stories to tell, hopefully in the form of displays and exhibitions, as well as articles and books.

Published papers and monographs, archival records and manuscripts (including laboratory notebooks, private correspondence, and email), personal interviews, and nonparticipant and participant observational studies of laboratory researchers in real time, all of these are valuable sources for historians of scientific and technological culture. The modest aim of this chapter has been to make the case that the collection of recent and contemporary artifacts deserves a place on this list. Historians of science and technology should look to their museum colleagues not merely for what existing museum collections have to offer by way of research resources but also for what new materials might yet be made available through programs of active, targeted collecting.

Let it be remembered, finally, that in this subject area, unlike some others in which museums take an active interest, artifacts that are not acquired into museum collections are apt to end their days not in the delicate, white-gloved hands of private collectors and their curators, but rather in the thick, rubber-gloved hands of waste disposal officers. In this as in other respects, the MIT Museum's recent experience with the Whitehead Institute/MIT Center for Genome Research's old, obsolete, but once upon a time and not so long ago "brand new three-hundred-thousand-dollar state-of-the-art DNA purifying machine" is hopefully instructive.

Notes

1. D. Douglas, *Countless Connecting Threads: MIT's History Revealed through Its Most Evocative Objects* (Cambridge, MA: MIT Museum, 2013). See also Sherry Turkle, ed., *Evocative Objects: Things We Think With* (Cambridge, MA: MIT Press, 2007).

2. Douglas, *Countless Connecting Threads*, 196. In her account, Douglas is rightly careful not to give the impression that the "problem" of gender discrimination at MIT was "solved" by these events; that was certainly not the case. Nevertheless, it is clear that these events had a major and lasting part to play in what is an ongoing debate. See Massachusetts Institute of Technology, "A Study of Women Faculty in Science at MIT: How a Committee on Women Faculty Came to Be Established by the Dean of the School of Science, What the Committee and the Dean Learned and Accomplished, and Recommendations for the Future," *MIT Faculty Newsletter* 11 (March 1999), http://web.mit.edu/fnl/women/women.html (accessed 10 March 2017).

3. For striking examples of scientists reflecting on the role of evocative objects in their own early experience, see Turkle, *Evocative Objects*, note 1.

4. William Jarvis, *Time Capsules: A Cultural History* (Jefferson, NC: McFarland, 2002).

5. See "MIT Museum Acquisitions Policy," http://web.mit.edu/museum/pdf/Manual-text2.pdf (accessed 10 March 2017).

6. For an account of the culture of student hacks at MIT, see Institute Historian T. F. Peterson, *Nightwork: A History of Hacks and Pranks at MIT* (Cambridge, MA: MIT Press, 2011).

7. The literature within the burgeoning field of museum studies essentially agrees on this basic point. For general anthologies, see Bettina M. Carbonell, ed., *Museum Studies: An Anthology of Contexts*, 2nd ed. (Oxford: Wiley-Blackwell, 2012); Sharon MacDonald, ed., *A Companion to Museum Studies* (Oxford: Wiley-Blackwell, 2011). For a critical review of alternative approaches in the field, see Randolph Starn, "A Historian's Brief Guide to New Museum Studies," *American Historical Review* 110 (2005): 65–98. For essays on some of the ways in which natural or found objects carry cultural meanings, see N. Jardine, J. A. Secord, and E. C. Spary, eds., *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996).

8. Clifford Geertz, "Thick Description: Toward an Interpretive Theory of Culture," in *The Interpretation of Cultures: Selected Essays* (New York: Basic Books, 1973), 3–30.

9. Steven Conn, *Museums and American Intellectual Life, 1876–1926* (Chicago: Chicago University Press, 1998).

10. Steven Conn, *Do Museums Still Need Objects*? (Philadelphia: University of Pennsylvania Press, 2010), 7.

11. Conn, *Do Museums Still Need Objects*?, note 9, chapter 4, 138–171.

12. Two cases in point are the Boston Museum of Science and the Chicago Museum of Science and Industry. Both started out as collecting museums but subsequently relinquished most or all of their curatorial work in favor of purely educational activities.

13. This point is addressed in more detail in John Durant, "'Whatever Happened to the Genomatron?' Documenting a 21st Century Science," *Studies in History and Philosophy of Science, Part A* 44, no. 4 (2013): 676–682.

14. M. Polanyi, "The Logic of Tacit Inference," *Philosophy* 41, no. 1 (1966): 4. See also M. Polanyi, *The Tacit Dimension* (Gloucester, MA: Peter Smith, 1966).

15. The literature on the role of tacit knowledge in scientific practice is enormous. One scholar who has paid particular attention to this subject is science and technology studies scholar Harry Collins. See, for example, *Artificial Experts: Social Knowledge and Intelligent Machines* (Cambridge, MA: MIT Press, 1990); *Changing Order: Replication and Induction in Scientific Practice*, with a new afterword (Chicago: University of Chicago Press, 1992); *Tacit and Explicit Knowledge* (Chicago: University of Chicago Press, 2010).

16. "Cracking the Code of Life," *Nova*, PBS, 17 April 2001. A full transcript is available online at http://www.pbs.org/wgbh/nova/body/cracking-the-code-of-life.html (accessed 10 March 2017; all of the details given in the text are drawn from this source).

17. At the time of writing, the only book-length treatment of the history of Human Genome Project by anyone other than a leading participant in the project itself is Victor K. McElheny, *Drawing the Map of Life: Inside the Human Genome Project* (New York: Basic Books, 2010). For accounts by some of the principal actors in the project, see Francis Collins, *The Language of Life: DNA and the Revolution in Personalized Medicine* (New York: Harper, 2010); J. Craig Venter, *A Life Decoded: My Genome, My Life* (New York: Penguin Books, 2007).

18. To make this extended quotation from the transcript of the documentary easier to follow, please bear in mind that the segment from which it is drawn features what appears to be a single extended scene in the Whitehead Institute/MIT Center for Genome Research. We listen to conversations among researchers, with occasional voice-over commentary from Krulwich and cuts to interviews between Krulwich and key actors, including both Collins and Eric Lander, who was then head of the Whitehead

Institute/MIT Center for Genomics Research. The Jane referred to in the voice-over is Jane Rogers, then head of sequencing at the Sanger Centre (now the Wellcome Trust Sanger Institute) near Cambridge, England.

19. The items formally donated by the Broad Institute to the MIT Museum as a result of this visit were as follows: (1) CCS Packard Sequencing Deck, no tag, serial number 2111; (2) CCS Packard Sequencing Deck, no tag, serial number 2114; (3) CCS Packard/Perkin Elmer MiniTrack, Whitehead tag number 3-11291, serial number 427517; (4) Genetix QPix, Whitehead tag number 3-10889; (5) Holman Miniveyor (Star Manufacturing), no tag, serial number C02100708A0024; (6) Multimek (Science), no tag, serial number 304260APS; (7) Perkin Elmer PlateStak, MIT tag number 0390338, serial number 795078; (8) Perkin Elmer PlateStak, MIT tag number 0390337, serial number 795075; (9) Perkin Elmer 377 Sequencer, Whitehead tag number 3-074271, serial number100000887; and (10) Genemachines HydroShear, Whitehead tag number 3-09980.

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History as Intellectual and Organizational Tool in Creating a Collections Rationale

The Smithsonian's National Air and Space Museum's Spaceflight Artifacts as Case Study

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Introduction

The title of this paper may seem odd: Should it be remarkable that a prominent national museum with stewardship over a collection of artifacts spanning more than a century uses history as an intellectual tool in creating a collections rationale—that institutional template used to guide decisions on acquisitions and deaccessions? This question, though, points at an interesting phenomenon. Even at the Smithsonian National Air and Space Museum (NASM), situated within an institution with a strong scholarly tradition, the use of academic thinking to conceptualize and manage a collection has been haphazard. In part, this reflected a curatorial culture that until the recent past, gave preference to the tacit expertise of an individual curator rather than requiring him/her to make explicit scholarly justifications as a basis for shared decision-making on collections matters. It also reflected, as will be described more fully below, the complex cultural position of a national museum. Only in the early 1990s, as a response to overarching Smithsonian policy mandates, did the museum begin to create formal collections rationales.[1] These initially were constituted primarily of taxonomies and lists: of the existing collection, of targets for acquisition, and of potential deaccessions. The next iteration, in 2000, inaugurated a requirement to prepare a revision every five years; that version and the next

in 2005 incorporated a modest move away from taxonomic thinking toward using scholarly literature to inform judgments embedded in the rationales. A revision undertaken in 2010, though, reoriented this prior practice and required that an assessment of relevant scholarly literatures provide the intellectual structure for the rationale. This essay explores that exercise in creating an academically grounded rationale covering the spaceflight-related collection, situating it in the larger museum context.[2]

Context

However, as the above suggests, such effort was not—and could not be—abstracted from the practical and political circumstances of providing stewardship of a collection. Rather, it was necessarily embedded in the ecology of institutional life—in the history of the organization, in its relations with donors and other constituents, in the use of artifacts in exhibitions (in which their meaning might differ from that provided in the rationale), and in the availability of specific organizational resources, such as museum-quality storage space. It also reflected a quirk in the museum's professional organization, in which aviation and spaceflight were divided between distinct curatorial departments, each composed of Ph.D. historians, each with the latitude to define the meaning of a rationale for collecting in its own subject area. Thus, a variety of issues ran through and around the creation of the rationale, raising the question of how history as a domain of expertise intersected with these other factors.

In this complex of relations, timing mattered, both as to curators' conception of historical valuation and the broader institutional context. Intellectually, the rationale had to confront, at least in outline fashion, a shift in the political and cultural economy of the creation of space artifacts. The great bulk of the museum's spaceflight collection documented the post–World War II period, with a heavy emphasis on the Cold War and on artifacts created mostly through state initiatives, which intimately involved U.S. industry and universities via contract (thus implicitly embodying the "military-industrial-academic complex" as narrative).[3] But by 2010, 20 years after the fall of the Berlin Wall, the Cold War template for the development and production of space-related technologies had been substantively altered; the market had risen in prominence as a source and definer of technologies. Such historical change not only meant fresh assessment of the relations between our collections and Cold War historiography but also raised the question of the proper framework for thinking about historical significance in this different set of relations among states, markets, and culture, including a different balance between national and transnational contexts via globalization.

Not insignificantly, this political economic trajectory overlapped with the development of history of science and technology as fields of inquiry, especially through the science and technology studies movement and with the concomitant reorientation of the humanities in the academy toward social and cultural history. In the 1990s, these intellectual developments took on even greater salience for museums in the heightened attention given to "objects" and "materiality" as critical sites of research. Such scholarly reorientations in combination had two consequences for

undertaking a collections rationale.[4] One, now prosaic, shift was to broaden the context of inquiry and thus of explanation—of what historical factors related to others, with what consequence. In short, it extended the range of potentially meaningful artifacts. As corollary, too, it enhanced the historical status of "nontechnical" artifacts, helping to decenter prior intellectual tendencies among curators that regarded innovation and progress as the primary rationales for collecting.[5] For NASM, such repositioning gained substance in 2004 through the hiring of a curator for space-related social-cultural history.

In juxtaposition with this background of scholarly conceptual change was the museum's own history. Technologies of early flight came into the Smithsonian in the first decades of the twentieth century, but only after World War II did the possibility of creating a specialized museum arise, inspired in large part by a donation from the U.S. Army Air Forces that included along with examples of U.S. technology a substantial number of captured German and Japanese aircraft and rockets. In 1946, an act of the U.S. Congress created the National Air Museum, but without funding to build a facility. In the mid-1960s, as the United States embarked on its spaceflight programs, a subsequent congressional act redesignated the facility as the National Air and Space Museum, yet again without requisite funding.[6] Only in the run-up to the U.S. bicentennial in 1976 did NASM gain the resources to create a separate museum, opening its doors in that year of national celebration on 4 July, Independence Day.[7] As this chronology suggests, the museum was embedded in a powerful set of foundational narratives that linked the nation, progress, American exceptionalism, and developments in aviation and spaceflight. In Benedict Anderson's useful phrase the museum served as a node in an "imagined community."[8]

By the 1980s this public face of the museum existed if not in tension then at least in difference with the professional cultures of the curatorial departments. For their Ph.D.-holding, humanities-trained staff such organizing narratives became increasingly subject to demythologizing, but the critique of which took a specific form. In the museum's exhibitions, in which the concerns of political and public stakeholders took precedence, these narratives largely remained intact. Yet in the individual, scholarly publications of curators the historiographic, intellectual positioning of research was indistinguishable from period academic output from the mid-1980s and after.[9] After 2000 (following the first and second iterations of preparing collections rationales), it became clearer to curatorial staff that the rationale was not a bureaucratic device but a critical professional document. It stood poised between exhibitions (and their metanarratives) and curatorial scholarly publication. In contrast to exhibitions, developed with a team composed of different skills, the rationale was composed solely by curators, providing a vehicle for more deeply integrating academic perspectives into a critical area of museum life and to do so as an explicit expression of their expertise.

This shift in perspective, however, was embedded in a pattern of change in the larger Smithsonian that made collections stewardship throughout the institution a higher priority. This change came from a reinvigorated belief in the centrality of collections to the institution's purpose and, as corollary, in creating stronger managerial practices to ensure their preservation for the long term,

both of which played into the need for marshaling political support to gain resources necessary to renovate or build professional-quality storage facilities.[10] It also drew motivation from the contemporaneous, vast expansion of digital culture, nationally and internationally. In this context, especially, objects and collections stood as the defining element of the museum as museum. They were the resource, compared to exhibitions or research, most easily translated to virtual visitors and their varied interests—that spoke to the shifting boundaries of authority between experts and multiple publics. Objects, thus, became vital means and measure for linking a range of visitors to the institution's educational mission. After 2000, these intellectual, institutional, and cultural developments came to be aligned and mutually reinforcing.

The Collections Rationale for Spaceflight and Rocketry, 2010

As the foregoing overview suggests a collections rationale, at least at the Smithsonian, is a document that straddles distinct interests. Making judgments about what to collect (or remove from the collection) is taken as an intellectual problem delegated to relevant subject matter experts—curators—in which practical considerations are distinctly secondary. Museum *approval* of such judgments, however, is fundamentally infused with such consideration, including provenance, storage, conservation, donor relations, and other concerns. But such approval is taken as a distinct step, subsequent to intellectual justifications for collecting as drawn from the departmental rationales. In the institution's division of labor, thus, curators have the responsibility and authority to create the rationales for collecting but do so in a complex symbiosis with the broader ecology of the museum and Smithsonian.

The 2010 collections rationale entered into this larger set of contextual relations in a specific way: it aimed to create an overarching narrative of the history of spaceflight and its relation to broader historical themes of the twentieth and early twenty-first centuries. In so doing, it sought to create a frame of meaning for objects, individually and collectively, and for the museum itself—one that stood in juxtaposition with other sources of meaning. As a core claim, the rationale argued that spaceflight and rocketry "have been central, not peripheral, to the course of recent decades—in terms of advances in science and technology, their relation to politics and world affairs, their intersection with daily life, and (especially with respect to spaceflight) the profound ways in which they have engendered new perspectives on the relation of humans to planet Earth and to the universe."[11] In short, these activities and their associated artifacts were broadly consequential in world history, at macro and micro levels of experience, showing the multiple, salient ways in which rocketry and spaceflight came to matter for and entered into individual lives, communities, nations, cultures, and the tangle of international relations. Thus, rather than offering a typology or a narrative of linear innovation or progress, the rationale sought to ground the collection in spaceflight's historical import and its contingent construction through a variety of factors—and in the process de facto offering a particular definition of the museum's relation to its subject matter.

At the broadest level, the rationale aimed to situate spaceflight in the messy, complex world of modernity—to see it as inseparable from the larger contours of the nineteenth and, especially, the twentieth centuries, part of the prominent, pervasive role of science and technology in Western culture, which, in turn, was bound to core concepts of politics, economics, and society. Such intellectual positioning is completely unexceptional—except when viewed against the backdrop of the museum's prior strong attachment to U.S. exceptionalist and progress narratives.[12] To take the modern as the broad frame opened up the range of historical issues and concerns that the museum's artifacts might document and to which they might speak.

This broad formulation was refined along three principal vectors, reflecting several major categories of historiography: (1) "America in the world" literature, primarily from diplomatic history; (2) history of science and technology accounts of research, development, and political economy; and (3) cultural history. These historiographic strokes provided a first-order characterization of relevant sites of production and consumption as well as modalities of causation and meaning. Such conceptualization provided the basis for the document's key means of setting the overarching relation between history as intellectual tool and the museum's collection of artifacts: to define historical periods and then relate claims of significance for particular artifacts or groupings to such orders or conditions. As this strategy suggests, the rationale was not only a tool to organize curatorial thought on the broader rather than narrower meanings of the collection but also to provide a reference for presenting spaceflight as subject matter to visitors. As the use of the diplomatic history literature implies, the rationale sought to accommodate national and transnational analytic perspectives but as a national museum give salience to a relevant fact: through the twentieth century, and increasingly so over its course, the United States became an actor of broad influence on the world stage. In the early decades, this primarily was via economic power, but with World War II, the Cold War, and post–Cold War period, this prominence was manifested through military and economic power, through a myriad of relationships between the state and the marketplace, between activities within the nation and abroad. "America in the world" captures these several connotations: of the importance of science and technology to the modern era, to U.S. national identity, and to the United States' sweeping role on the international stage. Spaceflight became integral to and signature expressions of each.

As pointed to above, spaceflight has not been a self-contained, insulated activity, whether viewed in national or international contexts. In collecting, the challenge for the curator and the museum is to develop an in-depth appreciation of the varied, often complicated specifics of scientific and technical knowledge and practice, of the work of laboratories, factories, test facilities, launch sites, and the operation of space hardware. But it also is to appreciate the often strong interrelations among science, technology, and culture, between government and private business, between military and civilian life, between high politics and consumer society, between social elites and everyday citizens. In short, on the basis of historical understanding, the rationale assumed the interconnectedness of spaceflight in its various guises, in the specifics of its development, and as a component of the American experience writ large. Not surprisingly, at the time of the writing of

the rationale, technical or scientific accomplishments and representations of spaceflight in consumer or workaday life coexisted in the collection—they just had not been explicitly connected in a conceptual narrative of what the collection documented and meant historically. The underlying claim was that such juxtaposition and convergence reflected the fluid nature of the American experience, especially after World War II—that there was and continues to be a causal interplay among different realms of activity, from the technical shop and laboratory, to social groups and individuals and an expanding, ubiquitous media, to consumer culture, and to politics.[13]

But how were such general organizing assumptions brought down to particular contexts for the purposes of making collecting (or deaccession) decisions? As noted, the rationale established a periodization that interrelated modernity, science and technology, nation-states, the markets, and spaceflight. This yielded three periods: pre-1945, 1945–1989, and post-1989, a canonical organization from the Western perspective. Conceptually, this was crosscut with several themes: innovation, context of innovation, modes of political and economic organization, and the role of American society and culture. For brevity here, the justification for these periods and themes will not be elaborated, but their intent was to help document spaceflight as an activity located in specific places and times and in relation to broader historical trends and forces. As a rationale, such framing was to help assess historical significance through a series of questions:

- What themes and stories might the collection document for a given period or overall? Which stories are important or essential? Which are peripheral?
- Is the existing collection, assessed in terms of a given period or overall, sufficient for documenting stories and themes deemed historically significant? Might it be pruned or expanded?
- Are there themes/stories not yet represented by artifacts in the collection that might be documented through new acquisitions?

As sketched here, the 2010 rationale undertook the critical tasks of integrating spaceflight into large historical narratives and of providing a template for historical significance. Curators used this framework then to prepare individual rationales for their respective collecting areas (human spaceflight; rockets and missiles; guidance, navigation, and control; international space programs; U.S. national security space programs; space sciences; civilian applications satellites; and the social and cultural dimensions of spaceflight), each of which as a subject has overlapping and distinct historical configurations of institutions, technical or scientific specialties, and relations to politics and culture. These various parts, in aggregate, compose the rationale. When a curator seeks to acquire (or remove) an object for (from) the collection, he/she prepares a proposal that requires a clear justification based on the rationale, which then goes through three levels of museum review: by the home department of curator, by a museum-wide committee, and by the museum director. For an object to be collected, a proposer must clear all these levels of review.

Since 2010, more than 1,000 artifacts have been added to the museum's spaceflight collection (and more than 200 have been deaccessioned). The rationale affected these actions in several

ways. At a broad level, it has altered practice indirectly: by discouraging curators from collecting objects whose justification might previously have been presented in taxonomic or progress-oriented terms. In preparing a proposal, too, the need to present historically grounded arguments to justify an acquisition has led to a greater level of scrutiny in the review process (particularly for the departmental review). In giving prominence to periodization as an analytic tool, the rationale also directly addressed two interconnected challenges. One was to provide for a clearer assessment of the existing collection: what artifacts does the museum need to tell the stories and meaning of particular moments in time, and thus, what can and should be deaccessioned? This was (and is still) not a trivial problem, as the core of the space collection arrived in bulk and absent any criteria of selection in the early 1970s, as the first wave of U.S. human spaceflight programs concluded. The other effect, noted earlier, was to bring into clearer focus the problem of documenting more recent history (the post–Cold War era), with its relative shift from state to market-sponsored initiatives. In short, the rationale sought to make historically grounded time its primary precept for thinking about the collection.

The most significant example, highlighting the interplay of these factors, came in collecting artifacts from NASA's space shuttle program, discontinued in 2011. NASA made many thousands of artifacts available for disposition to educational institutions; the museum collected only several hundred, emphasizing the acquisition of those which could be connected to prominent period historical themes, bridging Cold War and post–Cold War history.[14] This discretion in collecting reflected not only the rationale's affirmative agenda but also a desire to avoid (as much as possible) making deaccession of shuttle artifacts a significant problem for future curators (in contrast to the early 1970s situation). The new rationale, with its emphasis on seeing technology in broad period context, also normalized collecting shuttle program artifacts associated, for example, with workplace culture and practices (motivational posters, tools, and the like). It also accommodated a variety of collecting postures, from passive "over the transom" collecting opportunities to proactive initiatives in individual collecting areas. The shuttle effort was a combination of the two, requiring proactive effort to identify the universe of possible acquisitions yet benefiting from NASA's preexisting commitment to direct artifacts to the museum.

Conclusion

The 2010 spaceflight rationale, in a sense, stood as a remedial document, post hoc imposing a unifying scholarly narrative on an existing collection but roomy enough in its conceptualization and the questions asked to provide guidance to future collecting. In its historical framing, it took a specific stance on integrating spaceflight into the narrative and conditions of modernity. This decision was purposeful, recognizing that other frameworks of interpretation might have been posed (with progress as one handy alternative). The approach chosen fit the skill set of the museum's curators, but equally important in the process was a basic desideratum: to articulate and make explicit our framework of judgments. We wanted to make clear to ourselves, our museum peers, and especially to our successors in the future our intellectualization of our collections

stewardship. There are no absolutely right choices in collecting; the best that can be done is to make the underlying process of judgment visible.

As the foregoing analysis suggests, the rationale was, in an important way, an idiosyncratic document, a product of the particular professional environment of the museum's Department of Space History. The Department of Aeronautics rationale written at the same time hewed more closely to the prior intellectual framing. This difference reflected (and still reflects) the two departments' relative independence in this area of museum life, a fragmentation that persists across the Smithsonian as a whole. The institution has no overarching mechanism for organizing and sharing rationales across its many museums. These circumstances only emphasize how institutionally and culturally specific the production of a collections rationale is, bound to the needs and history of local circumstances. If the scholarly derived, retrospective work had been done in a prior spaceflight rationale, the 2010 effort might have looked different, focusing perhaps more intensively, say, on the specific challenge of representing the post-1980 sociotechnical elaboration of the turn to the market. The document, too, is modern in its own way, taking expertise as its organizing principle.[15] One can easily envision a future model in which networked or crowdsourced modes of knowledge play a much more prominent role in collecting, not merely out of a democratic impulse but because they speak to the historical conditions that museums may seek to document.

Notes

1. For a partial accounting of this shift see National Air and Space Museum, "Collections Management Guide," (unpublished document, 1992). The preparation of this document was stimulated by Smithsonian Institution Office Memorandum 808, 1990 rev., which required each Smithsonian museum to develop a collections plan.

2. This collection also includes artifacts relating to rockets, some of which (such as the V-2 or intercontinental ballistic missiles) do not in their own historical context derive their primary meaning from their association with space. In this essay, *spaceflight*, in relation to the museum collection, is meant to include rocketry artifacts.

3. As of 2014, the national collection of rocketry and space artifacts numbers almost 15,000 artifacts, of which about 1,400 are on display at the museum's two facilities (the National Mall building and the Udvar-Hazy Center), almost 1,100 are on loan, and approximately 12,500 are in storage. Artifacts range in size from the massive Saturn V rocket (over 350 feet long) to a fingernail-size silicon chip used in the search for extraterrestrial life and arc in time from an early nineteenth-century Congreve rocket to twenty-first-century developments such as SpaceShipOne.

4. One useful marker of this intellectual interest is Tony Bennett and Patrick Joyce, eds., *Material Powers: Cultural Studies, History and the Material Turn* (London: Routledge, 2010).

5. The narrative of progress has been a defining characteristic of the museum since its inception, waning but not disappearing in recent years. For a critique of the museum in this regard see Michal McMahon, "The Romance of Technological Progress: A Critical Review of the National Air and Space Museum," *Technology and Culture* 22, no. 2 (1 April 1981): 281–296.

6. What this new legislation foregrounded was U.S. civilian initiatives in science and human spaceflight, which comported with those national narratives just mentioned. Not highlighted were U.S. national security space programs, often executed under classification strictures. By the mid-1970s, such programs garnered the majority of U.S. space expenditures.

7. For an overview history of the museum see Michael J. Neufeld and Alex Spencer, *Smithsonian National Air and Space Museum: An Autobiography* (Washington, D.C.: National Geographic Society, 2010).

8. Benedict R. O'G. Anderson, *Imagined Communities: Reflections on the Origin and Spread of Nationalism*, rev. ed. (London: Verso, 2006). See especially chapter 10, "Census, Map, Museum." Such cultural positioning provides the background for the widely publicized controversy in 1994–1995 over the museum's proposed exhibition on the Enola Gay and the end of World War II.

9. An indicator of this might be those examples of museum scholarship that received awards from professional societies. See Robert W. Smith, *The Space Telescope: A Study of NASA, Science, Technology, and Politics* (Cambridge: Cambridge University Press, 1989), History of Science Society, Watson Davis and Helen Miles Davis Prize, 1990; Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: Free Press, 1995), Society for History of Technology, Edelstein Prize, 1997; and Martin Collins, "One World One Telephone: Iridium, One Look at the Making of a Global Age," *History and Technology* 21 (2005): 301–324, Society for History of Technology, IEEE Life Members Prize, 2006.

10. This turn in its timing and emphasis was captured by the Smithsonian's key policy document on collections management, *Smithsonian Directive 600: Collections Management* (Washington, D.C.: Smithsonian Institution, 2001). It set the framework

and requirement for the creation of collections rationales by individual museums as well as the meaning of collections in the institution's ethos: "The acquisition, preservation, management, and study of collections are fundamental to the Smithsonian's mission and have been the foundation upon which its reputation rests. Assembled over more than 150 years, the national collections are central to many of the core activities and to the vitality and significance of the Smithsonian. Collections serve as an intellectual base for scholarship, discovery, exhibition, and education. Collections also provide content for Smithsonian ventures such as publishing, licensing, and media projects."

11. Department of Space History, National Air and Space Museum, collections rationale, 2010. Note that at present this document is not available publically.

12. A 1981 review of the museum, five years after its opening, in *Technology and Culture* made the commitment to such narratives the centerpiece of its critique; see McMahon, "The Romance of Technological Progress." Such intellectual dissonance between the progress narrative and the broader complexities of history has been acutely reflected, as a key example, in the museum's evolving exhibit treatment of the German V-2 missile; for an account of this see David H. DeVorkin and Michael J. Neufeld, "Space Artifact or Nazi Weapon? Displaying the Smithsonian's V-2 Missile, 1976–2011," *Endeavour* 35, no. 4 (2011): 187–195.

13. As the leader of the Department of Space History's 2010 revision of the rationale, I developed this intellectual framework; individual curators then used it to write the rationales for their specific collecting areas, filtered through their understanding of historiography relevant to their objects. I then reviewed and edited their drafts to ensure a close relationship between the overarching framework and their contributions to the rationale. The finished product was composed of an introduction presenting the rationale's overall organizing ideas and the individual curatorial rationales, the entire effort identified as a collective statement of the department.

14. Two aspects of this process should be noted. Since 1967, by a memorandum of understanding (MOU) with NASA, the museum had the right of first refusal for objects the agency no longer deemed as having operational value. This MOU made it possible for the museum to receive, among other objects, the iconic spacecraft of the Mercury, Gemini, and Apollo programs. In the early 1970s, the museum acquired, with little discrimination, thousands of objects from these programs. This MOU still is in force, and the museum could have acquired objects from the shuttle program on a similar scale. But the 2010 rationale made thoughtful, intellectually supported collecting a high priority, thus resulting in a smaller number of acquisitions. This approach was reinforced by a heightened pragmatic concern that emerged in the 2000s: the reduced availability of and the costs associated with developing additional museum storage space.

15. A critique of this curator-centered collecting methodology at the Smithsonian is put forward in Steven Lubar, "Fifty Years of Collecting: Curatorial Philosophy at the National Museum of American History," *Federal History Journal,* no. 7 (2015): 82–99.

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Understanding "Contemporary Collecting"
Modern Collecting at the Science Museum

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With its focus upon the delocalized "now," the category of "contemporary collecting" is inherently ahistorical. Yet the category itself can be analyzed historically. At particular times, the practice has been a part of institutional strategies designed to respond to intense societal pressures and to make important cultural contributions. A former director of the Science Museum, Neil Cossons, has argued that the "tension, between the need to educate and instruct, and the wish to preserve and record, forms a continuous thread throughout the history of the Science Museum and of its great sister institutions overseas."[1] The changing resolutions of this enduring tension has been a critical part of the history both of museums and of societies. The Science Museum itself is the second-oldest collection of its kind, after the museum at the Conservatoire National des Arts et Métiers. It is also hugely influential worldwide. Its development therefore provides an interesting case study that might provide insight into the entire sector as well as its own distinctive history. This paper explores the relationship of past and present across the museum's history, examines the concept of contemporary collecting, and argues that the category itself, as it operated at the Science Museum, needs to be understood in terms of the special historical circumstances of the 1980s and 1990s.

Late Nineteenth and Early Twentieth Centuries: Evolutionary Models, Objects from the Past Point the Way to the Contemporary and the Future

The particular meaning of the late twentieth-century context is highlighted by contrasts, and also analogies, with the period a century earlier when the museum was founded and, more generally, the relationship between past, present, and future were being renegotiated. The decade of the 1880s was a period in which the British had become aware of the world their last century had wrought and also the passing of that industrial hegemony. Reevaluating that period, the historian and social commentator Arnold Toynbee popularized the term "Industrial Revolution" to denote its disruptive social turmoil. The writings of the social evolutionist Herbert Spencer, familiarly summarized as "survival of the fittest," were popular. They would deeply influence the most important philosopher of technology in the English-speaking world of the early twentieth century, Patrick Geddes.[2] Historian Jose Harris has talked of "the widespread (albeit temporary) collapse of confidence in the doctrines of classical economics."[3] Harris suggests that even if the political recommendations of Marx and Engels were not widely accepted, their historicism was popular.[4] Foreign competition, particularly from Germany and the United States, was a matter of grave concern, and an enduring industrial recession was addressed by a Royal Commission on the Depression of Trade and Industry of 1885–1886. Within this context of national reevaluation, models of engineering and of training were changing. New colleges in South Kensington, Manchester, Leeds, Newcastle, Glasgow, Aberystwyth, and elsewhere were established to provide an academic background in science and engineering hitherto despised. The heroic self-educated individuals mythically associated with Britain's supremacy, James Watt, George Stephenson, and William Arkwright, had been replaced by a new generation of chemists, electrical engineers, and specialist mechanical engineers, exemplified by Sir William Siemens, calling for more technical education. The alternative, it was widely warned, was relative economic decline and political eclipse that even a newly entitled empire could not prevent.[5]

The beginning of the decade also saw the formation of the Science Museum in South Kensington. This was effected, as a matter both of conviction and convenience, by amalgamating three collections and three visions.[6] The recently presented Loan Collection of Scientific Apparatus, including both contemporary and historic artifacts, had been assembled as a celebration of the culture of science. The nearby Patent Office Museum was dedicated to the history of invention rather than anything contemporary. On the other hand, the miscellaneous artifacts contributed by the South Kensington Museum were intended to be part of technical education. The founders were well aware of this heterogeneous legacy. The science collections were overseen by a committee whose first chairman was Thomas Huxley, Darwin's bulldog. The museum moved
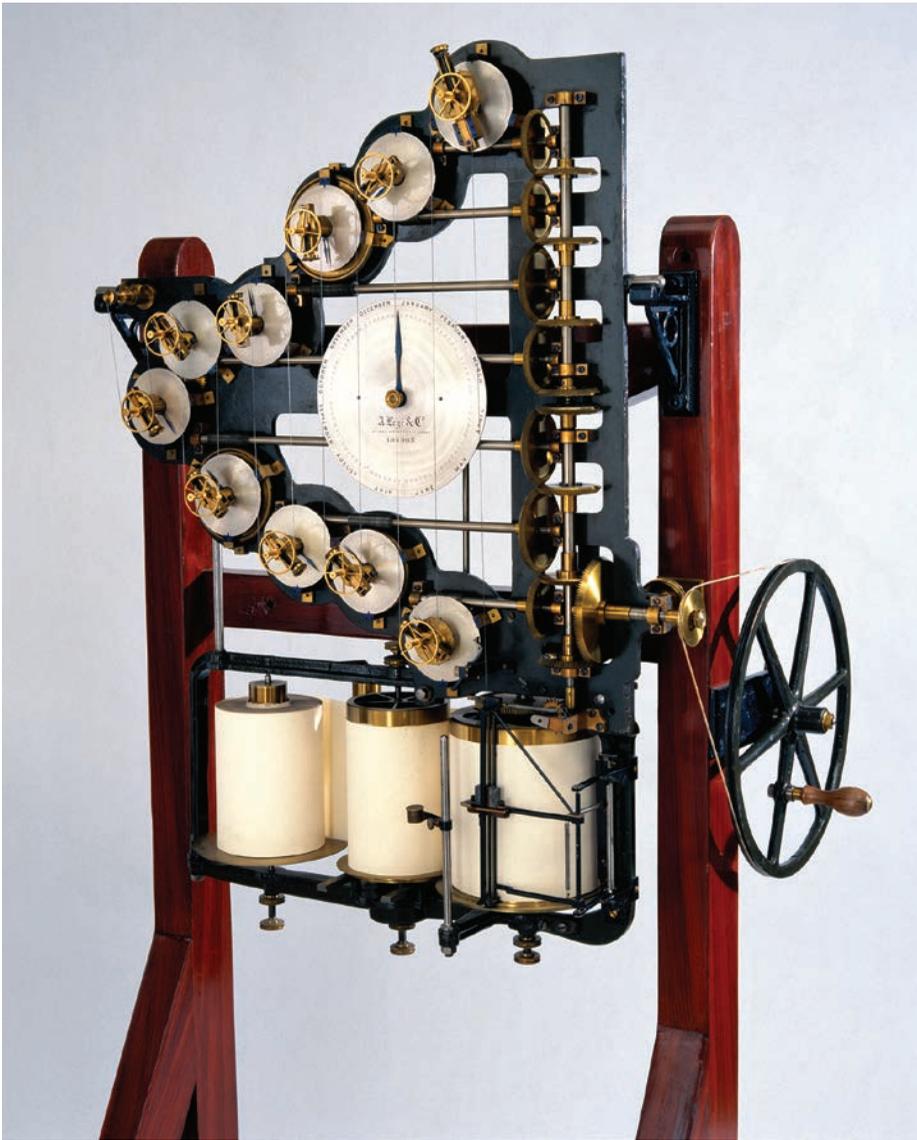
1.
An acquisition of contemporary science acquired in 1876: Lord Kelvin's recent tide predictor. © Science Museum / Science & Society Picture Library.

into a space vacated early in its life by an exactly contemporary private museum of General Pitt Rivers devoted to showing the evolution of the rifle and of war. This collection was based in South Kensington from 1879 to 1884 before moving to Oxford, where it is still today.[7] Perhaps not surprisingly, the Science Museum that replaced it also sought to integrate its collections within an evolutionary model, emphasizing "various steps in physical discovery and its applications" and "critical discoveries and methods."[8] The engineering committee rejected "objects as have no historical interest, and are neither good examples of accepted practice or modern improvements, nor steps or links in invention."[9] This evolutionary metaphor was therefore also a matter of both conviction and heuristic convenience (Figures 1 and 2).
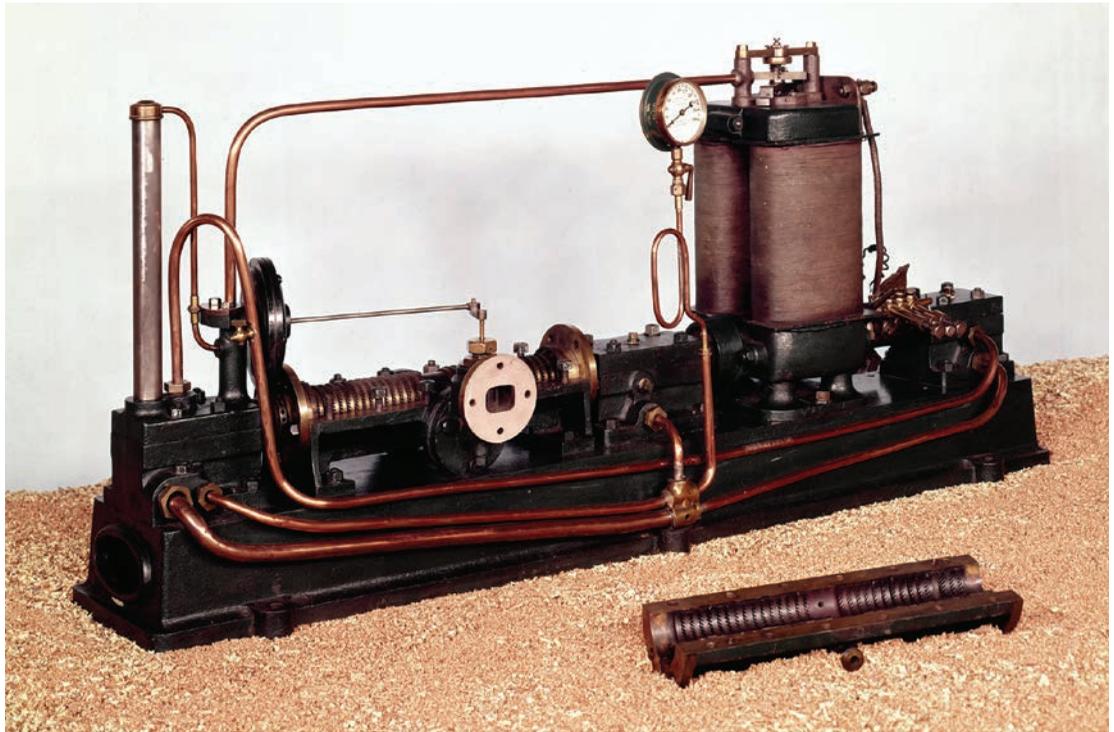
2.
A late nineteenth-century contemporary science acquisition: Parsons's steam turbine generator. © Science Museum / Science & Society Picture Library.

Until 1909, both the art museum next door and the Science Museum were part of the same administrative structure within the Department of Science and Art (later the Board of Education). This arrangement had gone back to long-superseded visions of Prince Albert of a holistic industrial culture expressed in the South Kensington Museum. By the end of the century, however, the two museums, on opposite sides of the road named after the Great Exhibition to which it had led (Exhibition Road) were entirely different. The art museum as a matter of principle acquired the timelessly beautiful and admirable, and since it would take two generations to confirm the timeless value of an item, objects less than 60 years old were not acquired.[10] The Science Museum by contrast was devoted to change. Acquiring and showing the modern and its ancestors lay at the heart of the enterprise. Beyond that there was the key objective of showing how modern machines and achievements, applied science, could be related to the discoveries of pure science.

However, the next 30 years were devoted to fighting for proper accommodation through endless Parliamentary enquiries and debates with members of Parliament skeptical of spending and of museums. The issue was not what to collect so much as how to make a case for existence. As a paper put to the government's key decision-making cabinet in 1910 explained, "Without more space to store and display there was In consequence of the want of accommodation and the danger from fire we have lost many valuable gifts and bequests, some of which have gone

to Germany."[11] The building that was then agreed opened, after a wartime intermission, in 1928 under an inspiring new director, Henry Lyons. The decade after the World War I would therefore be the critical period for the museum to sort out a philosophy relating past, present, and future.

The objects acquired in the 1920s would be critically important to the museum's success then and future identity. One in eight of the museum's most important objects identified in the 1990s were acquired in the 1920s. This was a decade that began with discussions over the very existence of the museum and ended with the accolades of being the most visited museum in the country, reaching a million visitors a year, and of being one of the five most exciting museums in the empire.[12] During this decade of the 1920s, the museum opened its major permanent galleries, and these were followed by important temporary exhibitions in the 1930s.

Even before its full reopening in a new building, during the 1920s the museum played an important role in the nation's reflection on the meaning of science after the trauma of the Great War. Unfamiliar industries, electricals, chemicals, airplanes, and motor cars competed with, and often replaced, the traditionally dominant staples of British manufacturing, textiles, shipbuilding, steel, and coal. New scientific concepts, such as electrons, radioactivity, and new materials, needed to be assimilated. In the wake of extreme dislocation, the Science Museum provided a way of locating the present and the future in terms of continuity with the past, albeit rewritten. The curators were scientists and engineers with little connection to the new discipline of the history of science. This disconnect between curators and discipline was striking even when the just-completed museum lecture theater hosted the famous 1931 Congress on the History of Science organized by Charles Singer, Britain's first professor in the discipline. The session on the interdependence of pure and applied science chaired by the museum's director was addressed by professional scientists making arguments about the present day, embellished with a few historical references.[13] To the Science Museum of the time, the past was not a foreign country.

In a recent doctoral dissertation, Imogen Clarke has given detailed attention to the development of physics at the Science Museum in the 1920s and 1930s.[14] She shows the inspiration of the British Empire Exhibition held in Wembley in 1924–1925. This exhibition was a huge event whose physical legacy would endure to the beginning of the twenty-first century and that was visited at the time by 27 million visitors. Much of the published secondary interpretation has focused upon its imperial representations. However, it had two huge "palaces" dealing with "industry" and "engineering," respectively, as well as a government building. The latter housed a section organized by the Royal Society on "pure science" that was concerned with physics and life sciences. Chemistry was treated in a separate exhibit within the Palace of Industry. Virginia Woolf visited the exhibit while she was writing her novel *Mrs. Dalloway*.[15] In the novel, a character reflects on the airplane as a symbol of man's determination "to get outside his body, beyond his house, by means of thought, Einstein, speculation, mathematics, the Mendelian theory."[16]
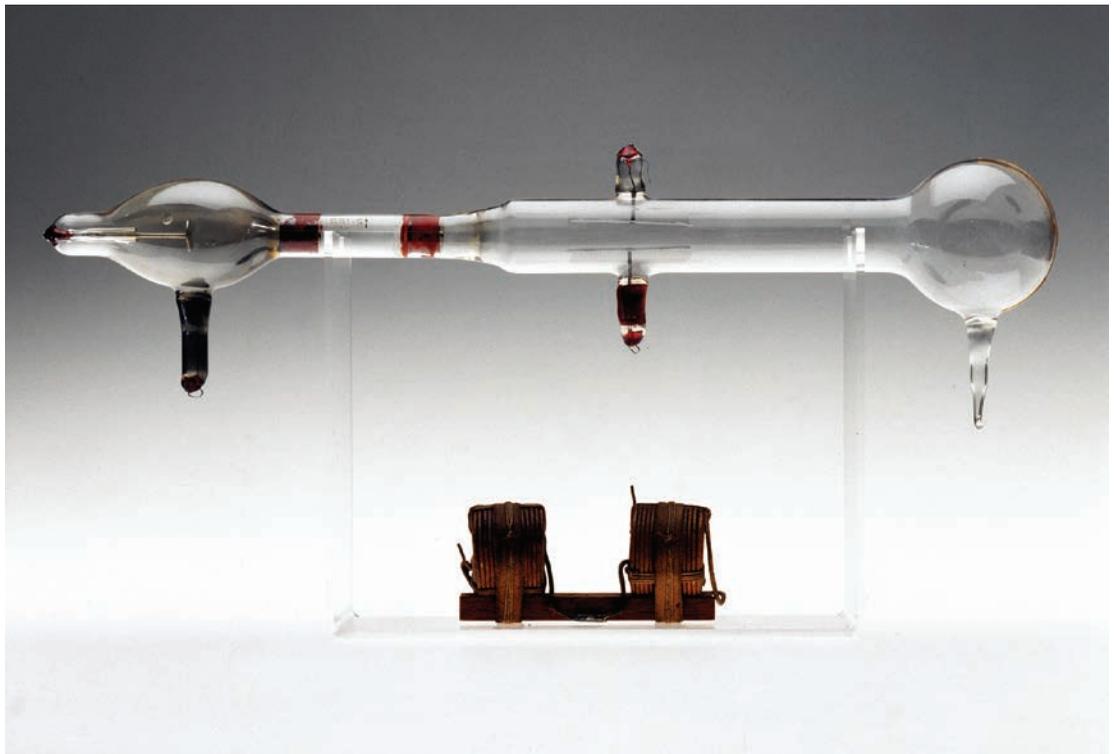
3.
The iconic Science Museum loan to the 1924 British Empire Exhibition. J. J. Thomson's "original" e/m tube. © Science Museum / Science & Society Picture Library.

The entire focus of this exhibition was on the contemporary and the future. However, objects from the past could be used to tell contemporary stories. Thus, artifacts of Faraday and Humphry Davy were shown, making the point that even science conducted for no practical purpose could have great industrial consequences, then or much later. A more recent example of such a story was embodied by the apparatus of the recently retired director of the Cavendish Laboratory in Cambridge, J. J. Thomson. His apparatus had already been donated to the Science Museum, where it had been shown demonstrating research on cathode rays. Now it represented the discovery of the electron, a discovery used by the wireless valve invented by Ambrose Fleming and shown in the only engineering-oriented section of this exhibit.[17] In other words, this exhibit used devices drawn from a variety of ages to show contemporary stories about science as conceived by Ernest Rutherford, then director of the Cavendish (Figure 3).

As Clarke has shown, this sort of strategy was followed in the 1930s with competing models of modernity including the pure science of the *Atom Tracks* exhibition, which included the Wilson cloud chamber from the Cavendish, and the applied science of geophysics, including the Eötvös torsion balance on which the curator Herman Shaw was himself conducting research (Figure 4). Meanwhile, the museum was under pressure from its advisory council to represent the "development and current practice of industry." Indeed, a secondary title for the institution, National Museum of Science and Industry, was introduced at this time.[18]

4.
Research on modern geophysics in the 1930s: Eötvös torsion balance. © Science Museum / Science &
Society Picture Library.

The museum acquired both inspiration and artifacts from the 1924 British Empire Exhibition. As the future director David Follett pointed out, "many of the exhibitors there responded generously to requests from the Museum and presented or lent examples illustrating current practice, a field which has always tended to be under-represented in the Museum, largely because of shortage of exhibition space."[19] Yet although a large number of new and recent artifacts were being acquired at this time, the emphasis was on their continuity with a past that could be seen to contain the seeds of the present. It was a model of history that in the postwar years would be severely tested and lead to great controversy, particularly at Cambridge University, as Seb Falk has recently shown.[20]

The Mid-Twentieth Century

At the Science Museum, the changing relationship between past and present was expressed in a more muted manner than in Cambridge. Singer's pupil Frank Sherwood Taylor enjoyed a short directorship (1950–1956) fraught with tension between historian director and scientific keepers and his own illness. A 1963 article in the *Guardian* newspaper dismissed the museum's "rare excursions into the twentieth century."[21] The next decade, however, saw major developments in design and display technique led by the pioneering keeper William Thomas O'Dea. He began his career in 1930 responsible for the lighting collections but would go on to mount the shipping collection and hang the great aircraft collection in the newly completed extension, entitled the Centre Block, of the museum. In 1966 he would leave to be the founder director general of the Ontario Science Centre. O'Dea's attention to visitor-oriented design was radically innovative, but his historiography, as Andrew Nahum has pointed out, was quite conventional. Aircraft were hung in chronological order, and engines were arranged taxonomically.[22] Moreover, remarkably little was collected in the 1960s.[23] More explicitly historically minded was the younger Frank Greenaway, a protégé of Sherwood Taylor and keeper of chemistry in the 1970s, who developed the relationship with the burgeoning discipline of the history of science (taking a Ph.D. himself), recruiting staff with an interest and qualifications in history and at the same time taking an interest in contemporary science. Increasingly, rather than history being seen as prologue to the present, the present was portrayed in terms of long-term trends established in the past and continuing into the future. Thus, the major gallery on gas opened in 1976 treated the newly found and supplied natural gas but as part of the history of the gas industry. This industry began early in the nineteenth century and was continuously pioneering, so that in the 1960s it supplied towns with gas no longer made only from coal but supplemented with catalytically reformed gas from petroleum and imported liquefied natural gas. The historical arguments were rehearsed in a chapter on the chemical industry for the twentieth-century volume of the great history of technology published in 1978.[24] Thus, by the early 1980s, a historicism that had been born at the same time as the Science Museum itself, was now a dominant motif within it.

1980s Onward: Responding to Changes in Society, Visitor Demands, and the Public's Relationship to Science

A quite different approach to history and the present developed in the 1980s and 1990s under the directorship of Neil Cossons, who held office from 1986 to the end of the century. This period saw the efflorescence of two related strategies within the museum and a rapidly changing environment. A radical technological revolution was associated with a great industrial transformation. Biotechnology and information technology took the place of the electrical and chemical industries. Unlike those predecessors, of course, although they had strong British representation, they were visibly centered overseas, in the United States and Japan. Meanwhile, the industrial partners of the museum, important stakeholders since the 1920s themselves and latterly British champions of their industries, were transformed: the Hawker Siddeley Group, whose chairman had been the Science Museum's first chairman of trustees in 1984, was taken over by "BTR" in 1992; Britain's General Electric Company (GEC) became Marconi in 1999 before disappearing in 2005; and the nation's longtime largest manufacturing company Imperial Chemical Industries (ICI) first ceased to be an integrated chemical company in 1993 before being taken over in the next decade. Nationalized industries British Gas, the Central Electricity Generating Board, and the United Kingdom Atomic Energy Authority were privatized and transformed. The great military laboratories were first brought together as a nationalized agency but then privatized. For the curators of the museum who had depended on gifts from the research and factories of these close partners for many of their acquisitions, this transformation in the international structure of business was a matter of daily import.

There was also a demand-side transformation. No longer were visitors to the museum likely ever to have been in a factory. They were potential consumers, not producers. Lord Weinstock, chairman of GEC, warned a select committee of the House of Lords in 1985 that Britain would be reduced to supplying the Changing of the Guard and Beefeaters.[25] Employment in manufacturing, which had been falling by 5% per decade since the 1960s as a percentage of the workforce as a whole, kept falling. It dropped from 36% in the 1960s to 31% in 1975 to 26% within a decade and by a further 10% in the following 20 years.[26] The Google Ngram Viewer shows how the term *deindustrialisation* took off in the decade from 1975 (when it was hardly known). Anxiety about what was happening to the country is represented by usage of the term in the late 1980s, which experienced a thirtyfold increase as a percentage of books scanned by Google compared with the figures from just five years previously.[27] Not only, therefore, were the companies of the past ceasing to be parts of the contemporary cultural landscape, but the experience of manufacturing which they had embodied was removed from visitor experience. Government science funding for basic science also fell as part of national expenditure cuts. In response, the Royal Society, British Association for the Advancement of Science, and Royal Institution launched the Committee for

the Public Understanding of Science (COPUS), which published its report in 1986. The lobby Save British Science was founded following a January 1986 advertisement in the *Times* newspaper. However, even when government policy became more positive to scientific research under Margaret's Thatcher's successor John Major, public skepticism of science remained. A report published by the House of Lords science committee in 2000 expressed the issues in a seminal manner, beginning under the heading "A crisis of trust":

> Society's relationship with science is in a critical phase. By "science" we mean the biological and physical sciences and their technological applications. On the one hand, there has never been a time when the issues involving science were more exciting, the public more interested, or the opportunities more apparent. On the other hand, public confidence in scientific advice to Government has been rocked by a series of events, culminating in the BSE fiasco; and many people are deeply uneasy about the huge opportunities presented by areas of science including biotechnology and information technology, which seem to be advancing far ahead of their awareness and assent. In turn, public unease, mistrust and occasional outright hostility are breeding a climate of deep anxiety among scientists themselves.[28]

In this atmosphere, the Science Museum's former assumptions of the continuity of past and future prevailed no longer. Instead the museum, under its director, Neil Cossons, had become a major player in the movement to enhance public understanding of and engagement with science. Indeed, John Durant, the museum's assistant director and head of science communication at the museum, was a specialist advisor to the House of Lords committee. This was no passive role of following an existing movement but rather an active response to shared problems. These were expressed by Cossons in a 1992 *Guardian* article based on a presentation he had made at the American Association for the Advancement of Science. He began with the attitudes he wished to combat: "Science is something one grows out of with the coming of civilized tastes." "The intelligence of the average Leicester businessman is subnormal." "To work in engineering or industry is a despicable life in which no sane person should be engaged."[29] The article chastised those for whom the enterprise of public understanding of science was merely a matter of professional one-upmanship.

The process of acquisition was not at the obvious forefront of this campaign, but it was a necessary component of it, at a time when every sinew had to be bent to institutional survival. Between 1987 and 1997 the museum, with strong government encouragement, charged many of its adult visitors to enter. The reported number of visitors fell by 33%.[30] Experimental temporary new exhibitions on such topics as chaos theory and passive smoking were launched under the distinctive brand of "science box."[31] These exhibitions were interpretation rich rather than object rich but also necessarily small because of the lack of free space. The museum therefore returned to an ambition for a westward expansion anticipated since the founding document of 1911. There was space for this to the west of the existing museum buildings but no funds to enable new

construction. An options appraisal from the years 1993–1994 for a mixed development in the west end through which property development would pay for new galleries on contemporary science began, "A fundamental shift is needed in the profile of science and technology." It explained that therefore, "the Museum intends to devote a higher proportion of its resources to modern science and technology." The paper accepted the separate responsibility to care for and interpret its historic collections, which were, it was claimed, the world's finest.[32]

At a time of increasing competition for the attention of citizens and visitors, the world-beating qualities of the collections came to be appreciated even more.[33] Soon after Neil Cossons was appointed, he called for the formulation of a collecting policy. This policy was constructed with the existing categories in mind, though the interest of contemporary artifacts was highlighted as both important signifiers of immediate issues and of long-standing processes. Similarly, in 1992, the director edited a high-profile volume, *Making of the Modern World: Milestones of Science and Technology*, based on individual treatments of 100 of the museum's objects from Huygens's aerial telescope to Marconi's transmitter, from the Merlin aircraft engine to the recently patented Oncomouse. This year saw the beginning of determined endeavors to promote the interpretation of distinctively contemporary issues, and to build up substantially the process of acquiring contemporary collections (Figure 5).

By 1992, the previous collecting policy needed to be superseded by a new policy for the next five years. Unlike its predecessor, this one foregrounded contemporary collecting, understood as covering post-1960 material. A Contemporary Acquisition Committee was created, under the

5.
The first patented animals: the Oncomice, patented 1987, acquired 1988. © Science Museum / Science & Society Picture Library.

chairmanship of the Head of the Division, and this committee identified three areas that did not fit the museum's subject-based typology but had a high public profile. "Software and simulation," "nanotechnology," and "biomedical engineering" were highlighted. Unfortunately, the staff allocated to work on these areas were soon needed for other duties, and the project was not in itself responsible for the acquisition of many new objects. Moreover, a major problem was reported in the next collecting policy of 1995:

> Increasingly, owners of contemporary frontier-technology are reluctant to donate their objects to the Museum due to the financial worth of the items involved and the difficulty of providing instant public display. Even near-frontier-technology is seen to have a high cash value since it is increasingly being sold to developing countries as the pace of innovation in developed countries increases to stay ahead of the competition; allied to this factor is the overall decline in altruistic donation.[34]

Such problems explained, in part, why an aspiration of getting up to 70% of the museum's annual acquisitions to be post-1960 was not reached. Nonetheless, this period was one in which large numbers of recent items were acquired. In the year 1994–1995, 1,618 inventory numbers were issued, of which 929, or 57.5%, related to post-1960 objects.[35] Fewer objects were acquired in subsequent years, but the percentage of these modern objects was somewhat higher. The airfield at Wroughton near Swindon, acquired in 1978, offered vast hangar space to accommodate new acquisitions, and even when a rented store at Hayes in Middlesex had to be vacated, it could be replaced by a brand-new building on the Wroughton site as well as the former Post Office Savings Bank building in Olympia. The availability of space at Wroughton to store aircraft, hovercraft, large cars, and suites of industrial machinery was a unique experience in the museum's history. This was an era, even before collecting specifically intended to populate the exhibits in the new Wellcome Wing, in which a large number of interesting artifacts were collected. Dolly, the first cloned adult mammal, was always destined for the Royal Scottish Museum (now the National Museum of Scotland), but her genetically modified predecessor Tracy was acquired, along with much technology associated with Dolly's conception and birth; a sweater made from Dolly's fleece did come to the Science Museum. The first PCR machine was brought in from California, to the dismay of the Smithsonian Institution, and an important Soviet supercomputer, the BESM-6, was bartered for a suite of IBM 486 personal computers.

In the history of the museum overall, the great peaks of acquisition have been associated with eras of new exhibition. Donors have been more supportive with the prospect of display, and until the mid-1970s storage for nondisplayed items was extremely limited. Despite the wonders of its collections, therefore, even the Science Museum had not aspired to the encyclopedic ambitions of museums in other fields. The availability of the stores at Wroughton and Blythe House briefly seemed to portend a new era. Topics such as biotechnology could be collected without an eye to immediate exhibition. Moreover, the emerging prospects of multimedia (first the CD and then the web) suggested new avenues for interpretation. In 2002 the museum began two major

projects toward the new online exhibitions, *Ingenious* and *Making the Modern World*, each of which would attract millions of visitors after their launch in 2004. These were explicitly intended to enable the interpretation of collections beyond the possibilities of the museum floor and to escape the tyranny of space in South Kensington.

The opportunity to deploy the new history of science and technology to interpret not just the distant but also the recent past to contextualize contemporary developments was exciting. Increasingly, the curators took doctorates in the history of science and technology. Wiebe Bijker, the Dutch pioneer of the social construction of technology, had drawn upon the museum's rich collections of bicycles and plastics as key resources. His approach was drawn upon internally, for instance, by Ghislaine Lawrence, the curator of clinical medicine, in her doctorate and by others in the volume *Technologies of Modern Medicine.*[36] Nonetheless, I have argued elsewhere that although new historical understanding and novel narratives could inform acquisitions of modern material, once this was incorporated within existing collections, it could easily be swamped by the older narratives that were embodied in those physical assemblages of interesting material.[37] Thus, the distinctive methodologies underlying the new Health Matters Gallery that dealt specifically with twentieth-century medicine were perhaps more obvious to the curators than to the visitor engaging with medicine as a whole.

This sense that the old had all-too-often swamped the new was, perhaps, the dominant driver to the presentation of the all-contemporary Wellcome Wing, which opened in 2000. With the ground floor devoted to breaking science news, the first floor to implications of modern genetics, the second floor to the digital revolution, and the third floor to imagined futures, this was a history-free zone. The objects acquired for the exhibitions illustrated narratives that were drawn from contemporary science journalism rather than historicism. At the same time, the wing is approached by a new gallery within the body of the existing building. *Making the Modern World* takes the visitor through a panorama of artifacts from the early industrial revolution to the end of the twentieth century. The inclusion of this historicist treatment was required to obtain a major contribution to the overall funding for the whole development from the National Heritage Lottery Fund.

The opening of the Wellcome Wing proved to be the high point of both historicist and contemporary collecting. Cossons's retirement shortly after the opening and his succession by Lindsay Sharp as director prompted a reevaluation of collecting practices. Collecting of all types of artifacts was reduced sharply. The relationship between collecting within the Collections Division and the interpretation within Communications Division had been one of a creative tension. Insofar as there were problems, there was duplication and unproductive competition within a cash-strapped institution. When it worked, however, as it frequently did, the results were immensely beneficial.

The partnership was not just between two internal divisions and between individuals but also between philosophies and communicative methodologies. The Wellcome Wing was specifically an achievement of the public understanding of science (PUS), a discipline whose journal was

founded and edited at the Science Museum by John Durant.[38] Although born out of a movement based on what was felt to be necessary propaganda for science, PUS became a sophisticated part of the broader new constellation of "science, technology, and society," represented, for instance, by the European Association for the Study of Science and Technology. This movement was quite separate from the history of science and technology, but the relationship of the two disciplines has developed over a quarter of a century.

Present and Future

By the early twenty-first century the former divisional structure that had firmly demarcated the territories of the historicist and the contemporary had been superseded. What had been tensions that could be caricatured as a split between a public understanding of science driven purely by the presentist concerns of the scientific community and the historians' concerns to see the present as an extension of the past were superseded. A focus on the deeply rooted cultures of the museum's many publics, with their own historical awareness framing current concerns, and engagement rather than conversion have provided a much more coherent intellectual model for both display and acquisition. This shift has required a new historiographic program not dependent on academic teaching models, of which the Artefacts consortium itself is an expression. In France it has been expressed through the PATSTEC (Patrimoine scientifique et technique contemporaine) website.[39] Such a program can inform decisions on not only exhibition but also acquisition and, indeed, web interpretation. The century-old distinctions, with which this paper has been concerned, were in themselves becoming superseded.

Acknowledgments

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Notes

1. Neil Cossons, introduction to *Making of the Modern World: Milestones of Science and Technology*, edited by Neil Cossons and Andrew Nahum (London: John Murray, 1992), 7.

2. Geddes (1854–1932) would coin the term "second industrial revolution" and, indirectly, through his protégé Lewis Mumford, would be influential until the end of the twentieth century. Directly, his greatest impact on a science museum was upon the Chicago Museum of Science and Industry, whose founding director he was about to visit at his death in 1932. Although never an employee of the Science Museum, he did apply for the directorship (unsuccessfully). Trained as a biologist under Thomas Huxley, he fell under the spell of Herbert Spencer, much to Huxley's displeasure. His most recent biography is Helen Meller, *Patrick Geddes: Social Evolutionist and City Planner* (London: Routledge, 1990).

3. Jose Harris, *Private Lives, Public Spirit: Britain, 1870–1914*, Penguin Social History of Britain (London: Penguin, 1994), 369

4. Harris, *Private Lives, Public Spirit,* 368

5. On the atmosphere of the period and the development of a philosophy of applied science, see Robert Bud, "'Applied Science' in Nineteenth-Century Britain: Public Discourse and the Creation of Meaning, 1817–1876," *History and Technology* 30, no. 1–2 (2014): 3–36. The classic study is still D. S. L. Cardwell, *The Organisation of Science in England: A Retrospect* (London: William Heinemann, 1957).

6. Robert Bud, "Infected by the Bacillus of Science: The Explosion of South Kensington," in *Science for the Nation: Perspectives on the History of the Science Museum*, ed. Peter J. T. Morris (London: Palgrave Macmillan, 2009), 11–40.

7. David K. Van Keuren, "Museums and Ideology: Augustus Pitt-Rivers, Anthropological Museums, and Social Change in Later Victorian Britain," *Victorian Studies* 28, no. 1 (1984): 171–189.

8. Interdepartmental Committee on the National Science Collections, *Report* PP. 1886[246].6, Appendix B, 19

9. Report of the Committee appointed on the 21st December 1883, to advise the Lords of the Committee of Council on Education as to the existing Patent Museum considered in connection with the Mechanical Section of the South Kensington Museum; especially as to what objects in their opinion should be retained by the Science and Art Department for the various sections of the Science Museum; and to offer suggestions as to the scope and development of the Mechanical Section of the Science Museum treated from the Scientific and Educational point of view. March 1884, Works 17/20/5, UK National Archives, Kew.

10. On the attitude to art and modernity of the Victoria and Albert Museum in this period, see Anthony Burton, "The Uses of the South Kensington Art Collections," *Journal of the History of Collections* 14, no. 1 (2002): 79–95.

11. Mr. Harcourt to Cabinet, October 1910, "Proposed New Science Museum," Ed 23/523, UK National Archives, Kew.

12. David Follett, *The Rise of the Science Museum under Henry Lyons* (London: HMSO, 1978), 55–59.

13. The speakers in this session included the former director of the meteorological office, Napier Shaw, who referred to Pythagoras in making his case for the importance of mathematics, but this he argued was not a crucial distinction between pure and applied science. No historical references are apparent from the extended reports by the *Times* of the speeches of the other speakers, metallurgist C. H. Desch, biochemist F. G. Donnan, and R. V. Vernon of the Colonial Office. "Pure and Applied Science," *Times* (London), 4 July 1931.

14. Imogen Clarke, "Negotiating Progress: Promoting 'Modern' Physics in Britain, 1900–1940" (Ph.D. diss., University of Manchester, 2012).

15. Scott Cohen, "The Empire from the Street: Virginia Woolf, Wembley, and Imperial Monuments," *Modern Fiction Studies* 50, no. 1 (2004): 85–109.

16. Virginia Woolf, *Mrs. Dalloway* (1925; repr., London: Wordsworth Classics, 2012), 21.

17. Alan Q. Morton, "The Electron Made Public: The Exhibition of Pure Science in the British Empire Exhibition, 1924–5," in *Exposing Electronics,* ed. Bernard Finn, Artefacts 2 (Reading: Harwood, 2000), pp. 25–43, http://www.artefactsconsortium.org/Publications/PDFfiles/Vol2Elect/2.02.Electronics-Morton,%20BritishEmpExhibitionBWPicsGrBlank3ppi75FWEB.pdf (accessed 13 March 2017).

18. Advisory Council of the Science Museum, *Report of the Advisory Council of the Science Museum for 1926* (London: HMSO, 1927), 9.

19. Follett, *Rise of the Science Museum*, 54.

20. Seb Falk, "The Scholar as Craftsman: Derek de Solla Price and the Reconstruction of a Medieval Instrument," *Notes and Records: The Royal Society Journal of the History of Science* 68, no. 2 (2014): 111–134.

21. G. Leach, "The Museum Piece," *Guardian,* 9 July 1963. See Scott Anthony, "The Science Museum 1950–1983," in Morris, *Science for the Nation*, 90–110.

22. Andrew Nahum, "Exhibiting Science: Changing Conceptions of Science Museum Display," in Morris, *Science for the Nation*, 176–193.

23. Only about 5% of the current non-Wellcome collections were acquired in the 1960s. See Robert Bud, "Collecting for the Science Museum," in Morris, *Science for the Nation*, 250–272.

24. Frank Greenaway, R. G. W. Anderson, Susan E. Messham, Anne M. Newmark, and D. A. Robinson, "The Chemical Industry," in *A History of Technology*, vol. 7, *The Twentieth Century c.1900 to c.1950*, ed. Trevor Williams (Oxford: Oxford University Press, 1978), 514–569.

25. Lord Weinstock, *Report from the Select Committee on Overseas Trade*, vol. 2, *Oral Evidence* (London: HMSO, 1985), 474.

26. Barry Supple, "Presidential Address. Fear of Failing: Economic History and the Decline of Britain," *Economic History Review*, n.s., 47 (1994): 441–458.

27. Graph of *deindustrialisation* using Ngram Viewer, https://books.google.com/ngrams/graph?content=deindustrialisation&year_start=1950&year_end=2000&corpus=18&smoothing=1&share=&direct_url=t1%3B%2Cdeindustrialisation%3B%2Cc0 (accessed 13 March 2017).

28. Select Committee on Science and Technology, Third Report, http://www.publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3803.htm (accessed 13 March 2017)).

29. Neil Cossons, "Public Misunderstanding," *Guardian,* 28 February 1992. Related articles include Neil Cossons, "Let Us Take Science into Our Culture," *ASM News* 58, no. 12 (December 1992): 648–649; "Let Us Take Science into Our Culture," *Interdisciplinary Science Reviews* 18, no. 4 (1993): 337–342.

30. "Museums: Visitor Statistics," 567 Parl. Deb., H.L. (5th ser.) (1995) 154-6WA.

31. Lorraine Ward, "Lessons of Science Box," in *Here and Now: Contemporary Science and Technology in Museums and Science Centres*, ed. G. Farmelo and J. Carding (London: Science Museum, 1997), pp. 83–90.

32. Eventually, the development of the West End opened in 2000 funded not through a mixed-property development but instead by the new Heritage Lottery Fund and by generous donations from the Wellcome Trust and other sponsors. The exhibitions in the new Wellcome Wing did hold a large number of artifacts, but the exhibitions were driven by the messages about current developments in science, and objects were used as illustrations where appropriate.

33. See Neil Cossons, "Museums in the New Millennium," in *Museums of Modern Science*, ed. Svante Lindqvist (Canton, MA: Science History Publications, 2000), 1–15.

34. National Museum of Science and Industry, "Acquisition and Disposal Policy, April 1995–March 1998," 13, Science Museum Archives.

35. National Museum of Science and Industry, *Corporate Plan 1996–2000. Objectives and Achievement*s (London: National Museum of Science and Industry, March 1996), 54.

36. Ghislaine Lawrence, "Hospital Beds by Design: A Socio-historical Account of the 'King's Fund Bed', 1960–1975" (Ph.D. diss., University of London, 2001), 1; Ghislaine Lawrence, ed., *Technologies of Modern Medicine: Proceedings of a Seminar Held at the Science Museum, London, March 1993* (London: Science Museum, 1994). On historical research at the Science Museum more broadly, see Robert Bud, "History of Science and the Science Museum," *British Journal for the History of Science* 30, no. 1 (1997): 47–50; Jane Insley and Robert Bud, *The History of Technology at the Science Museum, London, 1993–1996*, Science Museum Papers in the History of Technology 1 (London: Science Museum, 1996).

37. Robert Bud, "Embodied Odysseys: Relics of Stories about Journeys through Past, Present, and Future," *Studies in History and Philosophy of Science, Part A* 44, no. 4 (2013): 639–642.

38. S. J. Lock, "Lost in Translations: Discourses, Boundaries and Legitimacy in the Public Understanding of Science in the UK" (Ph.D. diss., University College London, 2008). I am grateful to Dr. Lock for kindly letting me see his dissertation.

39. Mission Nationale de Sauvegarde du Patrimoine Scientifique et Technique Contemporain, http://www.patstec.fr/PSETT (accessed 13 March 2017).

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Software Archives and Software Libraries

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Defining the Software Collection

Conversations about historical software archives and collections preceded the rise of the web and the advent of digital libraries, events of the early 1990s that stimulated projects for the preservation of digital objects. The problem of how to document computing hardware and activities emerged even earlier, before much attention was paid to software as a historical object. In this essay, I will focus on collecting software with three points of emphasis. The first is historical. When did cultural institutions in the United States begin to collect software, and what did they collect? This historical background sets up the rest of the essay. Second, my discussion of "software" will be limited generally to formats that have thus far, for better or worse, dominated collections in cultural institutions. This means microcomputer software and digital games of the period from the late 1970s through the early twenty-first century. I understand the limitations of collections that do not nearly reflect the full range of historical software development, but they do provide a foundation for addressing issues of preservation, access, and exhibition that museums and libraries will face as we move forward. Those issues will be the third point of emphasis. The endgame will be a discussion of the challenges faced by institutional curators in developing priorities for their care of historical software collections.

Institutions and individual collectors began in the late 1970s to gather archival documentation and build libraries for research on the history of computers. The Charles Babbage Institute (CBI), for example, was founded in 1978. Its efforts dovetailed with those of a History of

Computing Committee formed by the American Federation of Information Processing Societies (AFIPS), and AFIPS became a major sponsor of CBI. Around that time the AFIPS committee produced a brochure called "Preserving Computer-Related Source Materials," which was distributed at the National Computer Conference. The brochure provided the following information:

> If we are to fully understand the process of computer and computing developments as well as the end results, it is imperative that the following material be preserved: correspondence; working papers; unpublished reports; obsolete manuals; key program listings used to debug and improve important software; hardware and componentry engineering drawings; financial records; and associated documents and artifacts.

In other words, paper records. The recommendations did not mention the preservation of data files or executable software, although there was a brief nod to the museum value of hardware artifacts for "esthetic and sentimental value" and to provide "a true picture of the mind of the past, in the same way as the furnishings of a preserved or restored house provides a picture of past society." One year later, in 1979, CBI received its first significant donation of books and archival documents from George Glaser, a former president of AFIPS. Into the 1980s institutional projects primarily gathered documentation: archival records, publications, ephemera and oral histories.[1]

Attention to historical software archiving and preservation followed documentation projects or historical work and to some degree grew out of them. Two noteworthy movers in shifting attention to software as archival objects were David Bearman and Margaret Hedstrom. Bearman left his position as deputy director for information resource management in the Office of Information Resource Management in the Smithsonian Institution in 1986 to create a company called Archives & Museum Informatics. He envisioned this new company as a research organization and a consulting firm. Bearman had written extensively on the application of new information technologies to archival and museum management. He began publishing the *Archival Informatics Newsletter* in 1987 (the title changed to *Archives and Museum Informatics* in 1989). Both the company and its newsletter offered a forum for exchanging information about informatics, particularly about how to automate archives and museums. Informatics did not simply mean institutional change, however. Bearman was also considering software both as a collection object and as an interactive medium that could extend museum programs.[2]

As one of its earliest consultations, Archives & Museum Informatics drafted policies and procedures for a "Software Archives" at the Computer History Museum (CHM) then located in Boston. In 1987, Bearman published the first important study of software as a collection object: *Collecting Software: A New Challenge for Archives and Museums.* Bearman's report provided reasons both for frustration and persistence. He wrote frankly that a telephone survey of "a few computer companies, high-technology firms, universities, professional associations and governments" conducted in 1987 had revealed that "no one seems to have formed a software archive nor is anyone collecting software documentation, except as an inadvertent biproduct of institutional archives." He named only one exception: CBI. Indeed, "the concept of collecting software

for historical research purposes had not occurred to the archivists surveyed; perhaps, in part, because no one ever asks for such documentation!"[3] He found neither actions nor intentions to build software archives among those surveyed. Meetings with the CHM, Smithsonian, and CBI had instead convinced him that "no single institution, or even group of institutions as prestigious and well situated as the sponsors [of his CHM report] were, could expect to collect the entire corpus of software related materials."[4] Undaunted, Bearman produced a report that carefully considered software archives as a multi-institutional endeavor, including collection policies and selection criteria, use cases, policies, a rough "software thesaurus" to provide terms for organizing a software collection, and a variety of practices and staffing models. Should an institution accept the challenge, here were some of the tools needed for the job.

Bearman found no signs of life for software archives. However, he took note of important work in related fields. His research revealed progress in archiving of machine-readable data files or archival documents such as email, as well as contributions to archival automation, an area familiar to him through his work at the Smithsonian. There was hardly an overabundance of these studies, yet at least there were reliable and informative publications. One of them was Margaret Hedstrom's *Archives and Manuscripts: Machine-Readable Records,* a practical guide that had been published by the Society of American Archivists in 1984.[5] Trained as a historian of technology and an archivist, Hedstrom was among the first U.S. archivists concerned with electronic records and data, first at the State Historical Society of Wisconsin (1979–1983) and then as director of the Center for Electronic Records at the New York State Archives (1985–1995). The interplay between digital archives and software collecting—or between documentation and software—continues to the present, and Bearman addressed the relationship of these siblings in his report. He was at first skeptical about the relevance of progress in building data archives for the different problem of collecting software, primarily because methods for preserving data in the 1980s involved a model of data migration that broke the connection between the original context of data creation and its eventual storage in a repository.

Bearman's remarks identified a tension between the goals and approaches of data archives and software archives. He was not, however, opposing work that emphasized documentation over software preservation. He was simply pointing out that these are different problems with different solutions. He praised Hedstrom's work and others in later issues of the *Archival Informatics Newsletter* and eventually collaborated with her on several publications and projects. The point was (and remains) that archives, libraries, and museums that chose to build collections for the history of computing and its impact faced a multifaceted challenge. They would have to develop new practices for assessing, collecting, and preserving in numerous and diverse formats and nuance these practices to account for different use scenarios for documents, data, and software. Hedstrom and Bearman provided one argument for linking software archives and digital records in a report coauthored in 1993: "Indeed in the electronic age, custody of archives may require the on-going maintenance of a range of hardware and software and continuing migration of both data and applications, both of which activities are never ending and very expensive."[6] In other words,

use of historical documents in digital form may require access to historical software. Writing in the late 1980s, Bearman's case for software archives rested on a simple proposition for the digital archives and libraries of the future: The more participants, the merrier.

Attention to the problem of software preservation took off during the 1990s. There probably are several explanations for this, but the deluge of commercial microcomputer software published during the 1980s surely played a leading role in awakening institutional repositories such as libraries and museums to the problem of software preservation. A specific moment for this awakening might have been the symposium organized by Columbia University called "Preservation of Microcomputer Software" that took place in March 1990 at Columbia's Arden House Conference Center in the Catskills. The invitation to participants noted that the proposed topic of "Planning a Center for the Preservation of Microcomputer Software" had become "necessary and urgent." The conference addressed topics such as a consortium of collection centers, the establishment of standards and techniques for migration and preservation of electronic data, collecting strategies, and technical problems with executing historical software.[7]

In his paper on the proposed centers, Bernard Galler addressed the kinds of materials that would "ideally [be] available for future study" in a collection devoted to the history of microcomputer software:

- executable code, including the complete environment (hardware, operating system, peripheral devices, and so on) to run it
- source language statements, preferably in machine-readable form but at least on paper
- enough of an environment so that executable code could be produced from the source code, if needed, for whatever system is available for execution
- representative code (source and executable) for each distinct version that appeared and that received a distinctive name or label
- user documentation, as supplied by the creator or vendor
- program logic documentation, as much as is available
- advertising/marketing materials
- environment specifications for both creating and running object code
- user statistics, both numbers of users and their profiles

This is a comprehensive list, running the gamut from source code to executable software and operating environment and on to documentation, marketing, and evidence of use. Galler must have known that this would be a tall order for any repository that one could imagine in 1990; he wrote that "as always, what can be saved will depend on the cost of acquisition, and on the priorities assigned to the kinds of information, just as with the product as a whole."[8] The Arden conference did not result in the creation of such a center, and Bearman described the papers as "largely disappointing" in a review.[9] However, the conference did spur a subsequent project that drew upon its energy: a proposed National Software Archives (NSA). The NSA proposal arose out of a series of meetings convened by David Allison of the Smithsonian Institution's National

Museum of American History. The participants included collection curators, historians, and representatives from several companies (Apple, Microsoft, Hewlett-Packard, WordPerfect). The NSA meetings reviewed many of the issues that had been vetted in Bearman's report and the Arden conference, adding participation by software developers and the notion of surveying, identifying, and marking materials held by developers and other institutions for eventual deposit in the NSA. Yet it failed to produce an active collecting program. The same could be said of a similar effort by a Software Task Force of CBI, completed in 1998.[10] These initiatives raised provocative issues about software archives, but they did not provide a model for building collections of historical software.

One of the papers at the Arden conference noted that future historians of computing would require access not just to "the numerous species of academic and business software;" it proposed that a "Center for the Preservation of Microcomputer Software" also include "software for such functions as games, entertainment and personal financial management."[11] This comment was prescient because the road into institutional repositories was paved with packaged consumer (microcomputer) software and digital games. Of course, there are other important classes of software and many domains other than personal use, ranging from computer science and academic software to business and military applications. Also, it is easy to name media used historically for data storage and software execution, such as punch cards, paper tape, and magnetic tape, that one will not run across in a collection of floppy diskettes, game cartridges, and optical discs associated with consumer software. The emphasis on consumer software in the first historical software collections to land in repositories thus provokes a question: Is there a rationale for "preferring" these kinds of software objects in libraries and museums, or was it just an accident of collecting history?

Two software collections will help us to consider this question. The Machine-Readable Collections Reading Room (MRCRR) and the Stephen M. Cabrinety Collection in the History of Microcomputing were made available to researchers by the Library of Congress and the Stanford University Libraries, respectively, under rather different circumstances and at different ends of the 1990s. Both collections were substantial and consisted primarily of software in the categories of microcomputer software intended for consumer use, including games and various forms of entertainment and educational software. They were, as far as I know, the first major collections of historical software that researchers used in controlled reading rooms, that is, within the walls of traditional research repositories. To the extent that these collections represent the first wave of software collecting in the United States, their acquisition emphasized specific kinds of software for specific classes of computers. This specificity, in turn, shaped a conception of not just the software object itself but also how software was organized, packaged, and documented and, in turn, how institutions would describe, preserve, and exhibit it. And yet collections consisting primarily of "software for such functions as games, entertainment and personal financial management" could document only a slice of software history. They omitted important categories of academic, scientific, and business software; computing environments other than microcomputer platforms and game consoles; and means of distribution other than retail stock (Figure 1).

Library of Congress

MACHINE-READABLE COLLECTIONS
READING ROOM

The Machine-Readable Collections Reading Room (MRCRR) is an **EXPERIMENTAL PILOT** project to last for one year. The purposes of the project are five:

- determine the best methods for acquiring machine-readable materials for the Library's Collections
- develop procedures for cataloging machine-readable materials
- provide access for research purposes to the Library's collection of machine-readable materials
- develop policies and procedures for servicing machine-readable materials
- suggest service locations for machine-readable materials

Machine-readable materials are:

- executable microcomputer programs on floppy or CD-ROM disks
- data on microcomputer floppy or CD-ROM disks

During the pilot year, only IBM, IBM compatible, and Macintosh titles will be available for use in the MRCRR.

Additional titles and documentation for other hardware are being collected and will be available for manual review only.

Staff from the Library's General Reading Rooms Division will provide services in the MRCRR. Researchers wishing to study these materials are welcome to use these facilities. Staff will:

- consult with researchers to determine their interest and skill in using machine-readable materials
- advise researchers as to what is available
- install or retrieve the desired titles for use

All materials will be handled only by Library staff.

LOCATION   Thomas Jefferson Building, First Floor, Room LJ-140G

HOURS   Monday through Friday, 12:00 noon - 4:00 p.m.

TELEPHONE   202-287-5278

1.
Library of Congress software reading room notice, 1998. Source: Lowood Papers, Stanford. Courtesy of Department of Special Collections and University Archives, Stanford University Libraries, Stanford, California.

In his annual report for the fiscal year ending 30 September 1988, the U.S. librarian of Congress, James Billington, described a new project of the library:

> In July the Library opened a new reading room, the first of its kind in the nation, as a one-year pilot project. The Machine-Readable Collections Reading Room is intended to be a facility for the study of the design, history, and documentation of software and information data files. It focuses attention on the Library's continuing program to acquire, catalog, and make available to researchers materials in this format. It brings these items together physically and serves to under score the significance of traditional library materials formatted in new technologies to contemporary society.[12]

The Library of Congress (LC) is the copyright deposit library of the United States, but its software collection in 1988 had been acquired mostly by other means, such as donations, exchanges for copyright registration (not the same process as deposit), and purchases. Indeed, the MRCRR collection featured items acquired by several LC divisions, from Science and Technology to Rare Books and Special Collections. "Machine-readable materials" had been collected since at least the early 1980s by these units, and three different LC committees had considered various aspects of the collection of these materials by 1987.[13] Mandatory deposit had recently been proposed and was still under discussion, with noteworthy resistance from the software industry. In light of the contentious matter of copyright deposit, it is worth noting that representatives from Apple, the Association of American Publishers, IBM, the Software Publishers Association, and other industry organizations attended a meeting held in May 1988 to discuss the operations of the MRCRR and attended a ribbon-cutting ceremony to launch the project after the meeting.[14]

The collection consisted of "executable programs" and "data" on "microcomputer or CD-ROM discs" and "video discs." Representative titles ranged from productivity titles such as bibliographic managers (ProCite, Sci-Mate) and word-processing software (MS Word, WordPerfect, WordStar) to reference databases (*Oxford English Dictionary*, ABI/Inform) and even a category for "windowing" (MS Windows, TopView). Only one entertainment title (arguably) was included in the MRCRR information flyer out of roughly 70 titles: Flight Simulator.[15] The entire collection comprised 1,419 IBM-compatible and Macintosh titles, with the largest number of titles, 861, having been acquired as of July 1989 by copyright registrations between 1978 and 1989.[16] The collection and the service registered a serious tone and purpose. Machine-readable materials could be retrieved, handled, and installed only by library staff. A columnist for the *Computer System News* reported in January 1989 that policies enforced in the room were set to mollify industry concerns about copying through access to software acquired by the proposed mandatory deposit. An MRCRR librarian cited "limitations on the use of software programs," noting that "we don't allow people to do their taxes here or write papers." The author commented that "the librarians spend a lot of time looking over patrons' shoulders, making sure the rules aren't broken."[17] It is difficult to rectify the lofty goals of studying the "design, history, and documentation of software"

with the wrangling over copying of software and copyright deposit that constrained the reading room's policies and, clearly, put a damper on research.

A report issued in January 1990 summarized what the Library of Congress learned from its yearlong experiment with providing access to software. The report called for the library to "expand the scope of the collections to include more sophisticated and expensive titles that are leaders in their areas."[18] It identified areas such as "computer-aided design/manufacturing, image processing, mathematics, expert systems and full-text optical disk publications." Today, about 25 years after the conclusion of the MRCRR pilot project, the current overview of computer files at Library of Congress notes an increase from the approximately 1,500 titles held in 1988 to more than 88,000 items, most of them in the Humanities and Social Sciences Reading Room. The collection scope and formats collected have not changed much, although the materials in the current collection "are usually PC compatible." The original goal of supporting work on the "design, history and documentation" of software has not resonated strongly with the services eventually implemented for the Machine-Readable Collections, but it has not been entirely absent either. The Humanities and Social Sciences Collection has collected "sample software products" selected "for their representation of the industry and as archival artifacts to represent computer and software development." These samples include software intended for use on operating systems and devices that are not included in the collecting policy of the Machine-Readable Collection.[19] Responsibility for preservation of roughly 3,000 entertainment and related educational titles in the collection has been assumed by the Moving Image Section, following its strong commitment to the history of media.[20]

The Cabrinety collection aligns neatly with patterns of collection building that have for centuries brought private collections from the idiosyncratic to the monumental into museums and libraries. Stephen Cabrinety, the son of a DEC (Digital Equipment Corporation) executive, began collecting software as a teenager and steadily added to his collection right up to his untimely death in 1995, at the age of 29. He wrote programs and founded a company called Superior Software. In 1989, two years after Bearman's conclusion that no institution had yet begun to collect historical software and just as the Arden conference was being planned, Cabrinety set up the Computer History Institute for the Preservation of Software (CHIPS)—at the ripe age of 23. His mother later described the goal of CHIPS as being "to preserve all software, and as much hardware as possible, so that future generations could visually see how the industry evolved."[21] In the CHIPS business plan completed in May 1989, Cabrinety reported that his collection included more than 18,000 pieces of software and 55 microcomputer systems. The plan also detailed staffing (including historians of computing and a curator) and fundraising plans and anticipated an annual collecting budget of about $150,000. Finally, Cabrinety indicated a preference for locating the new institution in the Boston area, near Washington D.C., or in "the world's single largest technological hotspot," Silicon Valley (Figure 2).[22]

Less than a decade later, the CHIPS collection arrived in Silicon Valley. The Stanford University Libraries acquired it from the Cabrinety family in 1997, two years after Stephen's
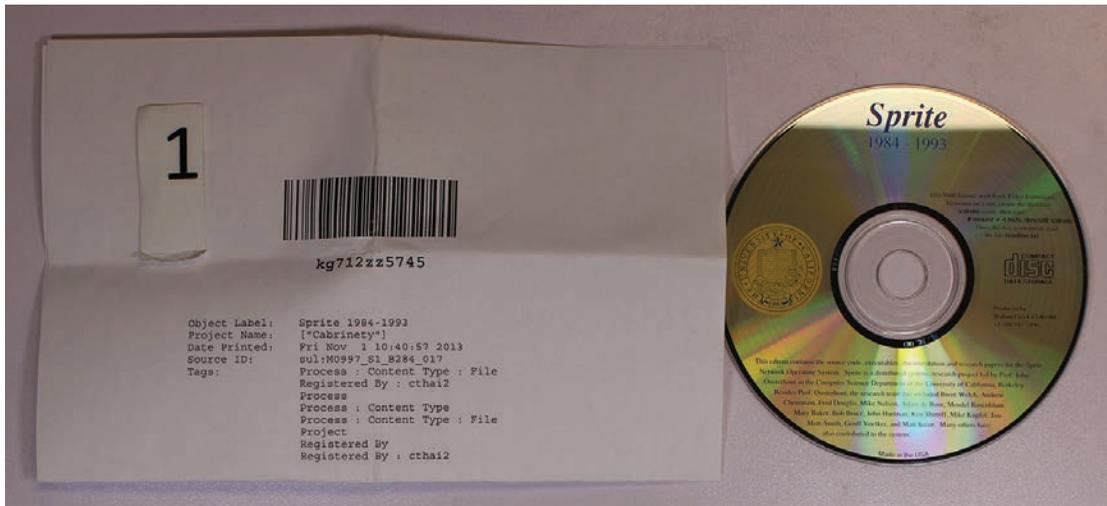
2.
An artifact from the CHIPS collection. Courtesy of Stanford University Libraries.

death. Shortly before the gift was finalized, a reporter for the *Los Angeles Times* marveled at the work of the youthful collector, noting that "one of the world's largest vintage software collections is not housed in the Smithsonian, or the Computer Museum in Boston, or even the in-house museum at Microsoft Corp."[23] The remark is not inaccurate, but at the same time it misses the longstanding importance of personal collecting and private initiatives as cornerstones of institutional collections. The Cabrinety Collection at Stanford complements hardware and software with documentation such as publications, ephemera, messages and files downloaded from bulletin board systems (BBS), Stephen Cabrinety's papers, and records of Superior Software and CHIPS. Like other collectors, Cabrinety also pursued specific interests within the larger framework of software history; for example, the collection is rich in various flavors of interactive books and "edutainment" titles, the areas in which Superior Software was active.[24]

Software as a Collection Object

Shortly after Stanford acquired the Cabrinety Collection, Doron Swade (coincidentally) concluded that "despite the formidable obstacles that face a fully-fledged software preservation programme, there is at least one modest but significant programme of software acquisition that is technically achievable and that has affordable resource implications—namely, software for PCs— 'shrink-wrapped' consumer software, as well as custom-written special applications software."[25] As we have seen, libraries first dipped their toes in the waters of software collecting in exactly this way. This first generation of collections thus implicitly defined the historical software object as Swade predicted, that is, as executable software carried on a media format packaged inside a physical container, along with a few other inserts such as a manual, publisher catalog, or even extras such as the "feelies" included with Infocom's games.

As we consider the ways in which cultural institutions collect, curate, and preserve software artifacts, both material and virtual, it is worth asking when software became an object or artifact in the sense of something that might find its way into a repository such as a museum or library. Today, we speak easily of software in terms that fit the parlance of artifact curation. Similar terms have been employed in other contexts such as programming for decades and allowed for slippage between the virtual and the material. To give only two examples, "object-oriented" programming emerged during the 1960s and was followed by the graphical interfaces of the 1980s that translated programs and file directories into a system of visual icons that represented trashcans, file folders, and other office objects on a computer display. Notions of software as an object or artifact have since proliferated. The distribution of consumer software (including games) accompanying the rise of home computers, personal computers, and videogame consoles opened up the possibility of speaking of software as an artifact with reference to actual physical items such as floppy diskettes and ROM cartridges, as well as retail packaging. In recent years, distribution units, including games, apps, and entertainment media, have joined the mix of "objects." Of course, all of these notions are relevant for libraries, museums, and other cultural repositories already possessing or hoping to acquire collections of historical software.

Despite having these reasons to talk about software at least potentially as a collection object, there is little evidence that anyone did that before the mid-1990s. As we have already seen, there was not much institutional collecting to encourage this manner of speaking. Moreover, it seems likely that museum curators and librarians initially resisted the idea that software could be considered as a collection object. Swade in his 1998 essay has carefully studied the hurdles an "object-centred culture" in museums put before software preservation, considering them at one point as "philosophical misgivings about the materiality of software" in institutions created to preserve physical objects.[26] The words "object" and "artifact" do not appear in Bearman's 1987 report about collecting software, although he does suggest that the "transformation of software into a consumer product" is a historical topic of concern to the software archive. Still, Bearman stresses that a software archive museum is about software history, which requires documentation but does not necessarily require the operation or even ownership of historical software. Conversely, a software library "has as its sole purpose the provision of software for use," not software history per se. In other words, software archives do not need to collect software objects. As for the early collections, Cabrinety refers to "hardware and software artifacts" in the 1989 CHIPS business plan, and he frequently uses the word "artifact" throughout the document.

Before turning to the place of software in the historical archive, it will be helpful to say a few more words about terminology. The early Library of Congress reports use terms like "titles," "collection of software," and "files."[27] When did software become an artifact or collection object? If we turn to Google's NGram viewer, we can generate trend lines for the use of terms such as "digital object" and "software artifact" in Google's huge corpus of works published between 1980 and 2008. This resulting visualization (Figure 3) suggests two tentative conclusions. The first is that use of "digital object" emerged during the mid-1990s and then increased rapidly.
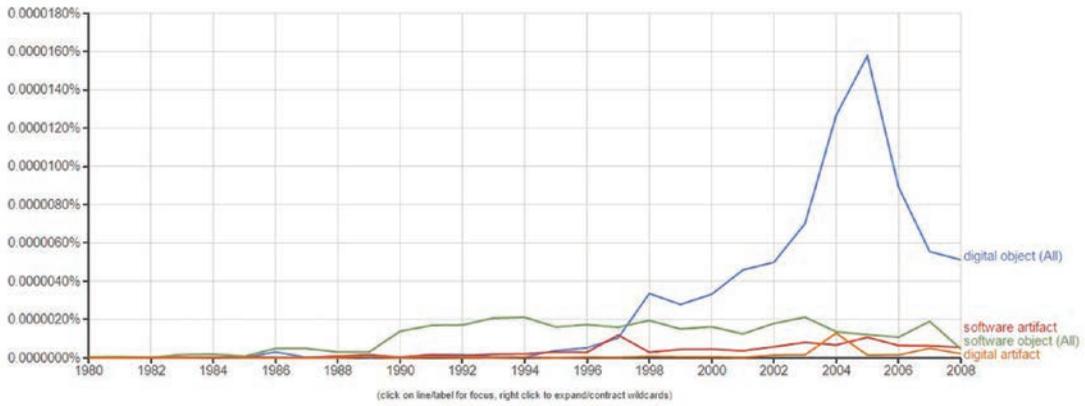
3.
Use of "digital object" and related terms in Google's corpus of published works. Created by Henry Lowood using Google's Ngram Viewer.

Looking at occurrences of this term shows that it was associated with writing about digital libraries, archives, and preservation or related technologies such as the "digital object identifier." In other words, we are dealing here with the vocabulary of data preservation, digital archives and documentation activities, rather than software preservation. An example in this context is Ross Harvey's "From Digital Artefact to Digital Object," published in the proceedings of a conference on digital preservation sponsored by the National Library of Australia in 1995. Harvey specifically deploys the term "digital object" to describe a method of preserving digital data. His topic is "efforts toward migrating the data (or digital 'object') to new systems as they are introduced," which he contrasts to methods that emphasize preserving original artifacts, meaning media formats such as optical disk.[28]

The second conclusion is that the term of art adopted by digital libraries and archives is "digital object." As already noted, this term's popularity has grown significantly over the past two decades. Roughly concurrently, the term "software object" has declined in use, despite its longer history of being connected to the "object-oriented" programming vocabulary. At least this is what the Ngram viewer tells us. Related terms such as "software artifact/artefact" and "digital artifact/artefact" have also become more popular, especially since the turn of the century. It seems we are becoming more comfortable with speaking of software as an artifact, and conversely, in contemporary speech our artifacts do not have to be material objects. The proliferation of digital libraries, archives, repositories, commercial stores and other collections of software and data has encouraged our general acceptance of virtual artifacts. Computing technology long ago inflected the meaning of "virtual" to mean something that does not physically exist but is made by software to appear as if it did exist. Consider "virtual memory," a term that goes back to the 1950s. The popularity of terms like "digital object" and "software artifact" in more recent years reflects the growth of stores of data and software as much as it has benefited from their increasing importance for cultural repositories. These institutions considered how to design and build digital libraries

and archives as their personnel (curators, technical staff, etc.) began to realize the necessity of considering the kinds of collections and objects that would be collected and, so to speak, fill virtual shelves and boxes. The pace of this work was accelerated by the increasing accessibility of the web after the release of the Mosaic browser in 1994 and the National Science Foundation's Digital Libraries Initiative, launched in the same year. It is hardly surprising that cultural repositories both old (Library of Congress, National Library of Australia) and new (Internet Archive) focused their collective attention at about the same time on what came to be seen as digital objects and artifacts. These intellectual shifts during the mid-1990s helped shape institutional commitments that included building and preserving software collections.

Software Archives or Software Libraries?

The early software collections and the rise of digital libraries during the 1990s both begged an essential question: What do we collect, and what do we do with these collections? Jim Bennett's observation about museums that collect scientific instruments applies equally to software collections: "One obvious thing to remember about museum collections is that they show you not what there was but what was collected."[29] Scholarly research, repository practice, and collection curation all are addressing this question of what to collect in one way or another. Studies have been devoted to a range of issues from low-level forensics and data capture to institutional frameworks for acquisition, data transfer, description, and use. They are also redefining curatorial work as it pertains to digital collections.

The writing and projects that paced the emergence of software collections did not resolve several tensions. The first was highlighted in Bearman's 1987 report and contrasted data preservation as a documentation or archival activity and software libraries. A second tension reflected different priorities in forms of software collecting. One line of projects led from electronic records to web archiving and concentrated on the collection, organization, and migration of vast stores of data and documentation, often created and stored in systems built around larger computing systems: mainframes, minicomputers, or the Advanced Research Projects Agency Network (ARPANET)/Internet. A second, often independent line produced collections that consisted mostly of discretely packaged software produced for use on microcomputers, personal computers, home computers, and game consoles. These two categories of software artifacts produced different ideas about repository design and curatorial activity. Collections featuring one or the other required different approaches toward curation, preservation, access, and use. The Internet Archive and the Department of Special Collections at Stanford, where the Cabrinety Collection is housed, are quite different operations—complementary rather than oppositional, but still different (Figure 4).

Why collect historical software at all? Since Bearman began to write about this question, responses have appealed to the profound impact of computers, software, and digital data on virtually every aspect of recent and contemporary history. Bearman, as we have seen, defined the "software archive" as serving the history of software as a research field, thus distinguishing it from

4.
An example of documentation accompanying historical software. Courtesy of Department of Special Collections and University Archives, Stanford University Libraries, Stanford, Calfiornia.

the software library. Hedstrom reported, however, that those present at the Arden conference "debated whether it was necessary to preserve software itself in order to provide a sense of 'touch and feel' or whether the history of software development could be documented with more traditional records."[30] More recently, David Allison of the Smithsonian's National Museum of American History has suggested that "supporting materials are often more valuable for historical study than code itself. They provide contextual information that is critical to evaluating the historical significance of the software products."[31] He too argues that operating historical software is not an aspiration in institutions that serve a historical mission. The needs of historians, of course, do not account for all potential uses of software collections. Computers have been a fact of life for more than a half century. As a result, archives collect historical records in digital formats, and the separation between data archiving and use cases for historical software is not as absolute as a casual reading of Bearman's report would suggest. (Indeed, a close reading shows that he respected their connections.) Yet institutional priorities must be set and resources allocated. As a result, curators prioritize among collections and services that provide access to documentation of software history and those that deliver the experience of using historical software. It is not (and cannot be) a necessarily binary choice between software archive and software library, but choices still have to be made.

More than a decade ago, I wrote an essay called "The Hard Work of Software History." I tried to come to grips with some of the then-emerging difficulties that cultural repositories were

beginning to face with collecting software.[32] The positions I have described above that separate the software library and archives as methods for preserving software history struck me then as being "partly stuck on different institutional and professional allegiances to the preservation of objects, data migration, archival functions, evidentiary value, and information content. … these issues are not likely to be sorted out before it is necessary to make serious commitments at least to the stabilization, if not the long-term preservation, of digital content and software."[33] Rapid changes in media formats and computing technologies add to the uncertainty associated with the future of software collections. For example, it remains to be seen whether practices associated with collecting packaged software will provide useful methods for collecting software distributed via streaming and software-as-a-service delivery models.[34] In addition to technological evolution, licensing and legal restrictions on both collecting activities and access to collections further constrain curatorial work in this area. The bottom line is that it is not yet clear how curation of software objects and the particular experiences associated with the virtual spaces created by software—whether a game or the white space facing me on the screen as I write these words—will be captured by established library or archival collecting, cataloging, exhibition, and preservation activities.

In May 2013, the National Digital Information Infrastructure and Preservation Program at LC held a conference called "Preserving.exe" with the goal of articulating the "problems and opportunities of software preservation." In my response to the conference included with the LC report issued a few months later, I described three "lures of software preservation," by which I meant potential pitfalls as we begin to connect the dots from software collections to digital repositories and from there to programs and services such as access to collections and exhibitions.[35] In a nutshell, the lure of the screen is the idea that what counts in digital is what is delivered to the screen. With respect to software preservation, the problem comes up when judging success in delivering significant properties of software entirely by auditing interaction with surface properties (graphics, audio) and not accounting either for the variable and contextual nature of these properties or the invisibility of software abstraction levels and procedural aspects of software design such as game mechanics in video games. The second lure is that of the authentic experience, which I consider the mandate that digital repositories at a minimum must be careful to not preserve digital objects in a manner that would interfere with re-enactment of such experiences as are deemed historically authentic. To put it bluntly, I believe that there is no such thing as unconstructed and pure authenticity in this sense, and it is a waste of resources to seek to provide it.

Finally, the third lure is the lure of the executable, and it will conclude my reflections here on historical software collections. As we have seen, the kind of historical resource that Bearman called a software archive had a head start on software libraries. The primacy of documentation was implied in the AFIPS brochure, and it was already being collected by CBI and, indeed, in corporate and university archives by the late 1970s. The first repository collections of software followed more than a decade later and more than 20 years on remain few and far between. As we have seen, these collections have generally been restricted to a limited set of software categories and platforms, and indeed, curators cited above have been skeptical about the potential for much

expansion beyond them. Indeed, some have doubted the value of maintaining software collections for historical research at all.

So what is the value of historical software for the history of software? An attractive version of the end product of software preservation is the well-maintained library of executable historical software. The work to reach that product involves a series of tasks from selection and collection through ingest and migration from original media and creation of technical and rights metadata, as well as provenance, descriptive, and contextual information. This workflow is at the heart of what has been called the life cycle model for digital preservation, the most influential statement of which has been that of the Digital Curation Centre.[36] Although the model says little about related physical components such as packaging, manuals, and box inserts, archiving these components can be considered a separate problem, and as projects at the Strong Museum, University of Texas, Stanford University, and elsewhere indicate, this work is underway. The point for software preservation is that the lure of the executable compels digital repositories to focus on building collections of verified historical software that can be executed on demand by researchers. This lure could well function for some institutions as a holy grail of digital curation with respect to software history.

What could possibly be wrong with this mission, assuming that it can be executed? I have argued on several occasions that there are at least three problems with the software library. Perhaps the good news is that they are problems of omission, rather than commission. The first problem is that software does not tell the user very much about how it has previously been used. In the best case, such as previously installed software available in its original use environment (not a common occurrence), application software might display a record of files created by users, such as a list of recently opened files found in many productivity titles like Microsoft Office. The more typical case for a software library, however, will be that software is freshly installed from the library and thus completely lacking information about historical use.

The second point might best be illustrated through the example of virtual world software, such as *Second Life* or a game world such as *World of Warcraft.* Let us assume that we can capture every bit of historical data from a virtual world server and then successfully synchronize all of these data with carefully installed (and patched) software; we can reverse engineer authentication controls, and we can solve the complex problems of ownership and rights. We will have accomplished an act of perfect software and data capture, and of course, we will then preserve all of the associated digital objects. Now we can create a historical time machine through which we can fly through the virtual world at any moment in time of its existence. Of course, historians would applaud this effort, until it becomes evident that all we can do is tour an empty world. In the absence of historical documentation that helps the researcher to understand motivations and reactions of the participants, the payoff will be limited. Such documentation generally will not be found in the recreation of such a virtual environment, content without context.

The third point and perhaps the most fundamental is that the documentation that is a prerequisite for future historical studies of software and digital media such as games and virtual worlds

is simply not located in software. It is, in a sense, on both sides of software: the design materials (including source code) that document software development and the archives, both digital and nondigital, that document context, use, and reception. It is important to understand that this is not just a problem for historical research. It is also a problem for repositories, whether they are doing the work of digital preservation or addressing the needs of a researcher requesting access to this software. If contextual information such as software dependencies or descriptions of relationships among objects is not available to the repository and all the retired software engineers who knew the software inside and out are gone, it may be impossible to get old software to run.

In *Best Before: Videogames, Supersession and Obsolescence,* James Newman argues that a host of publishing, retail, marketing, journalistic, and other practices have cultivated a situation "in which the new is decisively privileged and promoted and the old is constructed either as a benchmark by which to measure the progress of the current and forthcoming 'generation' or as a comprehensively worn out, obsolete anachronism to be supplanted by its update, superior remake or replacement."[37] Newman is not optimistic about software preservation. This does not mean that he is pessimistic about every possibility for historical preservation, however. In a section of his book provocatively called "Let Videogames Die," he argues that a documentary approach to gameplay might be a more pragmatic enterprise than the effort to preserve playable games. We might generalize his conclusion about digital games to other classes of software. Newman calls for a "shift away from conceiving of play as the outcome of preservation to a position that acknowledges play as an indivisible part of the object of preservation."[38] Stated more generally, software preservation is not about preserving historical software for enactment as historical research and even less about reenactment of past experiences. Rather, it provides a method for producing documentation about contemporary use for (later) historical purposes. The lure of the executable is not just about following a false idol; recognizing the lure leads to acknowledging that the library of executable software can at best be only a partial solution to the problem of software preservation.

Software archives or software libraries? That is the question. Is it nobler to collect documentation or to suffer the slings and arrows of outrageous software installations? The case for documentation is strong. The consensus among library and museum curators (including myself) who have taken a side is that historical documents are a stone-cold lock to be a winning prerequisite for future historical studies of software. Useful records of software could be virtually anything from source code to screenshots. Moreover, historians will not be the only users of these documents. There is even a software library case to be made for software archives: The success of software preservation will depend on the availability of historical documentation. Documents provide contextual information that can be included in transfer protocols or descriptive metadata and inform long-term preservation activities by documenting software dependencies and relationships among objects or clarifying ownership of intellectual property. Documents tell us how software was used historically, and they can also help tell us what we are supposed to do or what we are looking at when operating ancient software on long-defunct operation systems or platform.

And yet every argument for software archives leaves room for preserving software, whether as artistic or cultural content, for technology studies or for forms of scholarship that treat aspects of digital games and virtual worlds as authored texts or artistic objects. Indeed, this tension between the collected artifact and archival documentation will be familiar to curators working with other object and media formats. The difference posed by software collections is that preservation of the software "artifact" necessarily involves commitment to a long-term cycle of data curation activities, rather than object conservation. It is an expensive proposition, involving skills, approaches, and technologies quite different from those required for the conservation of physical artifacts. The problem of institutional commitments to software collections thus ultimately boils down to the identification of relevant use cases and the allocation of resources. It is virtually impossible that any one institution will be able to do it all, but every collecting institution committed to supporting software history should at least try to do something.

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Networks of Collecting

Interpreting the Collection and Display of Contemporary Science in Chinese Museums as a Reflection of Science in Society

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This chapter remarks on gradual changes in practices of collection and display of science in China. It begins by investigating the roots of science collecting that stem from the nineteenth century. It proceeds to inspect the years from the division between the People's Republic of China (hereafter China) and Republic of China (hereafter Taiwan) in the 1950s, over the Cultural Revolution into the boom in museums after 1980. In the final overview of the present state of science museums in China, one national science museum and one provincial-level science museum are exemplified to explain differences in science museums occupying different levels of the museum hierarchy. The analysis focuses on exhibition design and audiences and is part of a larger ongoing doctoral project on contemporary science museum culture in China and the United Kingdom; collecting is discussed mainly in terms of cultural heritage and the inclusion of oral records.[1]

Objects can be collected for the purpose of preserving the past for the benefit of the future. In a way, even demonstrations of innovative science in contemporary museums can be interpreted as a collection of modern-day ideas for the benefit of future generations. This notion appears to be the main idea behind the collections in contemporary Chinese science museums. Where collecting was once a pastime available only to the elite, stakeholders of the twentieth

and twenty-first centuries in China have propagated the "taking over" of artifact collection by museums as being to the benefit of a larger number of people. Furthermore, exhibitions of collections after 2000 mainly apply ideas whose realization is, paradoxically, limited only by the abilities of existing science and technology. The commission-based and exhibition-driven collecting that is common in Eastern and Western science museums today allows scientific content (textbook-style information) to be presented in a scientific context (interactive exhibits of both high- and low-tech varieties). The basic idea of collecting remains the same as that of the earliest collectors of natural history and philosophy, but the collections themselves cater to an audience of their own time.

Since the first Chinese museums opened in the late nineteenth century, collecting practices of science in the Chinese-speaking world have been influenced by the historical notion of a European origin of science. This influence can be seen in gradual changes in naming practices, patterns of collection, the identity of stakeholders, and the social and political role of the museum as a didactic method in the Chinese-speaking world. After 1948 the sciences of the past held a venerated place in history museums. China's investment in new science museums and centers since 2000 has reinforced the stark distinction between the sciences of the past and the sciences of the present. Although both are sources of power and pride, reformers and traditionalists, the Communist Party in China and the Guomindang in Taiwan, venerate past and present sciences differently and in separate venues. Both Taiwan and China equally represent the past with artifacts, whereas modern science is displayed conceptually for didactical purposes. Rather than drawing on a body of curatorial expertise and existing objects, science exhibitions are "designed." They display objects in a neutral space, unconnected to local or contemporary concerns to delineate the universally valid essence of natural sciences.

Throughout the Chinese-speaking world, naming practices are informed by a variety of ideals rather than revealing the actual structure of collection and display. Stakeholders often choose the name "museum" (*bowu guan* 博物館, literally "hall for the erudite study of objects," abbreviated as "science and technology museum," *kexue jishu guan* 科學技術館), implying a relation to the twentieth-century Western idea of displaying a collection. The favored science center model is actually a departure from the "traditional" museum.[2] Structurally, these science museums are fashioned on the twenty-first-century North American model of the Exploratorium. This approach is particularly evident in the booming science museum culture (*kexue bowu guan* 科學博物館) and science and technology museums (*kexue jishu guan* 科學技術館) that have been established since 2002 in China after a law to popularize science passed by the 9th National People's Congress.[3]

Collecting in the Chinese-speaking world is generally defined by a limited number of stakeholders. Although scientists and scientific institutions held major stakes in collecting between the 1950s and 1970s, throughout the twentieth century state actors dominated public museum culture. Politicians defined the agenda of modern-day exhibitions that were then designed and implemented locally by assigned administrators. Then objects were sourced and delivered. In

museums, exhibitions were built as permanent galleries. The designs chosen in the competitive calls for exhibitions in post-2010 science museums demonstrate that Chinese political stakeholders prefer advanced technical methods of display that encourage interaction between the visitors and the exhibits, which in turn can reassure the public of the progressiveness of the exhibited science, technology, and China's approach to it. Individuals or industries that began to engage in exhibition culture commercially after 2000 thus far rarely address scientific or technological contexts.

Education has been a key to late twentieth- and twenty-first-century collection practice, especially in the case of governmental bodies and state-funded science museums, such as the two case studies discussed below. Scientists feature in this arrangement as the purveyors of requested information that is then communicated to the public via the museum. Academic discourses in China consider a museum's task of collecting and exhibiting to be accomplished when the audience responds positively to the prime educative goal of the Popularization of Science and Technology law that aims at improving China's standing in the basic natural sciences of physics, mathematics, and chemistry and in life sciences.[4]

How then do Chinese science museums acquire their collections? At the Zhejiang Science and Technology Museum (浙江省科技馆, hereafter ZJSTM) the provincial-level science museum of Zhejiang Province situated in its capital Hangzhou, a group of decision-makers consisting of the directorial staff of the science museum together with members of the regional science association, meets and draws out plans for each of the galleries in the museum.[5] The plan is then fulfilled by external designers, with each revised proof overseen by the attendees of the aforementioned meeting. Decision-makers and gallery developers do not work in the museum on a daily basis and are therefore not necessarily aware of public engagement levels.[6] As educational institutions, science museums are free of charge. Stakeholders indeed struggle with their responsibilities toward the public and grapple with visitor numbers because these "designed" fixed exhibitions do not invite repeat visits. The majority of these permanent galleries run the risk of being out of date relatively quickly as science advances. Museums collect "science" then only as an accidental by-product driven by the constant necessity to create new shows. Systematic collecting for the purpose of preservation is not the goal.

Political Competition: The Roots of Science Collecting in China and Taiwan in the 1950s

Research on science and technology collecting in China is still in its infancy, as is the institution of the science museum itself. Studies on museums up until the late 1990s, emphasizing the break with China's imperial traditions, suggest that natural history museums (*ziran lishi bowu guan* 自然歷史博物館) such as the Zhendan Museum (*Zhendan bowu yuan* 震旦博物院) installed in the

year 1872 by the Jesuit French Asian Society in Shanghai, were the modern science museum's natural ancestor.[7] At that time, research institutions were already displaying geological collections within classificatory schemes of "Western learning" (*xixue* 西學) or "science" (*kexue* 科學). Previous studies have mainly discussed this within the context of a growing public understanding of the science (*kepu* 科普) of the West, imperialism, and capitalism during the prewar era.[8] In this vein, Lisa Claypool and Qin Shao inquired into the first domestically founded—and funded— natural history museum in China, established in 1905 in Nantong, Jiangsu Province.[9]

The late nineteenth- and early twentieth-century Chinese notion of science as the savior of the nation and a source of power and pride carried through during the establishment of the Communist government of China on the mainland and the Guomindang government of Taiwan. Competitive claims over international standing and political legitimacy made by the Communist Party and the Guomindang heavily influenced the historical formation of collections and their displays after 1948.

The politicization of science collecting and display continued. From 1948 onward China and Taiwan both collected and showcased scientific and technological achievements of an ever more distant past in history museums to underline the legitimacy of their rule over the Chinese civilization. Scientific achievements featured in archaeological and art exhibitions.[10] At the same time natural history and science museums were tailored as educational sites for students and the public so they would learn modern sciences and technologies and thus increase the wealth and power of the country.

Political legitimacy figures prominently in the science-collecting politics of Taiwan. When the Guomindang government launched an extensive program in the 1950s, it claimed to be connecting and continuing a science museum culture active since 1900. The National Taiwan Museum (*Guoli bowuguan* 國力博物館) in Taipei Park, Taipei, originally established in 1908 and still located on the same premises, was turned into the "first modern museum" (*diyi xiandai bowuguan* 第一現代博物館).[11] It hosted over 23,000 items in 11 categories: geological features, plants, animals, ethnography, historical education, agriculture, forestry, hydraulics, mining, craftsmanship, arts, and trade. The museum disseminated 10,000 copies of their monthly newsletters throughout the province and placed them on public display. In 1956 the Guomindang government also established an Exhibition Hall for Science Education (*Taiwan kexue jiaoyu guan* 台灣科學教育館) in Taipei city with the mission to popularize science throughout the country. The second floor of the four-story building hosted an exhibition of material sciences, and the third and fourth floors exhibited permanent collections. Since the 1980s a computer and information technology section and life sciences have filled adjacent halls. After its relocation in 2003 to the Shilin District, it is now jointly managed with the Maritime Museum (*Haiyang shengwu bowuguan* 海洋生物博物館) and the Communal Centre for Industry (*Gonggong fuwu yewu* 公共服務業務). In 1990 Wu Xiangkuang 吳湘匡 reported on 33 science museums in Taiwan, including multiple research-oriented collections in academic institutions directly subordinate to the Education Ministry (*jiaoyubu* 教育部).[12]

Meanwhile, on the mainland, China conversely emphasized a break with imperial and republican bourgeois traditions and a move toward modernity. Throughout the 1950s, the Communist Party in China increasingly opened private, research, and imperial collections to the public. Examples are the Hall for Geological Survey of Hunan Province (*Hunan sheng dizhi diaocha suo chenlie guan* 湖南省地質調查所陳列館), which was installed in 1927 for students and staff, and the zoo in Beijing, which was initially founded by the Qing government.[13] Policy statements by the government of China from the 1950s onward emphasize science museums as "places resolving major research questions related to the national economy" (*jiejue duiyu guomin jingji juyou zhongyao yiyi de guanjian xing de kexue wenti* 解決對于國民經濟具有重要意義的關鍵性的科學問題).[14] Issues of public hygiene (*weisheng* 衛生), agricultural development (*nongye* 農業), and heavy manufacturing (*gongye* 工業) were exhibited.

China in the 1960s to 1990s: Inquiring into the Sciences of the Past for the Future

Inquiring into the varying historical modes of science popularization, Lou Xihu 楼锡祜 distinguishes three major periods of science museums in China: 1950–1966, 1977–1990, and 1990 to present.[15] In his scenario the period of 1950–1966 deserves only scant attention because during this period actors mainly attempted to overcome the cultural destruction that had hit China during the civil wars. However, we suggest the beginnings of later developments were initiated in this period. During the Great Leap Forward museums took on the baton of science popularization for the prime purpose of educating. They informed visitors about the intricacies of traditional methods to melt iron or forecast earthquakes as one of the ways to advance the country to modernity. In 1958 a national committee was put in charge of the reconstruction of ancient sites of natural history museums in Shanghai, Tianjin, and Dalian. The committee promoted the need for the resurrection of the Beijing Zoo, for instance, for "the education of society" (*shehui jiaoyu* 社會教育), advertising the site as a "second classroom" (*di'er ketang* 第二課堂). Collecting aimed at comprehensiveness to "illustrate the richness of things" (*wu* 物).[16]

The display of the archaeological site of the Peking Man at Zhoukoudian (周口店) exemplifies the huge impact of modernity debates. Soon after 1948, the Communist government shaped the museum to educate the population in Darwinian understanding of human evolution and to propagate political ideologies such as "labor creates humanity" (*laodong chuangzao le ren* 勞動創造了人).[17] The collecting efforts, by contrast, underline this era's concern about political legitimacy. The Communist Party employed Peking Man as a political emblem for the persistence of Chinese ethnicity. When the bones of Peking Man were lost (it has never been clarified whether Japanese or Americans looted the remnants of Peking Man or they simply got lost in transit), the Communist government dispatched scientists to conduct further excavations that would help to

verify the early traces of human activity in China. The collecting continued even after 1966 into the Great Proletarian Cultural Revolution when another two skull fragments were discovered. At the height of the Cultural Revolution between 1972 and 1973, scientists excavated another *Homo sapiens* premolar. Some science and science collecting hence clearly continued despite political rupture and distress.[18]

In general, however, the period of the Great Proletarian Cultural Revolution (*wenhua da geming* 文化大革命) between 1966 and 1976 marks a major rupture in the history of Chinese approaches to any kind of heritage. As Mao Zedong 毛澤東 (1893–1976) mobilized China's youth to attack the "four olds" (customs, culture, habits, ideas), intellectuals and scientists were also prosecuted as bourgeois elements, and some scientific research came to a standstill. Politicians such as Zhou Enlai 周恩來 (1898–1976) could protect some places such as the Forbidden City in Beijing and its collection of astronomical instruments or clocks. Individual scientists such as the meteorologist and specialist in atmospheric physics Tao Shiyan 陶詩言 (1919–2012) continued their work privately and managed to safeguard books, scientific instruments, and institutional assets.[19]

One immediate effect of the destructive activities of the Great Proletarian Cultural Revolution period was an increased awareness of the value of heritage and history in the creation of national identity after the end of this era. Archaeology and China's natural history as well as its technological achievements moved back into political purview. By 1977 the archaeologist Pei Wenzhong 裴文忠 (1904–1982) and the leader of the scientist committee Pei Lisheng 裴麗生 (1906–2000) engaged enthusiastically on behalf of China's natural science museums.[20] The prospering provinces of Zhejiang, Jilin, and Guangxi quickly established topical museums such as the National Silk Museum (*Guojia sichou bowu guan* 國家絲綢博物館) in Hangzhou City, Zhejiang Province.[21] A national research institute for the popularization of science (*Zhongguo kepu yanjiu suo* 中國科普研究所) was established in 1994.

But it was almost another decade before economic and ideological shifts brought another quantitative leap in science museum culture. On 29 June 2002, the National Committee announced a five-year plan to establish 200 new museums for the promotion of the hard sciences in China by 2020 "for the development of the sciences and technologies."[22] The annual report on the "National Scheme for Scientific Literacy" (*Zhongguo kepu baogao* 中國科普報告) aimed at raising the number of science museums from 250 nationwide in 2006 to 581 in 2010.[23] Although China's policies from the 1980s to 2000 targeted mainly applied sciences, the latest attempts to use science museums to popularize science are aimed explicitly at basic science research, an area that China's leading politicians still identify as deficient in comparison to Europe and North America.[24] In contrast, politicians are confident in China's growing capacity in engineering and the production of high-end consumption technologies.

Although the state features, indeed, as the most visible actor in collecting and display, providing resources for both science and museums, with the twenty-first-century economic shift and changing notions of heritage, collections of resources, books, and scientific apparatuses such as those Tao Shiyan gathered during the Great Leap Forward (*Dayuejin* 大躍進; 1958–1961) also

come into the purview of modern museum culture.[25] As of 2014, private collectors are willing to share information on an individual basis, although public display of this part of contemporary history is still rare as these periods are politically sensitive. State bodies can lawfully appropriate or confiscate artifacts thought to be of national importance at any time.[26]

Documenting Science in Twenty-First-Century Chinese Science Museums

Current trends in Chinese state-supported science museums include a strong emphasis on educational hands-on activities for visitors. More emphasis is placed on featuring Chinese science and what science could provide for humanity in the future. Science museums in China are something of a nationwide project for the state, with many new sites emerging in large cities, mostly provincial capitals, since 2000, following the trends created in three flagship museums: the China Science and Technology Museum (*Zhongguo keji guan* 中國科技館; CSTM) in Beijing, the Shanghai Science and Technology Museum in Shanghai, and the Guangdong Science Center (廣東科學中心) in Guangzhou. These state-supported science museums fit into a political and regional hierarchy, where the flagship museums in cities such as Beijing and Shanghai are at the top, the provincial museums are in the middle, and city-level museums are farther down. We employ two case studies: CSTM and ZJSTM. It can be shown that political agendas, new exhibition ideas, and designs begin in the top-tier museums and then trickle down the political structure to regional and local museum culture. Museum staff who generally have a background in science, science and technology studies, or the history of science aim at moving up the career ladder along such hierarchies.

Confronted with a tech-savvy public, China's science museums on all tiers rely on interactive high-tech displays of the most up-to-date science. Genuine objects such as the space suit of China's first taikonaut, Yang Liwei 楊利偉 of the Shenzhen 5 mission, are a rarity, displayed by CSTM as a Chinese first.[27] The aforementioned space suit is displayed in a gallery dedicated to astronomy and aeronautical engineering, with a moon landing theme even though Shenzhen 5 was an Earth orbital mission. The theme is devoid of historical references to earlier, less successful attempts or even historical references to China's gunpowder and rocket sciences. Since Shenzhen 5, there have been five crewed missions (2003–2013, with plans for a sixth imminent and 20 unmanned space launches pending for 2016 alone), suggesting that the museum ties into a larger political agenda of promoting this area of research (Figures 1 and 2).[28]

The current approach to science exhibitions combines the idea of science as a designed, purchasable event with the desire to display the most up-to-date sciences. Although the event character, emphasizing the universal validity of scientific ideas, does not cater to ideas of collecting, the quick pace of change in modern sciences provides an important incentive for future practices. In science, new theories or facts, provided there is sufficient evidence, can replace older theories. Theoretically, this change should mean that a science museum's exhibits can display

1.
Taikonaut display at the China Science and Technology Museum. Photo by the authors.

2.
Taikonaut display at the China Science and Technology Museum. Photo by the authors.

the relevant background scientific theories even if the political and social landscape and public opinion on the relevance of science change. This aspect of social and political influence on science museums in the East and West means that although they can showcase future innovations, they also preserve history for informational purposes. In the current climate, the flagship, CSTM, is beginning to keep documentation of its old exhibitions, creating a dossier-like record of past events at the museum. This is a standard procedure for museums in the West. Museums in China have long opted to completely discard previous exhibitions without any form of documentation after use.

Current attempts to document exhibitions are motivated by a growing awareness of the historicity of the contemporary in a culture that ideologically tends to venerate the longue durée and most ancient traits. Actors remain aware of the politically hazardous implications of archiving contemporary or recent history, even though political relaxation and economic growth since the 1990s have contributed to making museum stakeholders want to showcase their previous achievements. In informal conversations, throwing away exhibits is also argued to be a waste of public resources, considering that they could be used again as temporary exhibitions.

Farther down the museum hierarchy, the ZJSTM creates many exhibitions and galleries with permanence in mind, commissioning them externally by design using the ideas of a council of top-level museum staff (assistant director and above) and relevant members of the local government. The latter spend little time in the actual museum. In these museums, temporary exhibition space is limited.

Science Collecting in the Present Day: The China Science and Technology Museum in Beijing and the Zhejiang Science and Technology Museum in Hangzhou

The following arguments utilize CSTM and ZJSTM as case studies to give concrete examples of the work carried out in science museums of different "ranks" in the Chinese museum hierarchy. The CSTM belongs to the elite three flagship science museums, whereas ZJSTM occupies the position of a provincial-level science museum and as such takes on responsibilities beyond the museum walls, such as outreach programs delivering museum content to (usually) children in rural villages. Provincial-level museums are still increasing in number as the state aims to provide accessible science museums across the country: there are 22 provinces in China, and one of the latest provincial museums is the Xinjiang Science and Technology Museum (*Xinjiang keji guan* 新疆科技館) in Ürümqi, the capital of the Xinjiang Uygur region in northwestern China. Note that the naming convention is consistent for all provincial museums.

The ZJSTM is not as heavily promoted and funded as the national-level science museums but has defined public engagement responsibilities in its region. It groups itself in the same classification schemes as the CSTM, that is, as an institution with a future purpose and not one that caters to the memory of the past. Historical artifacts, including replicas, are few and far between—mere concessions to an audience that needs didactic support and emotional anchors to an otherwise global and universalized science. At CSTM the commissioned collection comes with a predetermined classification scheme. Currently, it appears that the collection strategy is only in the emerging stages, created a posteriori by the actual need to communicate ideas to the targeted audience. For instance, samples and models of emerging technology, ranging from 3-D printed mechanical components to increasingly resilient man-made materials, dominate the scene and provide contextualizing objects meant to represent future science (Figure 3).

Science museums in the United Kingdom use this collection display method to link future achievements closely to their own past, whereas the Chinese equivalent emphasizes new inventions and future ventures as features of a modern world to come. If modern sciences have any anchor, it is in the traditions of the nineteenth- and twentieth-century West, that is, western Europe and the United States, invoked by global hero figures such as Charles Darwin, Albert Einstein (1879–1955), and more recent Nobel laureates such as the American chemist Glenn T. Seaborg (1912–1999), who first isolated transuranium elements. The only Chinese individual in the gallery passage thus far is the aeronaut Yang Liwei.
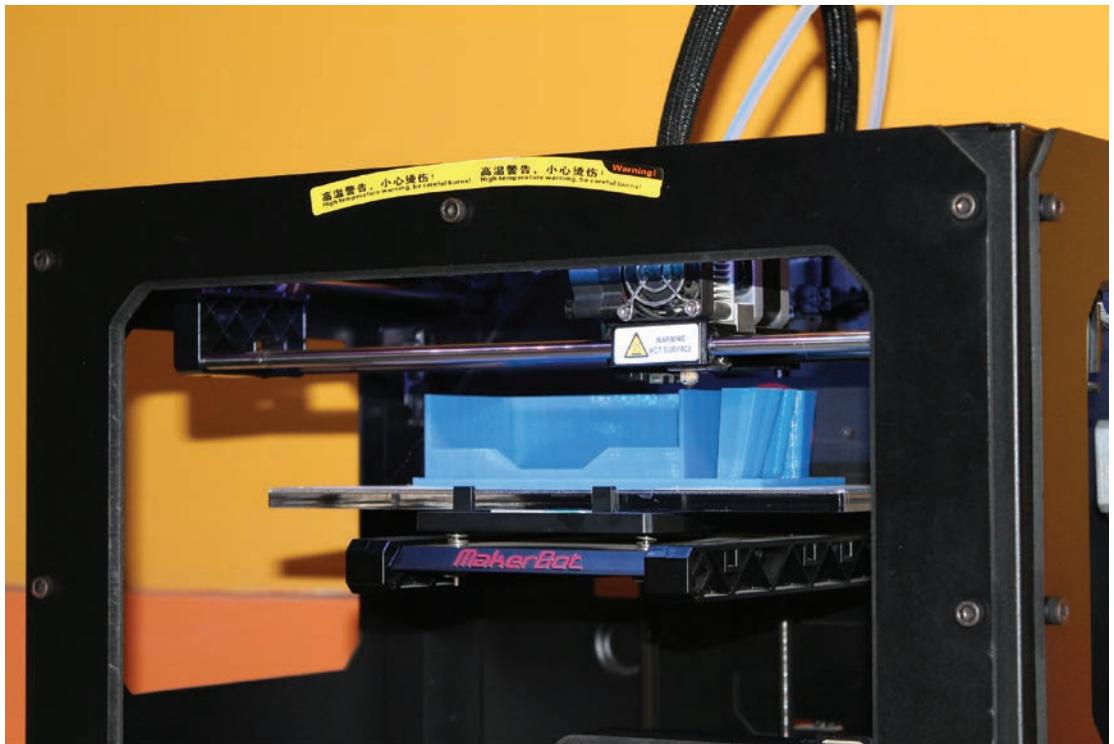
3.
The 3-D printing exhibit at the China Science and Technology Museum. Photo by the authors.

For this reason, we consider the exhibition development procedure in most Chinese science museums to be concerned primarily with theories and ideas. Its aim is display, and its approach to collecting is a combination of determinism and constructivism. It assumes that there is something to learn in the first place, then proceeds to search for this information, in contrast to classical constructivist ideas that claimed to furnish visitors with a comprehensive information landscape that they were invited to use to create their own ideas of the world.[29] Local or historical anchoring is deemed unnecessary because the value of science is universal. More research has to be done to confirm the impression received, that this Chinese audience perceives the "value" of scientific and technological artifacts differently than a European one, but it appears as if, within the universalism of modern science, this audience perceives the artifact as incidental and illustrative and not valuable per se.

The method of acquiring objects is interesting because of the reasoning behind each object. Chinese researchers assume that Western science museums possess large collections of material and that the star of the show often involves a superlative: the first, the last, the oldest, the newest, the only.[30] This focus of China's museums on firsts vividly underlines how much modern museum culture is still affected by China's late nineteenth-century colonial experience and the notion of a weak empire and republican system being depressed by the scientific and technological prowess of the West. Collections of objects curated by contemporary museum staff and commissioned exhibitions of modern objects provide museums and science, as a community and concept, with an opportunity to narrate an open-ended story. At a glance, this approach is different to the object-based narration and collection practices favored in British and European museums.

Summary

Political agendas and an emphasis on education have marked the development of post-1949 collecting practice in the Chinese-speaking world, which until recently occurred mainly in the public museum sphere. In Taiwan, institutional structures have increasingly stabilized since the 1980s, and discourse, in line with international developments, has also increasingly concentrated on display technologies and audience participation.[31] Conversely, science museum culture in China has been influenced by heavy state investment in a new generation of science museums since the early 2000s, and a prospering economy has only started to change ideas of audience participation and spur discourse on the public role of science. At the moment, historical objects in China, even those of a scientific persuasion, are found in regional or archaeological museums, where the focus is on their historical significance rather than their representation of scientific China.

Science museums such as CSTM have a few collages of well-known scientists with their profiles on a label next to their picture. The overwhelming majority are Western. This presentation gives the impression that China still looks to the West for scientific guidance. However, there are signs of increasing confidence here, such as the plaque with China's first man in space.

When viewing the "collections" of scientists and their ideas, albeit with vested interest, we were left with the impression that science is best studied in the West but is becoming of increasing importance in China once again, even at this theoretical level.

Presently, the collecting of historical science in Taiwan and China is distinguishably the work of natural science and historical museums, whereas when it comes to modern and present-day sciences, the scientific topic is in focus. Exhibitions are frequently updated, and the archiving of outdated exhibits is only slowly becoming the responsibility of museum staff. Stakeholders in both Taiwan and China have only just started to develop an interest in the most recent past from 1950 to the present. Museums in China that feature science as their main topic first determine an exhibition topic and then focus on commissioning their collections. However, as the study of science communication, including collecting for museums, in the modern-day Chinese-speaking world is constantly changing, this study will remain open-ended for the time being. At the time of writing, CSTM in China is preparing an upcoming exhibition that will look to past materials, such as archived publications, transmissions, and images, to create a gallery they think will speak to a contemporary visitor, effectively turning a new leaf in "traditional" museum collection practices and recapturing the fascination of a new audience. This exhibition will use the images of science past to underline the modernity of collections of science present (Figure 4).

4.
Traditional Chinese puzzle at the Zhejiang Science and Technology Museum. Photo by the authors.

Notes

1. Literature on science popularization strategies and the role of museums is vast. For an overview see Xihu Lou 楼锡祜, "Zhongguo ziran kexue bowu guan de fazhan" 中國自然科學博物館的發展 [The development of the natural science museums of China], *Kepu yanjiu* 15 (2008): 48–52; Lian Duan 段煉, "Ziran kexue bowu guan yu koushu lishi" 自然科學博物館與口述歷史 [Science museums and oral history], *Zhongguo keji shi zazhi* 32 (2011): 78–82.

2. The museum in Guangzhou explicitly refers to itself as a science center (*kexue zhongxin* 科學中心), but it is in the minority. Smaller units are occasionally called a "science and technology exhibition hall" (*kejiyuan* 科技院). Shengguo Wu (Peking University), in discussion with the author, 26 May 2014.

3. The Regulation for the Popularization of Science and Technology of the People's Republic of China (*Zhonghua renmin gonghe guo kexue jishu puji fa* 中華人民共和國科學技術普及法) was signed by Jiang Zemin as head of the National Congress on 29 June 2002. The communiqué consists of six chapters that outline strategies and aims and give recommendations for organizational structures and content of popularization efforts. Museums are addressed in section 16 together with science and technology exhibition halls (*keji guan* 科技館), libraries (*tushuguan* 圖書館), and cultural centers (*wenhua guan* 文化館). Their "purpose is to disseminate and popularize science education" (*yinggai fahui kepu jiaoyu de zuoyong* 應該发挥科普教育的作用). The regulation is a strong recommendation (*yinggai* 應該) rather than obligatory (*bixu* 必須). For the full text see Ministry of Science and Technology of the People's Republic of China, http://www.most.gov.cn/fggw/fl/200601/t20060106_53394.htm (accessed 25 June 2014).

4. See, e.g., Wu Xiaoming 吳曉明, "Lun goujian ren yu ziran hexie shehui shiqi de ziran lei bowu guan zhanshi – jian tan Zhejiang ziran bowu guan xinguan zhanshi shijian" 論構建人與自然和諧社會時期的自然類博物館展示—兼談浙江自然博物館新館展示實踐 [Natural history museum exhibitions during the period of harmonious society of human and nature—Exhibition practice of new Zhejiang Museum of Natural History], *Kepu yanjiu* 4 (2010).

5. Representative of the Chinese provincial-level science museums, in discussion with the authors, October 2013.

6. Ruihong Li (director, ZJSTM), in discussion with the author, 9 October 2013.

7. Jianchang Lü 呂建昌, "Shanghai gezhi shuyuan datie fang bowu guan zhiyi"上海格致書院大鐵房博物館質疑 [A question about the Great Iron-House Museum of the Gezhi Academy in Shanghai], *Shanghai daxue xuebao* 12, no. 1 (2005): 95–98. Imperial households and elites often collected curious things and exotic and historical artifacts, as well as fossils (in their rendering, "dragon bones," *longgu* 龍骨), plants, minerals, and animals. See, for instance, Yu Huichun, "Qianlong's Divine Treasures: The Bells in Rhyming-the-Old Hall," *Asia Major* 22, no. 2 (2009): 121–144. Rogerio Miguel Puga pinpoints that British traders and naturalists first established a museum in Macao (which was distanced from mainland China). Europeans, in particular British natives, used it as a gateway to trade plants and channel specimens home and indulge themselves in the sciences of the West. There is no record of Chinese visitors. See Rogerio Miguel Puga, "The First Museum in China: The British Museum of Macao (1829–1843) and Its Contribution to Nineteenth Century British Natural Science," *Journal of Royal Asiatic Society* 22, nos. 3–4 (2012): 575–586.

8. Guofang Wang 王國方, "Woguo zaoqi dizhi chenlie guan gailüe" 我國早期地質陳列館概略 [Analysis of early geological museums in our country], *Zhongguo keji shiliao* 10, no. 2 (1989): 67–72.

9. Qin Shao, "Exhibiting the Modern: The Creation of the First Chinese Museum, 1905–1930," *China Quarterly* 179 (2004): 684–702; Lisa Claypool, "Zhang Jian and China's First Museum," *Journal of Asian Studies* 64, no. 3 (2005): 567–604.

10. Iwo Amelung, "Die Vier großen Erfindungen. Selbstzweifel und Selbstbestätigung in der chinesischen Wissenschafts- und Technikgeschichtsschreibung," in *Selbstbehauptungs-diskurse in Asien: Japan-China-Korea*, ed. Iwo Amelung, Matthias Koch, Joachim Kurtz, Eun-Jeung Lee, and Sven Saaler (Munich: Iudicium, 2003), 243–272.

11. Originally called the Taiwan Viceroy's Office Museum when inaugurated on 24 October 1908, after funds were collected to expand the building, it was renamed the Viceroy Kodama Gentaro and Chief Civil Administrator Goto Shinpei Memorial Museum in 1913. In 1949, with the relocation of the national government of the Republic of China to Taiwan, the museum's name was changed to the Taiwan Provincial Museum. After a period of renovation in 1999 the museum was reopened and received its current name. National Taiwan Museum, "History," http://www2.ntm.gov.tw/en/About_5_1.htm (accessed 23 May 2016). Wu Xiangkuang 吳湘匡, "Taiwan de kexue bowu guan" 台灣的科學博物館 [Taiwan's science museums], *Da ziran* 3 (1990): 41–42. See also Junyuan Hong 洪俊源 and Yufu Yang 楊裕富, eds., *Taiwan bowu guan zhanshi sheji zhi lishi huigu yu weilai qushi* 台灣博物館展示設計之歷史回顧與未來趨勢 [Future trends and past designs of Taiwan's museums] (Taipei: Taiwan Taoyuan, 1999).

12. For discussion of topics in this paragraph, see Wu 吳, "Taiwan de kexue bowu guan."

13. Wang, "Woguo zaoqi dizhi chenlie guan gailüe." For the Beijing Zoo as a natural history collection, see Xianhua Zhu 朱先華, "Qingdai dongwuyuan" 清代動物園 [The Qing Dynastic Zoo], in *Jinjin cheng* 23 (1984): 34–39.

14. Zhongguo kexueyuan dangzu 中國科學院黨組, " Zhonggong zhongyang dui zhongguo kexue yuan dangzu 'Guanyu muqian kexue yuan gongzuo de jiben qingkuang he jinhou renwu gei zhongyang de baogao pishi'" 中共中央對中國科學院黨組《關於目前科學院工作的基本情況和今後任務給中央的報告》的批示 [Commentary on the 'Report on the working conditions of earlier science research centers and their current tasks and duties' given to CCP Central Committee by the Party Leadership Group of the CAS], in *Jianguo yilai zhongyao wenxian xuanbian* 建國以來重要文件選編(第五冊), ed. Zhonggong zhongyang wenxian yanjiushi 中共中央文獻研究室, vol. 5 (Beijing: Zhongyang wenxian chuban she, 1992). See also Xuemin Zhong 鐘學敏 and Yiping Chen 陳一平, "Lun jianguo chuqi de kexue puji yundong" 論建國初期的科學普及運動 [Science popularization movements during the establishment of the People's Republic of China], *Guiyang xueyuan bao* 9 (2008): 17–21.

15. Lou, "Zhongguo ziran kexue bowu guan de fazhan," 48.

16. Continuity is created in this purposeful interpretation of museums as educational institutions. Scholars such Dunru Liao 廖敦如 see this didactic purpose also as a major mission of U.S. and U.K. science museums. See Archive of the Beijing Zoo (Beijing Dongwuyuan dang'an 北京動物園檔案), quoted in Dunru Liao 廖敦如, "Wo de jiaoshi zai bowu guan: Ying Mei 'guanxiao hezuo' tuizhan ji qi dui woguo de qishi" 我的教室在博物館: 英美'館校合作'推展及其啓對我國的啓示 [My classroom is in the museum:

The push for museum-university cooperation in the United Kingdom and United States and its inspirational spirit for our country], *Bowu guan xueji kan* 19, no. 1 (2005): 79–98.

17. Sigrid Schmalzer, *The People's Peking Man: Popular Science and Human Identity in Twentieth-Century China* (Chicago: University of Chicago Press, 2008), 66–68.

18. Schmalzer, *Peking Man*, 66–68.

19. Zhenghong Chen, Guifang Yang, and Robert A. L. Wray, "Shiyan Tao and the History of Indigenous Meteorology in China," *Earth Sciences History* 33, no. 2 (2014): 346–360.

20. The Natural History and Dinosaur Museum (*Zigong konglong bowu guan* 自貢恐龍博物館), for instance, was established by the end of the 1980s, the Agricultural Museum (*nongye bowu guan* 農業博物館) was established in 1986, and the China Science and Technology Museum (*Zhongguo kexue jishu bowu guan* 中國科學技術博物館) was established in 1988.

21. Quoted in Feng Zhao 趙豐, "Sichou bowu guan yu sichou shi yanjiu" 絲綢博物館與絲綢史研究 [Silk museums and silk history research], *Sichou-Silk Monthly* 12 (1987): 47–49. See the same article for the politics of silk collecting and display in its relation to research.

22. Jianhua Lü 呂建華, ed., *2010 Quanmin kexue suzhi xingdong jihua gangyao nianbao: Zhongguo kepu baogao* 2010 全民科學素質行動計劃綱要年報: 中國科普報告 [The annual report on the outline of national scheme for scientific literacy: Science popularization report of China, 2010] (Beijing: kexue puji chuban she, 2010), 4.

23. Lü, *2010 Quanmin kexue suzhi xingdong jihua gangyao nianbao,* 4. See also Hepeng Jia and Li Liu, "Unbalanced Progress: The Hard Road from Science Popularisation to Public Engagement with Science in China," *Public Understanding of Science* 23, no. 1 (2014): 32–37.

24. Similar trends can also be observed in South Korea, which favored applied science between 1960 and 1990 but now increasingly invests in basic research; see, e.g., Dong-Won Kim and Stuart D. Leslie, "Winning Markets or Winning Nobel Prizes? KAIST and the Challenges of Late Industrialization," *Osiris* 13 (1998): 154–185.

25. For the role of historical and science museums in the Great Leap Forward, see Donald Wagner, *The Traditional Chinese Iron Industry and Its Modern Fate* (Copenhagen: Curzon Press, 1997); Fa-ti Fan, "Collective Monitoring, Collective Defence. Science, Earthquakes, and Politics in Communist China," *Science in Context* 25 (2012): 127–154.

26. Since the 1990s, privateers in China have opened museums in response to national and international tourism. The state can legally contest private ownership of such artifacts (*Zhonghua renmin gongheguo wenwu baohu fa* 中華人民共和國文物保護法, 19 November 1982, section 6), although there is no record that stakeholders enforce such rights. Research on this topic is still in its infancy.

27. The training suit is on display at the Hong Kong Space Museum (*Xianggang taikong guan* 香港太空館). See also their virtual exhibition, http://www.lcsd.gov.hk/CE/Museum/Space/ (accessed 20 May 2014).

28. China launched the Tiangong 1 space station on 29 September 2011 and two sortie missions to it in 2012 and 2013 (Shenzhou 9 and 10). With Shenzhou 9 (2012) the news featured China's first female astronaut, Yang Liu 劉洋. See Stephen Clark, "Successful Start of China's Fifth Human Spaceflight," *Spaceflight Now*, 11 June 2013, http://www.spaceflightnow.com/china/shenzhou10/130611launch/#.V4GbRjmLR0s (accessed 5 June 2016).

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A National Program for Safeguarding Scientific and Technical Heritage

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Since World War II, science and technology have experienced tremendous development. However, the obvious gap between the concerns of civil society and the world of science and research appears to be troublesome.[1] Contemporary science has changed the scale of exploration, from the infinitely small to the infinitely large. In the field of observation, we went from the micrometer, in the 1960s, to the nanometer. In the same period, France was engaged in research programs involving heavy and often very large equipment, an area that scientists and historians of science have denominated "big science."[2] The areas covered by this development are, for example, space research and nuclear research. These programs have often been funded at the European or international level. A recent example is the construction of the Large Hadron Collider at the European Organization for Nuclear Research (CERN).[3] These developments have advanced the sciences and influenced scientific practices.

The recent development of science and technology has also resulted in the formation of important scientific communities. With the ongoing retirement in the years from 2000 to 2020[4] of a large number of researchers and engineers who created research laboratories and teaching institutions in the 1960s,[5] some of the knowledge and material evidence will disappear, erasing irreplaceably the memory of this half century of scientific and technical development.

In this contribution, we would like to share the experience of the creation and expansion of a national mission for safeguarding and promoting the scientific and technical heritage, material

and immaterial, of the past 60 years initiated and run by the museum of the Conservatoire National des Arts et Métiers. This mission, entrusted to the museum in 2003 by the French Ministry of Higher Education and Research, celebrated its tenth anniversary in 2013–2014. It started in 1996 in Nantes and was extended in 1999 to the scale of a region, Pays de la Loire, located in western France. During the past 18 years new practices, methods, and tools have been built to adapt and innovate with the progress of the program.

The Preservation of Material and Immaterial Culture

Technology and science significantly evolved in the past 60 years regarding the manufacturing of scientific and technological instruments in small and large series. Sometimes bought in large numbers in a period of robust scientific growth, they accumulated in laboratories and have now become obsolete, been cannibalized, or been scrapped to make room in the laboratories for new usage. Their appearance, often in black boxes, did not attract the attention of researchers and enthusiasts who might prefer "beautiful objects" in wood, brass, or copper. In 1996, historians of science and technology began to show substantial interest in the topic.[6] As for heritage professionals, working on a period so close in time—less than 30 years past—was not a priority. To this fact are added the lack of experience needed to make a reasoned selection a priori, the deficiency of information resources, and the mass of objects, which probably created some negligence or ignorance with regard to their preservation. In this climate, without intervention few material traces would have remained of these scientific studies and technical innovations of the period, with the exception of perhaps a few isolated objects or collections formed through the initiative of scientists and instrument collectors. The same would have happened regarding the knowledge of the design and use of the instruments, their usage in research, and the history of the creation of laboratories.

Therefore, it seemed essential to safeguard the memory of these scientific instruments and material traces of research to put them in the context of innovation and to keep testimonies by professionals in higher education, research, and business. This history can then be transmitted to current and future generations. Safeguarding this heritage-to-be helps retain some memory of this half century of technical and scientific evolution.[7] But which history of the twentieth century does our society leave to the twenty-first century?

Safeguarding Programs of Scientific and Technical Heritage in France

In the 1980s, in France, during the Year of Heritage, the notion of heritage extended to all areas of culture.[8] However, it did not affect much public-sector research and development in industry. Ten years later, several programs were started to educate scientists and heritage experts. This was the case of the Remus program, funded by the Ministry of Higher Education and Research

and the Ministry of Culture.[9] This program encouraged exchanges between teams of museums, university researchers, and museum professionals to reflect on the museum of science and technology.[10] Another example is the national program for safeguarding the heritage of astronomical observatories jointly funded by the Ministry of Higher Education and Research and the Ministry of Culture in 1995.[11] But in the years 1995–1996, despite these efforts, no national, comprehensive, and systematic policy safeguarding tools and know-how of scientific research existed.

By 1996, a mission to safeguard heritage, created at the University of Nantes, allowed us to develop the first methods for safeguarding scientific laboratory equipment on the scale of a region, capable of becoming partly a "heritage of contemporary research."[12] Three years later in 1999, this operation was extended to the regional level after a second survey indicating that research and higher education institutions in the region of Pays de la Loire had a collection of instruments (over 30,000 were identified, with more than a tenth to be preserved and inventoried) that might be of scientific interest, depending on the selection criteria that were applied.[13] However, the documented inventory and photographs of parts of these objects provided little visible action for politicians and the public. With the support of regional authorities, the Ministry of Higher Education and Research, and the European Regional Development Fund, the regional mission team developed multimedia tools that followed the technological developments over this period, in particular from 1999 to 2004. The concept of "life stories" was used to narrate 30 years of research experience in several scientific fields. Scientists and their teams were interviewed and filmed, and a collection
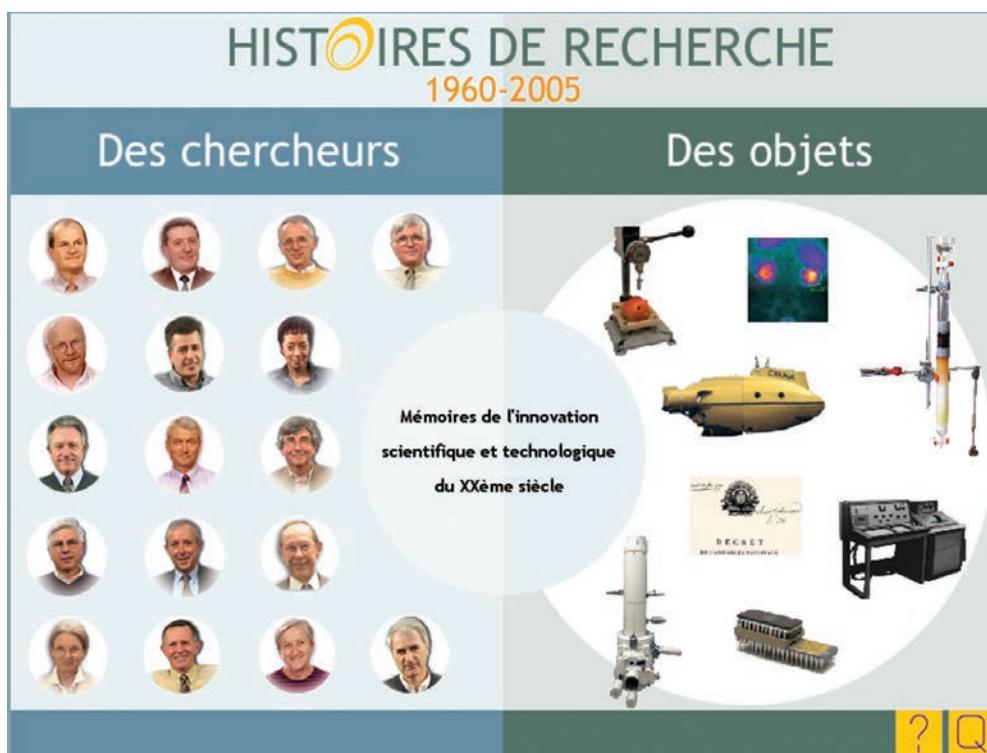
1.
DVD with testimonials of scientists and their teams. Mission PATSTEC-Pays de la Loire-Université de Nantes.

of the testimonials was edited on DVD (Figure 1). The Mission de Sauvegarde du Patrimoine Scientifique et Technique Contemporain (PATSTEC) website (http://www.patstec.fr) was built to make the resources available for cultural professionals, teachers, historians, and the general public. The project contributed to the networking of more than 200 people: scientists and cultural and industrial professionals. It is this dual sense, the dissemination and preservation of heritage, that defines the objectives and operations of the national mission of the Musée des Arts et Métiers.

The Launch of the National Mission

In 2001, at a conference of the faculty of Centre National de la Recherche Scientifique (CNRS) in Orsay, near Paris, on the theme "Great Scientific Instruments," a meeting between the director of the Musée des Arts et Métiers and the mission team of Pays de la Loire reinforced the need to safeguard this "new heritage."[14] Continuing the policy in the field of scientific and technical culture of the Ministry of Higher Education and Research, in 2003 the museum director was entrusted with a national mission for the safeguarding of contemporary scientific and technical heritage: to make an inventory and to value the material and immaterial memory of the science and technology of the twentieth century. To be able to respond to this request quickly and to implement this national program, the director wanted to use the skills, methods, and tools developed in Pays de la Loire, acquired through many years of experience, and to anchor them more firmly in the development of the national program.

The objectives of the museum were and still are to create collaborations, to promote the establishment of reasoned collections covering this period, to contribute to debates on the scientific and technical culture, and to define the terms of cultural transmission of science and technology. The aim is to place the objects, practices, methods, results, and failures in cultural context and thus in the development of science and technology in society.[15]

The difficulties that have arisen in the national mission are located at the intersection of many disciplines: How do we make a choice among the mass of instruments identified in laboratories? Is the danger of decline sufficient to constitute such a heritage? The development of scientific and historical criteria led to questioning the evolution of instruments and scientific innovation. Thus, a striking feature of the twentieth century is the advent of computers in research, industry, and daily life, which radically altered habits in less than 20 years.

The objectives are of interest to higher education institutions, research organizations, and businesses: to safeguard contemporary scientific and technical heritage, equipment (instruments and related documents), and immaterial products (know-how); to create a national network of professionals and enhance heritage research and industry; and to play an advisory role and provide expertise, fostering regional initiatives and supporting the implementation of the program in different regions.

Selection Criteria

How do we make choices from the mass of instruments identified in laboratories? Is the danger of decline sufficient to constitute such a heritage?

The development of criteria for sorting objects leads to a reflection on the evolution of instruments and scientific innovation. In practice, the preservation—collections of instruments and know-how—is subject to a dual approach. It is first necessary to keep as many items as possible during the first selection along with documentation that can be considered representative of this period since the work is done in vivo. In general, however, the lack of space to store objects leads to the requirement to make quick and thoughtful yet reasoned and meaningful empirical selections in the second step.

Reflecting on heritage shows that multiple mechanisms are responsible for its formation. When does an object or a set of objects become "heritage"? How are "contemporary" objects perceived as "cultural property"? Sorting criteria remain classical: historical interest and the scientific and social utility of an object by a community at a given time. Obviously, prototypes and rare and significant objects are immediately set aside, and then the scope of the selection must be refined. The difficulty with the contemporary object is to identify its scientific and historical interest. Is the object part of a line demonstrating a technological evolution or a single moment of creation of an innovation such as the development of a prototype, or is a set of instruments so widely used that it needs to be retained as specific to the period? What can be done with large instruments of big science or "systems," for example, the coupling of a gamma-ray camera with other measuring devices? Do we keep any part if we cannot keep it all? If nothing can be kept, a photographic report, the preservation of oral archives, and/or a scan of the whole are immediately required.

The abundance of scientific and technological objects within institutions requires several successive selections. A working group based on the network of the national mission attempts to answer these questions.[16] It is composed of scientists from various disciplines and museum professionals and historians of technology. The main objective that we initially set at the national level is to create a "corpus of representative objects" of the past 60 years in a historical sense. It will serve as a reference for members of the network in different regions. At the same time, the project managers conduct empirical selections based on research topics chosen by a local scientific committee that are considered to be significant. These choices narrate a local story based on these material traces and testimonials.[17] These two approaches, conservation of immaterial and material culture, are complementary and enrich each other (Figure 2).

The Organization

To accomplish its objectives, the mission has a national coordination structure, located at the Musée des Arts et Métiers. The museum receives funding from the Ministry of Higher Education and Research to contribute to the achievement of regional inventories and to establish common national inventory preparation multimedia tools. The mission is based on a national scientific advisory board, which meets once a year and gives an opinion on the activity performed.

The national network developed by the mission today has 16 French partner regions and will cover all of France starting between 2014 and 2018. Over 50 people are directly involved in local missions. Their affiliation is usually a higher education and research institution, a science

2.
Trebuchet balance, 1900–1925. Number 2905_01, Mission PATSTEC-Pays de la Loire- Université de Nantes.

museum, or a regional center of the Conservatoire National des Arts et Métiers (CNAM). The project managers are the local representatives in each partner region.

Local missions rely on the network of local representatives of the ministry of research and technology and on CNAM regional centers, universities, research organizations and French Grandes Ecoles (higher education schools outside the main framework of the university system), museums, technical and industrial archives, centers of scientific culture, companies, and associations whose representatives are members of the local steering committees. Actions of this

3.
The PATSTEC website. Mission PATSTEC-Pays de la Loire-Université de Nantes.

network add the intervention of more than 200 volunteers participating in inventory valuation and events and leverage the efforts of the mission in the country. Regional teams are in regular contact with the national unit. Two technical workshops and a professional national day take place every year in Paris and in the provinces to exchange and share best practices. Actions and results are available in the National Database and on the PATSTEC website (Figure 3). The national database includes more than 17,000 fact sheets registered and 50,000 documented media sources that are also available from the website.

4.
X-ray lamp, 1900–1925. Number 3083, Mission PATSTEC-Pays de la Loire-Université de Nantes.

The National Catalog

The PATSTEC local centers regularly integrate their data into the national database after verification by the coordination unit, which controls the data quality and homogeneity through an empirical classification developed with the network. It thus constitutes a knowledge base that gradually facilitates the work of describing objects. Once the data are embedded in the national database, additional indexing is no longer useful, and only additions should be specified. Thus, a real division of labor is implemented, allowing us to progressively accelerate the indexing tasks (Figure 4).

This program was consistently developed over 10 years. Institutional partners that have joined the mission and are members of the network are CNRS, Météo France, the Fondation EDF, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, CERN, and industry partners such as Essilor and Michelin (Figures 5 and 6).

International and Future Development

The French program has attracted interest from international museums and academic institutions, including in Belgium, Italy, Greece, Germany, England, Switzerland, Serbia, Hungary, Bulgaria, Spain, and Portugal. These countries formed a consortium in 2008 to respond to a European project tender. The objectives of this consortium were to build a similar classification, to develop a common methodology for data entries, to create a European database, and to consider sharing collection tasks between the different countries.

Given the scale of this program and the issues related to the selection of large objects such as large scientific instruments or aircrafts, which may involve the framework of European projects in several countries, it was essential to bring together museums and university scientists holding collections from this period. A network of Belgian universities, Wallonne, has now been

5.
Example of mission partners. Mission PATSTEC-Pays de la Loire-Université de Nantes.

implemented and collaborates with PATSTEC.[18] Major scientific and technical museums, including the Museum of Science and Technology of Milan, the Deutsches Museum in Munich, and the Science Museum in London, are grouped within the European network called ESTHER (European Scientific and Technical Heritage). This group is led by the Musée des Arts et Métiers. Fruitful discussions revolve around the safeguarding and exchange of best practices and acquisition policies for contemporary scientific and technological heritage. On an international level beyond the European Union, discussions are ongoing with the Canada Science and Technology Museum (Ottawa) and the MIT Museum in the United States, institutions that are also aware of this theme.

Looking toward the future of our work in France, it will become important to establish the permanence of the regional missions so that they become sustainable. Each French region brings its own research agenda to the project. The heritage-to-be of each region has a local identity that is enrooted in the region.

6.
Range of fields covered. Mission PATSTEC-Pays de la Loire-Université de Nantes.

Notes

1. D. Ballé and D. Poulot, *Musées en Europe, une mutation inachevée* (Paris: La Documentation française, 2004).

2. D. Pestre, *Physique et physiciens en France, 1918–1940* (Paris: Les archives contemporaines, 1984).

3. J. Krige and D. Pestre, eds., *Science in the Twentieth Century* (Amsterdam: Harwood Academic, 1997); John Krige, ed., *History of CERN*, vol. 3 (Amsterdam: Elsevier, 1996).

4. Y. Thomas and C. Cuenca, "L'apport des technologies de l'information et de la communication (TIC) à la sauvegarde du patrimoine scientifique et technique contemporain," *Documents pour l'histoire des techniques* 18 (2009): 73–80.

5. C. Ballé, "Les sciences et techniques, une tradition muséale," *La Revue du Cnam*, nos. 51–52 (2010): 126–133; Estimated retirements are 500 per year in 2000 and 1,700 per year between 2004 and 2007, or 60 percent in six years.

6. P. Brenni, "L'importance des instruments scientifiques comme témoignages matériels de l'histoire des sciences et des techniques," in *Le Patrimoine scientifique et technique contemporain: Un programme de sauvegarde en Pays de la Loire*, ed. C. Cuenca, Y. Thomas, and C. Ballé (Paris: L'Harmattan, 2005), 29–40.

7. C. Cuenca and Y. Thomas, "Constitution d'un patrimoine scientifique et technique contemporain," in *Programme de recherche Néopat: Les nouveaux patrimoines en Pays de la Loire, 2013*, ed. Guy Saupin, Jean-René Morice, and Nadine Vivier (Rennes, France: Presses Universitaires, 2013), 669–680.

8. C. Ballé, "Les sciences et techniques."

9. Serge Chambaud is at this time head of the Mission Musées at the French Ministry of Higher Education and Research.

10. "La muséologie des sciences et des techniques," *Actes du colloque, 12 et 13 décembre, Palais de la Découverte* (Dijon: OCIM, 1993).

11. C. Cuenca, "Le patrimoine scientifique et technique contemporain: Naissance d'une politique," *U-Culture: Revue culturelle annuelle de l'université de Bourgogne*, no. 2 (September 2007): 4–11.

12. C. Cuenca, Y. Thomas, and C. Ballé, eds., *Le Patrimoine scientifique et technique contemporain: Un programme de sauvegarde en Pays de la Loire* (Paris, L'Harmattan, 2005).

13. "Histoire d'un programme: Mémoires de l'innovation scientifique et technologique du XXᵉ siècle," *op. cit.*, p. 81–102.

14. D. Thoulouze, "La sauvegarde du patrimoine instrumental," conférence-débat d'Orsay, *La Revue pour l'histoire du CNRS*, no. 5 (November 2001): 86–87.

15. D. Thoulouze, "Pour une véritable culture scientifique et technique," *La Revue*, nos. 43–44 (September–November 2005): 4–9.

16. C. Cuenca, "Patrimoine scientifique et technique sauvegarde, collecte et tri," in *Le patrimoine scientifique et technique: un projet contemporain*, ed. C. Ballé, C. Cuenca, and D. Thoulouze (Paris: La Documentation française, 2010), 153–161.

17. Led by Robert Halleux, professor of the history of science and technology, who has closely followed the program since 1997. See R. Halleux, "Patrimoine scientifique et développement regional," in *Le patrimoine scientifique et technique contemporain: Un programme de sauvegarde en Pays de la Loire,* ed. C. Cuenca, Y. Thomas, and C. Ballé (Paris: L'Harmattan, 2005), 24; R. Halleux, "Des collections en quête d'une destinée," in *Les collections scientifiques des universités* (Nancy, France: Presses universitaires de Nancy, 2008).

18. S. Chambaud and C. Cuenca, "A National Mission for Safeguarding the Contemporary Scientific and Technical Heritage—Musée des arts et métiers, Paris" (paper presented at Ecsite, Musée des sciences et techniques, Milan, 5 June 2009).

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Dialogue and Diversity

Collecting Twentieth-Century Chemistry
A Reevaluation of the Collecting Philosophy and Goals at the Chemical Heritage Foundation

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Introduction

The Chemical Heritage Foundation (CHF) is relatively new to the world of artifact collecting—the organization began collecting artifacts in only the late 1980s, long after most other history of science institutions had started. From the beginning, the primary focus of artifact collecting was on the post-"second chemical revolution" or scientific instrumentation revolution, the period after the development of the first electronic analytical instruments.[1] The purpose of collecting was initially to build a research collection that would be a resource to historians and provoke nostalgia among retired practitioners. However, the opening of CHF's new museum and first permanent exhibition in October 2008 signaled a strategic shift for the organization from a primarily research-based institution to an increasingly public-focused organization and caused reflection on both the methods and reasons for collecting.

The opening of the museum at CHF provided the first real opportunity for the organization to look critically at its artifact collections and to think about how its significant collection of electronic-era instrumentation would be interpreted and understood not just by scholars and practitioners but also by curators, museum visitors, and the larger public. Not surprisingly, the planning process and resulting exhibition revealed the importance of collecting and documenting more than just the "black box." The curatorial staff discovered during the museum development

process that in order for the artifacts to have relevance to a larger science-curious public we needed to target the collecting of artifacts and complimentary materials that helped communicate human stories and the social impact of science on our world. Museum staff also began to see a need for engaging, relevant stories around the artifacts to engage specialists in scientific fields—if the subject was outside their area of specialization, then scientists also needed a hook or draw to give them an entry point into less familiar subjects. These institutional shifts caused us to spend the first several years after opening the museum reexamining our scope, our targeted collecting initiatives, and what we actually collect. An internal critique led to fundamental changes in our philosophy about collecting instrumentation and supporting materials. This chapter will evaluate how the early motivations for collecting and the process of creating the museum led to this philosophical shift and how the still-evolving, revised collecting strategy is moving the collection forward.

The Origins and Early Days of Collecting at CHF: "Action Is a Matter of Some Urgency"

The Chemical Heritage Foundation began as a center for studying the history of chemistry on the campus of the University of Pennsylvania in 1982. The organization had originally planned to act as a clearinghouse and appropriate home seeker for archives and artifacts. Early newsletters of what was then called the Center for the History of Chemistry (CHOC) show an organization resisting the urge to collect and acquire collections. The Chemical Heritage Foundation sought to follow the model established by the American Institute of Physics:

> The immediate aims of [CHOC] are to develop a program of interviews and undertake oral histories . . . to locate manuscripts and archival records of individuals, societies, chemical engineering and the chemical process industries; to offer aid in sorting and cataloging . . . to encourage the deposit of personal papers and other records in appropriate regional archives, to develop a central computerized catalog of manuscripts . . . Rather than attempting to build one central collection of historical records . . . CHOC will serve as a clearinghouse for information about materials held in repositories around the country.[2]

However, the need for an institution devoted to collecting the history, especially recent history, of chemistry quickly became apparent. The large volume and historical wealth of materials available was surprising as were the small number of institutions interested in taking on modern scientific collections. As early as 1983, at the third CHOC policy council meeting, there was a report given on the lack of active collecting by any institution or organization, and the council appointed a committee to pursue the issue, recognizing that "action is a matter of some urgency" because history was being lost.[3]

In the first years of the organization, collecting began because of collections identified during themed initiatives that CHOC was undertaking. For example, the Polymer Project included an oral history initiative and a survey of over 100 scientists and industry people about the disposition of their archives; this led to two of the first major acquisitions: the papers of Paul Flory, recipient of the 1974 Nobel Prize in Chemistry for his achievements in polymer science, and Carl Marvel, an important organic chemist who is often referred to as the father of synthetic polymer chemistry.[4] It was not until 1988, however, when Arnold O. Beckman gave a transformative financial gift to the young organization, that interest was shown in collecting instruments. To mark the occasion, the BCHOC (the gift also added Beckman to CHOC's name) held a Chemical Instrumentation Symposium to discuss the importance of analytical instrumentation in the history of science. Beckman was a significant figure in analytical instrumentation, so it is not surprising that in 1989 BCHOC issued a call for Beckman instruments to "decorate" the center. No longer a seeker of appropriate homes for collections, the actively collecting organization's home was quickly becoming overwhelmed with archives, books, and artifacts.

By the early 1990s CHF was beginning to grow exponentially in both its activities and its collections; the organization now had an established research library and quarterly magazine. Searching through CHF institutional archives, the first reference to a plan to develop a CHF museum to showcase the objects that CHF was acquiring occurs in 1995, when it was initially conceived of as an *instrumentation* museum, one that would be focused on the great analytical instruments that have so dramatically shaped science and the laboratory since 1930.[5] This desire to develop an instrumentation museum was given momentum by a group of retired chemists who were early instrument developers, adopters, and employees of instrument companies. During the early collecting days at CHF, this group was the primary audience for the instrument collections. The group, which became known as the Heritage Council Instruments and Artifacts Committee (HCIAC), had bigger aspirations, however; they wanted to share their history and the impact of instruments on society with a larger public. This desire spurred a boom in the collecting of twentieth-century analytical instruments. It was opportune timing, for few other institutions were interested in collecting modern chemical history on a large scale. By 1998, CHF had collected its first large instrument that could not be stored on site, a Consolidated Electrodynamics Corporation (CEC) Model 21-103 mass spectrometer (Figure 1).[6]

When one of the HCIAC members who was a PerkinElmer retiree heard that PerkinElmer's Bodensee Collection and Museum in Überlingen, Germany, was to be dismantled, he reached out to the company and arranged for CHF to become the permanent home for the collection; this significant acquisition greatly added to CHF's small but growing collection of artifacts.[7] The Bodensee Collection helped increase the diversity of CHF's collection because it included not only PerkinElmer instruments but instruments from makers in many different countries, including the United States, Germany, the United Kingdom, eastern Europe, and Japan.

1.
Archival photo of CEC Model 21-103, from the Consolidated Electrodynamics Operation and Maintenance Manual, Mass Spectrometer, Analytical and Control Division, 1964. Chemical Heritage Foundation Archives, Philadelphia, PA.

As a result of this donation and the momentum it generated to bring other offers, CHF's collection grew rapidly to include hundreds of analytical instruments by the early 2000s. This intensive collecting, however, was not overly systematic, which meant that the collection included many highlights and technological milestones but was not a cohesive or comprehensive collection of artifacts. Nor were there overarching themes or stories that were necessarily emerging out of the collecting of instruments. These early collecting decisions and the rapid growth of the collections *were* beginning to have a significant impact on limited resources and space, and by 2003 it was clear that CHF needed to become more strategic in its collecting. The Chemical Heritage Foundation as a whole was maturing; the organization was crafting its first strategic plan, and the newly formed special collections group of professional curators and archivists was working with the library to develop a collections policy that included detailed goals and a collecting scope for the institution. The special collections staff came from backgrounds not in science but in history and public history. The historical training of the staff certainly had an impact on how the collections scope developed, applying a lens of social and public history and not strictly scientific and technological advancements. In addition, as part of the professionalization of the department, CHF also assembled an advisory group of curators and special collections librarians from other

significant history of science repositories to advise and provide input on the collections policy and the development of the permanent exhibition.

It was during this period that CHF embarked on an initiative, in collaboration with the Heritage Council Instruments and Artifacts Committee, to identify and collect the "fifty chemical laboratory instruments that changed the world in the twentieth century." These instruments would demonstrate analytical instrumentation's impact on science, medicine, and industry and how instrumentation benefits society. The HCIAC established a list of criteria for determining which objects would go on the list. To make it onto the list, an instrument had to meet one or more of the following criteria:

1. It had to be historically significant; for example, it was the first of its kind or it marked a great scientific discovery.
2. It was commercially or socially significant.
3. It dramatically changed chemical laboratory practice.
4. It was innovative or disruptive, requiring scientists to rethink or learn new or expanded principles of analysis.
5. It was representative of a class or was the first of a class.
6. Its design was based on some significant component/technological advancement such as the vacuum tube or DNA on a microchip.[8]

The resulting list included more than 60 instruments, some of which CHF already held, along with a targeted list of 10 must-haves that were considered the most important or at the greatest risk of disappearing. The "10 Most Wanted" list helped CHF focus its collecting efforts and identified the instruments that CHF most actively sought to find (Figure 2).

It was a successful campaign; over the next five years approximately 75% of the total 60 instruments list was collected by CHF. However, there were some flaws. The list was (not surprisingly) shaped by the backgrounds of those on the committee; their specialties were mainly spectroscopy and mass spectrometry, and the list reflected this. Also, the committee favored the "first of its kind" and "representative of its class" criteria more often than specific objects related to scientific discovery or of a historical significance. The items on the list tended to be representative, not specific, a particular model that had commercial success rather than a particular artifact that had been a part of a historic discovery or used in a way that lent itself to a significant story. For the committee, nostalgia and personal memory of many of the instruments were drivers for wanting to collect and preserve the artifacts on the list. Nonetheless, the collecting initiative allowed CHF to greatly expand its instrumentation collection both in quantity and quality; the additions to the collection made by the initiative were essential to the successful planning of the museum, and many of the instruments on the list are in the permanent exhibition. The collecting project also helped legitimize CHF as an artifact-collecting institution—it showed the instrument and historical communities that the building of collections was something CHF was now serious about doing. This, in turn, led to more donation offers.

1. Model A Coulter Counter, Coulter Electronics, 1956 2. Cary Model 14 UV-Vis Spectrophotometer, Applied Physics Corporation, 1957 3. Cary Model 81 Raman Spectrometer, Applied Physics Corporation, 1954 4. AA 1 Autoanalyzer, Technicon, 1957 5. ALC 100 HPLC, Waters Corporation, 1967 6. MS-9 Mass Spectrometer, Associated Electrical Industries, 1963 7. Model 5MX FTIR Spectrophotometer, Nicolet, 1982 8. Model 1015 GC-MS-DS, Finnigan Corporation, 1967 9. Model FTS-14 FTIR Spectrophotometer, Digilab, 1969 10. Beckman Model DK-2A Vis-NIR UV Spectrophotometer, Beckman Instruments, 1954

2.
Graphic of 10 Most Wanted instruments list. Chemical Heritage Foundation Archives, Philadelphia, PA.

Exhibitions Change Everything

As the planning of the museum moved into design development in early 2006, the group of curators that would develop the museum content was assembled, and the definitions of scope as well as audience became defined. The curatorial team for the permanent exhibit, which comprised primarily historians of science, curators, and collections managers, determined that the exhibit would be focused around real artifacts (not interactives or large graphics), have a strong narrative focus that was storytelling in style, emphasize the social context of the artifacts, and tell human-themed stories as opposed to the technical how and why (Figure 3).

In order to tell narrative-based stories, however, the artifacts needed to have stories to tell. It was here that the curatorial team encountered an important lesson: simply having the artifact is not enough. Commonly referred to as "black boxes," the instruments present definite challenges in exhibitions. To the nonpractitioner, they all look very similar, and their covers present a barrier to understanding how they work and why they are important. The Museum at CHF presents the instruments without the technical details and instead emphasizes the historical and social context to provide the visitors an engaging human-focused story. However, in order to present an artifact, especially black boxes, in an engaging way—whether in an exhibit, online database, or as a resource for historians—there needs to be supporting documentary materials that help with the interpretation and allow the instrument to "speak." The instrument ideally has documented provenance of how it was used, who used it, and for what purpose. In a perfect scenario, there are laboratory notebooks, archival materials, manuals, photographs, and personal accounts that help the curators interpret the object.

The exhibit that opened in 2008 was successful in creating narrative-based displays that place the instruments and artifacts into the context of a larger human story.[9] Opening the museum was really just the beginning, however, in shifting the ideology on collecting, and the unexpected success with a larger public audience caused much institutional adjustment. The completion of CHF's first permanent exhibition caused curatorial staff to reflect on what we had learned. It also raised the question of where to go from there. From developing the museum, the collections and curatorial staff learned that the collecting strategy needed to be more aggressive in seeking instruments and artifacts that tell interesting historical stories and are accompanied by supporting materials. But how do you develop and implement targeted collecting strategies with limited resources? With limited storage space, how do you select which instruments to collect, especially when many scientific artifacts are large and very heavy? Perhaps most challenging, how do you identify what will be historically significant in the more recent history of science without the long lens of time and historical assessment to guide you?

After a period of reflection and assessment, we spent the next several years grappling with how to articulate a new collecting plan and revised scope that both achieves mission and future needs and is reasonably achievable given limited resources, particularly staff resources. It is a work in progress and will continue to evolve as the institution changes and grows. What follows is an account of the progress made in the five years following the museum's opening and reflections on lessons learned and possible future directions.

3.
Image of people in the museum. First Friday at the Museum at CHF, April 2013, Chemical Heritage Foundation Archives, Philadelphia, PA. Photograph by Conrad Erb.

We began the reevaluation process by considering some important questions with regard to scope: What would the ideal collecting strategy look like? How do we use the experiences and lessons learned from building the museum to inform the collecting strategy and documentation methods? How do we ensure stakeholder buy-in? The collections staff decided to first look at items in the collection that we considered successful and ideal examples for both exhibit

possibilities and research potential. In the study, we sought to identify what made certain artifacts successful examples in the hopes of pinpointing some benchmarks or qualifying statements for evaluating future potential acquisitions. Several examples with their accompanying notes help bring clarity to the thought process:

1. CEC Model 21-103 Mass Spectrometer, 1940s (Figure 4). Not only do we have the instrument itself, which is quite large and stored at our off-site storage facility, but we also have early components, images, manuals, and trade literature, and in the papers of Charles Judson we have a wealth of material about the development of the 103 and its predecessors that provides insight into the early commercialization of mass spectrometry. We also have an

4.
Image of CEC components assembled as they would have appeared in instrument. CEC 21-103, components. Gift of Charles Judson, Chemical Heritage Foundation Collections, Philadelphia PA. Photograph by Gregory Tobias.

oral history with Judson that gives an account of the early development days at CEC. What marked this as a success was the comprehensive story that could be told through a variety of materials and the potential research value to historians. While this particular Model 103 lacked a pedigree, the personal recollections of Judson give the instrument and components an interesting story to tell.

2. Beckman IR-1 Spectrophotometer, 1941 (Figure 5). This artifact is currently on display in the museum; the IR-1 at CHF is one of two complete Beckman IR-1's believed to still exist. Its history and role in the United States' effort to develop synthetic rubber during World War II is well documented, as is its use in research relating to aviation fuels and determining the structure of penicillin.[10] In addition to the already established historical significance, the special collections staff had the opportunity in 2007 to travel to Houston, Texas, and research the archival material in the Shell Oil Company's archive about Shell employee Dr. Robert Brattain, his role in the development of the instrument as part of the secret war project, and how Arnold Beckman, a key player in the early development of electronic analytical instruments, came to be involved.[11] The Chemical Heritage Foundation also conducted an oral history with Arnold Beckman and more recently acquired the Beckman Archives. The IR-1 provided an example of an object with significant provenance as well as great documentation.
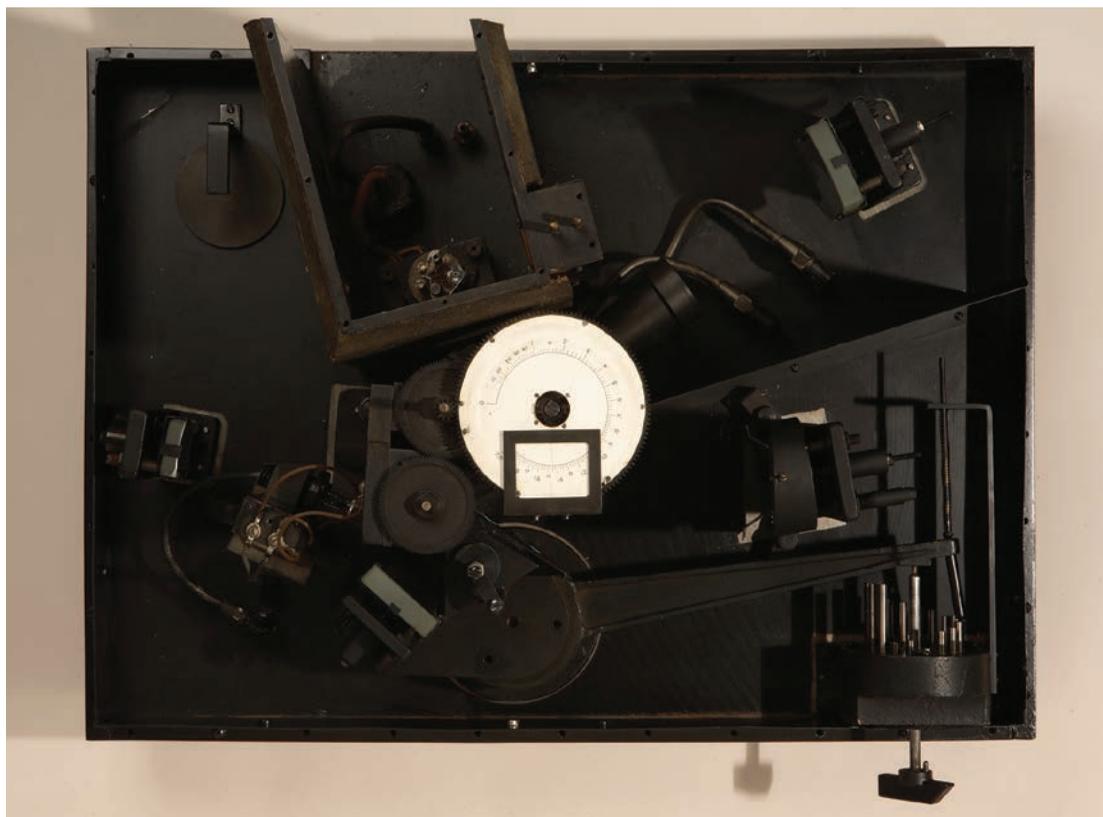
5.
Image of the Beckman IR-1, overhead shot. On loan to the Chemical Heritage Foundation from Danaher Corporation, Washington, D.C. Photograph by Gregory Tobias.

6.
Image of Fenn Electrospray prototype in museum. Gift of John Fenn, Chemical Heritage Foundation Collections, Philadelphia, PA. Photograph by Gregory Tobias.

3. Fenn Prototype Electrospray Ionization Mass Spectrometer, 1980s (Figure 6). The main component of this instrument is on display in the museum, and it is the instrument that led to Dr. John Fenn being awarded the Nobel Prize in Chemistry in 2002.[12] The instrument, although large, has a significant aesthetic quality and was a prototype of a technology that changed the field of mass spectrometry. The Chemical Heritage Foundation Archives also has blueprints and John Fenn's personal papers. But what makes this instrument particularly special is that it was one of the early candidates in a program CHF developed called Instrumental Lives. Instrumental Lives is a video oral history project that focuses specifically on an instrument and an individual who either, in the case of John Fenn, created it or worked extensively with it. Not designed to be a traditional oral history, these interviews take place with the instrument itself, allowing the interviewee to discuss in detail how the instrument worked (or did not) and recount candid stories about their experiences, trials, and tribulations with the instrument and with colleagues.[13]

Once we had identified artifacts that met our goals, we looked for commonalities in what made them successful acquisitions. From this assessment, we were able to craft collecting criteria that serve as a guide when making decisions about a possible acquisition. Not all of the criteria are required for an acquisition, but instead, criteria are treated more like a sliding scale—the

more criteria or stronger case made for a certain criterion increase the "rating" of a potential acquisition and its value as an addition to the collection.

Collecting 2.0

After our reevaluation, the following collecting criteria help guide decisions about a possible acquisition:

1. What is the artifact's displayability and requirements for long-term preservation? The Chemical Heritage Foundation has numerous objects in off-site storage that we now know will never be able to fit at CHF's home location because of size or weight. The size of an instrument or artifact does not immediately rule it out for collecting (the items in the warehouse are significant enough to justify holding onto, and in fact, several made the list of successful acquisitions), but the burden of care in perpetuity is a significant consideration when accepting new donations. The visual appeal of an artifact is also important; not everyone finds instruments or black boxes beautiful, but they do often have an aesthetic interest that makes an artifact more likely to be used in an exhibition. Most new acquisitions go into either on-site storage (which is severely limited) or off-site storage that CHF rents (by weight, a significant expense when thinking about heavy analytical instruments and components) because there is limited exhibition space. However, long-term planning for the permanent exhibition space and temporary exhibitions are considerations when looking at potential acquisitions.

2. What is the provenance and the object's history? What stories can the object tell us? Was it in a laboratory of a significant scientist? Was it used for a groundbreaking discovery, or did it fundamentally change laboratory practice? Conversely, was it a prototype that was an abysmal failure? Does the object itself serve as window into an important part of history, or could it serve as a representative of one that was used (and is no longer available)? We found that this criterion is an important lens to apply when thinking about potential research value of an artifact as well as potential exhibition value; the richer the history of the instrument is, the greater interest there is both from a scholarly perspective and for a visitor.

3. Is there supporting material? Does CHF already have material in the collections that would be enhanced by the acquiring of the instrument? Are there archives, manuals, trade literature, and photographs available along with the instrument that would help tell a more complete history and help create a valuable resource for researchers? We have learned that simply having an instrument offers very limited research value for historians; however, complementing the instrument with primary source material and literature related to the instrument greatly increases the ability for a scholar to delve into the history of the artifact.

4. How does the instrument fit with existing collections? Does it fall within the established scope, or is it a new technology that CHF needs to consider expanding the scope to accommodate? Conversely, is it similar to or a duplicate of an instrument already in the collections?
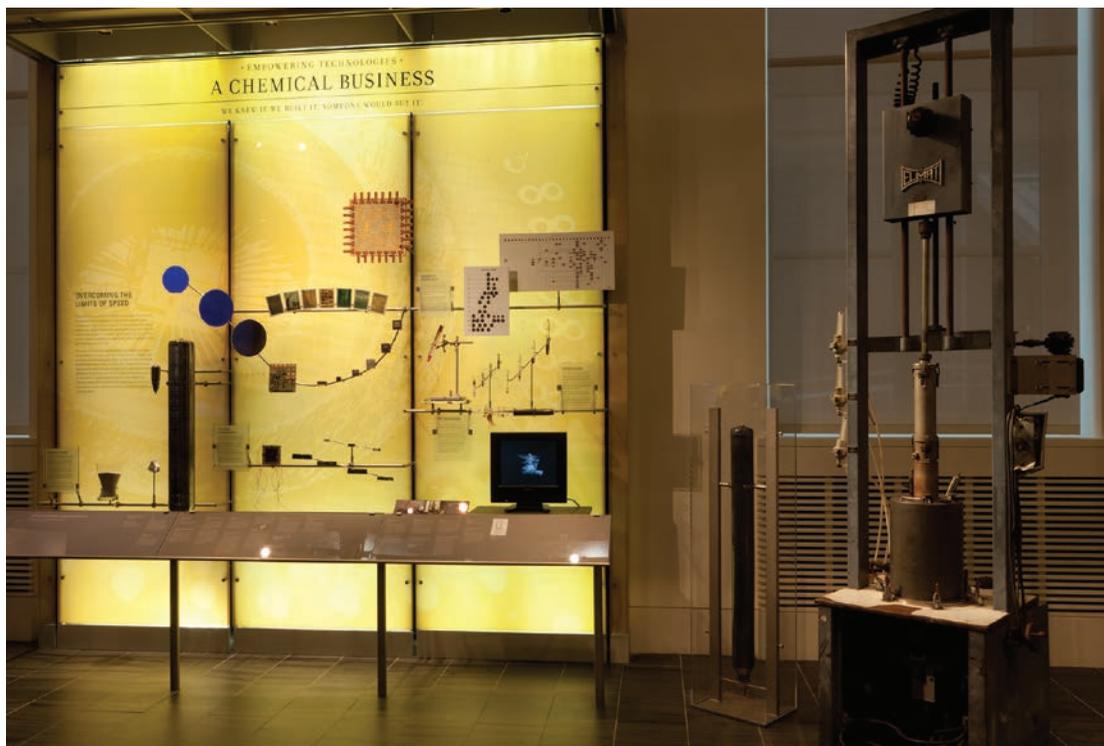
7.
Image of crystal puller in the museum showing placement with ingot and other key history of electronics artifacts. Chemical Heritage Foundation Collections, Philadelphia, PA. Photograph by Gregory Tobias.

5. Does it help tell a bigger story? Can the instrument be used to tell part of a larger story in the history of science? For example, CHF has an early crystal puller that is in poor condition and is not overly significant as a stand-alone artifact. However, used in the context of telling the chemical story of the semiconductor industry, silicon chips, and the production of ingots, it becomes a key piece of the story.[14] It is also an interesting industrial artifact that draws visitors to it because they wonder what it is. It is paired with a silicon boule with silicon wafers nearby, which makes for a powerful story arc in the permanent exhibition (Figure 7).

6. Is a video oral history possible? As previously mentioned, this is a program that CHF started and hopes to continue and expand. Funding and resources limited the ability to keep this project active after the museum opened, but it is hoped that it can be revived. The availability of the donor or other key individual to conduct an interview about the instrument is something that adds significant historic value to a potential acquisition.

Implementation and Revisions

As most curators will attest, the hardest part of acquisitions is not the acquiring of artifacts but the rejection of artifacts. There is an art to saying no, and the criteria that we have developed are a key tool for curators when helping potential donors understand why an offer is turned down.

However, this tool does not always make the job easier. When an artifact has reached a vintage to be considered "valuable" by a potential donor, it usually means they have held onto the object for a long period of time, often storing it at their own residence despite spousal protest! The motivations for holding on to an item are usually very personal, and it is essential to make sure the donor understands that their memories and attachment to an object are valid, and by using the criteria as a point of reference, the curators can make a stronger argument for or against the collection of an artifact.

There have been examples since the new criteria were implemented where an artifact donation offer was declined that might have been collected in the previous era of collecting. In most instances, the instrument was very similar to one already in the collection or lacked the provenance/object history that we are now looking for in acquisitions. Most potential donors understand if an offer is declined. There are exceptions, of course, and sometimes potential donors have "gone to the top" or to one of our advisory groups in protest. This is when transparency is absolutely essential. The criteria are not kept secret, nor are the reasons for accepting or declining an offer, and because of the policy of transparency the curators feel supported in their decisions. There will always be those instances where a declined offer creates hurt feelings, just as there will always be instances where bigger institutional needs or interests demand the accepting of donations that don't necessarily meet the criteria. What the criteria provide, however, is the empowerment and confidence that curators' decisions about donation offers are based on sound institutional policy.

Collections staff have also found that the criteria provide opportunity to reconsider what is already in the collection. If a donation offer is made for an instrument that is the same make and model or very similar to one already in the collection but the potential acquisition better meets the criteria, we now have the ability to consider deaccession of an earlier acquisition in favor of a duplicate that has better provenance and research potential. The collections policy at CHF includes a policy and procedures on deaccessioning that follow professional museum standards, and the addition of the new criteria led the collections staff to begin evaluating existing collections for potential deaccessions.[15] Assessing existing collections for potential deaccessioning must be handled with great care and thought; there is always potential that the public or constituents will interpret deaccessioning as rash or uncaring. It can also be overwhelming for staff; these are decisions that should never be taken lightly. For these reasons, the collections staff decided to take a conservative and measured approach to deaccessioning.

Knowing that the off-site storage is a drain on resources, staff began by identifying some key subject areas that included artifacts in off-site storage. A spreadsheet was developed that included all the instruments in a particular subject area (spectroscopy, gas chromatography, etc.) and the vital information on each object. The spreadsheet was then circulated to members of the HCIAC, and the committee members were encouraged to further disseminate the list to experts and retirees (often those that had worked with the instruments) in the field that they knew. The collections staff was surprised at how receptive the instrument community was to this

assessment, and the quality and number of responses far exceeded expectations. Comments included definite "must keep" objects and justifications about why instruments should be saved as well as arguments for disposal, such as there was a better example already in the collection or the instrument never became relevant to the field (a favorite comment was that a particular instrument "was a real dog"). By having an open discussion about deaccessioning we were able to confidently identify three instruments in the first assessment that should not be part of the collection (unfortunately, because they had no value to any other museums, there was little choice but to let them go for scrap and recycling). Future assessments will undoubtedly identify additional items, and the process showed that a conservative and transparent approach led to positive results.

Like many curators and collections managers, we all too often find ourselves with more projects and to-do lists than staff or funds. The challenge of limited resources means that CHF is primarily passive in collecting methods for instruments and artifacts. In most instances, the offers come to CHF; donors find CHF either through word of mouth, online, or because of the museum. The new list of criteria provides staff with a means of evaluating donation offers, and its application over the last several years has proven it to be a highly useful tool. However, moving forward, CHF would ideally like to again target particular instruments, discoveries, and fields that it feels are significant enough to be permanently preserved.

The collecting of more recent chemistry strikes us as particularly important: identifying the instruments of the last 20–30 years that need to become part of a permanent historical record. How do we make historic judgments on the recent past? In addition, in January 2014, CHF completed a new strategic plan. In the new plan CHF aims to expand its scope to be broader than the history of chemistry and include the history of material sciences as well. How will this revised and expanded focus impact collecting? The Chemical Heritage Foundation is still determining if it needs to adjust the collecting criteria for this change and what collecting initiatives would look like in these new territories. Using a concept like the 50 instruments list along with the new collecting criteria is part of the solution but not the whole. Moving forward, collections staff feel confident and are well positioned to make decisions on donation offers—the real challenge lies in how to assess the vast existing landscape of potential artifacts and identify those items that CHF wants to actively go out and seek in order to ensure that the institution continues to collect and document the history of chemistry and material sciences and provide a valuable resource to scholars and museum visitors.

Acknowledgments

Notes

1. Further information regarding the influence of instrumentation on modern science can be found in Davis Baird, *Thing Knowledge: A Philosophy of Scientific Instruments* (Los Angeles: University of California Press, 2004); Pierre Laszlo, "Tools, Instruments, and Concepts: The Influence of the Second Chemical Revolution," in *From Classical to Modern Chemistry: The Instrumental Revolution*, ed. Peter J. T. Morris (Cambridge: The Royal Society of Chemistry in association with the Science Museum, London and the Chemical Heritage Foundation, 2002), 170–187.

2. "Center for History of Chemistry Created," *CHOC News* 1, no. 1 (1982): 2–3.

3. John T. Stock, "The Conservation of Historic American Chemical Instruments," *CHOC News* 1, no. 3 (1983): 12.

4. Nobelprize.org, "The Nobel Prize in Chemistry 1974," Nobel Media AB, 2013, http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1974/ (accessed 17 April 2015); Norman J. Leonard, "Carl Shipp Marvel, 1894–1988: A Biographical Memoir," National Academy of Sciences, 1994, http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/marvel-carl.pdf (accessed 17 April 2015).

5. "CHF Move to Independence Park Draws Near," *Chemical Heritage* 12, no. 2 (1995): 3.

6. The Chemical Heritage Foundation Archives contains an impressive collection of instrumentation manuals and advertising literature, including materials related to the early instruments developed at Consolidated Electrodynamics Corporation (CEC). Extensive archival materials that document the early development of the company can also be found in the Papers of Charles M. Judson, Incorporating the Papers of Harold F. Wiley and the Records of Consolidated Electrodynamics Corporation (1918–2000, bulk 1940–1980), Chemical Heritage Foundation, Philadelphia, PA.

7. David Brock, email message to author, 16 June 2014.

8. Rob Lukens, "Instrumental Heritage," *Chemistry World* 2, no. 6 (June 2005): 50–53.

9. Success in museum exhibitions is often difficult to quantify, but in CHF's case, success was defined by several indicators: (1) our core constituents, particularly the HCIAC, were highly pleased with the content, (2) we received numerous positive reviews in the press, including the *Wall Street Journal* (Julia M. Klein, "Chemistry as Catalyst," 5 November 2008), (3) visitor numbers far outpaced expectations, with over 1,800 visiting in the first three months the museum was open, and (4) several formal evaluations showed high visitor satisfaction, and visitor comments in the guest book are consistently positive.

10. More about the synthetic rubber program during World War II can be found in Peter J. T. Morris, *The American Synthetic Rubber Research Program* (Philadelphia: University of Pennsylvania Press, 1989).

11. More information on the IR-1 and the synthetic rubber program can be found in the Beckman Collection, Chemical Heritage Foundation, Philadelphia, and the Shell Corporate Archive, Shell Energy North America, Houston, TX.

12. The Nobel Prize in Chemistry 2002 was awarded "for the development of methods for identification and structure analyses of biological macromolecules," with one half jointly to John B. Fenn and Koichi Tanaka "for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules" and the other half to Kurt Wüthrich "for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution." Nobelprize.org, "The Nobel Prize in Chemistry 2002," Nobel Media AB, 2013, http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2002/ (accessed 17 April 2015).

13. The Chemical Heritage Foundation recognizes Instrumental Lives as primary material, much like an oral history, and long-term preservation is a concern. Currently, the recordings are transferred to DVD and stored in climate-controlled storage with CHF's other archival audiovisual materials. The Chemical Heritage Foundation is currently in the process of developing a program for digital collections and digital asset management, and these materials will be included in those long-term preservation plans.

14. For further information on the history of electronics, see Christophe Lecuyer, *Making Silicon Valley: Innovation and the Growth of High Tech, 1930–1970* (Cambridge, MA: MIT Press, 2006); David Brock, ed., *Understanding Moore's Law: Four Decades of Innovation* (Philadelphia: Chemical Heritage Foundation, 2006); Computer History Museum, "Revolution Timeline," http://www.computerhistory.org/revolution/timeline (accessed 17 April 2015).

15. For information on professional museum standards for deaccession, see Rebecca A. Buck and Jean Allman Gilmore, eds., *MRM5: Museum Registration Methods,* 5th ed. (Washington, D.C.: AAM Press, 2010).

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A Snapshot of Canadian Kitchens
Collecting Contemporary Technologies as Historical Evidence for Future Research

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Introduction

This article explores the *Memories Are Made in the Kitchen* project, conducted by the Canada Science and Technology Museums Corporation (CSTMC) between 2012 and 2014. The project had two main goals: to bring the food-processing artifact collection up to date and to preserve a snapshot of Canadian kitchens at the beginning of the second decade of the twenty-first century for future historians.

The project allowed the CSTMC's curatorial staff to invert their well-established acquisition process. Rather than collect historical artifacts and documentation as pieces of evidence for contemporary historians, the museum collected contemporary technologies and supplementary information for future historians, who may want to study the subject several decades from now. Despite being firmly based in the collection development strategy and the material culture, material-semiotic, and materiality methodologies, collecting contemporary technologies posed some particular challenges and required novel approaches. Curatorial expertise was complemented by a crowdsourcing and social media campaign to identify and document artifacts that best reflect domestic technologies used by Canadians today. In addition to more traditional printed and audiovisual resources, social media were also used to collect intangible information crucial to future research, such as consumer behavior and evidence of societal

perception of kitchen appliances. Nonmaterial data, such as sounds and software, were also preserved for future researchers.

This chapter describes the material and methodological context in which the project was conducted and then looks at the process used to identify and gather artifacts and supplementary pieces of evidence to allow future historians to decode the cultural practices embedded in contemporary objects. Finally, it concludes by summarizing the benefits and drawbacks of the approach taken by the CSTMC.

Canada's Domestic Technology Collection

The Canada Science and Technology Museums Corporation, one of Canada's six national museums, includes the Canada Science and Technology Museum, the Canada Agriculture and Food Museum, and the Canada Aviation and Space Museum. The national collection held by CSTMC reflects seven major areas of Canadian technologies: agriculture and food, aviation and space, communication, domestic technologies, energy and natural resources, physical sciences and medicine, and transportation. Domestic technologies constitute one of the largest collections and include artifacts related to four aspects of the household: the equipment used in the home; the building or the infrastructure for housework; the people, that is, household members; and activities conducted within the house such as cleaning and food preparation. The collection contains over 3,000 artifacts, 2,000 pieces of trade literature, and extensive documentation consisting of textual, photographic, and audiovisual material. The scope of the collection is grounded in CSTMC's overarching theme, the "Transformation of Canada," which guides all acquisition activities. In this context, the domestic technology collection has been developed over the years to reflect the process of household electrification and urbanization in Canadian society. The artifacts in this collection reveal progressive mechanization, electrification, and, finally, automation of housework; carry evidence of gender roles and class issues; and document distribution of time spent on household chores, mainly child rearing, cleanliness, and food-related activities (Figure 1 shows some artifacts in storage). The collection contains artifacts dating from the 1850s to the 1980s and includes very few objects produced since the last decade of the twentieth century. As such, it successfully documents the Canadian home during the nineteenth and twentieth centuries but does not reflect new technologies pertinent to households in the twenty-first century, which leaves a significant gap in the collection.

Challenges of Contemporary Collecting

To fill the gaps in the existing collection, in 2010 the acquisition of new technologies became one of the top priorities of the CSTMC, giving its curators a mandate and resources to acquire, preserve, and document technologies that reflect Canadian culture at the beginning of the twenty-first century. From 2012 to 2014, the CSTMC embarked on a project to bring the collection of food preparation technologies, a category within the Domestic Technology Collection, up to date. Aptly titled *Memories Are Made in the Kitchen* to reinforce the storytelling strength of museum collections, this pilot project was an exercise in contemporary collecting.

1.
Collection of small kitchen appliances in one of CSTMC's three artifact warehouses.

Contemporary collecting poses some interesting challenges. First, museum curators, many of whom are trained historians, may not be best equipped to assess the future significances of new technologies, and curatorial procedures may not provide adequate tools for such evaluations. The collecting activities at the CSTMC are guided by a strict collection development strategy, which outlines an intellectual framework and the direction of collection and curatorial research. The strategy identifies "Transformation of Canada" as a broad theme guiding all acquisitions. The national science and technology collection is based on a premise that "scientific and technological endeavour has transformed Canada and its peoples."[1]

Focused on past events, the strategy does not include any criteria that facilitate the assessment of the long-term impact of current technologies on Canadian society. As historians are well aware, the success of a technology depends on complex social, economic, and political factors, which can be fully assessed only after some time has passed. The CSTMC curators use historical assessments—histories of science and technology in Canada produced by the CSTMC—to identify and analyze the important issues influencing the evolution of technologies. Although crucial for historical artifacts, these assessments offer limited information on current technologies. Furthermore, with no history of systematic contemporary collecting within the CSTMC,
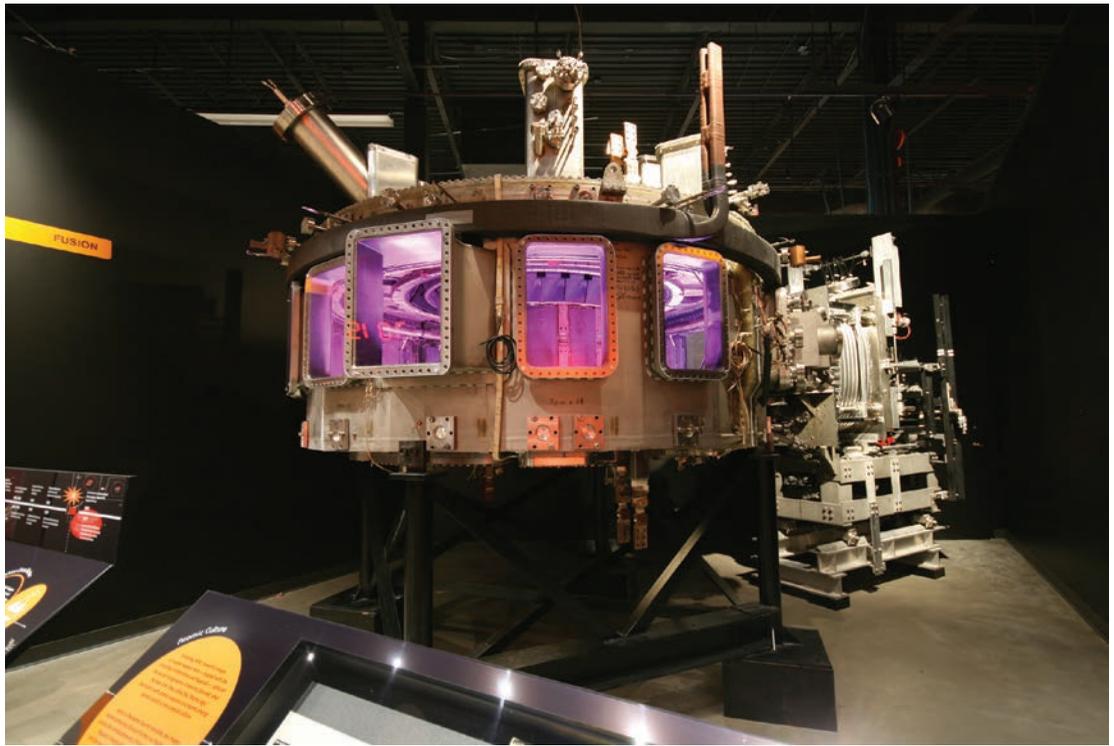
2.
The Tokamak de Varennes nuclear fusion reactor is the largest artifact in the CSTMC's collection. It was difficult to collect, transport, preserve, and interpret, but it is the only fusion reactor on display in North America.

there is little precedent that can guide preparation of acquisition proposals in this area. Additionally, there are no formal visitor studies that confirm visitors' interest in new technologies that could be used by curators as justification for acquiring artifacts under the category of "exhibition enhancement."

Contemporary collecting also poses practical challenges (Figure 2 shows a recent example at CSTMC). Curators have to take into consideration costs, as new technologies are often expensive to purchase. Recent technologies have commercial value, and companies and inventors may not be as inclined to share proprietary knowledge with museums. Finally, "black box" technologies may be perceived as exoteric and alienate a large portion of CSTMC's target audience, families with small children.[2]

In the context of these constraints, CSTMC's curators chose to focus the pilot contemporary collecting project on small domestic technologies, specifically on food preparation artifacts.[3] Arguably, collecting recent food preparation technologies presented less of a challenge than other curatorial subject areas such as mining, energy, and heavy industries. Food preparation technologies are relatively small, affordable, and easily accessible on the market and familiar to the museums' target audience. Moreover, Canada has one of the largest kitchen appliances penetration rates in the world.[4]

A Snapshot of Twenty-First Century Canadian Life

The Canadian kitchen of the 2010s is at an interesting consumption junction, an intersection of sociotechnical relations that influence consumers' technological choices.[5] Customers have a choice of a vast array of kitchen technologies—gas, electric, microwave, induction, and combination equipment—available all across urban and rural Canada. Appliance manufacturers offer a wide variety of features and a spectrum of colors and designs for any lifestyle and decor preference. There is also a noticeable shift in the social attitudes to and perception of food preparation. In the 2000s, Canadians spent more time at home than in the 1980s and the 1990s. They dined out less frequently and were willing to invest in high-end appliances for their kitchens. This trend is well summarized in a 2013 Euromonitor report that states, "It is not lost on consumers that a dinner for two in a nice restaurant could easily pay for a high-end mixer or food processor which would potentially last for several years and make countless healthy and delicious meals."[6] Many Canadian kitchens are equipped with relatively new appliances; for example, approximately 40% of surveyed households in 2007 owned a range and a refrigerator that were less than five years old, and more than 50% of households purchased a new microwave between 2002 and 2007.[7] Historically perceived as the site of women's housework and all activities that constituted caring for the family, the contemporary Canadian kitchen is now often considered the hub of entertainment.

3.
Aristocrat Kitchen. Photo courtesy of Mehrzad Mehr, Peach Interior Design, Inc., Vancouver, BC.

Tiled floors, marble counters, glossy cooktops, and mood lighting have transformed Canadian kitchens into a performance stage. Cooking is no longer a mundane task of feeding the family. The act of food preparation is now a display of artistry and skills, and the cook, be it a woman, a man, or the couple working together, is redefined as an artist. Semantics of the kitchen appliance has shifted from that of a labor and time-saving device to a high-end and well-designed prop (as illustrated by the example in Figure 3).[8] Even though it is not possible to predict if this change, most apparent among the middle class—Canada's largest population category—is a lasting trend or if it will contribute to a major transformation of Canadian society, the current shift in the attitudes associated with food preparation presents an interesting sociotechnological stage in the development of domestic technologies. It is then worthwhile for the curator to acquire recent kitchen appliances for the national collection and to document the current middle-class perceptions on 2010s kitchens for future researchers.

To achieve its goal of taking a snapshot of Canadian kitchens between 2012 and 2014, the project comprised two overlapping yet distinctive tasks: crowdsourcing and purchase of artifacts and the acquisition of documentation that would provide future researchers with valuable contextual information.

Building the Collection: Kitchen Crowdsourcing

The crowdsourcing portion of this initiative was conducted over a six-month period by the Curatorial Division, with the support of CSTMC's Membership Services and Public Affairs. This process started with an appeal to CSTMC's membership, easily accessible and representative of Canadian middle class, to cocurate an acquisition of small kitchen appliances that reflected current wants and trends. The members were asked two questions: (1) What is your favorite small electric kitchen appliance? (2) What will this appliance tell your great-grandchildren about Canadian lifestyle at the beginning of the twenty-first century?

The CSTMC's 7,000 members were asked to reply via email to the curator. As with any direct mail campaign, there was an expectation of a 1% to 2% response rate, which would have provided the curator with between 70 and 140 suggestions, enough to start an artifact selection process. Surprisingly, the response was minimal. Out of 7,000 members, only five people submitted answers to the two questions. With such a limited response, the curator extended the crowdsourcing exercise to other museums' clients and to the general public. The donors, a group that already recognized the value of museum acquisitions, proved to be a great resource. A media campaign, conducted via social media, national radio, and newspaper interviews and organized by the curator with the support of the CSTMC's Public Affairs Division, offered the most success in soliciting suggestions. These approaches gathered over 170 suggestions from across Canada.

To extend the data set beyond direct suggestions from the public, the curator complemented these with information gathered from wedding registries and popular press, as well as with a

selection of the 10 best kitchen appliances published in the *Style at Home* magazine and appliances included in an online resource, Canadian Tire's House of Innovations.[9]

Crowdsourcing was conducted across Canada in both official languages. The vast majority of contributions came from English-speaking Canadians, and over 80% were sent by women. Many responses focused directly on the first question and suggested different appliances but did not describe in any great detail the significance that future generations could attribute to 2010s kitchen equipment. Still, the submissions offered some cultural connotations that provided clues to the respondents' lifestyles. Many alluded to overconsumption in purchasing kitchen appliances. As one participant noted, "Appliances I cannot live without in my kitchen include: my Keurig, and my oversized toaster oven that has a rotisserie (reason for using toaster oven is the oven in stove houses all the cookie trays and casserole dishes that never get used)." Others, such as the author of the following comment, described fashion trends and social expectations: "The hottest thing in kitchen appliances seems to be single serving coffee machines. All my friends have a Keurig machine on their counters."

Building the Collection: Selecting Representative Artifacts

The most frequently suggested appliance was a high-quality coffee maker, particularly Keurig brand (as shown in Figure 4). KitchenAid mixers, Cuisinart blenders, and Braun choppers closely followed the coffeemaker as the most desirable appliances. The suggestions also included toaster ovens, electric kettles, handheld mixers, microwaves, waffle makers, rice cookers, and the Touch$_2$O hand-free Delta faucet. Wine-making equipment, electric wine openers, and wine coolers made the list. A particularly interesting appliance was a T-fal ActiFry (Figure 5). Promoted as a healthy alternative to a deep fryer, this visually interesting multipurpose cooker was among the most common items on wedding registries. It was also the item that was most often left not purchased after the wedding date.

A few general trends emerged from the submitted responses: the participants focused on healthy cooking and fresh ingredients and often prepared food daily. They owned more than one appliance that performed the same action, for example, a regular coffee maker and a cappuccino machine or an upright blender and a handheld mixer. The appliances were used as often to prepare every day meals as to make desserts, ice cream, and smoothies; mix drinks; and serve wine. The home cooks wanted technologies that minimized actual handling of food, offered single-touch control, performed many actions, and were easy to operate. They desired appliances that were efficient and effective. The respondents invested in their kitchens. They owned, and recommended that the museum collect, high-end, well-designed, and expensive appliances. Although the responses came from across English Canada, it is still difficult to judge how representative the suggested appliances are of a "typical" Canadian kitchen since it was impossible to gather reliable demographic information during the crowdsourcing campaign. Rather, we have to consider

4.
This Keurig coffee maker was among the first purchases made by a couple in their early twenties for their new apartment.

5.
In 2012 the T-fal ActiFry was one of the most often listed items on Canadian wedding registries.

the submissions as representative of the type of appliances Canadians believe should represent the typical Canadian kitchen of the twenty-first century in a national collection.

It is important to note a contradiction between the upscale, costly appliances suggested for the national collection and data acquired by the Natural Resources Canada Office of Energy Efficiency. According to the Natural Resources survey, Canadians pay more attention to prices of appliances than to features and overall quality.[10] Although the museum did not track income level of respondents, it is possible that submitted suggestions came from Canadians particularly interested in food preparation who could afford to spend more on kitchen appliances. It is also possible that expensive, high-end appliances were suggested for the national collection because of the value placed on the collection itself. Respondents commented on aesthetic appeal of kitchen technologies and preferred appliances finished in black, silver, or chrome. Surprisingly, no one alluded to stainless steel, which had been a very popular trend in the late 1990s. Most suggestions referred to new appliances, produced after 2000. The submissions received from the general public and data from other sources consulted in the project confirm a 2013 Canadian market trend analysis, conducted by Euromonitor:

> The product categories exhibiting the most impressive growth among small cooking appliances are those which have been able to benefit from the combined trends towards healthy eating, convenience and speed, and dining-in. . . . Conversely, product categories such as slow cookers experienced another year of declining sales as such products do not offer the speed and convenience consumers seek when cooking at home.[11]

The curator compiled the final list of eight appliances, which were acquired for the national collection. Ultimately, this selection was based on trends observed in the crowdsourced suggestions and in sources used during the project and was rooted in the existing food preparation collection. The 2012 appliances were selected to complement those already in the collection in terms of function, features, and design and also to provide continuity within the larger collection. For example, whenever the crowdsourcing did not refer to a specific maker, the curator made a decision to purchase an appliance produced by a manufacturer already well represented in the collection. This approach allows for technological changes to be documented and understood as a process and for material culture comparison.

The cutoff value for the acquisition had been set at the beginning of the initiative at C$1,000 to provide monetary framework for the project and to document the number of the suggested appliances that in fact could be purchased in the early 2010s in Canada for this amount. In the end, this price point limited the curatorial selection to eight appliances, all produced in 2012 (see Figure 6), which added up to the actual cost of C$1,075.92:

1. Keurig coffee maker
2. Cuisinart SmartPower blender
3. KitchenAid Imperial Black Artisan stand mixer

4. Black & Decker Kitchen Tools 6-slice convection toaster oven
5. Think Kitchen automatic electric kettle
6. Oster electric wine opener
7. T-fal ActiFry
8. Black & Decker 6-speed hand mixer with storage case

The appliances were acquired in stores across Canada. The curatorial staff took photographs of the stores and retail displays to record the manner in which appliances were presented to the customer. Several appliances were purchased online through websites commonly used by Canadians to buy kitchen technologies, such as Amazon and the Canadian Tire website. All original packaging and trade literature, such as manuals and catalogs that came with the appliances, were accessioned into the collection. The price of each appliance was recorded, and the purchase orders, invoices, and store receipts were kept in order to document the source of the appliance, the name and address of the store, the date and time of purchase, and the amount of taxes paid on the domestic kitchen equipment. Such documentation, it is hoped, will allow future researchers to gain a better understanding of the consumer's experience in relation to the displays and sales processes.

6.
Eight appliances acquired for the national collection through a crowdsourcing campaign represent trends popular in Canadian kitchens at the beginning of the twenty-first century.

Providing Context:
Beyond the Material Artifact

The crowdsourcing and the purchase of appliances was the first phase in the *Memories Are Made in the Kitchen* project. Although crowdsourcing the acquisition was time-consuming, it was arguably the least complicated element in this contemporary collecting exercise. Ontic in their nature, objects are straightforward to purchase and store. Acquiring and preserving nonmaterial information embedded in artifacts poses more of a challenge. To provide future historians with meaningful documentation, the second phase of the initiative focused on preserving nonmaterial components inherent to technologies and on recording the consumption context of these appliances.

Data crucial to future understanding of the technology, such as the sound of an appliance or the software used to program its operation, can be difficult to acquire and preserve. Many technologies conserved in science and technology museums, especially electrical artifacts, cannot be safely operated within a few decades from the date of their production as wiring standards change; also, plugging in such appliances may place the artifacts themselves in jeopardy. Therefore, nonmaterial data have to be preserved independently of the artifact to be accessible to future researchers.

As the crowdsourced appliances were acquired and accessioned to the collection, the CST-MC's Curatorial and Conservation departments used their judgment to determine which intangible features characteristic of each technology might be valuable for future researchers. The museum staff decided to videotape the artifacts' operations, focusing particularly on their sound; the speed at which they operated; the look of hot components; and some artifact-specific characteristics, such as the amount of steam coming out of the electric kettle (Figure 7).

Several of the collected appliances were programmable, and it was essential to preserve the software used to run these appliances. Software conservation is still a new domain that presents many unresolved issues. The software data are stored on a ROM chip incorporated into a control board and cannot be extracted without removing the board from the artifact, which in turn would scarify the integrity of the object. In theory, one way to ensure that the data are preserved is to acquire a spare control board together with its schematics. The data can then be converted and preserved as a binary file. Another way is to acquire an emulator from the appliance manufacturer. Emulators allow for duplication of the functions of the original software that runs an appliance on any computer system. However, in practice, software preservation is one of the most complicated aspects of contemporary collecting because of the proprietary nature of many programs. The manufacturers of kitchen appliances are not inclined to share commercially valuable software with museums. At the time of writing, the curator was still negotiating issues around the software acquisition with manufacturers. One way to address the producers' concerns around commercial value of the software may be to seal the data for the duration of patents.

7.
Museum staff recorded operations of all purchased appliances and provided commentary on the look and feel as well as use and cleaning of the objects.

Providing Context: Capturing Cultural Context

Canadian kitchens are complex social constructs, and appliances together with the nonmaterial data inherent to these objects should be preserved in their cultural context to allow future researchers to make sense not only of the technologies but also of their integration in people's daily lives. Many human and nonhuman actors are involved in various stages of design, manufacturing, promotion, and, finally, consumption of kitchen appliances. The *Memories Are Made in the Kitchen* project needed to curtail the enormous amount of technical, socioeconomic, and political information surrounding the contemporary kitchen. Since the acquisition of artifacts was structured in the context of consumer crowdsourcing, the curator made a decision to narrow the focus of supplementary documentation to the consumer/owner of the appliances.

Consumers go through a complicated decision-making process before they purchase an appliance. They identify a need for an appliance based on personal criteria. They research technologies and styles that best suit their practical and aesthetic needs. Finally, they interact with a store display and talk to a salesperson. How can we preserve this process? The consumer behavior is extremely difficult to collect. The *Memories* project attempted to assemble documentation from various sources. Marketing material, magazines, popular kitchen websites, and online advice offered some evidence. This type of documentation was also relatively simple to preserve either as textual material or downloads. YouTube proved most helpful in sourcing videos of customers shopping for appliances and talking about their purchases. Most appliance stores are fitted with security cameras. The footage from such cameras would offer future researchers a unique glimpse at customer behavior and their interactions with the display, the store staff, and each other. However, access to shop videos is complicated by the fact that they are not only regularly erased by stores but also subject to privacy laws. Although difficult, acquisition of such material for the collection is ultimately worth the effort. To comply with privacy regulations, the exact date and time of the videos can be erased, and the identity of shoppers can be concealed. If necessary, the curator may request that the material be acquired for research purposes only and never exhibited or that the videos are sealed for a period of time.

To engage Canadians in talking about kitchen appliances that they own and use, the CSTMC organized a social media campaign. The campaign invited Canadians to send photographs of their kitchens to the CSTMC and to tell stories associated with kitchen appliances (Figure 8). The public responded via email, Twitter, Facebook, and a dedicate Flickr group page. The majority of contributions came through Twitter and email.[12] Tweets, which generally included a snapshot, were short but meaningful: "This is my city kitchen - I think of it as my laboratory. The shiny red #kitchenAid mixer was used to make scones this morning." An attached photograph showed a color-coordinated kitchen in red and gray. A KitchenAid mixer, the third most frequently suggested appliance in the crowdsourcing phase of the project, was neatly displayed in the counter with a spot light directly above it. Email submissions were longer and included one or more

8.
One of very few photographs submitted to the *Memories Are Made in the Kitchen* project that shows appliances after use. Most images depicted freshly cleaned kitchens.

photographs and kitchen plans. The stories were often nostalgic and recalled memories of cooking with a mother or a grandmother. Some submissions, such as this email from Joana, included valuable details that allowed for a better appreciation of the organization and the workflow in a contemporary kitchen:

"It is a fully functional kitchen, with good appliances, laminate flooring, lots of natural light and ventilation, and plentiful storage. Basically, I am using the U-form storage like this: down cabinet near the fridge: pots, pans and cooking trays; upper cabinets near the fridge: everyday plates, cups and glasses, plus coffee, tea and sugar; near the stove: each of the three drawers have, respectively, cutlery, cooking utensils and wiping cloths. . . . The white wall functions as a large pantry where I keep everything from morning cereal, lunch snacks, potatoes, flour, rice, herbs to fine china and crystal glasses. I walk a lot in this kitchen when cooking (maybe it's a good thing given that I'm not a gym-goer!)."

The submitted stories conveyed very personal attitudes and perceptions on Canadian kitchens and corroborated the trends noticed during the crowdsourcing. The images provide excellent evidence of styles and aesthetic of an average Canadian kitchen in the 2010s, including kitchens in new houses, older kitchens, and newly renovated kitchens. Both the stories and photographs complement the suggestions sent during the crowdsourcing exercise and complete supplementary documentation gathered in the *Memories Are Made in the Kitchen* initiative.

Conclusions

At the end, this pilot project in contemporary collecting, although time-consuming and requiring resources from various divisions within the CSTMC, met its goals. It allowed the CSTMC to select interesting new kitchen technologies and bring the food preparation technology collection up to date. It also allowed the corporation to extend its collection of domestic technologies, heavily focused on the electrification of Canadian homes, to include evidence of a shift in the kitchen semantics that is taking place in the early twenty-first century. Ultimately, *Memories Are Made in the Kitchen* assembled a large collection of data that combined material culture with digital, textual, audio, and visual documentation in order to take a snapshot of Canadian kitchens in the 2010s.

The approach to the contemporary collecting tested in this pilot will inform future collecting projects. As mentioned at the beginning of this chapter, artifact acquisition and documentation in the area of domestic technologies are relatively simple compared to other sectors of Canadian technology. We can expect that challenges encountered in the project such as limited response to crowdsourcing, acquisition costs and deadlines, difficulty accessing proprietary data, and privacy issues will become only more complex when dealing with other subjects. Any future contemporary collecting projects will require considerable time and financial and human resources and can succeed only with full institutional support.

Notes

1. Canada Science and Technology Museums Corporation, *Collection Development Strategy* (Ottawa: Canada Science and Technology Museums Corporation, 2006), 3.
2. There is some evidence of this response in the visitor evaluations conducted by the corporation. The CSTMC's target audience, families with children, found an exhibition on nuclear fusion and fission intimidating and would leave the display almost immediately after entering the space. This response was largely due to the interpretive approach, which focused on physics and pure research rather than applications and social relevance of nuclear fusion and fission projects.
3. To ensure that the motivation behind this acquisition was clear to future researchers, the curatorial decision-making process has been recorded in a written and archived acquisition proposal for the artifacts, which has been presented to the CSTMC Acquisition Committee.
4. Floating Path, "Global Penetration Rate in Appliance Market," 17 July 2013, http://www.floatingpath.com/2013/07/17/global-penetration-rates-of-home-appliance-ownership/ (accessed 30 April 2014).
5. R. Schwartz Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in *The Social Construction of Technological Systems,* edited by Wiebe Bijker, Thomas Hughes, and Trevor Pinch (Cambridge, MA: MIT Press, 1987), 261–280.
6. Euromonitor, "Food Preparation Appliances in Canada," January 2013, http://www.euromonitor.com/food-preparation-appliances-in-canada/report (accessed 30 April 2014).
7. Natural Resources Canada, *Survey of Household Energy Use* (Ottawa: Natural Resources Canada, 2007).
8. This shift in meaning of food preparation is reflected in and propagated by magazines such as *Chatelaine, Canadian House and Home*, and *Style at Home*, as well as a number of popular television shows such as *MasterChef Canada*. The shift is also reinforced by numerous food preparation and decorating classes, which are often run by large chain stores such as the arts and crafts store Michaels or the grocery business Superstore.
9. C. Tully, "10 Items Every Kitchen Needs," *Style at Home*, 28 October 2008 http://www.styleathome.com/kitchen-and-bath/kitchen/10-items-every-kitchen-needs/a/426 (accessed 30 April 2014). House of Innovations was a yearlong project conducted between June 2011 and June 2012 by Canadian Tire, one of the largest retailers, to educate Canadians on house renovation techniques and the newest appliances available on the market. The project's website, HouseofInnovations.ca, is no longer valid.
10. Natural Resources Canada, *Survey of Household Energy Use*, Table 6.7.
11. Euromonitor, "Food Preparation Appliances in Canada."
12. One drawback of soliciting images via social media is the fact that photographs are generally taken with a cell phone and are of low quality. They provide research evidence but are not useful for exhibitions or publications.

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Preserving Norway's Oil Heritage

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Norwegian Petroleum Museum Stavanger, Norway

Introduction

Since 1971, hydrocarbons have been produced from deep under the Norwegian continental shelf. In order to receive and process the "black gold," huge structures have been built, transported, and installed on the seabed in water depths ranging from 60 to 1,000 m. These giant platforms and subsea installations have made it possible for Norway to become a wealthy and prosperous nation.

Toward the end of the twentieth century, some of the hydrocarbon reservoirs were being emptied, and plans were made for the platforms to be decommissioned and removed. Given the size of the structures, it was not feasible to store them anywhere close enough for the public to visit. Instead, the Norwegian Petroleum Museum has created documentation projects, establishing an archival solution for preserving sources, with the emphasis on drawings, photographs, film, publications, objects, interviews, and other material. Digital databases represent the principal medium for storing these sources. So Norway's oil heritage is now captured online via dedicated websites, as a digital national memory.

Background

Norwegian oil history started after large gas reservoirs were discovered in the Dutch region Groningen in 1959 and the geological structures spreading out to sea awoke the interest of the big oil companies for the whole North Sea.

Nobody in Norway really believed that oil could be found outside our coast since a letter from the Norwegian Geological Survey in 1958 stated that "the chances of finding coal, oil or

sulphur on the continental shelf off the Norwegian coast can be discounted." However, interest was raised, and several seismic investigations were made in the, at that time international, waters of the North Sea in the first half of the 1960s.

In 1965, the Norwegian government was convinced, and on 7 August, nine different industrial groups, dominated by the international majors, were given licenses to drill for hydrocarbons on a total of 74 blocks. The blocks were all about 500 km^2 each, and all were situated south of 62° latitude.

The spudding of the first well was done 19 July 1966 by the drilling rig Ocean Traveler under contract by Esso. The first wells were empty, or the little oil that was actually found was not economically profitable.

The real history began right before Christmas 1969, however, when the Ekofisk field, which is a giant oil and gas field, was found by Phillips Petroleum Company Norway. A speedy development project resulted in oil production starting from the Norwegian continental shelf on 9 June 1971.

In 1971 the Frigg field was discovered, in 1973 the Statfjord field was found, and in 1975 the Valhall field was found and so on. Operating companies submitted plans for development and operation of the different oil fields to the government for approval, with a predicted production period based on how much oil and gas it was possible to produce with acceptable profit.

The available technology in the 1970s and 1980s and the knowledge of the size and composition of oil-bearing layers suggested the production period would be about 20 years. Operating companies or groups were required to set aside money for the decommissioning and removal of structures from the outset of the construction phase.[1]

As we were closing in on the turn of the millennium, some of the oil fields were going to close down. Questions arose as to whether the platforms should be scrapped on decommissioning or whether aspects should be kept intact and become museums as symbols of Norway's early oil age. The environmental action plan for the petroleum sector produced by the Ministry of Petroleum and Energy in 1999 stated the necessity to ensure that important and historical structures were preserved and made accessible for future generations, as well as documenting the development of government administration.[2]

Scrapping the platforms was the alternative preferred by the oil companies because it would be fast and relatively cheap and was already factored into their plans. Historians and representatives from museums may have preferred the second alternative—preservation. However, the structures were so huge that there was no place to store them anywhere close enough for the public to visit. The maintenance would also be very expensive. The largest platform, Troll, is almost 500 m tall and weighs more than 1 million metric tons (see Figure 1). The deck areas of several of the platforms are the size of more than three football fields! Thus, only one option remained: to document the platforms and the oil fields.

In a March 2000 letter to several museums with interests related to the offshore activities, the Norwegian Directorate for Cultural Heritage raised a challenge: "What cannot be preserved should be documented."[3] Early in 2001 the Norwegian Petroleum Directorate (NPD) wrote a
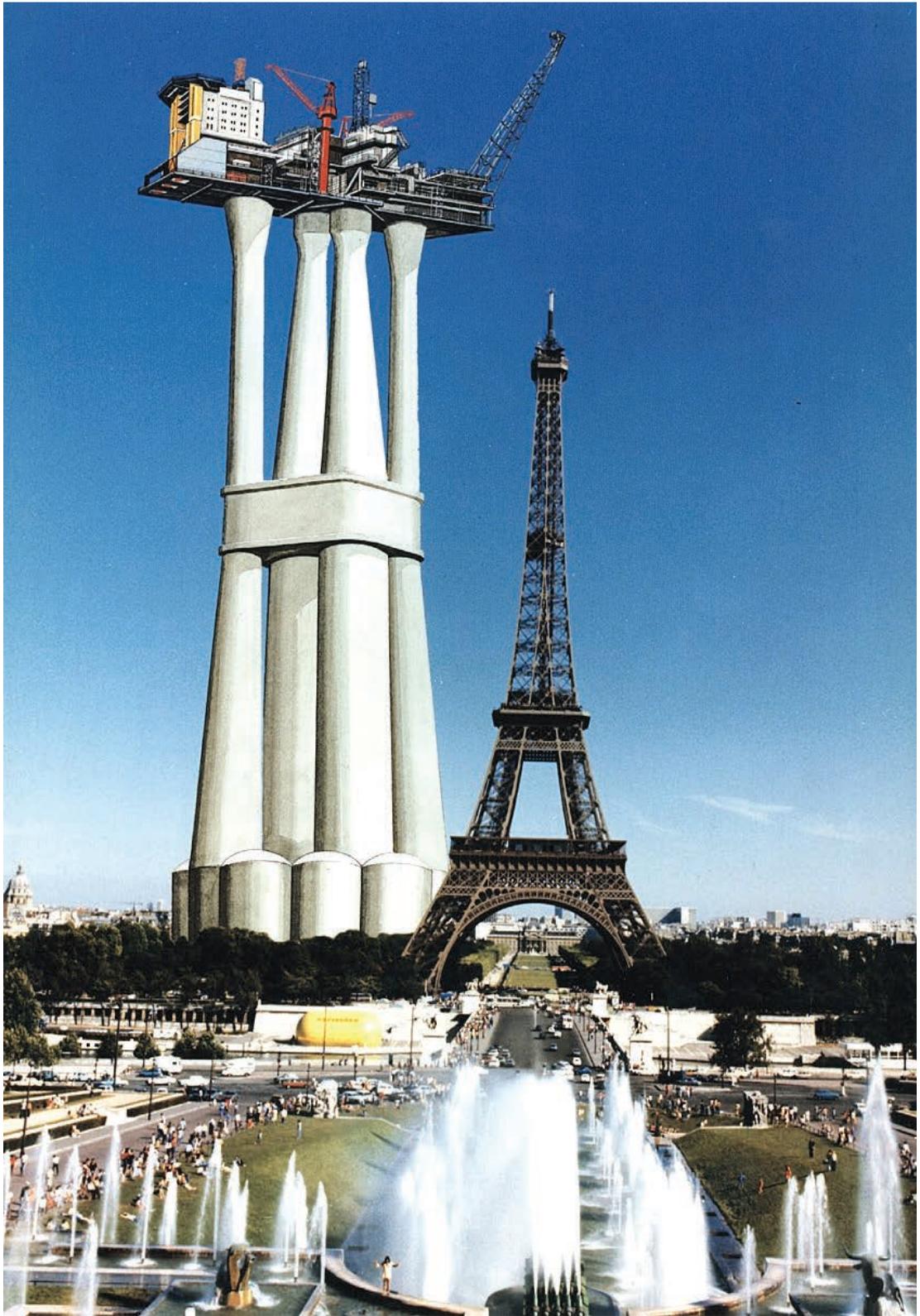
1.
The Troll platform compared with the Eiffel tower in Paris. Photo: Statoil/Norwegian Petroleum Museum

letter to the operator of the Ekofisk field urging Philips Petroleum to initiate a study of how such a documentation project could be done and indicating that the Norwegian Petroleum Museum (NPM) was best fit to perform the task.[4] Within a fortnight, Philips Petroleum accepted the challenge, and the Petroleum Museum delivered a preliminary report by early October.[5]

This was the background for the NPM to start the first oil field documentation project in 2002, the Ekofisk Industrial Heritage, completed in 2004.[6] Since then other fields have been documented, and further projects are underway. The aim of the documentation projects has been twofold: first, to collect source material to be preserved for future generations and, second, to create access to this material via the Internet and books, making it easier to understand technical processes and working life and placing the historical material in context.

Choosing Sites for Documentation: Ekofisk and Beyond

Ekofisk occupies a central place in Norway's petroleum history as the first producing oil and gas field on the Norwegian continental shelf. The original owners were the Phillips Group, consisting of the Phillips Petroleum Company, Norske Fina A/S, and Norsk Agip A/S, with Phillips Petroleum as the operating company. Today, the owner group (the License) consists of ConocoPhillips Skandinavia AS, Eni Norge AS, Petoro AS, Statoil Petroleum AS, and Total E&P Norge AS, with ConocoPhillips as the operating company. The industrial heritage project was funded by the License (Figure 2).

The Ekofisk field is situated on the border between Norway, the United Kingdom, and Denmark. Originally, the field was planned to operate for 30 years, but new technology and new discoveries of oil and gas in the area have made it possible to prolong the life of the field toward the middle of the twenty-first century. More than 30 installations (platforms, tanks, subsea units, etc.) have been installed on the field, but only half of them are still in use. Up until 1 January 2013 the total production from the Ekofisk area amounted to the equivalent of more than 5 billion barrels of oil—oil, gas, and natural gas liquids combined (Figure 3).

Following the completion of the Ekofisk Industrial Heritage Project, three other similar documentation projects were introduced: Frigg (completed in 2008),[7] Statfjord (completed in 2012),[8] and Valhall (completed in 2015). The projects were realized thanks to financing from the owner group of each field.

Because of the large number of installations in the Ekofisk field only six platforms were chosen to give a representative and detailed picture of field's development. For Frigg, Statfjord, and Valhall, which have fewer installations, all platforms were documented.

2.
The logo for the Industrial Heritage Ekofisk website.

3.
The Ekofisk Center, 1976. Photo Michael Davis/ ConocoPhillips/Norwegian Petroleum Museum.

Priorities and Plans

How did NPM select which of the many fields to document? The first two, Ekofisk and Frigg, were the obvious candidates. Ekofisk was the very first oil-producing field on the Norwegian continental shelf, whereas Frigg, now totally decommissioned, was a major gas field on the border with Great Britain and an important supplier of natural gas to British homes. Since the Frigg field, operated by a French company, was part of both the U.K. and Norwegian continental shelves, it was of particular interest and allowed for collaboration with the University of Aberdeen on the documentation project.[9] The British archivists wanted to learn from the Norwegian experiences with documenting the Ekofisk field, which was the first documentation project of its kind.

In Scotland a network called Capturing the Energy was established in 2006 to encourage oil and gas companies to keep their most important records, ensuring that they could be safely stored in an archive repository, so that they could be made accessible for current public research and for future generations.[10] In 2009 European Oil & Gas Archives Network (EOGAN), a European network of archives and cultural institutions related to oil and gas, was founded, with the purpose of promoting preservation and usage of relevant archives and sharing skills and experience.[11] The Norwegian Petroleum Museum is one of the participants.

During these early stages, NPM suggested to the Ministry of Petroleum and Energy (MPE) and the Norwegian Oil Industry Association (NOIA) that there should be a national industrial heritage plan.[12] An estimated project cost of 2.8 million Norwegian kroner (about 350,000 euros) was proposed, with a suggested split between the two institutions.[13] In September 2004, the

NPM was commissioned by the MPE, NPD, and NOIA to draw up such a plan. A necessary starting point for conserving industrial heritage is that the industry in question has a satisfactory overview of what it administers and how it is to be conserved. In 2010, this resulted in a book covering all 92 fields that had been developed since 1971.[14] Both the project management and the production of the book were handled by the NPM.

An important element in the production of the industrial heritage plan was the early introduction and formation of a steering and reference group consisting of 10 people with outstanding experience in many different aspects of the oil industry and with professional museum and historical backgrounds.[15] The group's main task, apart from ensuring the quality of the final product, was to establish significant selection criteria for choosing facilities to be defined as industrial heritage monuments. Their final criteria were as follows:

- installations representing different development eras
- the first, most important, or most representative technology
- installations illustrating the breadth in development solutions or platform types
- special projects (i.e., CO_2 removal, subsurface production from satellite fields)
- installations unique in a Norwegian or international context
- economic significance
- social significance
- special historical events associated with the installations
- political decisions and debate over the development

Using these criteria, the project's steering and reference group conducted an integrated assessment of all potential fields. They came up with lists of priority areas (in alphabetic order); the A list includes the following:

- Ekofisk area (project completed 2004)
- Frigg area (project completed 2008)
- Oseberg area
- Snøhvit
- Statfjord area (project completed 2012)
- Troll area
- Valhall area (project completed 2015)
- Åsgard area

The B list contains these areas:

- Balder area
- Draugen
- Grane
- Gullfaks area

- Ormen Lange
- Snorre area
- Ula area

In addition, the rest of the fields that were producing at that time were given either C or D priorities. Since the introduction of the Industrial Heritage Plan, several fields have been developed and discovered, and there are now more than 100 fields producing hydrocarbon from the sectors along the coast of Norway: the North Sea, the Norwegian Sea, and the Barents Sea. How to update the priority list has not yet been decided, but the museum cooperates with NPD to compile an updated map of the operating fields, and the map is also on display in the museum.[16]

Digital National Memory

Documentation highlights the physical structure above the water and on the seabed, including wells, exteriors, interiors, machinery and equipment, and major modifications (Figure 4). It also includes descriptions of the work processes, work environment, and effects on the economy, politics, and society. The projects also include documentation of the characteristic features of the development of the field, such as technological development, special projects, historical events, negotiations and decisions that underlie development decisions and options to expand, political decisions, and debates related to the development. Each industrial heritage project
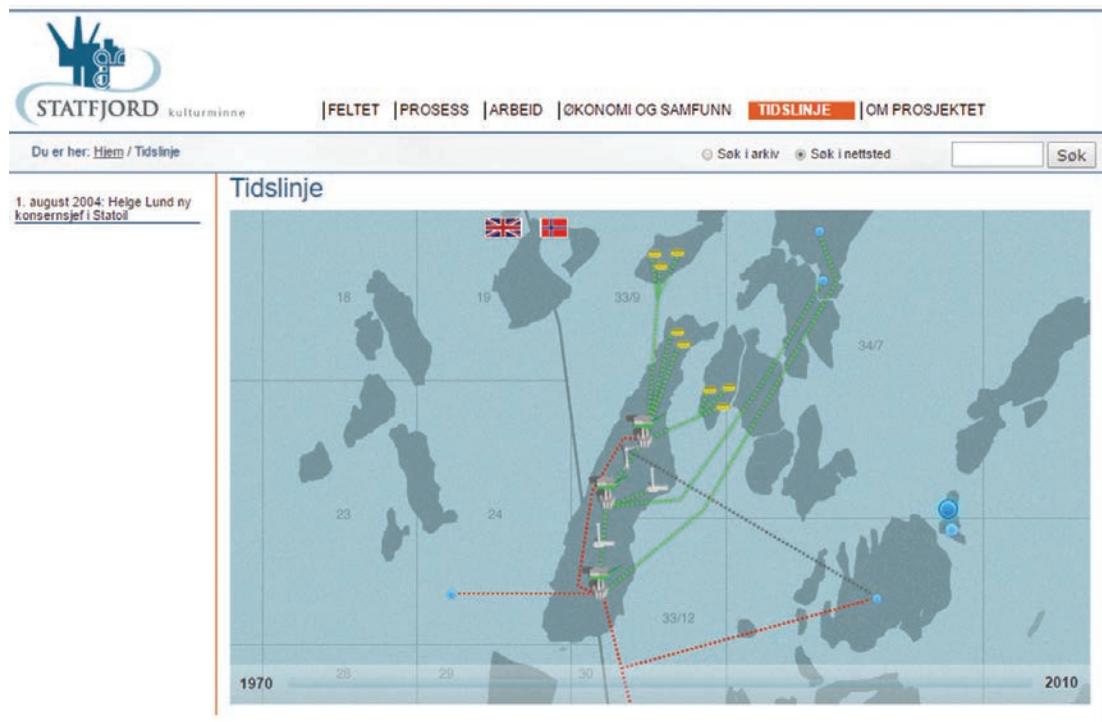
4.
Illustration from the Industrial Heritage Statfjord.

could include an article about the geological structures containing the hydrocarbons forming the basis for the development of the fields. However, this might be sensitive information for the oil companies.

About a year before a project is completed, the museum makes a decision on which field from the A or B list is to be targeted next. We try to choose different operators in order to be able to document the differences in practices and procedures among the large international oil companies. The museum has established an archival solution for preserving sources, with the emphasis on documents, reports, drawings, photographs, film, publications, objects, interviews, and other material. Digital databases represent the principal medium for storing these sources.

It is essential to collect source material that represents complementary ideas and opinions. In the selection of source material, it is important to be aware that the documentation will form the basis for future research and dissemination. The projects have utilized original sources and made an extensive selection of these materials in order to present comprehensible documentation of the oil fields. In addition to the help of the operating companies of each field, these projects have been made possible only through close cooperation with the Regional State Archives in Stavanger, the National Archives of Norway, and the National Library of Norway.

ARCHIVES

The Regional State Archives in Stavanger (RSAS) has devised its own criteria for the selection of the companies' archive material from a field's history to document the development and operation offshore and parts of the land-based activities. Material not found elsewhere has been given priority, whereas information being preserved by the NPD and the MPE has not been selected. Basically, the operators' company archives fill several thousand shelf meters, but the RSAS has selected to store only a few hundred shelf meters of information for the documentation projects. Through organization and registration duplication has been reduced. The catalog to the archive is available online, and perhaps a reflection of the transparency of Norwegian culture, the RSAS has even been allowed to present some material that could be considered commercially sensitive on the web. For instance, original reports from board meetings at Mobile Oil Corporation in Houston, Texas, regarding the Statfjord projects are included.

Drawings are a separate category within the archives. From the thousands of original drawings the National Archives has selected a few hundred. Saving different types of drawings such as flow diagrams, artist's impressions, arrangement drawings, geological maps, well descriptions, etc., has been important.

OBJECTS

Through the documentation projects, several hundred physical objects have been gathered and stored at the NPM. Examples of such items include a large number of models, signs and posters from the platforms, and control panels, to mention a few. All the objects are described, photographed, and registered in a special database called Primus.[17]

5.
The Statfjord gas compressor on display at the Norwegian Petroleum Museum. Photo: Jan A. Tjemsland/ Norwegian Petroleum Museum.

The exhibition uses many models to show how platform design has developed, but we also want to show real objects to give a feeling of the dimensions in the industry. The heaviest piece placed inside the exhibition is a compressor from one of the Statfjord platforms (weighing about 10 tons; Figure 5). It has a special story. To be able to get the gas through the pipeline all the way to the west coast of Norway, the gas coming from the wells had to be under high pressure for the gas to reach shore. Several compressors were installed on the platform to achieve this. Today, gas from Statfjord is shipped through pipelines to the United Kingdom, and the compressors are no longer needed. Before the compressor was taken to the museum, donated by the License, it was cut open to make it possible to see the inside and make it easier to understand how a compressor works.

Having enough storage space in the external magazines is a challenge. Some items are too large to go inside the museum or even the magazine buildings and have to be exhibited outside the building. Some of them, for example, one of the jacks from Ekofisk, tell great stories. The jack

is unique because it symbolizes a great accomplishment by the engineers. In 1987, 19 jacks were used to simultaneously raise all the platform decks on the Ekofisk Center and extend the legs 6 m due to subsidence of the total field. The operating company paid for the installation of one jack outside the museum in 2004 as part of the exhibition marking the opening of the Industrial Heritage Ekofisk website.

Between 2008 and 2013, an 80-ton piece of the bridge from Frigg leading from the Norwegian to the British continental shelf was on display in front of the museum. The exhibited piece was the exact part of the bridge that contained the actual border between Norway and the United Kingdom, thus illustrating the fact that the Frigg field was part of both countries' continental shelf. On this bridge, people had been able to walk from Great Britain to Norway! The operating company Total paid to place the bridge outside the museum but did not want to assume the cost of maintenance for more than five years. The museum did not have storage space for this big object and could not afford the maintenance costs, so unfortunately, we had to scrap it in 2013.

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Documentation of an industrial plant means that consideration should also be given to material that is not directly related to field development and operation. References to books, reports, and newspaper articles set the development and operation in a wider historical context.

In order to secure access to published material about Ekofisk, Frigg, Statfjord, and Valhall NPM has collected a number of magazines, reports, and published articles and forwarded them to the National Library for scanning and optical character recognition to make them searchable. These publications can now be accessed through the Internet. All the books related to the oil field projects are registered and made searchable on the websites. Some of them can be read in full. For the Frigg Norwegian-British project a special book, *Crossing Boundaries: Frigg Industrial Heritage*, was published.[18] Articles from the projects have also been published in the NPM's yearbooks.[19]

AUDIOVISUALS

Much of the history is documented in the form of archival material, which is either already in digital form or can be transferred to digital form, such as photographic and film material.

Close to 20,000 photographs can be found on the websites for Ekofisk, Frigg, Statfjord, and Valhall. They range from aspects of building sites, full views of platforms during installation, interiors, portraits, and scenes from life on board the platforms during both work and leisure periods. The NPM's own photographers have been offshore to take pictures in addition to collecting pictures from the archives of the oil companies and private photographs taken by offshore employees (Figure 6). The private pictures are especially interesting since they often present a different aspect of life on board than the official photographs. Metadata for all of the pictures have been registered and can be searched from the websites. The photos can also be found through the Internet portal Europeana.eu.[20]

6.
Celebrating 17 May, Norway's Constitution Day, on board Ekofisk. Photo: Karianne Knutsen/
Norwegian Petroleum Museum.

Film is an interesting source category with the ability to tell vivid stories. A couple of hundred movies are now available on the websites. The films have been digitalized and registered in a special database program by the National Library. The archives of the Norwegian National Broadcasting Company (NRK) provide another unique source that can convey the attitude toward oil field exploitation during different periods. The National Library has stored a large number of radio and television clips related to the history of the different oil fields that can be found through the websites.

The documents in the collection are in a wide variety of media and formats. In many cases, it will be necessary to take special precautions to ensure that the documents, including digital documents, photographs, and original movies, are not damaged or become inaccessible over time. Digitally stored material must be preserved in such a way that it can migrate to other formats as new storage media develop. Management of this diverse material therefore requires a thoughtful and robust document management solution. The National Library of Norway has adequate systems, procedures, and strategies for managing documents and digital objects, as well as preservation and retrieval of these, and has also built a physical digital repository to protect and preserve digital objects in the long term.[21]

Oral Histories

The NPM has made an attempt to preserve some immaterial heritage by interviewing a number of people with personal experience working offshore. Historians at the NPM conducted the interviews. The Ekofisk project also involved a social anthropologist from the University of Bergen.[22] All interviews were recorded, transcribed, and filed at the museum, but as they may contain sensitive information, only an excerpt is available on the cultural heritage websites. Researchers who want to study a whole interview can do so by asking the museum.

Through the interviews new unique source material was created. To provide a broad picture of work on the oil fields, we selected individuals with a wide range of professional careers, such as geology, drilling, well technology, production, communication, maintenance, and offshore support services like safety, medical care, and catering. For the Statfjord project, people with experience related to the engineering and construction of the platforms were interviewed.

Interviews were also conducted with persons representing the various trades and occupations offshore, as well as management and labor unions. This cross section provides different viewpoints about particular incidents and information about important development steps and organizational changes that is more in depth than that found in the documentation projects as a whole. Emphasis has been placed on finding respondents who have extensive experience in each company and who know the organization well. The interviews reflect personal beliefs related to the interviewee's own professional experiences.

Types of Materials and Volumes

The material for each documented field made available for the Norwegian Petroleum Museum to use is extensive. Table 1 indicates the total number of sources and how much information is typically presented on the website. Table 2 shows a summary of the different available items for each documentation project.

Lessons learned from the earlier projects have shown that it is crucial to the quality of the project for it to be completed while the fields are still in operation and there are still people who have personal experience from the fields' pioneer periods. This timing ensures finding

Table 1.

Available sources of information for use in a typical industrial heritage documentation project.
N/A = not applicable.

Source	Number of sources available	Number selected for use
Archives (letters, reports, etc.)	5,000–10,000 shelf meters	200 shelf meters
Technical drawings	200,000	500–1,000
Photographs	10,000–15,000	5,000
Films and videos	100 titles	100 titles
Audio files	100	100
Publications (books, pamphlets, etc.)	5,000 pages	5,000 scanned pages
Illustrations (maps, artists' impressions, etc.)	1,000	350
Operating manuals	500	50
Interviews	N/A	30–50
Objects	N/A	>100

Table 2.

Items found for the three completed industrial heritage projects.

Items	Project		
	Ekofisk	Frigg	Statfjord
Published articles	279	188	266
Photographs	4,037	4,604	5,222
Books	390	169	1,425
Films	104	52	93
Objects	291	308	68
Audio clippings	95	22	50
Magazines/pamphlets	24	608	552

documentary sources and gathering firsthand testimony from people who were central to the work of the development and operation of the fields.

Making the Industrial Heritage Available

The histories of the fields, installations, work processes, daily life on board, and economic and social effects on Norwegian society are presented in a well-organized and vivid manner on the dedicated websites for the industrial heritage of Ekofisk, Frigg, Statfjord, and Valhall.[23]

Presentations in the form of editorial texts are used as a gateway to understanding how field installations, workplaces, important historical events, and the economic and social consequences for each field have developed. Around 250 articles were written for each project, many accompanied by linked media elements (photography, film, drawings, etc.) drawing on the original source material in the databases. The researchers at the museum have written the majority of these articles, although some were written by specially commissioned external experts when there was a requirement to cover special disciplines or technologies beyond the scope of NPM's expertise.

All of the editorial presentations except for those of the Ekofisk project have been translated from Norwegian into English.

All of the industrial heritage project websites can be accessed from the NPM site.[24] The websites are usually organized around six main themes:

- the field: geology and the reservoir, production strategy, transport solutions
- installations: platforms, subsea templates, pipelines (see Figure 5)
- timeline of key events
- the production process: work and leisure
- economy and society: value, technology, impact on subcontractors, politics, etc.
- search function for the databases

None of the industrial heritage websites are alike, even though they have been created using the same general pattern. The museum has tried to give each website a special focus: The Ekofisk site focused on the technology, the jobs, and the people that made the history. The Frigg project focused more on the cooperation between the workers and the technology and the fact that the gas field was on the border between Norway and the United Kingdom. For the Statfjord industrial heritage project, we looked more at the fabrication of the installations and Norwegian influence. Of course, the special geology of each field caused different challenges for the operating companies. The cultures of the operating companies were also looked at, and the American (Ekofisk), French (Elf/Total) and Norwegian (Statoil) companies were given special attention in the projects.

Conclusion

In our roles as creators and distributors of knowledge about Norway's oil heritage, we regularly ask ourselves whether these projects are fulfilling their aims. We are aware of projects such as the Historic American Buildings Survey/Historic American Engineering Record in the United States and Völklingen Ironworks in Germany, but their focus is mainly on the visible buildings and artifacts.[25] Our projects focus on the intangible heritage and are already proving fruitful for both researchers and the general public and are more in line with the website of the Branobel History.[26]

The most important task is to select and preserve materials concerning this important period of Norwegian history for future generations. In this regard we are confident that the projects are successful.

For the task of public dissemination of information on each specific oil field project, each website launch is accompanied by a temporary exhibition at the museum (Figure 7). Previous exhibitions have been popular, and visitor traffic to the websites has been encouragingly high (see Table 3).

We do not monitor the sites for cultural heritage, but we know from inquiries that many journalists from newspapers, television, and radio have used the sites. Students from universities, colleges, and high schools have also approached the museum to find relevant information for

7.
Photo from the exhibition introducing the Industrial Heritage Frigg. Photo Jan A. Tjemsland/ Norwegian Petroleum Museum.

Table 3.
Visitors to industrial heritage websites. A dash (—) indicates the site was not yet in operation for
a particular year.

Site	Visitors							
	2009	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Ekofisk	13,847	31,683	32,149	33,145	27,571	20,967	16,801	12,996
Frigg	7,824	13,282	10,951	9,167	7,200	7,019	5,861	4,121
Statfjord	—	—	—	1,041	5,478	5,098	1,725	1,066
Valhall	—	—	—	—	—	—	2,533	7,782
Total	21,671	44,965	43,100	43,353	40,249	33,084	26,920	25,965

theses of different kinds. Some textbooks also cite information from the sites, including a Norway history series from 2011, *Norvegr*.[27]

Documentation projects have been presented at several conferences for technology history: The Society for the History of Technology, The International Committee for the Conservation of the Industrial Heritage, Tekna (the Norwegian Society of Graduate Technical and Scientific Professionals), Norwegian Technical Museum, and Capturing the Energy (Scotland). In connection

with the Frigg project, we collaborated with the University of Aberdeen, which has largely used our method but on a smaller scale since they documented only one platform.

We have also been working with the Norwegian Water Resources and Energy Directorate for their four books on different types of cultural heritage items. Our way of documenting major industrial monuments has been presented to Norsk Vegmuseum (Norwegian Road Museum), which also has plans to document large-scale issues. In the fall of 2015 the Norwegian Petroleum Museum cohosted a conference on documenting health institutions in Norway.

Thus, the Norwegian Petroleum Museum's approach to collecting and presenting the heritage of large oil- and gas-producing fields on the Norwegian continental shelf can be useful for others. Nevertheless, for everyone it will be a challenge to cope with the technology of the computing world. Systems and technology change very rapidly, and to be able to preserve the websites, it is important to find the most likely durable solutions for digitalization and presentation. This choice, of course, also limits the fanciest ways to present the available material. Finding good solutions is very valuable. It makes it possible to have historical material visible on the Internet—today, many young people claim that what is not on the net does not exist.

However, we have plans to continue producing industrial heritage projects for a long time. The outcomes of such projects, made accessible through the Internet, constitute important digital national memories of how the exploitation of black gold has shaped modern Norway.

Notes

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The Balance between Recent Heritage and Ongoing Research
The Case of Jodrell Bank Observatory

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Introduction

Jodrell Bank Observatory is one of the world's most significant sites for radio astronomy. The site's signature is the 76-m-diameter Lovell Telescope, which dominates the Cheshire plains and embodies the particular challenges of Jodrell Bank. On the one hand, the telescope is an enormously historically significant artifact, famous for tracking Sputnik 1 in 1957 and carrying the United Kingdom's highest heritage status. On the other hand, it is a working telescope, part of a world-class research facility that operates 24 hours a day, 365 days a year.

Similar dualities can be found across the Jodrell Bank site, a unique landscape of the material record of postwar radio astronomy, but one whose primary raison d'être is continued astronomical research. Alongside the needs of the heritage and scientific communities there are those of a third group, public visitors, who have been an important part of Jodrell Bank's strategy since the 1960s.

Balancing the three distinct areas of activity at Jodrell Bank—scientific research, science heritage, and public engagement—has tended to operate on an informal, case-by-case basis in the past. However, with the opening of a dedicated Discovery Centre for public engagement in 2011 and in light of the recent death of Sir Bernard Lovell, the observatory's founder and first director, in 2012, a more formal approach is now being developed to the conservation and curation of equipment, layout, and artifacts either located at or related to Jodrell Bank.

In terms of contemporary collections, this essay sets out the challenges facing the authors, who are taking the lead on establishing the curation and conservation of the heritage of Jodrell Bank and balancing this with the other two activities that are central to its identity. We begin by providing some background on the site, discuss the challenges posed by each of the three main strands of activity, and conclude with a summary of the position at this early stage.

Background

JODRELL BANK AND THE DEVELOPMENT OF RADIO ASTRONOMY

"At the time of the outbreak of the European War in September 1939, radio astronomy did not exist as a viable astronomical subject," wrote Sir Bernard Lovell in his review of the development of radio astronomy in the United Kingdom.[1] Extraterrestrial radio waves had been discovered by Karl Jansky in the United States in the early 1930s, but Grote Reber, also in the United States, carried out the only other noteworthy attempts of any measurement of these waves during that decade. This led Woody Sullivan, in his comprehensive account of the early years of radio astronomy, to claim that "the independent wartime discoveries in England of extra-terrestrial radio waves meant that the post-war course of radio astronomy around the world would undoubtedly have proceeded much as it did even if Jansky and Reber had never made their discoveries."[2]

As Sullivan describes, work on radar during World War II led directly to the development of the four world-leading radio astronomy groups in the postwar decade: Cambridge (led by Martin Ryle), Sydney (led by Edward G. Bowen and Joseph L. Pawsey), the British Army Operational Research Group at Richmond Park and later at Malvern, Worcestershire (led by James S. Hey), and Bernard Lovell's group at Jodrell Bank.

Lovell, fresh from his wartime work on the development of H2S radar, arrived at the botany huts on the University of Manchester's botanical grounds at Jodrell Bank in December 1945, seeking a rural site free from radio interference to use his ex-army radar equipment.[3] The site, located in a rural area of Cheshire East in open countryside and surrounded by agricultural land, proved well suited to his purposes.

Lovell's original 1945 observations were designed to detect radar echoes from the atmospheric ionized trails of cosmic rays, but he soon realized that the echoes they detected were actually from meteors. This discovery led to a major investigation of their properties and origins.[4]

In order to detect weaker echoes from cosmic ray trails, in 1947 Lovell's team built what was then the world's largest telescope, the 218-foot Transit Telescope, a fixed mesh bowl that pointed toward the zenith. This instrument turned out to be ideal for detecting radio waves from the Milky Way and beyond, shifting Jodrell Bank's focus of research from studies of relatively nearby phenomena, such as the radar work on meteors, to what soon became known as radio astronomy: the study of the wider universe.[5] Lovell's colleague Hanbury Brown, together with

Cyril Hazard, used the Transit Telescope to detect radio waves from the Andromeda galaxy (the first known extragalactic radio source) and the remnant of Tycho's supernova, not seen since the 1570s.[6] Although it was demolished in the 1960s, traces of this telescope remain alongside its control building ("Park Royal"), later used as the control building for the Mark II Telescope (see below).

The success of the Transit Telescope demonstrated the importance of dishes with a large collecting area, so plans were made for an even larger, but fully steerable, instrument. Construction of the Mark I Telescope began in 1952. When completed in 1957, it was the world's largest telescope, taking over from the Transit Telescope.[7] Its first scientific act was to track by radar the carrier rocket of Sputnik 1. It was then the only instrument in the world capable of doing so.[8] With various modifications, including new surfaces in 1971 and 2002, the Mark I, now known as the Lovell Telescope, is still the third largest fully steerable telescope in the world.

From the early 1950s into the 1960s, first Hanbury Brown and then others at Jodrell Bank, including Roger Jennison and Henry Palmer, developed the technique of long-baseline radio-linked interferometry.[9] This development was a response to the problem of determining the angular sizes of radio sources discovered in large sky surveys. Individual radio telescopes operate at long wavelengths and hence have poor resolving power, a rather blurred view. The larger the telescope is, the better this resolution is and the sharper the view is, but it was not possible (nor is it now) to build a single dish much larger than the Mark I radio telescope at Jodrell Bank. The solution was to combine signals from pairs of separated telescopes or antennas in an interferometer. The angular resolution could then be improved to that of a virtual telescope whose diameter was equal to the separation of the most widely spaced elements of the interferometer. The Jodrell group concentrated on the longest separations (or baselines) and highest angular resolutions by taking mobile antennas to remote locations across the country and bringing their signals back to Jodrell Bank with radio links. This work played a key role in identifying many of the radio sources as quasars, distant galaxies powered by supermassive black holes.

The developments of long-baseline interferometry have continued to the present day with the e-MERLIN network, an array of seven radio telescopes across the United Kingdom initially connected by radio links and now by optical fibers. This array includes the Lovell and Mark II telescopes. The signals from all seven telescopes are combined at Jodrell Bank, so that the array operates as if it is a single telescope 217 km in diameter, providing a resolving power similar to that of the Hubble Space Telescope. Even farther afield, Jodrell plays a major role in very long baseline interferometry (VLBI) networks linking radio telescopes across the planet and even into space.

Jodrell Bank also hosts the headquarters for the world's next great radio telescope, the Square Kilometre Array (SKA). With telescope sites in Australia and South Africa, SKA will be built on the principle of long-baseline interferometry using optical fibers connecting thousands of dishes and millions of other antennas. Hence, e-MERLIN is a pathfinder for this ambitious new global project, and the Jodrell group is leading work on signal and data transport for SKA.

THE SITE TODAY

Jodrell Bank's continuous use for radio astronomy from the subject's postwar rebirth in late 1945 to the present day has left a unique landscape. An indicative layout of the site is shown in Figure 1.

Jodrell Bank Site Layout

A : Botany huts
B : Powerhouse
C : Remains searchlight meteor aerial
D : Site of 218ft Transit Telescope
E : Park Royal building
F : Remains meteor radar groundplane
G : Hut for Moon research
H : Hut for meteor research
I : Blackett's hut for magnetism research
J : Remains polar axis telescope
K : "Noise" hut for scintillation/H-line research
L : Another original research hut
M : Original workshop
N : Original offices (including Lovell's), lecture room, library
O : Lovell Telescope
P : Original Control Building for Lovell Telescope

1.
Layout of the Jodrell Bank Observatory site (edged in red). Various current and heritage features are labeled. Courtesy of The University of Manchester.

Since Lovell set up his first experiment at the most southerly part of the 35-hectare site, activity has moved northward with many new instruments constructed across the site as the field of radio astronomy developed. Although much of the early equipment was demolished or reused in subsequent instruments, remains of some equipment still survive either above or below ground, as do the buildings in which the research took place. These remains have effectively laid down the history of the development of radio astronomy on the landscape, from its inception to the present day.

The most prominent feature of the observatory is the Lovell Telescope. At 76 m in diameter and standing 89 m high, it dominates the Cheshire plains (Figure 2). The original bowl of the telescope was made of welded mild steel sheets supported on a steel frame. The bowl tips in elevation on gear racks that were recycled from gun turrets of two warships, HMS *Royal Sovereign* and HMS *Revenge*, which were both decommissioned at the end of World War II. In 1971 a new

2.
The Lovell Telescope at Jodrell Bank viewed from the Roaches in the Peak District. The cathedrals in Liverpool can be seen on the skyline 40 miles away. Courtesy Anthony Holloway.

reflecting surface was installed above the original surface, and the support structure was significantly strengthened, including a new central track to support around half the weight of the bowl. This new surface was itself replaced in 2001–2002. Each upgrade has increased the capability of the telescope for scientific research.

Although the Lovell Telescope is the most publicly recognizable part of the Jodrell Bank site, it effectively represents the culmination of the work that went before it, and many other elements of the site are highly important in terms of its heritage. For example, the Mark II Telescope, built in 1964, was the first telescope in the world to be controlled by a digital computer.[10] The Mark II sits on the site of the 1947 Transit Telescope, which is no longer in existence, although traces of it remain below ground. The building known as Park Royal that housed the Transit Telescope's receivers was subsequently used as the control room for the Mark II. Remnants of the earliest meteor radar systems also remain on the site, as do the first significant buildings that marked its transition from a temporary field station to a long-term scientific establishment.

The site also includes the purpose-designed "Control building," which was conceived to oversee the Lovell Telescope and provide lab, reception, and office space for the burgeoning site. Today, this building is the hub of the UK e-MERLIN network. Alongside the control building is the office for the international headquarters of the Square Kilometre Array.

Challenges

DEVELOPING A CULTURE OF PRESERVATION AND CONSERVATION

Although Jodrell Bank is a leading heritage site for radio astronomy, it is first and foremost a working observatory, prioritizing current research over the preservation of early equipment or other artifacts generated in the process of developing the field. This prioritization has resulted in a "progression" of technologies moving northward across the site, as the scientists abandoned early experiments and moved into new space to build new equipment.

The fact that the site is wholly owned by the University of Manchester has ensured that traces of the early work carried out on the site, including some "archaeological" remnants of early equipment, still remain. The telescopes and equipment still in use at the site are covered by a meticulous maintenance regime. Existing buildings and infrastructure are repaired and developed as necessary, whereas new buildings, for example, the SKA headquarters and public Discovery Centre, are constructed. In order to ensure that the ongoing maintenance necessary to keep the site scientifically operational does not overwrite the historical material record, the site's custodians have sought formal heritage recognition for key apparatus and the site itself.

In 1987, the Mark I Telescope was renamed the Lovell Telescope in honor of its creator. It was given Grade 1 listing, the highest possible conservation status awarded in the United Kingdom, by the statutory conservation body Historic England in 1988. This step was the first toward

formalizing the preservation of the telescope and the first formal recognition of the importance of the site's heritage. The listing in the National Heritage List for England reads

> Radio Telescope. Built 1952–57. Designed by engineers Husband and Company of Sheffield to the requirements of Sir Bernard Lovell. Bowl of welded sheet steel, carried on a space frame of structural steel. Paraboloid bowl of 250 feet in diameter, with supporting lattice triangles to left and right of 180 feet high, braced to form a yoke under the bowl and mounted on a track of 2 concentric rails of an overall diameter of 353 feet. The Sir Bernard Lovell Telescope (formerly known as Mark I) was the largest fully steerable radio telescope in the world of its time.[11]

The Grade 1 listing describes just the telescope structure; however, in 2010, the University of Manchester applied for the site to be included on the United Kingdom's Tentative List for UNESCO World Heritage Site status.

The decision to do this was taken largely because of a growing awareness of the importance of the site in the development of radio astronomy and modern astronomy in general. The fact that the site has been in continual operation since 1945 has resulted in it being viewed almost exclusively as a working observatory. However, the celebration of the 50th anniversary of the Lovell Telescope in 2007, which gathered together many alumni of the site with international colleagues and incorporated a number of public events, stimulated a new appraisal of the historical importance of the site. We are fortunate that a few scientists and engineers from the early days of this field, including some at Jodrell Bank, are still able to augment existing records of its development, and a number of historical research activities are ongoing (including the work of Woody Sullivan as part of the National Radio Astronomy Observatory Archives).[12] There is a clear need to engage stakeholders, the wider public, and a younger generation in the heritage of science and its cultural contribution. Inscription of places such as Jodrell Bank as World Heritage Sites will undoubtedly help.

The application to place Jodrell Bank on the UK Tentative List occurred within the context of the heritage sector recognizing that it has not embraced the history and heritage of science to the extent that it has other areas of culture. For example, the International Council on Monuments and Sites (the advisory body of the World Heritage Committee for the implementation of the World Heritage Convention of UNESCO) designated the theme for the 2009 International Day for Monuments and Sites as "Heritage and Science," with the intention of promoting science as a new category of heritage.

Several other observatories are included on the Tentative Lists of Member States, but all are optical observatories. However, a number of radio astronomers are conducting exercises in research and communicating their heritage. Most notably, there is a working group of the International Astronomical Union devoted to historic radio astronomy whose aims include assembling and maintaining a master list of surviving historically significant radio telescopes and associated instrumentation found worldwide, coordinating and documenting the technical specifications and scientific achievements of these instruments, maintaining an ongoing bibliography of

publications on the history of radio astronomy, and monitoring other developments related to the history of radio astronomy (including the deaths of pioneering radio astronomers). A relevant activity of this group was the campaign to preserve the Karl Jansky monument at the former Bell Laboratories site in Holmdel, New Jersey, which is being sold to a commercial developer. This place is where extraterrestrial radio waves were first detected. We expect to work with this group over the coming years.[13]

The Jodrell Bank site was included in the UK Tentative List in 2011, and the authors are now completing subsequent steps in the process of moving the site to full UNESCO World Heritage Site listing.[14] The proposed listing will encompass the entire site and will include many areas and structures either now in disuse or that have new uses (for example, as workshops in former offices and storage in former lab space). In order to achieve this, the process required the preparation of a formal conservation management plan (CMP) and the creation of a formal site steering group including Historic England and the UK government's Department for Culture, Media & Sport (DCMS).

The first version of the CMP is now complete and is being updated with formal versions of the many maintenance and repair plans in place at Jodrell Bank. The CMP is also likely to require new measures that will recognize the importance of the heritage of the site alongside the ongoing research. The CMP will consider the way in which a successful World Heritage Site listing will affect the future development of the site, including any construction necessary for the future of the science on the site and the current ensemble of structures. It should be noted that continuous development of new facilities to conduct scientific research is an overarching feature of Jodrell Bank, and we expect this to be incorporated into the statement of outstanding universal value of the site required for World Heritage Site inscription.

The initial stages of this process have included constituting a governance group for the site as a whole. This group is currently internal to the university but does, for the first time, bring together all site users and support functions under a chair from the university's senior leadership team. This group establishes the first internal forum that discusses the state and use of the site as a whole, rather than more narrow groups concerned with specific functions or areas of activity. Consultation and communication activities have also been increased in parallel with this group, both internally and externally.

This phase is new for Jodrell Bank and requires a new communication regime for all those concerned with the use and conservation of the site. It has already required that staff, who would generally recycle components of equipment from one experiment into another, now consider whether equipment would be better conserved, which has both cost and sourcing implications and requires discussion with colleagues not usually involved in the decision. The communication regime extends beyond the people who work on site to the wider university and to Cheshire East Council, English Heritage, and the Department for Culture, Media & Sport and also, of course, includes the wider national and international community concerned with radio astronomy research and the heritage of science.

Balancing the Needs of Heritage and Scientific Research

Although these early steps in formalizing a culture of heritage preservation at the site are very positive, Jodrell Bank's custodians face a constant challenge in striking a balance between preserving and curating the site's heritage and the need to push forward the boundaries of world-leading radio astronomy research—the site's raison d'être.

In the past, this balance point has been found in an informal way on a case-by-case basis, for example, the installation of an entirely new reflecting surface, nested in the original 1950s surface, at the beginning of the 1970s. This second surface was itself replaced at the beginning of the 2000s. In all such engineering works on the Lovell Telescope, Jodrell Bank staff work closely with Historic England in cognizance of the Grade I listing of the telescope.

However, the need to establish a more formal framework for future planning was brought to the fore in the process of preparing the case for UNESCO World Heritage Site listing; UNESCO requires the site's custodians to express the importance of the site in terms of a number of attributes that encapsulate both the tangible and intangible elements that must be conserved in order to preserve important aspects for humanity. In identifying these attributes, the site's custodians were conscious that they must both preserve the remnants of the early science at the site and also safeguard the use of the site for astronomical research, recognizing that it has been in constant use for world-leading research since the inception of the field of radio astronomy.

Scientists at Jodrell Bank have been developing and testing new equipment and techniques since 1945, work that continues to this day. The ongoing and regularly changing nature of scientific research at the site is an intangible element and perhaps hard to conceptualize, but it is extremely significant since it gives the site its character, underlying and determining the physical structures (such as the Lovell Telescope) that exist and are most apparent. At Jodrell Bank, we take the position that enabling this continued activity is as important as preserving and conserving the site's material record.

At the time of writing, we have identified five attributes for Jodrell Bank, all of which must be taken into account:

1. Jodrell Bank's pivotal role in the development of the field of radio astronomy
2. the development of the field of radio astronomy in relation to the landscape of the Jodrell Bank site
3. Jodrell Bank's unique position as the home of the Lovell Telescope, an internationally iconic scientific structure
4. ongoing science at the site, which results in new scientific equipment and facilities constantly developing in parallel with the Lovell Telescope and the original control building and structures at the site
5. innovative public engagement with science, which has captured public imagination and has been a key feature of Jodrell Bank's activities since the Lovell Telescope first began working in 1957

As noted above, the Lovell Telescope is a particular case where balance must be carefully struck. The telescope is still in constant use, alone and as part of the United Kingdom's e-MERLIN network of radio telescopes, so the requirements of its Grade I listing must be constantly balanced against the requirements of the operation of a large scientific instrument, with all the maintenance and safety regulations that this entails. One small example of a tension that can emerge from this constant balancing occurred in the recent replacement of the elevators in the two towers supporting the bowl. These elevators are not open to the public and are used solely by engineers and scientists at Jodrell Bank during maintenance and for changing radio receivers. Clearly, it is important to have safe and reliable elevators, necessitating their replacement. However, in discussion with Historic England and local planning officers, it was important to retain as many features from the original elevators as possible in order to comply with the Grade I listing. For example, an original safety plate, stipulating the restriction on weight carried by the elevator in Imperial units (pounds and ounces) had to be replaced with an identical plate. However, the use of Imperial units does not comply with current health and safety regulations, which require the use of metric units. This meant that an additional plate, showing the weight limits in kilograms, also had to be displayed in the elevator. Similarly, the original panels of buttons for selecting floor, alarm, etc., were also transferred to the new elevators but were fitted on top of the new switching system so that the original appearance was retained. Although relatively minor, these items exemplify the extra measures that need to be taken to ensure that curation of heritage and the requirements of scientific research are balanced across the site.

The attributes of the site will be preserved via the implementation of a conservation management plan that will encompass not only the tangible heritage of the site (equipment, buildings, layout, etc.) but also the intangible heritage—in particular the ongoing science. The CMP, for example, includes a gazetteer of structures on the site, as well as detailed catalogs of equipment. However, the observatory also has comprehensive maintenance programs and records, which will now be categorized, additionally, as conservation practice (as well as ongoing engineering practice). Other records and archives of the history and heritage of the site will also be included in the CMP, including, for example, the National Jodrell Bank Archive (held by the University of Manchester's John Rylands Library), other archived material currently at Jodrell Bank, Pathé news footage, material in the North West Film Archive, etc.[15] The university is also planning an oral history project and an image collection project, both of which were launched in 2015, marking the 70th anniversary of the inception of the observatory.

The current and former scientists and engineers at Jodrell Bank are very supportive of these heritage plans, including recognition of balancing them with the demands of ongoing science. The radio astronomy community, at Jodrell Bank and beyond, has a great sense of pride in its history, and observatory staff members regard themselves as custodians of its heritage as well as contributors to its future.

Engaging the Public with Radio Astronomy and Its Heritage

There has been great media and public interest in Jodrell Bank since it first came to the public's awareness in the early 1950s.[16] Largely as a result of the development of the Lovell Telescope (as it is now known) and its role in the early space race, there has been considerable demand, which persists to this day, from the public for information about its work. Although this interest was originally focused on the site's scientific and engineering achievements, it now also contains an element focused solely on the site's heritage and its role in world events.

In the United Kingdom, scientists who receive public funding for their research are required to ensure that their work delivers "impact" for wider society, as well as pushing the frontiers of knowledge in their field. Impact includes economic and social benefit and, particularly, public engagement with science and engagement with school groups.[17]

Although public curiosity about science remains high, the challenge for science engagement professionals is to build confidence in engaging with science—particularly cutting-edge research of the sort carried out at Jodrell Bank—and reaching a broad demographic. The *Public Attitudes to Science 2014* report shows that more people do not feel informed about science (55%) than feel informed (45%). Breaking this down, young adults feel better informed than the average (51% feel informed versus 45% overall). However, more affluent people tend to feel more informed: half (51%) of ABC1s feel informed compared to a third (35%) of C2DEs.[18] Women are much less likely to feel informed than men (34% versus 56%); the same difference exists among young women and men aged 16–24.[19]

The report also found that there are no substantive differences in participation in science-related leisure or cultural activity either by gender or by age (within the adult population). However, other demographic differences suggest a certain type of person is more likely to take part in these sorts of activities, including the more affluent (80% of ABs have undertaken a science-related activity in the past year compared with 67% on average; among C2DEs, this drops to 55%). White people are also more likely than those from ethnic minorities to have done a science-related activity over this period (69% versus 51%). So although in some cases the lack of engagement reflects a lack of interest in the topics themselves, in others it reflects the fact that there are barriers to participation, a large number of which are cultural and social.

In 2011, the first phase of a new Discovery Centre was built with £3 million funding from the North West Development Agency and the European Regional Development Fund. The new center was designed to showcase current research and was so popular that an additional building was added in 2015. At the time of writing the center has around 160,000 visitors each year. Its core aim is to "inspire the scientists of the future" and to this end has a vibrant education program, which engages over 22,000 school pupils per year (with an aim to grow this to 30,000 over the next two years). The team at the new center have developed several new approaches to engaging the public with the research that is carried out at the site and is now piloting new ways of engaging the public with the site's heritage. Key to this outreach is finding

new ways to reach audiences that would not naturally gravitate toward either science or science heritage engagement.

The area of the site that is accessible to the public (and in which almost all of the public engagement is delivered) is distinct from the working area of the observatory, although the Lovell Telescope is visible from the Discovery Centre. As the observatory area is where the significant (immovable) heritage elements are located, the geography of the site allows the public engagement strand to be managed with minimal impact on either the research or the heritage. However, the blend of research and heritage is a key selling point for visitors to the site, and new engagement projects are making increasing use of the site's heritage and its material culture to attract new audiences.

Examples of approaches used to attract new audiences to Jodrell Bank include the hosting of the Live from Jodrell Bank and bluedot science-music festivals, which feature music as the main attraction but also include a science fair staffed by around 100 scientists who engage the public with their work. These festivals can attract 12,000 people per day, and demographic analysis of attendees shows that they are a good way of reaching new audiences.

Archive image and film related to the creation of both the observatory and the Lovell Telescope have been projected onto the telescope itself, reaching an event audience of around 6,000 people, most of whom would not normally engage with astronomy's heritage.

New galleries are planned in the next three to five years that will provide spaces in which the public can engage with the heritage of both the site and the emergence of modern multiwavelength astronomy that began with radio astronomy. It is now routine for astronomers to use terrestrial and space telescopes that observe across the electromagnetic spectrum, and it seems fitting that Jodrell Bank, which is a key location in this modern approach, should provide a hub for public engagement in this area. The new galleries, and associated events and education programs, will transfer the innovative public engagement techniques developed at the site into the treatment of this heritage.

Conclusions

The Jodrell Bank Observatory site is moving from an informal conservation regime to a framework that formalizes maintenance and preservation work, linking these to curation and interpretation of the site's heritage. This process was stimulated by the fiftieth anniversary of the Lovell Telescope in 2007, the redevelopment of facilities for public engagement, and the subsequent move toward UNESCO World Heritage Site listing. In the future, Jodrell Bank's scientific priorities will be balanced with heritage priorities, and a growing preservation culture will be built within the staff group. The site as a whole will be included in the preparation of a conservation management plan, and its heritage will be interpreted in a new exhibition, which will be housed in new purpose-built galleries.

The heritage approach to Jodrell Bank is in its infancy, and changing the working culture of the site has already required much consultation and discussion. However, we have found that

working astronomers have a keen interest in their heritage and are embracing ways of preserving the historical record while continuing to use and develop world-leading technologies. This balance of heritage and current research is also finding its way into our public engagement program. We hope that this transition will ensure that the heritage of the emergence of radio astronomy at Jodrell Bank, effectively the start of modern multiwavelength astrophysics, is protected and celebrated alongside its world-leading research for many decades to come.

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Alternative Approaches

Against Method

A Story-Based Approach to Acquiring Artifacts from Nobel Laureates

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Those are my principles, and if you don't like them . . . well, I have others.

—*Groucho Marx*

The Nobel Museum in Stockholm opened to the public in 2001. Today, 16 years later, the museum holds a fantastic collection spanning all Nobel Prize categories, including peace, literature, and economics.[1] The stories behind each artifact bind the collection together. We endeavor to interview each donor, and in many cases, the stories we collect are even more important than the artifacts themselves. But is there or should there be a standard policy or method for collecting artifacts related to modern science?

Before I try to give my view on this question, let me give a few examples from the process of establishing the Nobel Museum in Stockholm, Sweden. In 2000, we were working intensively to acquire objects with which to fill the new museum. True to our cultural heritage, we turned to a famous Swedish children's book by Astrid Lindgren, *Pippi Longstocking*, for inspiration (Figure 1).[2] In one of the book's episodes the main character, Pippi (who by nature is incredibly strong but also kind and fair), comes to an agreement with her two young friends that they should devote themselves to collecting interesting objects. What's more, Pippi even invents a word for their newfound endeavor. They shall become *sakletare* (that is to say, "thing-finder"), she

1.
Illustration from *Pippi Longstocking*. © Astrid Lindgren/Ingrid Vang Nyman/Saltkråkan AB.

declares. Anything they find lying on the ground is fair game. Their hunt for physical objects yields rusty tin cans, bottles, and the like but also takes a somewhat unexpected turn when Pippi tries to lay claim to a man whom she finds lying on the grass, sunning himself.

The upshot was that the daring nature of Pippi's artifact hunting became an example for us to aspire to. Thus emboldened, we summoned the courage to contact Nobel laureates and their relatives as we began what was an artifact hunt of global proportions.

And search far and wide we did! Although we did not set out to acquire a particular type of object, we did decide to concentrate on a small group of selected laureates. The collected artifacts came to play an important role in our storytelling. We wanted to make our stories as rich and multifaceted as possible and so gave the involved curators largely free rein to develop "their" stories using their own imaginations. As long as the artifacts fit through the doorway, they didn't cause the floor to collapse under their weight, and we had room for them inside the museum building, we imposed no other restriction. We also worked to create combinations of artifacts, films, photographs and archival materials. Adopting such a broad-minded approach also meant that we received a wide array of artifacts. If a plate from the dining hall at Cornell University meant something to Richard Feynman (physics, 1965), then we tracked one down.[3]

Naturally, many of the objects we acquired came from the laboratories of Nobel laureates working in the sciences. One of the problems we faced was that many objects used by modern science are not self-explanatory. On one occasion we visited the European Organization for Nuclear Research (CERN), where we were presented with (among other things) a light conductor made from acrylic plastic (Figure 2).
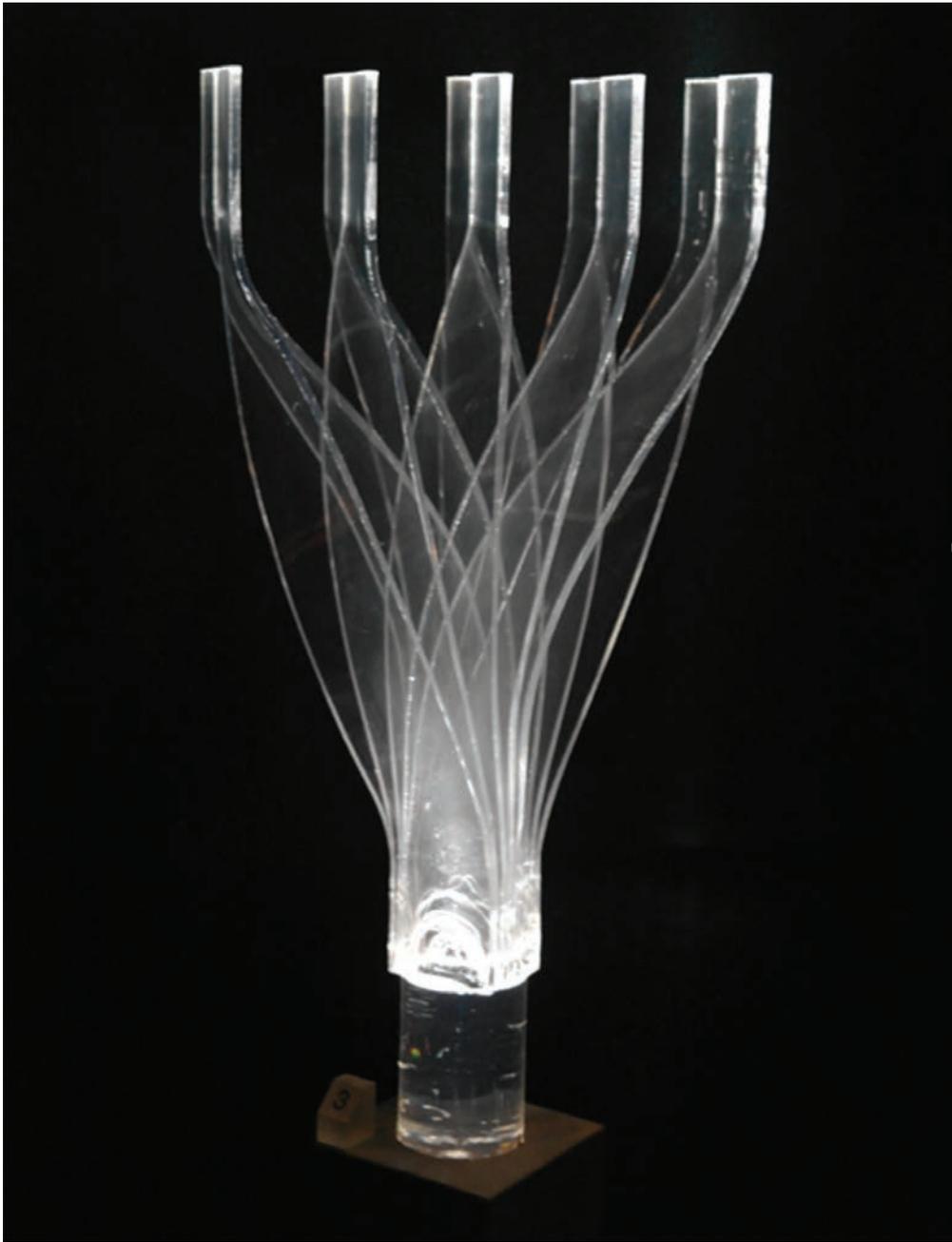
2.
Light conductor in acrylic plastic from CERN. Photo by the author.

When boarding the plane to Stockholm at Geneva Airport, we carried the conductor on board with us, and naturally enough, the cabin staff wondered what it was. My predecessor, Professor Svante Lindqvist, told them it was a trophy. He claimed we were the National Swedish Mixed Bowling Team and that we had just won the European Championship. The light conductor was our first-prize trophy. This fanciful explanation turned out to have an unexpected

consequence: the entire "team" was served champagne and congratulated on our sporting achievement!

In truth, this is not just a funny story but also well illustrates the problems involved in trying to collect modern scientific artifacts and, thereby, also the kinds of problem we faced when trying to collect objects for the Nobel Museum. The story that accompanies an artifact is just as important as the artifact itself and must be verifiable to maintain a collection's high standard.

Here is another example to illustrate my point. Russian physicist Pyotr Kapitsa (Figure 3) was awarded a Nobel Prize in 1978 for his work in the field of low-temperature physics. Kapitsa conducted his prize-winning work at Cambridge in the 1930s. A critical problem at the time, of course, was being able to achieve sufficiently low temperatures to conduct these studies. Among the apparatuses Kapitsa invented to enable his research was what is known as a helium liquefier. Although we were not able to acquire the original apparatus, with the help of Kapitsa's son we were able to make contact with the instrument maker who had worked in his father's laboratory, and he offered to make us a helium liquefier (Figure 4). A related "artifact" that turned out to be a very valuable find for us was a film in which Kapitsa demonstrates how his apparatus functions. This kind of combination of film, images, and objects was exactly what we were looking for. The fact that this particular helium liquefier was newly manufactured was of no consequence at all.
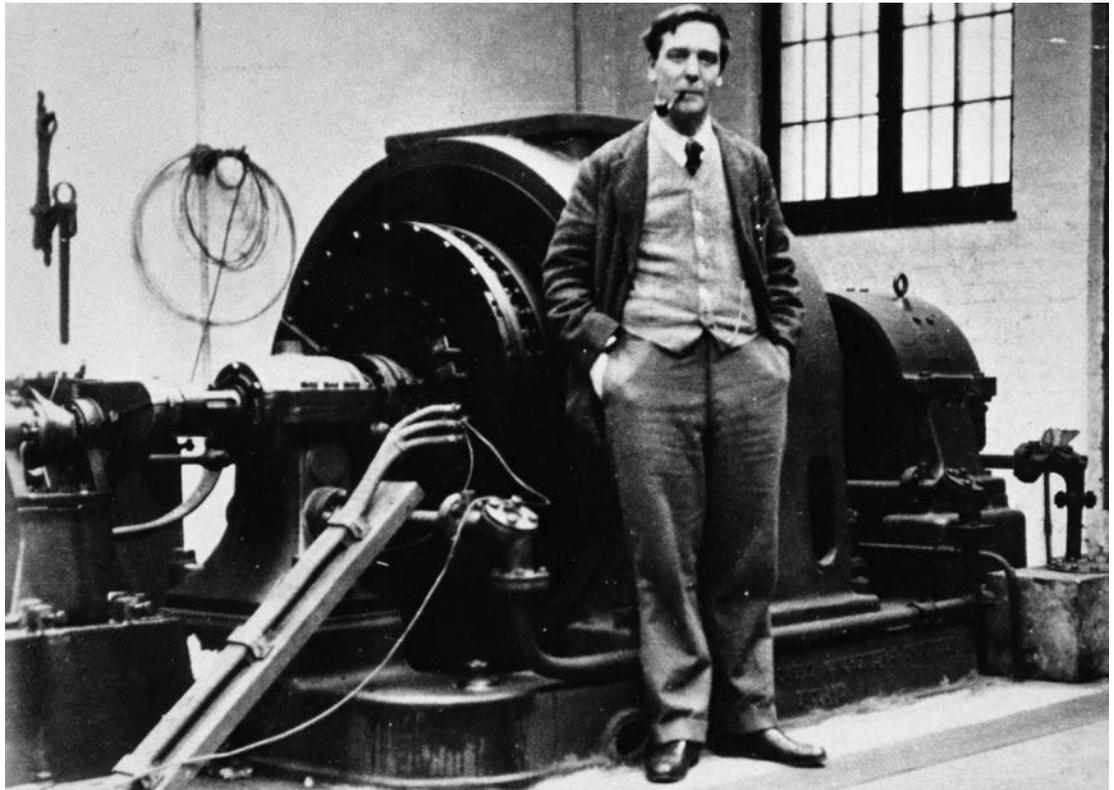
3.
Pyotr Kapitsa in his laboratory in Cambridge, around 1930. Emilio Segré Visual Archives, Margrethe Bohr Collection.

4.
Part from Pyotr Kapitsa's helium liquefier. Photo by Gabriel Hildebrand, Nobel Museum.

There is a footnote to this story. In the end we were forced to smuggle the instrument out of Russia to get it home safely to the museum, a fact that makes the tale we tell about Kapitsa richer and also says something about the situation in Russia in the late 1990s.

Our primary task is to disseminate information about the Nobel Prize and the work of Nobel laureates. In our work we strongly emphasize the pedagogical, popular scientific side of the prize. Collecting artifacts through which to portray the material culture of scientific fields is not an explicit part of our mission. In practice, however, it often becomes an unintended consequence of long-term projects, for example, in charting the progress of nuclear physics.

Just as important are examples of artifacts that were not especially difficult to comprehend. We are often inclined to associate modern science with large, mysterious machines. I suggest, however, that the opposite is at least equally true. An object simple in nature is often equally well suited to complementing the explanation of a recent scientific achievement. For example, the discovery of *Helicobacter pylori* (the bacterium that causes gastric ulcers), for which Barry Marshall and Robin Warren received the 2005 Nobel Prize in Physiology or Medicine, involved a pivotal experiment in which Marshall tested the bacterium's potency and ability to survive in the stomach by drinking a solution with the bacterium. Marshall fell seriously ill and developed gastric ulcers

5.
Artifacts from Barry Marshall: glass jars, comic book, tie. Photo by Gabriel Hildebrand, Nobel Museum.

as a result. The bacteria were able to multiply, thereby proving that *H. pylori* is able to survive the harsh environment inside the human stomach. The Nobel Museum was later donated the beaker from which Marshall drank the bacterial culture. It is a fantastic artifact that contributes enormously to our telling of the story of Marshall's discovery and his Nobel Prize. Although the beaker itself may seem a very simple object, it is, nonetheless, an indispensable tool in almost every laboratory in the world and is a very fitting artifact to add to our collection. Barry Marshall's discovery has also been retold as a comic book, which, naturally, we have also added to our collection. In addition, we have also included a necktie decorated with a *H. pylori* bacterium motif, which Marshall wore to a reception held in connection with the 2005 Nobel festivities (Figure 5).

A similar example is that of laureate Osamu Shimomura, who was awarded the 2008 Nobel Prize in Chemistry for the discovery and development of green fluorescent protein (GFP), together with two American scientists: Martin Chalfie of Columbia University and Roger Tsien of the University of California, San Diego. Today, GFP is widely used for many different types of applications. Proteins are marked by adding the fluorescent protein to the original DNA chain, thereby creating a simple method for tracing different proteins in the body.

The protein was discovered and later harvested by collecting thousands of luminous jellyfish from which it was extracted. Shimomura involved his whole family and even friends and acquaintances in his harvesting work. New tools were required to permit harvesting GFP effectively. Shimomura constructed nets to catch the jellyfish and a special cutting machine with which he could cut off their edges, where the protein was located. The separation process itself required little more than off-the-shelf technology to perform. What was special about it was Shimomura's dogged determination to harvest the jellyfish and isolate the protein chain responsible for their luminous quality. Although the work required only simple tools, they proved to be crucial to his success.

Shimomura personally picked out items to donate to the Nobel Museum that he feels best illustrate his work. These include plastic jugs and rudimentary nets that his family members and colleagues used in their hunt for the jellyfish (Figure 6). Shimomura provided his own in-depth explanation of his work in the Nobel Lecture he gave during the 2008 Nobel Week. In the introduction to his lecture, Shimomura held up a test tube filled with the GFP extracted from 20,000 jellyfish (Figure 7). This test tube and its contents now form part of the Nobel Museum's collection. Once again, the combination of artifact and story proved to be a winning formula.

Finally, there is an experiment replica from the time of radioactivity's infancy. In choosing this particular example, I acknowledge that I may digress somewhat from what is genuinely "modern science," but I feel passionate about this replica of the Curies' laboratory, which we displayed to the public in 2012. And I do believe that passion is a very important criterion when selecting what to present and what to omit.

In discovering the elements radium and polonium, Pierre and Marie Curie (Nobel Prize in Physics, 1903; Marie Curie received

6.
Net for catching jellyfish, made by Osamu Shimomura and his family. Photo by Gabriel Hildebrand, Nobel Museum.
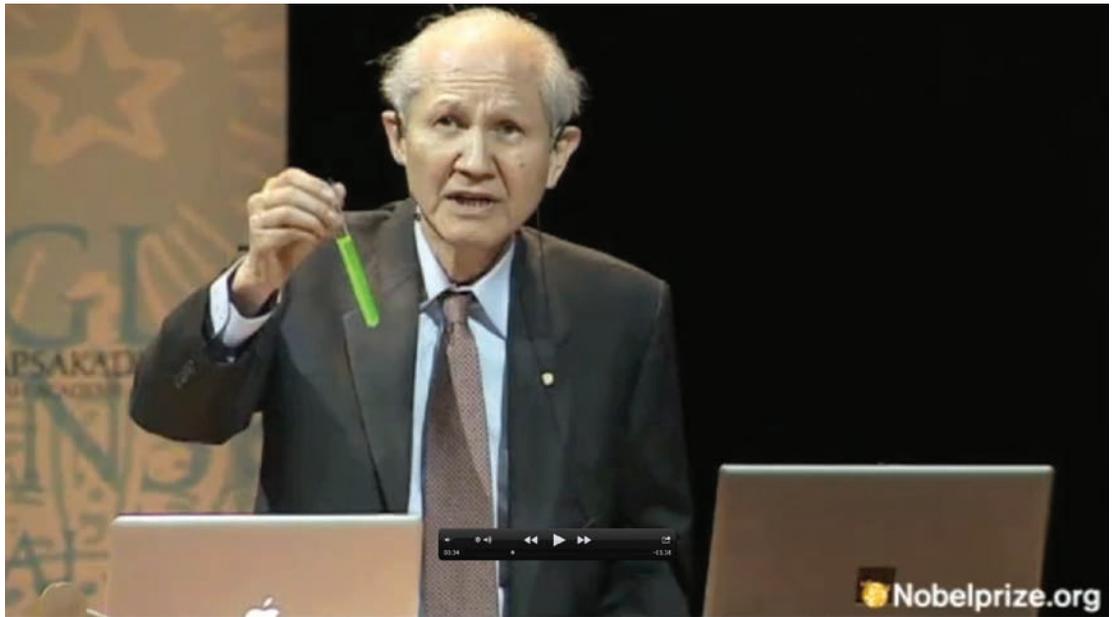
7.
Osamu Shimomura displaying a test tube with GFP protein made from 20,000 jellyfish during his Nobel Lecture in December 2008, Nobel Media, image from film, Shimomura's Nobel Lecture, December 8, 2008.

a second Nobel Prize, for chemistry, in 1911) used a set of equipment consisting of an electrometer, an ionization chamber, a piezoelectric balance, and a stopwatch. They were attempting to discover a way to measure the strength of the radioactivity emitted by different elements. There were no Geiger counters at that time, so the pair was forced to find an indirect way to measure radiation.

Previously, Pierre had worked on developing a new type of electrometer, a quadrant electrometer, capable of measuring low voltages with extreme precision. The pair had come to understand that radioactivity affected the conductivity of air in approximately the same way salt in a saline solution does when two metals are present (i.e., the ions migrate). They constructed an ionization chamber, inside which radioactive compounds were positioned between two plates. This setup allowed them to confirm that a weak charge was generated between the plates in the ionization chamber when a radioactive substance was present. They still had difficulty measuring the magnitude of the radiation. The trick proved to be supplementing the equipment with a piezoelectric balance, which emitted a voltage directly proportionate to the pressure its plate was exposed to. By connecting the piezoelectric balance to the electrometer, the charges from the balance and the chamber soon canceled one another out. The pressure created by a weight was then removed from the balance's plate, and the Curies measured the time it took for the charge generated inside the chamber to cause the electrometer's needle to return to its original position. Thus, time became a relative gauge of the strength of the radiation emitted (Figure 8).

We recreated this very elegant experiment at the Nobel Museum under the supervision of the brilliant technician and amateur historian Bernard Pigelet. Our experiment deviated
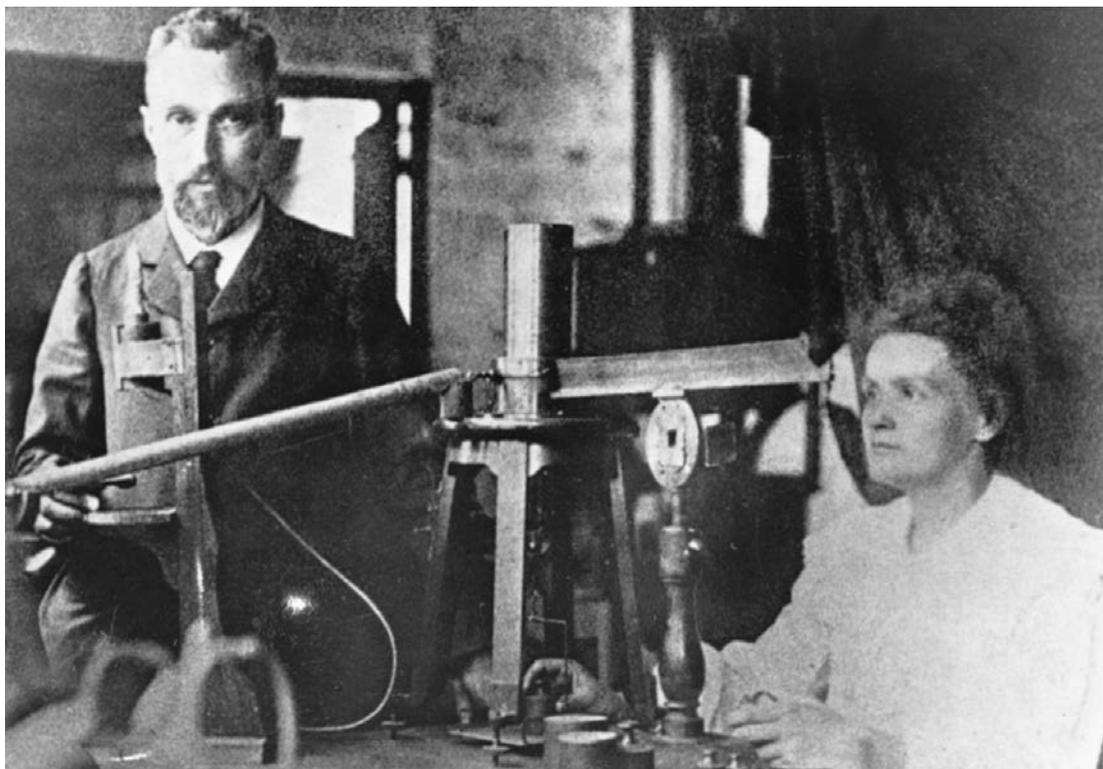
8.
Pierre and Marie Curie working with the experiment they constructed in order to measure radioactivity. Marie Curie is removing a weight from a piezoelectric balance and is controlling a stop watch with her left hand. Image courtesy Musée Curie (coll. ACJC–Archives Curie et Joliot-Curie), Paris.

somewhat from the original. We used a laser beam to channel light toward the mirror attached to the electrometer. In all likelihood, Marie Curie used a carbon filament lamp and a lens. The batteries used to generate the basic voltage in the ionization chamber and electrometer were also of a different type than the lead accumulator used by Curie. Nevertheless, the instruments are, in principle, the same as Curie's, and the original instruments were also on display in the same room. With the help of an installation constructed using fully functional replicas, we were able to explain effectively a concept that is highly abstract (Figure 9).[4]

Now to my conclusions.[5] In Sweden there has long existed an organization that supports contemporary studies and collecting by museums. It is best known by its acronym, SAMDOK, short for *samtidsdokumentation* ("contemporary documentation"); SAMDOK's international equivalent is the International Committee for Collecting, which is one of many committees under the International Council of Museums.

For many years, SAMDOK has done excellent work in organizing and promoting the active collection of contemporary materials, but as a researcher I have often reacted negatively to its tendency to want to establish a common policy or standard for collecting contemporary materials. This focus began with the shift to computerized records and was in the form of standard forms that required filling in specific well-defined fields. Conferences were held on what should be

9.
Ionization chamber used by Marie and Pierre Curie. Photo by Gabriel Hildebrand, Nobel Museum.

collected. As I listened to these discussions, I always had a strong sense that, in fact, they were more focused on deciding what not to collect. In my opinion, this is a dangerous path to take. In truth, we can know nothing of the future. What future museologists, researchers, and the general public will want to know about our time is not something we can or should decide. The day we establish standardized rules for what and how we should document our era is the day we plot a dangerous course, the day when our collections will begin to tell the story of our rules rather than anything of use or substance.

I do not mean to suggest that collecting should be mindless. On the contrary, freedom always demands responsibility, and no matter which path we choose, it will become meaningful only once we attempt to explain it. Provenance has always been an important concept when speaking about artifacts. But such descriptions reveal nothing about the collector's motives for including the particular piece in a collection. No motive is too banal. Did the collector simply think it beautiful? Had it just become too old and worn to be used any longer and so was removed from service and donated to a museum collection? This is the only occasion on which I advocate the application of a rule or principle. Yes, in fact, the only principle that not even Groucho Marx

can move me to relinquish: Explain! Tell us why you felt that this particular object was worth saving. Otherwise, I hope to see every kind of collection imaginable composed for reasons of which we cannot even conceive.

No, in this context I am convinced that methods, rules, and regulations are obstacles. Each example of the ways in which different institutions tackle this problem is inspirational and exciting to hear about. However, for the sake of posterity, I would encourage us all simply to let a thousand blossoms bloom and to let the width of the doorway, the beauty of the color, or even the weight limit of the floor of your institution determine what is collected, as much as what we find interesting and fascinating at present. Contemporary motives are certainly interesting and will undoubtedly remain of interest to those who use our collections in the future. Documentation of every kind is invaluable in further heightening the value of modern science's material relics. Interviews, photographs, film, archival material, and suchlike are keys that help us understand a technique or manufacturing process. That said, do not allow a serious approach to stifle creativity or the desire to collect whatever strikes you or fits in with your own idea. Remember that archaeologists studying ancient civilizations often make their most fascinating discoveries in rubbish heaps.

Naturally, one might ask just how appropriate such a liberal approach to collecting is for modern science. Or could it perhaps be applied in all contexts? Technological development provides a good answer. Thanks to modern methods of analysis, objects that were previously considered to be of little value have taken on a completely new status in many collections. Our methods of reading historical objects are continually changing and developing, which reminds us of the importance of collecting less obviously interesting artifacts. Breadth, randomness, and variation are important, regardless of whether we are discussing older collections about science history or current collections of modern objects. The "epistemological anarchy" that Paul Feyerabend wrote about is well suited to our work of collecting artifacts, whether they be materials relating to Curie or to Shimomura. The same applies to the differences between the collections of large institutions and smaller collections (like the Nobel Museum, which I represent).

Another aspect worth considering is the unique situation of the Nobel Museum. This museum tells the stories of less than a thousand of the world's most talented people (in 2017 there were 911 Nobel laureates). It is a museum that celebrates excellence and where, in each case, failures and remarkable sidetracks are followed by success. A clear example of how we view ourselves is when, a few years ago, our marketing department printed T-shirts for our staff who were participating in a footrace. The shirts had the text "The Nobel Museum — We Only Have Winners" (athletically, however, we placed in the middle of the field).

I do not believe that the Nobel Museum, with the natural delimitations imposed by the subject areas and themes that can be tied to the Nobel Prize, Nobel laureates, and Alfred Nobel, is uniquely suitable for an open and tolerant collection policy. The stories we convey include people who have succeeded and failed, been praised and persecuted. Additionally, all the prize-winning research has not escaped reevaluation once the consequences of its application have been fully understood. Good examples of this include lobotomy, for which António Egas Moniz received

the 1949 medicine prize, and DDT, for which Paul Hermann Müller received the 1948 medicine prize. I would argue that having an open approach to what should be collected is applicable to all types of institutions, whether large or small and whether they collect success stories or present disaster scenarios.

Is our proximity to the individuals whose stories we are supposed to tell a problem? Yes, there is definitely a risk that we may overemphasize objects that tell the winner's stories. This issue is something we need to be very aware of. The fact that the laureates themselves often choose what they want to give to the museum and, additionally, tell us why they chose to donate just those objects means that we have a group of objects marked by vested interests. It is up to our docents to provide nuance to the picture and our curators to find objects that add perspective to the stories we tell, or indicate clearly that this is a particular Nobel laureate's version of what happened. In all honesty, we have yet to begin gathering the stories of the assistants and competitors, which are just as interesting.

Digital technology has provided us with completely new opportunities to work with our collections of artifacts. If collections are well organized and can be easily searched, then we can use them in many different ways, such as creating new and fascinating exhibitions in which artifacts can be brought together into new and unexpected combinations. These unique combinations can help us better understand a technique, a scientific culture, a creative work environment, or whatever it might be. In today's digital world we are also increasingly less restricted to our own collections. The current level of international collaboration between institutions is hardly likely to decrease. It will continue to grow and allow us to embrace a tremendously exciting future to which our collections will contribute enormous amounts of surprising information. For their users—whether exhibition visitors or researchers—the boundaries between different artifacts owned by different institutions will dissolve as an increasing amount of our material history becomes accessible via readily searchable digital media. This, too, speaks in favor of a policy-free approach to collecting.

The examples I have provided of how the Nobel Museum collects artifacts are most definitely not intended as a recommendation to others. No, I would advise against it. Instead, I encourage you to find your own creative approach. Our method works for us. In fact, I am passionate about our approach. Through our unmethodical method, in which the slightly anarchistic Pippi Longstocking serves as our role model, I am convinced that we, being good *sakletare* ("thing-finders"), will acquire a host of interesting artifacts both for our own use in future research and exhibition activities and for use by you.

Notes

The title of this chapter is borrowed from Paul Feyerabend's 1975 book *Against Method*. I do not claim to follow Feyerabend or otherwise subscribe to his philosophy, but his book has become iconic and the concept he introduced, epistemological anarchism, may prove useful in this context.

1. Our collections include artifacts, archival material, photographs, film footage, oral history, etc. In this text I will focus on the artifacts even though I believe the approach I describe is just as applicable to any other kind of collection, including those just mentioned.

2. Astrid Lindgren, *Pippi Långstrump* (Stockholm: Rabén & Sjögren, 1945); translated as *Pippi Longstocking* (New York: Viking, 1950).

3. The theme for our first exhibition was creativity and was entitled *Cultures of Creativity*. The selected laureates were intended to exemplify different categories of creativity and also to highlight the dichotomy between individual creativity and creative environments. Roughly 50 individual laureates and a dozen environments from all parts of the world were included.

4. The things we collect are not always placed on display and are not always creative. Whenever we bring something into our collection, a motivation or, rather, an explanation is written. Artifacts collected this way could very well be part of future, not yet envisaged projects, whether exhibitions or research projects. A consequence of having no policy for what we bring into our collections is that replicas are treated, in many respects, as originals and kept for posterity.

5. In relation to this matter, I take the opportunity to thank Matts Ramberg, head of the Collections Department at Sweden's Museum of Technology, who at a Society for the History of Technology conference held in Uppsala in 1992 argued that artifact collection should be as free and unrestricted as possible. His words made an impression on me, and I have found no reason to reevaluate the somewhat anarchistic approach for which he argued that day and which I quickly adopted as my own.

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CHAPTER 13

Hands-on Science Centers as Anticollections?

The Origins and Implications of the Exploratorium Exhibits Model

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In May 1969, "without so much as an announcement" to the public, the Exploratorium in San Francisco welcomed its first visitors: a pair of joggers who had wandered into the building by mistake during a marina-side run. These impromptu visitors "never slowed up," director Frank Oppenheimer noted, "they just went back and forth, and finally went through the curling path [from one exhibit to another] and out the door again." A relative stranger to the Bay area, Oppenheimer—a physicist and the brother of J. Robert Oppenheimer—envisioned the Palace of Fine Arts site on which his new museum sat as emblematic. The new institution, a New York Times reporter wrote, was a proper museum, connected to the long tradition of exhibition and public outreach, but it was also a novelty: "it was the first museum in the country to get the Unites States Department of Health, Education, and Welfare to recognize museums as educational institutions."[1] For the first exhibits Oppenheimer quite publically copped what might be described as an anticuratorial, or at the very least anticollections, attitude: he scrounged old, discarded physics lab equipment from Stanford and worked with designers to reassemble them into what he envisioned as a raw "woods of natural phenomena," to be explored in any order and at visitors' own pace.[2] San Francisco Chronicle science writer David Perlman later expressed some skepticism about such an open-minded—and

open-ended—approach: "I thought he was pretty far out. He talked about things I had never thought about in the context of a museum. I thought: This is never going to fly at all."[3]

In retrospect, the Exploratorium model had an enormous impact on both the nation's museum and science education communities. The Exploratorium's twinned values of informal learning and hands-on experience became the foundation on which many science and natural history museums have developed new relationships between content, pedagogy, and the objects on display within their walls. Institutions as far flung as children's museums and art museums all eventually adopted rhetoric and exhibition techniques that the Exploratorium pioneered.[4]

At the same time, the new antiestablishment museum embodied the ideological contradictions and practical problems of its leader's unique approach. Although the populist pedagogy of "no one flunks a museum" offered an enticing alternative to more traditional educational and display polemics, it did not, by itself, solidify the idealistic and almost naïve institutional consensus about science, museums, displays, and collecting to which it aspired. Although Oppenheimer's Exploratorium embodied a critique of existing formal school science education, it did not eschew existing modes of object-based learning. Finally, it sidestepped questions of where science and museum-based science education should fit into the Cold War's politically electrified culture.[5]

Historical understanding of these origins, in turn, might prove instructive for contemporary science museum collectors as they seek to understand and address contemporary public misunderstandings among visitors about both science education and the museum experience.[6] Neither object-centered nor collections-averse approaches by themselves can resolve these misunderstandings. The history of the Exploratorium, as explored through the vision of its director and the experiences of its exhibits staff with one specific exhibit, I argue, can provide some new starting points from which museums might begin to envision challenging collections: more specifically, by widening their conceptualization of the history of museum-based education and artifacts, they can consider hands-on exhibits (and the often invisible, behind-the-scenes work that went into them) more systematically in framing their own exhibits-driven, rather than curator research-driven, acquisition policies.[7]

Oppenheimer's Museum Synthesis: Object-Based, Antiexpert Pedagogy

Admirers have often suggested that Oppenheimer's methods were original and a product of his unique genius, but midcentury trends in science education and museum exhibit reform also strongly shaped his approach.[8] In the broadest historical context, his Exploratorium vision was a long-awaited realization of idealistic desires—voiced first by the Progressive museum educators who advocated visitor participation and, later on, by those biology teachers in the early 1950s who promoted science in action—to bridge divides between formal and informal learning.[9] Ultimately, Frank Oppenheimer's path to museums was circuitous, to say the least, but was

undoubtedly the product of his own personal and professional encounters with both progressive education and Cold War politics.

Frank initially turned to science at the urging of his more famous older sibling, Robert, who later admitted that his younger brother had a superior talent for "getting his hands dirty in the laboratory," but he left unwillingly as a result of purely political machinations.[10] After attending the Ethical Culture Fieldston School and obtaining a Ph.D. in experimental physics from the California Institute of Technology (Caltech), Frank took a basic research position at Stanford. Throughout World War II, the wiry young physicist worked with his brother on the Manhattan Project, and in 1947, he took his first regular academic appointment in physics at the University of Minnesota. But in 1949, three months from being awarded tenure, he was forced to resign from Minnesota under harassment from the FBI for his involvement with Berkeley's Youth Communist Party. Deeply disillusioned and unable to find work as a physicist, he left research science entirely.[11]

By 1959, with McCarthyism on the wane and attention to science education on the rise, Oppenheimer returned to higher education and took an appointment in the physics department at the University of Colorado, where pedagogical work allowed him (most easily, after years absent) to return to hands-on science. Specifically, he revamped the university's physics laboratory curriculum according to the most basic scientific and experimental principles in order to, he explained, give students "a sense of power to actually do something" in science and in life.[12] At the center of the new plan was what he called a "library of experiments": around 100 classic physics experimental models he used to teach physics first principles with hands-on, student-paced methods.[13] In 1958, he was invited to participate in a national curriculum reform project, the Physics Science Study Committee (PSCC), which aimed, in the words of one participant," to revise high school physics curricula according to the same ideas."[14]

Oppenheimer's desire to expand the reach of his successful object-based methods beyond the classroom came directly from his experience of the Cold War politics of science. "There is an increasing need to develop public understanding of science and technology . . . to bridge the gap between the experts and the layman," he declared, so that laymen could evaluate scientific arguments on their own merits.[15] But by the mid-1960s, he had become convinced that museums, even more than schools, offered the only place where a depoliticized version of this mutual educational engagement could occur. In 1965 Oppenheimer applied for and received a Guggenheim Fellowship;[16] although the fellowship was officially intended to fund the study of the history of physics at University College London, Oppenheimer instead took the year to explore various European science museums.[17]

From the beginning, Oppenheimer argued that museums might transform science education, not by eschewing objects and collections but rather by refiguring them—as earlier nature educators had—in the active service of student-centered learning. He believed, in the words of his PSCC colleagues Jerome Bruner and Jerrold Zacharias, that "the intellectual work of a research scientist and an elementary school pupil are essentially identical."[18]

Museums, he wrote, should therefore not display precious artifacts or peddle prepackaged scientific expertise; rather, they should allow visitors to "become familiar with science and technology and gain understanding by controlling its props," for "explaining science and technology without props can resemble an attempt to tell what it is like to swim without ever letting a person near the water."[19]

Challenges and Successes of the Exploratorium Model: Less Executive Driven, More Unity of Nature

The collection and exhibit-making challenges of this approach became immediately obvious. Moving beyond earlier pedagogical philosophies of science museums—where mere exposure to cutting-edge scientific knowledge, through spectacle or button pushing, often counted as an important and effective visitor experience—Oppenheimer insisted that the Exploratorium's displays embody a less "executive driven" style of science education. Nevertheless, he also strove to have visitors leave the Exploratorium with some "sense of the connectedness" of nature because (he would later argue) "one of the major accomplishments of science has been to demonstrate that there is a unity to the diversity of nature." He analogized the ideal science museum to a symphony, to which listeners (visitors) may not be able to explain and replicate the exact structure of the music but by experiencing it they know it exists and that is what gives them pleasure as well as comfort.[20]

The Exploratorium's initial organization and content reflected and carefully managed the tension between two core values, free-choice learning and unity-of-nature-driven pedagogy, and it involved objects but not artifacts. One of Oppenheimer's only rules for the new museum was that it should avoid "any reliance on the types of diorama displays," not because they contained objects but because they were too expensive and too static.[21] Instead, Exploratorium exhibits were to be works in progress, themselves experiments (at once in education and display) done with objects intended to be touched, broken, fixed, and improved by the fixing. The institution foregrounded this value by placing its so-called exhibits "shop" at the museum's entrance to convey, Oppenheimer wrote, a "sense of honesty . . . like restaurants that let customers see inside the kitchen — and with a sign that read: 'Here is Being Created the Exploratorium, a Community Museum Dedicated to Awareness.'"[22]

The Exploratorium's first few exhibits, which explored visual perception, were a succinct embodiment of Oppenheimer's vision.[23] He sought, in the words of philosopher and former Exploratorium employee Hilde Hein, to "teach the public (or rather…induce museum visitors to discover for themselves) how visual perception takes place and how it is modified by experience."[24] Thus, he included exhibits that "plunged visitors into a disorienting visual environment" by means of visual effects produced by visitors putting on glasses that reversed left and right or looking through binoculars with two different images (which causes eye-brain confusion,

vacillating between alternative interpretations of the signal or, if this cannot be accomplished, nausea) or viewing themselves through unusual lighting effects that encouraged the juxtaposition of multiple perspectives.

Just as the Exploratorium's exhibits departed from existing museum taxonomies of knowledge and hierarchies of expertise, so, too, did its educational programs dispense with traditional practices. Rather than providing docent-led tours, supplying miniature exhibits to schools, or setting aside a gallery to display student science projects, the museum instituted a Student Science Project Program. This program opened up the exhibits building shop to high school students working on projects for science fairs and encouraged them to work alongside the museum's own exhibit development teams. The museum also hired interested students to be "explainers," offering them training and a combination of academic credit and an hourly wage. Explainers also built and repaired exhibits, using the manual and mechanical skills that Oppenheimer believed so crucial to scientific discovery.[25]

Coinciding with other visual experiences of the late 1960s, from drug-induced psychedelic hallucinations to pop art, the Exploratorium's thematic focus on the science of perception was understandably popular with visitors. By emphasizing the visitor's interaction process, rather than standardized school curriculum or curator-created content, the museum's approach resonated with other countercultural trends of the late 1960s and early 1970s, among them, the celebration of individual choice and the challenge to spoon-fed knowledge (Figure 1 shows the floor in

1.
The Exploratorium's "open" floor, around 1975. © Exploratorium.

the 1970s).[26] Yet the Exploratorium also promised—and delivered—to scientists and educational policy makers a shared experience of something that was in many ways quite traditional and conservative: learning about well-established scientific ideas, methods, and first principles through object manipulation.

Notably, Oppenheimer insisted that visitors interact with exhibits and draw their own conclusions from what they encountered on the museum's floor, so he refused to provide the kind of obvious, even pedantic, narrative explanations that twentieth-century Americans had come to expect from more established museums' artifact-based displays. Oppenheimer contended that such lack of explanation led to closer observation. This, in turn, led to fascination, which, in turn, led to a more profound kind of commitment to learning. "If we do not tell people what they are supposed to find, many will leave with a sense of frustration, but a few will have become addicted to finding more than anybody knew was there," Oppenheimer reflected in 1976. This approach worked brilliantly for some visitors, but others, uncertain of what to make of the displays, found the museum's exhibits maddeningly opaque. But Oppenheimer refused to accommodate those who preferred their science predigested. "How many frustrated people is one addict worth? Since there is no going back if one gives away too much, we tend to lean toward [one] . . . answer to this arguable question," he explained. "And we do have a large number of addicts who come back for more."[27]

Oppenheimer's decision to cater to the hands-on museum "addicts" may have shocked some more conservative educators and museum professionals, but the Exploratorium's successes spawned imitation on a larger scale. In the decade between 1968 and 1978, the United States experienced what museum policy-maker Lee Kimche described as science museums' "greatest growth in ten years," as measured by the number of new institutions and the expansion of existing facilities. To mark their departure from traditional museum practices, many of these organizations came to adopt the moniker Dixy Lee Ray had coined in the late 1950s: "science center." Between 1973 and 1975, visits to science centers more than doubled, rising from 14.4 million visits per year to 36.5 million.[28] "There is no sign," Kimche observed, "that the trend will slow down soon." Kimche was hopeful that science centers' influence would ripple into schools, suggesting that teaching science through hands-on exploration might be "adapted to enhance more conventional methods of teaching."

Hands-on (Life) Science: (Re)modeling Exhibit Experimentation

Despite this success, the Exploratorium staff's subsequent efforts to expand their own style of displays in house, specifically, by displaying live animals and plants and having visitors interact with them, began to reveal the practical and political challenges of the Exploratorium's exhibits model. Although the new life science displays at the Exploratorium were hailed among some science educators as a "tour de force of exhibit construction," the labor-intensive logistics of

maintaining living artifacts and the inability to control visitors' interactions with and interpretations of them suggested that there were limits to the kind object-centered, open-ended pedagogy that Oppenheimer so passionately advocated.[29] Exploring these limits, as revealed in one particular archival case study of an exhibit, suggests why Exploratorium-style displays became influential models even while they did not become the panacea of Cold War science literacy that Oppenheimer had envisioned. Although hands-on exhibits are relatively common in science centers and atypical of science and technology museums, this example is illustrative of the new types of artifacts that I argue museums should consider collecting.

Shortly after the Exploratorium obtained its second National Science Foundation (NSF) grant, Oppenheimer hired Evelyn Shaw as the first curator of life science and charged her with developing hands-on biology displays. Shaw had extensive experience with live animals in museums: she worked in Gladwyn Kingsley Noble's old department (now renamed Animal Behavior) at the American Museum of Natural History. Oppenheimer offered her a chance to continue her scientific work (on marine animal biology) and to publicize her methods and results through exhibits in the Exploratorium.[30] In 1972, Shaw also hired a young Berkeley alumnus, Charlie Carlson, to assist her. Carlson was, temperamentally, a perfect fit: he was comfortable with interdisciplinarity, experimentation, and idealism—he had double majored in zoology and communications and embraced the creative culture of 1960s Berkeley—but he was also committed to making scientific concepts meaningful.[31]

Throughout the next several years, Shaw and Carlson together created a series of innovative interactive displays themed around animal behavior. Unlike earlier live animal displays in natural history and science museums, Shaw and Carlson's exhibits demanded more of visitors than just observing (under glass or in a distancing enclosure) or animal petting (as with popular live animal demonstrations in zoos and science museums); instead, following the Exploratorium's hands-on learning philosophy, they put the visitor in the role of an experimental scientist. In this way, Shaw and Carlson relocated a large measure of control of the animal-human interaction away from the exhibit designer or the educational demonstrator to the visitor.[32]

Perhaps the exhibit best illustrating Shaw and Carlson's approach was the *Watchful Grasshopper*, which featured a live grasshopper under a dome with wire electrodes inserted into its ventral nerve cord (Figure 2 shows an illustration from the *Exploratorium Cookbook*). This procedure, explained the signage, did not make the grasshopper uncomfortable and allowed visitors to explore the grasshopper's visual field, in order to determine what triggered impulses in the insect. The electrodes were hooked up to measuring devices that were also a part of the display: an oscilloscope, which recorded extracellular signals in the grasshopper's brain, and amplifying speakers, which allowed visitors to hear, not merely see, the oscilloscope's active "clicks." Shaw and Carlson imagined that when visitors moved in front of the animal's visual field, they could watch and hear the neural effects of the grasshopper watching them.

The relative sophistication of the grasshopper exhibit setup, combined with the fact that it featured a live animal, presented significant challenges for its creation and maintenance.
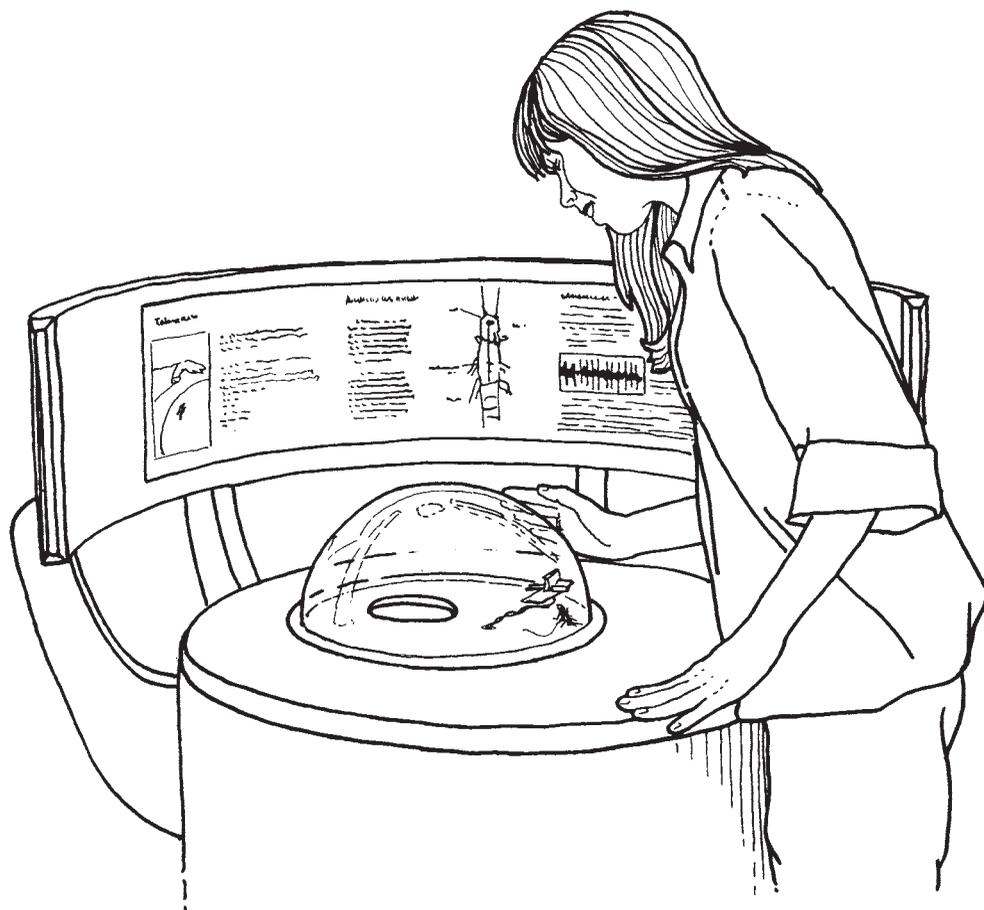
2.
A line drawing the Exploratorium's *Watchful Grasshopper* exhibit, taken from *Exploratorium Cookbook II* (1983).
© Exploratorium.

Although Carlson and Shaw settled quickly on *Schistocerca nitens* as the insect that would most clearly illustrate the relationship between neurological stimuli and animal behavior for visitors, *S. nitens*'s status as an agricultural pest in California meant that the insects were nearly impossible to acquire through commercial venues. This challenge forced staff members into temporary careers in grasshopper husbandry, breeding whatever grasshoppers would be used in the display. Exhibit builders promptly incorporated their newly acquired knowledge of grasshopper husbandry and anatomy into the exhibit. Carlson created a supplementary display explaining the grasshoppers' life cycle, featuring the museum's grasshopper colony and the exhibit designers' scientific knowledge of behavior and husbandry.[33]

Ironically, given Oppenheimer's dislike for putting expertise on display, the grasshopper exhibit also required museum staff to master the frustrating field of grasshopper surgery. Carlson read what he could on *S. nitens*, conducting his own intensive observations and experiments to learn how to insert electrodes into their ventral nerve cords, and then he taught his exhibit

support staff to do the same. This required considerable practice and skill. Grasshoppers were immobilized with dental wax—if they moved too much, they were anesthetized through 10 minutes of refrigeration—then placed under a dissecting microscope, and the electrode was implanted and tested. Finally, the preparator used a mixture of beeswax and rosin to cement the electrodes inside the animals. "If this preparation is carefully made without too much trauma to the animal," Carlson wrote, "it will last one week or more, up to a month, without noticeably affecting the behavior or health of the animal," a period of time already overextended staff members must have found short.[34] Graphics that accompanied the *Watchful Grasshopper* went to great pains to illustrate the delicate electrode implantation procedure, also emphasizing that it didn't hurt or permanently injure the insects.[35]

However, although popular with scientists, these displays did not draw the same response from the public: according to an in-house study, only approximately 5% of the Exploratorium's 560,000 annual visitors interacted with the living animal displays.[36] Furthermore, visitors drew conclusions about science and animal behavior from the museum's exhibits, but these conclusions were problematic: they didn't always echo those drawn by the Exploratorium's own staff and the broader scientific community. In 1981, for example, a local teacher (M. Clausen) lauded the Exploratorium as a "wonderful place for making people become aware of and excited by science" but noted that she found the *Watchful Grasshopper* downright disturbing. "Whatever the instructional value of such an exhibit it represents cruelty to animals and only encourages people to treat animals as playthings without feeling," she wrote to Oppenheimer. "I sincerely hope you will remove that torture chamber. I did not go through the animal behavior section after seeing the grasshopper in fear of seeing more of such disturbing sights."[37] Perhaps the museum could show a short animated film with sound to illustrate this phenomenon instead, she suggested.

Another visitor, Leelane Hines, also noted his discomfort with the exhibit, describing it as "counterproductive" and noting that "what we learn is not always what people think they are teaching." Rather than conveying information about animal behavior and neurological pathways, Hines argued, the exhibit propagated a reprehensible lesson: "when creatures are less than human, we, as superior more knowledgeable beings, need not treat them with respect or kindness. Lesser beings may freely be used for our own (scientific) (genetics) (self-defense) purposes."[38]

Oppenheimer himself sought to assuage these concerns, by explaining both the scientific methods and motivations behind Shaw and Carlson's life science displays, especially to a number of visitors who championed animal rights. In 1981, for example, he attempted to reassure an angry Henrietta Gennrich that the grasshoppers in the exhibit weren't receiving visitor-administered electrical shocks. "The live grasshopper that you saw was not hooked up to a shock stimulator!" he protested. "Fine, flexible wires were connected to the back of the grasshopper who lives very happily and can move around," but measurement was very different than torture, he explained. Still, he agreed, the exhibit could probably use some clarification. Going forward, he promised, "we will do everything we can to make it clear that we are showing that animals, as well as people,

transmit information by generating their own electricity and that this process is going on all the time in all of us."[39]

That said, because Oppenheimer sought to "show, not tell" about science and he had been burned by the politicization of science, the Exploratorium actively disavowed exhibits whose lessons could be easily applied to social issues. This curatorial mandate, although understandable given his Progressive educational philosophy and his personal experiences, ran counter to his institution's populist commitment to start from visitors' own questions and experiences. It also worked against the efforts of other more establishment museums to develop what Erminia Pedretti has called "critical exhibitions" that speak to the process and nature of science in sociocultural context.[40] Because Oppenheimer believed that the educational mission of his reformed museum "was not to give people the right answers . . . but to help them gain the confidence to make discoveries for themselves," he resisted staff and visitor calls to develop exhibits promoting environmental or popular cultural interests.[41] "We have to develop new tools to persuade people to act sensibly," he told a reporter in 1979, and "we don't have to rely on coercion. That is the meaning of a free society." Scientists, who believed their work to be largely apolitical, admired this stance, but museum publics—visitors and science educators—saw it as either naive or misguided. Science was necessarily political, some seemed to argue, and as such, science education should place scientific developments and discoveries in the broadest possible social and cultural context.[42] Other cultural commentators outside of the museum community disagreed. The Exploratorium was right to maintain a careful innocence, Lexington, Kentucky, reporter Walter Sullivan editorialized, for it was only this way it could demonstrate a "clean" message: "in science, there is also beauty and joy."[43]

More specifically, those visitors committed to animal rights were unconvinced by Oppenheimer's reasoning and not easily converted to his almost naive proscience perspective. In the case of the *Watchful Grasshopper* the comparison between animals and humans generated ethical controversy that actively disrupted the museum's pedagogical mission and methods. Visitor Muhaima Startt made this point explicit: she insisted that the Exploratorium would never conduct a similar experiment on a human being and, as a result, that the museum's life science exhibits were fundamentally incompatible with a broader respect for life in all its forms. "My simple point of view is that animals have their own things to do in their natural environment, and that should be respected," Startt wrote. If visitors wanted to experiment on something, she concluded, they would do better to experiment on themselves. "It may be of more learning to folks to have more tools for self-exploration available—the bicycle reading one's heartbeat and the simple EMG register are well thought through in this respect."[44] Ultimately, many Exploratorium visitors concluded that the museum prioritized scientific methods and discoveries over the preservation of biological life. Rather than teaching a simple scientific concept and drawing attention to the excitement of doing life science, as its designers had intended, the *Watchful Grasshopper* interaction with live animals through experimentation led museum visitors to reflect on the limits of science.

Conclusions: Reflections on the Implications of the Exploratorium Model for Collecting

Oppenheimer had argued (in a 1972 *American Journal of Physics* essay) that his institution contributed to the post-Sputnik goal of general science literacy but that it also "responded to the criticisms and the tenor of its times." The Exploratorium, he wrote, provided opportunities for its visitors to "become involved in their own [science] education process [in ways] that are difficult to achieve in school classrooms or through books, films, or t.v. programs."[45] Still, Oppenheimer's insistence on object-based learning and on the centrality of the museums to realizing this pedagogical objective remained atypical in the science education and public understanding of science communities of its founding time and place: the early 1970s in the United States. For instance, in its 1971 position statement "Science Education for the '70s," the U.S. National Science Teachers Association identified a very Oppenheimer-esque understanding of scientific literacy as its most important objective: "The major goal of science education is to develop scientifically literate and personally concerned individuals with a high competence for rational thought and action" in society, but at the same time, this statement made no mention of museums or their exhibits as institutionally central to this goal.[46] Likewise, later that same year, when the more scientist-heavy American Association for the Advancement of Science (AAAS) Commission on Science Education issued its summary recommendations, museums were similarly neglected as possible sites for new programs. Also in 1970, when the first AAAS "Report of the Committee on the Public Understanding of Science" appeared, it too heralded the importance of science literacy but made no mention of museums.[47]

The successes and failures of hands-on science centers in the United Kingdom reflect historical complexities similar to those of the U.S. context but perhaps could be distinguished by a greater unity of curatorial purpose than the U.S. experience of what might be called "the Exploratorium effect."[48] In the United Kingdom, the growth of hands-on interactive displays like those at the Exploratorium took off slightly later, in the 1980s and 1990s, and was tied up with the Public Understanding of Science movement.[49] But if, as Dorothy Nelkin has argued about the communication of science in America most broadly, U.S. science education was a major force and was to be "shaped by the co-operation and collaboration of several communities, each operating in terms of its own needs, motivations and constraints," then the late 1960s represented a time when there was little sustained coordination and cooperation between what would later become American science museums' most important backers: educational policy makers, scientists, and science educators.[50] This lack of coordinated communication persists in the United States, and to some extent in the United Kingdom, to this day. Even while professional organizations like Association of Science and Technology Centers work hard to promote dialogue about the effectiveness of hands-on exhibits through conferences and online platforms, much of this dialogue

stands to be lost to history. It remains professional chatter (often not published in peer-reviewed museum studies journals), or when it is published, it appears in places that are far-flung, tailored to one or another of those groups with a contemporary interest in science museums' display practices (for instance, science educators or curators or historians of science) rather than to the broader interdisciplinary audience whose experiences with these displays might enliven and inform the conversation.

Such historical insights, in turn, might prove instructive for contemporary science museum collectors interested in both documenting and displaying the material complexity and the critical dialogue around hands-on displays as artifacts themselves. Collecting the remnants of retired, but long-running, hands-on exhibits, like the *Watchful Grasshopper*, would create opportunities for the curatorial narration of science museums' institutional conflicts in the creation of displays. This, in turn, might one day provide useful for enabling future museum visitors (not to mention historians) to understand how science centers' successes and failures were not inevitable but achieved, not born writ large from the genius of one man but created through trial and error. Although any original hands-on visitor-driven exhibit interaction can (almost by definition) never be authentically recreated for future museum visitors, present and future heirs to the Exploratorium experience could be encouraged to think critically—in the best sense—about how hands-on exhibits often fail before they succeed (just as science and scientists do). They might be engaged to think about the purpose and meaning of displays that were contested by visitors even while they were supported by designers and scientists and what that contestation tells us about productive—or unproductive—public involvement with exhibit design. The Exploratorium itself has shown some self-awareness in this regard by staging an online exhibit, for instance, about how a single exhibit—the Bernoulli blower—has been appropriated and modified by museums around the world in order to fit site- and culture-specific contexts.[51] But the story of hands-on exhibits could potentially be of interest as more than just a tale of local variations on a universal form—as one might narrate, say, regional takes on objects like pottery vessels or fine china.

The diversity and complexity of hands-on exhibits further justify collecting them for display since they are powerful artifacts, capable of inducing visitors to be more reflective about the experiences (present and past) of encountering displays in science centers and museums. Hands-on exhibits embody received explanations of the natural world given by scientists of a particular era while at the same time being representative of the science education ideals and (literally) sites of the public consumption of science in the post–World War II era.[52] As such, although perhaps not precious or aesthetically beautiful one-of-a-kind objects, they merit some consideration for displaying the intersecting histories of museums, public science, and science education.[53]

This view may not be one Oppenheimer himself would have supported, for his designers' Exploratorium displays aspired to be ephemeral in quality and design even while they appealed to universal scientific principles and assumptions about learning. But surely we, as historians and museum practitioners, must rally behind the important idea of collecting to convey the science museum experience itself to a broader public in each generation[54]—and it is in this sprit that

curators must begin to engage more systematically with the legacy of the Exploratorium exhibit model. The Exploratorium model's successes and failures pose an ongoing challenge, but it is a challenge not unlike one that curators already face in the contradictory nature of technoscience itself, so why should it not also apply to its museums: to put on display a phenomenon and a set of practices that are at once both responsible for major scientific and quality of life improvements and sustained and driven by complicated constellations of personal and professional experiences and motives.

Notes

1. William Carlsen, "Science Museums: Do-It-Yourself Teachers," *New York Times*, 22 April 1979.

2. K. C. Cole, *Something Incredibly Wonderful Happens: Frank Oppenheimer and the World He Made Up* (Boston: Houghton Mifflin Harcourt, 2009), 152, 149. Notably, Oppenheimer did not distinguish between what J. J. Wellington would later describe as two types of science center exhibits: experiential (where visitors interact with natural phenomena) and pedagogical (where visitors are expected to come away with some knowledge of scientific concept). See J. J. Wellington, "Formal and Informal Learning in Science Centers: The Role of Interactive Science Centers," *Physics Education* 25 (1990): 247–252.

3. Cole, *Something Incredibly Wonderful Happens*, 157.

4. For a broader description of the Exploratorium's influence on art museums and children's museums, as well as a more general history of the institution's precursors, see Marjorie Schwarzer, *Riches, Rivals and Radicals: 100 Years of Museums in America* (Washington, D.C.: American Association of Museums, 2010), 145–150; Elaine Heumann Gurian, "The Molting of the Children's Museum," in *Civilizing the Museum: The Collected Writings of Elaine Heumann Gurian*, ed. Elaine Heumann Gurian (New York: Routledge, 2006), 19–32; Richard Toon, "Science Centers: A Museum Studies Approach to Their Development and Possible Future Directions," in *Museum Revolutions: How Museums Change and Are Changed*, ed. Simon Knell, Suzanne MacLeod, and Sheila Watson (New York: Routledge, 2007), 105–116; Ibrahim Yahya, "Mindful Play! Or Mindless Learning!: Modes of Exploring Science in Museums," in *Exploring Science in Museums*, ed. Susan Pearce (Atlantic Highlands, NJ: Athlone Press, 1996), 123–147.

5. Audra Wolfe, "The End of Consensus," in *Competing with the Soviets: Science, Technology, and the State in Cold War America* (Baltimore: Johns Hopkins University Press, 2013), 105–121. For an excellent general history of the Exploratorium and its approach to informal education, see Rodney Ogawa, Molly Loomis, and Rhiannon Crain, "Institutional History of an Interactive Science Center: The Founding and Development of the Exploratorium," *Science Education* 93, no. 2 (2009): 269–292.

6. See, for instance, Eric Gyllenhaal, Deborah Perry, and Emily Forland, "Visitor Understandings about Research, Collections, and Behind-the-Scenes at the Field Museum," *Current Trends in Audience Research and Evaluation* 10 (1996): 22–32.

7. Steve Lubar, "Fifty Years of Collecting: Curatorial Philosophy at the National Museum of American History," *Federal History*, July 2010, 82–99, http://shfg.org/shfg/wp-content/uploads/2010/07/Lubar.pdf (accessed 20 May 2015).

8. See Ogawa et al., "Institutional History of an Interactive Science Center." See also George E. Hein, *Learning in the Museum* (New York: Routledge, 1998).

9. For more on "dynamic biology," its practice and politics, see John L. Rudolph, "Teaching Materials and the Fate of Dynamic Biology in American Classrooms after Sputnik," *Technology and Culture* 53, no. 1 (January 2012): 1–36.

10. On Frank Oppenheimer's youth and relationship with his brother, see Kai Bird and Martin Sherwin, *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer* (New York: Knopf, 2006).

11. On Frank Oppenheimer's work on the atomic bomb, see Bird and Sherwin, *American Prometheus*, 305. On Oppenheimer's relationship with his family's wealth, see Cole, *Something Incredibly Wonderful Happens*, 106.

12. In 1961, Oppenheimer obtained the first of a series of National Science Foundation grants for physics research on "Elementary Particle Interactions from Bubble Chamber Photographs." See a series of letters between 16 March 1961 and 22 September 1966 between Oppenheimer and various NSF officials regarding these grants in the Exploratorium Archives, Bancroft Library, University of California, Berkeley (hereafter, BL-UCB), BANC 98/136; 1:19, BL-UCB. A collection guide to the Exploratorium Archives is available at http://www.oac.cdlib.org/findaid/ark:/13030/kt3q2nb1rh/entire_text/ (accessed 29 September 2015).

13. Frank Oppenheimer and Malcolm Correll, "A Library of Experiments," *American Journal of Physics* 32, no. 3 (1964): 220–225.

14. Historians of education argue about whether PSSC's goal included general science literacy or whether members sought merely to refine and sharpen disciplinary preparation for future physics researchers; scientist members like Zacharias clearly had different goals than members representing education, which included educational psychologists like Bruner, as well as representatives from Eastman Kodak's education film unit, the Educational Testing Service. For varying perspectives, see Ralph A. Raimi's 2004 review of Jerome Bruner's *The Process of Education*, http://www.math.rochester.edu/people/faculty/rarm/bruner.html (accessed 29 September 2015), and David Turner, "Reform of the Physics Curriculum in Britain and the United States," *Comparative Education Review* 28, no. 3 (1984): 444–453. Also see Norman Ramsey, "Jerrold R. Zacharias, 1905–1986," *Biographical Memoirs, National Academy of Sciences of the United States of America*, 68(1995), 435–450.

15. Frank Oppenheimer, "The Importance of the Role of Science Pedagogy in the Developing Nations," *Scientific World* 10, no. 4 (1966): 21–23, 28.

16. UNESCO adopted this recommendation in December 1960 and enlisted art, science, and history museum directors to give advice on the issue. See UNESCO, *Museums, Imagination and Education*, 2nd ed., Museums and Monuments 15 (Paris: UNESCO, 1973). Oppenheimer was an observer for the Federation of American Scientists at the 1965 World Federation of Scientific Workers (WFSW) meeting; before this, UNESCO and WFSW clashed throughout the 1940s and 1950s. See Patrick Petitjean, "A Failed Partnership: WFSW and UNESCO in the Late 1940s," in *Sixty Years of Sciences at UNESCO, 1945–2005*, ed. P. Petitjean, V. Zharov, G. Glaser, J. Richardson, B. de Padirac, and G. Archibald (Paris: UNESCO, 2006), 78–80, http://halshs.archives-ouvertes.fr/docs/00/16/66/25/PDF/PP_Unesco60-8.pdf (accessed 18 March 2010).

17. Oppenheimer, "History," n.d., BANC MSS 87/148c, folder 5:3, BL-UCB.

18. See Raimi, review of *The Process of Education*; Jerrold R. Zacharias and Stephen White, "The Requirements for Major Curriculum Revision," *School and Society* 92 (1964): 66–72; Cole, *Something Incredibly Wonderful Happens*, 174. On the existing difficulties of implementing hands-on pedagogy in school classrooms, see John Rudolph, "Ward's Dynavue and the Hybridization of Classroom Apparatus in the Post-Sputnik Era" (paper presented at the Annual Meeting of the National Academy of Education, New York, NY, 2005).

19. Frank Oppenheimer, "Rationale for a Science Museum," *Curator* 11 (1968): 206–207.

20. Frank Oppenheimer, "Exhibit Conception and Design," in *Working Prototypes: Exhibit Design at the Exploratorium* (Washington, D.C.: Association of Science-Technology Centers, 1986), 5.

21. Frank Oppenheimer, "Some Special Features of the Exploratorium," n.d., BANC MSS 87/148C, 5:8, BL-UCB.

22. Cole, *Something Incredibly Wonderful Happens*, 156–157. The analogy of the shop as a restaurant kitchen came from Cole, who once worked at the Exploratorium as a science communicator.

23. The broader public, which had recently developed a taste for drug-induced psychedelic hallucinations, pop art, and other alternative visual experiences, found the topic fascinating: the Exploratorium was soon blurbed everywhere from *Playboy* to *Artweek*. Although these first exhibits emphasized vision, Oppenheimer made sure to create components that would appeal to the blind. Indeed, creating exhibits for visitors with poor or no sight was a challenge Oppenheimer welcomed. Science "must be developed as a series of experiments and demonstrations which elucidate the topic without benefit of many words," he wrote. See "Museums," *Playboy*, April 1972, 44–48; Philip Morrison, "The Palace of Arts and Sciences," 1971, BANC 87/148c: 21 36, BL-UCB. On the media's role in the Exploratorium's success, see Ogawa et al., "Institutional History of an Interactive Science Center." On the museum's attempts to reach the blind, see Frank Oppenheimer, "The Content of the Museum," n.d., BANC MSS 87/148C, 5:2, BL-UCB.

24. Hilde S. Hein, *The Exploratorium: The Museum as Laboratory* (Washington: Smithsonian Institution Press, 1990), 72.

25. "Auxiliary Program," ca. 1970, BANC MSS 87/148c, 5:13, BL-UCB. See also Morrison, "Palace of Arts and Sciences," 345; Oppenheimer, "Some Special Features of the Exploratorium," 96–97.

26. On the antiestablishment vibe of the late 1960s, see, among others, David Farber, *The Age of Great Dreams: America in the 1960s*, ed. Eric Foner, American Century Series (New York: Hill and Wang, 1994); Howard Brick, *The Age of Contradiction: American Thought and Culture in the 1960s* (New York: Twayne, 1998).

27. Frank Oppenheimer, "Everyone Is You...Or Me," *Technology Review* 78, no. 7 (1976): 6–7.

28. Lee Kimche, "Science Centers: A Potential for Learning," *Science* 199, no. 4326 (1978): 270.

29. Hein, *The Exploratorium*, 107.

30. Phyllis Cahn and Evelyn Shaw, "A Method for Studying Lateral Line Cupular Bending in Juvenile Fishes," *Bulletin of Marine Science* 15, no. 4 (1965): 1060–1071; see also Karen Rader and Sylvie Gassaway's Oral History Interview with Charles Carlson (2005), unpublished transcript and tape held by author.

31. As cited in Cole, *Something Incredibly Wonderful*, 167.

32. Brine Shrimp Ballet design is outlined in Hipschman and the Exploratorium Staff, *Exploratorium Cookbook II* (San Francisco: Exploratorium, 1983), recipe 99.

33. These additional *Watchful Grasshopper* graphics are described in Hipschman and the Exploratorium Staff, *Exploratorium Cookbook II,* recipe 124.

34. Carlson describes the display setup in Charles Carlson, Bernard Jones, and Wayne LaRochelle, "Two Simple Electrophysiological Preparations Using Grasshoppers," *Association of Biology Laboratory Education Proceedings* 2 (1980): 182.

35. See Hipschman and the Exploratorium Staff, *Exploratorium Cookbook II*, recipe 124.

36. Carlson, "Report to Grass Foundation," 1977, BANC MSS 87/148c, 35:38, BL-UCB; see earlier in-house study that is extant in archives: "Documentation of Exhibits, The Exploratorium, December 1974 to June 1975," BANC 87/148c, 39:8, BL-UCB.

37. M. [name illegible] Clausen (who identified herself as a teacher) to Director of the Exploratorium, October 1981, BANC MSS 87/148c, 4:4, BL-UCB.

38. Leelane E. Hines to Frank Oppenheimer, BANC MSS 87/148c, 4:13, BL-UCB.

39. Frank Oppenheimer to Henrietta Gennrich, March 1981, BANC MSS 87/148c, 3:18, BL-UCB.

40. Erminia Pedretti, "T. Kuhn Meets T. Rex: Critical Conversations and New Directions in Science Centres and Science Museums," *Studies in Science Education* 13, no. 1 (2002): 9. On efforts of natural history museums in the 1970s and 1980s to respond to political concerns about science, see Karen A. Rader and Victoria E. M. Cain, *Life on Display* (Chicago: University of Chicago Press, 2014), chapters 6 and 7.

41. See Theodore Sudia to Frank Oppenheimer, 19 November 1975, BANC MSS 87/148c, 4:23, BL-UCB, which suggests that Oppenheimer consider some exhibits under development with the "Man-in-the-Biosphere" program of UNESCO.

42. Hein, *The Exploratorium*, 109; Hein also notes (p. 103) that Oppenheimer and Carlson were both "summoned to debates" on local radio and television programs to defend the *Watchful Grasshopper* from animal rights critics.

43. Walter Sullivan, "In Science, There Is Also Beauty and Joy," *Courier News* (Blytheville, AK), 17 September 1975, 17.

44. Muhaima Startt to Executive Director, Exploratorium, 28 July 1984, BANC MSS 87/148c, 4:23, BL-UCB.

45. Frank Oppenheimer, "The Exploratorium: A Playful Museum Combines Perception and Art in Science Education," *American Journal of Physics* 40, no. 7 (1972): 978, 980.

46. National Science Teachers Association, "NSTA Position Statement on School Science Education for the '70s," *Science Teacher* 38, no. 1 (1971): 47.

47. Gerard Piel, "1970 Report of the Committee on the Public Understanding of Science," 11 December 1970 as cited in S. G. Kohlstedt, M. M. Sokal, and B. V. Lewenstein, *The Establishment of Science in American Association for the Advancement of Science* (New Brunswick, NJ: Rutgers University Press, 1999) 211.

48. See Rader and Cain, *Life on Display*, chapter 6.

49. Stella V. F. Butler, *Science and Technology Museums* (Leicester: Leicester University Press, 1992); John Durant, the Science Museum, and the Committee on the Public Understanding of Science, *Museums and the Public Understanding of Science* (London: Science Museum in association with the Committee on the Public Understanding of Science, 1992).

50. Dorothy Nelkin, *Selling Science*: *How the Press Covers Science and Technology* (New York: Freeman, 1987), 11. See Bruce Lewenstein, "The Meaning of 'Public Understanding of Science' in the United States after World War II," *Public Understanding of Science* 1 (1992): 45–62.

51. See Exploratorium, "Bernoulli Blower," http://www.exo.net/ref/balancing_ball-cbk-200.pdf (accessed 23 March 2017).

52. On a related point, see, for instance, the discussions of David Lowenthal, "Science Museum Collecting," in *Museum Collecting Policies in Modern Science and Technology* (London: Science Museum, London, 1991), 11–15; and Doron Swade, "Napoleon's Waistcoat Button: Modern Artefacts and Museum Culture," in *Museum Collecting Policies*, 19–23.

53. On telling the history of museums through biographies of their objects, see Samuel J. M. M. Alberti, "Objects and the Museum," *Isis* 96, no. 4 (December 2005): 559–571. Steven Conn takes on the question of object-based learning and collecting from a museological perspective in *Do Museums Still Need Objects?* (Philadelphia: University of Pennsylvania Press, 2009), especially the eponymous chapter 1 and chapter 4 ("Where Have All the Grown-Ups Gone?").

54. Sally Gregory Kohlstedt makes a similar point in her article "'Thoughts in Things': Modernity, History, and North American Museums," *Isis* 96, no. 4 (December 2005): 586–601.

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Insights and Experiments

James Hyslop

The following is an interview with James Hyslop, Associate Director and Head of Department, Science and Natural History, Christie's, London, UK, from 23 July 2014. Private collecting offers a particular route for the commodification and preservation of artifacts; while the market for recently-made science and technology items remains small, some trends can be discerned.

Could you describe a particularly memorable encounter with a post-1945 artifact of science and technology?

I remember it very well—it arrived just too late to fit into the catalog alongside scientific instruments and books, so it was offered in a general books and manuscripts sale. It was a typescript of the communications between Mission Control and the crew of Apollo 13. In terms of desirability it had a lot going for it: rarity—it was one of 41 copies given out to journalists covering the event; the condition was very good, and it had desirability that would appeal not only to book collectors but to a wider audience. Perhaps it appeals to a public audience because of the Tom Hanks movie, but it is certainly a great example of big science producing an iconic item that fits nicely into well-established collecting categories.[1]

Does postwar science and technology feature much in your work?

While postwar and contemporary art is a huge sector of the market, it's still relatively rare to see items of postwar science and technology. For example, in the sale of the Richard Green Library of important scientific books, of the 347 lots only 17 were postwar.[2] Collectors tend to favor much older texts. We see even greater disparity with instruments.

I don't think this is a matter of aesthetics—although practical considerations of space are, of course, an issue, a private collector could have room for 20 Victorian microscopes or one scanning electron microscope. Very recent items don't often come to dealers as there tends to be a lag before families send them to market. But, generally, there is a preference for older items which have acquired the prestige of age.

Collectors tend to lag behind curators historiographically—they're still interested in "great men of science" and heroic narratives of progression. Texts from the Scientific Revolution, Newton, Darwin, and Halley are always popular. This creates a survival bias in what is collected and preserved. A small number of collectors do specialize in areas like phrenology or specifically seek out "dead ends."

▬▬ What kinds of postwar artifacts might interest collectors?

Ultimately, to sell an item for a top price in the current art market, you need a brand. What would we consider the masterpieces of postwar science? Maybe DNA, the Higgs boson, K-T boundary, plate tectonics, or climate change. Famous names like Stephen Hawking would also appeal. While it's possible to identify episodes or people that would have appeal, identifying an artifact is harder. I wasn't surprised when Francis Crick's "Secret of Life" letter was sold for $6 million by Christie's in New York in 2013—the type of collector who would happily spend millions on a work by Copernicus or Newton is looking for something unique or rare, whereas offprints of Crick and Watson's 1953 *Nature* paper are relatively common so not of huge value.[3]

In recent years it's become even harder to identify a "collectable moment." When the Human genome was published in 2000, it was still possible for dealers to buy up offprints and sell them on. But in 2012 the Higgs boson discovery was announced to the world via an online seminar. The subsequent publications in *Nature* and *Science* are again too common to be valuable, as are the newspaper front pages. Some of CERN's [the European Organization for Nuclear Research] technology is beautiful, but it's unlikely to come to the commercial market—and again space is an issue.

Collectors who are interested in current science might find a past artifact speaks to their interests—in 2012 Christie's sold nine samples of deep-sea mud collected by H.M.S. *Egeria.* Such samples are now often used to build up historical climate records.[4]

One area which has generated plenty of physical relics is space technology, which has built up its own industry. There's the relative rarity of space-flown items, but I also think the appeal of this topic goes beyond the science collectors to enthusiasts of Americana or the wider art market. For example, the Lunar Orbiter geologic maps are visually stunning in their own right.

▬▬ Are there any particular artifacts of post–World War II science and technology that you would single out?

For collectors, one item of major interest is the Enigma machine—wartime, of course, but only available on the market some time later. Many acquire this as a representation of the protohistory of computing because there's nothing of Bletchley Park or the first computers to collect. Enigma machines keep making headlines at auction, and their value is growing as the Turing story becomes more widely known.

The Apple 1 is also very popular—the "birth certificate" of what is now such a famous brand (Figure 1). There's a tension that many collectors want items to be in their original form but

1.
An Apple 1, likely to be one of the first 25 assembled, sold by Christie's in 2013. © Christie's Images Limited 2017.

also in working order—so an Apple 1 that had a different capacitor to usual, even though Steve Wozniak informed me that they were routinely replaced, would have less market value.

Notes

1. Christie's Sale 7590, Lot 94, "Mission Commentary" for Apollo 13, http://www.christies.com/lotfinder/books-manuscripts/apollo-13-the-mission-commentary-for-apollo-5080788-details.aspx?from=searchresults&intObjectID=5080788&sid=0f156665-55cf-4f1b-a7d4-439d0867fcb0 (accessed 12 April 2017).
2. Christie's Sale 2013, Important Scientific Books: The Richard Green Library, New York, 17 June 2008, http://www.christies.com/lotfinder/salebrowse.aspx?intSaleid=21644&viewType=listview (accessed 12 April 2017).
3. Christie's Sale 2806, Lot 1, The Francis Crick "Secret of Life" Letter, http://www.christies.com/the-francis-crick-secret-24391.aspx (accessed 12 April 2017).
4. Christie's Sale 4826, Lot 35, Nine Deep Sea Mud Samples, http://www.christies.com/lotfinder/lot/nine-deep-sea-mud-samples-june-july-1890-5548756-details.aspx (accessed 12 April 2017).

Osamu Kamei

The following is an interview with Osamu Kamei, Deputy Director, Center of the History of Japanese Industrial Technology, National Museum of Nature and Science, Tokyo, Japan, from 15 July 2015. As the origins of the museum go back to the 19th century, its practices of collection are of particular interest in view of the transformation processes in science and technology in Japan from the Meiji period onwards, and the acceleration of industrial production post-1945.

Please highlight examples of post-1945 artifacts of science and technology that are special to you.

As a first example of the Japanese history of industry and technology, I'd like to select the high-speed train Shinkansen, which completely changed people's attitude toward transportation. In particular, the speed of the service, where a distance of 500 km covered during a journey takes approximately two hours, and its reliability, with no accident casualties over half a century since its opening in 1964, are remarkable.

Second, I would like to highlight the first mass-produced electronic pet, named AIBO (artificial intelligence robot), developed by Sony Corporation from 1998 on. The price of this robot was very high, but we bought one as a collection object, or "specimen," if you like, for our institution, which is a museum of both natural history and the history of science and technology.

How did today's National Museum of Nature and Science emerge from predecessor institutions?

Established in 1877, the National Museum of Nature and Science (NMNS) is one of Japan's oldest museums. The names and functions of the museum have changed over time; they included Ministry of Education Museum, Tokyo Museum, Tokyo Science Museum, the National Science Museum of Japan, and, currently, NMNS as of 2007. Its missions were also transformed; they ranged from social education, school material provision, and the study of and education in the fields of engineering, the environment, biodiversity, science communication, and the Anthropocene.

At the time when social education was necessary, NMNS contributed to raising people's awareness of the foundation of modern industry through events such as the Time Day (from 1920 on) and the Green Cross for Safety and Hygiene of working environments (from 1919) using lectures and exhibitions. During the nation's era of robust economic growth (1954–1973), it served as a museum of science and technology and also became a natural history museum from the 1970s, with a thematic focus on biodiversity amid growing concerns regarding pollution and environmental degradation. As such, the museum today is a combination of two genres, a science and technology museum and a natural history museum. Over time, natural history has increased in importance and is now the major focus.

Today, the museum hosts laboratories conducting polar research and research in other fields while also providing facilities engaged in natural history studies. The sections of the museum handling material collection and material preservation are located in Tsukuba City on the outskirts of Tokyo, consisting altogether of 11 institutes, centers, and departments, which also compose the Center of the History of Japanese Industrial Technology.

When did the documentation of post-1945 artifacts of science, technology, and industry become a priority at your center?

Starting in 1997 and going to 2001, the museum conducted a first research study entitled "Research on the Evaluation, Preservation and Publication of Materials on Industrial Technology," drawing on contributions from industry, academia, and the public sector. The study led to the creation of a public online database of artifacts that illustrate the development of industrial technology in Japan. The approach created a network of information and documentation through systematic surveys of key technological developments. The study also established a system for registering important artifacts to promote their preservation. On the basis of their findings, the committee in 2001 outlined the need to create a central source of information on historical industrial technologies and their applications. At that time, the vast number of artifacts to be preserved was so large that it looked to be physically almost impossible. Therefore, we decided to at least establish documentation on the technologies. The NMNS has published the information on its website. In the case of emergency of preservation, other museums or the NMNS could save the artifacts. In 2002, the museum launched the Center of the History of Japanese Industrial Technology, which opened to the public in Tokyo in 2003. In 2012, it moved to its current location in the museum's newly built Tsukuba Research Wing.

The center collects, evaluates, and preserves material related to the industrial history of Japan from 1900 on with a focus on the period after 1950 until around the year 2010. Major initiatives of the center include (1) conducting surveys on the whereabouts of artifacts and documents related to the history of industrial technology, (2) performing systematic historical research on the development of technologies, and (3) selecting and registering essential historical records on science and technology with the aim of preserving them. Surveying the whereabouts of artifacts and documents involves creating records listing their locations, with the aim to create an exhaustive

catalog of items covering the approximately 500 industrial categories of the Japan Standard Industrial Classifications System. The process requires the support of academic, industrial, and other stakeholders in locating historic industrial and technological materials.

What does the documentation process look like?

Surveys are at the heart of the documentation process. The surveys target physical artifacts, facilities, or records that have contributed to the development of Japan's industrial technologies in selected technological fields. These are objects for which at least 10 years have elapsed since their manufacture, creation, or use. Such items include the following categories: (1) facilities and structures, (2) equipment, machines, instruments, and tools, (3) manufactured products, including finished goods, prototypes, and mass-produced items, (4) components, materials, and samples, (5) specimens, models, replicas, photos (particularly rare images taken in the prewar period that are not easily duplicated), and microfilm, (6) blueprints, specifications, industrial standards, and catalogs, (7) printed matter (such as documents, books, and periodicals related directly or indirectly to the development of selected technologies, generally excluding company histories), archival footage, and patent publications, (8) diaries, notes, and other manuscripts, and (9) other actual objects.

The director general of the NMSI extends commendations for such materials after surveys have been conducted by the center and deliberations have been completed by an external committee of experts. Registered materials are given registration cards and awarded commemorative plaques and then posted online. Systematic surveys on the history of technologies are conducted over roughly one-year time frames by NMNS teams of chief investigators, often assisted by retired engineers who have been actively involved in the development of industrial technology. The center publishes the results of its research in report form for library and online access (http://sts.kahaku.go.jp/) and has released survey and research reports in 100 fields since 31 March 2017. The center intends to release more English translations of entire surveys, but at this point only a few such translations are available online.

What aims do you foresee for the work of the center? Where do you see challenges?

A first immediate aim is to increase the number of research reports of the center. We hope that the survey results, increasing in number and range, will be used by a larger variety of persons. The second aim is to deepen the research into the life of humans, in conjunction with the research units within the museum that are more focused on natural history. Fortunately for us, awareness of the activities of the center has been increasing. Recently, we started to establish a framework in order to discuss the linkage between diverse findings in the history of technology by surveying changes from the perspective of the Anthropocene. We aim to identify the characteristics of industrial technology in Japan and other countries by examining the temporal and spatial characteristics of the Anthropocene from the perspective of global natural history.

■ Please provide us with an example of an artifact that for you describes typical features of recent science and technology.

One salient artifact in the history of Japanese industrial technology is the development of the Walkman by Sony, represented by the TPS-L2 series introduced in 1979, which became an innovation in consumer electronics (Figure 1). Several features in the history of the Walkman, which became a huge commercial success, are remarkable: (1) It led to the creation of a worldwide social phenomenon of public listening in which mobile music became part of youth culture. (2) Mass production of this device was at the front of the future trend of miniaturization. (3) From the perspective of history, it was a rather short lived analog technology that was replaced by the increasing availability of digital formats from the 1990s on.

1.
Sony Walkman TPS-L2, the first stereo cassette player. The first iteration of the worldwide smash hit Walkman. Courtesy Sony.

Roland Wittje

The following is an interview with Roland Wittje, Chair of UNIVERSEUM Working Group on Recent Heritage of Science and Associate Professor in History of Science and Technology, Indian Institute of Technology, Madras, India, from 15 April 2014. At the time of the Interview Roland was lecturer in history of science at the University of Regensburg, Germany. Universities are key sites for the advancement of knowledge through research and teaching, and hence, for the emergence of scientific and technological collections beyond museums. In this interview, we ask about the changing perspectives for university collections during the twentieth century.

What were your first encounters with post-1945 artifacts of science and technology?

This is a simple question to answer, as it makes reference to my motivation to follow this cause. When I started to become interested in scientific and technological heritage, my interest was mostly in the nineteenth century, in particular Heinrich Hertz's experiments on the propagation of electric waves. At the Research Group on Higher Education and History of Science of the University of Oldenburg, we were conducting research in the history of science through reworking or replicating historical experiments by studying historical instruments and other sources, building precise replicas, and carrying out experiments. By the way, nobody called things "material culture" back then. Only when I went to the Norwegian University of Science and Technology (NTNU) in Trondheim in 1997 as a Ph.D. student working with Mikael Hård on the history of physics in Norway did I get in touch with more recent things: we were looking for archive material but also dealt with a scientific instrument collection that I assembled and curated. These were mostly teaching objects that would have been part of a physical cabinet, a typical canon related to the experimental lectures on physics.

There is, however, a strong discontinuity when looking at the objects that came to the physics department after World War II. This is partially due to changes in the department personnel but also due to the dramatic growth of research activity after 1945. This is very typical of university

collections; you find this in many places in Germany as well in view of the new institutions that were created in the 1960s and 1970s. In Trondheim out of initially one professorship they created three professorships, and a large industrial research institute was founded. I did select some of the objects from the post-1945 period for the collection.

What makes collecting post–World War II artifacts of science and technology special?

While it was relatively easy to decide what to collect until 1945, as you basically preserve what is still there and it was not a big problem in terms of space requirements and it was easy to convince people that these are things that have to be taken care of, with the objects of the time after 1945 you do have a whole series of problems. Some of the objects are actually installations that are too large to be moved, e.g., a large particle accelerator that was built locally into the building. A second issue is that, often, it turns out that experiments had been disassembled and that parts were missing. This can be called the "laboratory cannibalizing phenomenon": a lot of the equipment that was there was modular, think of instrument racks, for example, and had been used by more than one person or research group in different experiments, with the result that things eventually went missing. While you can present essential parts of a particle accelerator as an iconic piece, they are not representative of the whole scientific experiment. Paolo Brenni has written a very nice article on this subject, how this development from tabletop to complex laboratory settings took place.[1] So while I tried to select objects from the post-1945 period, there were reasons why it could not be as systematic.

How can post-1945 artifacts be embedded into historiography?

A lot of the historiography for post-1945 history of science is American historiography, and a lot of it is directly related to political history. I have made that point in one of my articles where I wrote about the first German nuclear research reactor in Garching.[2] As we are dealing with contemporary history, this is, of course, problematic but at the same time also highly interesting. History writing in itself is getting more and more contested when approaching the present. To exemplify this point, I recall a process at NTNU where a group of retired scientists wrote on the development of physics at their own department. Clearly, writing on a period in which these researchers were active themselves was very difficult, in particular getting agreement on what actually had happened, what went wrong, and what went right. Scientists being engaged in their own history, therefore, is one of the topics to deal with when looking at building collections after 1945.

Which stakeholders need to be involved in the collection of recent artifacts of science and technology?

When establishing the collections in Trondheim, I conducted a survey across the whole technical university, which was a very interesting experience for me. I worked with scientists but also with technicians and instrument makers. One of my most important sources turned out to be a

glassblower who had rescued a lot of instruments about which he also knew a lot of things, having built or repaired them. In fact, the professor or the manager of the group does not always turn out to be the most important source of information; he or she might not even know how to use the equipment. With this survey, we were trying to get an understanding of the work of the departments and institutions through their material culture as you would call it today. Still today, I find that concept of material culture problematic; nobody really knows what it refers to. When collaborating with the people at the university, it was important to avoid any kind of museological jargon that they would not know. One has to remember that these staff members have a lot of things to do; if I wanted to get their support, I had to make their life easy. Working with scientists and technicians has the advantage of having a kind of peer preselection and preservation of what is relevant for describing their trade. In terms of the risks and pitfalls, of course, you cannot adopt the scientists' narratives as historical narratives without investigation, and some of them actually can be competing with each other. One local anecdote related to this assessment: When visiting the Physics Department at the University of Regensburg in Germany with my seminar, the students found out that there are several retired professors claiming to have been the first professor of physics at the University of Regensburg! Of course, there might be different interpretations of what it means to be first. So with material heritage, you always have to challenge and question the selection of the actors who are often still around. But I argue that we should try to establish a dialogue with them, and we should listen to them as at some point, in fact, the history does belong to them as well.

Which narratives should be considered for the collection of recent artifacts?

When I started to write my Ph.D. thesis in Trondheim, there were people expressing the opinion that there was nothing to be written about there as nobody got the Nobel Prize. Then I had to start to argue against that, stating that Nobel laureates cannot be representative of the development of science. And scientists are, in fact, aware of this; there is also a lot of local narrative of perceived failure, and sometimes one has to battle against resistance. Disproving local myths and anecdotal history can be quite difficult; even if you show evidence from the archives, some people will strictly follow the narratives that they have created. What makes the university collection a very different setting from a museum is that a large part of your audience is located within the university itself. Take the collections in Regensburg: very little is on display, and we actually do not want it all to be on display; the collection is a resource for the history of science. Public understanding of science is not the single relevant mission; the university collection is part of the university and should be seen as a resource for teaching and research within the university in the first place.

Which challenges need to be addressed in the future?

Acknowledging that not enough is being done to preserve recent scientific heritage at universities, one also has to see that there is no easy solution to the problem. Universities as institutions have to realize that large national museums cannot solve their problem of material heritage. Becoming

aware of and protecting their own heritage offers many opportunities, and universities have the intellectual resources to protect as well as to mobilize this material in all kinds of interdisciplinary projects. There should be guidelines, but we cannot be too procedural. With the working group, we are working on selection criteria and a toolkit that can help with the development of collections.[3]

The reaction from the community was actually very positive. Within German universities, the decentralized *Kustodie* structure is a good model if it is properly implemented. There should be staff qualified to survey the material who know the spaces and the university. One of the things to look at is, of course, equipment that is still being used. A second aspect to cover is to have control over the procedure of the retirement of staff, a process in which, often, a lot of things disappear very rapidly. One should not leave these decisions to only scientists; there should be a larger dialogue on the value and the potential of these objects. The basic message to understand here—this is true for recent history of science and technology as well as other periods—is that if you don't have an archive, be it papers or object collections, you don't have history.

Please describe an artifact that represents the challenges of post-1945 collections.

A typical object is the canonical electronics rack of the physics laboratory. Figure 1 is a photograph from May 1955 showing engineer Utne in the klystron laboratory at the Norwegian Institute of Technology in Trondheim.
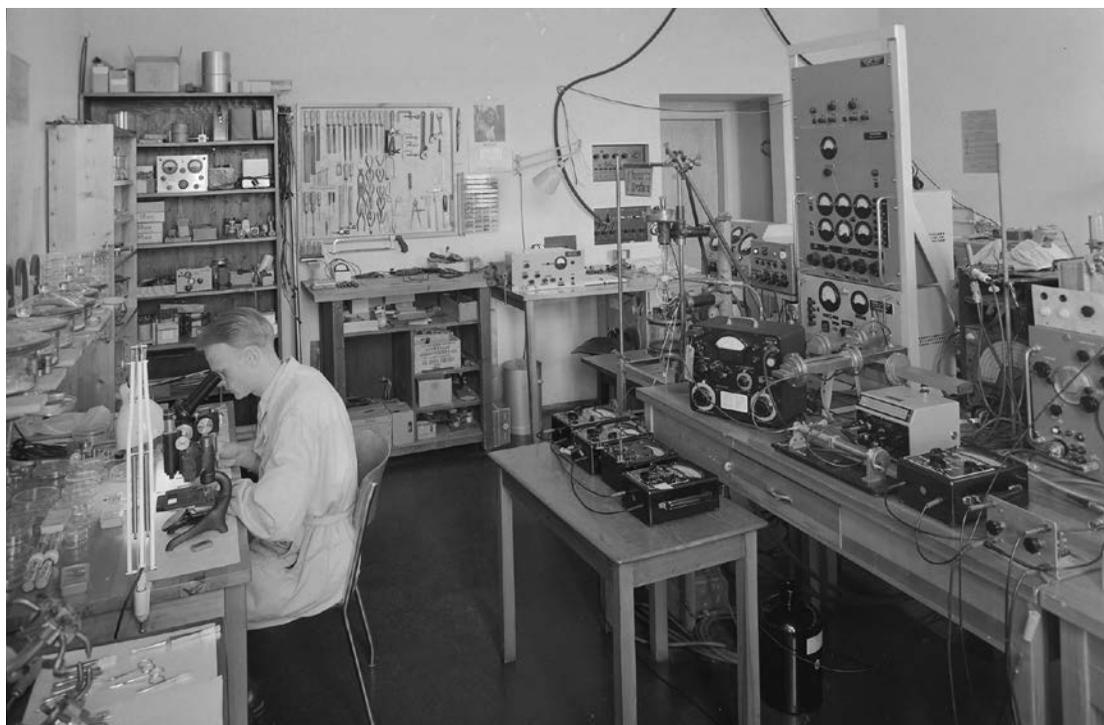
1.
Engineer Utne in the klystron laboratory, May 1955, Trondheim, Norwegian Institute of Technology. Courtesy of Schrøderarkivet, Trøndelag Folk Museum, Trondheim, Norway.

Notes

1. P. Brenni, "Physics Instruments in the Twentieth Century," in *Science in the Twentieth Century*, ed. J. Krige and D. Pestre (Amsterdam: Harwood Academic, 1997), 741–758.
2. R. Wittje, "The Garching Nuclear Egg: Teaching contemporary history beyond the Linguistic Turn," *Studies in History and Philosophy of Science, Part A* 44, no. 4 (2013): 683–689.
3. UNIVERSEUM Working Group on Recent Heritage of Science, "Selection Criteria for Recent Material Heritage of Science at Universities," http://universeum.it/docs/doc/Universeum-Selection-criteria-recent-heritage-2014.pdf (accessed 21 February 2017).

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Thomas Söderqvist

The following is an interview with Thomas Söderqvist, Emeritus Founding Director and Professor Emeritus, Medical Museion, Copenhagen, Denmark, from 12 June 2014. Söderqvist is particularly interested in the representation of recent biomedicine, and has criticized museums for being overly pedagogical in display and interpretation. Here, he argues for closer engagement with artifacts themselves.

What are your early memories of encountering post-1945 artifacts of science and technology?

I grew up in Sweden in the 1950s and 1960s, when everyday life was still pretty unaffected by modern science and technology. I mean, there were quite a few pre-1945 artifacts around, like cars, tin cans, electric bulbs, and AM radios and so forth. We had an Electrolux refrigerator in the kitchen and a black Ericsson telephone in the living room. But I never thought about these as science-technology (sci-tech) artifacts, of course. They were just mundane items in our mundane life.

I don't think I encountered any post-1945 sci-tech artifacts until the early 1970s, when I began my first (aborted) Ph.D. in biochemistry at Karolinska Institute in Stockholm. I remember becoming immediately fascinated by things like scintillation counters, NMR spectrometers, and automated protein sequencers.

I didn't have a clue about the history of these things, of course. But I still remember feeling they were qualitatively different from the traditional mechanic instruments I had had my hands on during my undergraduate studies. With their plastic casings and LED indicator lights they looked like science fiction objects, and they fitted perfectly into the futuristic vision of Gordon Rattray Taylor's 1968 bestseller *The Biological Time Bomb*, which, by the way, made an immense impression on me.[1]

◼ Could you outline some of the challenges of collecting artifacts of recent science and technology?

It shouldn't be necessary to remind museum directors that collecting recent biomedical science and technology means that their curators must have quite advanced sci-tech training. I think you definitely need a Master's degree or even a Ph.D. in a biomedical, medical engineering, biotech field or something similar.

First of all, you need it because you must make decisions about what to preserve from the deluge of things of recent sci-tech culture. The volume and diversity of new biomedical scientific instruments and medicotechnical gadgets is just overwhelming, and you need sci-tech training simply to sort the wheat from the chaff.

You need sci-tech training also because you must be able to cooperate with scientists and engineers on a kind of peer-to-peer basis. You must be able to ask the right questions at the right moment to get your hands on the many accessory utensils of the biomedical platform behind the instrument that the scientists, doctors, or engineers wish to donate to the museum, things which the practitioners usually don't consider important but are as important as the instrument itself.

For example, a genome sequencing platform isn't just the Illumina machine—it's also the many protocols and procedures that precede the actual sequencing and the interpretation procedures afterward—and you need all of that as part of your acquisition project.

◼ Is it possible to embed the study of post-1945 artifacts into the historiography of recent science and technology?

First, I must apologize for having edited two volumes about the historiography of recent science and technology without paying any attention whatsoever to museums, collections, and material history.[2] The omission reflects the fact that the material history of science and technology has been badly neglected in historiography. My only excuse is that I put these volumes together before I became involved in museums.

That said, I think all the problems and advantages of recent historiography that were discussed in these two volumes are true for material history as well. It is difficult to construct history as it is happening and to handle the insanely accelerating amount of new artifacts. On the other hand, the fact that practitioners are still alive is a great source of joy and is an immense advantage for historians, at least if they bother to use the time and energy to engage with them.

◼ What's your view of the recent trend toward more storytelling-based acquisition policies in museums?

Narratives are so much overrated. There is a growing mythological discourse around the primacy and value of storytelling in museums that I think needs to be stemmed.

I would say that the belief in storytelling is a consequence of the contemporary transition of museums from being research institutions with artifact collections to becoming teaching

and entertainment institutions. Curators have been replaced by museum educators and communicators, who believe exhibitions must tell "stories" to catch the attention of kids and their guardian members of the public.

But this is nonsense because stories actually play a pretty subordinate role in human lives, whereas episodic accounts, descriptions, instructions, explanations, and direct object handling are very important in our everyday routines. The same goes for museums. In spite of the fact that communicators and pedagogues try to construct more or less fancy overarching narratives, visitors still (wisely, in my mind) direct their attention to the singular artifacts and the descriptive labels and maybe cast a glance at the accompanying explanatory poster to catch the basic concept of the room or display. The alleged story blissfully gets lost.

In addition, I'm sure that narrative-driven acquisitioning is bound to fail. Museums shouldn't collect artifacts as "examples" to fit preconceived stories, but rather base their acquisitions on the merits of the things themselves, their composition, their historical significance, and their aesthetic value.

I must admit I very much prefer artifact-driven collecting and exhibitions. When I do exhibitions, I browse collections of our own and other museums for things I never thought existed, and then I visit working laboratories and clinics to watch how things are used in action—and bang! I get an idea for an exhibition or display. So I use theoretical concepts, and I use concrete material things, but stories have very little place in my description of what museums do.

How are different types of museum addressing the challenges of post-1945 artifacts?

The material history of post-1945 molecular biology and biotech is largely about what happened in the United Kingdom and United States, and therefore, curators in the Science Museum and the Smithsonian have an immense advantage when it comes to collecting on a national basis. Yet these museums allocate few resources to preserving their extremely rich contemporary national sci-tech heritage. It's pretty disappointing.

University museums, on the other hand, don't need to think in terms of systematic and representative collections. I think our job instead is to develop curation as a field of academic research and practice. We should concentrate on developing a kind of best practice for collecting, preserving, exhibition and event making, and not least artifact-based teaching at the university, all based on our own research, of course—whether it be in history, philosophy, aesthetics, ethnography, or material culture studies.

Could you identify an artifact that for you sums up recent science and technology?

Illumina Genotyping BeadChips (Figure 1) were used in a University of Copenhagen research project to identify novel genetic variations that result in increased risk of common metabolic disorders. Six hundred fifty chips donated by BGI, Shenzhen, were assembled for the installation *Genomic Enlightenment* at Medical Museion.[3]

1.
Illumina Chip. Photo by the author.

Notes

1. Gordon Rattray Taylor, *The Biological Time Bomb* (London: Thames and Hudson, 1968).
2. Thomas Söderqvist, ed., *The Historiography of Contemporary Science and Technology* (Amsterdam: Harwood Academic, 1997); Ronald E. Doel and Thomas Söderqvist, eds., *The Historiography of Contemporary Science, Technology and Medicine: Writing Recent Science* (London: Routledge, 2006).
3. Medical Museion, *Genomic Enlightenment*, http://www.museion.ku.dk/whats-on/exhibitions/genomic-enlightenment (accessed 11 April 2017).

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About the Contributors

Anna Adamek is a historian of technology and a Curator, Natural Resources and Industrial Design at the Canada Science and Technology Museums Corporation. She has been with the museum for over 20 years and is active in the public history community. She curated *Energy: Power to Choose*, an award-winning, controversial exhibition that examined the Canadian energy sector's socioeconomic and environmental impacts, and *Potash: Feeding the Wor*ld, an exhibition on a correlation between Canadian mining and fertilizer industries. She likes to experiment with open curation, use of social media in the acquisition process, and application of digital tools to the interpretation of material culture.

Olov Amelin has held the position of Director of the Nobel Museum in Stockholm since 2010. Previously, he was head of exhibitions in the same museum and before that he was Director of Museum Gustavianum, the University Museum of Uppsala University and was also responsible for organizing the museum (1996–1999). In 1989–1996 he worked with the Observatory Museum in Stockholm and was its director from the opening in 1991 until 1996. During this period he also held the position as Assistant Director at the Center for History of Science at the Swedish Royal Academy of Sciences. In 1986–1989 he was Curator at the National Museum of Science and Technology, Stockholm. He has a Ph.D. in the history of science and ideas from Uppsala University (1999). He has written articles and books in the field of history of science and museology and curated a large number of exhibitions both in Sweden and internationally.

Teresa Anderson is Director of the University of Manchester's Discovery Centre at Jodrell Bank, a Centre that she created and now leads. She is responsible for the center's public galleries, which receive over 160,000 visitors each year, and for a range of public engagement events, including Live from Jodrell Bank science-music festivals and girls night out events. She also leads on the process for Jodrell Bank's application for UNESCO World Heritage Site status. She has a first degree in physics and a Ph.D. in electrical engineering and has spent many years working in science policy and engagement with UK organizations such as NESTA and Practical Action. In addition to her role at Jodrell Bank, she is also currently Chair of the Board of Trustees of the UK Association for Science and Discovery Centres (ASDC) and Chair of the Board of Trustees of the Daphne Jackson Trust. In 2013 she was awarded an MBE in the Queen's Birthday Honours list for services to astrophysics and in 2014 was awarded the Institute of Physics Kelvin Medal

for public engagement with physics. In 2015, she was awarded an Honorary Professorship in the School of Physics and Astronomy at the University of Manchester.

Alison Boyle is Keeper of Science Collections at the Science Museum, London. She has overall responsibility for the Museum's physical sciences collections, which span from the tenth century to the present day, with particular focuses on physics and astronomy. She is working toward a PhD from University College London, in the museum practices of collecting and displaying physics throughout the twentieth century. She was lead curator of the *Collider* exhibition in 2013 (in house and touring versions, winner of the 2014 Dibner Award for Excellence in Museum Exhibits.

Robert Bud is Research Keeper at the Science Museum, where he has been a curator since 1978. He has previously published books on the histories of chemistry, medicine, biotechnology, scientific instruments, military research, and penicillin. Currently, he is involved in projects studying the history of the concept of applied science and the history of nuclear power.

Serge Chambaud was the Director of scientific and technical culture and of the Museum at the Conservatoire National des Arts et Métiers, Paris, France, from 2007 to 2014. From 1991 to 2007 he was affiliated with the French Patent Office, first in charge of data dissemination using new technologies, then in charge of the information system reengineering. He also represented the French Patent Office at the European Patent Office technical group. From 1973 to 1991, he was in charge of the development of scientific and technical information and culture policy at the Ministry of Industry, then at the Ministry of Research, and, finally, at the Ministry of National Education in charge of database development policy and of scientific museums at the Direction des Bibliothèques , des Musées et de l'Information Scientifique. Since 1994, he has been an associated professor at Université Paris-Est Marne-la-Vallée. He initially trained as a chemical engineer with degrees in management.

Martin Collins is a Curator at the Smithsonian National Air and Space Museum. His research focuses on the history of the United States in the world after 1945, as seen through the history of technology. He recently concluded his tenure as editor of the journal *History and Technology* (Taylor & Francis) and is managing editor of the book series Artefacts: Studies in the History of Science and Technology, published by the Smithsonian Institution Scholarly Press. His history of communications satellites and globalization in the 1990s, as seen through the multinational satellite telephony venture, Iridium, is forthcoming from Johns Hopkins University Press.

Rosie Cook is an independent museum consultant and recognized expert in the history of the chemistry set in America. Previously, she was the Assistant Curator and Collections Manager at the Chemical Heritage Foundation, where she was part of the curatorial team that planned

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Catherine Cuenca is the Director Adjointe and General Conservator nationale de sauvegarde du patrimoine scientifique et technique (PATSTEC) at the Musée des Arts et Métiers in Paris. She also serves as the head of the regional mission PATSTEC-Pays de la Loire at the University of Nantes. She received her Ph.D. in the history of art with specialization on scientific and technical heritage in museums and scientific cultural institutions from the University of Paris 1–Sorbonne. She completed her master's in marine biology (oceanography) at the University of Paris VI–Pierre et Marie Curie. From 1982 to 1996, she was the Director of the Natural History Museum of Nantes. From 1996 to today, she is in charge of the PATSTEC program at University of Nantes. Her publications cover the areas marine biology (until 2000) and museology and the history of heritage, museums, and cultural policy.

John Durant is the Mark R. Epstein (Class of 1963) Director of the MIT Museum and an Adjunct Professor in the Science, Technology & Society Program at MIT. He received his B.A. in natural sciences from Queens' College, Cambridge, in 1972 and went on to take a Ph.D. in history and philosophy of science, also at Cambridge, in 1977. After more than a decade in university continuing education (first at the University of Swansea in Wales and then at the University of Oxford), in 1989 he was appointed Assistant Director and Head of Science Communication at the Science Museum, London and Professor of Public Understanding of Science at Imperial College, London. In 2000, he was appointed Chief Executive of At-Bristol, a new independent science center in the west of England. He came to MIT in July 2005. In 2013, he and his wife, Anne Harrington, were appointed Co-Masters (now, Faculty Deans) at Harvard University's Pforzheimer House.

Kristin Ø. Gjerde is First Curator and Senior Researcher at the Norwegian Petroleum Museum. She has authored and coauthored a number of books on shipping, the history of electricity, local history, and the history of oil, including *On the Edge, under Water: Offshore Diving in Norway* (2014). At the museum her main tasks are within documentation and research, and she was project leader for Industrial Heritage Frigg, launched in 2008. She is also one of the authors of the four-volume *History of the City of Stavanger* (2012).

Johannes-Geert Hagmann is head of Curatorial Department AII–Technology and Officer for Museum Cooperation at the Deutsches Museum in Munich. After a PhD in physics, he joined the Deutsches Museum in 2009 as a curator for the exhibitions and collections on physics, geophysics, and geodesy. His research interests focus on collection practices, the history of physical sciences from the mid-nineteenth century to World War I, and science diplomacy in the interwar period. At present, he is leading the development of the new permanent gallery on optics, covering collections from the early modern period to the twentieth century.

James Hyslop is Head of Department for Science and Natural History at Christie's in London and catalogs globes and scientific instruments for all Christie's sale sites internationally. He has previously worked for the Whipple Museum of the History of Science in Cambridge, United Kingdom. He holds a B.A. in natural sciences from the University of Cambridge, and from 2009 to 2013 he sat on the committee of the Scientific Instrument Society.

Osamu Kamei is the Deputy Director of the Center of the History of Japanese Industrial Technology at the National Museum of Nature and Science of Japan and a Visiting Professor at the Open University of Japan. He is a Board member of the International Council of Museums' International Committee for Museums and Collections of Natural History and has been studying the Anthropocene as the history of technology and nature.

Jennifer Landry is Director of Museums for the City of Irving, Texas and was the first Director of the Museum at the Chemical Heritage Foundation, where she worked for 11 years, helping to build and launch the museum at CHF. She organized the 18th gathering of Artefacts at CHF in 2013. She earned her B.A. at Clarion University of Pennsylvania and her M.A. in public history at Duquesne University.

Henry Lowood is Curator for history of science and technology collections and for film and media collections at Stanford University. Since 2000, he has led How They Got Game, a research and archival preservation project at Stanford devoted to the history of digital games and simulations. His most recent books are *The Machinima Reader*, published by MIT Press (2011) and coedited with Michael Nitsche, and *Debugging Game History: A Critical Lexicon*, also by MIT Press and coedited with Raiford Guins, published in 2016.

Tim O'Brien is a Professor of Astrophysics and Associate Director of the University of Manchester's Jodrell Bank Observatory and also Associate Dean for Social Responsibility in the university's Faculty of Engineering & Physical Sciences. His research is focused largely on the study of exploding stars using telescopes around the world and in space. A new area of development is in the search for extraterrestrial intelligence. In 2014, he was awarded the Kelvin Medal of the Institute of Physics for innovative public engagement and makes regular contributions in the broadcast media, including hosting the hugely popular BBC *Stargazing Live* TV series from Jodrell Bank.

Dominique Pestre is Professor at EHESS, Centre Alexandre Koyré. Following his work on the history of physics and the relations between sciences and warfare, his interest turned to the transformation of knowledge regimes as well as historiographic and theoretic reflection on the studies of science and society. His most recent publications include *A contre-science* (Seuil, 2013) and *Histoire des sciences et des savoirs*, 3 volumes (Seuil, 2015).

Karen A. Rader teaches science and technology studies and history of science courses, as well as advises the medical humanities minor, at Virginia Commonwealth University in Richmond, Virginia. She recently coauthored (with Victoria E. M. Cain) *Life on Display: Revolutionizing U.S. Museums of Science and Natural History in the Twentieth Century* (University of Chicago Press, 2015).

Finn H. Sandberg is the manager of the Documentation and Research Unit at the Norwegian Petroleum Museum. He graduated from the Norwegian University of Science and Technology as a naval architect and marine engineer in 1974. He has 30 years of experience in the Norwegian oil industry. He has authored and presented several technical papers at different conferences both international and domestic. He was involved in two government-initiated studies on cost performance of large investment projects for the Norwegian continental shelf. He was the project manager for Industrial Heritage Valhall, which was launched in 2015.

Dagmar Schäfer is Director of Department III and Managing Director of the Max Planck Institute for the History of Science in Berlin and Honorary Professor of the history of technology at the Technical University, Berlin. Her main interest is the history and sociology of technology of China, focusing on the paradigms configuring the discourse on technological development, past and present. She has published widely on materiality, the processes and structures that lead to varying knowledge systems, and the changing role of artifacts—texts, objects, and spaces—in the creation, diffusion, and use of scientific and technological knowledge. Her monograph *The Crafting of the 10,000 Things* (University of Chicago Press, 2011) won the History of Science Society Pfizer Award in 2012 and the Association for Asian Studies Joseph Levenson Prize (Pre-1900) in 2013. Her current research focus is the historical dynamics of concept formation, situations, and experiences of action through which actors have explored, handled, and explained their physical, social, and individual worlds.

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Index

Page numbers in *italics* indicate figures and tables.

Michelin, 111

Mission de Sauvegarde du Patrimoine Scientifique et Technique Contemporain (PATSTEC)
    fields covered, *113f*
    local centers, 111
    mission partners, 111, 112, *112f*
    website, 106–107, 110, *110f*

MIT Museum
    contemporary artifacts, collection of, 24–39
    "do museums still need objects?," 28–30
    gender discrimination and, 26, 27
    Human Genome Project, 31–35, *36f*, 37–38, *37f*, 39n19
    MIT 150 Exhibition, 24–27
    objects and the problem of tacit knowledge, 30–31
    PATSTEC and, 112
    tape measure, 24–28, *25f*

Mobile Oil Corporation, 157

modern collecting. *see* contemporary collecting

Moniz, António Egas, 194–195

Mrs. Dalloway (Woolf), 54

Müller, Paul Hermann, 195

Mumford, Lewis, 63n2

Mumford, Robert, 3

Musée des Arts et Métiers, France, 107, 108, 112

Museum at CHF. *see* Chemical Heritage Foundation

Museum Boerhaave, Leiden, vi

Museum of Science and Technology, Milan, 112

Museum of Technology, Sweden, 196n5

museums. *see also* exhibits; science museums
    functions, vii
    object-based epistemology, 28
    relationship with public, vii
    success indicators, 131n9
    twentieth-century roles, 28–29

The Mysterious Island (Verne), 10–12, *11f*

Nahum, Andrew, 57

Nantong, Jiangsu Province, China, 91

NASA artifacts, 46, 48n14, 216

National Air and Space Museum (NASM), Smithsonian Institution, Washington, D.C., 40–48
    collecting areas, 45
    collections rationale, spaceflight and rocketry (2010), 43–46
    context, 41–43
    creation of, 42
    Enola Gay and the end of World War II (proposed exhibition), 47n8
    foundational narratives, 42
    interpretive frameworks, 42, 44, 46–47, 48n12
    NASA, letter of understanding with, 48n14
    periodization, 45, 46
    progress, as museum narrative, 42, 44, 48n12
    rocketry artifacts, 47n8
    scholarly publications of curators, 42
    spaceflight artifacts, 41, 46, 47nn2–3

National Archives of Norway, 157

National Computer Conference, 69

National Heritage List for England, 174

National Heritage Lottery Fund, 62

National Human Genome Research Institute, 32

National Jodrell Bank Archive, 177

National Library of Australia, 78

National Library of Norway, 157, 159, 160–161

National Museum of American History, Smithsonian Institution, Washington, D.C., 71–72, 80

National Museum of Nature and Science, Tokyo, Japan, 219–222

National Museum of Science and Industry. *see* Science Museum, London

National Museum of Scotland (formerly Royal Scottish Museum), 61

National Radio Astronomy Observatory Archives, 174

"National Scheme for Scientific Literacy" (*Zhongguo kepu baogao*), 93

National Science Foundation (NSF), 79, 204, 210n12

National Software Archives (NSA), 71–72

National Taiwan Museum, Taipei, 91, 100n11

natural history museums (*ziran lishi bowu guan*), 90–91

naturalist cosmology, 5

Natural Resources Canada Office of Energy Efficiency, 142

Nelkin, Dorothy, 208

networks of collecting, 87–114
    Chinese museums, ix, 88–102
    French scientific and technical heritage, ix, 104–114

Newman, James, 83

Newton, Isaac, 217

New York Times, 198

Nobel Museum, Stockholm, 184–196
    acquisition criteria, 185, 193–194
    artifact documentation, 187, 194, 196n4
    artifact hunting, 184–185
    artifacts, 185–190, *186f*, *188f*, *189f*, *190f*, *191f*, *193f*, 195n1
    collection, 184, 195n1
    Cultures of Creativity (exhibition), 196n3
    mission, 188
    recreation of Curie experiment, 191–192
    story-based approach, 184–196

Nobel Prize in Chemistry (1911), 190–191

Nobel Prize in Chemistry (1974), 118

Nobel Prize in Chemistry (2002), 126, 131n12

Nobel Prize in Chemistry (2008), 189–190

Nobel Prize in Physics (1903), 190

Nobel Prize in Physics (1965), 185

Nobel Prize in Physics (1978), 187–188

This most recent volume in the Artefacts series, *Challenging Collections: Approaches to the Heritage of Recent Science and Technology*, focuses on the question of collecting post–World War II scientific and technological heritage in museums, and the challenging issue of how such artifacts can be displayed and interpreted for diverse publics. In addition to examples of practice, editors Alison Boyle and Johannes-Geert Hagmann have invited prominent historians and curators to reflect on the nature of recent scientific and technological heritage, and to challenge the role of museum collections in the twenty-first century. *Challenging Collections* will certainly be part of an ever-evolving dialogue among communities of collectors and scholars seeking to keep pace with the changing landscapes of science and technology, museology, and historiography.

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